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BERKSHIRE GAS MARKET POTENTIAL STUDY

April 2021

Report prepared for:
BERKSHIRE GAS COMPANY

Energy Solutions. Delivered.

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EXECUTIVE SUMMARY

In 2020, Berkshire Gas Company (Berkshire), Liberty Utilities, and Unitil (Fitchburg Gas and Electric) contracted with Applied Energy Group (AEG) and our partner Cadeo to perform a comprehensive demand-side management (DSM) market potential study (MPS). This study is an integral part of the utilities' program planning process; ultimately the MPS provides guidance for the development of the utilities' program plans. This report covers the market characterization, baseline, and potential for Berkshire Gas Company.

Definitions of Potential

In this study, the savings estimates are developed for five types of potential: technical potential, economic potential, and three levels of achievable potential: Business as Usual (BAU), Business as Usual Enhanced (BAU Plus), and Maximum Achievable. These are developed at the measure level, and results are provided as annual savings impacts over the three-year planning period. The various levels are described below.

- Technical Potential is the theoretical upper limit of efficiency potential, assuming that customers adopt all feasible measures regardless of their cost or customer preference. At the time of existing equipment failure, customers replace their equipment with the most efficient option available. In new construction, customers and developers also choose the most efficient equipment option.

  Technical potential also assumes the adoption of every other available measure, where applicable. For example, it includes installation of high-efficiency windows in all new construction opportunities and smart thermostats installed on all applicable space heating systems. These retrofit measures are phased in over a number of years to align with the stock turnover of related equipment units, rather than modeled as immediately available all at once.

- Economic Potential represents the adoption of all cost-effective energy efficiency measures. In this analysis, the cost-effectiveness is measured by the total resource cost (TRC) test, which compares lifetime energy and documented non-energy benefits to the incremental costs of the measure, including additional operations and/or maintenance if applicable. If the lifetime benefits outweigh the costs (that is, if the TRC ratio is greater than 1.0), a given measure is considered in the economic potential. Customers are then assumed to purchase the cost-effective option at any decision juncture.

- Achievable Potential refines economic potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and recent Berkshire program history. This study assesses three levels of achievable potential developed in coordination with the other PAs and vendors conducting studies in Massachusetts. These are described in more detail in Chapter 2:

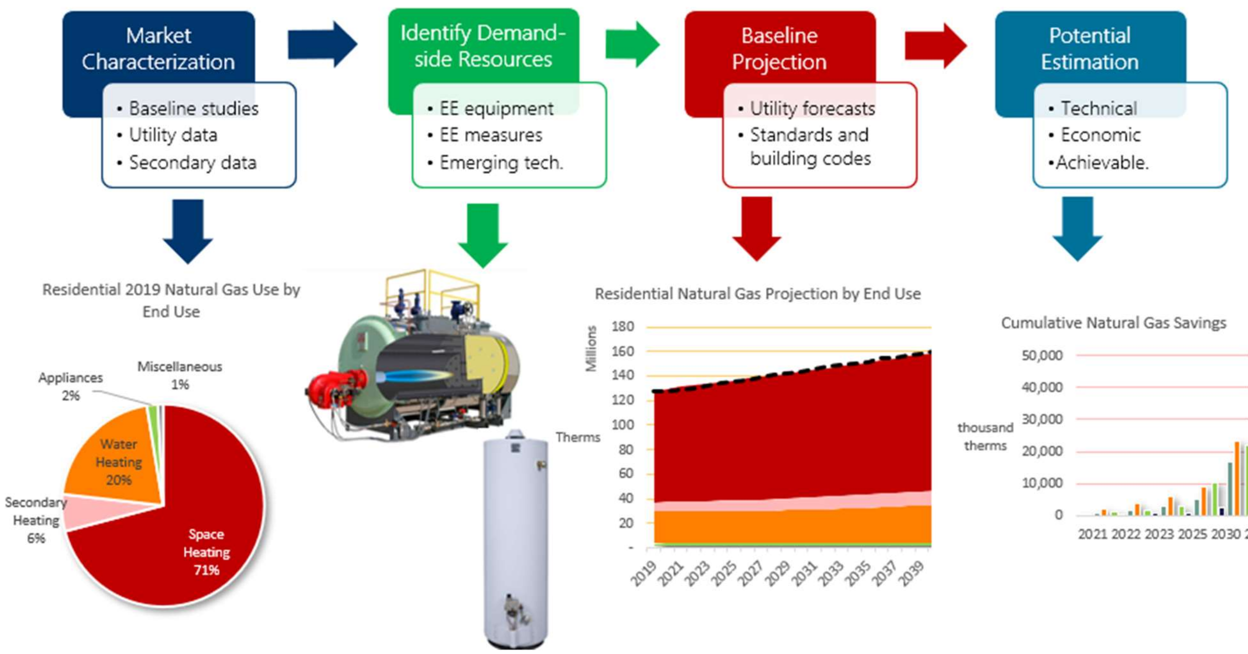
  - Business as Usual (BAU) Potential is calibrated to current program activity and assumes incentives (and as a result, program participation) remain as they are today.
  - BAU Plus and Maximum Achievable both reflect likely participation increases due to incentive increases described in Chapter 2.

Study Approach

To perform the potential analysis, AEG used a bottom-up approach following three major steps which are illustrated in Figure ES- 1. The analysis steps are described in more detail in Section 2.

1. Characterize the market in the base year (2019) using customer surveys, information and data from Berkshire and secondary data sources, to describe how customers currently use energy by sector, segment, end use and technology.
2. Develop a baseline projection of how customers are likely to use natural gas in absence of future energy efficiency programs. This defines the metric against which future program savings are measured. This projection uses up-to-date technology data, modeling assumptions, and energy baselines that reflect both current and anticipated federal, state, and local energy efficiency legislation and standards that will impact potential.
3. Estimate technical, economic and achievable potential at the measure level for 2022 through 2024 to inform Berkshire's program design.

Figure ES- 1 Analysis Approach



Key Findings

First-year potential savings for 2022 through 2024 and lifetime savings are presented in Table ES- 1. The achievable BAU potential is in the range of 292,560 therms to 300,869 therms per year, or 0.4% of the baseline projection. The commercial sector accounts for the largest share of savings, approximately 52% of achievable BAU potential savings in each year.

Table ES- 1 Berkshire First-Year Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Reference Baseline	**74,730,936**	**74,831,660**	**74,978,604**
First-year Savings			
Achievable BAU Potential	292,560	298,094	300,869
Achievable BAU Plus Potential	344,396	349,943	352,753
Achievable Max Potential	447,623	453,260	455,564
Economic Potential	1,039,842	1,044,128	1,041,522
Technical Potential	1,346,103	1,349,256	1,349,515
Savings as % of Baseline			
Achievable BAU Potential	0.39%	0.40%	0.40%
Achievable BAU Plus Potential	0.46%	0.47%	0.47%
Achievable Max Potential	0.60%	0.61%	0.61%
Economic Potential	1.39%	1.40%	1.39%
Technical Potential	1.80%	1.80%	1.80%

Figure ES- 2 Berkshire BAU Achievable Savings by Sector (Therms)

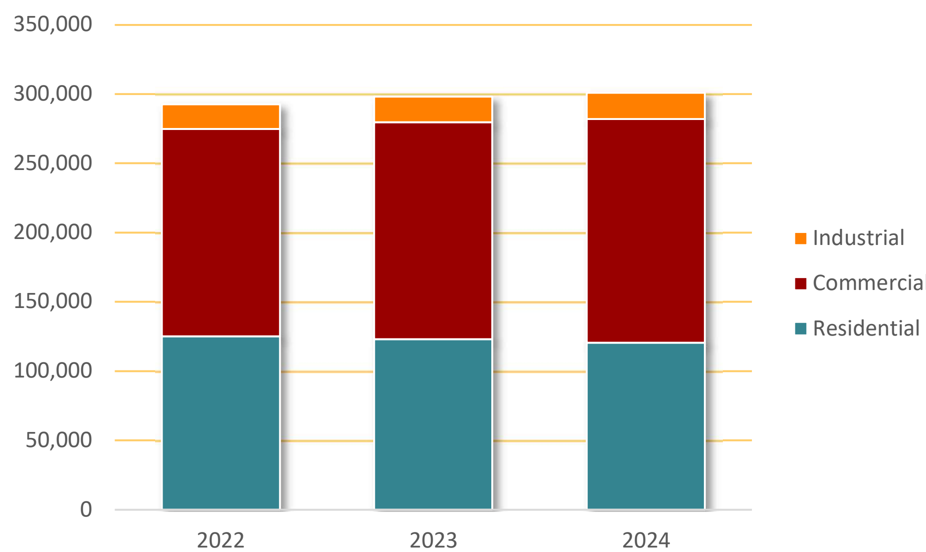


Table ES- 2 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Berkshire's actual costs will naturally vary.

Table ES- 2 Berkshire Natural Gas Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$4,166,284	$4,122,425	$4,144,235
BAU Plus	$5,760,972	$5,697,213	$5,725,179
Max	$8,702,535	$8,587,095	$8,618,120

Conclusion

Berkshire's portfolio of energy efficiency programs is performing solidly, however there is room for some modest increase in annual potential acquisition if incentives are increased and programs can address market barriers. However, both of these prospects will increase the cost of acquiring potential.

This study provides important information for planning the next program cycles. This study:

- Describes and characterizes the customer base by energy source, sector, customer segment and end use. At a glance, it is possible to see where the opportunities for program savings are likely to come from.
- Defines a baseline projection of energy use by end use against which savings can be measured. This baseline takes into account existing and planned appliance standards and building codes, as well as naturally occurring efficiency.
- Evaluates a diverse set of energy efficiency measures in all three customer sectors.
- Estimates the total amount of savings possible from cost-effective measures; these are savings above and beyond those already included in the baseline projection.
- Describes a set of achievable potential savings scenarios – BAU, BAU Plus, and Max – based on increased incentives driving increased savings achievement that can be useful for program development in the upcoming planning years 2022 through 2024.

The results presented in this report are estimates based on the best available information available at the time of the analysis and we expect variation in outcomes in the real world. This fact gives staff the opportunity to deviate from specific annual values developed in the study as they design programs and commit to annual program targets as well as gather more territory-specific information about baselines, saturation and demand for program offerings.

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INTRODUCTION

In 2020, the Berkshire Gas Company (Berkshire), Liberty Utilities, and Unitil (Fitchburg Gas and Electric) contracted with Applied Energy Group (AEG) and our partner Cadeo to perform this comprehensive demand-side management (DSM) Market Potential Study (MPS) for their natural gas service territory. The key objectives of the study were to:

- Estimate demand-side savings associated with traditional and emerging energy efficiency measures.
- Engage with the statewide coordinators during the study to coordinate assumptions, measure lists, and preliminary analysis results across vendors and utilities.

This study begins with market characterization to help Berkshire understand how their customers use natural gas today, then proceeds with baseline projection estimates incorporating the latest information on federal, state, and local codes and standards for improving energy efficiency. Finally, the study assesses various tiers of energy efficiency potential including technical, economic, and three levels of achievable potential.

Berkshire will use the results of this study as guidance for upcoming DSM planning process to optimally implement energy efficiency programs over the 2022-2024 term.

Potential Study Tasks

To produce a reliable and transparent estimate of efficiency potential, AEG performed the following tasks to meet Berkshire's key objectives:

- Characterize the market in the base year (2019) using Massachusetts statewide baseline study data, customer data from Berkshire, and secondary data sources to describe how customers currently use energy by sector, segment, end use and technology.
- Develop a baseline projection of how customers are likely to use natural gas in absence of future energy efficiency programs. This defines the metric against which future program savings are measured. This projection used up-to-date technology data, modeling assumptions, and energy baselines that reflect both current and anticipated federal, state, and local energy efficiency legislation and standards that will impact potential.
- Estimate the technical, economic, and achievable potential at the measure level for energy efficiency over the 2022 to 2024 planning horizon to inform Berkshire's program design.

This report documents the results of the study as well as the steps followed in its completion. Throughout this study, AEG worked with Berkshire to understand the baseline characteristics of their service territory, including a detailed understanding of energy consumption, the assumptions and methodologies used in Berkshire's official load forecast, and recent DSM program accomplishments.

Abbreviations and Acronyms

Throughout the report we use a number of abbreviations and acronyms. Table 1-1 shows the abbreviation or acronym, along with an explanation.

Table 1-1 Explanation of Abbreviations and Acronyms

Acronym	Explanation
AEO	Annual Energy Outlook forecast developed by EIA
AESC	Avoided Energy Supply Components
BCR	Benefit Cost Ratio
BEST	AEG's Building Energy Simulation Tool
C&I	Commercial and Industrial
DRIPE	Demand Reduction Induced Price Effect
DSM	Demand Side Management
EE	Energy Efficiency
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EUL	Effective Useful Life
EUI	Energy Utilization Index
HH	Households
HVAC	Heating Ventilation and Air Conditioning
LoadMAP™	AEG's Load Management Analysis and Planning tool
mTherms	Thousand therms
MMtherms	Million therms
NEI	Non-Energy Impacts
O&M	Operations and Maintenance
PA	Program Administrator
Sq.Ft.	Square feet
TRC	Total Resource Cost
TRM	Technical Reference Manual
UEC	Unit Energy Consumption

2

ANALYSIS APPROACH AND DATA SOURCES

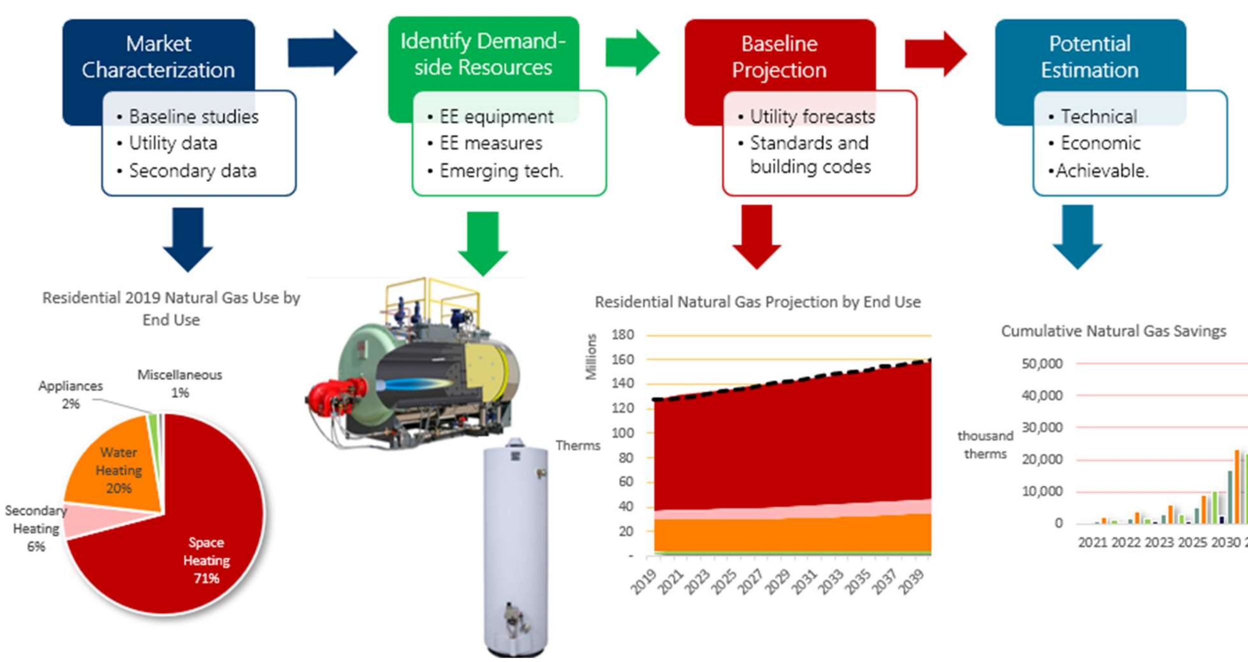
This section describes the analysis approach taken for the study and summarizes the data sources used to develop the potential estimates.

Overview Analysis Approach

To perform the potential analysis, AEG used a bottom-up approach following three steps illustrated in Figure 2-1. We describe these analysis steps in more detail in the remainder of this section.

1. Performed a market characterization to describe natural gas use at an end-use level for the residential and commercial sectors for the base year, 2019. The Massachusetts Baseline Studies for the Residential and Commercial sectors are the primary data source for this characterization. They were supplemented as needed by a variety of secondary data sources.
2. Defined and characterized energy efficiency measures to be applied to all sectors, segments, and end uses. AEG developed the measure list using Berkshire's current programs, the Massachusetts state TRM, measure lists developed in coordination with the other Massachusetts Potential Study teams, measure lists from other studies, and new/emerging technologies.
3. Developed a baseline end-use projection of energy consumption by sector, segment, end use, and technology for 2020 through 2024.
4. Estimated technical, economic and three levels of achievable potential at the measure level for 2022 through 2024.

Figure 2-1 Analysis Approach



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  - Business as Usual (BAU) Potential is calibrated to current program activity and assumes incentives (and as a result, program participation) remain as they are today.
  - BAU Plus and Maximum Achievable both reflect likely participation increases due to incentive increases described later in this chapter.

LoadMAP Model

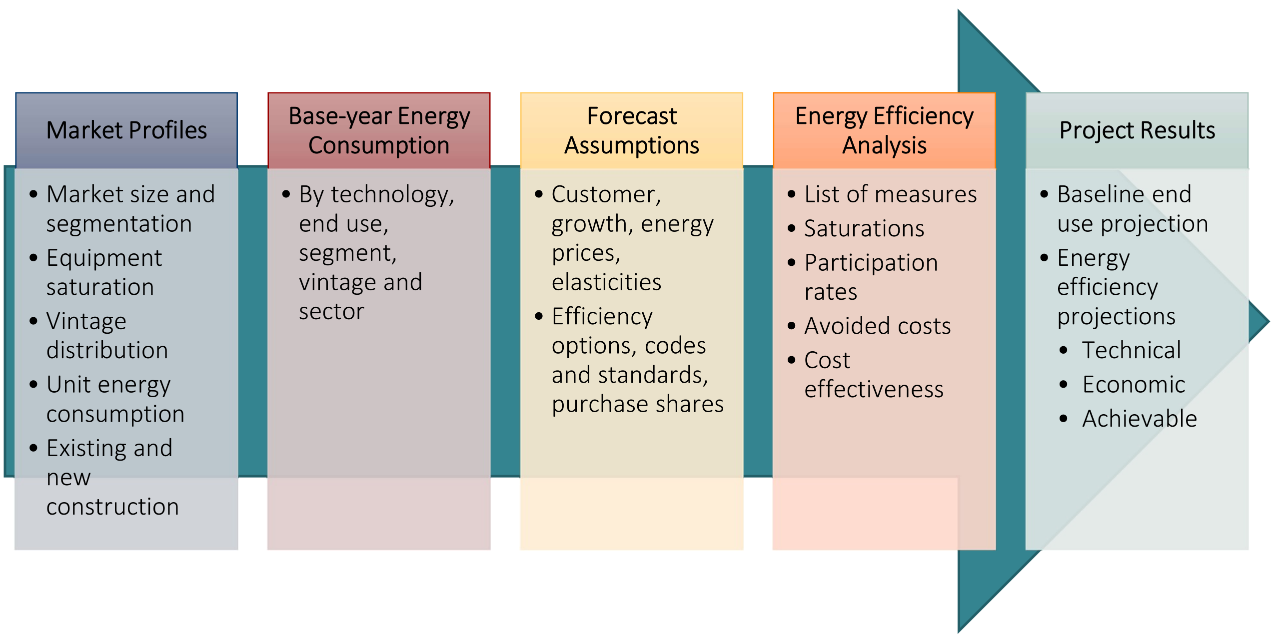
For this analysis, AEG used its Load Management Analysis and Planning tool (LoadMAP™) version 5.0 to develop both the baseline end use projection and the estimates of potential. AEG developed LoadMAP in 2007 and has enhanced it over time. Built in Excel, the LoadMAP framework (see Figure 2-2) is both accessible and transparent and has the following key features.

- Embodies the basic principles of rigorous end use models (such as EPRI's REEPS and COMMEND) but in a more simplified, accessible form.
- Includes stock-accounting algorithms that treat older, less efficient appliance/equipment stock separately from newer, more efficient equipment. Equipment is replaced according to the measure life and appliance vintage distributions defined by the user.
- Balances the competing needs of simplicity and robustness by incorporating important modeling details related to equipment saturations, efficiencies, vintage, and the like, where market data are

available, and treats end uses separately to account for varying importance and availability of data resources.

- Isolates new construction from existing equipment and buildings and treats purchase decisions for new construction and existing buildings separately.
- Uses a simple logic for appliance and equipment decisions. Other models available for this purpose embody complex decision choice algorithms or diffusion assumptions, and the model parameters tend to be difficult to estimate or observe and sometimes produce anomalous results that require calibration or even overriding. The LoadMAP approach allows the user to drive the appliance and equipment choices year by year directly in the model. This flexible approach allows users to import the results from diffusion models or to input individual assumptions. The framework also facilitates sensitivity analysis.
- Can accommodate various levels of segmentation. Analysis can be performed at the sector level (e.g., total residential) or for customized segments within sectors (e.g., housing type or income level).
- Natively outputs model results in a detailed line-by-line summary file, allowing for review of input assumptions, cost-effectiveness results, and potential estimates at a granular level.
- Consistent with the segmentation scheme and the market profiles we describe below, the LoadMAP model provides projections of baseline energy use by sector, segment, end use, and technology for existing and new buildings. It also provides forecasts of total energy use and energy efficiency savings associated with the various types of potential.[1]

Figure 2-2 LoadMAP Analysis Framework



[1] The model computes energy projection for each type of potential for each end use as an intermediate calculation. Annual-energy savings are calculated as the difference between the value in the baseline projection and the value in the potential projection (e.g., the technical potential projections).

MPS Analysis Tasks

Market Characterization

To estimate the savings potential from energy-efficient measures, it is necessary to understand how much energy is used today and what equipment is currently in service. This characterization begins with a segmentation of Berkshire's energy footprint to quantify energy use by sector, segment, end use application, and the current set of technologies used. For this we rely primarily on information from the Massachusetts' baseline studies.

Segmentation for Modeling Purposes

The segmentation scheme for this study is presented in Table 2-1.

Table 2-1 Overview of Berkshire Analysis Segmentation Scheme

Dimension	Segmentation Variable	Description
1	Company	Berkshire Gas Company
2	Sector	Residential, Commercial, Industrial
3	Segment	Residential: by housing type (single family and multi-family), income level (low-income/ not low-income) Commercial: office, retail, restaurant, grocery, college, school, health care, lodging, warehouse, miscellaneous Industrial: By industry type as appropriate to the utility customer base
4	Vintage	Existing and new construction
5	End uses	Space heating, water heating, etc. (as appropriate by sector and energy type)
6	Appliances/end uses and technologies	Technologies such as furnaces, boilers, etc. for space heating, etc.
7	Equipment efficiency levels for new purchases	Baseline and higher-efficiency options as appropriate for each technology

With the segmentation scheme defined, we then performed a high-level market characterization of energy sales in the base year, 2019. We used secondary sources to allocate energy use and customers to the various sectors and segments such that the total customer count and energy consumption matched the Berkshire system totals from 2019. This information provided control totals at a sector level for calibrating the LoadMAP model to known data for the base-year.

Market Profiles

The next step was to develop market profiles for each sector, customer segment, end use, and technology. A market profile includes the following elements:

- Market size is a representation of the number of customers in the segment. For the residential sector, the unit is number of households. In the commercial sector, it is floor space measured in square feet.
- Saturations define the fraction of homes or square feet with the various technologies. (e.g., percent of homes with gas water heating).
- UEC (unit energy consumption) or EUI (energy-utilization index) describes the amount of energy consumed in the base year by a specific technology in homes or buildings that have the

technology. UECs are expressed in therms/household for the residential sector, and EUIs are expressed in therms/square foot for the commercial sector.

- **Annual energy intensity** for the residential sector represents the average energy use for the technology across all homes in 2019. It is computed as the product of the saturation and the UEC and is defined in therms/household terms. For the commercial sector, intensity, computed as the product of the saturation and the EUI, represents the average use for the technology across all floor space in the base year.
- **Annual usage** is the annual energy used by each end use technology in the segment. It is the product of the market size and intensity and is quantified in mTherms.

Baseline End Use Projection

The next step was to develop a baseline projection of annual natural gas use for 2020 through 2024 by customer segment and end use to quantify the likely consumption in the future in absence of any energy efficiency programs. The end-use projection includes the relatively certain impacts of codes and standards that will unfold over the study timeframe. All such mandates that were defined as of January 2021 are included in the baseline[2]. The baseline projection also includes projected naturally occurring energy efficiency during the potential forecast period. The baseline projection is the foundation for the analysis of savings from future efficiency cases and scenarios as well as the metric against which potential savings are measured.

Inputs to the baseline projection include:

- Current market growth forecasts (i.e., customer growth, income growth) provided by Berkshire
- Trends in fuel shares and equipment saturations from the US Department of Energy
- Existing and approved changes to building codes and equipment standards
- Naturally occurring efficiency improvements, which include purchases of high-efficiency equipment options outside of EE programs.

Energy Efficiency Measure Development

This section describes the framework used to assess the savings, costs, and other attributes of energy efficiency measures. These characteristics form the basis for measure-level cost-effectiveness analyses as well as for determining measure-level savings. For all measures, AEG assembled information to reflect equipment performance, incremental costs, non-energy impacts, and equipment lifetimes. We used this information along with avoided cost data from the 2021 final AESC in the economic screen to determine economically feasible measures.

Figure 2-3 outlines the approach for measure analysis. The framework for assessing savings, costs, and other attributes of measures involves identifying the list of measures to include in the analysis, determining their applicability to each market sector and segment, fully characterizing each measure, and performing cost-effectiveness screening. AEG participated in coordinating calls arranged by Apex Analytics[3] so that high profile measure inputs could be discussed among the various potential study vendors.

We compiled a robust list of measures for each customer sector, drawing upon Berkshire's program experience, measures identified in coordination with the other Massachusetts Potential Study teams, the

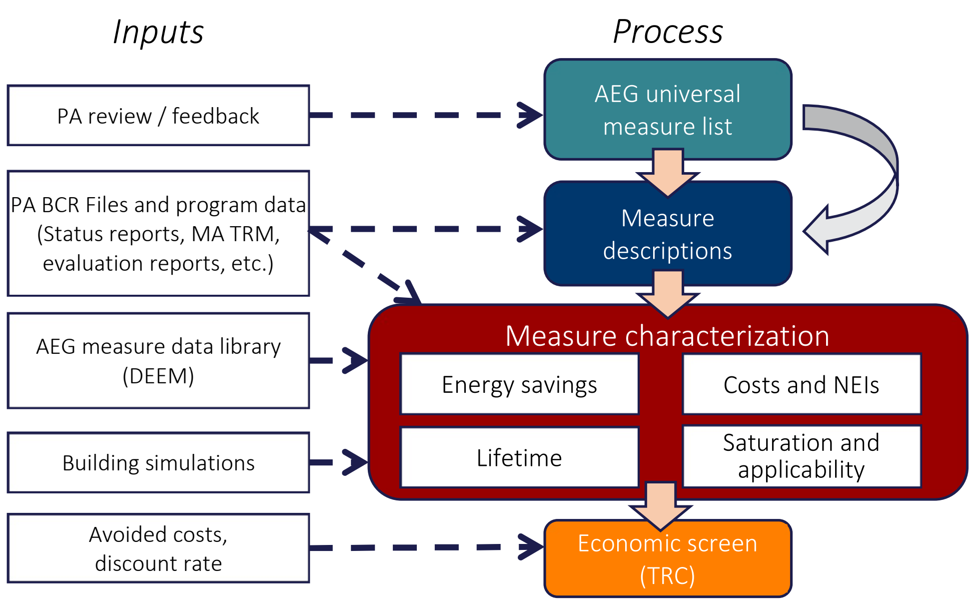
[2] The findings of the recently passed MA Clean Energy Climate Plan were not available in time to be incorporated into this analysis

[3] Apex Analytics served as a facilitator to assist PAs and vendors in coordinating their assumptions.

Massachusetts Technical Reference Manual (TRM), AEG's measure databases and building simulation models, and secondary sources. New and emerging technologies were identified for inclusion in the list through a detailed screening process that assessed the feasibility of measures. AEG engineers, through the AEG DEEM database, constantly monitor for new and emerging measures by following trends in energy-efficient technologies that are available on the market, as well as those expected to be on market in the coming years.

This universal list of measures covers all major types of end use equipment, as well as devices and actions to reduce energy consumption. If considered today, some of these measures would not pass the economic screens initially but may pass in future years as a result of lower projected equipment costs or higher avoided cost benefits.

Figure 2-3 Approach for Measure Assessment



The selected measures are categorized into two types according to the LoadMAP modeling taxonomy: equipment measures and non-equipment measures.

- **Equipment measures** are efficient energy consuming pieces of equipment that save energy by providing the same service with a lower energy requirement than a standard unit. An example is an ENERGY STAR® residential water heater that replaces a standard-efficiency water heater. For equipment measures, many efficiency levels may be available for a given technology, ranging from the baseline unit (often determined by code or standard) up to the most efficient product commercially available. These measures are applied on a stock-turnover basis, and in general, are referred to as lost opportunity measures since once a purchase decision is made, there will not be another opportunity to improve the efficiency of that equipment item until the lifetime expires again.
    - Equipment Life. Energy using equipment is modeled with both a minimum and maximum lifetime rather than a single average value. This provides a more real-world smooth curve of decaying and replaced equipment as opposed to a single mass failure in which a whole population of equipment would be replaced. Instead, the model assumes some equipment will be replaced earlier than the average lifetime, and some replacements may be delayed past the average useful life.

- Purchase Shares. In the base case, market data from surveys or the Department of Energy's Annual Energy Outlook (AEO) provide the foundational assumptions of how replacement or new construction equipment will be distributed across the available options. These purchase shares will then be altered in the potential scenarios according to their definitions above. For example, in the technical potential case, 100% of replacement and new construction purchases will be the most efficient option and for economic potential, 100% of purchases will be in the most efficient cost-effective option (if any). For the achievable cases, only a subset of the purchases is diverted to the economic efficiency option, defined by the participation rates.

- **Non-equipment measures** save energy by reducing the need for delivered energy, but typically do not involve replacement or purchase of major end use equipment (such as a furnace or water heater). Since measure installation is not tied to a piece of equipment reaching the end of its useful life, these are generally categorized as "retrofit" measures. Non-equipment measures can apply to more than one end use. An example would be insulation that modifies a household's space heating consumption, but does not change the efficiency of the furnace. The existing insulation can be achievably upgraded without waiting any existing equipment to malfunction, and saves energy used by the furnace. Non-equipment measures typically fall into one of the following categories:
  - Building shell (windows, insulation, roofing material)
  - Equipment controls (smart thermostats, water heater setback)
  - Whole-building design (advanced new construction)
  - Displacement measures (destratification fans to reduce use of space heating equipment)
  - Retro-commissioning
  - Energy management programs
  - Behavioral

Once we assembled the list of measures, AEG assessed their energy-saving parameters and characterized incremental cost, effective useful life (EUL), and other performance factors. Following the measure characterization, we performed an economic screening of each measure, which serves as the basis for developing the economic and achievable potentials.

Representative Measure Data Inputs

Table 2-2 and Table 2-3 present examples of the detailed data inputs behind both equipment and non-equipment measures, respectively, for the case of residential furnaces. Table 2-2 displays the various efficiency levels available as equipment measures, as well as the corresponding useful life, energy usage, and equipment cost estimates. The columns labeled On Market and Off Market reflect equipment availability due to codes and standards or the entry of new products to the market.

Table 2-2 Example Equipment Levels for Residential Furnaces (Single Family Homes)

Efficiency Level	Min. Life (years)	Max Life (years)	Full Equipment Cost	Energy Usage (therms/year)	On Market	Off Market
AFUE 85% (Baseline)	10	20	$3,148	480	2019	2023
AFUE 90% (Baseline 2023+)	10	20	$3,661	453	2019	n/a

ENERGY STAR (4.1) - AFUE 95%	10	20	$3,864	429	2019	n/a
AFUE 97%	10	20	$4,222	421	2019	n/a

Table 2-3 lists some of the non-equipment measures applicable to residential furnaces. All measures are evaluated for cost-effectiveness based on the lifetime benefits relative to the cost of the measure. The total savings, costs, and monetized non-energy benefits are calculated for each year of the study and depend on the base year saturation of the measure, the applicability[4] of the measure, and the savings as a percentage of the relevant energy end uses.

Table 2-3 Example Non-Equipment Measures

End Use	Measure	Base-Year Saturation[5]	Applicability	Lifetime (yrs)	Installed Cost per Unit	Energy Savings (therms/unit)	Analysis Unit
Space Heating	Insulation - Ceiling Installation	0%	5%	25	$1.22	0.03	Sq.ft (roof)
Space Heating	Insulation – Wall Cavity Installation	0%	5%	25	$1.72	0.04	Sq.ft (wall)
Space Heating	ENERGY STAR Connected Thermostat	35%	100%	15	$303	31.1	unit
Water Heating	Water Heater – Faucet Aerators	35%	100%	7	$3.00	2.1	faucet

Calculation of Energy Efficiency Potential

The approach used to calculate the energy efficiency potential adheres to the approaches and conventions outlined in the *National Action Plan for Energy-Efficiency (NAPEE) Guide for Conducting Potential Studies*.[6] This document represents credible and comprehensive industry best practices for specifying energy efficiency potential. Three types of potential developed as part of this effort are described below.

Technical Potential

The calculation of technical potential is a straightforward algorithm which, as described in the Definitions of Potential section, assumes that customers adopt all feasible measures regardless of their cost.

Economic Potential – Screening Measures for Cost-Effectiveness

With technical potential established, the next step is to apply an economic screen and arrive at the subset of measures that are cost-effective and ultimately included in achievable potential.

LoadMAP performs an economic screen for each individual measure in each year of the planning horizon. This study uses the TRC test as the cost-effectiveness metric, which compares the lifetime energy benefits and monetized non-energy impacts of each applicable measure with its costs. The lifetime benefits are calculated by multiplying the annual energy savings for each measure by Berkshire's avoided cost and

[4] Applicability factors take into account whether the measure is applicable to a particular building type and whether it is feasible to install the measure. For instance, duct repair and sealing is not applicable to homes with zonal heating systems since there is no ductwork present to repair.

[5] Note that saturation levels reflected for the base year change over time as more measures are adopted.

[6] National Action Plan for Energy Efficiency (2007). *National Action Plan for Energy Efficiency Vision for 2025: Developing a Framework for Change*. www.epa.gov/eeactionplan.

discounting the dollar savings to the present value equivalent. Lifetime costs include not only incremental measure cost, but also any non-energy impacts as quantified in the Massachusetts TRM – which may include one-time or annual values, also discounted to present value. The analysis uses the measure savings, costs, and lifetimes that were developed as part of the measure characterization process described in the Energy Efficiency Measure Development section.

The LoadMAP model performs the economic screening dynamically, taking into account changing savings and cost data over time. Thus, some measures might pass the TRC test for some — but not all — of the years in the forecast.

It is important to note the following about the economic screen:

- The economic evaluation of every measure in the screen is conducted relative to a baseline condition. For instance, in order to determine the energy savings potential of a measure, consumption with the measure applied must be compared to the consumption of a baseline condition.
- Economic screening is conducted only for measures that are applicable to each building type and vintage; thus, if a measure is deemed to be irrelevant to a building type and vintage, it is excluded from the respective economic screen.

The economic potential includes every program-ready opportunity for energy efficiency savings.

Achievable Potential - Estimating Customer Adoption

Once the economic potential is established, estimates for achievable customer adoption rates for each measure are applied specifying the percentage of customers assumed to select the highest–efficiency, cost-effective option. This phases potential in over a more realistic time frame that considers barriers such as imperfect information, supplier constraints, technology availability, and individual customer preferences.

For this potential study, AEG leveraged existing database of customer participation from across the country for territories similar to the PAs, then calibrated these adoption rates to match existing program performance, establishing the business-as-usual (BAU) case.

The BAU Plus and maximum achievable cases were then derived from the BAU case using lift factors that AEG developed through analysis of utility programs throughout the country and the scenario definitions agreed upon in coordination with the PA's potential study vendors.

- Business as usual (BAU): Pre-COVID incentive levels. Expected that 2022-2024 participation will look like the past and does not introduce new measures unless substantially similar to current program offerings.
- Business as Usual Enhanced (BAU Plus): Increases weatherization incentives to 90% of incremental cost, and other incentives by up to 50%, to a maximum of 90% (unless current incentives are already higher than this). In this scenario we also introduce adoption of cost-effective measures not currently part of existing programs, based on the average participation of existing program measures.
- Maximum Achievable: Takes all incentives to 100% and assumes best practices regarding program delivery and outreach.

Data Development

This section details the data sources used in this study, followed by a discussion of how these sources were applied. In general, data were adapted to local conditions, for example, by using local sources for measure data and local weather for building simulations.

Data Sources

The data sources are organized into the following categories:

- Berkshire-specific data
- Massachusetts Statewide Residential and Commercial surveys
- Cadeo's analysis and research
- AEG's databases and analysis tools
- Other secondary data and reports

Berkshire Data

Our highest priority data sources for this study were those that were specific to Berkshire.

- **Berkshire customer account database.** The data request included billing data for 2019, the most recent year for which complete billing data was available. Berkshire provided 2019 natural gas sales and customers by sector.
- **Load forecast data.** Berkshire provided the following forecast data: customer growth forecasts, and sales forecasts.
- **Energy efficiency program data (BCR Models).** Berkshire provided historical energy efficiency program accomplishments for 2019.

Massachusetts State Data

- Massachusetts Baseline studies for the residential and commercial sectors
- Economic Information. Avoided costs and discount rate from the 2021 Avoided Energy Supply Components study (AESC), final draft
- Massachusetts Statewide Technical Reference Manual (TRM) : AEG used the 2019 Report edition of the Massachusetts TRM

Cadeo Analysis and Research

Cadeo contributed research and analysis to improve the clarity of data used to inform the potential study, utilizing existing data source noted in this section as well as their past experience with energy efficiency programs in the region, including:

- Analysis of the current and past Massachusetts Commercial baseline studies in combination with the EIA data noted below to improve the quality of the commercial natural gas market characterization
- Reviewed program history in the PA territories to provide insight and analysis on the remaining market available for residential measures

AEG Data

AEG maintains several databases and modeling tools that we use for forecasting and potential studies. Relevant data from these tools has been incorporated into the analysis and deliverables for this study.

- **AEG Energy Market Profiles.** For more than 15 years, AEG staff has maintained profiles of end use consumption for the residential, commercial, and industrial sectors. These profiles include market size, fuel shares, unit consumption estimates, and annual energy use by fuel, customer segment and end use for 10 regions in the U.S. The Energy Information Administration surveys (RECS, CBECS and MECS) as well as state-level statistics and local customer research provide the foundation for these regional profiles.

- **Building Energy Simulation Tool (BEST)**. AEG's BEST is a derivative of the DOE 2.2 building simulation model, used to estimate base-year UECs and EUIs, as well as measure savings for the HVAC-related measures.
- **AEG's Database of Energy Efficiency Measures (DEEM).** AEG maintains an extensive database of measure data for our studies. Our database draws upon reliable sources including the California Database for Energy Efficient Resources (DEER), the EIA Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case, RS Means cost data, and Grainger Catalog cost data.
- **Recent studies**. AEG has conducted more than sixty studies of EE potential in the last five years. We checked our input assumptions and analysis results against the results from these other studies, within the region and numerous studies from across the U.S.

Other Secondary Data and Reports

Finally, a variety of secondary data sources and reports were used for this study. The main sources are identified below.

- **Annual Energy Outlook**. The Annual Energy Outlook (AEO), conducted each year by the U.S. Energy Information Administration (EIA), presents yearly projections and analysis of energy topics. For this study, we used data from the 2019 AEO.
- **Energy Information Administration Surveys**. The Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) provided supplemental and benchmarking data for market characterization.
- **Local Weather Data**. Weather data (heating degree days both actual and normal) was provided by the PAs
- **Other relevant resources:** These include reports from the Consortium for Energy Efficiency, the Environmental Protection Agency, and the American Council for an Energy-Efficient Economy.

Application of Data to the Analysis

We now discuss how the data sources described above were used for each step of the study.

Data Application for Market Characterization

To construct the high-level market characterization of energy consumption and market size units (households for residential, floor space for commercial), we used Berkshire-provided billing data, Massachusetts baseline studies, and secondary data from AEG's Energy Market Profiles databases.

Data Application for Market Profiles

The specific data elements for the market profiles, together with the key data sources, are shown in Table 2-4. To develop the market profiles for each segment, we used the following approach:

1. Developed control totals for each segment, which are the authoritative total market size, segment-level annual natural gas, and annual intensity (use per customer or market unit) to which the models will be calibrated. This analysis relied primarily on detailed customer data provided by the PAs which included designations of customer type (such as single family residence or commercial office), as well as data on building/home size and associated energy consumption.

2. Compared and cross-checked with other recent AEG studies.
3. Worked with Berkshire staff to vet the data against their knowledge and experience.

Table 2-4 Data Applied to the Market Profiles

Model Inputs	Description	Key Sources
Annual energy consumption	Base-year energy consumption by sector as well as detailed market segment	Berkshire account database Berkshire customer surveys Berkshire Load Forecasts
Market size	Base-year residential dwellings, commercial floor space	Berkshire customer forecasts Berkshire account database Berkshire customer surveys Previous Berkshire MPS
Annual intensity	Residential: Annual use per household Commercial and Industrial: Annual use per square foot	Berkshire customer surveys AEG's Energy Market Profiles Other recent studies
Appliance/equipment saturations	Fraction of dwellings with an appliance/technology Percentage of C&I floor space with equipment/technology	Massachusetts Baseline Studies American Community Survey (ACS) Previous Berkshire MPS AEG's Energy Market Profiles
UEC/EUI for each end use technology	UEC: Annual natural gas use in homes and buildings that have the technology EUI: Annual natural gas use per square foot for a technology in floor space that has the technology	Massachusetts TRM HVAC uses: BEST simulations using prototypes developed for Berkshire AEG's DEEM Recent AEG studies
Appliance/equipment age distribution	Age distribution for each technology	Massachusetts Baseline Studies Previous Berkshire MPS Recent AEG Studies

Data Application for Baseline Projection

Table 2-5 summarizes the LoadMAP model inputs required for the market profiles. These inputs are required for each segment in each sector, as well as for new construction and existing dwellings/buildings.

Table 2-5 Data Applied for the Baseline Projection in LoadMAP

Model Inputs	Description	Key Sources
Customer growth forecasts	Forecasts of new construction and turnover of existing buildings in residential and C&I sectors	Berkshire customer forecasts
Equipment purchase shares for baseline projection	For each equipment/technology, purchase shares for each efficiency level; specified separately for existing equipment replacement and new construction	Shipment data from AEO and ENERGY STAR AEO regional forecast assumptions[7] Appliance/efficiency standards analysis

In addition, assumptions were incorporated for known future equipment standards as of January 2020, as shown in Table 2-6 and Table 2-7. The assumptions tables here extend through 2025, after which all standards are assumed to hold steady.

Table 2-6 Residential Natural Gas Equipment Standards

End Use	Technology	2020	2021	2022	2023	2024	2025
Space Heating	Furnace – Direct Fuel	AFUE 85%				AFUE 92%*	
	Boiler – Direct Fuel	AFUE 84%					
Secondary Heating	Fireplace	N/A					
Water Heating	Water Heater <= 55 gal.	UEF 0.60					
	Water Heater > 55 gal.	UEF 0.603					
Appliances	Clothes Dryer	CEF 3.30					
	Stove/Oven	N/A					
Miscellaneous	Pool Heater	TE 0.82					
	Miscellaneous	N/A					

[7] We developed baseline purchase decisions using the Energy Information Agency's *Annual Energy Outlook* report (2019), which utilizes the National Energy Modeling System (NEMS) to produce a self-consistent supply and demand economic model. We calibrated equipment purchase options to match distributions/allocations of efficiency levels to manufacturer shipment data for recent years and then held values constant for the study period.

Table 2-7 Commercial and Industrial Natural Gas Equipment Standards

End Use	Technology	2020	2021	2022	2023	2024	2025
Space Heating	Furnace	AFUE 85% / TE 0.85					
	Boiler	Industry Standard Practice Baseline (AFUE 85%)					
	Unit Heater	Standard (intermittent ignition and power venting or automatic flue damper)					
Water Heater	Water Heating	TE 0.80					

Efficiency Measure Data Application

Table 2-8 details the energy-efficiency data inputs to the LoadMAP model. It describes each input and identifies the key sources used in the Berkshire analysis.

Table 2-8 Data Needs for the Measure Characteristics in LoadMAP

Model Inputs	Description	Key Sources
Energy Impacts	The annual reduction in consumption attributable to each specific measure. Savings were developed as a percentage of the energy end use that the measure affects.	1. MA TRM Algorithms or deemed savings 2. AEO 2019 3. Building Energy Simulations 4. AEG DEEM library 5. Other secondary sources
Costs	Equipment Measures: Includes the full cost of purchasing and installing the equipment on a per-household, per-square-foot, or per employee basis for the residential and commercial sectors, respectively. Non-Equipment Measures: Existing buildings – full installed cost. New Construction - the costs may be either the full cost of the measure, or as appropriate, it may be the incremental cost of upgrading from a standard level to a higher efficiency level.	1. PA BCR files (EM&V) 2. AEO 2019 3. AEG DEEM 4. Other secondary sources
Measure Lifetimes	Estimates derived from the technical data and secondary data sources that support the measure demand and energy savings analysis.	1. MA TRM 2. AEO 2019 3. AEG DEEM 4. Other secondary sources
Applicability	Estimate of the percentage of dwellings in the residential sector, or square feet in the commercial sector, where the measure is applicable and where it is technically feasible to implement.	1. MA TRM 2. MA Baseline Studies and PA specific inputs 3. AEG DEEM 4. Other secondary sources
On Market and Off Market Availability	Expressed as years for equipment measures to reflect when the equipment technology is available or no longer available in the market.	AEG appliance standards and building codes analysis

Data Application for Cost-Effectiveness Screening

To the extent feasible, costs for measures in the potential study were derived from the BCR files provided by the PAs. In cases where costs needed to be normalized and adjusted for different customer segments (e.g., properly sizing furnaces for different home sizes or commercial buildings), values from well vetted sources such as the US Energy Information Administration were used to supplement the BCR data.

To perform the cost-effectiveness screening, a number of economic assumptions were needed. All cost and benefit values were analyzed as real 2020 dollars, using information from the AESC study including:

- Avoided costs of energy
- DRIPE values and other benefits
- Discount rate (real)[8]

Estimates of Customer Adoption Rates

Adoption rates for equipment and non-equipment measures are described separately below.

Customer adoption rates, also referred to as take rates or ramp rates, are applied to measures on a year-by-year basis. These rates represent customer adoption of measures when delivered through a portfolio of well-operated efficiency programs under a reasonable policy or regulatory framework. The approach for estimating Berkshire adoption rates had two parts:

1. **Initial adoption rate assumptions from AEG past research.** AEG has performed numerous market research studies in various jurisdictions across the country and initially developed potential estimates using adoption rates based on this past research in territories broadly analogous to Berkshire's as a first stepping stone towards BAU potential.
2. **Calibrating adoption rates to current programs** . AEG next compared Berkshire's historic program participation and accomplishments to the model's initial estimate to determine necessary adjustments.

To recap, BAU adoption rates were estimated as follows:

  - Group measures in the potential study into categories that align with existing Berkshire programs
  - Assess achievable potential using AEG's past research and estimates of participation
  - Calibrate the final BAU participation by comparing participation in current programs to potential under AEG's original assumptions and adjusting the participation rates accordingly

- These adoption rates are applied to economic potential in 2022-2024 to compute achievable potential.
- Adoption rates are held fixed for the three-year planning period. Assuming the same incentive and delivery structure across these three years (for BAU), participation is assumed to hold constant.
- The BAU Plus and Maximum Achievable cases were produced by applying a "lift" factor to the BAU adoption rates. AEG's previous market research into customer behavior and program interest provided guidance on the amount of increased adoption that could be expected under each of the defined scenarios.
- Adoption rates for each potential case are provided in the appendix worksheet accompanying this report.

Technical diffusion curves for non-equipment measures. While equipment measures are driven by the stock turnover model and have a natural limit to how many units come available in a given year, non-equipment measures do not have this natural periodicity. A home's insulation or thermostat, for

[8] Discount rate was 0.81%, taken from the AESC 2021 final workbooks.

example, can be upgraded or replaced at any time, and there is rarely a "failure" condition that would force this decision. To reflect this, rather than installing all available non-equipment measures in the first year of the projection (instantaneous potential), AEG generally assumes these measures phase in over a 20-year period, providing a steady rollout of available market for each year.

Following this technical diffusion step, the process from technical to economic and achievable adoption and potential follows the same sequence as above.

3

ANALYSIS AND RESULTS

This section details the study results and potential estimates for Berkshire as a whole and by sector.

Overall Energy Efficiency Potential

This section presents the natural gas energy efficiency potential for the planning period 2022-2024.

Incremental Potential for Planning Cycle Years

First-year potential savings for 2022 through 2024 are presented in Table 3-1. The achievable BAU potential is in the range of 292,560 therms to 300,869 therms per year, or 0.4% of the baseline projection. BAU Plus potential is approximately 18% higher with a range of 344,390 therms to 352,753 therms per year, or 0.47% of the baseline. Maximum achievable potential is approximately 53% higher than BAU, with a range of 447,623 therms to 455,564 therms per year, or 0.61% of the baseline.

Notably, the majority of technical potential is economic, which is unusual in most potential studies, but due in this case to very high avoided costs in Massachusetts and significant non-energy impacts associated with a number of measures.

Table 3-1 Berkshire Gas First-Year Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Reference Baseline	**74,730,936**	**74,831,660**	**74,978,604**
First-year Savings			
Achievable BAU	292,560	298,094	300,869
Achievable BAU Plus	344,396	349,943	352,753
Achievable Max	447,623	453,260	455,564
Economic	1,039,842	1,044,128	1,041,522
Technical	1,346,103	1,349,256	1,349,515
Savings as % of Baseline			
Achievable BAU	0.39%	0.40%	0.40%
Achievable BAU Plus	0.46%	0.47%	0.47%
Achievable Max	0.60%	0.61%	0.61%
Economic	1.39%	1.40%	1.39%
Technical	1.80%	1.80%	1.80%

Table 3-2 presents the breakout of each level of potential by sector. The commercial sector accounts for the larger share of Achievable BAU potential, approximately 52% of achievable BAU potential savings in each year as illustrated in Figure 3-1.

Table 3-2 Berkshire First-Year Achievable Savings Potential by Sector (Therms)

Achievable Potential by Sector	2022	2023	2024
Achievable BAU Potential			
Residential	125,077	122,988	120,566
Commercial	149,763	156,699	161,451
Industrial	17,720	18,406	18,852
Achievable BAU Plus Potential			
Residential	146,172	143,796	141,280
Commercial	176,969	184,196	189,081
Industrial	21,254	21,951	22,392
Achievable Max Potential			
Residential	206,145	202,397	198,493
Commercial	215,541	224,104	229,804
Industrial	25,938	26,758	27,267
Economic Potential			
Residential	393,926	383,323	373,992
Commercial	601,591	615,881	622,299
Industrial	44,325	44,924	45,230
Technical Potential			
Residential	462,068	450,440	440,349
Commercial	839,581	853,765	863,810
Industrial	44,454	45,051	45,356

Figure 3-1 Berkshire BAU Achievable Savings by Sector

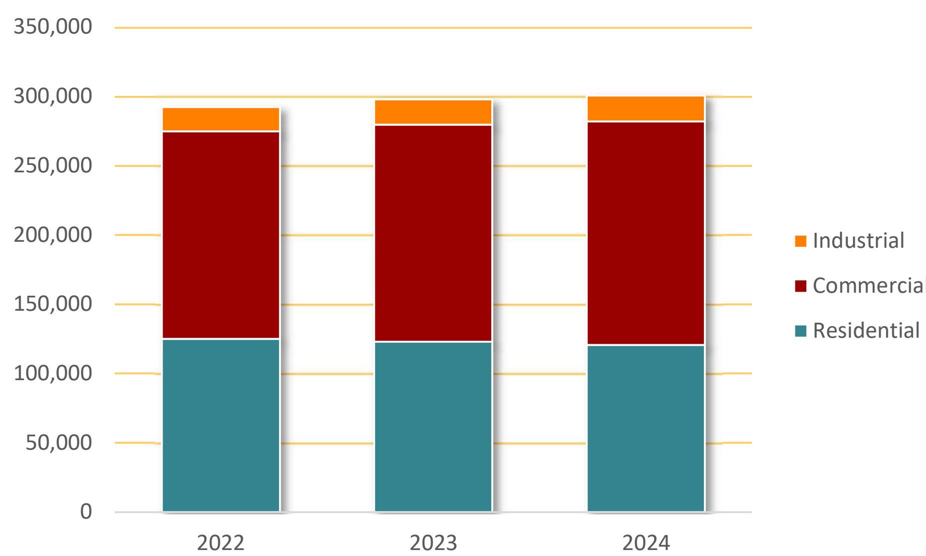


Table 3-3 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Berkshire's actual costs will naturally vary.

Table 3-3 Berkshire Natural Gas Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$4,166,284	$4,122,425	$4,144,235
BAU Plus	$5,760,972	$5,697,213	$5,725,179
Max	$8,702,535	$8,587,095	$8,618,120

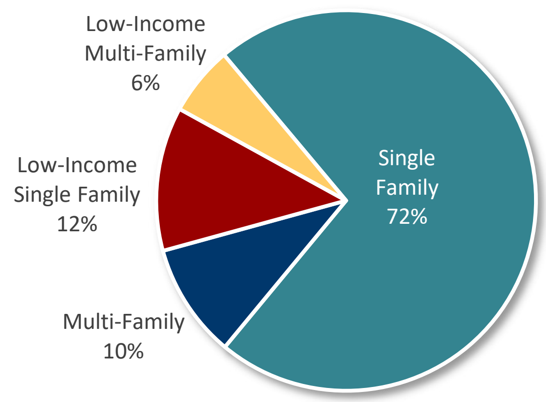
Residential Sector

In 2019, there were approximately 58,742 households in Berkshire's Residential sector that used a total of 3,633,185 Dth. These numbers are inclusive of estimated multifamily apartment dwellings billed on commercial rate classes[9]. Average use per household was 619 therms.

AEG relied on customer segmentation information already contained in the billing data for classification of residential customers into single and multifamily homes, and into low income and non-low-income households. Household counts for some mass-metered multifamily buildings were estimated using RECS[10] average consumption per home and the total consumption of the building.

As shown in Table 3-4, non-low-income single family[11] customers account for 72% of total usage, and multi-family customers account for 10% (Figure 3-2). Low-income single family and multi-family customers together account for the remaining 18%.

Figure 3-2 Berkshire Residential Use by Segment, 2019



[9] Though they are on a commercial rate class and often targeted through commercial programs, the energy use characteristics for multifamily apartments, and the resulting potential, are best modeled through the residential sector in our process. C&I metered multifamily accounts for ~51% of multifamily consumption, or ~8% of the overall residential consumption shown here.

[10] DOE Residential Energy Consumption Survey, data for New England households with natural gas

[11] Single family here includes homes with 2-4 units (aka single family attached)

Table 3-4 Berkshire Residential Control Totals, 2019

Segment	Households	Annual Use (Dth)	Intensity (therms / HH)
Single Family	32,683	2,620,978	32,683
Multi-Family	9,105	352,388	9,105
Low-Income Single Family	5,897	445,244	5,897
Low-Income Multi-Family	5,888	214,575	5,888
Total	**53,573**	**3,633,185**	**53,573**

Figure 3-3 shows the average annual natural gas consumption by end use for all residential customers. Space heating accounts for the largest amount total usage, followed by water heating.

Figure 3-4 presents the energy intensity by end use and housing type. Single family homes have the highest use per household at 800 therms per year.

Figure 3-3 Berkshire Residential Gas Consumption by End Use, 2019

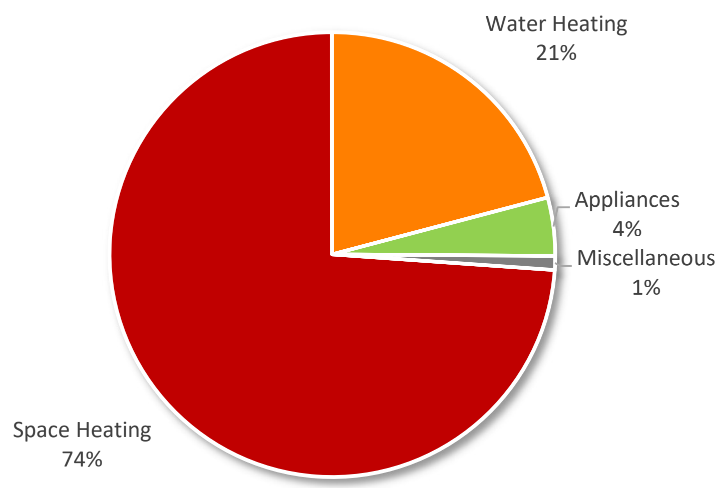
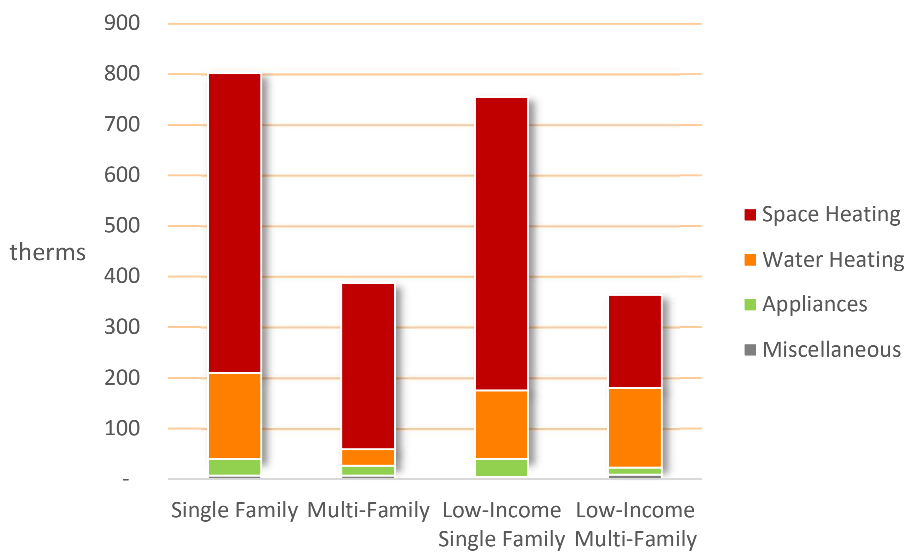


Figure 3-4 Berkshire Residential Natural Gas Intensity by End Use and Segment, 2019



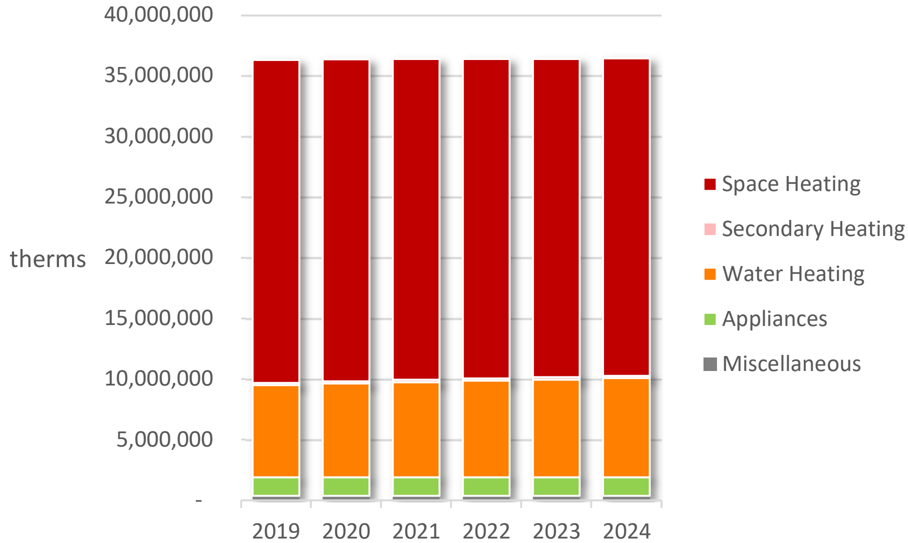
Residential Baseline Projection

Table 3-5 presents AEG's natural gas baseline projection at the end use level for the residential sector. The projection includes effects of standards, codes, and naturally occurring conservation, but not future DSM program activity (see Chapter 2 for more details on the development of the baseline). The projection shows very slight growth in consumption from 2019-2024 due to the net effect of market growth opposed by turnover of vintage equipment into code or higher models. Figure 3-5 illustrates the total residential baseline project by end use in therms.

Table 3-5 Berkshire Residential Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	26,642,089	26,558,785	26,461,062	26,355,235	26,250,509	26,172,822
Secondary Heating	194,532	195,142	195,530	195,701	195,745	196,004
Water Heating	7,595,171	7,724,017	7,843,281	7,953,149	8,057,897	8,173,691
Appliances	1,537,162	1,539,546	1,540,143	1,539,129	1,537,325	1,537,575
Miscellaneous	362,897	364,522	365,693	366,432	366,907	367,694
Total	**36,331,851**	**36,382,012**	**36,405,709**	**36,409,646**	**36,408,382**	**36,447,786**

Figure 3-5 Berkshire Residential Baseline Projection by End Use



Residential Potential

Table 3-6 presents the residential sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 125,077 therms, or 0.34% of the baseline projection.

Table 3-6 Berkshire Summary of Residential Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**36,409,646**	**36,408,382**	**36,447,786**
Potential Savings			
Achievable BAU	125,077	122,988	120,566
Achievable BAU Plus	146,172	143,796	141,280
Achievable Max	206,145	202,397	198,493
Economic	393,926	383,323	373,992
Technical	462,068	450,440	440,349
Potential Savings as % of Baseline			
Achievable BAU	0.34%	0.34%	0.33%
Achievable BAU Plus	0.40%	0.39%	0.39%
Achievable Max	0.57%	0.56%	0.54%
Economic	1.08%	1.05%	1.03%
Technical	1.27%	1.24%	1.21%

The single family segment accounts for more than two-thirds of the residential savings (67%). The low-income single family segment represents 17% of the savings with the multi-family segments representing 16% of the savings combined. Single family dwellings include buildings with 2-4 units.

Figure 3-6 Berkshire Residential Natural Gas Potential by Segment

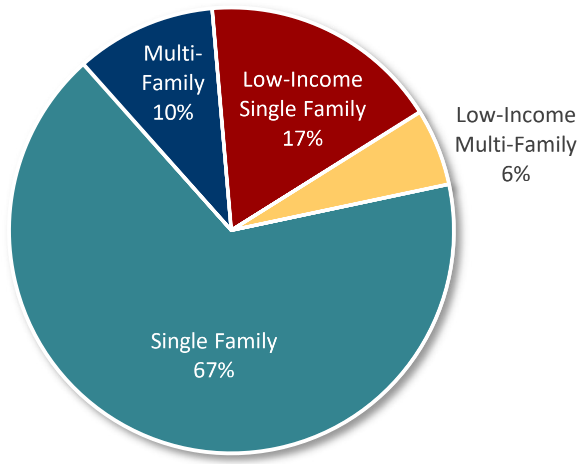


Table 3-7 shows residential potential by segment for all cases and for each year of the planning cycle.

Table 3-7 Residential Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Single Family	83,355	81,915	80,452
	Multi-Family	13,097	12,767	12,333
	Low-Income Single Family	21,534	21,341	21,056
	Low-Income Multi-Family	7,092	6,965	6,724
BAU Plus	Single Family	97,397	95,757	94,251
	Multi-Family	15,713	15,349	14,895
	Low-Income Single Family	24,806	24,579	24,285
	Low-Income Multi-Family	8,256	8,110	7,848
BAU Max	Single Family	138,342	135,725	133,347
	Multi-Family	21,626	21,097	20,433
	Low-Income Single Family	34,765	34,382	33,905
	Low-Income Multi-Family	11,412	11,193	10,808
Economic	Single Family	275,618	267,923	262,139
	Multi-Family	36,220	35,183	33,847
	Low-Income Single Family	56,397	55,194	53,943
	Low-Income Multi-Family	25,691	25,023	24,064
Technical	Single Family	324,851	316,486	310,224
	Multi-Family	43,426	42,199	40,705
	Low-Income Single Family	65,260	63,953	62,630
	Low-Income Multi-Family	28,532	27,802	26,790

Figure 3-7 breaks down potential according to the end use and measure category (equipment or non-equipment). The "weatherization & controls" category, affecting the space heating end use, accounts for the largest share of the residential BAU achievable potential, followed by space heating and water heating equipment.

Figure 3-7 Berkshire Residential Natural Gas Achievable BAU Potential by End Use

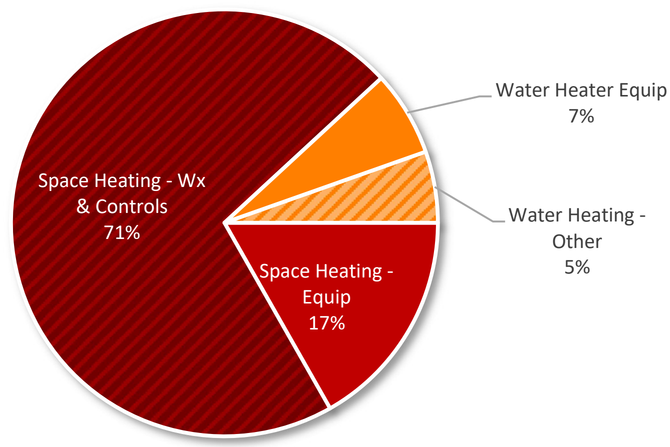


Table 3-8 shows potential broken out by vintage – new construction vs existing buildings.

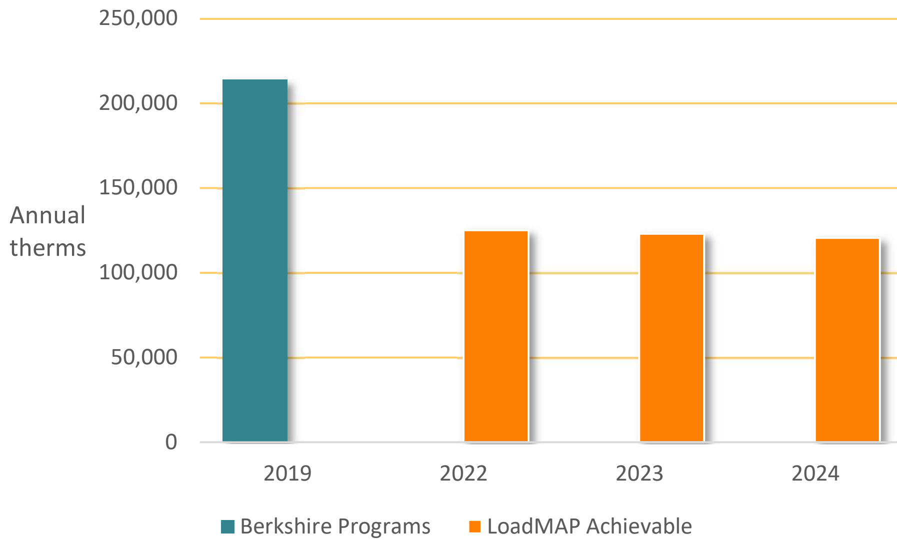
Table 3-8 Residential Natural Gas Potential (therms) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	120,772	119,283	116,866
	New	4,305	3,705	3,700
BAU Plus	Existing	140,825	139,225	136,586
	New	5,347	4,570	4,693
BAU Max	Existing	198,420	195,814	191,737
	New	7,724	6,583	6,756
Economic	Existing	372,995	365,800	355,365
	New	20,931	17,523	18,627
Technical	Existing	440,613	432,449	421,130
	New	21,454	17,991	19,219

Finally, Figure 3-8 compares the residential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. While measure participation is similar to Berkshire's past achievements, savings per unit against the market average for some equipment types – notably boilers, furnaces, and water heaters – are smaller due to the effects of naturally occurring efficient purchases in the reference baseline as taken from AEO's future purchase assumptions[12].

[12] See chapter 2 for a description of the counterfactual baseline and how AEO data informs the reference baseline

Figure 3-8 Berkshire Natural Gas Residential Savings Historical Comparison



Commercial Sector

In 2019, Berkshire commercial customers used a total of 3,108,963 Dth. We allocated this usage to nine commercial segments, shown in Table 3-9. As shown in Figure 3-9, the miscellaneous segment accounted for approximately 19% of the total commercial natural gas consumed in 2019, followed by office (17%), retail (17%), education (14%), lodging (13%), warehouse (10%), restaurant (4%), and grocery (2%). Please note that industrial customers are segmented separately later in this section.

Table 3-9 Berkshire Commercial Control Totals, 2019

Segment	Annual Use (Dth)	Intensity (therm/sqft)	Floor Space (Million Sq. Ft.)
Office	537,606	0.42	12.79
Retail	537,347	0.32	16.95
Restaurant	116,214	1.37	0.85
Grocery	45,050	0.71	0.64
Education	443,265	0.45	9.91
Healthcare	107,756	0.91	1.19
Lodging	413,971	0.55	7.56
Warehouse	307,306	0.43	7.22
Misc.	600,449	0.66	9.15
Total	**3,108,963**	**0.47**	**66.25**

Figure 3-9 Berkshire Commercial Use by Segment, 2019

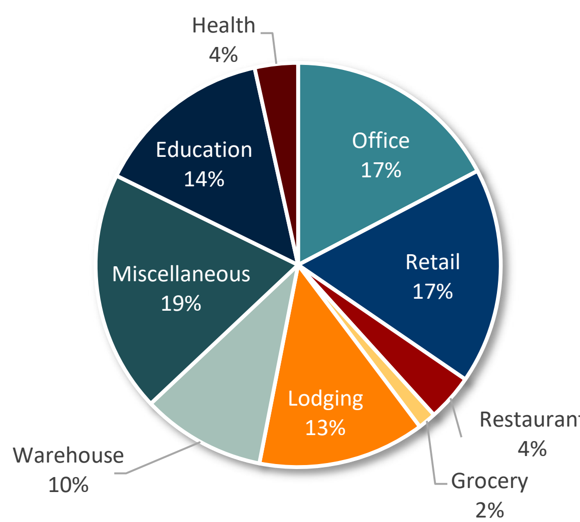
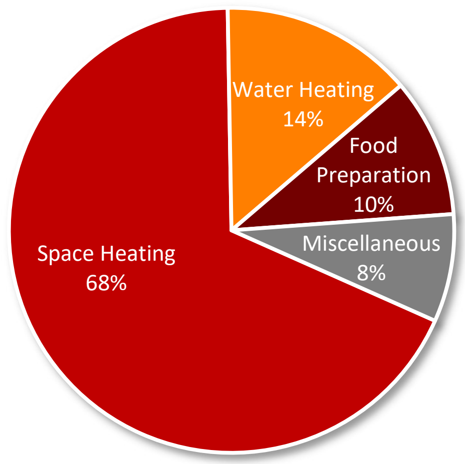


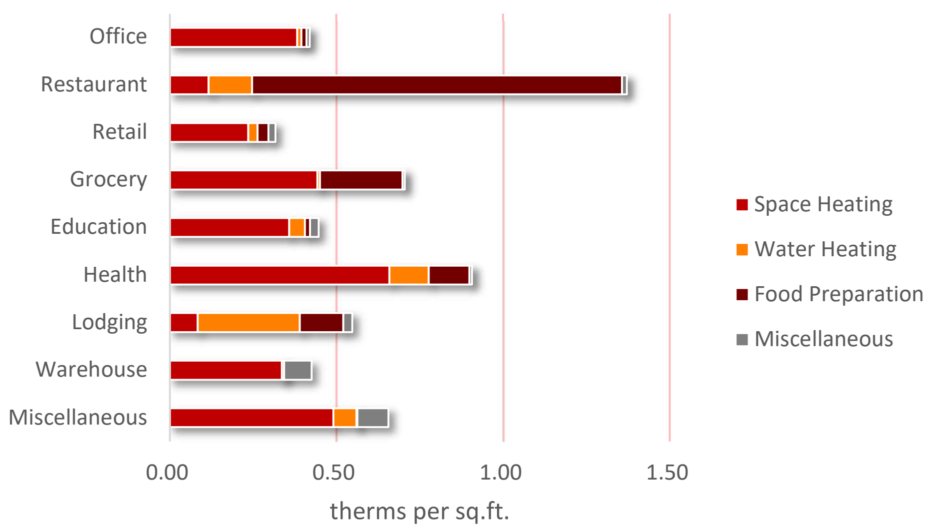
Figure 3-10 shows the distribution of annual natural gas consumption by end use across all commercial buildings. Space heating accounts for roughly two-thirds of commercial natural gas consumption.

Figure 3-10 Berkshire Commercial Natural Gas Consumption by End Use, 2019



As shown in Figure 3-11, natural gas intensity by end use varies significantly across segments. For example, due to cooking equipment consumption, the restaurant segment is the most energy intensive, with significantly higher usage per square foot than any other segment.

Figure 3-11 Berkshire Commercial Intensity by End Use and Segment, 2019



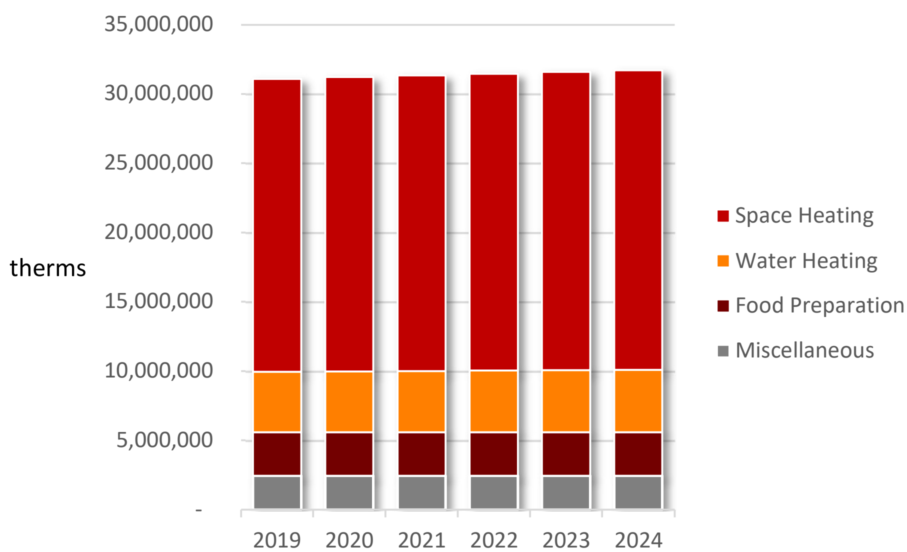
Commercial Baseline Projection

Table 3-10 presents AEG's independent natural gas baseline projection[13] at the end use level for the commercial sector.

Table 3-10 Berkshire Commercial Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	21,154,660	21,245,940	21,339,633	21,434,391	21,529,048	21,622,600
Water Heating	4,352,995	4,382,672	4,412,997	4,443,274	4,472,913	4,501,417
Food Preparation	3,148,389	3,148,389	3,148,389	3,148,389	3,148,389	3,148,389
Miscellaneous	2,433,590	2,433,590	2,433,590	2,433,590	2,433,590	2,433,590
Total	**31,089,633**	**31,210,591**	**31,334,608**	**31,459,643**	**31,583,940**	**31,705,996**

Figure 3-12 Berkshire Commercial Baseline Projection by End Use



[13] As noted elsewhere above, this is the counterfactual, no-DSM projection based on market growth assumptions provided by Berkshire

Commercial Potential

Table 3-11 presents the commercial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 149,763 therms, or 0.48% of the baseline projection.

Table 3-11 Berkshire Summary of Commercial Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**31,459,643**	**31,583,940**	**31,705,996**
Potential Savings			
Achievable BAU	149,763	156,699	161,451
Achievable BAU Plus	176,969	184,196	189,081
Achievable Max	215,541	224,104	229,804
Economic	601,591	615,881	622,299
Technical	839,581	853,765	863,810
Potential Savings as % of Baseline			
Achievable BAU	0.48%	0.50%	0.51%
Achievable BAU Plus	0.56%	0.58%	0.60%
Achievable Max	0.69%	0.71%	0.72%
Economic	1.91%	1.95%	1.96%
Technical	2.67%	2.70%	2.72%

Achievable BAU potential for 2022 through 2024 is primarily accounted for in lodging (38%) followed by restaurant (22%) and retail (9%) segments (Figure 3-13).

Figure 3-13 Berkshire Commercial Natural Gas Achievable BAU Potential by Segment

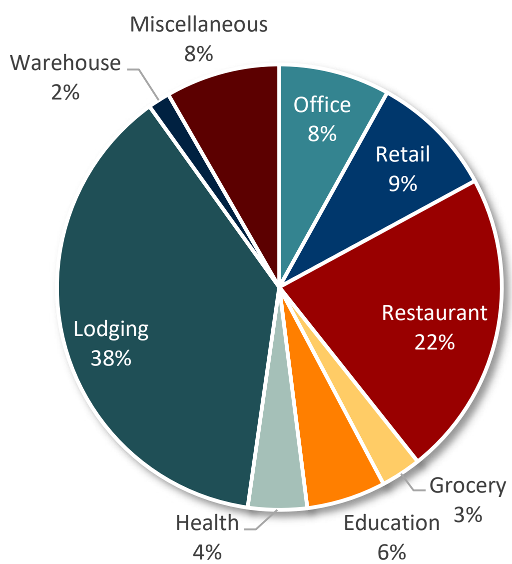


Table 3-12 shows commercial potential by segment for each potential case and for each year of the planning cycle.

Table 3-12 Commercial Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Office	12,227	12,662	13,000
	Retail	13,961	14,309	14,589
	Restaurant	32,433	34,377	35,906
	Grocery	4,290	4,534	4,728
	Education	9,399	9,710	9,269
	Health	6,388	6,692	6,929
	Lodging	55,817	58,740	61,004
	Warehouse	2,439	2,515	2,578
	Miscellaneous	12,808	13,160	13,450
BAU Plus	Office	17,207	17,651	17,987
	Retail	17,440	17,800	18,086
	Restaurant	35,797	37,936	39,619
	Grocery	4,817	5,084	5,296
	Education	13,201	13,517	13,005
	Health	7,746	8,073	8,328
	Lodging	57,420	60,372	62,659
	Warehouse	3,207	3,286	3,352
	Miscellaneous	20,134	20,476	20,749
BAU Max	Office	22,515	23,092	23,530
	Retail	22,811	23,275	23,642
	Restaurant	45,782	48,517	50,667
	Grocery	6,303	6,653	6,929
	Education	17,273	17,685	17,013
	Health	10,136	10,564	10,897
	Lodging	60,382	63,444	65,821
	Warehouse	4,196	4,300	4,385
	Miscellaneous	26,143	26,575	26,918
Economic	Office	104,177	104,844	105,152
	Retail	102,976	104,556	105,667
	Restaurant	53,408	56,364	58,685
	Grocery	10,603	11,167	11,619
	Education	74,396	75,419	71,801
	Health	20,810	21,436	21,915
	Lodging	115,805	121,081	125,256
	Warehouse	29,931	30,348	30,658

Case	Segment	2022	2023	2024
	Miscellaneous	89,485	90,668	91,546
Technical	Office	162,998	162,631	161,917
	Retail	127,837	130,229	132,123
	Restaurant	53,408	56,364	58,685
	Grocery	12,128	12,680	13,120
	Education	166,748	166,251	164,924
	Health	38,708	39,220	39,580
	Lodging	117,352	122,812	127,168
	Warehouse	49,202	50,267	51,204
	Miscellaneous	111,200	113,311	115,090

Table 3-13 shows potential by case and vintage – new construction vs existing buildings.

Table 3-13 Commercial Natural Gas Potential (therms) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	113,071	120,416	125,574
	New	36,692	36,283	35,877
BAU Plus	Existing	137,756	145,371	150,639
	New	39,213	38,825	38,441
BAU Max	Existing	168,750	177,740	183,864
	New	46,791	46,364	45,941
Economic	Existing	498,267	512,414	518,808
	New	103,324	103,467	103,491
Technical	Existing	716,119	724,064	728,141
	New	123,462	129,701	135,669

Industrial Sector

In 2019, Berkshire industrial customers used a total of 687,661 Dth). We allocated this usage to 10 industrial segments based on a combination of direct assignment for large customer accounts and distribution of the remaining consumption according to MECS[14] averages. As shown in Table 3-14, the chemical manufacturing segment accounts for approximately 25% of the total natural gas consumed in 2019, followed by paper and printing (20%), other industrial (19%), food (12%), petroleum and coal products (9%), primary metals (6%), plastic and rubber products (6%), and machinery (3%). Wood products and textiles each make up less than 1% of natural gas consumed.

[14] DOE Manufacturing Energy Consumption Survey

Although some of these customer segments are not significant consumers of energy in Berkshire's territory, the Industrial segment list was developed in coordination across Berkshire, Liberty, and Unitil and reflects segments that are significant for at least one of them.

Table 3-14 Berkshire Industrial Control Totals, 2019

Segment	Annual Use (Dth)	Annual Use (% of therms)
Chemicals	172,802	25.10%
Food	79,484	11.60%
Paper & Printing	134,735	19.60%
Petroleum & Coal Products	63,485	9.20%
Primary Metals	38,115	5.50%
Textiles	3,110	0.50%
Plastics & Rubber Products	42,467	6.20%
Machinery	23,600	3.40%
Wood Products	2,927	0.40%
Other Industrial	126,936	18.50%
Total	**687,661**	**100.0%**

Figure 3-14 Berkshire Industrial Use by Segment, 2019

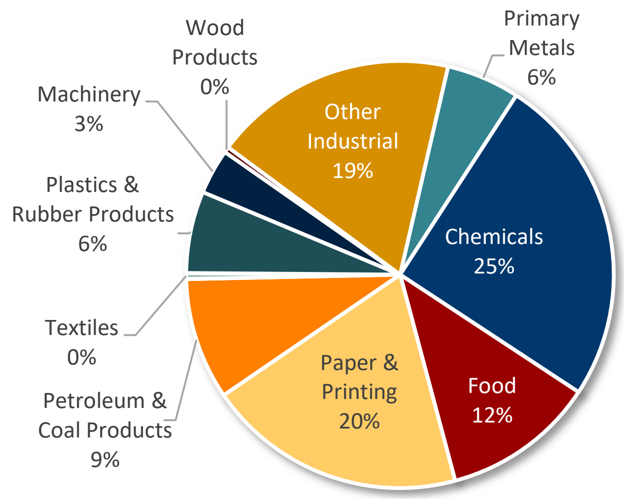
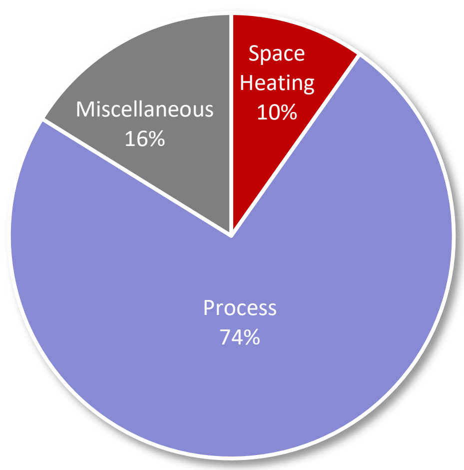


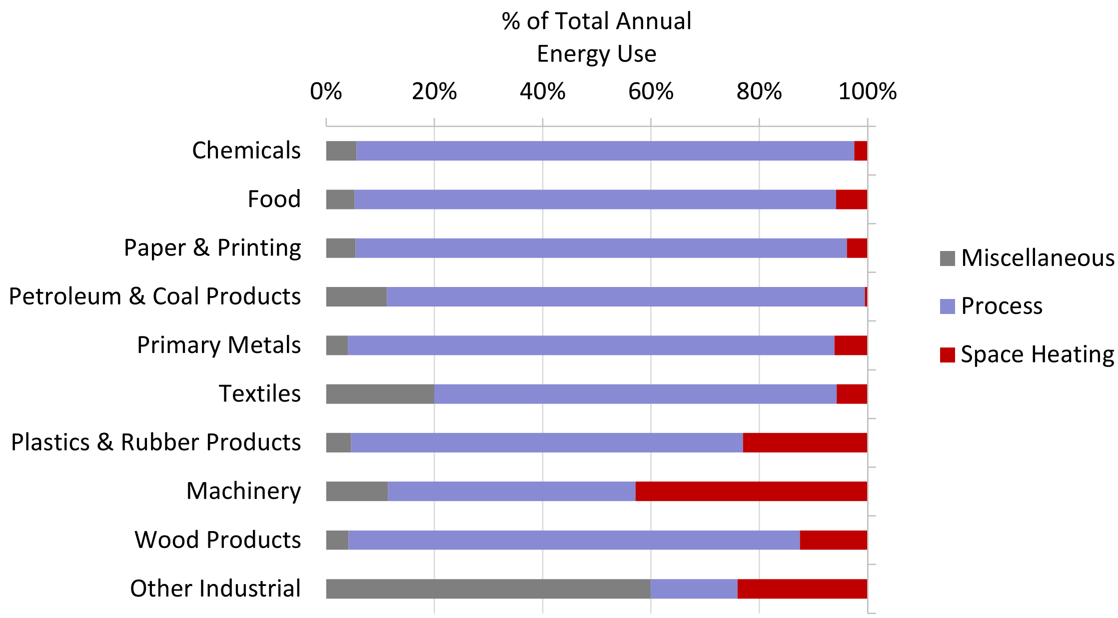
Figure 3-15 shows the distribution of annual natural gas consumption by end use across all industrial facilities. Industrial processes account for the majority of natural gas consumption in this sector.

Figure 3-15 Berkshire Industrial Consumption by End Use, 2019



Natural gas intensity is driven largely by process for almost all segments other than Machinery and Other Industrial. Figure 3-16 shows how natural gas is apportioned across industrial end uses, taken from EIA's Manufacturing Energy Consumption Survey (MECS).

Figure 3-16 Berkshire Industrial Intensity by End Use and Segment, 2019



Industrial Baseline Projection

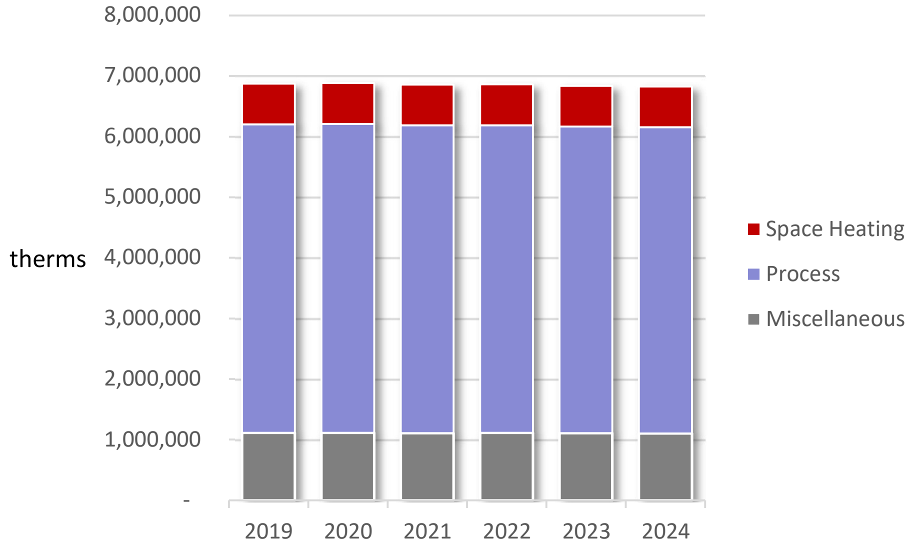
Table 3-15 presents AEG's natural gas baseline projection[15] at the end use level for the industrial sector.

Table 3-15 Berkshire Industrial Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	673,564	674,554	672,468	673,119	671,178	669,957
Processing	5,089,408	5,093,675	5,075,091	5,077,497	5,060,786	5,049,879
Miscellaneous	1,113,638	1,114,571	1,110,505	1,111,031	1,107,375	1,104,988
Total	**6,876,610**	**6,882,800**	**6,858,064**	**6,861,647**	**6,839,338**	**6,824,823**

[15] As noted elsewhere above, this is the counterfactual, no-DSM projection based on market growth assumptions provided by Berkshire

Figure 3-17 Berkshire Industrial Baseline Projection by End Use



Industrial Potential

Table 3-16 presents the industrial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 17,106 therms, or 0.26% of the baseline projection.

Table 3-16 Berkshire Summary of Industrial Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**6,861,647**	**6,839,338**	**6,824,823**
Potential Savings			
Achievable BAU	17,720	18,406	18,852
Achievable BAU Plus	21,254	21,951	22,392
Achievable Max	25,938	26,758	27,267
Economic	44,325	44,924	45,230
Technical	44,454	45,051	45,356
Potential Savings as % of Baseline			
Achievable BAU	0.26%	0.27%	0.28%
Achievable BAU Plus	0.31%	0.32%	0.33%
Achievable Max	0.38%	0.39%	0.40%
Economic	0.65%	0.66%	0.66%
Technical	0.65%	0.66%	0.66%

The other industrial segment accounts for nearly half (43%) of the industrial achievable BAU potential from 2022 through 2024. The plastics & rubber products and machinery segments each represent 14% of the savings (Figure 3-18).

Figure 3-18 Berkshire Industrial Natural Gas Achievable BAU Potential by Segment

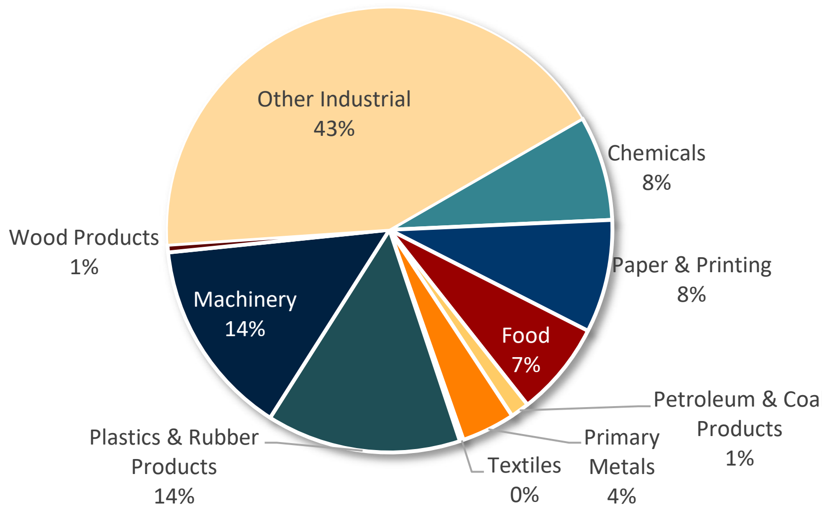


Table 3-17 shows industrial potential by segment and case.

Table 3-17 Industrial Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Chemicals	1,332	1,393	1,435
	Food	1,204	1,259	1,298
	Paper & Printing	1,439	1,505	1,550
	Petroleum & Coal Products	238	248	256
	Primary Metals	687	714	731
	Textiles	46	48	50
	Plastics & Rubber Products	2,513	2,605	2,663
	Machinery	2,556	2,650	2,708
	Wood Products	99	102	105
	Other Industrial	7,606	7,883	8,057
BAU Plus	Chemicals	5,419	5,620	5,758
	Food	2,936	3,044	3,117
	Paper & Printing	2,390	2,469	2,518
	Petroleum & Coal Products	479	495	504
	Primary Metals	547	564	574
	Textiles	52	54	55
	Plastics & Rubber Products	2,095	2,157	2,193
	Machinery	1,879	1,934	1,966
	Wood Products	79	82	83
	Other Industrial	5,377	5,533	5,624

Case	Segment	2022	2023	2024
BAU Max	Chemicals	6,613	6,850	7,011
	Food	3,583	3,710	3,795
	Paper & Printing	2,917	3,009	3,067
	Petroleum & Coal Products	585	603	614
	Primary Metals	668	688	699
	Textiles	64	66	67
	Plastics & Rubber Products	2,557	2,629	2,670
	Machinery	2,293	2,358	2,394
	Wood Products	97	100	101
	Other Industrial	6,561	6,745	6,847
Economic	Chemicals	11,951	12,145	12,268
	Food	6,348	6,450	6,512
	Paper & Printing	5,244	5,307	5,337
	Petroleum & Coal Products	1,164	1,176	1,182
	Primary Metals	1,177	1,191	1,196
	Textiles	112	113	114
	Plastics & Rubber Products	4,181	4,229	4,247
	Machinery	3,659	3,702	3,718
	Wood Products	162	164	165
	Other Industrial	10,325	10,447	10,492
Technical	Chemicals	11,953	12,147	12,270
	Food	6,350	6,452	6,514
	Paper & Printing	5,246	5,309	5,339
	Petroleum & Coal Products	1,165	1,176	1,182
	Primary Metals	1,178	1,192	1,197
	Textiles	112	113	114
	Plastics & Rubber Products	4,185	4,233	4,251
	Machinery	3,663	3,706	3,722
	Wood Products	163	164	165
	Other Industrial	10,438	10,560	10,604

Table 3-18 shows potential by case and vintage – new construction vs existing buildings.

Table 3-18 Industrial Natural Gas Potential (therms) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	12,825	13,223	13,460
	New	4,895	5,184	5,392
BAU Plus	Existing	18,327	18,711	18,875
	New	2,927	3,240	3,517
BAU Max	Existing	22,366	22,809	22,984
	New	3,572	3,949	4,283
Economic	Existing	39,201	39,239	39,032
	New	5,124	5,685	6,198
Technical	Existing	39,324	39,359	39,150
	New	5,129	5,692	6,207

C&I Combined Potential by End Use

The following two graphs show the potential for the entire nonresidential segment by end use. Custom programs account for the majority of savings, with industrial process at third place and commercial food prep equipment coming in fourth with 9% of total savings, owing to Berkshire's highly active program (Figure 3-19).

Figure 3-19 Berkshire Nonresidential Natural Gas Achievable BAU Potential by End Use

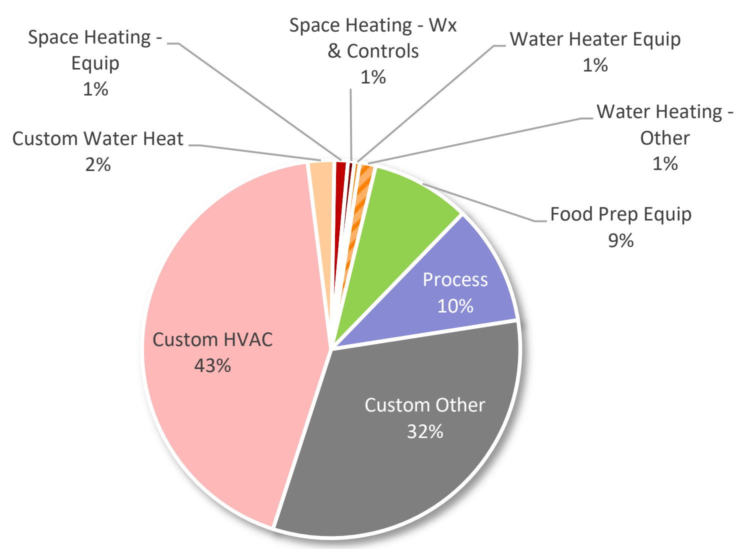
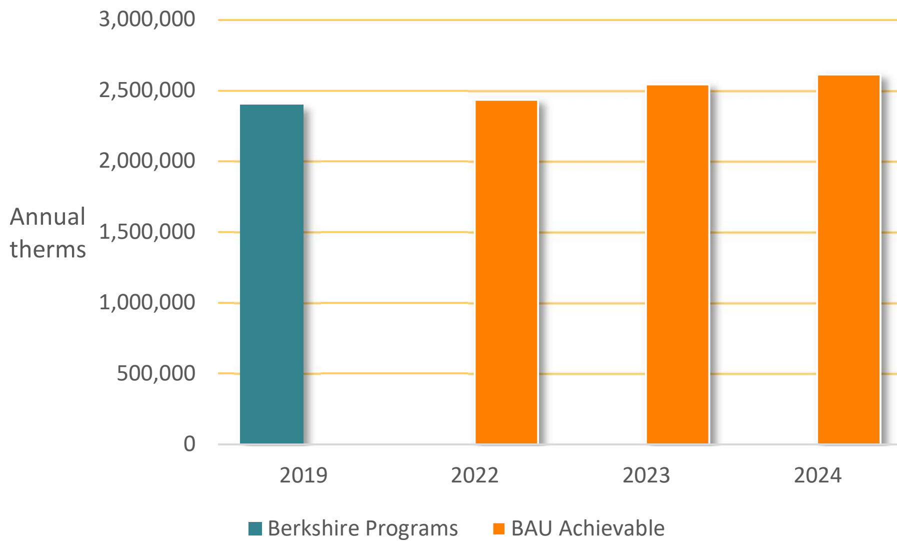


Figure 3-20 compares the nonresidential savings achieved in 2019 with the BAU achievable potential over the next 3-year planning cycle. The potential estimates are in line with historical achievements, with potential increasing slightly in the later years of the cycle.

Figure 3-20 Berkshire Nonresidential Natural Gas Savings Historical Comparison



4

INSIGHTS AND CONCLUSION

Berkshire has been running energy efficiency programs in Massachusetts for several planning cycles, and the Business-as-Usual case presented in this report has been aligned with recent program activity. Comparing recent accomplishments with AEG's prior market research on general market acceptance and interest in energy programs shows that Berkshire has areas of strong success and also that in several cases acquiring additional potential beyond current performance may be challenging.

High Performing Programs

- Residential Weatherization. Berkshire's residential insulation and air sealing offerings show significantly more activity (as a % of economic potential) than AEG typically sees and may not have much more room to plausibly grow in annual acquisitions.
- Residential Smart Thermostats. Activity for this offering is modestly higher than AEG's typical take rates, indicating a mature, robust program.
- Commercial Food Prep Equipment. This customer segment is typically difficult to reach, however Berkshire's program shows significant activity in these measures.

Possible Opportunities for Growth

- Water heating equipment. Although these measures are already an active part of Berkshire's programs for both the residential and nonresidential sectors, existing participation in this offering is not very high compared to expected turnover rates based on the generally accepted lifetimes for this equipment.

  This suggests there may be more units that require replacement each year but are not coming through the program, possibly because customers who lose water heat suddenly are faced with an emergency decision, rather than a planned one that can consider the available rebates and benefits of a high efficiency model.
- Smart Thermostats in Nonresidential Buildings. Given Berkshire's strong success with residential smart thermostats, the much lower activity for this measure in the nonresidential sector presents an opportunity for growth. Customer outreach may help small business owners become more fully aware of the benefits of web-enabled thermostats for their business space.

Challenges to increasing participation

Customer participation in energy efficiency measures reflects a combination of factors, including the economic conditions of potential program participants, urgency of timing, customers' general attitudes towards energy and efficiency, the perceived value of the efficiency measure to the customer, the value of the incentive itself, and obstacles that can arise when projects are assessed or begun.

Relating to that last point, internal analysis by the PAs[16] found that nearly 90% of residential homes that were assessed in preparation for weatherization installations encountered significant unanticipated

[16] Pre-Weatherization Barrier analysis, data taken from RISE and provided by Berkshire Gas

barriers that either increased the cost of the project significantly or made it impractical to continue, such as pest control issues, asbestos, mold, or structural issues.

This combination of factors means that simply raising incentives, even to 100% of incremental costs, cannot guarantee a large increase in participation if underlying obstacles are not addressed. In 2020, a Residential Nonparticipant Customer Profile Study similarly found that the barriers to program participation run far beyond simply incentives or measure payback.[17]

Conclusion

Berkshire's portfolio of energy efficiency programs is performing solidly, however there is room for some modest increase in annual potential acquisition if incentives are increased and programs can address market barriers. However, both of these prospects will increase the cost of acquiring potential.

This study provides important information for planning the next program cycles. This study:

- Describes and characterizes the customer base by energy source, sector, customer segment and end use. At a glance, it is possible to see where the opportunities for program savings are likely to come from.
- Defines a baseline projection of energy use by end use against which savings can be measured. This baseline takes into account existing and planned appliance standards and building codes, as well as naturally occurring efficiency.
- Evaluates a diverse set of energy efficiency measures in all three customer sectors.
- Estimates the total amount of savings possible from cost-effective measures; these are savings above and beyond those already included in the baseline projection.
- Describes a set of achievable potential savings scenarios – BAU, BAU Plus, and Max – based on increased incentives driving increased savings achievement that can be useful for program development in the upcoming planning years 2022 through 2024.

The results presented in this report are estimates based on the best available information available at the time of the analysis and we expect variation in outcomes in the real world. This fact gives staff the opportunity to deviate from specific annual values developed in the study as they design programs and commit to annual program targets as well as gather more territory-specific information about baselines, saturation and demand for program offerings.

[17] https://ma-eeac.org/wp-content/uploads/MA19X06-B-RESNONPART_Report_FINAL_v20200228.pdf

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Cape Light Compact 2022-2024 Potential Study

Volume I: Results

April 26, 2021

Opinion Dynamics

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Opinion Dynamics

1. Executive Summary

This report summarizes the results of the 2022-2024 Cape Light Compact ("CLC" or "the Compact") Potential Study, conducted by Opinion Dynamics and Dunsky Energy Consulting ("the Potential Study Team"). This study is the third study conducted by the Potential Study Team, following the comprehensive *2014 Penetration, Potential, and Program Opportunities Study* (hereafter referred to as the "2014 Potential Study") and a 2017 update (hereafter referred to as the "2017 Potential Study").

The goal of this study was to determine the remaining achievable potential from electric energy efficiency (EE), heating electrification (HE), and active demand reduction (ADR)[1] measures among customers in three sectors—Residential Market Rate, Residential Low Income, and Commercial and Industrial (C&I)—for the three-year period 2022-2024 and to inform the Compact's program planning efforts. This study assesses potential at the technical, economic, and program achievable levels. For each component, the study explores three program achievable scenarios to determine how incentive levels can impact achievable savings (BAU, BAU+, and Max).[2] The outputs of this study satisfy the requirements of the Massachusetts Department of Public Utilities (DPU) that each Program Administrator "conduct a service territory-specific energy efficiency potential study every three years."[3] This study does not include an assessment of savings from combined heat and power (CHP) and other distributed energy resources such as distributed generation.

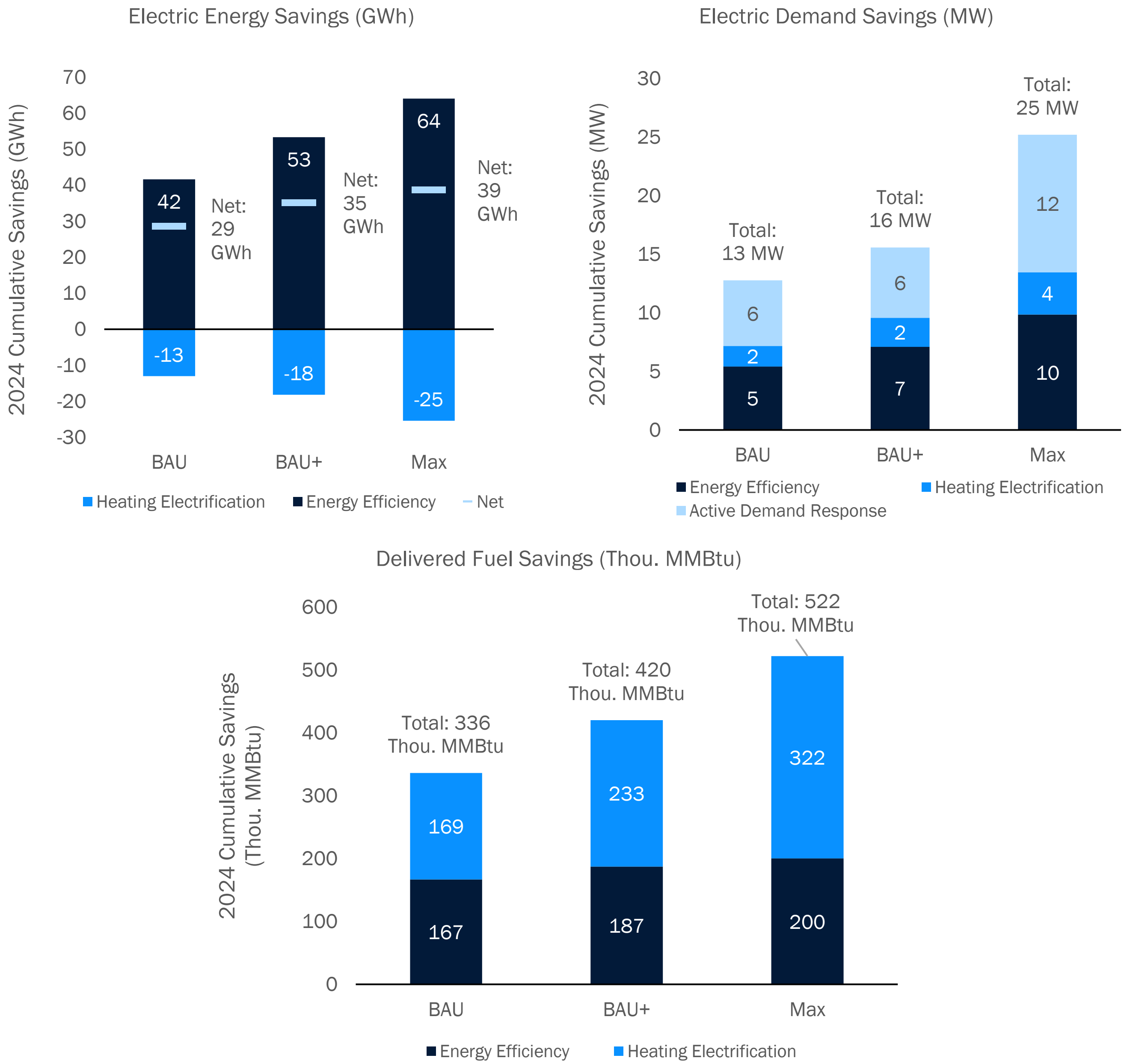
The results presented in this Volume are based on several data sources, including data collected by the Potential Study Team for the 2014 Potential Study, recent, statewide data collection efforts, and other secondary data. Inputs and assumptions are based on the best available information at the time of the study and account for current evaluation factors (e.g., net-to-gross ratios, realization rates, etc.) wherever possible. Where these factors are not available, the study makes reasonable assumptions as appropriate but does not try to forecast future evaluation factors based on potential program changes.

1.1 Results Overview

The study finds that the Compact's EE, HE, and ADR programs can continue to generate substantial savings throughout the study period and that increasing incentives would likely drive significant increases in savings relative to the business-as-usual (BAU) scenario. Over the three-year study period, the combined impact of these programs will reduce CLC's customers' consumption of electricity, gas, and delivered fuel, and reduce their contribution to peak electric demand as summarized in Figure 1 below.

[1] The Active Demand Reduction measures may be referred to as Demand Response (DR) measures throughout this report.
[2] Detailed descriptions of these scenarios are provided for each component (EE, HR, and ADR) in the subsections below.
[3] MA DPU. D.P.U. 15-160 through D.P.U. 15-169. January 28, 2016. Page 25.

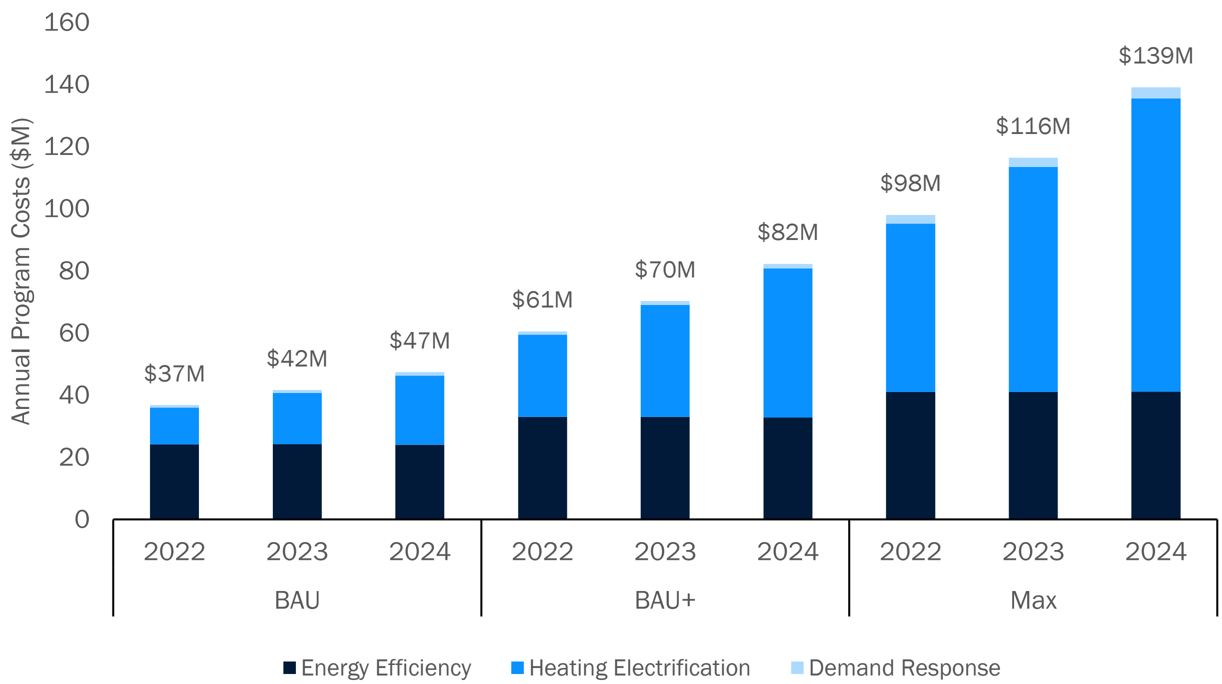
Figure 1. 2024 Combined Cumulative Savings (EE, HE, and ADR)



Note: Results in above figure represent the combined cumulative impact of modeled EE, HE, and ADR programs over the study period (2022-2024).

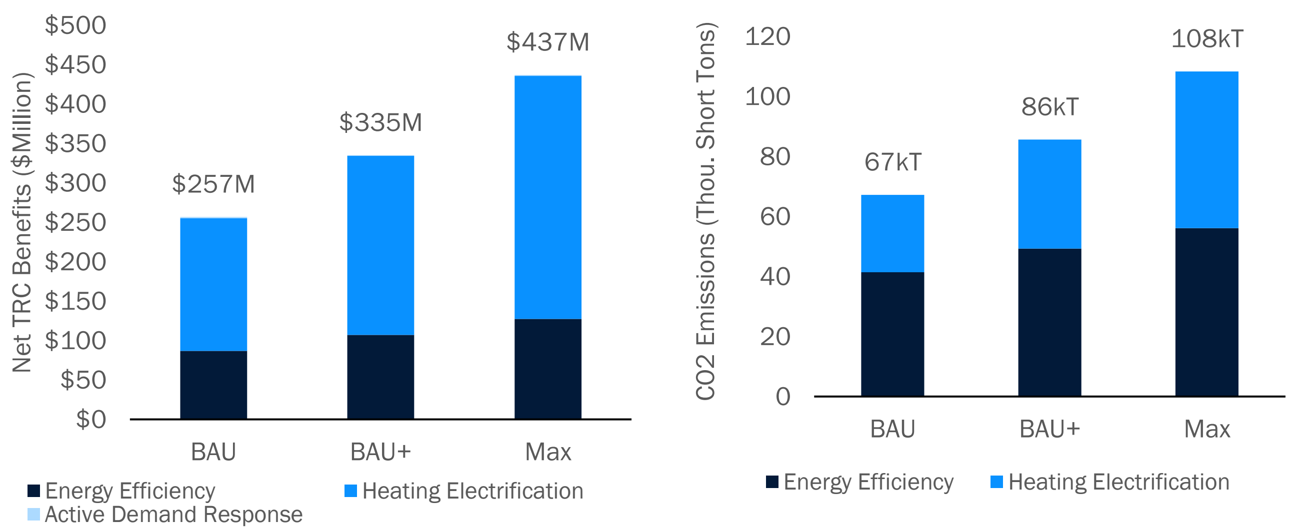
The combined estimated program costs (including incentives and non-incentive administrative program costs) to achieve these savings are presented in Figure 2. As expected, increasing incentive levels increases overall costs as participation increases and the incentives per participant increase. Under all assessed scenarios, costs increase each year primarily due to growth in HE and ADR measure adoption. Under BAU conditions, costs top out at $47 million in 2024. Under the Max scenario, costs nearly triple to $139 million in 2024.

Figure 2. Combined Annual Program Costs (EE, HE, and DR)



While the modeled programs will require significant expenditures, these costs will be outweighed by the benefits as measured by the total resource cost test (TRC) results. Over the three-year study period, the total estimated combined net TRC benefits range from $257 million under the BAU scenario to $437 billion under the Max scenario as shown in Figure 3. The reduction in energy consumption from EE and HE measures will also drive significant greenhouse gas (GHG) emission reductions – reducing annual CO_2 emissions by 67 thousand tons in 2024 under the BAU scenario and up to 108 thousand tons under the Max scenario.

Figure 3. Total 2022-2024 Net TRC Benefits and 2024 Cumulative Annual Emission Reductions (EE, HE, and ADR)



1.2 Energy Efficiency Potential

The analysis explores three achievable program scenarios as described in Table 1. The BAU scenario is designed to emulate savings that can be achieved under existing program structures and incentive levels albeit with measures and technologies that may not be currently offered by existing programs. The BAU+ and Max scenarios demonstrate what is possible with increased incentive levels.

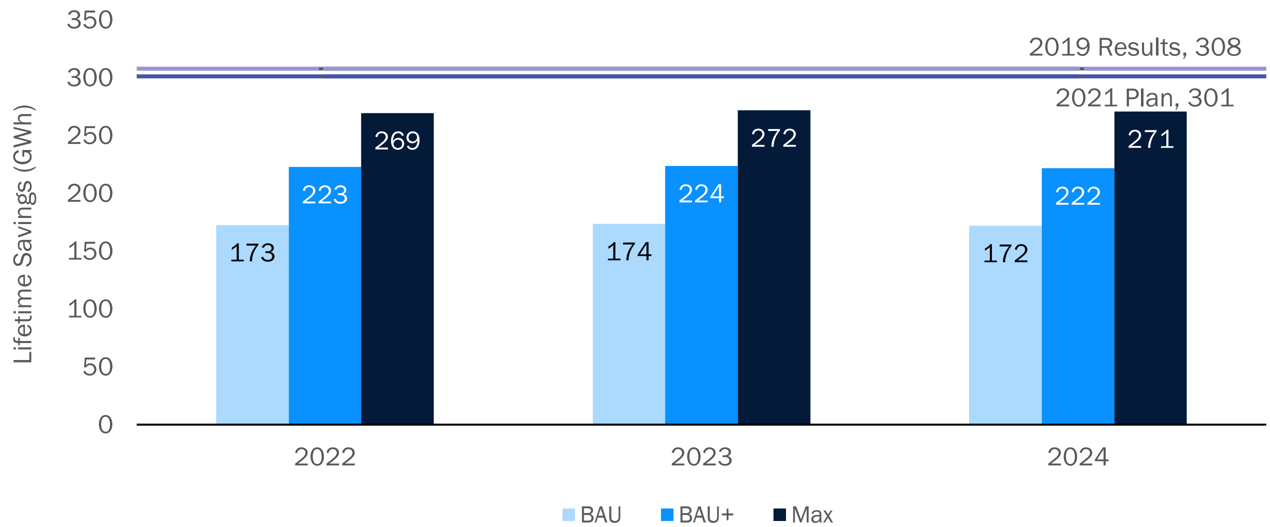
Table 1. Energy Efficiency Achievable Program Scenario Descriptions

BAU	Applies incentives and program configurations in line with the Compact's incentives paid in 2019 to simulate **business as usual**. Additional prescriptive measures beyond those currently offered may be included.
BAU+	Increases incentives **above and beyond** BAU levels. Specifically, weatherization measure incentives are set at 90% of incremental costs and all other incentives are set 50% higher than BAU levels with a maximum of 90% of incremental cost unless BAU scenarios already exceed this threshold).
Max	Completely **eliminates incremental customer costs** associated with installing efficiency measures (all incentives set to cover 100% of the efficiency measure incremental cost).

1.2.1 Electric Savings

The study finds that achievable lifetime electric savings for CLC's efficiency programs will decline relative to savings achieved in the past under all scenarios as shown in Figure 4.

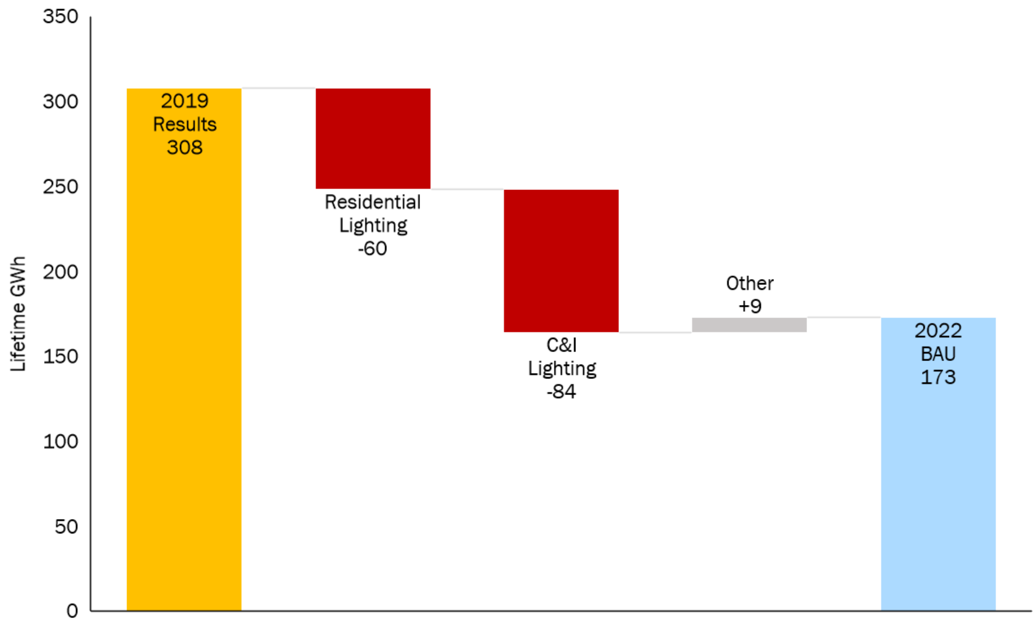
Figure 4. Electric EE Lifetime Savings by Year



Compared to CLC's 2019 program results and the 2021 Plan savings, achievable lifetime electric savings are expected to decline precipitously. Under BAU incentive levels, 2022-24 average lifetime savings are approximately 44% lower than past program savings. While modest increases in some measures are expected as heat pump markets grow – primarily impacting residential HVAC savings – the difference between the BAU scenario and recent electric savings achievements is almost entirely attributable to reductions in lighting savings from both the residential and C&I sectors as shown in Figure 5.[4]

[4] While the reduction in lighting savings explains most of the difference between 2019 Results and 2022 BAU, it should be noted there are other differences that result in both increases and decreases in savings, but these largely offset each other (i.e., increases in home energy report savings and HVAC measure savings, decreases in residential envelope and commercial refrigeration measures).

Figure 5. Electric EE 2022 BAU Lifetime Savings vs. 2019 Results

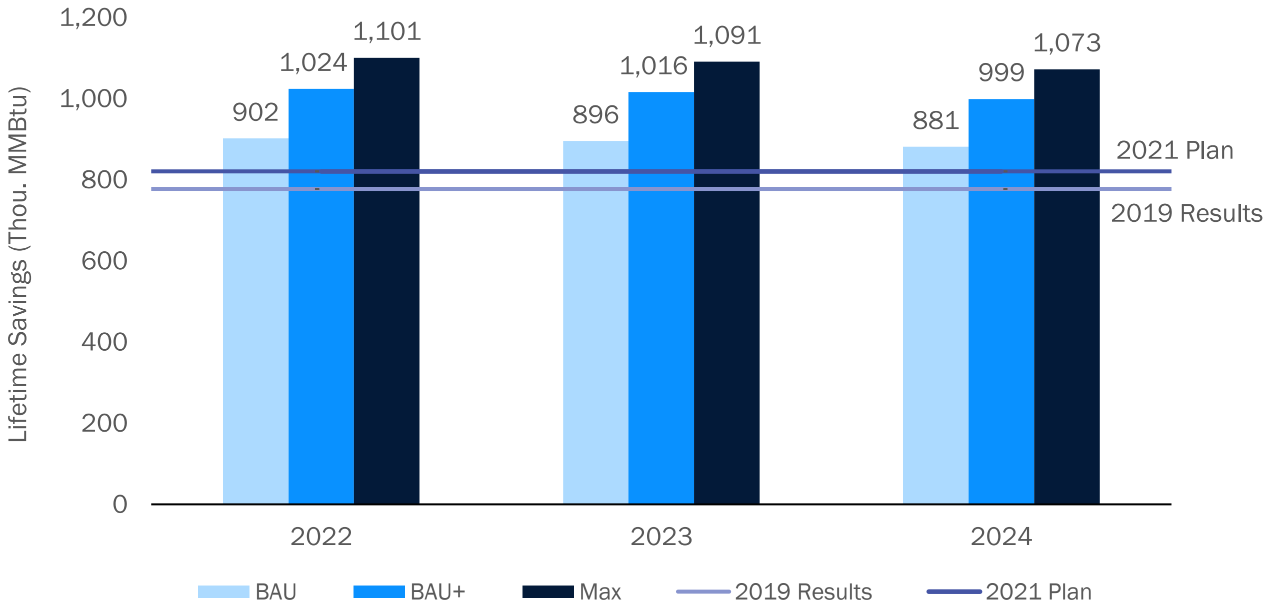


The reduction in lighting savings is significant enough that even under Max incentive levels, savings do not reach levels achieved in the past. Under the BAU+ and Max scenarios, 2022-24 average lifetime savings increase by 29% and 57% relative to BAU, respectively, yet still fall short of past achievements. This suggests that maintaining electric savings at historical levels will not be possible even if the programs offer incentives to customers that offset 100% of the incremental costs associated with efficient technologies.

1.2.2 Delivered Fuel Savings

CLC's efficiency programs also offer measures targeted at delivered fuels (oil and propane) savings. The achievable delivered fuel savings are assessed to exceed past program savings as shown in Figure 6.

Figure 6. Delivered Fuel EE Lifetime Savings by Year



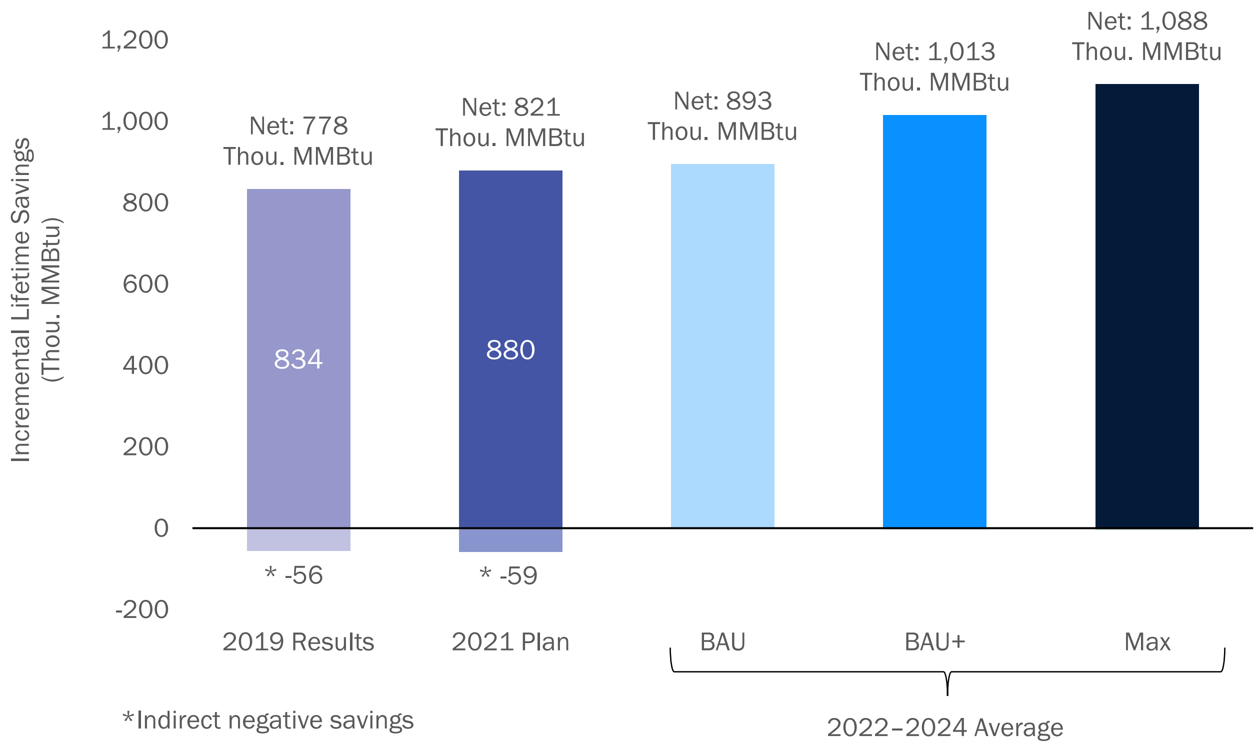
The increase in savings relative to past achievements is attributable to two main factors:

- First, the study includes prescriptive C&I delivered fuel measures that are not currently part of CLC's programs.
- Second, the delivered fuel savings in CLC's 2019 Results and 2021 Plan were reduced due to a significant amount of indirect negative savings from lighting measure interactive effects.[5] With reduced lighting savings in the study period, negative savings stemming from lighting interactive effects are reduced, thereby increasing overall net delivered fuel savings.

When lighting interactive effects are removed as shown in Figure 7, the study estimates that residential savings will continue at levels achieved in 2019 with the remaining increase in savings driven by the prescriptive C&I measures. With increased incentives under the BAU+ and Max scenarios, 2022-24 average lifetime savings increase by 13% and 22% relative to BAU, respectively.

[5] LED lighting produces less waste heat than inefficient lighting equipment requiring heating systems to consume additional energy to maintain the same indoor temperature.

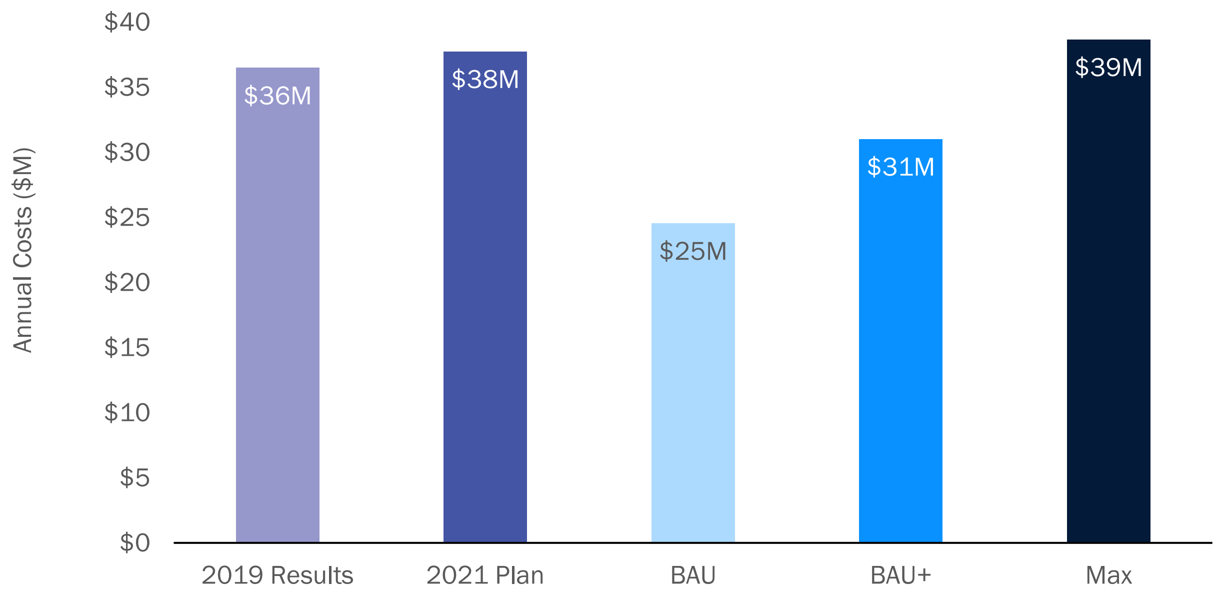
Figure 7. Delivered Fuel EE Lifetime Savings with Lighting Interactive Effects Removed



1.2.3 Portfolio Metrics

Figure 8 presents the estimated 2022-24 average annual cost of administering CLC's programs (including electric and delivered fuel measures) under each achievable scenario.

Figure 8. Energy Efficiency Program Costs



In the BAU and BAU+ scenarios, program costs are significantly below 2019 Results and the 2021 Plan, which is commensurate with the decline in overall electric savings. With significant reductions in the incentives paid for lighting measures, overall costs are reduced by 34% under the BAU scenario relative to 2019 Results. Under the Max scenario, overall costs eclipse 2019 Results and the 2021 Plan even though achievable electric lifetime savings do not reach 2019/2021 levels.

The higher budgets coupled with lower electric savings increase the cost per kWh of savings relative to past years. This is partly driven by a larger portion of program budgets going towards delivered fuel measures as diminishing lighting savings reduce overall electric savings. As diminishing lighting savings reduce overall electric savings, the relative portion of budgets going towards delivered fuel measures is expected to increase. This increases program cost per unit of electric savings as more program dollars go towards measures that do not procure significant amounts of electric savings. This trend increases the study's estimated program cost per unit of electric savings, but it does not explain the entire difference.

Even when delivered fuel incentive costs are excluded, the cost to deliver electric savings is still higher than the past as shown in Table 2, where **program costs per lifetime kWh under the BAU scenario are 15% greater than in 2019.** This difference is driven by the programs capturing more higher-cost savings opportunities to replace lost lighting savings, which tend to be among the lowest cost opportunities. Therefore, as lighting savings decrease in the portfolio, the average program cost per unit of electric savings should be expected to increase.

Table 2. Energy Efficiency Program Costs with and without Delivered Fuel Incentive Costs

	With Delivered Fuel Incentive Costs			Without Delivered Fuel Incentive Costs		
	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh
2019 Results	$36	$0.121	$0.944	$32	$0.105	$0.820
2021 Plan	$38	$0.134	$1.088	$34	$0.120	$0.974

	With Delivered Fuel Incentive Costs			Without Delivered Fuel Incentive Costs		
	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh
BAU	$24	$0.140	$1.455	$19	$0.111	$1.159
BAU+	$33	$0.148	$1.607	$25	$0.113	$1.230
Max	$41	$0.152	$1.706	$32	$0.117	$1.314

Overall, CLC's efficiency programs have the potential to continue to generate significant benefits as measured by the TRC as well as emission reductions. Table 3 displays the overall TRC ratio, net TRC benefits, and net benefits per lifetime and first-year kWh saved.

Table 3. Energy Efficiency TRC Benefits (2022–2024 Average, All Scenarios)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime kWh	CO_2 Annual Emission Reductions (Short Tons)
2019 Results	2.3	$58M	$0.19	30,100
2021 Plan	2.9	$87M	$0.31	27,500
BAU	2.0	$29M	$0.17	14,000
BAU+	2.0	$36M	$0.16	16,000
Max	2.1	$42M	$0.16	19,000

1.2.4 Key Takeaways

Based on the results of this study, the following key take-aways emerge for EE:

- Under **BAU incentive level**s and current program configurations, savings levels are projected to vary significantly from past program results:
  - **Electric savings** will decline sharply as lighting savings continue to drop due to the rapid transformation of Massachusetts' lighting markets, despite increased opportunities from growing heat pump penetrations.
  - **Delivered fuel savings** could increase with the inclusion of new prescriptive C&I measures in existing programs while residential savings continue at past levels.[6]
- **By increasing incentives**, programs can obtain substantially increased savings albeit with significant increases in program costs. Under the Max scenario:
  - **Electric savings** increase by 57% relative to the BAU scenario. While this is a substantial increase, it is still not sufficient to replace the declining lighting opportunities and as a result overall electric savings will still be lower than past program achievements.

[6] Toward the end of the study, the PAs elaborated plans to restrict propane and gas heating equipment replacements to only replace non-condensing equipment with condensing equipment. In addition, The PAs planned to eliminate incentives for high efficiency oil boilers and instead offer incentives to replace oil boilers with heat pumps. If these changes take place, residential delivered fuel savings would be expected decline relative to past program performance and the achievable potential savings results presented in this report.

  - **Delivered fuel savings** increase by 22% over the BAU scenario projections. Relative to electric and gas savings, raising incentives offers a relatively smaller incremental increase in delivered fuel savings. Existing programs already capture a large portion of net economic potential and due to the relatively high cost of delivered fuel in Massachusetts, customers are already highly incentivized to use these fuels efficiently. Thus, providing greater upfront incentives has less of an impact of customer decision-making.
- **Program Enhancements:** Raising incentives can lead to increased program savings, but for some measures and end-uses—even at the Max scenario incentive levels—a substantial portion of the net economic savings remain untapped. These uncaptured savings represent cost-effective opportunities that are inhibited for reasons beyond customer economics. For example, under the Max scenario:
  - 41% of 2024 cumulative net economic **electric savings** are not captured by programs,
  - 14% of 2024 cumulative net economic **delivered fuel savings** are not captured by programs, and

While *completely* eliminating all market barriers for all efficient technologies is likely not feasible (particularly in just the next three years), uncaptured economic savings may represent opportunities for enabling program strategies and market transformation approaches to further reduce market barriers and increase savings. While these strategies take time to implement and their impacts are more uncertain than increasing incentive levels, CLC and the state of Massachusetts as a whole have consistently succeeded in reducing market barriers as shown by the state's consistent top rank ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near complete transformation of the Massachusetts lighting market.

1.3 Heating Electrification

Heating electrification potential in this study includes the electrification of existing buildings that contain gas, oil, and propane-fired primary space and water heating systems among CLC's residential and commercial electric customers. It also includes an assessment of the potential to encourage the installation of electric heating systems in newly constructed buildings. The analysis explores three achievable program scenarios as described in Table 4.

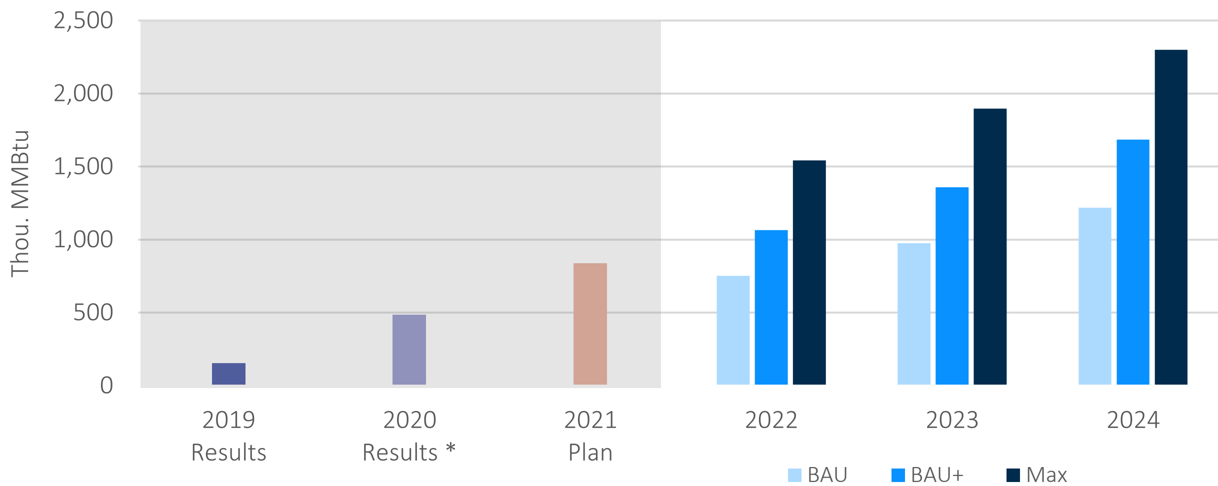
Table 4. Heating Electrification Achievable Program Scenario Descriptions

BAU	Applies incentives **in line with CLC's 2019-2021 Energy Efficiency Plan** to simulate business as usual: ▪ $1,250 a ton for air-source, $3,000 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost. ▪ HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). ▪ Measures not currently offered within programs are also included (gas, units > 5.4 tons).
BAU+	Increases incentives **above and beyond** levels within CLC's 2019-2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: ▪ $1,875 a ton for air-source HPs, $4,500 a ton for ground-source HPs. ▪ Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives further above and beyond levels within CLC's 2019-2021 Energy Efficiency Plan. Incentives **are twice the BAU levels**: ▪ $2,500 a ton for air-source, $6,000 a ton for ground-source HPs. ▪ Incentive levels are capped at 90% of full heat pump installation cost.

1.3.1 HE Program Results

The study finds that potential from energy optimization offerings will continue to grow under all scenarios as shown in Figure 9. As heating electrification is an emerging technology, the analysis projects large year-over-year growth that is in line with the planned expansion in CLC's programs in the years preceding the study period.

Figure 9. Lifetime Building-Level Fuel Savings Compared to Program Benchmarks

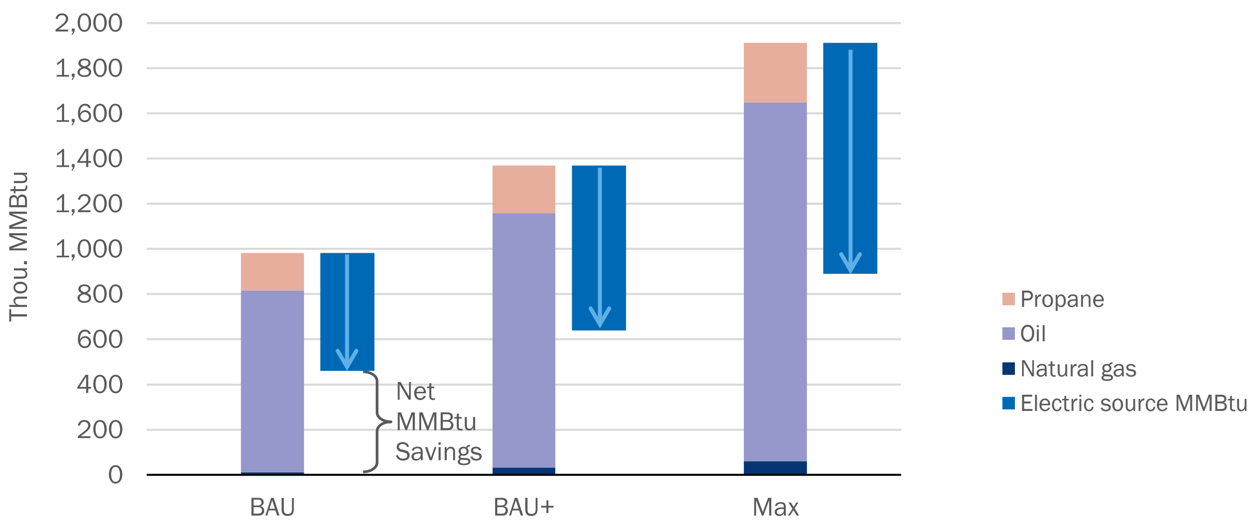


* Results for the first 10 months extrapolated to a full year

These measures will result in significant reductions in building-level fuel consumption throughout the lifetime of the installed equipment. Under BAU conditions, the study estimates HE measures installed in 2022 will result in 750,000 lifetime MMBtu building-level fuel savings. By 2024, achieved fuel savings will increase to over 1.2 million lifetime MMBtu under BAU. For the Max scenario, these fuel savings estimates increase to 1.5 and 2.3 million MMBtu, respectively.

Figure 10 shows 2022-24 average lifetime fuel savings broken down by fuel type. As can be seen, the potential in all three achievable scenarios is dominated by oil, which is driven by the high penetration of oil boilers among residential customers and the relatively favorable economics of replacing oil-fired heating systems with heat pumps. Propane customers are disproportionately represented in the achievable potential due to favorable customer economics. Because the customer economics are already strong under the BAU scenario, increasing the incentive levels in BAU+ and Max has a limited effect on propane adoption. Despite gas being the most widely used heating fuel among CLC's customers, heat pump adoption in gas heated buildings remains limited due to poor customer economics.

Figure 10. Lifetime MMBtu Savings and Electric Source MMBtu Increases (2022-24 Average)



While HE measures will have significant impacts on building-level fuel use, they will also drive an increase in electricity consumption. Figure 10 also illustrates the impact of this electricity consumption increase in MMBtu equivalent units based on the fuel consumed by electric generators in New England by showing the negative electric source MMBtu savings. As can be seen, the anticipated increase in electric generation fuel consumption is less than half the decrease in building-level heating fuel consumption due to the high efficiency of heat pump technologies.

Table 5 summarizes the estimate program costs, net TRC benefits, and CO_2 reductions resulting from HE measures under each scenario. As HE measure adoption continues to grow, costs are expected to increase relative to past program costs. At the same time, net TRC and emission benefits will increase as well.

Table 5. HE Program Costs, Net TRC Benefits, and CO2 Reductions (2022-2024 Average)

	2019 Results	2020 Results*	2021 Plan	BAU	BAU+	Max
Program Costs	$0.7 M	$1.8 M	$5.4 M	$4.7 M	$9.6 M	$18 M
Net TRC Benefits	$1.9 M	$8.2 M	$12 M	$14 M	$19 M	$26 M
Annual CO_2 Emission Reductions (Short Tons)	247	1,295	2,237	2,376	3,294	4,588

*Results for the first 10 months extrapolated to a full year

1.3.2 Key Takeaways

Based on these results, the following takeaways emerge:

- Overall, **energy optimization offerings show continued growth in potential under all scenarios.** As heating electrification is an emerging technology, the results project large year-over-year growth that is in line with the planned expansion in CLC's heat pump programs in the years preceding the study period. This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like ground source heat pumps (GSHP) and the emergence of new C&I measures.
- Most delivered fuel (oil and propane) replacement measures pass TRC screening and provide customer bill savings, but almost all gas replacement measures either do not pass TRC screening and/or do not

provide customer bill savings. For all fuels, the achievable potential is *very* small relative to the economic potential because it is very **difficult to entice customers to electrify.** For gas customers, the main reason is related to poor customer economics, as adopting most heat pumps will lead to bill increases given current gas and electricity rates. For delivered fuel, it is mostly caused by the significant market barriers that electrification measures face, largely as a result of cold climate heat pumps being a relatively new technology in Massachusetts - customers and contractors are still unaware or unfamiliar with the technology.

- Finally, **heating electrification is expected to drive a net reduction in overall energy consumption** (i.e., net MMBtu savings) when including all energy sources and accounting for the associated increase in electricity consumption.

1.4 Active Demand Reduction Potential

Electric active demand reduction potential is assessed for CLC's ADR programs to reduce CLC's peak load during the 10-40 highest demand hours of the year. This represents incremental additional peak load reduction to the passive peak demand reductions resulting from energy efficiency measures. The analysis explores three achievable program scenarios as described in Table 6.

Table 6. Active Demand Reduction Achievable Program Scenario Descriptions

BAU	**Current ADR programs and incentives**, when applied across the full applicable market, to obtain projected equilibrium participation levels as predicted by the DROP model's propensity curves[7] under evolving market conditions and through ongoing marketing and outreach without altering incentives or measures offered.
BAU+	Tests the ability to **expand participation by increasing incentives** under the current ADR programs, while maintaining cost-effectiveness.
Max	Applies BAU+ scenario incentive levels and further **expands ADR programs to include a range of new cost-effective measures**.

[7] Propensity curves available in Appendix E.

1.4.1 ADR Program Results

The study finds that achievable peak load reduction from CLC's ADR programs can reach 5.6 MW under BAU conditions and up to 11.8 MW under the Max scenario as shown in Figure 11. 1.9 MW of this potential is currently being captured by CLC's ADR program enrollment to date, which indicates that up to 10 MW of additional potential could be achieved by expanding the range of ADR measures and increasing incentives.

Figure 11. Achievable ADR Potential by Year

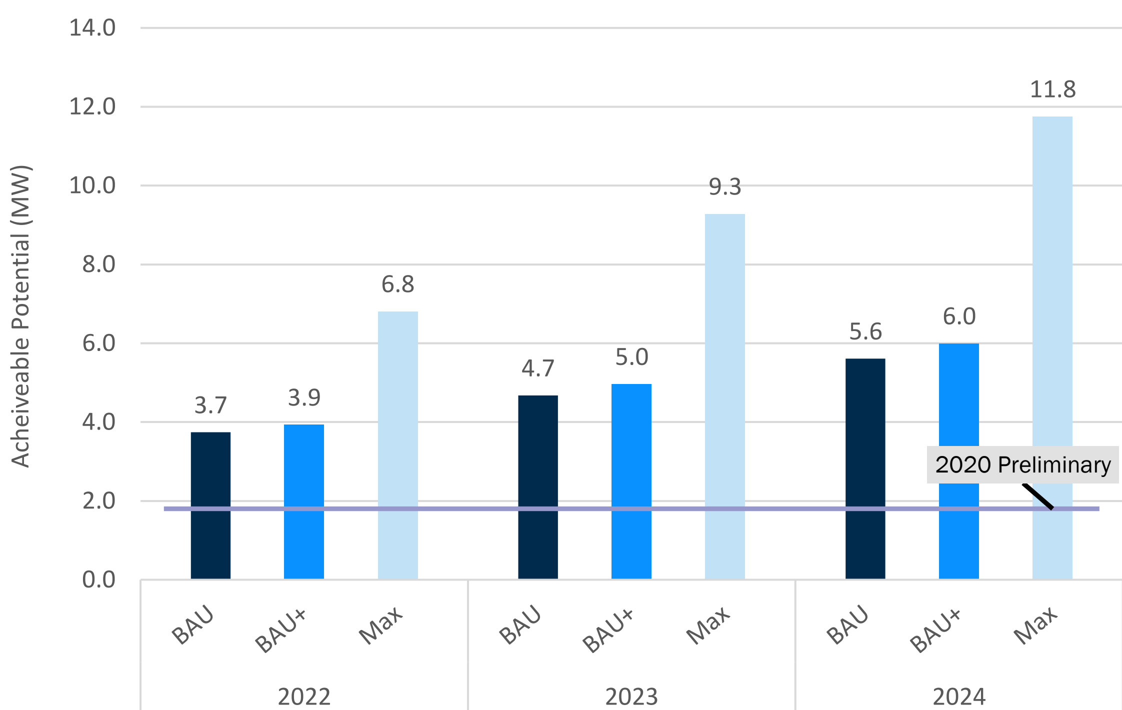


Table 7 summarizes the achievable potential in 2024 for each of the assessed scenarios, as well as the average portfolio TRC ratio results and annual program costs. Annual costs increase as ADR programs continue to grow, amounting to $1.1 million in 2024 under BAU conditions and $3.6 million under the Max scenario. While achievable potential under all scenarios is cost-effective, the benefit-cost ratio, as measured by the TRC, declines under the BAU+ and Max scenarios, which is in contrast with the modeled EE TRC ratios under each scenario. This is due to the inclusion of ADR incentive costs in the TRC calculation because they typically do not cover a portion of the customers' own equipment incremental costs.

Table 7. ADR Achievable Potential, TRC Ratio, and Annual Spending in 2024 by Scenario

Scenarios	BAU	BAU+	Max
Achievable Potential (MW)	5.6 MW	6.0 MW	11.8 MW
Average Portfolio TRC	1.3	1.1	1.1
Portfolio Annual Spending	$1.1 million	$1.5 million	$3.6 million
Average Supply Cost ($/kW)	185 $/kW	250 $/kW	300 $/kW

1.4.2 Key Takeaways

Based on these findings, three key takeaways emerge:

- **CLC's current offerings (i.e., C&I curtailment and Smart Thermostats) are effective at capturing a significant portion of the ADR potential associated with those measures**; however, there remains room for further growth. The current ADR measures are capturing a large share of their existing potential (e.g., above 80% of the 2024 BAU C&I Curtailment).
  - An increase in incentives (BAU+) results in a modest increase in potential. However, CLC's high peak demand avoided costs can support an expanded pool of ADR measures alongside new and increased incentives, which could increase impacts approximately three-fold (under the Max scenario) in 2024 in a cost-effective manner.
- **The current focus on BYOD approaches for residential HVAC measures appears to limit the program's potential.** Because residential cooling is a key driver of the ISO-NE annual peak, connected thermostats that control AC units can play an important role in curtailing the peak demand. The study shows that offering connected thermostats to customers who would not adopt these on their own could help unlock significant potential. Broadly speaking, two approaches can help improve adoption of connected thermostats and thereby expanded ADR program participation:
  - Offering to provide smart thermostats to customers specifically to encourage ADR program participation could help overcome some market barriers to thermostat adoption, as has been witnessed in recent programs in a handful of other states. Although this unlocks the potential quickly, it does carry notable upfront cost, and there is some uncertainty as to the how long customers will remain with the program if they are not required to sign a multi-year participation contract.
  - Further thermostat adoption can also be encouraged by integrating marketing and incentive offers between ADR and efficiency programs. This approach may lead to a slower penetration rate, but it would likely be more cost-effective overall.
- **Battery storage offers a large swath of cost-effective ADR potential.** While C&I curtailment has the highest benefit-cost ratio, it cannot be applied in all cases. The analysis indicates that there is significant room for batteries to grow, particularly in the Residential sector. Compared to the rest of Massachusetts, CLC has three times more batteries per residential customer. Leveraging these batteries can lead to important ADR savings. This trend is expected to gain further momentum beyond the study period in both the residential and C&I sectors, as battery costs continue to decrease each year.

Overall, these finding indicate that both expanding to new measures and increasing incentives can play an important role in increasing active demand reduction potential in CLC's service territory.

2. Introduction

2.1 Study Overview and Scope

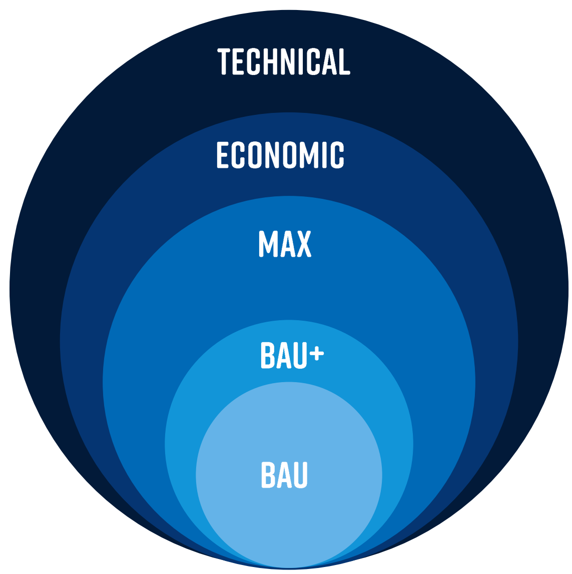
This report presents the results of the 2022–2024 CLC Potential Study. The study quantifies the savings potential from the Compact's demand-side management (DSM) programs and includes three components covering the following savings streams:

- Energy efficiency,
- Heating electrification, and
- Electric active demand reduction.

The study covers the three-year period between calendar years 2022 to 2024 and includes electricity, natural gas (herein referred to as "gas"), oil, and propane energy savings; passive and active electric demand reduction savings; and the costs and benefits associated with these savings.

As is standard practice in potential studies, the study assesses potential at the technical, economic, and program achievable levels. For each component, the study explores three program achievable scenarios to determine how incentive levels can impact achievable savings:

- A **BAU** (business-as-usual) scenario emulating existing incentive levels and program configurations,
- A **BAU+** scenario that increases incentives above BAU levels, and
- A **Max** scenario that represents the highest feasible achievable potentials



The specific incentive parameters employed for each study component are described in more detail in their respective chapters, and the description and methodological approaches for determining technical, economic, and achievable potential are described in Volume II of this report.

In addition to quantifying savings potential, study results can be used to support:

- Resource planning,
- Program planning, and
- State policy and strategies.

While the study provides granular information such as savings for specific measures in specific building segments, the study is not a program design document meant to accurately forecast and optimize savings and spending through DSM programs in a given future year. The study is meant to quantify the total potential opportunities that exist under specific parameters as defined under each scenario.

The study does not include an assessment of energy savings from combined heat and power (CHP). CHP is an energy efficiency technology that simultaneously generates electricity and useful heat that would otherwise be wasted, and CLC provides technical assistance and incentives for eligible CHP systems in its territory. Investments in these systems tend to be highly variable in terms of project size and lead times, which limits the value of projecting the achievable potential for this technology—particularly over short study periods.

The study also does not include other distributed energy resources such as distributed generation.

2.2 Savings Terminology

This study expresses savings in terms of **program savings** and **cumulative savings**:

- **Program savings** are the primary focus of this report and represent the savings from measures that are incentivized by DSM programs *in a given year*. Program savings are expressed in terms of first-year savings and lifetime savings:
  - **First-year program savings** are expressed in terms of savings achieved in the first year of measures incentivized through PA programs.
  - **Incremental lifetime savings** are expressed in terms of savings expected over the entire useful lives of incentivized measures.
- **Cumulative savings** are a rolling sum of all *new* savings from measures incentivized by DSM programs. Cumulative savings provide the total expected impact of incentivized measures on energy consumption and peak demand. Where applicable, cumulative savings are modified to account for the retirement of equipment that has reached the end of its effective useful life (EUL). For this reason, cumulative savings do not equal the sum of all program savings over a given period. For short-duration studies such as this one, however, cumulative savings and the sum of program savings across years will not diverge significantly.
- Unless otherwise noted, all program savings are expressed in terms of **net program savings**, which accounts for free ridership and spillover effects attributable to the modeled programs.

2.3 Report Structure

This report consists of two volumes. This volume (Volume I) presents the potential study results, while Volume II outlines the study's supporting data, inputs, and methodological approaches.

In Volume I, each study component's results are presented in individual chapters. For each component, results are shown by sector, segment, and end-use. Portfolio metrics including benefits and costs are also presented within each chapter. The final chapter of Volume I provides a high-level combined savings overview from all study components.

In Volume II, general study inputs and methodological approaches are presented along with specific information for each study component. Volume II also includes detailed results and inputs, including data tables in Excel workbook format.

3. Summary of Baseline Results

A key input into the potential model is the penetration and saturation of major electricity-using equipment in homes and businesses. These two concepts are defined as follows:

- **Penetration:** A percentage representing the proportion of customers that have one or more of a particular piece of equipment. It is calculated by dividing the number of customers with one or more of a piece of equipment by the total number of customers. For example, the penetration rate of fuel oil boilers for Single Family residential market rate customers is 17%, meaning that 17 out of every 100 Single Family households have at least one fuel oil boiler installed.
- **Saturation:** A number representing how many of a particular piece of equipment exist, on average, among all customers. It is calculated by dividing the total number of a particular piece of equipment by the total number of customers (*including* those who do not have the equipment). For example, the saturation of refrigerators in Single Family homes is 1.57, meaning that on average each Single Family home (including those with no refrigerator) has 1.57 refrigerators.

The following tables summarize key Compact-specific residential and C&I metrics developed as inputs for the potential model. These metrics were developed from recent statewide data collection efforts, data collected by the Potential Study Team for the 2014 Potential Study, and secondary data sources. The complete baseline results are provided in Appendix F. A detailed description of the baseline market characterization methodology is provided in Appendix A.

Table 8 presents equipment penetrations for three residential segments: Single Family Market Rate, Multi-Family Market Rate, and Low Income. Table 9 presents saturation estimates, and Table 10 presents general population and building characteristics.

Table 8. Residential Penetration Results

Metric	Market Rate		Low Income
	Single Family	Multi-Family	
HVAC - Heating			
Primary Heating – Natural Gas	67%	33%	59%
Primary Heating – Fuel Oil	20%	5%	16%
Primary Heating – Electricity	8%	24%	13%
Primary Heating – Propane	4%	<1%	<1%
Primary Heating – Biomass	1%	<1%	<1%
Primary Heating – Shared	<1%	38%	11%
Natural Gas Furnace	34%	15%	29%
Natural Gas Boiler	31%	8%	34%
Fuel Oil Boiler	17%	1%	14%
Fuel Oil Furnace	3%	<1%	4%
Electric Baseboards	4%	9%	11%
HVAC - Cooling			
Central AC or Central HP	47%	38%	36%
Ductless Minisplit Heat Pumps	16%	2%	7%
Water Heating			

Metric	Market Rate		Low Income
	Single Family	Multi-Family	
Primary Water Heating – Natural Gas	46%	39%	41%
Primary Water Heating – Electricity	18%	44%	21%
Primary Water Heating – Fuel Oil	4%	1%	7%
Primary Water Heating – Propane	4%	4%	0%
Primary Water Heating – Indirect	28%	<1%	24%
Primary Water Heating – Shared	<1%	13%	6%

Table 9. Residential Saturation Results

Metric	Market Rate		Low income
	Single Family	Multi-Family	
Lighting			
Standard bulbs	35	14	28
Reflector bulbs	15	8	6
Candelabra and globe bulbs	35	14	28
Appliances			
Refrigerators	1.57	1.00	1.34
Standalone Freezers	0.22	0.10	0.20
Dishwashers	0.96	0.80	0.85
Clothes Washers	1.04	0.80	0.87
Clothes Dryers	1.07	0.80	0.89
Room Air Purifiers	0.19	0.14	0.21
Dehumidifiers	0.85	0.23	0.49
Electronics			
Power strips (incl. smart strips)	2.23	1.00	2.48
Smart strips	0.15	-	0.02
HVAC - Cooling			
Room AC	0.82	0.38	1.06
Ductless Minisplit Heat Pumps	0.16	0.02	0.07
Water Heating			
Mean number of faucets per household	4.00	2.88	3.23
Mean number of faucet aerators per household	2.38	1.00	1.07
Mean number of showerheads per household	2.12	1.75	1.80

Table 10. Residential General Characteristics Results

Metric	Market Rate		Low income
	Single Family	Multi-Family	
Number of Electricity Customers (Population)	169,751	8,485	11,358
Number of Gas Customers	99,429	3,125	5,645
Number of Oil Customers	33,906	397	2,067
Number of Propane Customers	9,315	342	0

Metric	Market Rate		Low income
	Single Family	Multi-Family	
Mean Annual Electricity Consumption (kWh) per Household	5,808	6,109	6,839
Mean Square Footage per Home	1,829	1,184	1,428
Annual Population Growth Rate (New Construction)	0.30%	0.30%	0.20%

Table 11 presents key C&I equipment penetrations and Table 12 presents general population and building characteristics.

Table 11. Commercial and Industrial Penetration Results

Metric	Overall
HVAC - Heating	
Primarily Use Natural Gas Heating	56.3%
Primarily Use Fuel Oil Heating	15.1%
Primarily Use Electricity Heating	12.7%
Primarily Use Propane Heating	8.2%
Primarily Use Biomass Heating	<1%
Primarily Use Another Fuel Heating	<1%
Unheated	7.6%
Water Heating	
Electricity as Primary Water Heating Fuel	35.3%
Natural Gas as Primary Water Heating Fuel	44.6%
Fuel Oil as Primary Water Heating Fuel	14.2%
Propane as Primary Water Heating Fuel	5.8%

Table 12. Commercial and Industrial General Characteristics Results

Metric	Overall
Annual Population Growth Rate (New Construction)	0.25%
Natural Gas	
Number of Gas Customers	8,176
Mean Gas Consumption (GJ) per Business	208.5
Percentage of Gas Customers with Small Consumption (< 8,000 therms)	91.0%
Percentage of Gas Customers with Medium Consumption (8,000 - 80,000 therms)	8.5%
Percentage of Gas Customers with Large Consumption (> 80,000 therms)	0.5%
Electric	
Number of Electricity Customers (Population)	16,651
Mean Electricity Consumption (kWh) per Business	50,419
Mean Electricity Demand (kW) per Business	14
Delivered Fuels	
Number of Oil Customers	3,272
Mean Oil Consumption (GJ) per Business	24.6
Number of Propane Customers	1,623

Metric	Overall
Mean Fuel Propane Consumption (GJ) per Business	26
Mean Fossil Fuel Consumption (GJ) per Business	259
Square Footage	
Mean Square Feet per Business	3,375
Percentage of Businesses 0 to 2,499 Square Feet	71.7%
Percentage of Businesses 2,500 to 4,999 Square Feet	16.1%
Percentage of Businesses 5,000 to 9,999 Square Feet	7.0%
Percentage of Businesses 10,000 to 24,999 Square Feet	3.6%
Percentage of Businesses 25,000 to 49,999 Square Feet	1.0%
Percentage of Businesses 50,000 to 74,999 Square Feet	0.3%
Percentage of Businesses 75,000 to 99,999 Square Feet	0.1%
Percentage of Businesses 100,000 to 199,999 Square Feet	0.2%
Percentage of Businesses 200,000 to 499,999 Square Feet	<0.1%
Percentage of Businesses More Than 500,000 Square Feet	<0.1%

4. Energy Efficiency Potential Results

4.1 Overview

This chapter presents results for the EE Potential Study. The EE module estimates energy savings for electric and delivered fuel (oil and propane) measures as well as summer and winter peak demand savings (i.e., passive demand reductions) for electric measures. It does *not* include HE or ADR savings or consumption impacts, which are discussed in subsequent chapters.[8]

The chapter briefly summarizes the methodological approach used to estimate EE potential, followed by study results. A full description of the methodology can be found in Volume II of this report.

4.1.1 Approach

The market potential for EE is assessed using the Dunsky Energy Efficiency Potential (DEEP) model. DEEP employs a bottom-up modeling approach that assesses thousands of “measure-market” combinations, applying program impacts (e.g., incentives and enabling activities that reduce customer barriers) to assess energy savings potentials across multiple scenarios. Rather than estimating potential based on the portion of each end-use that can be reduced by energy saving measures and strategies (often referred to as a “top-down” analysis), the DEEP model approach applies a highly granular calculation methodology to assess the energy savings opportunity for each measure-market segment opportunity in each year.

4.1.2 Achievable Scenarios

The EE module explores three achievable program scenarios as described in Figure 12. The BAU scenario is designed to emulate savings that can be achieved under existing program structures and incentive levels albeit with measures and technologies that may not be currently offered by existing programs. The BAU+ and Max scenarios demonstrate what is possible with increased incentive levels.

Figure 12. Energy Efficiency Achievable Scenario Descriptions

BAU	Applies incentives and program configurations in line with the PA’s incentives paid in 2019 to simulate **business as usual**. Additional prescriptive measures beyond those currently offered may be included.
BAU+	Increases incentives **above and beyond** BAU levels. Specifically, weatherization measure incentives are set at 90% incremental costs and all other incentives are set 50% higher than BAU levels with a maximum of 90% of incremental cost (unless BAU scenarios already exceed this threshold).
Max	Completely **eliminates incremental customer costs** associated with installing efficiency measures (all incentives set to cover 100% of the efficiency measure incremental cost).

[8] HE and DR savings are estimated with separate models as described in Volume II of this report and thus are presented separately. Adjustments are made for interactive effects between study components. These adjustments are described in Appendix B.

Program Enhancements and Measure Adoption

Energy efficiency programs typically combine incentives (or rebates) to improve customer cost-effectiveness, along with enabling strategies, such as contractor training, marketing and education, and other approaches that can help reduce market barriers to widespread adoption of efficient technologies.

There is a substantial body of empirical evidence available to help quantify customers' willingness to pay for an efficiency upgrade, which is captured in the adoption curves applied in this study to predict the impact of varying incentive levels on the achievable potentials. Conversely, the impact of specific enabling strategies can be more difficult to quantify, and there is little empirical data available on how specific strategies may impact program performance.

Considering these factors, this study focuses the achievable potential scenarios on varied incentive levels but does not account for changes to other program features or enabling strategies. Instead, for each savings stream and sector, the end-uses that show a significant amount of untapped economic potential are identified as opportunities where further enabling strategies and market transformation approaches could help grow the program impacts.

Results Presentation and Benchmarking

Throughout this chapter, results are benchmarked to evaluated savings from CLC's 2019 Plan-Year Report ("2019 Results") as well as the projected 2021 savings in the 2019–2021 Energy Efficiency Plan ("2021 Plan"). To enable commensurable comparisons, the benchmark metrics remove savings attributable to measures outside the scope of the EE analysis, including CHP savings (out of scope for this study) and HE savings (presented separately in this report).

2019 Results benchmarks are derived from the detailed workbooks provided with the 2019 Energy Efficiency Plan-Year Report. 2021 Plan benchmarks are derived from the BCR model workbooks provided with the 2019–2021 Electric and Gas Three-Year Energy Efficiency Plan.

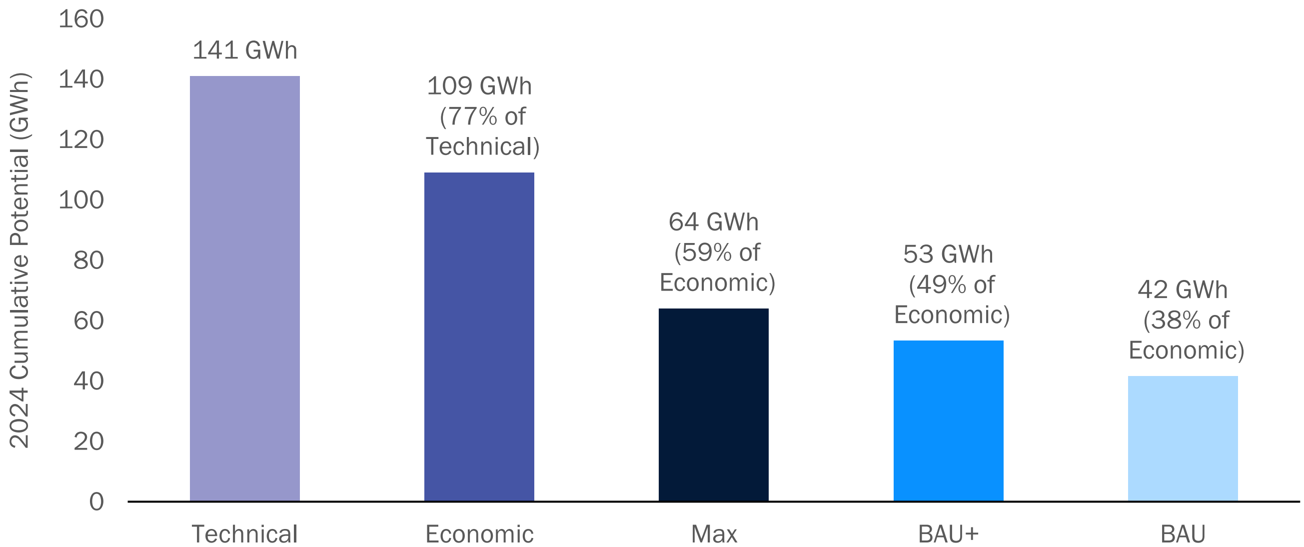
4.2 Electric Potential Results

This section presents **electric savings potential** for CLC's electric efficiency programs. The results focus on electric energy and passive electric demand as these are the primary focus of programs.[9] The next subsection presents delivered fuel savings.

Figure 13 presents technical, economic, and achievable electric energy savings potential in terms of cumulative annual impacts in 2024 from measures installed during the 2022–2024 study period.

[9] Active electric active demand reduction potential is discussed in the DR chapter.

Figure 13. 2024 Cumulative Technical, Economic, and Achievable Electric Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

The top-level insights across scenarios are presented below.

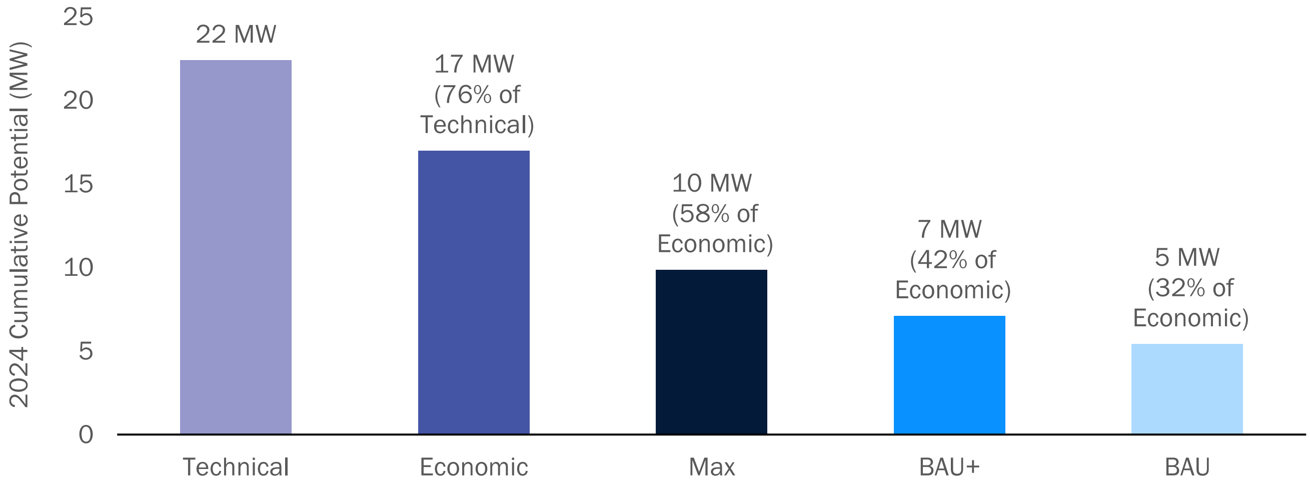
- **Compared to CLC's previous potential study, electric technical potential has declined significantly.**[10] The previous study estimated 431 GWh of cumulative annual impacts over the three-year study period (2019–2021). In this study, technical potential is estimated at 141 GWh—approximately 67% lower than the previous study.
  - This difference is primarily driven by a reduction in lighting savings potential. Over the last three years, the lighting market in CLC's territory has continued to transform and a significant portion of lighting equipment has been replaced with efficient products. By the first year of the study period (2022), this study assumes most existing lighting equipment is efficient. For example, the study assumes only 20% of residential bulbs and 10% of C&I bulbs will have not been replaced with efficient products by 2022.[11] With such a high penetration of efficient lighting, there is significantly less technical potential for electric savings from lighting improvements.
- **Most electric savings pass economic screening.** Net economic potential is 32 GWh less than technical potential, with approximately 23% of this difference due to measures failing the Total Resource Cost (TRC) test. In total, 95% of technical electric savings pass economic screening.[12] The remaining difference is due to the application of net-to-gross ratios (NTGR), which generally reduce net electric savings due to large free ridership effects for many electric measures.
- **The BAU scenario captures less than 40% of economic savings.** Under current incentive levels, only 38% of net economic savings are captured, suggesting there is significant room to grow electric savings with increased incentives and enhanced program designs.

[10] *CLC Electric & Gas Efficiency Potential Study Report – Volume 1.* Opinion Dynamics & Dunsky Energy Consulting. June 2018.
[11] For additional detail on the specific assumptions regarding lighting penetration, see Appendix C.
[12] Gross economic potential nears technical potential for two primary reasons. First, the study employs a phased-in potential assessment approach that accounts for expected market turnover in the study period. Second, the study focuses on measures that are commercially viable; thus measures that may offer technical potential, but are not expected to be cost-effective were largely omitted from the study.

- **Increasing incentives can significantly increase savings.** Under the Max scenario, the portion of net economic savings captured increases by 21 percentage points relative to the BAU scenario. When 100% of customers' incremental costs are covered, CLC's electric programs have the potential to capture over half of net economic electric potential.

Figure 14 presents technical, economic, and achievable **passive electric demand savings** potential in terms of cumulative annual impacts in 2024 from measures installed during the 2022–2024 study period.

Figure 14. 2024 Cumulative Technical, Economic, and Achievable Demand Potential

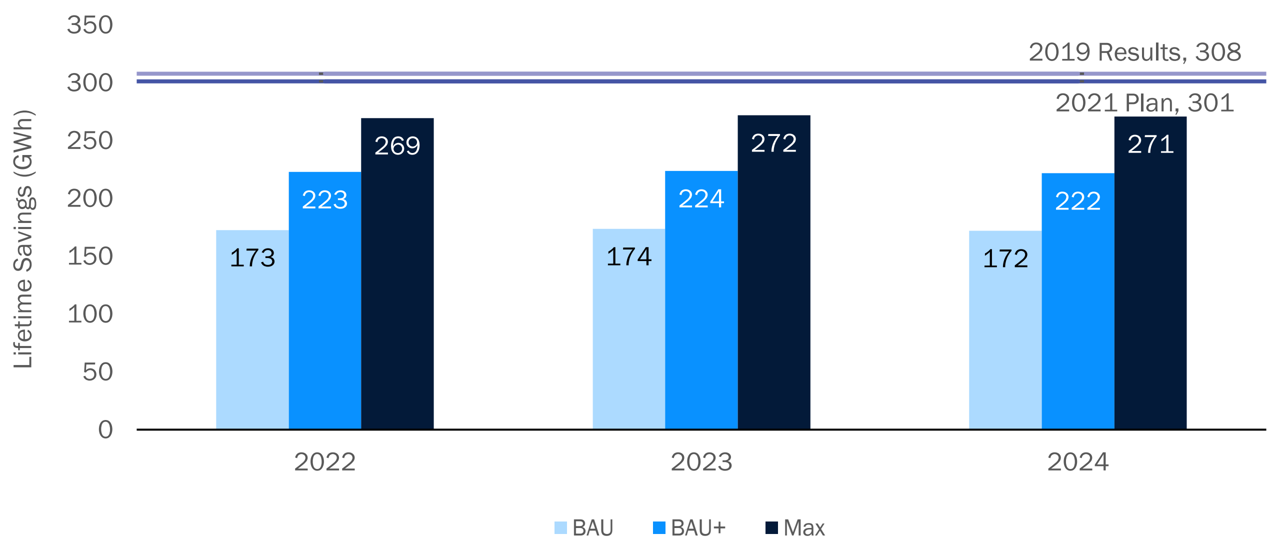


Potential for passive electric demand savings mostly mirrors electric energy savings with economic potential representing 76% of technical potential and the achievable potential scenarios capturing between 32% and 58% of net economic potential.

4.2.1 Overall Program Savings

Figure 15 presents lifetime savings in each study year under each achievable scenario.

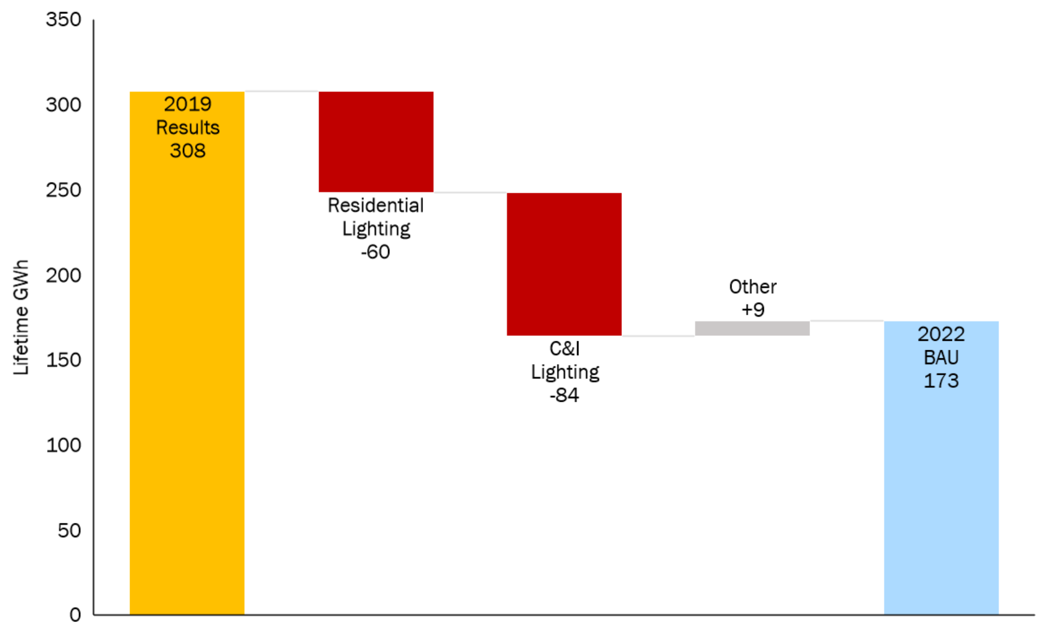
Figure 15. Electric Lifetime Savings by Year



Compared to 2019 Results and the 2021 Plan savings, achievable lifetime electric savings are expected to decline precipitously. Under BAU incentive levels, 2022–2024 average lifetime savings are approximately 44% below past program savings. The decline is almost entirely attributable to reductions in lighting savings from both the residential and C&I sectors. As shown in Figure 16, reductions in residential and C&I lighting savings reduce lifetime savings in 2022 by 144 GWh compared to 2019 Results, which accounts for much of the difference between the two years. As previously described, this reduction in lighting savings is driven by the rapid transformation of lighting markets, which is demonstrated by the high penetrations of efficient lighting in both the residential and C&I markets and growing free ridership within CLC's lighting programs as efficient lighting becomes the default choice for the majority of customers.[13]

[13] For additional detail on assumptions regarding lighting net-to-gross factors, see Appendix C.

Figure 16. 2022 BAU Electric Lifetime Savings vs. 2019 Results



While the reduction in lighting savings explains most of the difference between 2019 Results and 2022 BAU in Figure 16, it should be noted that there are additional differences between the two years that result in both increases and decreases in savings—albeit in magnitudes that largely offset each other (i.e., increases in home energy report savings and HVAC measure savings, decreases in residential envelope and commercial refrigeration measures). These differences are discussed later in the chapter.

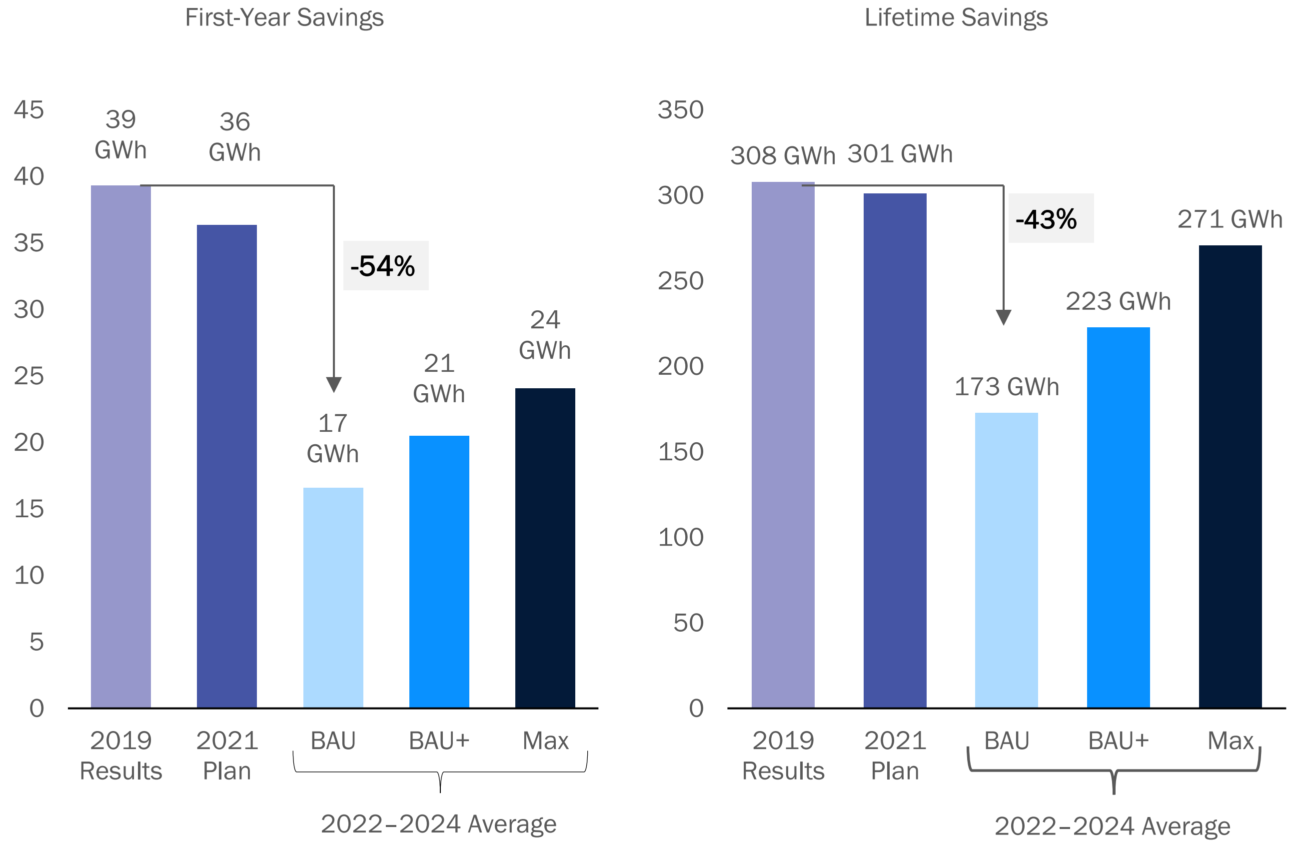
The reduction in lighting savings is significant enough that even under Max incentive levels, savings do not reach levels achieved in the past. Under the BAU+ and Max scenarios, 2022–2024 average lifetime savings increase by 29% and 57%, respectively, relative to BAU yet still fall short of past achievements. This suggests that without additional program enhancements that further reduce customer market barriers for non-lighting measures, maintaining electric savings at historical levels will not be possible even with 100% incentives.

Savings are stable across study years. Slight year-over-year differences are due to general market growth, changing baseline standards, and the plateauing of some discretionary measures with significant historical uptake. Overall, these impacts are small and counteract each other, resulting in year-over-year fluctuations of less than 1% under every scenario. Due to this stability, the remainder of this section expresses savings as the 2022–2024 average.

First-Year versus Lifetime Electric Savings

Figure 17 compares first-year and lifetime electric savings. Relative to 2019 Results, the observed reduction in electric savings potential from recent program savings levels is starker when measured in first-year savings, than it is when considered on a lifetime savings basis. In first-year terms, BAU savings are 54% below 2019 Results levels compared to the 43% drop when measured in lifetime savings.

Figure 17. Annual vs. Lifetime Electric Savings Comparison



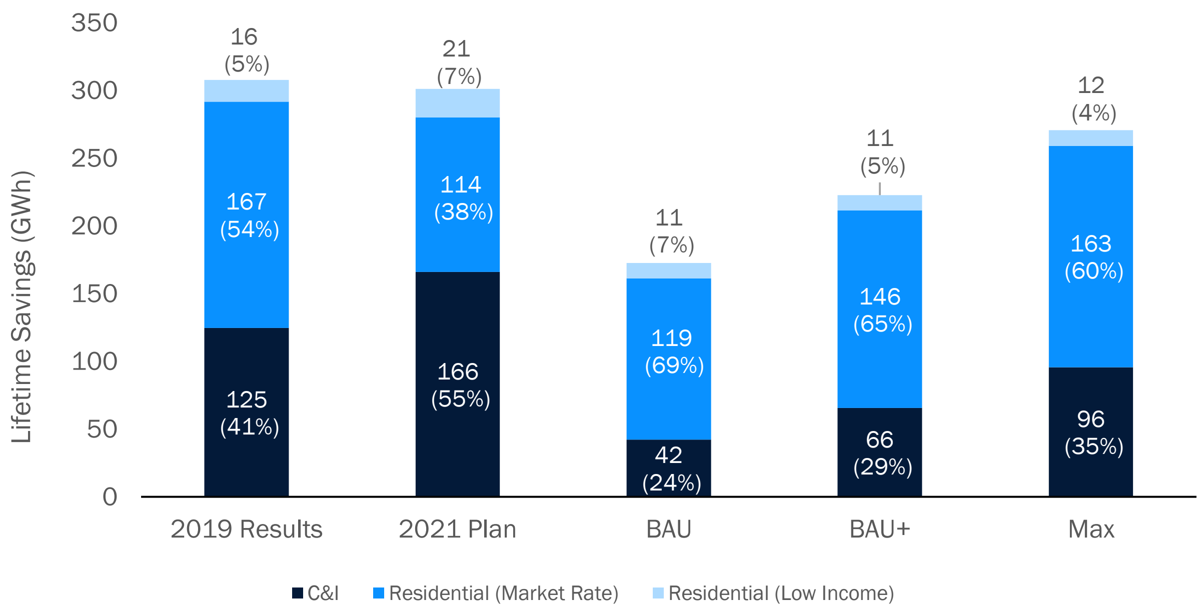
This difference is driven by two main factors:

- **Lighting measures have short EULs.** First, the reduction in lighting savings has a greater proportional impact on first-year savings relative to lifetime savings due to the generally short savings persistence of many lighting measures. In particular, savings from efficient LED bulb measures within the 2019 Results and 2021 Plan persist for under 5 years as these measures generally replace baseline lighting equipment with short EULs (e.g., halogen bulbs). Thus, these measures have lower lifetime savings relative to first-year savings, when compared to measures with longer EULs. This effect is particularly pronounced in the 2019 Results due to larger amount of residential lighting savings relative to the 2021 Plan.
- **Home Energy Report (HER) savings have a short persistence.** Second, changes in assumptions for the HER measure compared to the 2021 Plan have a much greater impact on first-year savings than lifetime savings. Due to low levels of savings achieved to date, the assumed per participant claimable savings attributable to behavioral changes from HERs has been reduced during the study period. This study assumes HER savings persist for a single year (i.e., EUL of 1 as specified in the MA TRM), which significantly reduces the measure's lifetime savings metric.

Savings by Sector

While both the residential and C&I sectors show reductions in savings potential compared to 2019 Results, the reduction in the C&I sector far outpaces that of the residential sectors. As a result, **the residential sectors dominate electric savings**, accounting for 76% of total BAU savings compared to 59% of 2019 Results (see Figure 18).

Figure 18. Electric Lifetime Savings by Sector



Note: 2022–2024 Average; All Scenarios

Both residential and C&I sectors show propensity for growth under higher incentives. While the residential and C&I sectors both respond to increasing incentive levels, the increase in potential from BAU to Max is significantly higher for the C&I sector (129% increase) than for the residential sectors (35%). The difference in potential for the residential low income sector is small, given already high incentive levels in the BAU scenario.

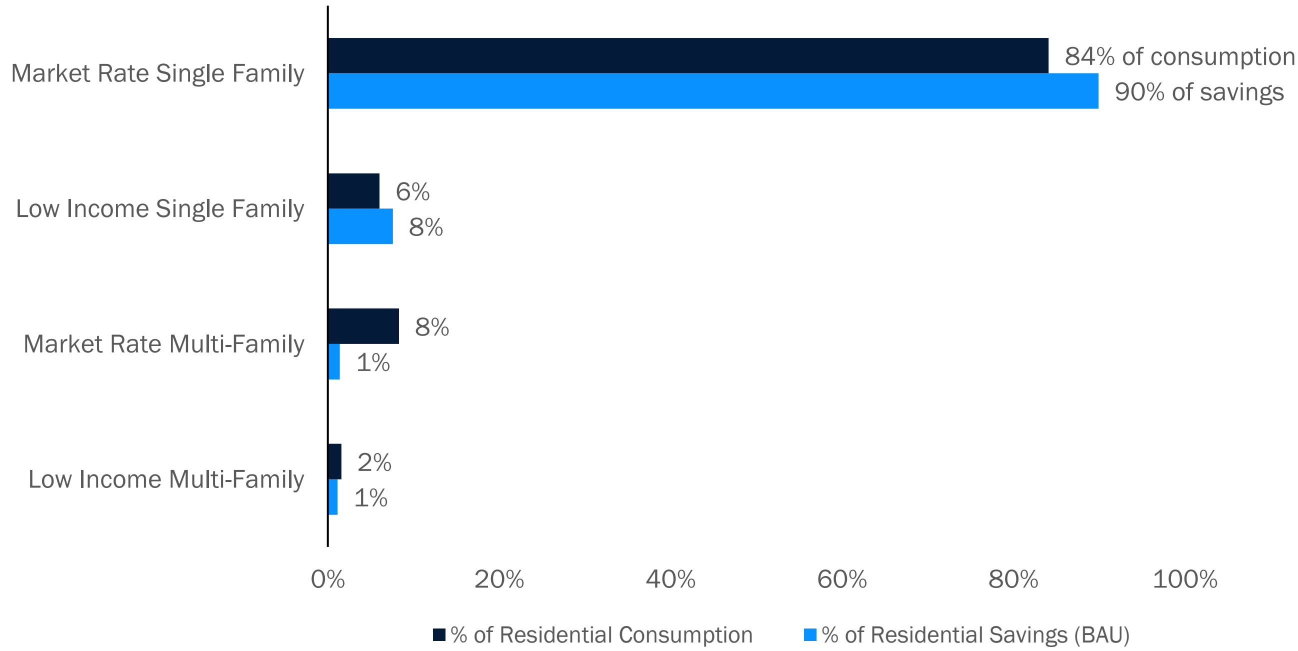
4.2.2 Residential Savings

Savings by Market Segment

In the residential sectors, the bulk of savings resides in the market rate single family segment (see Figure 19). When compared to the portion of electric consumption within each segment, however, the single family market rate and low income segments claim a greater share of savings, while the multi-family segments' portion of savings are less than their portion of consumption.[14] This is indicative of the success of existing programs at reaching single family households (including low income households, which are traditionally hard to serve) as well as the general barriers inherent in reaching multi-family customers.

[14] Multi-family market segment savings include savings from large master-metered buildings and multi-family common areas. For modeling purposes, these savings are modeled in the C&I sector and apportioned to the residential sector outside of the model. See Appendix A (Customer Population) for more detail.

Figure 19. Percent of Residential Lifetime Electric Savings vs. Percent of Electric Consumption by Segment



Note: 2022–2024 Average, BAU Scenario

As incentives increase, the shares of savings from the four residential segments are relatively stable, with a slight decline in the portion of savings in the low income single family segment (see Table 13).

The proportion of residential savings from the low income single family market segment decreases since incentives are already at 100% under the BAU scenario. Savings in the other segments grow under increased incentives in BAU+ and Max while low income savings remain constant, leading to a decline in the relative portion of residential savings that the low income segment represents.[15]

Table 13. Percent of Residential Lifetime Electric Savings by Segment (2022–2024 Average)

Segment	2022–2024 Average Lifetime GWh (% of Total)		
	BAU	BAU+	Max
Single Family	117 (90%)	143 (91%)	160 (91%)
Low Income Single Family	10 (8%)	10 (6%)	10 (6%)
Low Income Multi-Family	1 (1%)	2 (1%)	2 (1%)
Multi-Family	2 (1%)	3 (2%)	3 (2%)

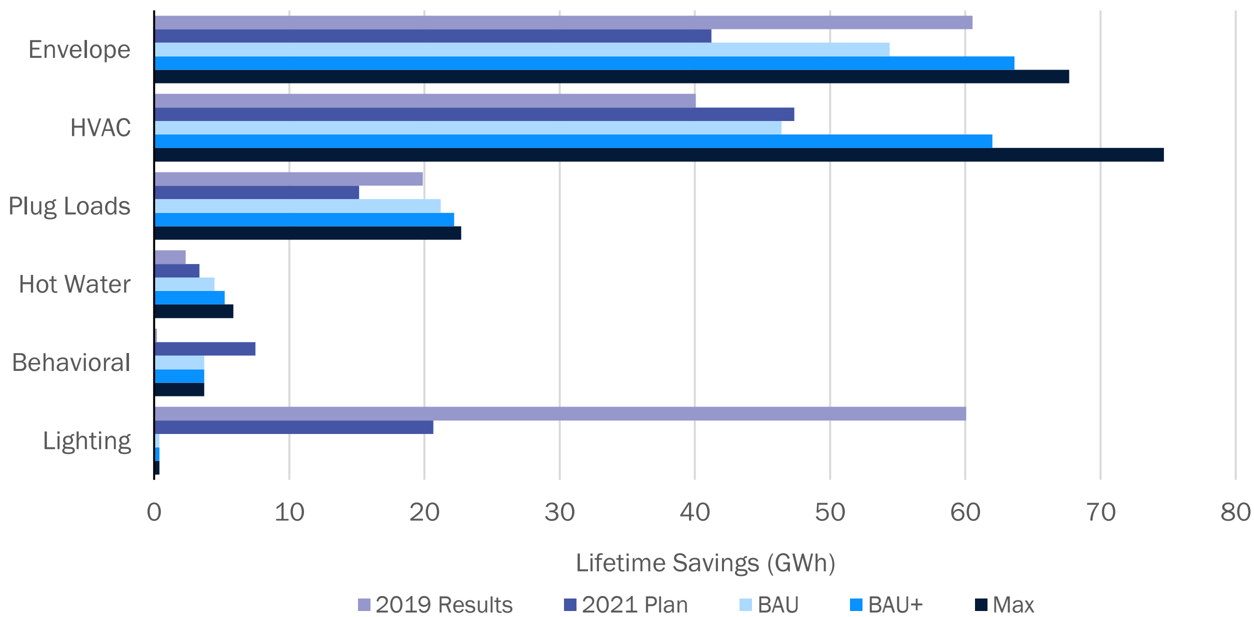
Note: Market segments are arranged by relative contribution to the sector's 2022–2024 average lifetime savings under the BAU scenario.

[15] Low income multi-family savings increase slightly in absolute terms under the BAU+ and Max scenarios because part of the potential in this segment is allocated from the C&I multi-family segment, which does have increasing incentive levels in the BAU+ and Max scenarios.

Savings by End-Use

Figure 20 shows residential market lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

Figure 20. Residential Electric Lifetime Savings by End-Use



Note: Categories are arranged by relative contribution to 2022–2024 average lifetime savings under the BAU scenario.

When viewed at the end-use level, several key trends emerge:

- **Lighting savings are eliminated for all but the low income customers.** The decline in residential lighting savings is stark—transitioning from one of the most prominent end-use categories to the least. Under BAU conditions, lighting savings become less than 1% of overall residential lifetime electric savings compared to 33% in 2019 Results and 15% in the 2021 Plan. Within the study, the only remaining lighting savings come from low income direct install programs, which is why lighting savings remain static between achievable scenarios.
- **HER savings are assumed to drop.** Behavioral savings, which consist entirely of HER savings, are significantly different from 2019 Results and the 2021 Plan. The HER Program was beginning to ramp-up in 2019 but achieving very low savings results (much lower than planned in 2019). Due to the low level of savings achieved to date, a conservative approach was taken for the study, halving the per-customer savings compared to the 2021 Plan (but keeping participation levels constant). Behavioral savings do not increase between achievable scenarios as the HER measure does not include a traditional incentive that can be changed between scenarios.[16]
- **Other end-uses remain largely consistent between past results and the BAU projections.** The remaining end-use categories are similar to 2019 Results and 2021 Plans under BAU conditions as assumptions

[16] This study does not explicitly attribute savings related to increasing program participation to the HER measure to avoided double-counting savings estimated in other programs. This aligns with the MA TRM and evaluations of MA's behavioral programs, which account for and "remove savings co-generated by behavioral and standard programs in order to avoid double counting savings." See "Massachusetts Cross-Cutting Behavioral Program Evaluation Power Results." Navigant Consulting, Inc. and Illume Advising, LLC. March 2015.

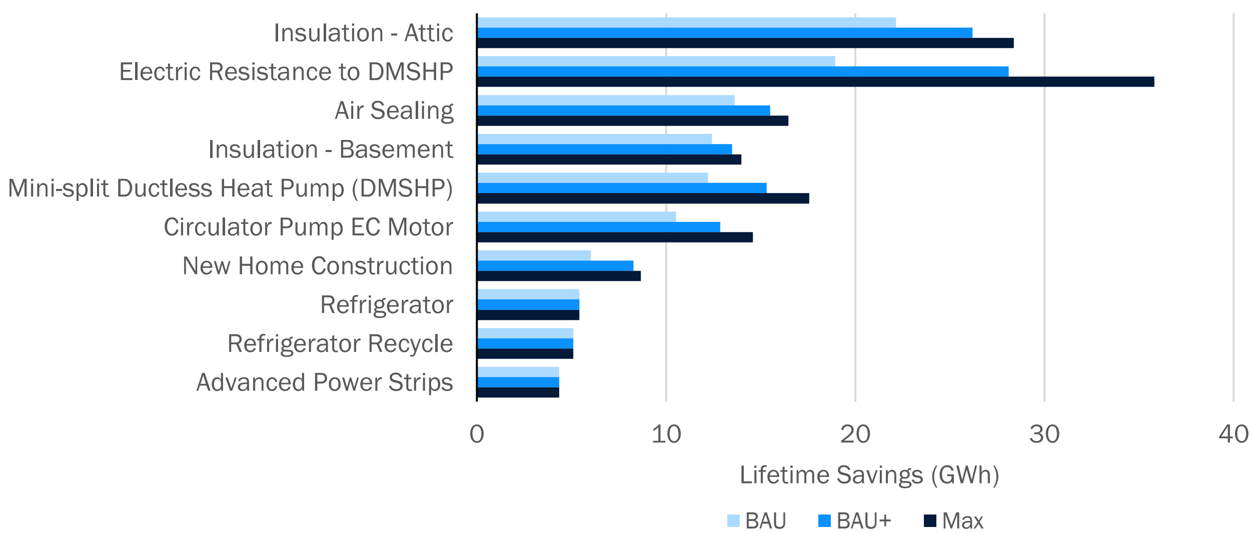
regarding exogenous factors (e.g., standards updates, market transformations) do not change significantly between 2019 Results, the 2021 Plan, and the study. One notable exception is HVAC savings, which exhibit an increase in savings in the BAU scenario compared to the 2019 Results due to general growth in heat pump adoption as this market becomes more mature. This growth in heat pump adoption and EE savings is distinct from additional growth expected through CLC's heating electrification programs (described in the HE chapter).

With increasing incentives, most end-uses see growth in savings, except behavior and lighting as noted above. In the BAU+ scenario, savings from hot water measures are particularly responsive—more than doubling relative to the BAU scenario. HVAC measures display the biggest absolute jump in savings increasing by 16 lifetime GWh under the BAU+ scenario—a 34% increase. When customers' incremental costs are completely eliminated under the Max scenario, HVAC savings grow significantly increasing by 61% relative to BAU savings.

Top Measures

With the loss of residential lighting savings, the most prominent end-use categories become envelope, HVAC, and appliance measures. As shown in Figure 21, most of the top measures for residential lifetime savings fall into these categories.

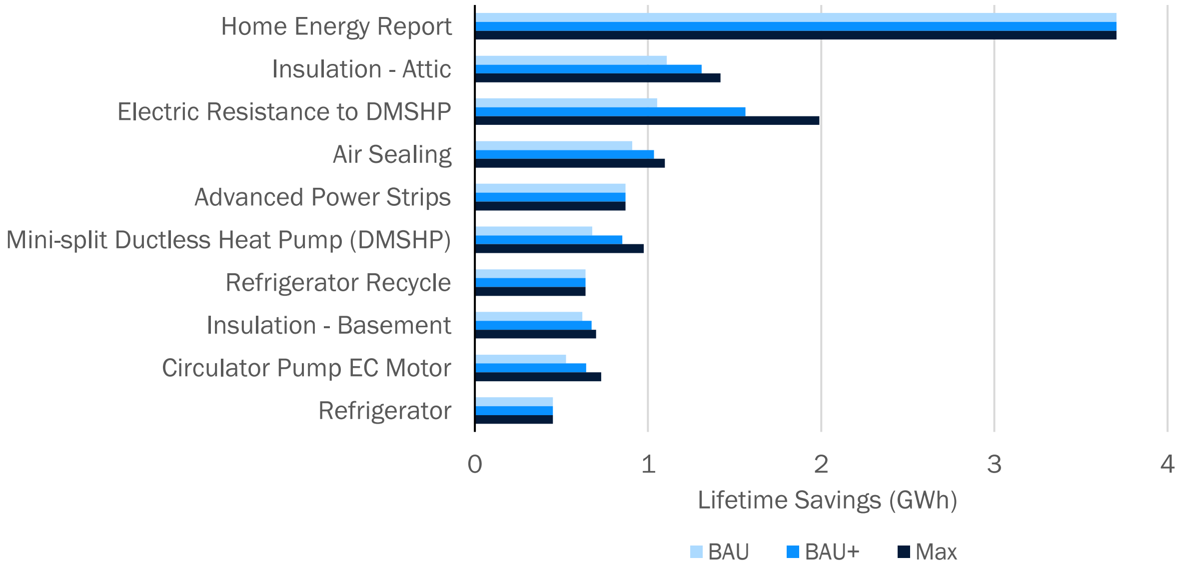
Figure 21. Top 10 Electric Residential Measures by Lifetime Savings (2022–2024 Average)



Note: Measures are selected and arranged by relative contribution to 2022–2024 average lifetime savings under the BAU scenario.

In terms of first-year savings, several other measures make the top 10 list. HERs become the most prominent measure (as shown in Figure 22) despite the change in per household savings assumptions, showing that a sustained behavioral program can have a significant impact on residential savings in a given year.

Figure 22. Top 10 Electric Residential Measures by First-Year Savings (2022–2024 Average)



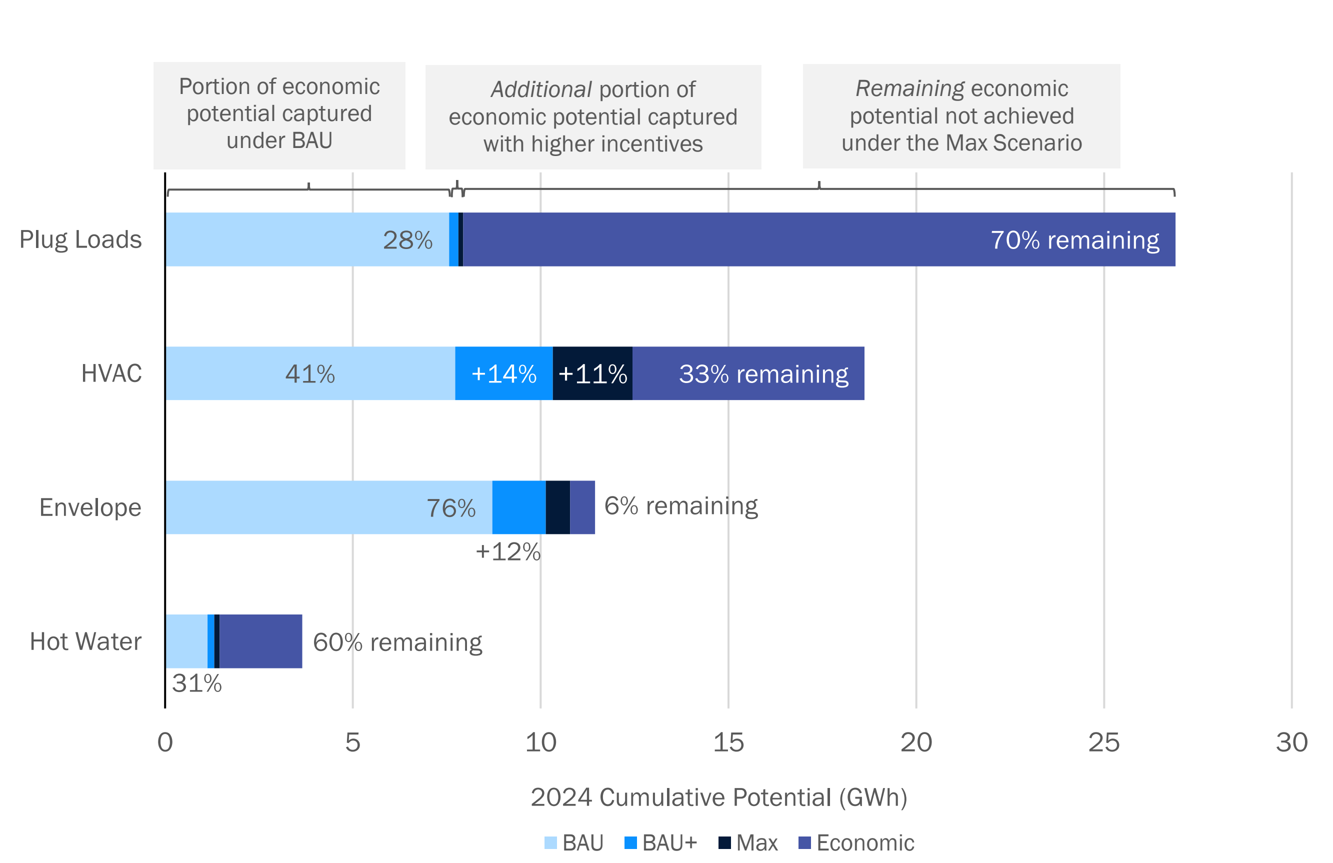
Note: Measures are selected and arranged by relative contribution to 2022–2024 average first-year savings under the BAU scenario.

Of note in this list of top 10 measures is the absence of thermostat measures. For delivered fuels, both programmable and Wi-Fi thermostat measures feature prominently in the top measure lists. A driving factor for their relatively lower importance to residential electric savings is thermostat savings assumptions. This study uses the deemed savings values for thermostats in accordance with the MA TRM. These deemed values are significantly lower than savings assumptions made in other jurisdictions.

Potential Growth Opportunities

Figure 23 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 23. Electric Residential Growth Opportunities



Note: Residential lighting and behavioral savings show minimal growth opportunities and are excluded from the above figure.

Under BAU incentives, varying shares of the economic potential are captured across the top end-use categories, ranging from 28% (plug loads) to 76% (envelope). Most end-uses see marginal growth with increased incentives, with the exception of HVAC measures, which add a further 25% of the economic savings under the Max scenario relative to BAU.

Even at 100% incentives under the Max scenario, a significant portion of economic savings remain in plug loads, HVAC, and hot water measures—suggesting that barriers beyond customer economics are inhibiting adoption of these measures. In contrast, 94% of the economic envelope savings are captured under the Max scenario, indicating that there is potential for growth beyond the significant BAU levels (76%).

Electric Efficiency Programs in a Post-Lighting World

As lighting savings fade from CLC's residential programs, strategies to encourage adoption of a more diverse mix of efficiency opportunities become essential. The remaining untapped economic potentials identified in this study may in many cases lend themselves more to market transformation approaches—training, qualifications, financing, new business models, regulation—rather than the traditionally successful "resource acquisition" strategies that rely on rebates and similar tools. This is particularly relevant for securing deep savings opportunities in the envelope and HVAC categories that typically require more capital and increasingly skilled labor across multiple trades.

While the transformation of the lighting market in Massachusetts should be viewed as a success, it does pose a challenge for the next phase of efficiency programs, as the state strives to meet historically high savings targets. The value of accessing new and deeper savings opportunities is apparent, given the increasing demand for electricity coupled with the significant remaining efficiency opportunities that remain more cost-effective than the cost of electricity supply. A partial pivot toward longer-term market transformation strategies could successfully replace more of the lost lighting savings but may also run up against the limitations of the current regulatory framework.

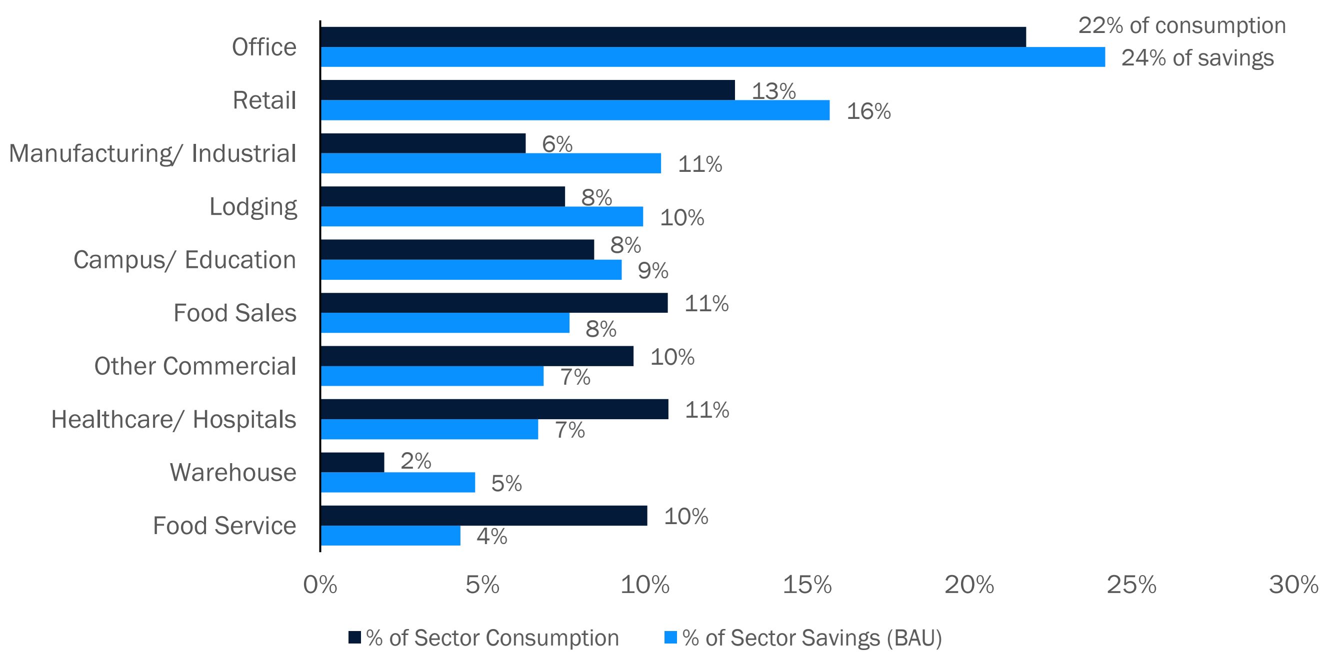
4.2.3 C&I Savings

The following section presents electric results for the C&I sector.

Savings by Segment

The C&I sector is split into ten market segments with each segment representing a pool of savings opportunities based on expected building configurations and operations across the segment. Under the BAU scenario, the office and retail segments, combined, represent 40% of overall C&I lifetime electric savings as shown in Figure 24.

Figure 24. Percent of C&I Lifetime Electric Savings vs. Percent of Electric Consumption by Segment (2022–2024 Average, BAU Scenario)



For most segments, their portion of electric savings is fairly aligned with their portion of sector-wide electricity consumption. Notable exceptions are the manufacturing/industrial and warehouse segments, where savings are higher than the portion of consumption, suggesting savings opportunities are relatively abundant in these segments. Additionally, food service represents 10% of consumption but only 4% of savings, suggesting relatively fewer savings opportunities in this segment.

While these results are indicative of which segments hold the greatest potential for savings, they should be interpreted with the following caveats:

- Updated baseline data collection for CLC C&I customers was limited and use of recent data was impractical (due to lack of sufficient observations). Consequently, it was necessary to leverage data from the previous baseline studies and nearby jurisdictions. While not ideal, the use of alternative data sources still provides reasonable estimates of C&I potential at the aggregate sector-wide level, but the uncertainty at the segment level is somewhat increased. See Appendix A for a complete description of the Baseline Market Characterization methodology.
- Available past program data is not broken down by segment. Therefore, it is not possible to calibrate modeled savings on a segment-by-segment basis. This may introduce some uncertainty in the distribution of savings among the various segments.

Table 14 shows the savings by segment across the different achievable potential scenarios. Segment contributions do not change significantly across scenarios, but some segments show higher growth with increased incentives, notably manufacturing/industrial under the Max scenario.

Table 14. Electric C&I Lifetime Savings by Market Segment

Segment	2022–2024 Average Lifetime GWh (% of total)		
	BAU	BAU+	Max
Office	10 (24%)	16 (25%)	22 (23%)
Retail	7 (16%)	10 (15%)	12 (13%)
Manufacturing/Industrial	4 (11%)	7 (11%)	18 (19%)
Lodging	4 (10%)	5 (8%)	6 (6%)
Campus/Education	4 (9%)	6 (9%)	8 (8%)
Food Sales	3 (8%)	6 (8%)	8 (8%)
Other Commercial	3 (7%)	5 (7%)	7 (7%)
Healthcare/Hospitals	3 (7%)	5 (7%)	7 (8%)
Warehouse	2 (5%)	3 (4%)	3 (3%)
Food Service	2 (4%)	3 (4%)	5 (5%)

Note: Market segments are arranged by relative contribution to the sector's 2022–2024 average lifetime savings under the BAU scenario.

Savings Opportunities for Microbusinesses

Within CLC's service territory, microbusinesses represent over 93% of office, lodging, and food service customer establishments but less than 35% of consumption in these segments.[17] Recent research within Massachusetts has demonstrated that these small businesses face particular barriers to achieving energy savings.[18]

A high-level analysis was completed on these three C&I segments (office, lodging, and food service) to differentiate between the savings potentials for microbusinesses and non-microbusinesses and to guide future program planning. We considered measure applicability for microbusinesses and excluded certain measures—including energy management systems, lighting controls, and custom measures—from the potential for microbusinesses subsegments. Table 15 shows the results of this analysis for the top three commercial end-uses, showing that the predominant opportunities in these segments are within non-microbusinesses, despite their small number of customer establishments.

[17] Microbusinesses are defined as small businesses consuming less than 0.11 GWh per year.
[18] See "Commercial and Industrial Small Business Nonparticipant Customer Profile Study", DNV-GL, April 2020.

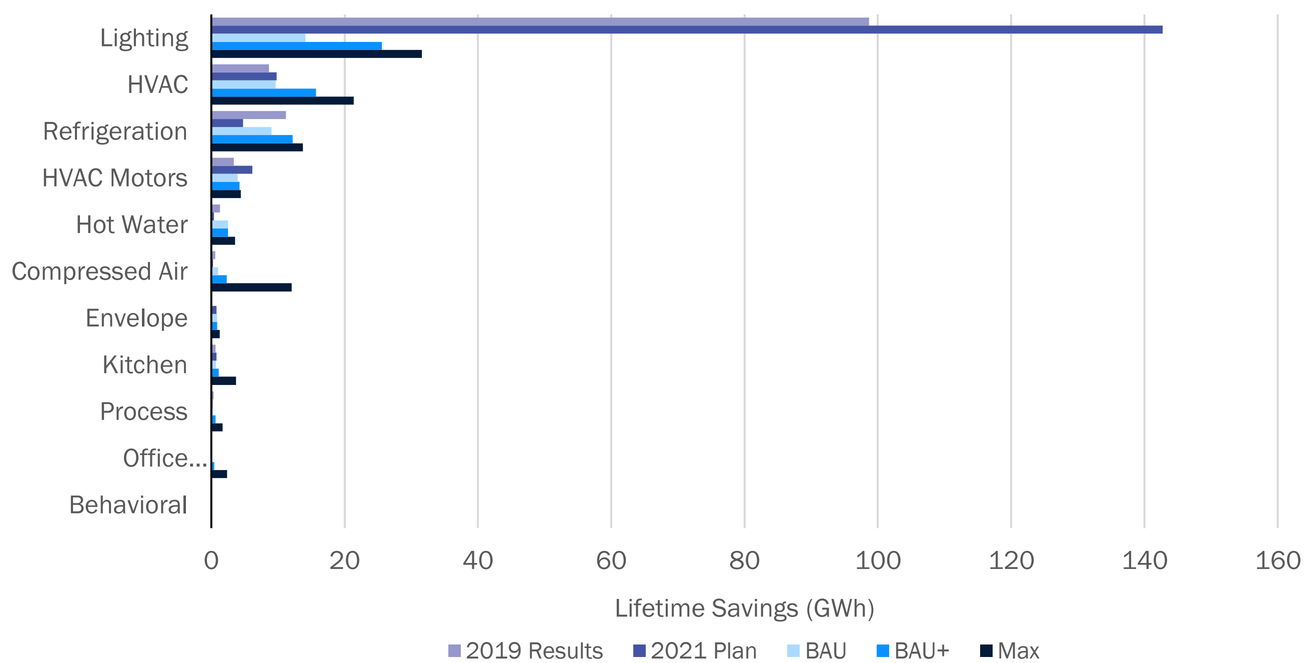
Table 15. Electric C&I Lifetime Savings by Subsegment for Selected End-Uses

Segment	2022–2024 Average Lifetime GWh, BAU Scenario		
	Lighting	HVAC	Refrigeration
Office	**3.6**	**3.2**	**1.9**
Non-Microbusiness	2.8	3.1	1.3
Microbusiness	0.8	0.1	0.6
Food Service	**0.6**	**0.1**	**0.4**
Non-Microbusiness	0.4	0.1	0.3
Microbusiness	0.2	0.1	0.2
Lodging	**0.3**	**0.9**	**2.4**
Non-Microbusiness	0.2	0.8	1.6
Microbusiness	0.1	0.1	0.8

Savings by End-Use

Figure 25 shows C&I lifetime savings by end-use, comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

Figure 25. C&I Electric Lifetime Savings by End-Use



Note: Categories are arranged by relative contribution to 2022–2024 average lifetime savings under the BAU scenario.

Similar to the residential sector, the C&I results show a significant decline in lighting savings with projected 2022–2024 average lifetime savings being approximately 10% of savings achieved in 2019 and 14% of savings planned for 2021. While the model included C&I programs support for efficient lighting measures, the ongoing transformation of the C&I lighting market is projected to lead to reduced NTGRs for these measures over time and an increasing penetration of efficient lighting products.[19] Together these factors lead to a steady decline in C&I lighting savings, despite the increasing lighting controls savings.

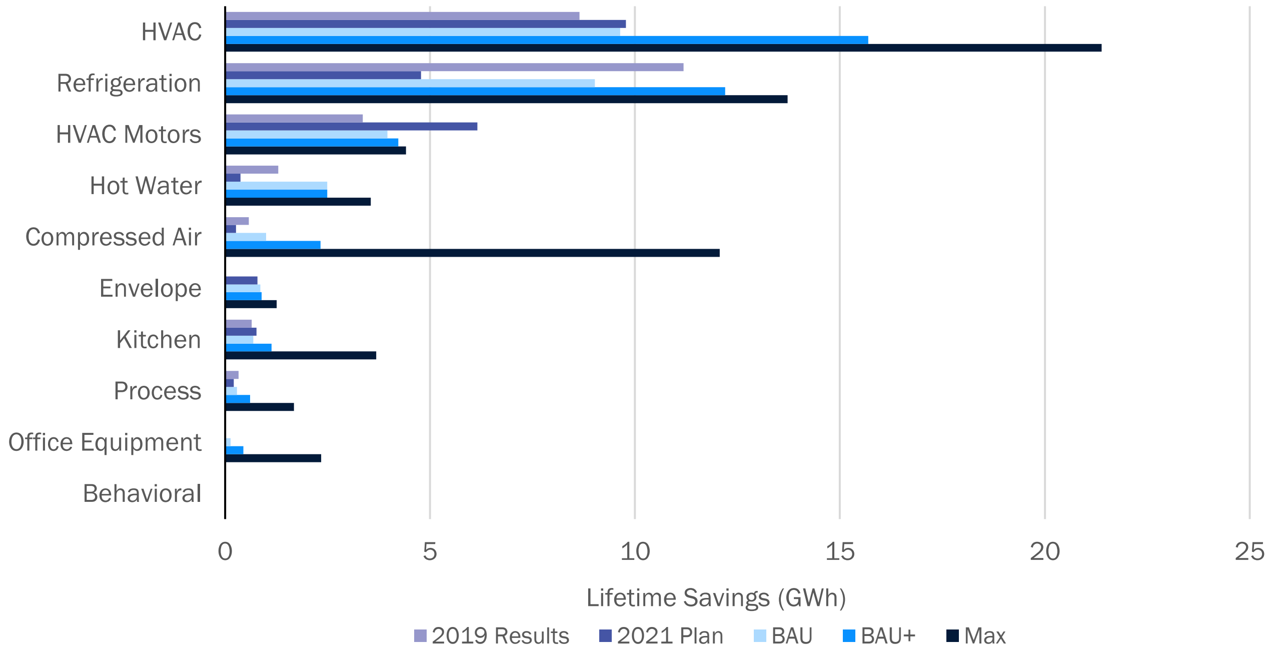
It is important to note that the reduction in C&I lighting savings is not as complete as with residential lighting savings. Lighting savings remain the most prominent C&I end-use category, in contrast to the residential sector, where it becomes the least prominent. For example, the study assumes that 23% of C&I linear lighting is still inefficient in 2022. It also assumes that 25% of C&I customers would opt for inefficient lighting in the absence of programs when their existing linear tubes burnout (i.e., an NTGR of 0.25), while the study assumes all residential market rate customers will choose inefficient lighting (i.e., an NTGR of 0.0). While these are relatively small percentages, the sheer amount of linear lighting in C&I establishments results in continued significant savings opportunities—albeit not at levels seen in the past.

Additionally, achievable results for lighting savings under BAU are slightly lower than would be expected under CLC's 2019 incentive levels—which have historically been higher than incentives provided by other PAs. The study uses incentive levels that match those paid by Eversource's 2019 programs as CLC plans to their align lighting incentives with MA more widely in recognition of the continued transformation of the market. Incentives for lighting under the BAU+ scenario reflect CLC's 2019 incentive levels and thus are more reflective of savings under existing program structures. This is discussed further in Appendix C.

Figure 26 shows C&I lifetime savings broken down by end-use with lighting excluded. Beyond lighting, C&I savings in many other end-use categories align with savings achieved in 2019; there is little reason to expect these savings to deviate significantly under existing incentive levels and program structures. HVAC, refrigeration, and HVAC motor savings are the most prominent opportunities for C&I electric savings with significant savings seen in many other categories as well. Though not the largest opportunities, hot water, and compressed air show more potential than past results and plans due to opportunities from prescriptive measures, such as C&I heat pump hot water heaters and air entrainment nozzles, that are not currently offered as prescriptive measures within CLC's existing programs.

[19] For specific details on the lighting assumptions employed in this study, see Appendix C. These assumptions were aligned with those used by other MA program administrators and were based on the best information available at the time. Nevertheless, they may not fully align with assumptions used in support of the upcoming 2022-24 Energy Efficiency Plan.

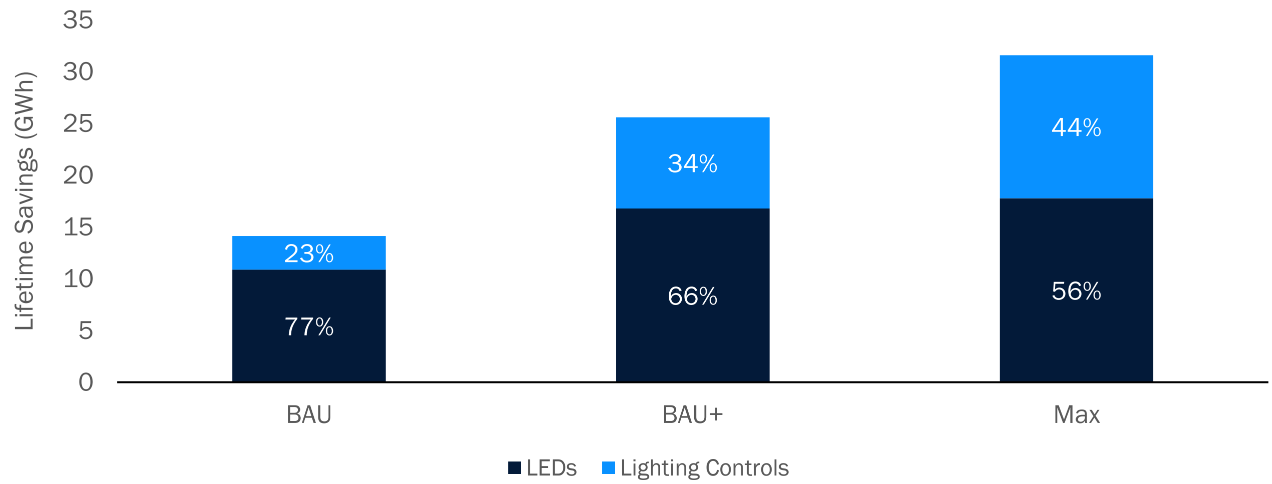
Figure 26. C&I Electric Lifetime Savings by End-Use (Without Lighting)



C&I end-use categories show varying responses to elevated incentives under the BAU+ and Max scenarios. HVAC, lighting, and compressed air savings increase significantly as incentives increase—more than doubling savings under the Max scenario relative to BAU. Compressed air in particular shows huge potential under the Max scenario due to relatively large increases in incentive levels (from 30% to 100%). When incentives are increased by such an extent, the customer economics for these measures reaches a tipping point which drives much greater customer adoption than has been seen in past programs. Similar observations are seen for kitchen, process, and office equipment savings. Refrigeration and HVAC motors savings, on the other hand, have more muted responses—increasing only 52% and 11%, respectively, when all customer incremental costs are eliminated under the Max scenario.

As shown in Figure 27, lighting controls are a substantial portion of the remaining C&I lighting potential. Under the BAU scenario, lighting controls contribute 23% overall 2022–2024 average C&I lighting lifetime savings. As incentives increase, the relative prominence of controls increases as well—becoming 44% of overall C&I lighting savings under the Max scenario.

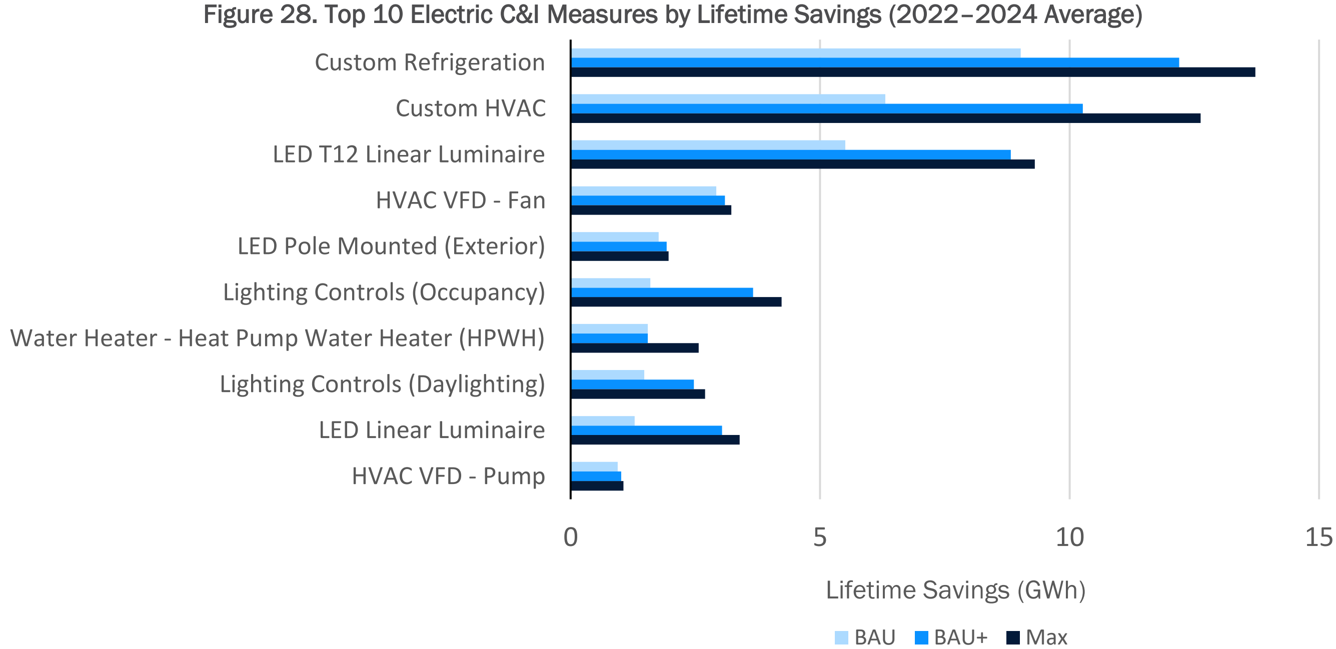
Figure 27. Electric C&I Lifetime Lighting Savings, LEDs vs. Lighting Controls



Top Measures

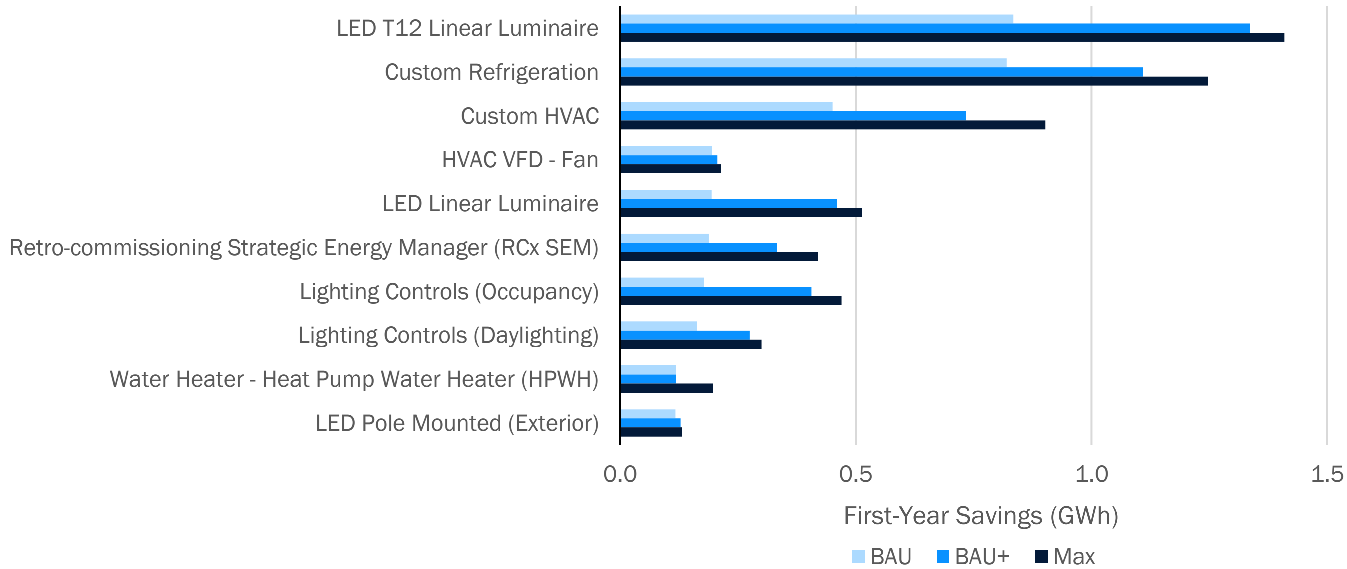
The top 10 C&I electric measures in terms of lifetime savings are shown in Figure 28. Custom measures feature prominently in this list, highlighting the importance of taking facility-specific approaches and considering savings from deeper reconfigurations of the building systems in the C&I sector. Additionally, even though overall lighting savings are reduced, lighting measures still feature prominently in the top electric measures.

Figure 28. Top 10 Electric C&I Measures by Lifetime Savings (2022–2024 Average)



In terms of first-year savings, the top 10 C&I measures are mostly the same, with some change in ordering, as shown in Figure 29.The two exceptions are HVAC variable frequency drive (VFD) pumps, which place tenth in lifetime savings but fourteenth on a first-year savings basis, and retro-commissioning strategic energy management, placing sixth in first-year savings terms but eleventh on a lifetime savings basis.

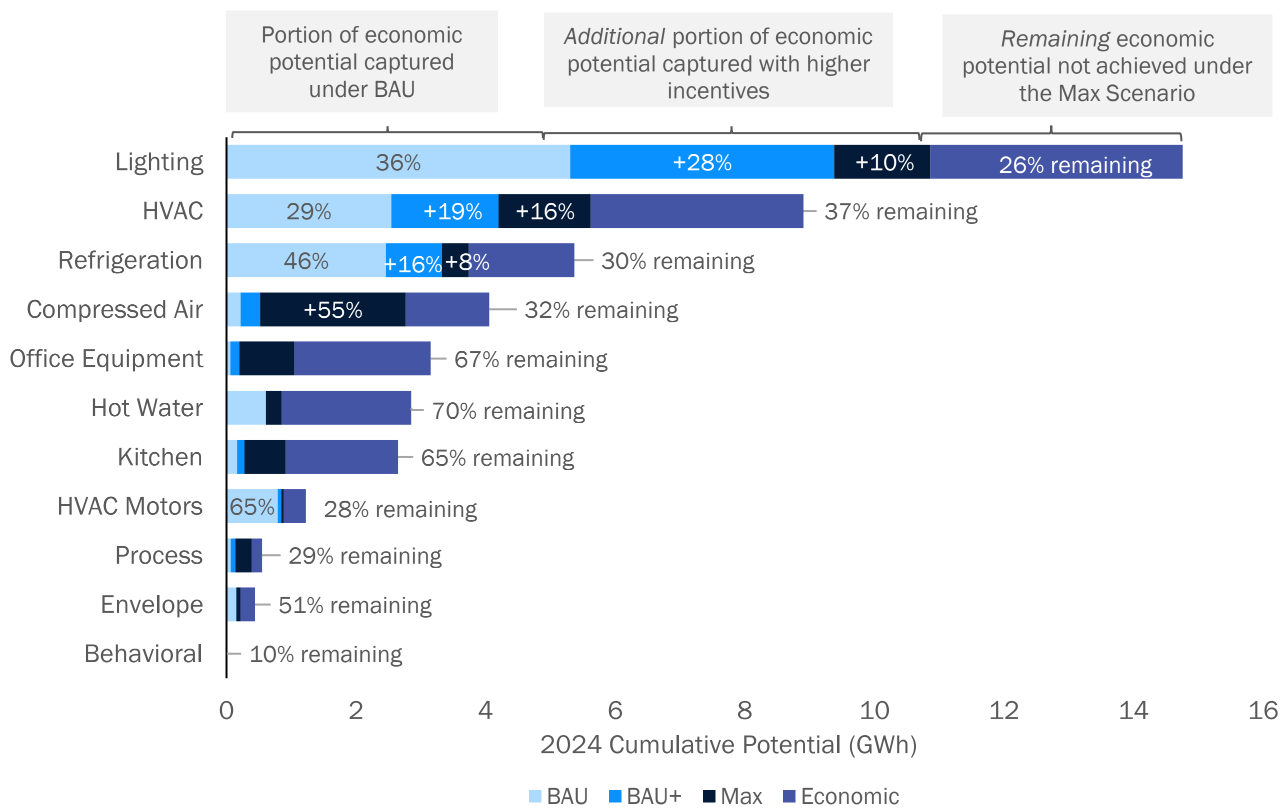
Figure 29. Electric Top 10 C&I Measures by First-Year Savings



Potential Growth Opportunities

Figure 30 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 30. Electric C&I Growth Opportunities



With maximum incentives, programs are able to capture over 50% of economic potential for most end-use categories. Notably, lighting and HVAC measures are able to more than double their share of economic savings captured between the BAU and Max scenario.

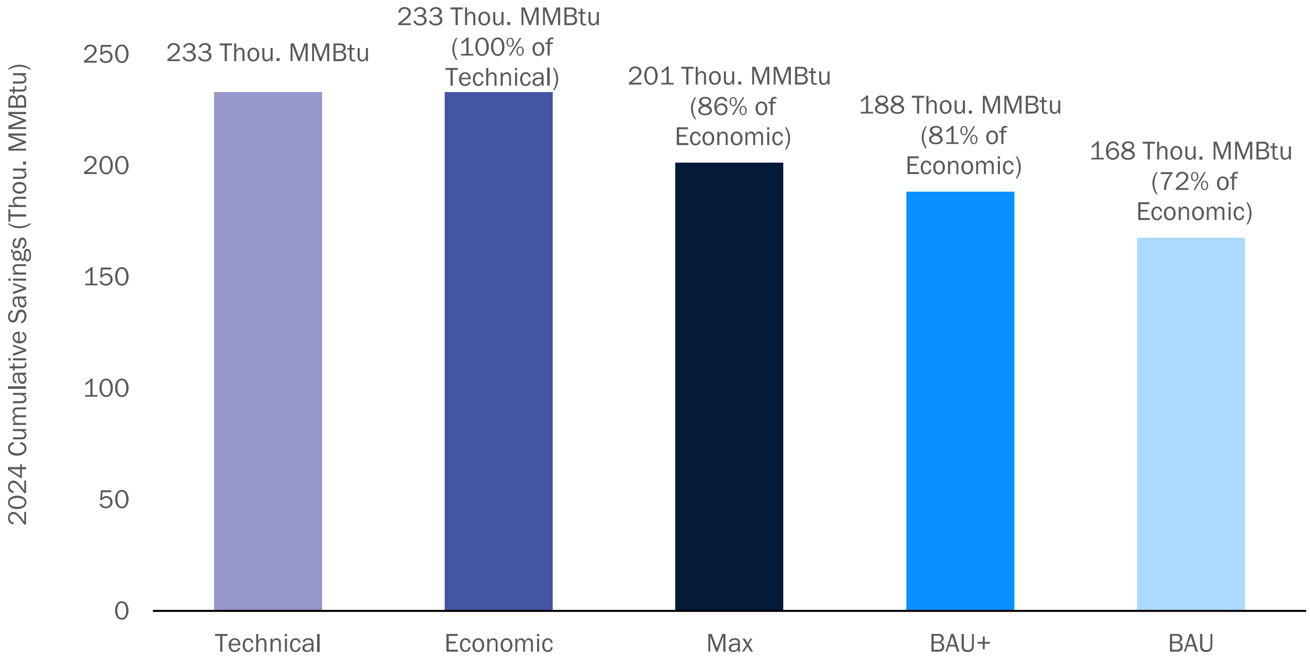
A fairly significant portion of economic potential remains in many end-uses even under the Max scenario, however, indicating that further barriers beyond customer economics remain in the electric C&I sector.

4.3 Delivered Fuel Potential Results

This section presents **delivered fuel savings potential** for CLC's electric efficiency programs. Delivered fuel included in this study are fuel oil and propane.

Figure 31 presents technical, economic, and achievable delivered fuel savings potential for CLC's electric efficiency programs in terms of cumulative annual impacts in 2024 from measures installed during the 2022–2024 study period.

Figure 31. 2024 Cumulative Technical, Economic, and Achieve Delivered Fuel Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

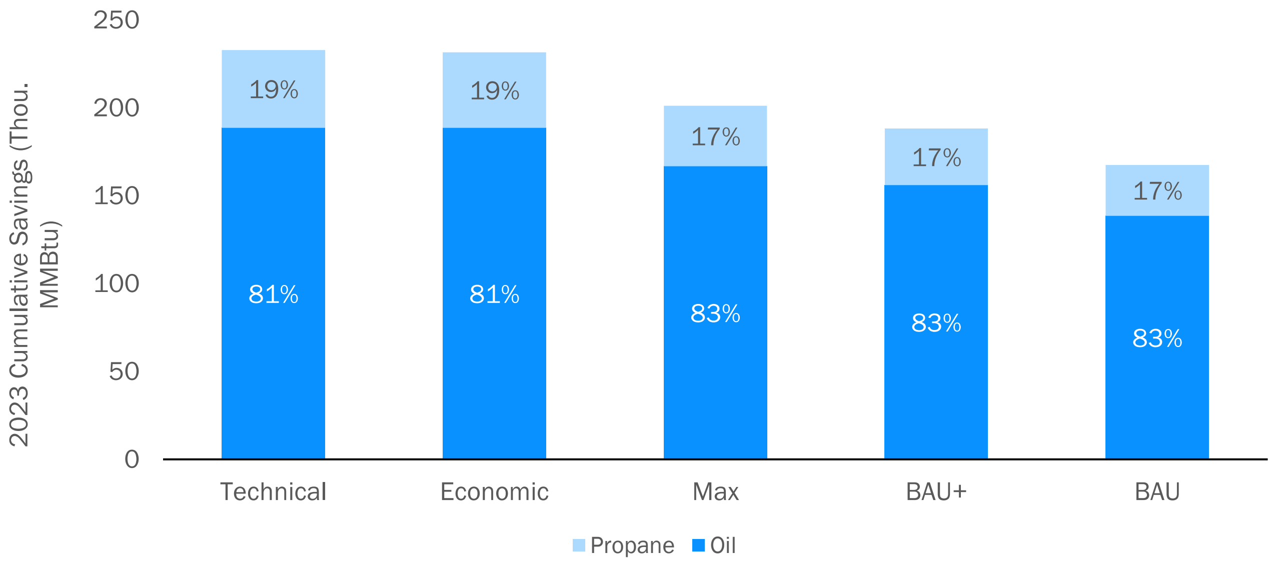
Net economic potential is the same as technical potential. There are two factors driving this observation. First, delivered fuel have relatively high avoided costs resulting in all measures passing the TRC. Second, there is significant economic savings potential from measures with NTGRs greater than 1.0, which indicates large participant spillover effects (e.g., insulation and air sealing measures). The additional spillover savings from these measures offset reduced savings from measures with NTGRs less than 1.0, resulting in net economic potential that equals technical potential.

Relative to electric potential, the BAU achievable scenario captures a larger portion of net economic savings (72% vs. 38%). This illustrates the relatively better economic proposition of delivered fuel efficiency measures for customers due to the high costs of these fuels, which makes customers more likely to participate in fuel savings programs.

4.3.1 Savings by Fuel Type

Figure 32 shows technical, economic, and achievable delivered fuel savings potential by fuel type (oil and propane). The majority of delivered fuel savings come from oil measures, but propane savings are still a substantial component making up around 19% of technical and economic savings potential.

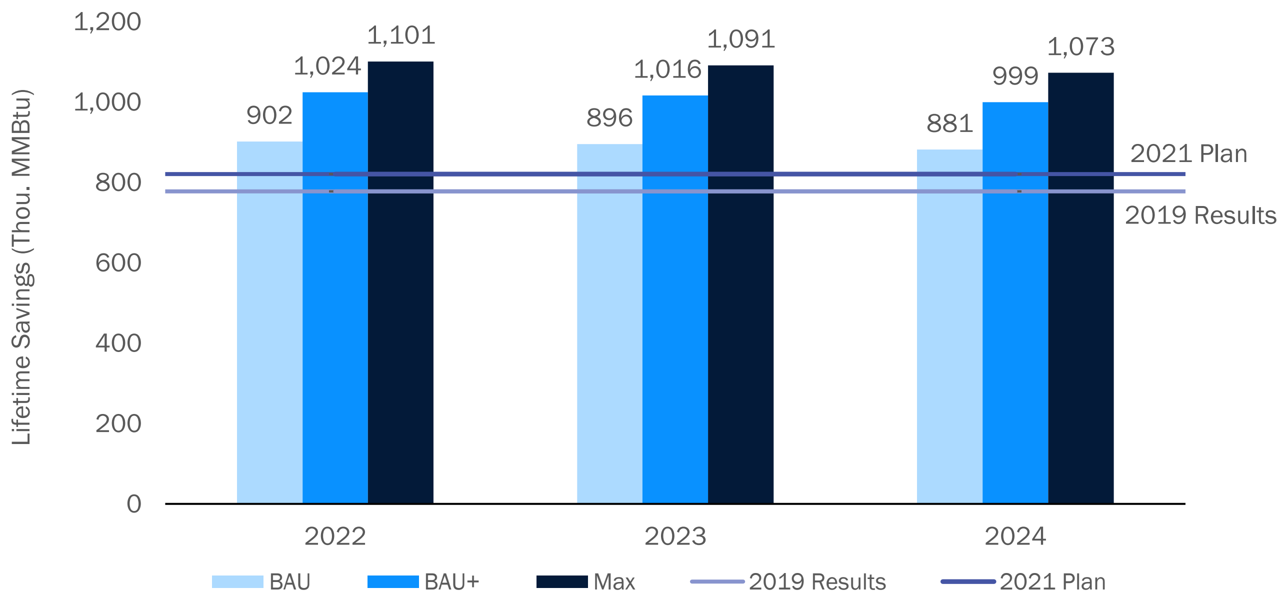
Figure 32. 2024 Cumulative Technical, Economic, and Achieve Delivered Fuel Potential by Fuel Type



4.3.2 Overall Program Savings

Figure 33 presents lifetime savings in each study year under each achievable scenario.

Figure 33. Delivered Fuel Lifetime Savings by Year

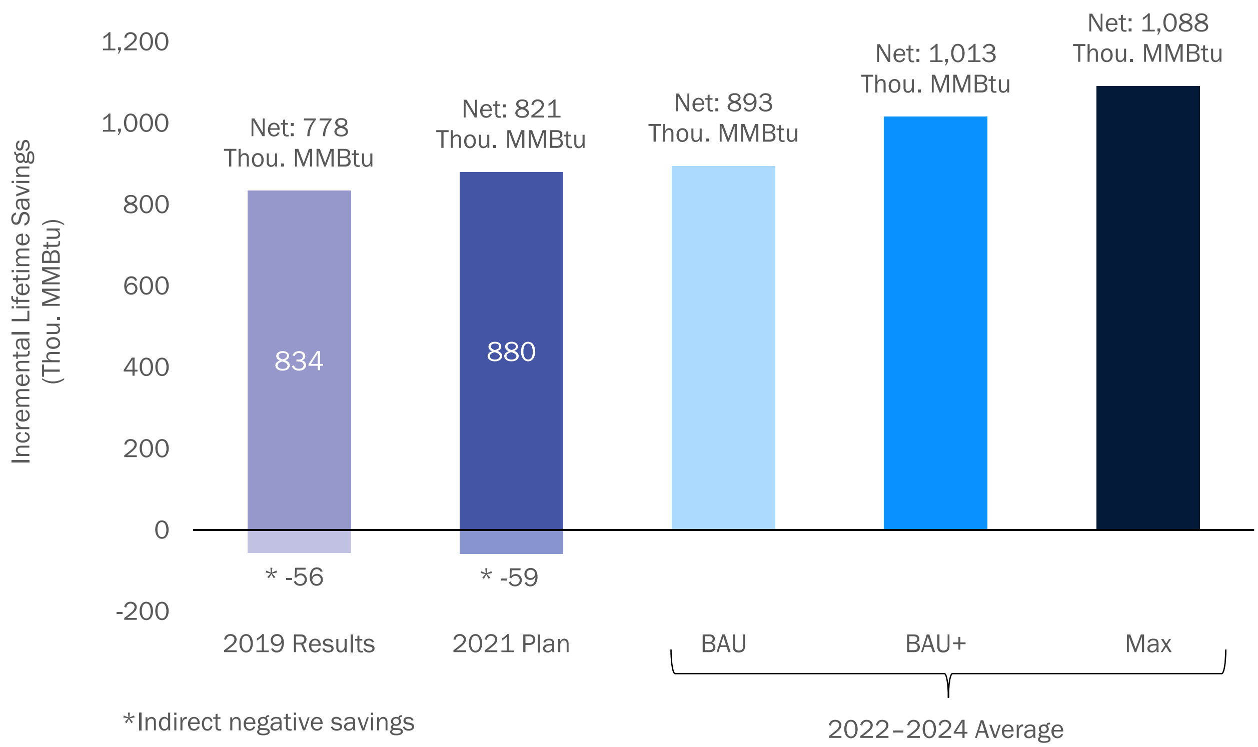


Compared to 2019 Results and the 2021 Plan, achievable lifetime delivered fuel savings are higher under all scenarios, including BAU. Under the BAU scenario, the higher savings estimate is due to two factors:

- This study includes some new prescriptive C&I delivered fuel measures that are not currently part of CLC's programs.

- Delivered fuel savings in 2019 Results and 2021 Plan are reduced due to a significant amount of indirect negative savings from lighting measures.[20] With lower lighting savings in the study period, indirect negative savings are reduced. Figure 34 shows lifetime savings with negative indirect savings displayed separately.

Figure 34. Delivered Fuel Lifetime Savings with Indirect Negative Savings Separate



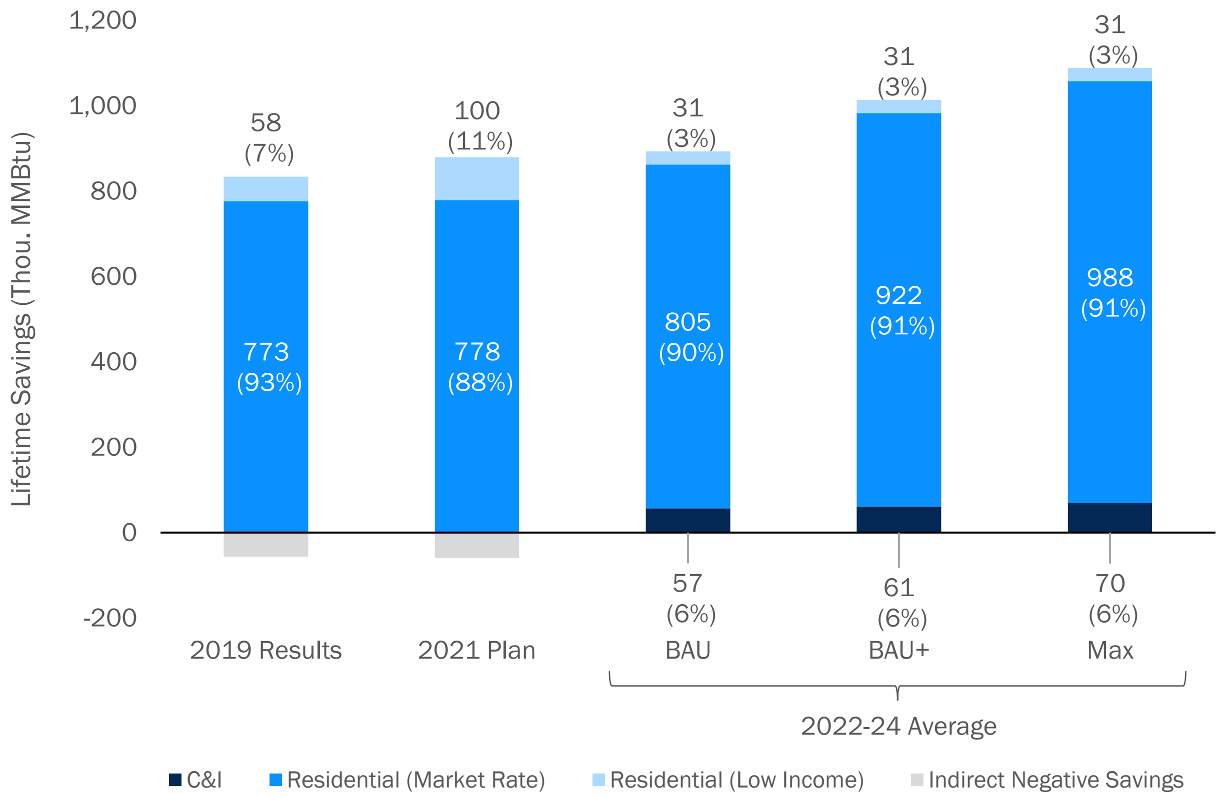
With lighting interactive effects removed, delivered fuel savings under the BAU scenario are approximately 7% above 2019 Results due to the inclusion of new prescriptive C&I measures.

Savings by Sector

At the sector level, most savings come from the residential sectors as shown in Figure 35. As can be seen, little to no C&I delivered fuel savings are claimed by past programs while the study finds C&I savings can contribute a small, but significant, amount of delivered fuel savings.

[20] LED lighting produces less waste heat than inefficient lighting equipment, which require heating systems to consume additional energy to maintain the same indoor temperature.

Figure 35. Delivered Fuel Lifetime Savings by Sector



4.3.3 Residential Savings

This section presents savings for the residential market rate and residential low income sectors.

Savings by Segment

The vast majority of residential delivered fuel savings resides in the market rate single family segment as shown Table 16.[21]

[21] Low income multi-family savings increase slightly in absolute terms under the BAU+ and Max scenarios because part of the potential in this segment is allocated from the C&I multi-family segment, which does have increasing incentive levels in the BAU+ and Max scenarios.

Table 16. Percent of Residential Lifetime Delivered Fuel Savings by Segment (2022–2024 Average)

Segment	2022–2024 Average Lifetime Thou. MMBtu (% of Total)		
	BAU	BAU+	Max
Single Family	800 (96%)	916 (96%)	982 (96%)
Low Income Single Family	24 (3%)	24 (3%)	24 (2%)
Low Income Multi-Family	6 (1%)	6 (1%)	7 (1%)
Multi-Family	5 (1%)	5 (1%)	6 (1%)

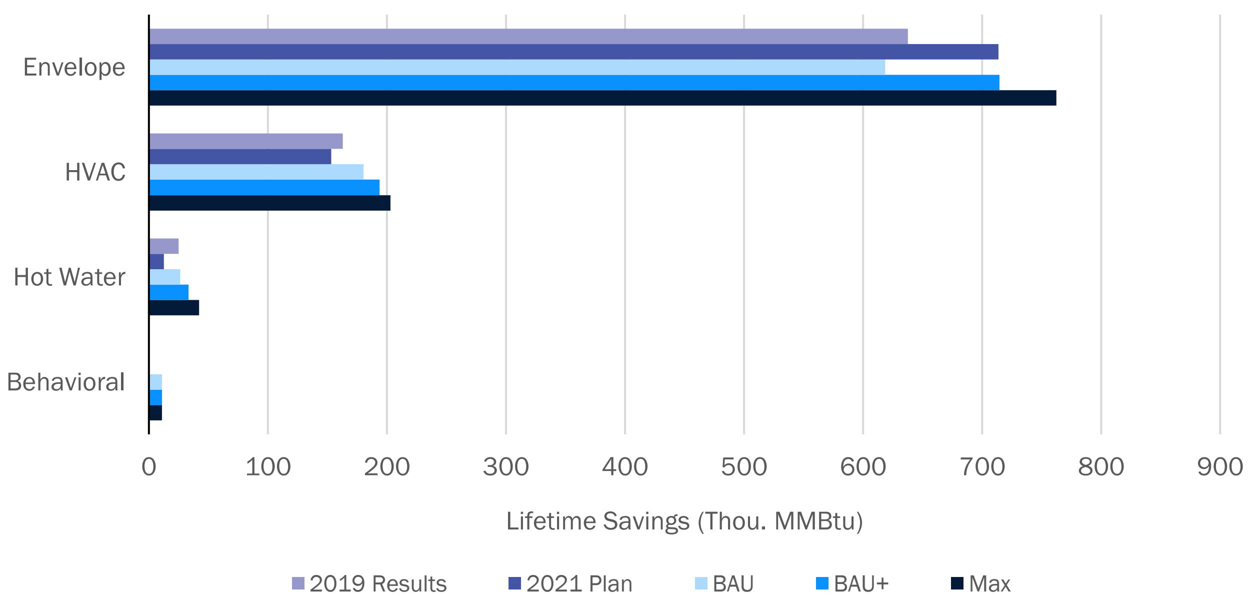
Note: Market segments are arranged by relative contribution to the sector's 2022–2024 average lifetime savings under the BAU scenario.

Little savings potential is found in the multi-family segments, primarily due to the small number of customers who heat predominantly with oil or propane and the generally higher barriers to reaching these populations. For example, according to baseline data, approximately 5% of multi-family customers heat primarily with fuel oil compared to 20% of single family customers. Delivered fuel savings are driven by envelope and HVAC measures (see Figure 36), making differences in heating fuel type a significant influence on savings potential by building type.

Savings by End-use

Residential delivered fuel savings are mostly distributed across envelope, HVAC, and hot water measures. The study assumes some delivered fuel savings from CLC's HER Program. In first-year savings terms, behavioral delivered fuel measures account for approximately 19% of residential savings. Due to the one-year EUL assumption, however, this measure contributes relatively little lifetime savings.

Figure 36. Residential Delivered Fuel Potential by End-Use

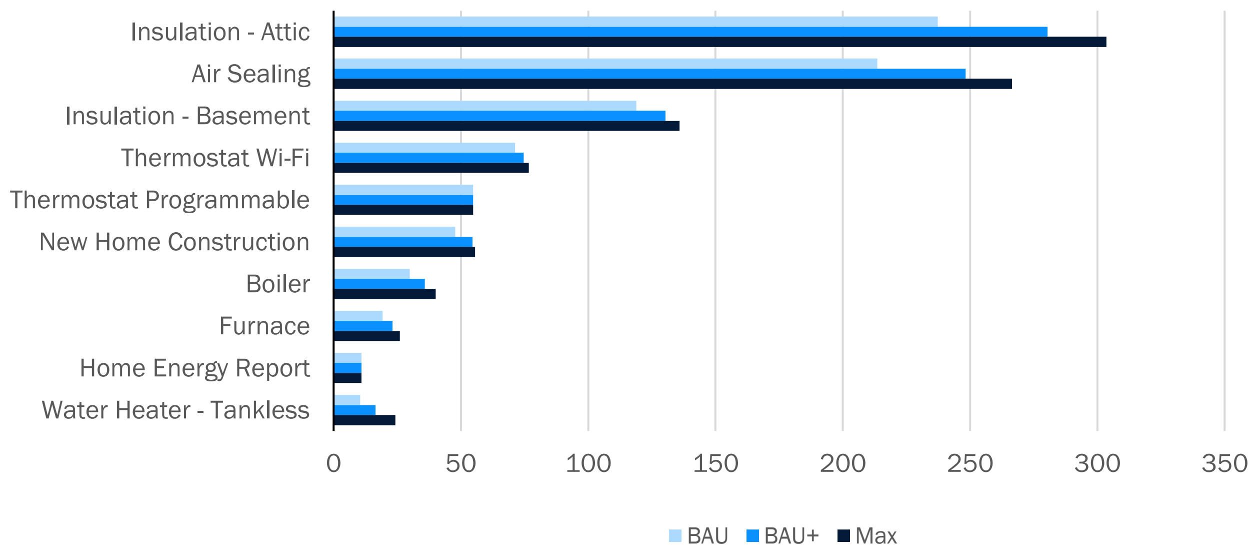


Envelope measures represent the most significant growth opportunity, in absolute terms, through increased incentives. Under the Max scenario, envelope savings increase by 144 thou. lifetime MMBtu compared to the BAU scenario. Hot water measures also show significant potential for growth—increasing by over 61% under the Max scenario relative to BAU; however, they only represent a small share of overall residential delivered fuel savings.

Top Measures

Envelope and HVAC measures compose most of the top residential delivered fuel measures as shown in Figure 37. Notably, Wi-Fi and programmable thermostats, respectively, are the fourth and fifth most prominent measures—highlighting the ability of this equipment to help reduce space heating energy consumption.

Figure 37. Top 10 Delivered Fuel Residential Measures by Lifetime Savings (2022–2024 Average)

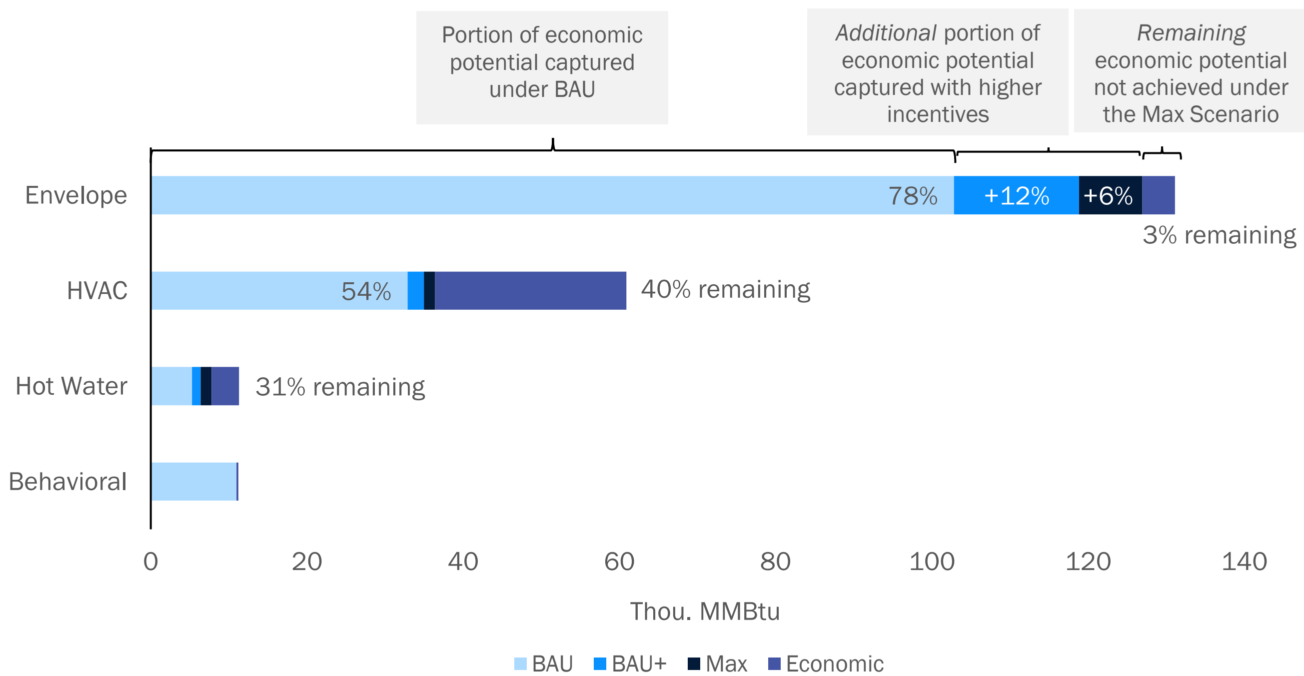


Note: Measures are selected and arranged by relative contribution to 2022–2024 average lifetime savings under the BAU scenario.

Potential Growth Opportunities

Figure 38 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant difference between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 38. Delivered Fuel Residential Potential Growth Opportunities



Under BAU incentives, 78% of envelope savings are achievable, indicating effective existing programs. Increasing incentives does capture an additional 18% of economic savings suggesting there is some further room to increase savings with higher incentives. In each end-use category, the Max scenario captures over 50% of economic savings. HVAC measures show 40% of uncaptured economic potential under the Max scenario, indicating that further market transformation approaches could help unlock a higher proportion of the economic potentials by addressing non-financial market barriers.

4.3.4 C&I Savings

As noted above, the study found that the C&I sector can contribute a small, but significant, amount of delivered fuel savings. In contrast, 2019 Results and the 2021 Plan showed little to no delivered fuel savings from this sector.

Savings by Segment

C&I delivered fuel savings are split among the ten market segments, with the lodging and office segments comprising nearly half of 2022–2024 average lifetime savings under all scenarios (see Table 17).

Table 17. Percent of C&I Lifetime Delivered Fuel Savings by Segment (2022–2024 Average)

Segment	2022–2024 Average Lifetime Thou. MMBtu (% of total)		
	BAU	BAU+	Max
Office	14 (24%)	15 (24%)	17 (25%)
Lodging	13 (23%)	14 (22%)	14 (20%)
Other Commercial	8 (15%)	9 (14%)	10 (14%)
Retail	7 (12%)	8 (13%)	9 (13%)
Manufacturing/Industrial	5 (8%)	5 (8%)	6 (9%)
Campus/Education	4 (6%)	4 (7%)	5 (7%)
Food Service	3 (4%)	3 (4%)	3 (4%)
Food Sales	2 (4%)	3 (4%)	4 (6%)
Healthcare/Hospitals	1 (2%)	1 (2%)	1 (2%)
Warehouse	(1%)	(1%)	1 (1%)

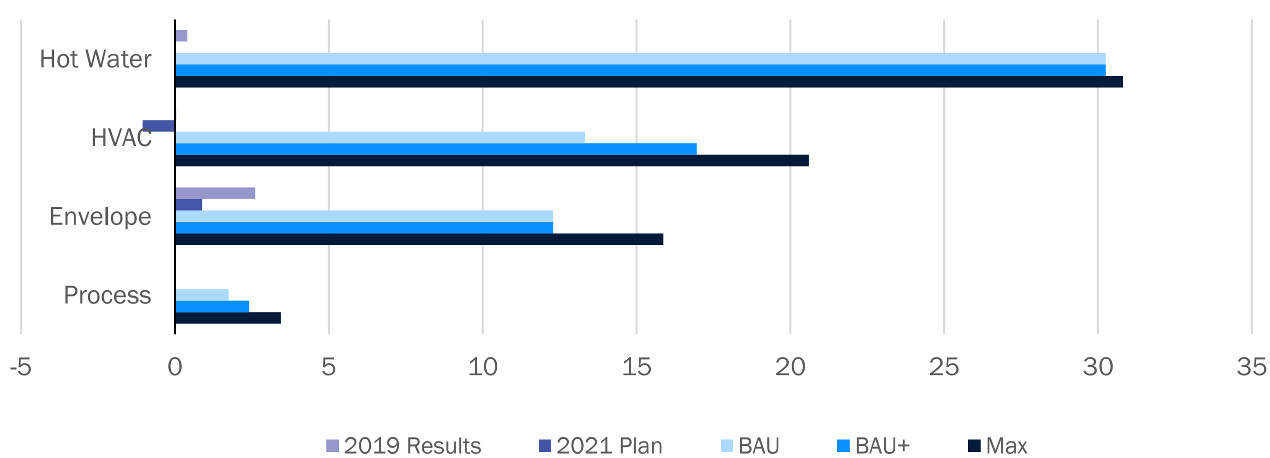
Note: Market segments are arranged by relative contribution to the sector's 2022–2024 average lifetime savings under the BAU scenario.

Savings by End-Use

As noted previously, prescriptive C&I delivered fuel measures are not currently part of CLC's programs but are included in this study. As a result, all end-uses show much higher BAU savings than the 2019 Results or 2021 Plan, which only consist of custom measures (hot water, envelope) or indirect negative savings from lighting (HVAC).

The vast majority of C&I delivered fuel saving potential comes from hot water, HVAC, and envelope measures although there is potential for some process-related delivered fuel savings as well. Notably, the most prominent end-use category under BAU incentives is hot water, reflecting relatively lower heating needs in C&I buildings compared to residential. Increasing incentives do not significantly increase hot water savings, however, compared to HVAC and envelope measures.

Figure 39. C&I Delivered Fuel Lifetime Savings by End-Use

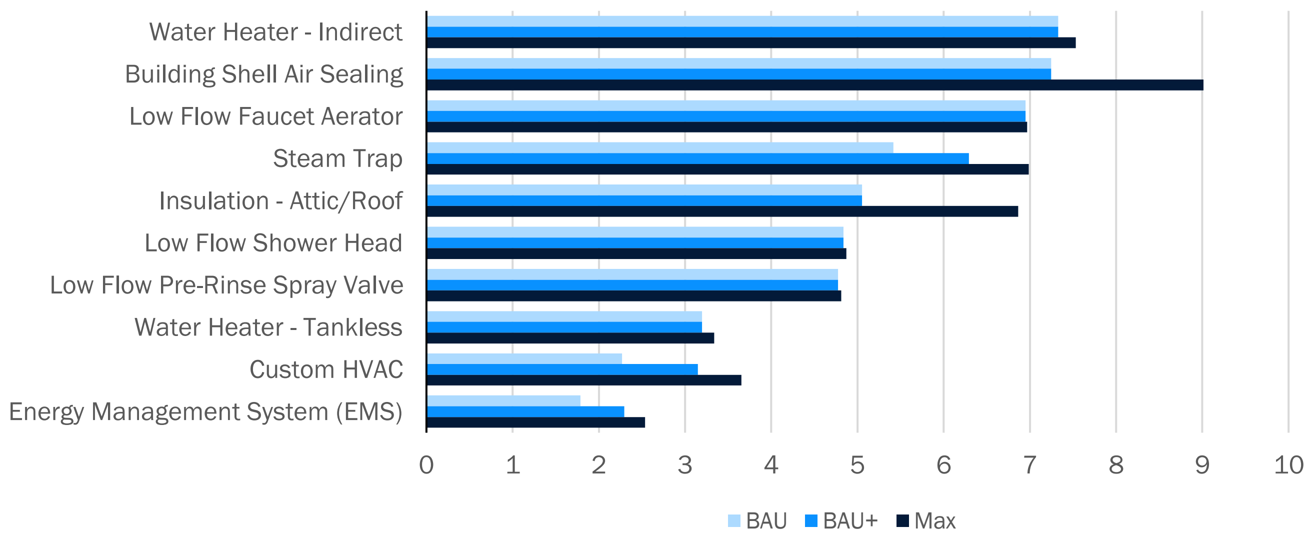


Note: Categories are arranged by relative contribution to 2022–2024 average lifetime savings under the BAU scenario.

Top measures

The significant amount of hot water savings is primarily driven by water heaters (indirect and tankless) and water consumption reducing measures (low flow faucet aerators, low flow shower heads and low flow pre-rinse spray valves) as shown in Figure 40.

Figure 40. Top 10 C&I Delivered Fuel Measures (2022–2024 Average Lifetime Savings)

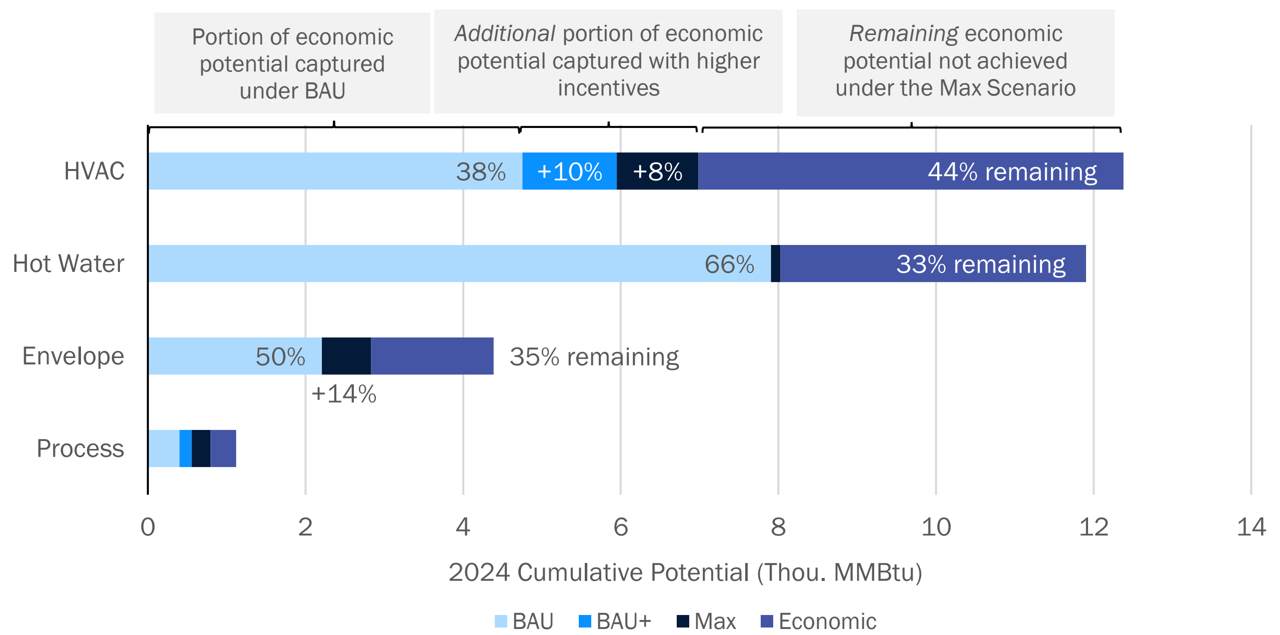


Note: Measures are selected and arranged by relative contribution to 2022–2024 average first-year savings under the BAU scenario.

Potential Growth Opportunities

Figure 41 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant difference between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 41. Delivered Fuel C&I Potential Growth Opportunities



The results suggest the greatest cumulative economic potential resides in HVAC measures, but only 38% of these savings are captured under BAU incentive levels. With increased incentives under the Max scenario, 56% of economic HVAC savings are captured, suggesting that other market barriers inhibit the adoption of these measures. This is similar for hot water measures, where 66% of economic savings are captured under BAU but minimal growth is seen from increased incentives, leaving a third of economic savings uncaptured within the Max scenario.

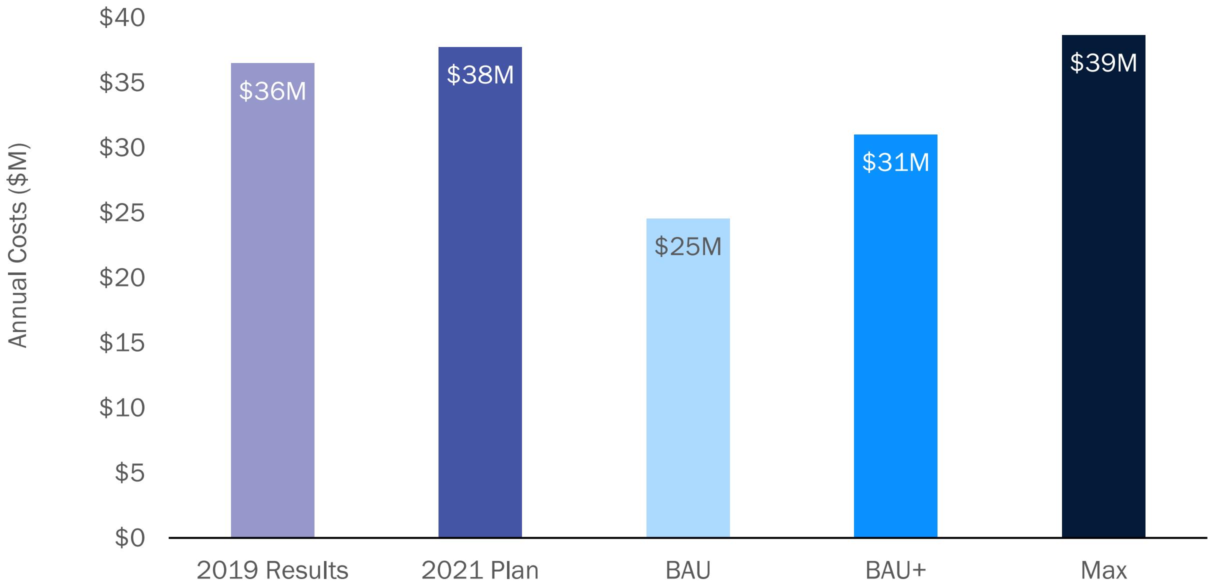
4.4 Portfolio Metrics

This section presents portfolio-level metrics for CLC program results including cost and benefit estimates.

4.4.1 Program Costs

Figure 42 presents the estimated 2022–2024 average annual cost of administering CLC's electric programs under each achievable scenario.

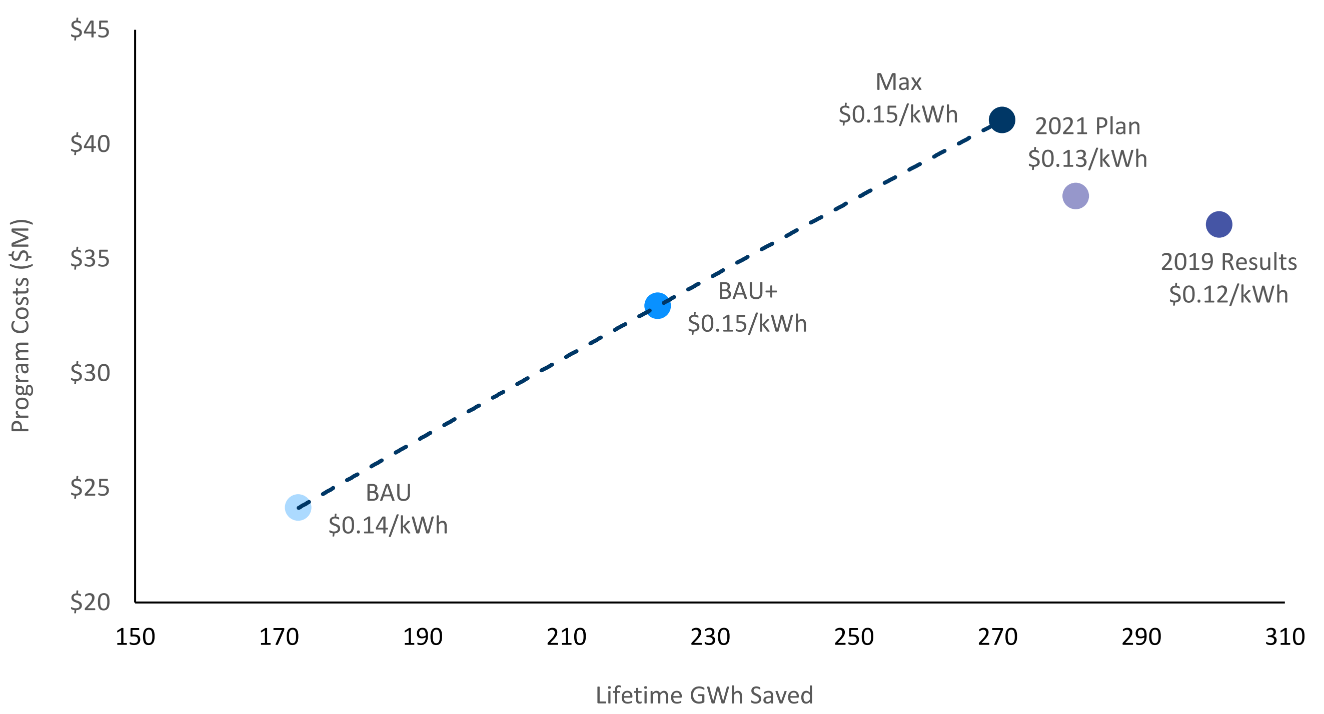
Figure 42. Program Costs



Commensurate with the decline in overall electric savings, overall electric program costs are significantly below 2019 Results and the 2021 Plan. With significant reductions in incentives paid for lighting measures, overall costs are reduced by 34% under BAU incentive levels compared to 2019 Results. Under the Max scenario, overall costs slightly exceed 2019 Results and the 2021 Plan even though achieved savings do not reach 2019/2021 levels.

While program costs decline under the BAU scenario relative to 2019 Results and the 2021 Plan, the cost per kWh of delivering electric savings is higher than in the past, as shown in Figure 43.

Figure 43. Program Costs vs. Lifetime GWh Saved



These results are driven by two key factors:

- As the reduction in lighting savings reduces overall electric savings, the **relative portion of budgets going towards delivered fuel measures will invariably increase.** This will also increase program cost per unit of electric savings as more incentive dollars go towards measures that do not procure significant amounts of electric savings. This trend increases the study's estimated program cost per unit of electric savings, but it does not explain the entire difference. Table 18 shows program costs with and without delivered fuel incentive costs. Even after removing delivered fuel incentives, the program cost per lifetime kWh under the BAU scenario is 6% greater than in 2019.

Table 18. Program Costs with and without Delivered Fuel Incentive Costs

	With Delivered Fuel Incentive Costs			Without Delivered Fuel Incentive Costs		
	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per Annual kWh
2019 Results	$36	$0.121	$0.944	$32	$0.105	$0.820
2021 Plan	$38	$0.134	$1.088	$34	$0.120	$0.974
BAU	$24	$0.140	$1.455	$19	$0.111	$1.159
BAU+	$33	$0.148	$1.607	$25	$0.113	$1.230
Max	$41	$0.152	$1.706	$32	$0.117	$1.314

- The remainder of the cost difference is again driven by the loss of lighting savings—this time because **lighting savings tend to be less expensive per kWh than other measures.** Therefore, as lighting savings decrease in the portfolio, the average program cost per unit of electric savings should be expected to increase.

A final observation regarding costs is that under higher incentive levels, costs increase slightly faster than savings. This result is to be expected as raising incentives increases the cost not just for newly acquired savings, but also for savings that would have been obtained under lower incentive levels as well—and thus at a lower unit cost. Increased incentives will also tend to drive greater adoption of measures with higher unit savings costs as these measures will also tend to have smaller customer benefits (e.g., bill savings). With increased incentives, these measures become more attractive to customers and are adopted at greater levels.

Cost Estimate Considerations

While the per unit acquisition costs of savings should be expected to increase with increased incentive levels, the precise magnitude of these cost increases presented in this study should be interpreted with the following caveats:

- **Costs are estimated based on historical cost data.** Fixed and variable program costs are based on historical spending data for CLC's 2019 efficiency programs. These inputs do not vary over the study period to account for factors that may increase costs (e.g., higher labor or technology costs as programs experience increased demand for specific services and/or equipment) or decrease costs (e.g., lower program implementation costs as programs mature and become more efficient or employ new delivery strategies).
- **Program scenarios are not optimized for program spending.** For each achievable scenario, incentive levels are set at the program level as a portion of incremental costs for all measures in the program. However, a real-world program design would likely set specific incentive levels for each measure, applying higher incentive levels for measures that may have had limited uptake in the past and maintaining or lowering incentive levels for measures that meet their expected adoption. Such an optimized program design approach would help avoid paying significantly higher acquisition costs for measures where increased incentives do not lead to significantly increased savings.

4.4.2 Program Benefits

Overall, CLC's electric efficiency programs have the potential to continue to create significant monetary benefits as measured by the TRC test as well as emission reductions. Table 19 displays the overall TRC ratio, net TRC benefits, and net benefits per lifetime and first-year kWh saved.

Table 19. TRC Benefits (2022–2024 Average, All Scenarios)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime kWh	Net TRC Benefits per First-year kWh	CO_2 Annual Emission Reductions (Short Tons)
2019 Results	2.3	$58M	$0.19	$1.49	30,100
2021 Plan	2.9	$87M	$0.31	$2.50	27,500
BAU	2.0	$29M	$0.17	$1.75	14,000
BAU+	2.0	$36M	$0.16	$1.75	16,000
Max	2.1	$42M	$0.16	$1.76	19,000

Note: TRC values for 2019/2021 benchmarks are derived using 2018 AESC values while modeled TRC values are derived using 2021 AESC values.

As expected, net TRC benefits decline relative to 2019 Results and the 2021 Plan in accordance with the reduction in overall electric savings. Even still, under the BAU scenario, CLC's electric programs are projected to create over $29 million of net benefits each year of the study.

While electric avoided costs used in this study (AESC 2021 values) are generally lower than the avoided costs used to estimate TRC values in the 2019 Results and the 2021 Plan (AESC 2018 values), the higher proportion of savings from delivered fuel measures—which generally have higher net TRC benefits—helps counteract lower electric avoided costs.[22]

In terms of annual CO_2 emission reductions, while these will also drop compared to past programs, CLC's electric programs will still have the potential to produce tens of thousands of short tons in CO_2 reductions each year during the study period under BAU conditions.

4.5 Sensitivity Analyses

4.5.1 COVID-19

The COVID-19 pandemic has led to economic uncertainty and business closures, and it may affect the achievable potential within the study period (2022-24). It is unclear what precise economic effects will be caused by COVID-19, how they will be distributed across various market segments, and how long these effects will persist. Since the energy efficiency potential study results do not account for the impacts of COVID-19 (results are calibrated to 2019 program results, before the pandemic started), we have performed a high-level assessment of how COVID-driven changes in market conditions may impact achievable program savings.

To test the sensitivity of model results to longer-lasting COVID-19 impacts, this analysis adjusts the following input parameters to reflect possible economic impacts of COVID-19:

- **Market sizes** have been adjusted in the C&I sector to reflect fewer customers within a given segment due to temporary or permanent business closures.
- **Barrier levels** have been increased in the residential and C&I sectors to reflect delayed projects, increased competition for capital, decreased resources, and other impediments to energy efficiency and electrification upgrades.

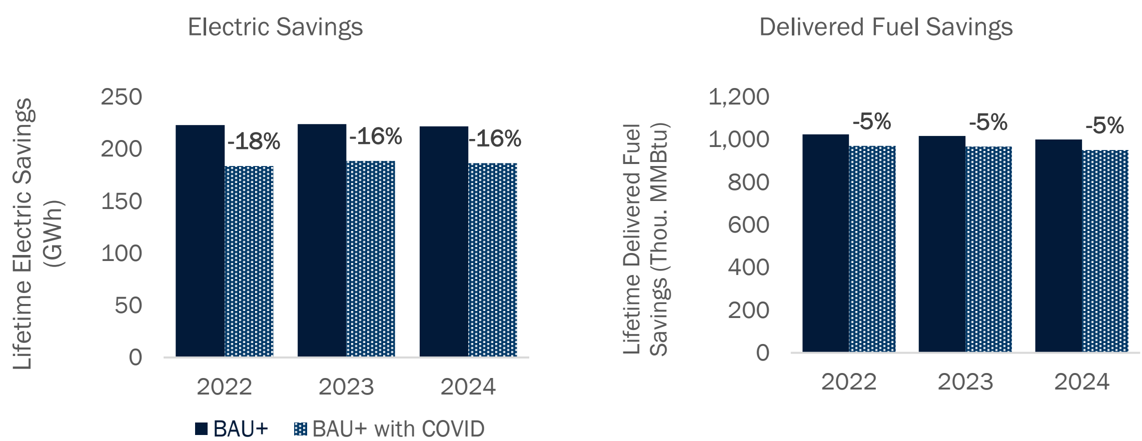
Appendix A and Appendix B summarize the methodology including market and barrier parameters used for each segment. It should be noted that the sensitivity parameter adjustments were selected prior to the rapid rollout of COVID-19 vaccinations in the spring of 2021 and that this sensitivity should be interpreted as an upper-bound worst-case scenario (e.g., the emergence of vaccine-resistant COVID variants). We performed this analysis on the BAU+ scenario.

Analysis Results

Figure 44 presents the results of the sensitivity analysis for the three years of the potential study compared to the BAU+ scenario.

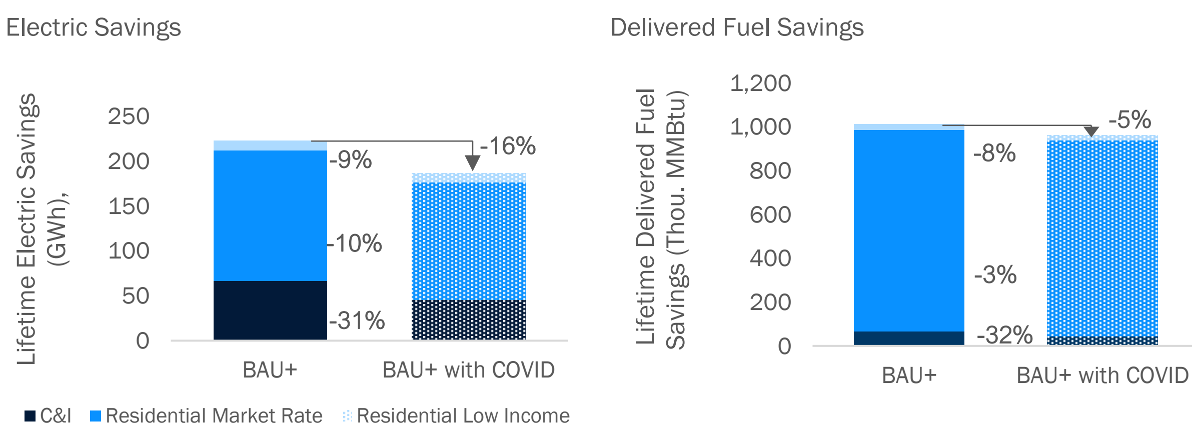
[22] For more information on differences between AESC 2018 and AESC 2021 values, see page 2 of the *Avoided Energy Supply Components in New England: 2021 Report*. Accessible at: https://www.synapse-energy.com/sites/default/files/AESC_2021_.pdf

Figure 44: COVID Sensitivity - Impact on First-Year Savings



In our modeling, COVID reduces the total achievable electric savings by 16-18% compared to the BAU+ scenario, with this impact less pronounced after the first year when some temporarily closed businesses reopen. On the delivered fuel side, a reduction of 5% is seen across all years. Delivered fuel savings are impacted less than electric savings due to the larger portion of savings coming from the residential sector as shown in Figure 45 and discussed below.

Figure 45. COVID Sensitivity - Impact by Sector (2022-24 Average)



The C&I sector shows a larger reduction in savings (31%) than residential (10% market rate; 9% low income), which is to be expected since this sector sees market size adjustments as well as barrier level increases. Both delivered fuel and electric savings demonstrate this trend.

Overall, our analysis suggests that the COVID-related impacts to the economy could result in reduced achievable savings for efficiency programs through the study period if economic impacts persist.

4.5.2 Codes and Standards

On March 26, 2021, Governor Baker signed "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy" into law. One of the (many) provisions of this law updates energy and water efficiency standards for common household and commercial appliances included in this study. By increasing baseline efficiency standards, the law will reduce technical, economic, and claimable achievable savings potential estimates for affected measures in this study.

This analysis looks at the group of achievable savings that could be impacted by this law. It is unclear to what degree *claimable* savings for the PAs will be impacted as on-going discussions will determine whether and to what degree the PAs can claim credit for the strengthening of these standards.

The following electric and delivered fuel measures included in this study are also included in the appliance standards included in the bill:

- Commercial hot food holding cabinets
- Commercial dishwashers
- Commercial fryers
- Commercial ovens
- Commercial steam cookers
- Low-flow showerheads
- Low-flow faucets
- T12 linear lighting

Under the BAU+ scenario, these measures account for approximately 1.4% of 2022-24 average lifetime electric savings and 3.1% of 2022-24 average lifetime delivered fuel savings. As shown in Table 20 and Table 21, the impact is not spread evenly across sectors. Overall, the C&I sector could experience a larger impact to savings than the residential sector, primarily due to the possible impact on claimable savings from T12 linear lighting measures.[23] Claimable C&I delivered fuel savings, in particular, could potentially decline by nearly 17% due to the large amount of savings from low-flow water measures.

Table 20. Electric Lifetime Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted (Lifetime GWh)	% Reduction
C&I	28.7	1.7%
Residential Market Rate	3.1	0.6%
Residential Low Income	0.4	0.3%

Table 21. Delivered Fuel Lifetime Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted (Lifetime Thou. MMBtu)	% Reduction
C&I	123.7	16.6%
Residential Market Rate	45.9	1.0%
Residential Low Income	5.1	1.2%

In addition to these appliance standards, the law also requires the state to develop a voluntary specialized stretch code for “net zero energy” buildings. Depending on requirements, net-zero buildings either emit no greenhouse gases or generate their own renewable energy to offset any emissions. These codes are often

[23] The precise impact on claimable savings – and for T12 linear lighting in particular – will depend on how savings from replace-on-failure (ROF) and early replacement (ER) measures are treated in light of the new standards. This analysis includes savings from both measure types to present an upper bound of the savings that may be impacted.

designed to be flexible and performance-based making, and at the time of writing the impact of the proposed stretch code on New Construction savings in this study are unclear.

Overall, a number of measures are likely to be impacted by the new law, and at the time of writing, the exact impact of measures, and what (if any) portion may still be claimable by the efficiency program administrators under the law, is uncertain.

4.6 Key Takeaways

Based on the results presented in this chapter, the following key take-aways emerge:

- Under **BAU incentive level**s and current program configurations, savings levels are projected to vary significantly from past program results:
  - **Electric savings** will decline sharply as lighting savings continue to drop due to the rapid transformation of Massachusetts' lighting markets, despite increased opportunities from growing heat pump penetrations.
  - **Delivered fuel savings** could increase with the inclusion of new prescriptive C&I measures in existing programs while residential savings continue at past levels.[24]
- **By increasing incentives**, programs can obtain substantially increased savings albeit with significant increases in program costs. Under the Max scenario:
  - **Electric savings** increase by 57% relative to the BAU scenario. While this is a substantial increase, it is still not sufficient to replace the declining lighting opportunities and as a result overall electric savings will still be lower than past program achievements.
  - **Delivered fuel savings** increase by 22% over the BAU scenario projections. Relative to electric and gas savings, raising incentives offers a relatively smaller incremental increase in delivered fuel savings. Existing programs already capture a large portion of net economic potential and due to the relatively high cost of delivered fuel in Massachusetts, customers are already highly incentivized to use these fuels efficiently. Thus, providing greater upfront incentives has less of an impact of customer decision-making.
- **Program Enhancements:** Raising incentives can lead to increased program savings, but for some measures and end-uses—even at the Max scenario incentive levels—a substantial portion of the net economic savings remain untapped. These uncaptured savings represent cost-effective opportunities that are inhibited for reasons beyond customer economics. For example, under the Max scenario:
  - 41% of 2024 cumulative net economic **electric savings** are not captured by programs,
  - 14% of 2024 cumulative net economic **delivered fuel savings** are not captured by programs, and

While *completely* eliminating all market barriers for all efficient technologies is likely not feasible (particularly in just the next three years), uncaptured economic savings may represent opportunities for enabling program strategies and market transformation approaches to further reduce market barriers and increase savings. While these strategies take time to implement and their impacts are more uncertain than increasing incentive

[24] Toward the end of the study, the PAs elaborated plans to restrict propane and gas heating equipment replacements to only replace non-condensing equipment with condensing equipment. In addition, the PAs planned to eliminate incentives for high efficiency oil boilers and instead offer incentives to replace oil boilers with heat pumps. If these changes take place, residential delivered fuel savings would be expected decline relative to past program performance and the achievable potential savings results presented in this report.

levels, CLC and the state of Massachusetts as a whole have consistently succeeded in reducing market barriers as shown by the state's consistent top rank ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near complete transformation of the Massachusetts lighting market.

5. Heating Electrification Potential Results

5.1 Overview

The HE module of this potential study provides an assessment of the market opportunity for electrifying existing buildings that contain natural gas, oil, and propane-fired primary space and water heating systems among the Compact's residential and C&I electric customers. It also includes an assessment of the potential to encourage electric heating systems to be installed in newly constructed buildings.

The analysis focuses on the ability for heat pump technologies to displace combustion-fired heating systems. Heat pump adoption in place of existing electric resistance heating systems is considered an efficiency measure and is therefore assessed within the energy efficiency (EE) chapter of this report. At the end of this report, the Combined System Impacts chapter includes an overall projection of efficient heat pump adoption, combining HE results with EE results.

5.1.1 Approach

The costs and benefits of heating electrification are not only dependent on the baseline heating system and the heat pump's costs, but also on:

- The decision to choose a **dual-fuel** (hybrid) or **all-electric** system;
- The **baseline cooling system**—–which may be the only equipment being replaced;
- The **size of the heat pump**—each additional ton increases costs but provides varying benefits;
- The **integrated control strategy** between the heat pump and its backup system (fuel or electric);
- The **remaining useful lives** of baseline heating and cooling systems; and
- The **local climate**, which impacts the capacity and efficiency of heat pumps.

To account for this, Dunsky's HEAT model assesses multiple permutations of replacement case, sizing strategy, and control strategy for each combination of baseline heating system, baseline cooling system and heat pump technology. HEAT simulates the baseline and heat pump cases to calculate the energy performance and full cost, which allows HEAT to yield the incremental costs and savings for thousands of modeled cases. Additional details on HEAT's modeling approach are provided in Volume II, Appendix D.

5.1.2 Achievable Potential Scenarios

Three achievable potential scenarios are assessed to determine the impact of varied incentive levels on the projected adoption of heat pumps in CLC's service territory. Figure 46 presents a summary of the BAU, BAU+, and Max scenarios as applied within the HE module. It should be noted that these scenarios do not account for the impact of other possible program enhancements (such as increased marketing and contractor outreach) or interventions by actors other than the Compact (such as state-level actions to promote heat pump adoption toward the target of 1 million housing units converted to heat pump systems by 2030).[25]

[25] "1,000,000 housing units are converted to heat pump system for heating and cooling, mostly from fuel oil but some from natural gas," from GWSA Implementation Advisory Committee Meeting, August 7, 2020.
Source: https://www.mass.gov/doc/presentation-slide-deck/download

Figure 46. Heating Electrification Achievable Scenario Descriptions

BAU	Applies incentives **in line with CLC's 2019–2021 Energy Efficiency Plan** to simulate business as usual: $1,250 a ton for air-source, $3,000 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost.[26] HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). Measures not currently offered within programs are also included (gas, units > 5.4 tons).
BAU+	Increases incentives **above and beyond** levels within CLC's 2019–2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: $1,875 a ton for air-source, $4,500 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives further above and beyond levels within CLC's 2019–2021 Energy Efficiency Plan. Incentives are **twice the BAU levels**: $2,500 a ton for air-source, $6,000 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost.

5.1.3 Benchmarking of Inputs and Results

Throughout this chapter, results are benchmarked to evaluated savings from the CLC 2019 and 2020 (up to October) Plan-Year Report ("2019 Results," "2020 Results") as well as planned savings for 2021 in the CLC 2019–2021 Energy Efficiency Plans ("2021 Plan").

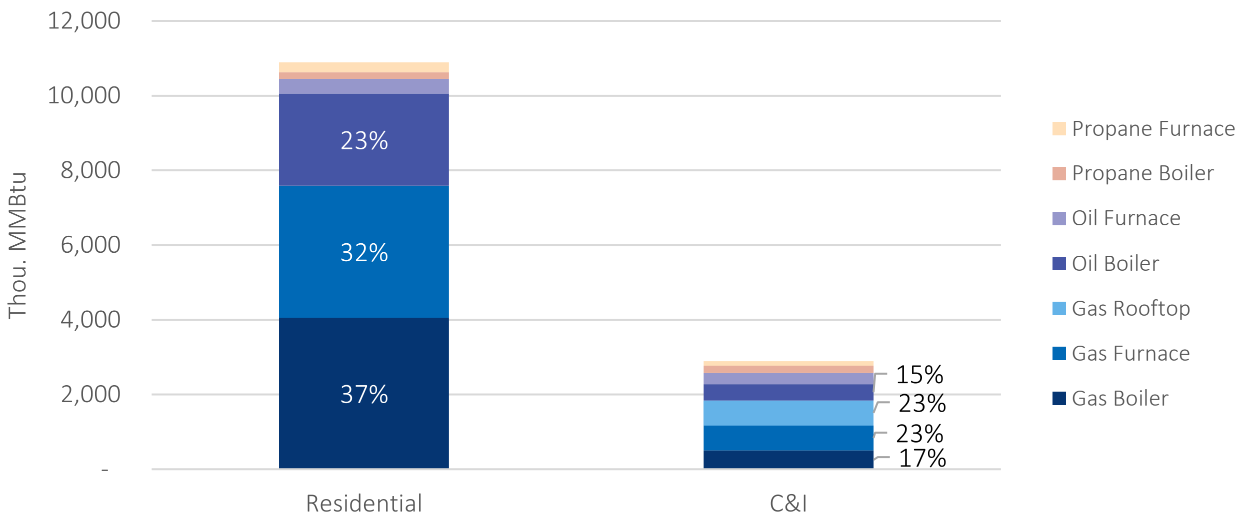
2019 and 2020 Results benchmarks are derived from the detailed workbooks provided with the Compact's 2019 and 2020 Energy Efficiency Plan-Year Report. 2021 Plan benchmarks are derived from the Benefit-Cost Ratio (BCR) model workbooks provided with the Compact's 2019–2021 Electric Three-Year Energy Efficiency Plan.

5.2 Results

To provide context for our results, Figure 47 presents the estimated fuel consumption for space heating by fuel type and baseline heating equipment. Technical potential is closely related to these shares of fuel, heating equipment, and sector.

[26] Current programs provide incentives as a function of heat pump capacity and not incremental cost. Moreover, incremental costs are highly variable from case to case due to the combination of heating and cooling system replacements. Incentives could therefore exceed the incremental cost, depending on the baseline.

Figure 47. Estimated Annual Space Heating Consumption by Fuel and Baseline Heating Equipment



Note: Results are based on the baseline study's fuel penetration and average floor areas for the modeled archetypes, as well as the heating loads and baseline heating equipment efficiencies as detailed in the methodology appendix.

The estimated annual consumption is dominated by residential customers. While C&I buildings are larger, and thus have higher heating loads per customer, this is outweighed by the significantly higher number of residential customers. The majority of residential heating is provided by gas (70%), but oil boilers also provide a significant portion (23%). Gas heating also dominates C&I, providing 64% of estimated total space heating.

5.2.1 Overall Fuel Savings

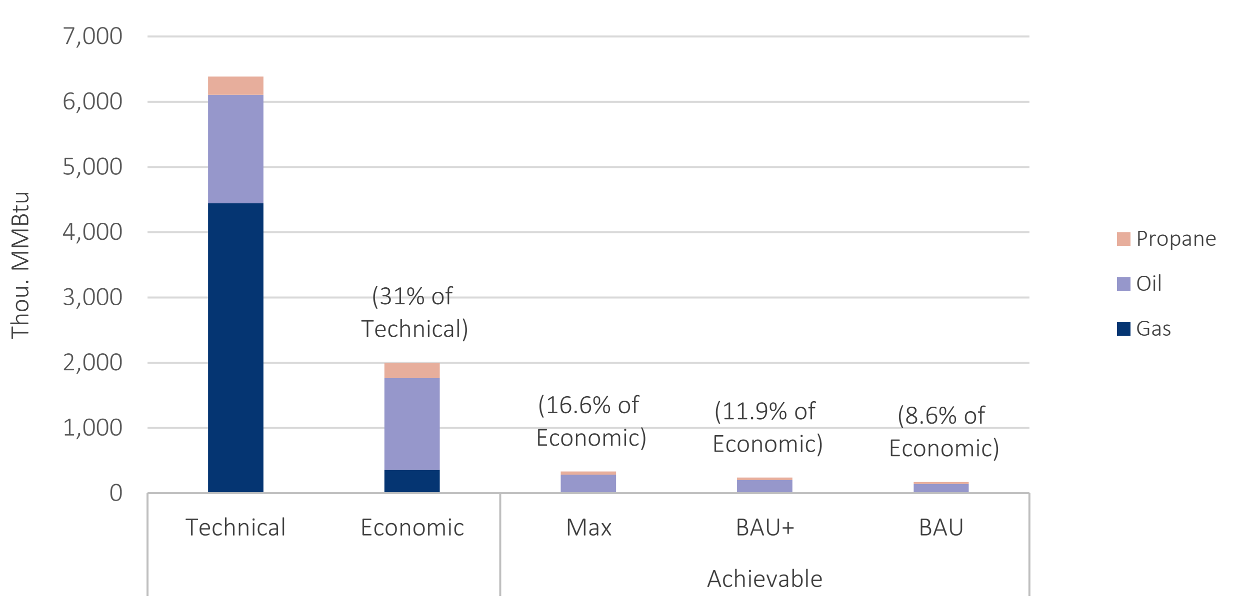
Figure 48 presents the technical, economic, and achievable potentials for heating electrification, expressed in terms of annual fossil fuel savings.

The technical opportunity for fuel savings through heating electrification is extremely large when compared to other savings streams (i.e., it is nearly an order of magnitude larger than delivered fuel efficiency technical potential). The majority of this potential comes from the displacement of gas equipment (which is not considered in the EE model for delivered fuels). In addition, electrification measures can feasibly displace most, if not all, of a building's fuel consumption, while efficiency measures just reduce consumption by a portion of the current amounts.

The technical potential includes opportunities related to end-of-life replacements of existing heating and cooling equipment, as well as some early replacement opportunities for cooling equipment (mostly related to existing AC units being replaced by heat pump equivalents). It also includes the potential to avoid installing combustion heating systems in newly constructed buildings or to reduce their consumption through partial electrification. Additional detail is provided in Appendix D.

The economic potential is defined as the sum of all opportunities that yield a TRC greater than 1.0, and represents 31% of the technical potential. Gas replacements account for almost all of the difference between the technical and economic potential, as they do not typically pass the TRC cost-effectiveness screening.

Figure 48. Overall Technical, Economic, and Achievable Potential



Note: Cumulative first-year building-level fuel savings by 2024.

The achievable potential is very small relative to the economic potential because it is very difficult to entice customers to electrify. A portion of the drop between economic and achievable potential is related to poor customer economics for some measures, especially those with a gas-fired baseline system since gas is a relatively cheap heating fuel. Figure 54 provides a comparison of customer and societal cost-effectiveness, which shows that they are not typically aligned, especially for gas measures. In addition to cost-effectiveness challenges for gas measures, market barriers to heating electrification are very high for all fuels, and adoption is limited due to the following factors:

- Heat pumps are a relatively new technology in Massachusetts—especially cold-climate units;[27]
- Customers are inexperienced in using heat pumps efficiently;
- Integrated controls are a new and still developing technology; and
- Customers are unfamiliar with the economics of heat pumps.

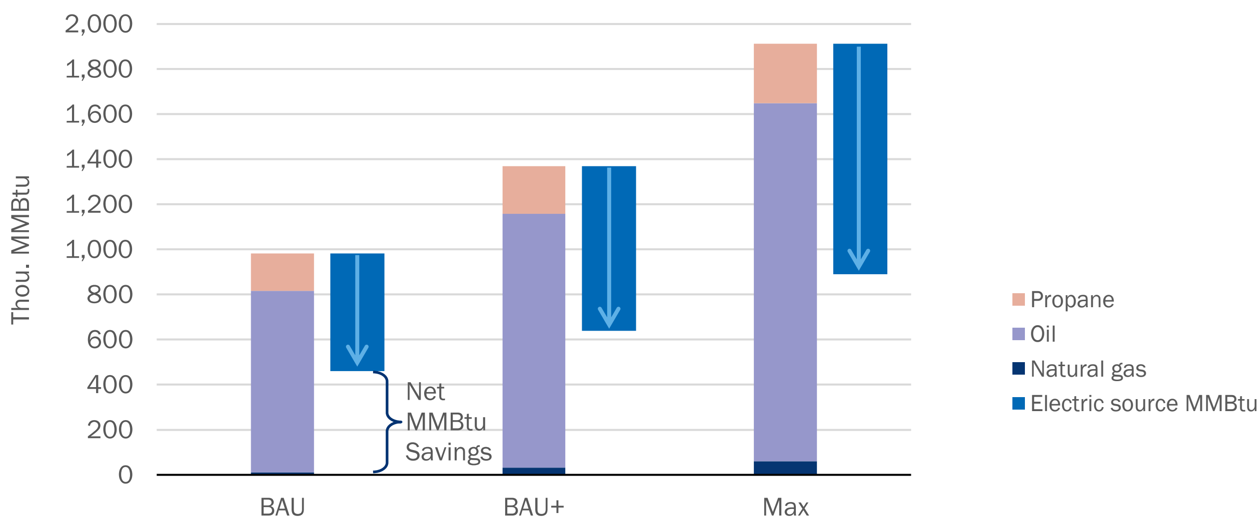
The HEAT model's adoption engine is driven both by customer economics and market barriers. The change in market barriers over time is represented using a Bass diffusion curve which is calibrated to 2019 and 2020 program results (additional methodological detail is provided within Appendix D). Results show that even in cases where heating electrification is economically beneficial to customers, the influence of market barriers restricts adoption.

Figure 49 provides the lifetime gross and net savings for the three achievable potential scenarios. The potential in all three scenarios is dominated by oil, which is driven by the high penetration of oil boilers among residential customers, and the relatively favorable economics of replacing oil-fired heating systems. Propane

[27] "Cold climate" refers to air-source heat pumps which are designed to provide efficient heating at low outdoor air temperatures—even below 5°F. NEEP created a cold climate air-source heat pump specification and product list which is usually used to define cold climate heat pumps: https://neep.org/high-performance-air-source-heat-pumps/ccashp-specification-product-list

customers are disproportionately represented in achievable scenarios due to favorable customer economics; because the customer economics are already strong in the BAU scenario, increasing the incentive levels in BAU+ and Max has a limited effect on propane adoption. Despite gas being the most widely used heating fuel among CLC's customers, heat pump adoption in gas-heated buildings remains limited due to poor customer economics.

Figure 49. Overall Achievable Lifetime Building-Level Fuel Savings



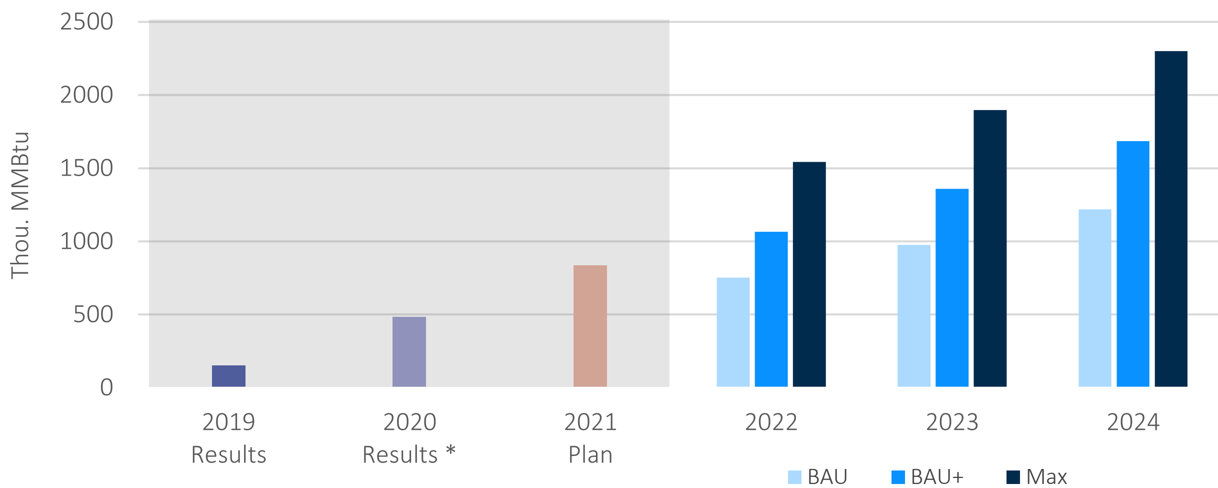
Note: Annual average over 2022–2024

Moreover, heating electrification is expected to drive a net reduction in overall heating and cooling energy (i.e. deliver net MMBtu savings) when including all energy sources and accounting for the associated increased electricity sales. The GHG savings from heating electrification are closely related to net MMBTU savings, as the site-to-source conversion factor of electricity is based on the amount of fuel burned at the source, therefore including the GHG emissions that gas-fired power plants would emit for each additional GWh needed to be generated because of heating electrification. Overall, because of the high efficiency of heat pumps, GHG emissions are reduced through heating electrification.

The analysis for the remainder of this chapter focuses on building-level fuel savings, excluding the increase in energy consumption related to additional electricity generation from heating electrification, apart from the portfolio metrics which include costs and benefits per net source MMBtu savings. Grid impacts from heating electrification are presented in section 5.2.4.

Figure 50 shows a comparison of annual results for the three potential study years and all three achievable scenarios, compared to program benchmarks.

Figure 50. Lifetime Building-Level Fuel Savings Compared to Program Benchmarks



* Results for the first 10 months extrapolated to a full year

Notably, energy optimization offerings show continued growth in potential under all scenarios. As heating electrification is an emerging technology, the model projects large year-over-year growth that is in line with that witnessed in CLC's programs. This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like ground source heat pumps (GSHP), the emergence of new C&I measures, and steadily improving customer economics for delivered fuels.

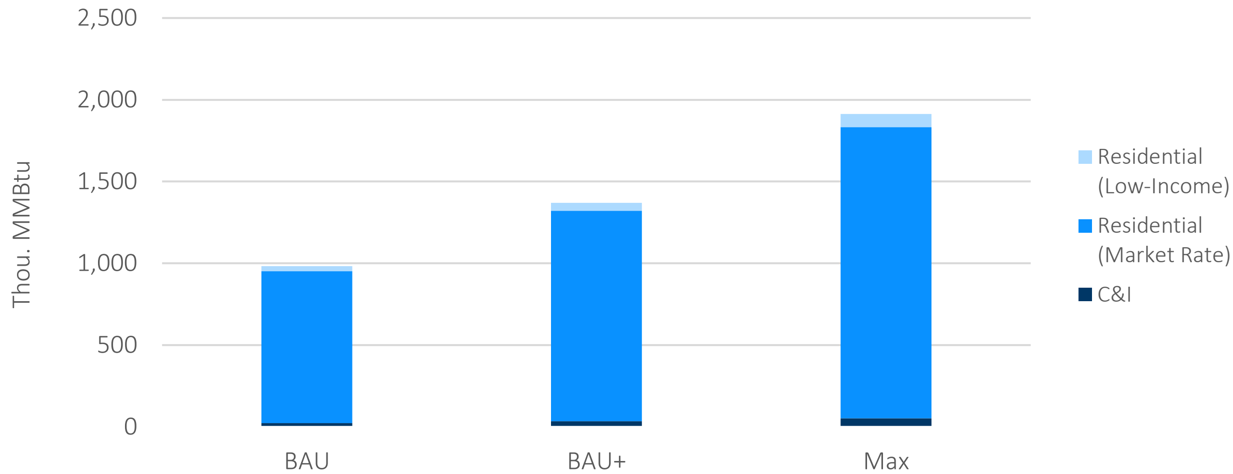
It should be noted that the model has been calibrated to past program results as well as the annual program growth rates. The resulting BAU achievable potential for 2022 is significantly larger than 2019 and 2020 Results but falls slightly short of the 2021 Plan for one key reason: As presented in the following sections, the ductless mini-split heat pump (DMSHP) is a top measure. While the TRM uses an average 2.5-ton unit for partial replacements, we have modeled both single-head units (1-ton) and multi-head units (2.5-ton), which lowers the savings per unit. The analysis assumes one outdoor unit per household.

Overall, regardless of the scenario and associated incentive levels, the results show that steady growth in heating electrification will likely occur over the study period, which is consistent with observed program trends in recent years. However, like any emerging technology, there is an inherent uncertainty in projecting the future growth of heating electrification. That uncertainty was addressed, to the degree possible, by calibrating the model to account for the growth between 2019 and 2020 program results. Moreover, the relatively short potential study period of only three years limits the impact of market growth uncertainty on the savings potentials.

Savings by Sector

Residential market rate customers present the largest electrification opportunity, as is shown in Figure 51 below. While the C&I sector represents an expansion opportunity for the program, the residential sectors account for 98% of achievable savings under the BAU scenario.

Figure 51. Lifetime Building-Level Fuel Savings by Sector

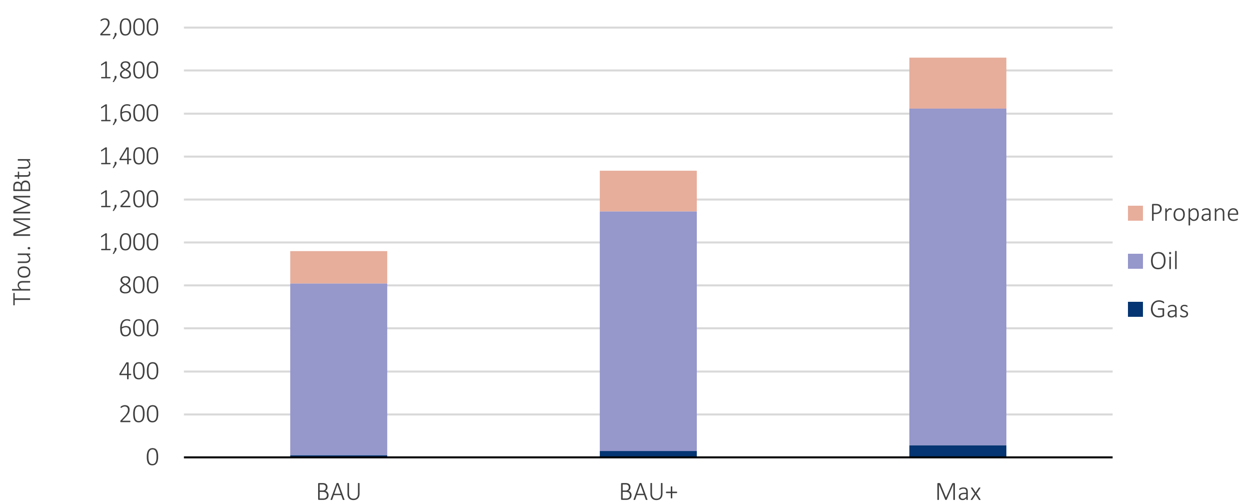


Note: Annual average over 2022–2024

5.2.2 Residential Fuel Savings

Oil savings tend to dominate residential heating electrification potential under all achievable scenarios, and gas replacement measures only see limited adoption (around 1% of total BAU savings, 3% of total Max savings). Oil savings potential increases with additional incentives, while propane savings remain relatively flat because customer economics are quite favorable even under BAU incentive levels. Figure 52 presents residential fuel savings from heating electrification by baseline system fuel savings.

Figure 52. Cumulative Residential First-Year Building-Level Fuel Savings by 2024



Residential Savings by Market Segment

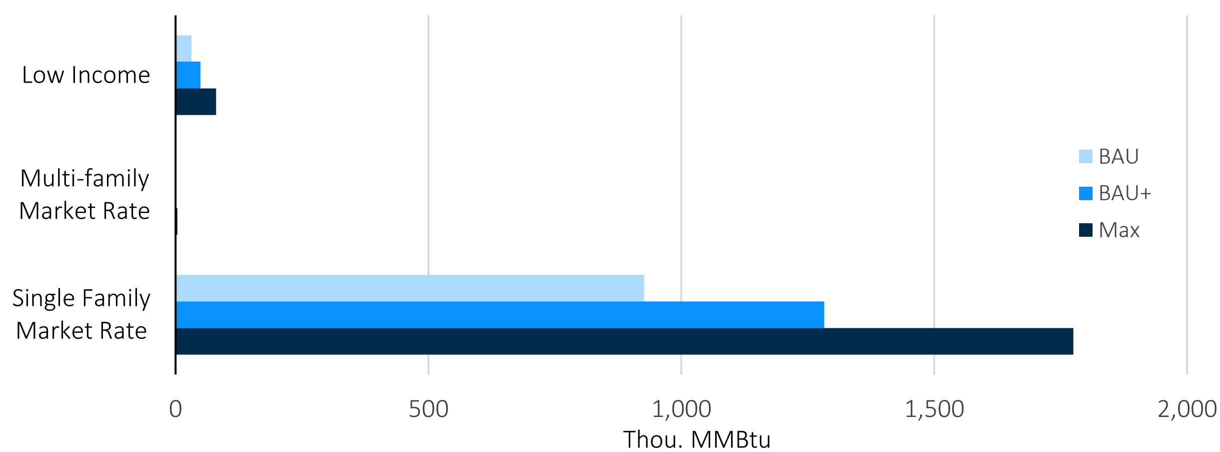
Three residential segments were modeled (Single Family Market Rate, Multi-Family Market Rate, and Low Income), and results show that the Single Family Market Rate segment has by the most potential (see Figure 53). This mostly follows the customer base, but the combination of the high penetration of delivered fuels in this market segment and the favorable customer economics for a handful of key electrification opportunities are also contributing factors.

Multi-family market rate buildings,[28] on the other hand, show close to no potential for two main reasons:

- Limited uptake, driven by the prevalence of gas systems, which show poor customer cost-effectiveness; and
- The exclusion of Central systems for larger multi-family buildings, which are modeled under the lodging C&I segment.

Low income households also show low potential illustrating the higher barriers for this segment due to financial limitations and the generally higher prevalence of rentals among low-income customers.

Figure 53. Residential Lifetime Building-Level Fuel Savings by Segment



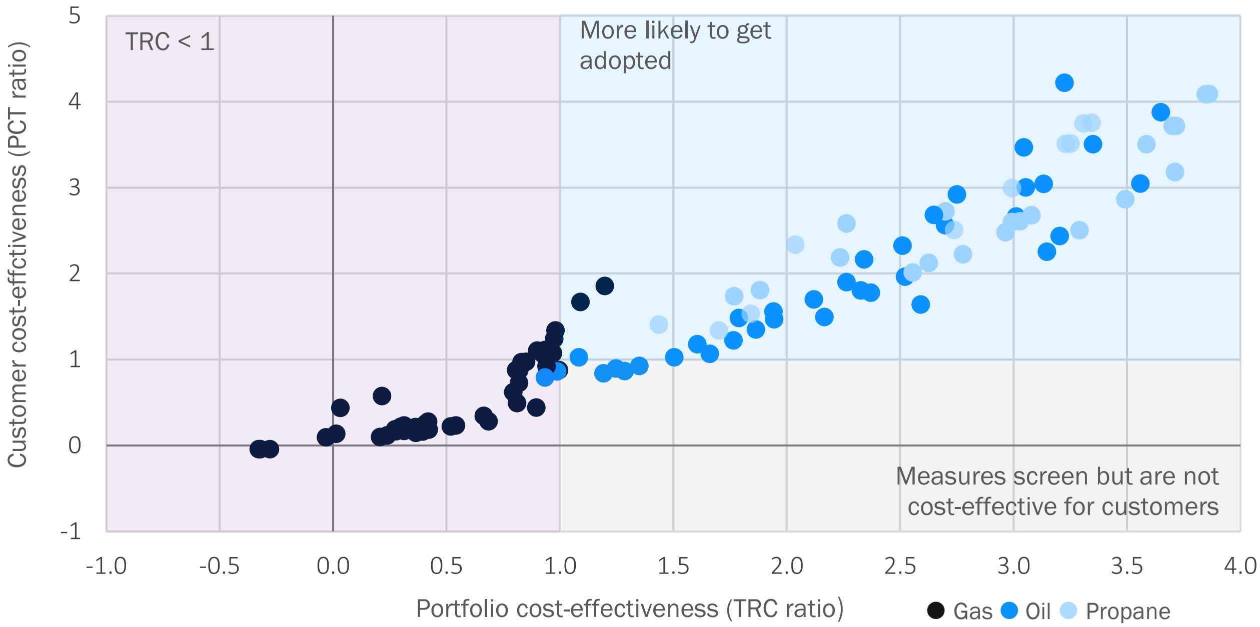
Note: Annual average over 2022–2024

Customer vs. Portfolio Cost-Effectiveness

Figure 54 highlights the relationship between customer economics, portfolio cost-effectiveness, and base system fuel type. It includes the full set of heating electrification measures applied under the BAU scenario to an archetypal existing single-family home in 2022. Customer economics are expressed by the Participant Cost Test (PCT) results. Three areas in the chart are highlighted: measures which do not pass TRC cost-effectiveness screening in purple, measures that do screen cost-effective but whose adoption is hampered by their low customer cost-effectiveness in gray, and measures more likely to get adopted in blue.

[28] As described in Appendix B, multi-family buildings represent those with 4 or more units.

Figure 54. Cost-Effectiveness Results from HE Measures in Existing Single Family Homes



Overall, the results show the following trends:

- **Gas measures:** No single-family gas measure passes the TRC screen, and most show low customer cost-effectiveness—some even providing a net increase in customer bills (negative benefits). As a result, there is little to no gas measure adoption under the BAU scenario. In fact, the only adoption comes from full gas replacement measures in specific cases where both the baseline heating and cooling systems burn out at the same time.
- **Oil measures:** Most oil measures pass the TRC screen but exhibit a range of PCTs, with many showing very high customer cost-effectiveness. The high-PCT oil measures drive the majority of savings in this study, due to their cost-effectiveness and the high penetration of existing oil heating systems.
- **Propane measures:** All propane measures pass the TRC screen *and* show favorable PCT values, and therefore show relatively high adoption rates. The limited adoption of propane-replacing heat pumps is largely a reflection of the low penetration of propane heating systems but also reflects general market barriers to heat pumps.

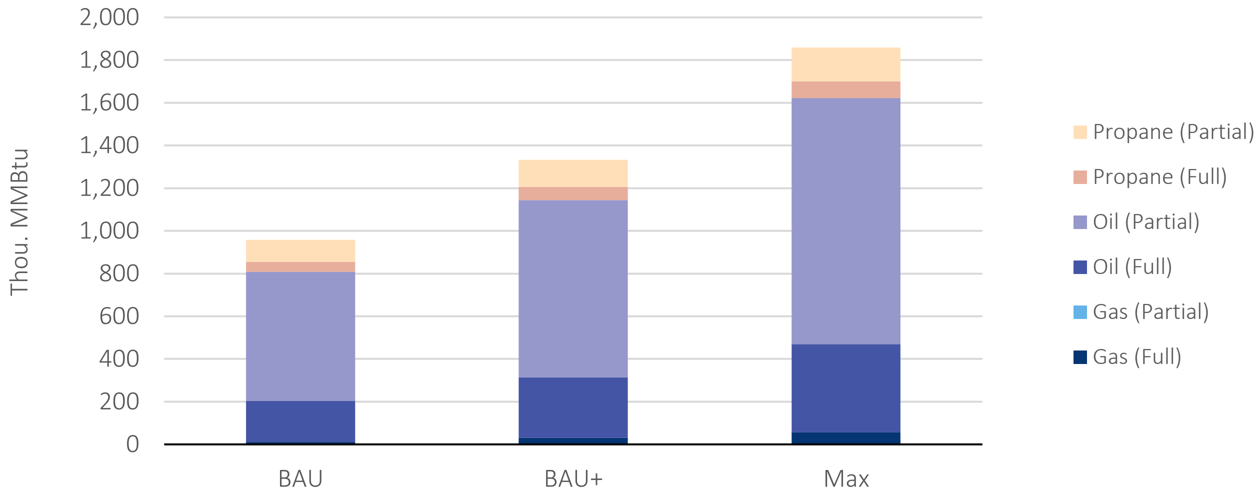
Increasing the incentive levels under the BAU+ and Max scenarios would effectively drive each dot upwards, making them more attractive for customers without impacting portfolio cost-effectiveness as expressed by the TRC.

Residential Savings by Baseline Heating Equipment

Figure 55 presents residential HE potential by fuel type and full or partial replacements. These two competing replacement types are defined as follows:

- **Partial replacements**: The addition of a heat pump in a building while keeping the existing fuel-based heating equipment as a supplemental source of heat, resulting in a dual-fuel or hybrid system. A portion of the fuel consumption for heating is displaced.
- **Full replacements:** Replacement of the existing fuel-based heating system with a heat pump and an electrical backup, resulting in an all-electric system. All the fuel consumption for heating is displaced.

Figure 55. Residential Lifetime Building-Level Fuel Savings by Baseline Heating System and Full/Partial Replacement



Note: Annual average 2022–2024.

The results show that despite the ability for full replacement measures to generate higher fuel savings per participant, partial replacements far outstrip full replacement measures in terms of adoption. This is largely consistent with 2020 program results, which show a small but not insignificant uptake of full replacements.

While full replacements are, in most cases, more cost-effective than partial replacements—mainly due to the electric backup being cheaper than its fuel-fired equivalent (furnace or boiler)[29] —two main reasons explain the domination of partial replacement measures:

- Partial replacements face **fewer barriers to adoption** than full replacements:
  - Lower project complexity (the AC unit is replaced by a heat pump equivalent);
  - Less resistance to change from the customer's point of view, as with full electrification some clients see two new heating systems (the heat pump and the electric backup equipment); and
  - Partial measures have been specifically pushed by the program, which might explain part of the domination of partial measures in 2019 and 2020 actual program results. The adoption diffusion curves have been calibrated to these results.

The model considers early retirement opportunities for space cooling systems in addition to cooling and heating system burnouts. A cooling system reaching two-thirds of its EUL is considered a replacement

[29] The improved cost-effectiveness for full replacement measures is mainly due to the electric backup being cheaper than its fuel-fired equivalent, but also because of the different control strategies used for partial and full replacements which lead to the heat pumps being used more in the full replacement measure than in the partial replacement – for an equivalent installed capacity, the heat pump is not restricted to operating only above a switchover temperature in full replacement measures.

opportunity—as the economics might not be favorable for a certain early replacement case, those who do not adopt an electrification measure are simply considered again the next year, when the economics are likely more favorable than the last. This continues until one equipment reaches the end of its life, which is then considered a replacement on burnout case. Early replacement options thus add opportunities every year (e.g., for a 15-year EUL for existing AC units, it is assumed that only 1/15th of the market reaches end of life every year, but four years' worth of the market (4/15th) is above two-thirds of its EUL). Results show that:

- Many early retirement opportunities for space cooling are more favorable to partial replacement, as there is still "value" left in the existing heating system. Partial replacement measures add a heat pump but keep the fuel-fired heating system in place as a supplemental source of heat, compared to full replacements where it is replaced with an electric equivalent. In other words, the timing would need to align between cooling and heating burnout for full replacement to be preferred.
- Heating system burnouts lead to a larger share of full replacements, where the heating system has to be replaced anyway, which improves the economics of an upgrade to an all-electric heating system. However, there are fewer heating system burnout opportunities compared to early replacement of the cooling system each year.

New program approaches could be designed and tested to encourage more full replacement measures in order to reach energy and climate goals. For example, CLC is proposing to offer a comprehensive heat pump, solar, and storage package upgrade through the Cape and Vineyard Electrification Offering (CVEO). Though the offering will only be available to a limited number of low- and moderate-income households, CLC will obtain important insights on the barriers to full electrification from CVEO. CLC is currently undertaking a separate study to analyze the potential of an expanded CVEO program.

It is notable that gas partial replacement measures do not pass the TRC screen in this study, and thus only the full replacement gas measures show any achievable potential. This is largely driven by the limited ability of control strategies to displace gas consumption in partial replacement measures.

Understanding the Gas Measure Results

This study models heat pumps whose performance levels correspond to Mass Save's Heat Pump Qualified Product List (HPQPL), which only includes cold-climate models, as described in Appendix D.

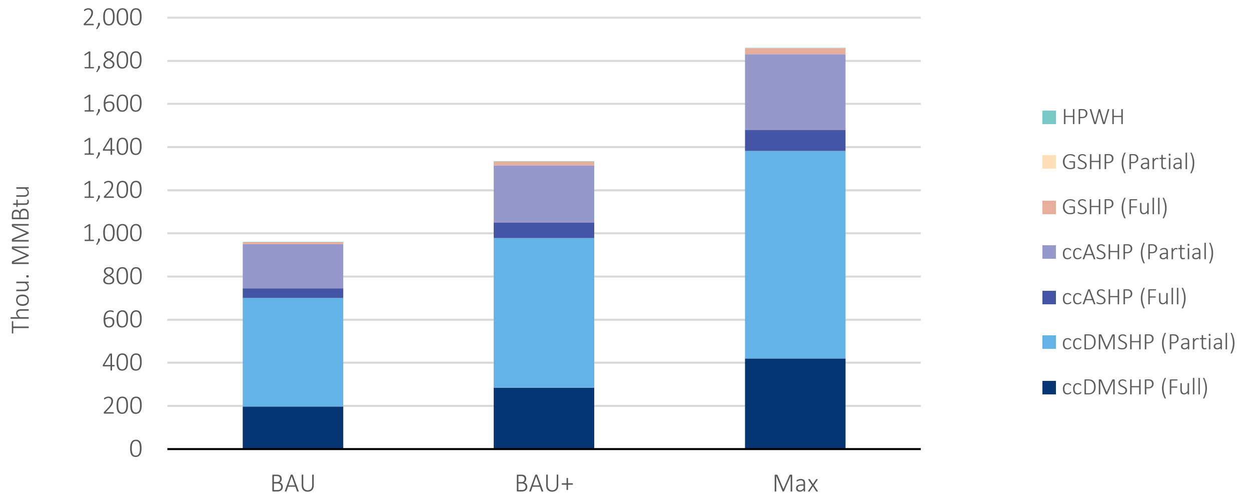
Cold climate models carry higher incremental costs as compared to standard heat pump models (i.e. heat pumps not rated for cold climate operation). However, because of the high switchover temperature of partial replacement gas measures, they are generally not able to generate sufficient savings to cover the high incremental cost of cold climate heat pumps.

Cheaper non-cold-climate heat pumps may offer somewhat better economics but not at a level that would improve program and customer cost-effectiveness enough to drive adoption. Therefore, adding standard heat pump models to the assessment would not likely impact overall potential significantly.

Residential Savings by Heat Pump Type

Figure 56 presents residential program fuel savings by heat pump technology. Overall, the cold climate ductless mini-split heat pump (ccDMSHP) and partial cold climate central ducted air-source heat pump (ccASHP) replacements dominate program uptake. This is driven by the prevalence of oil-fired boilers and furnaces, and the positive customer economics associated with partial replacement measures.

Figure 56. Residential Lifetime Building-Level Fuel Savings by Heat Pump Type and Full/Partial Replacement

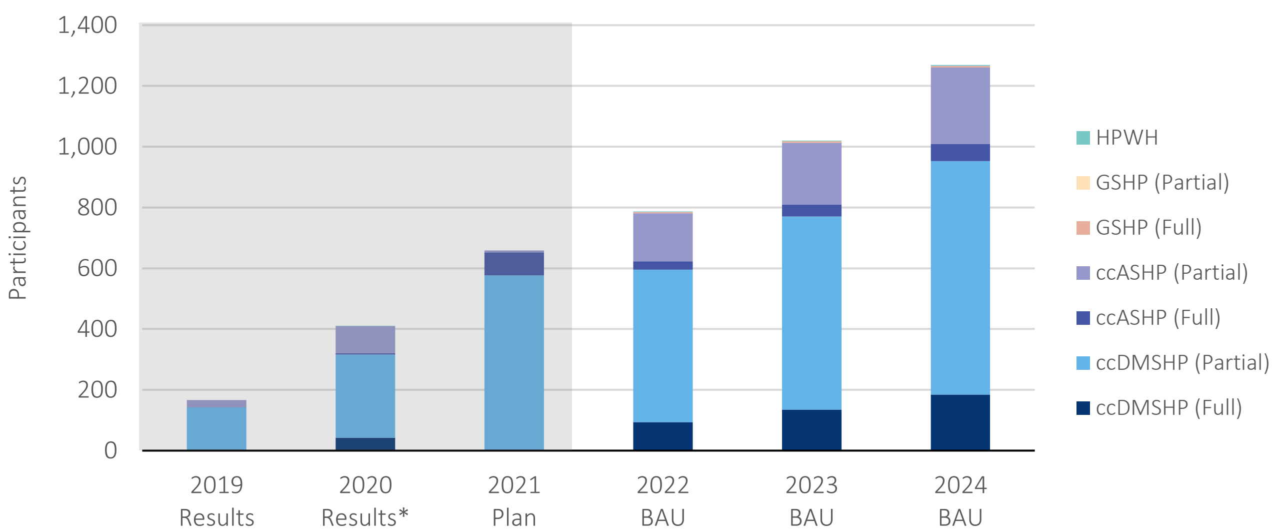


While their adoption is somewhat negligible, GSHPs achieve higher levels of uptake in the Max scenario, where their significant upfront costs are overcome with increased incentive levels.

Heat pump water heaters (HPWH) for domestic hot water do not see significant uptake under any of the scenarios despite the favorable customer economics due to the significant market barriers associated with this technology.

Figure 57 compares the annual number of participants for the BAU scenario to recent program benchmarks. Overall, these show that while there is an expected growth in full system replacement measures, the ccDMSHP and ccASHP partial replacement measures account for the majority of program growth over the study period. While the 2019–2021 Plan did not include much uptake from full replacement measures, 2020 program results show some uptake, which aligns with the results of the BAU scenario.

Figure 57. Residential Participants by Heat Pump Type and Full/Partial Replacement Compared to Benchmarks

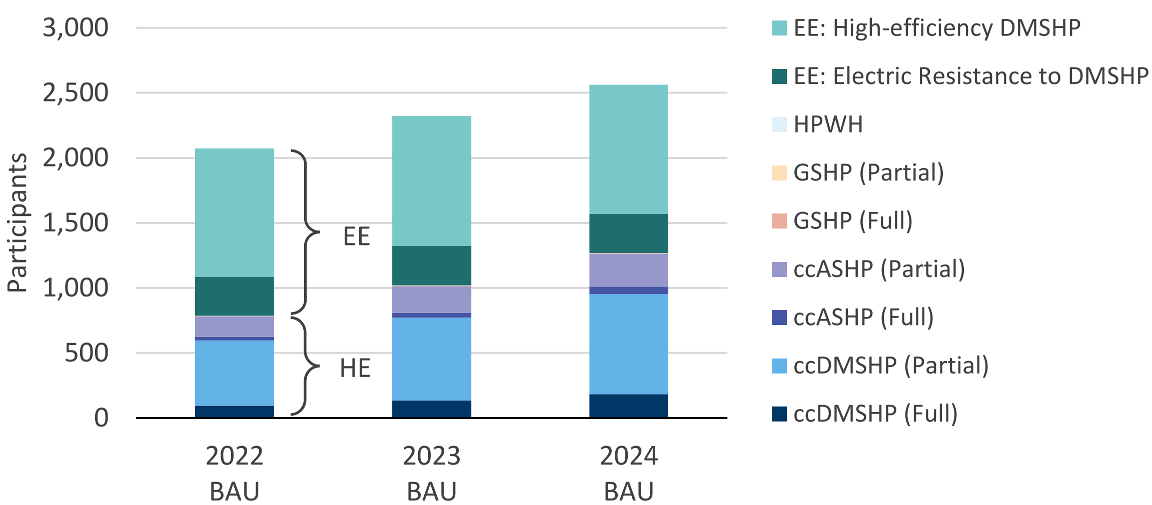


* Results for the first 10 months extrapolated to a full year

Heat Pump Adoption Across EE and HE Programs

While this chapter focuses on the ability for heat pump technologies to displace combustion-fired heating systems, heat pumps also get adopted in place of existing electric resistance heating systems or to replace existing heat pumps at the end of their useful lives. These measures are assessed within the EE chapter of this report. Figure 58 shows the evolving share of residential heat pump adoption through EE and HE programs under BAU conditions. As can be seen, EE measure heat pumps represent approximately 62% of total residential heat pump adoption in 2022. As HE programs expand, this proportion decreases to 51% by 2024.

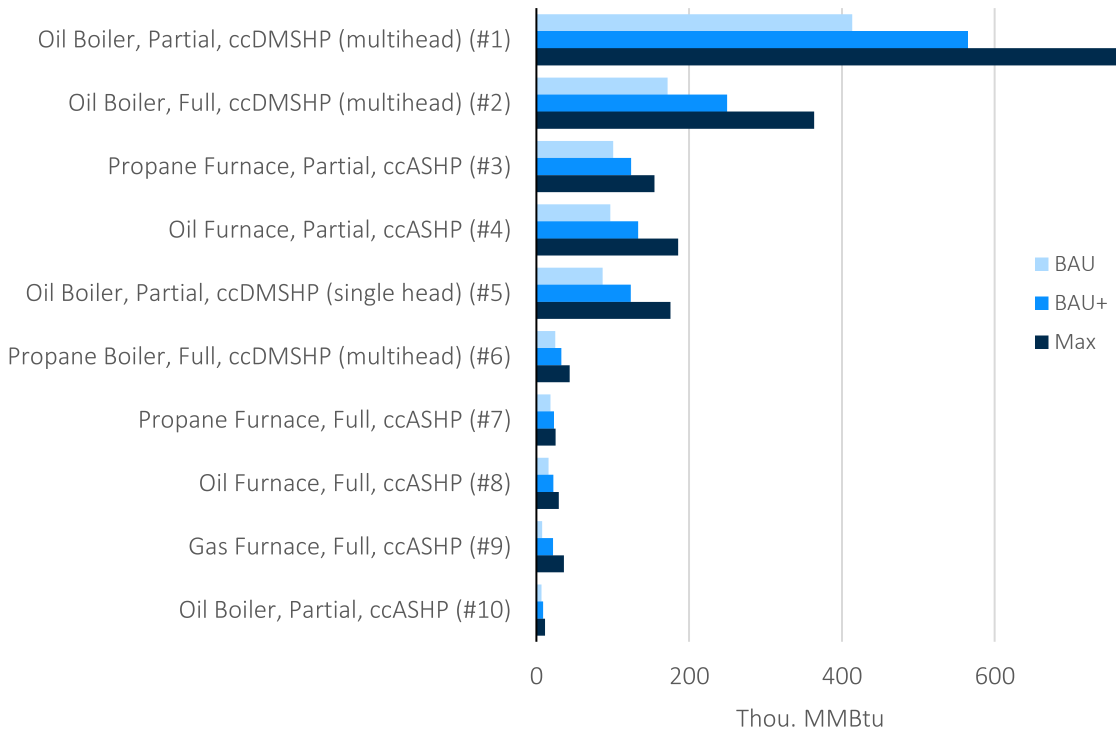
Figure 58. Combined Residential Heating Electrification and Electric Efficiency Heat Pump Adoption.



Residential Top Savings Measures

Figure 59 presents the top 10 measure list sorted by lifetime fuel savings under the BAU scenario.

Figure 59. Top 10 Residential Measure List Sorted by BAU Building-Level Lifetime Savings



Note: Annual average over 2022–2024.

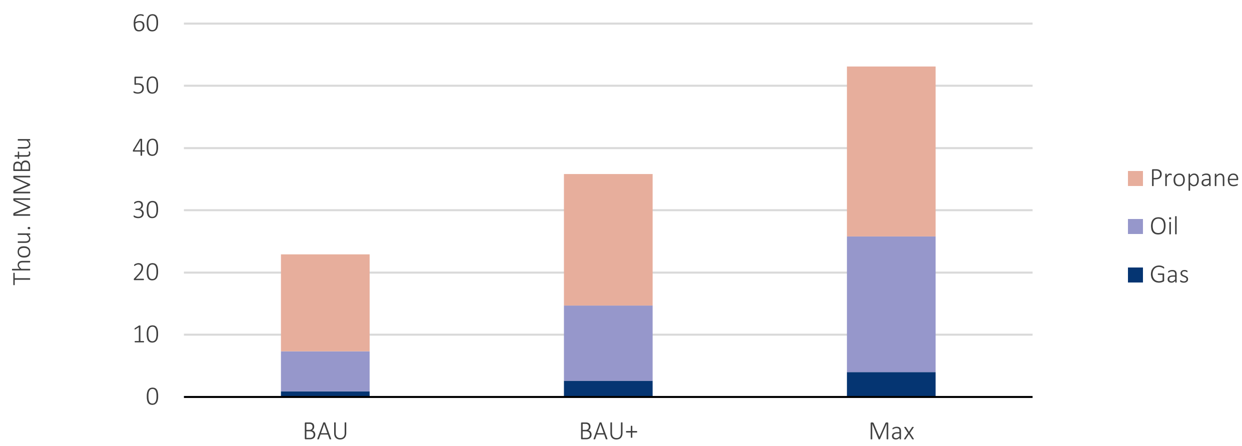
The top ten measures with the highest lifetime potential generally are the measures with the largest market base (mostly oil) and the most favorable customer cost-effectiveness (particularly high for propane and for ccDMSHPs). Of note, the partial ccDMSHP measure is split in two equipment sizes: one assessing single-ton units (average of 1.0 ton), and another assessing multihead units (average of 2.5 tons).

Figure 59 also shows that propane measures are less impacted by incentive levels due to their relatively favorable customer cost-effectiveness even at BAU scenario incentive levels.

5.2.3 C&I Fuel Savings

Figure 60 presents the cumulative savings potential by 2024 under each scenario. The results show a mix among the three baseline heating fuels, with a notable amount of uptake for propane replacements in the BAU scenario and an increasing level of oil savings in the BAU+ and Max scenarios. Overall, this is not a reflection of C&I heating consumption, which is dominated by gas (around 64%) and oil (around 25%). This means that propane is disproportionately represented due to favorable customer economics and that most gas measures are either not passing program cost-effectiveness screening or are not adopted due to poor customer economics.

Figure 60. Cumulative C&I First-Year Building-Level Fuel Savings by 2024

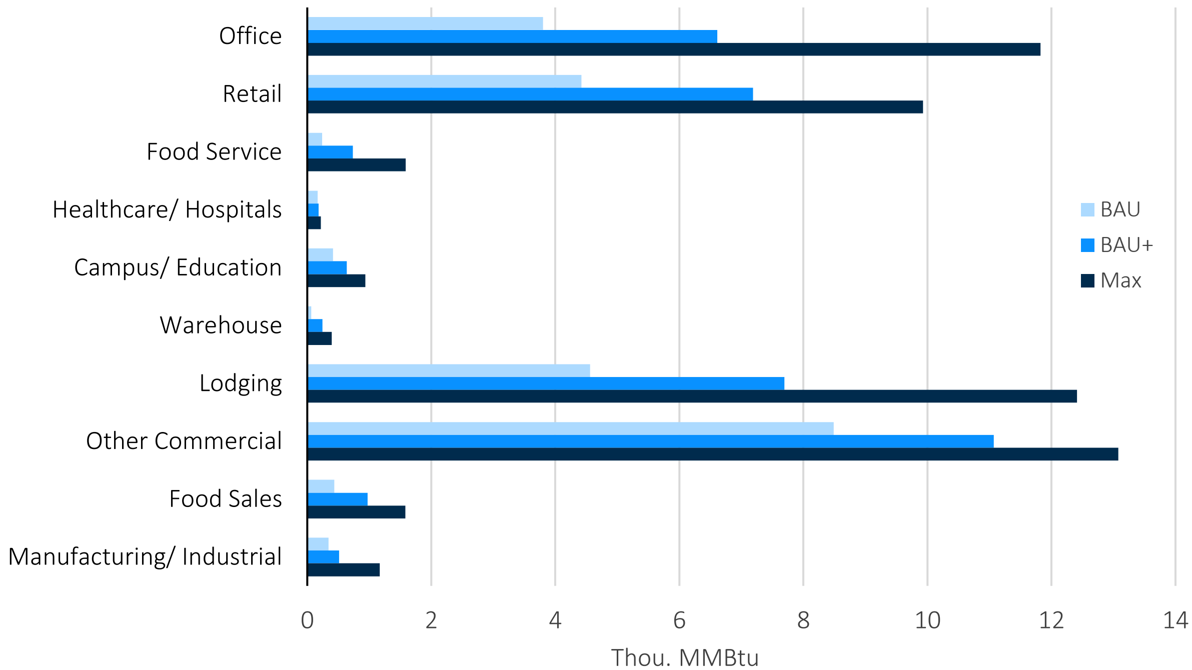


C&I Savings by Market Segment

Figure 61 details the achievable savings potential in each C&I market segment. The results show that the Office, Retail, Lodging, and Other Commercial segments dominate the electrification opportunities. These results are reflective of their large customer base as well as their larger proportion of propane users. The varying impact from incentive levels in each segment largely depends on their proportion of propane and oil user, as propane already shows good customer economics in the BAU scenario.

Of note, the Lodging segment includes central systems from multi-family buildings, and they make up approximately 83% of that segment's population. Additionally, almost all of the achievable potential from heat pump water heaters (HPWH) is found in the Lodging segment, due to some Lodging buildings having individual storage water heaters for each unit, while the other C&I segments tend to have large combustion-fired central water heaters.

Figure 61. C&I Lifetime Building-Level Fuel Savings by Segment

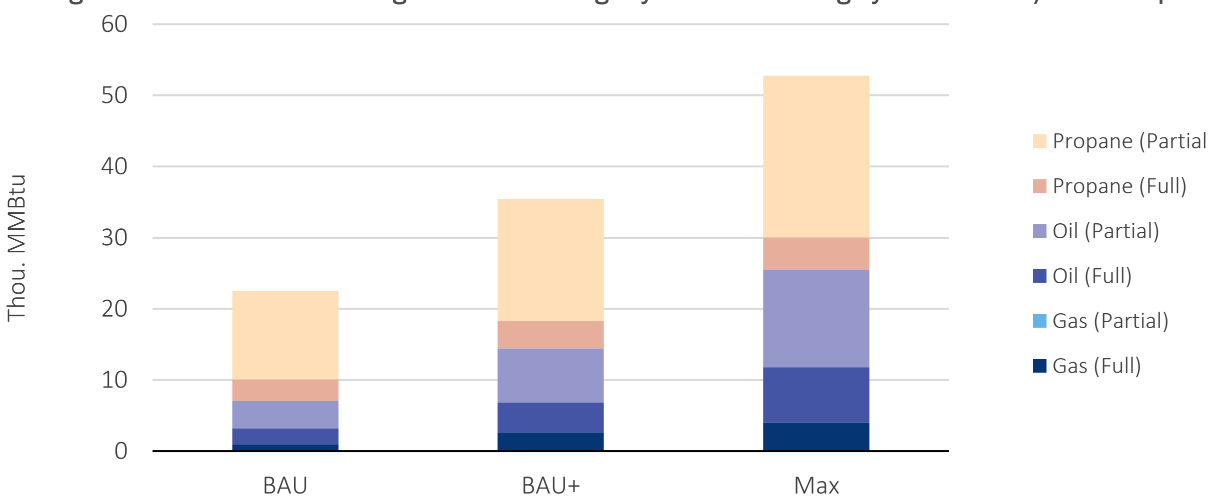


Note: Annual average over 2022–2024.

C&I Savings by Fuel Type

Figure 62 shows fuel savings by the fuel type of the baseline heating system and full or partial replacement measures. Oil and propane measures are largely dominated by partial replacements, which mostly follows the barrier levels, but also the switchover temperatures defined in the TRM, which are lower for propane than oil and therefore comparatively improve the savings offered by propane partial measures. Similarly, the gas switchover temperature is very high, which prevents the partial gas measures from passing the economic screening.

Figure 62. C&I Lifetime Building-Level Fuel Savings by Baseline Heating System and Full/Partial Replacement

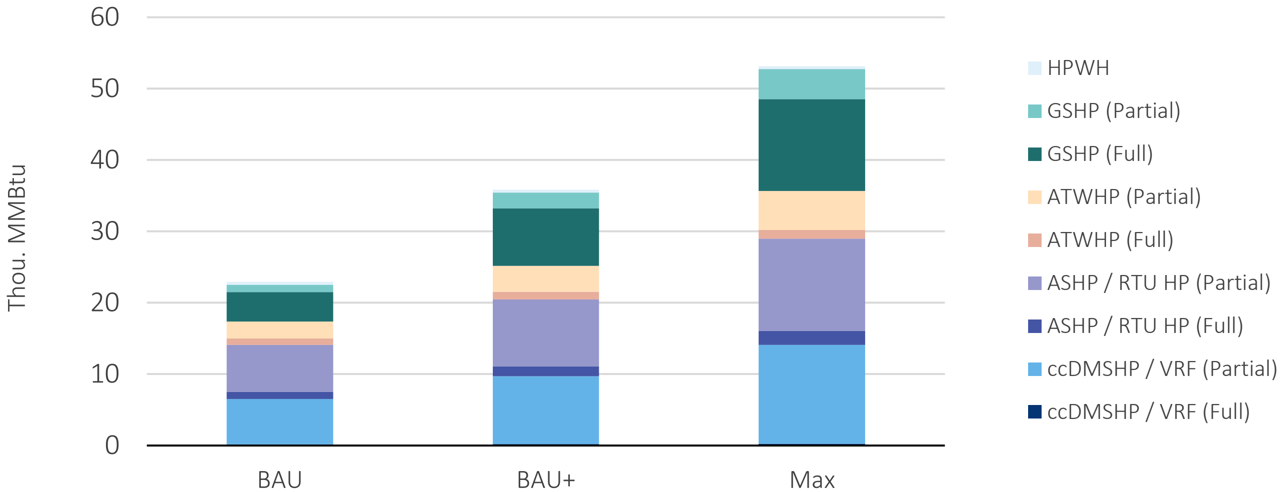


Note: Annual average 2022–2024.

C&I Savings by Heat Pump Type

Figure 63 shows the C&I savings potential by heat pump technology under each scenario. Results show that the BAU scenario is mostly driven by ccDMSHPs partially replacing oil and propane boilers, and ccASHPs partially replacing oil and propane furnaces.

Figure 63. C&I Lifetime Building-Level Fuel Savings by Heat Pump Type and Full/Partial Replacement



Note: Annual average over 2022–2024.

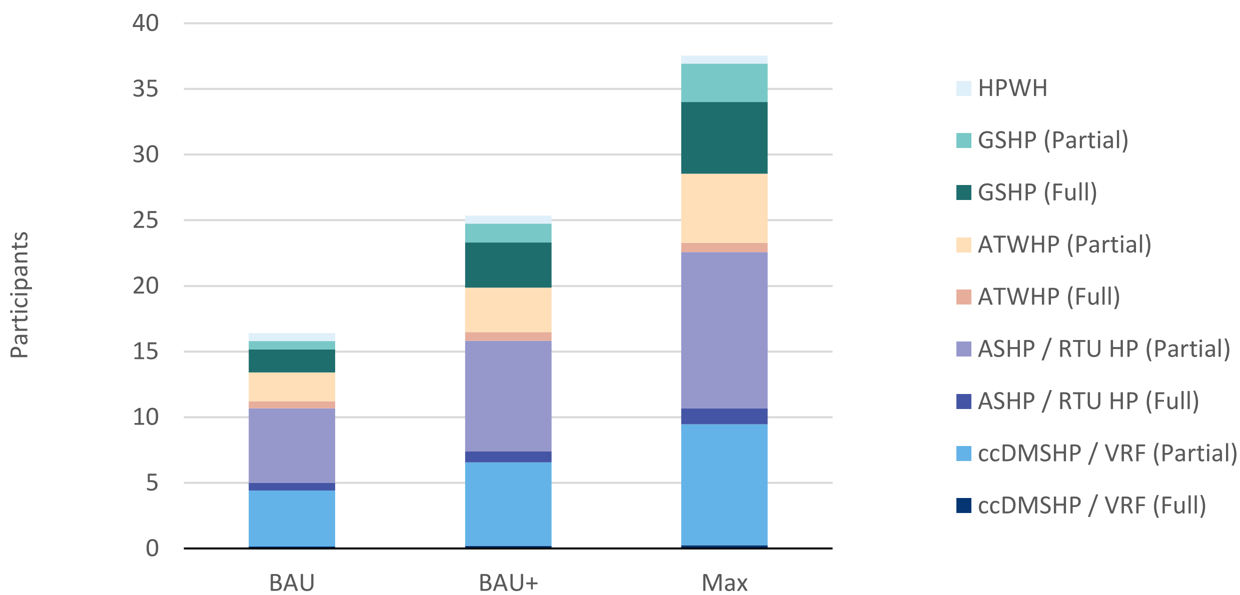
While GSHP adoption is relatively low under the BAU scenario, it is mostly related to full replacements, which increases its share of fuel savings. Increasing incentive levels are seen to drive significantly higher adoption levels, as can be seen in the BAU+ and Max scenario results. Most of the gas adoption in all scenarios is related to GSHPs fully replacing furnaces.

The ductless heat pumps technologies in Figure 63 are shown in dark blue and include both mini-split and larger variable refrigerant flow (VRF) heat pumps. To note, VRF heat pumps are only included as a measure for new construction and major retrofits, as they are not deemed economically feasible in existing buildings that do not go through a deep retrofit of their HVAC systems. Air-to-water heat pumps (ATWHP), however, provide a viable option to retrofit existing buildings with boilers, and some savings are seen from these measures under all scenarios.

For most measures, the partial replacement options outweigh the full replacement measures, with the exception of the high savings driven by full heating GSHP replacement measures.

Figure 64 shows a representation of adoption in terms of C&I participants. This breakdown shows a similar trend to the savings perspective, with partial displacement measures representing the majority of C&I participation over the study period.

Figure 64. C&I Participants by Heat Pump Type and Full/Partial Replacement



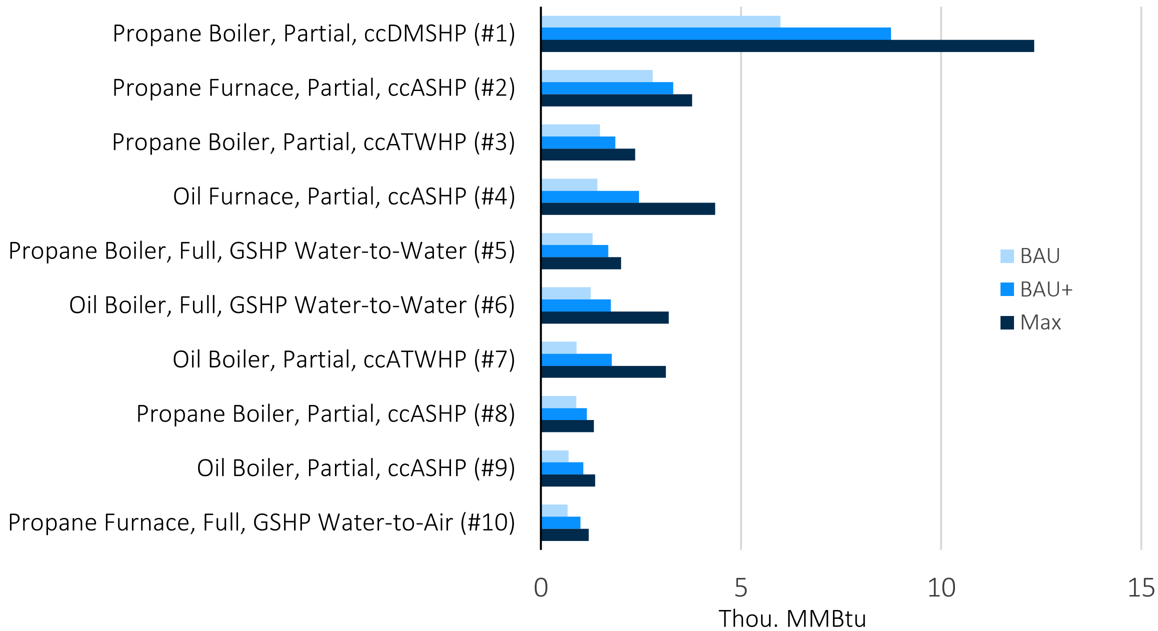
Note: Annual average over 2022–2024

C&I Top Savings Measures

The C&I top 10 measure list is presented below in Figure 65. Most C&I top measures are partial replacements, mainly because of higher market barriers for full replacement measures. Key barriers to full replacements include the project complexity (real or perceived), equipment reliability (real or perceived), resistance to change, and risk aversion from the customer's point of view. On the contrary, partial replacement measures keep the existing fuel-based heating equipment as a supplemental source of heat and are often simply replacing the existing AC equipment with a heat pump equivalent.

The only full replacement exceptions in the top 10 list are GSHPs, which is explained by the fact partial GSHPs typically do not pass TRC cost-effectiveness. Moreover, the electric backup systems (buffer tank electric boiler, electric resistance coil, etc.) are comparatively cheaper than their fuel equivalents, which further improves the business case for full replacements.

Figure 65. Top 10 C&I Measure List Sorted by BAU Building-Level Lifetime Savings

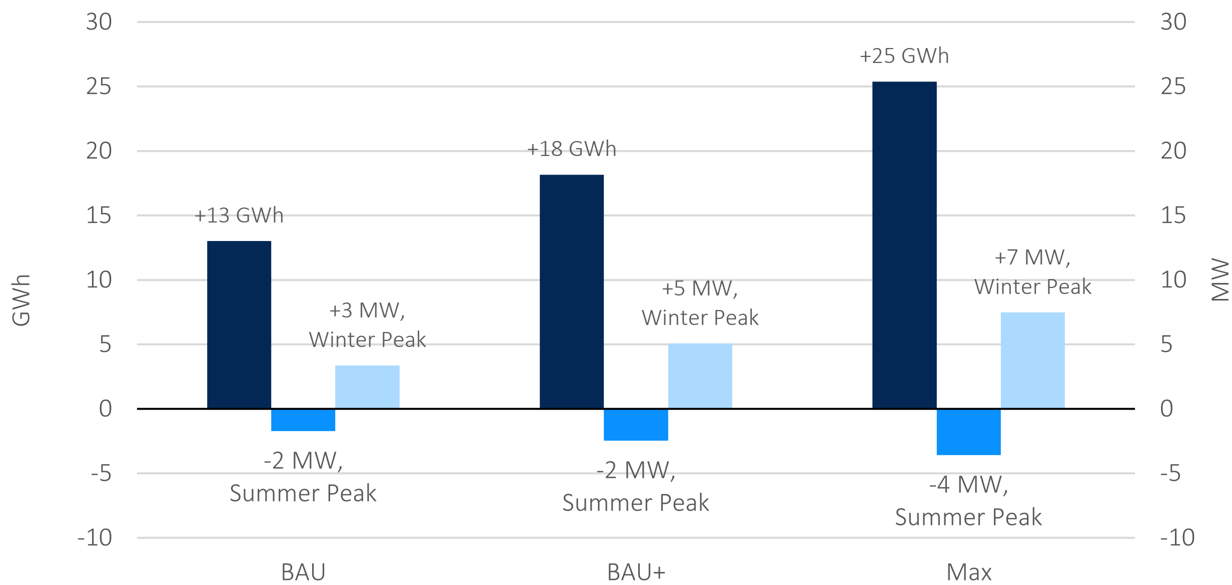


Note: Annual average over 2022-2024.

5.2.4 Grid Impacts

Figure 66 shows the overall impact that heat pump adoption is expected to have on electricity sales over the study period. While heating electrification increases customer electricity consumption (kWh) and the winter peak demand, it reduces the summer peak demand, as most heat pumps have higher cooling efficiency than the existing AC equipment they replace (e.g., a baseline central AC has a SEER of 13 where the ccASHP equivalent has a SEER of 18).

Figure 66. Grid Impacts



Note: Cumulative First-Year by 2024.

Both full and partial replacement measures can have an impact on the summer peak. Conversely, partial replacement measures are not typically expected to affect the winter peak demand as their controls will switch over to the combustion fired back-up system under the temperature conditions that drive winter peak demand days.

Results show that heating electrification is not yet sufficient to significantly impact system wide winter and summer peaks (±0.5 %). However, widespread electrification could lead to local and system level peak demand, which in turn could change avoided cost structures. If a winter peak avoided cost should arise, it would reduce the cost-effectiveness of full air-source replacement measures, which would comparatively increase the appeal of GSHPs and partial replacements, for example, as they have limited to no impact on the winter peak.

5.2.5 Portfolio Metrics

Energy optimization offerings show continued growth in potential under all scenarios, which impacts program costs and benefits. As heating electrification is an emerging technology, the model projects large year-over-year growth that is in line with past growth witnessed in CLC's programs. However, like any emerging technology, there is an inherent uncertainty in projecting the future growth of heating electrification. That uncertainty was addressed, to the degree possible, by calibrating the model to account for the growth between 2019 and 2020 program results. Moreover, the relatively short potential study period of only three years limits the impact of market growth uncertainty on the savings potentials.

Program Costs

Figure 67 details the program costs by year and achievable scenario. Similar to program savings, program costs are expected to follow a relatively large year-over-year growth as heat pump adoption grows across CLC's territory.

Figure 67. Program Costs by Year and Scenario

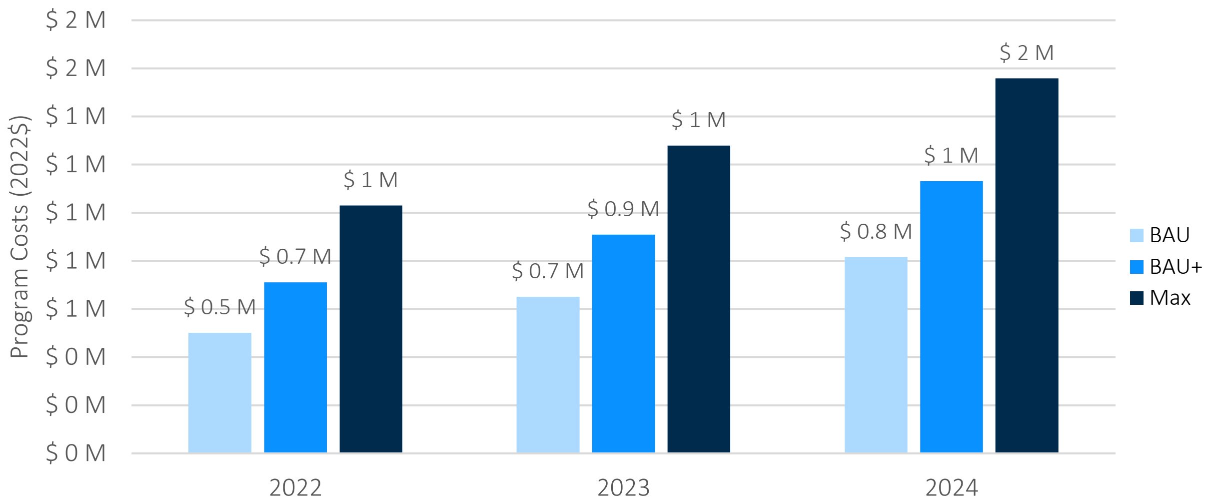
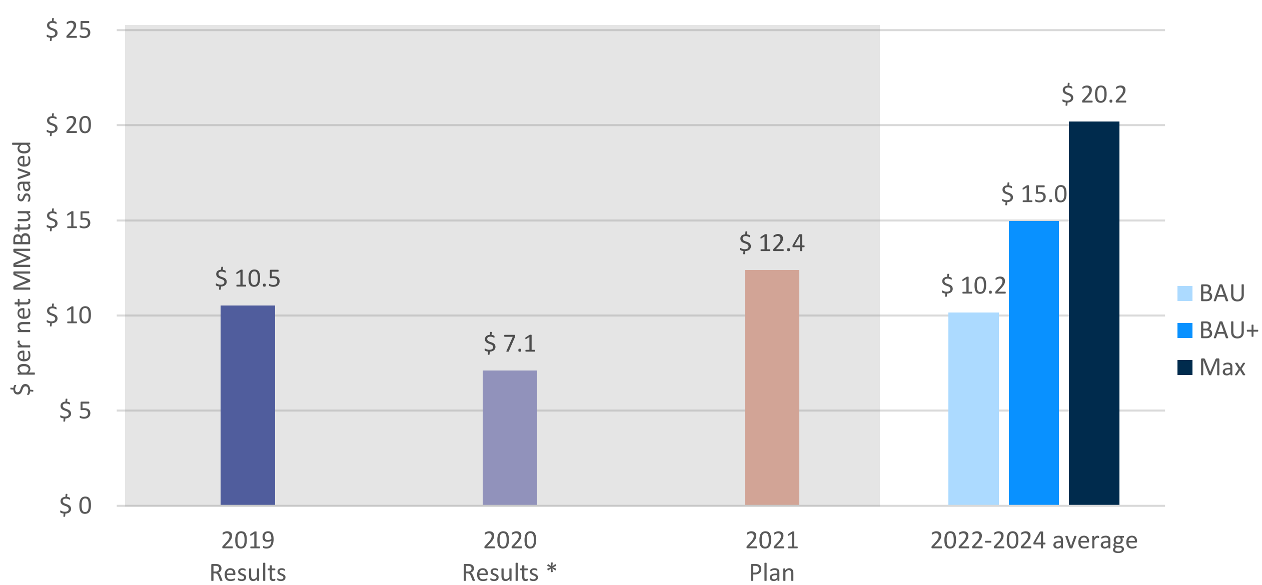


Figure 68 compares average program costs per lifetime net source MMBtu saved.

Figure 68. Program Costs Per Lifetime Fuel MMBtu Saved Compared to Benchmarks



*Results for the first 10 months extrapolated to a full year

The higher cost per MMBtu for the BAU compared to the 2019 and 2020 benchmarks is partially related to new measures added in the modeled programs that cost more than the currently offered measures:

- **GSHPs:** Although not offered in 2019 or 2020, or included in the 2021 Plan, GSHPs will be added for the 2022–2024 study period. Incentives are set at a higher level than current air-source heat pumps ($3,000 vs $1,250 per ton) incentives to account for GSHP's higher costs and savings.

- **ccDMSHPs**: While the TRM assumes that the average installed capacity of DMSHPs in partial replacement measures is 2.5 tons, this study includes both single-head (1.0 ton) and multi-head (2.5 tons) units for residential applications, which lowers the average savings per unit compared to the TRM.

Figure 69 shows lifetime fuel savings compared to program costs for all three achievable scenarios. The large year over year program growth is clearly visible, as well as the increasing cost per MMBtu saved as incentive levels rise with the scenarios.

Figure 69. Program Costs vs Lifetime Net MMBtu Saved

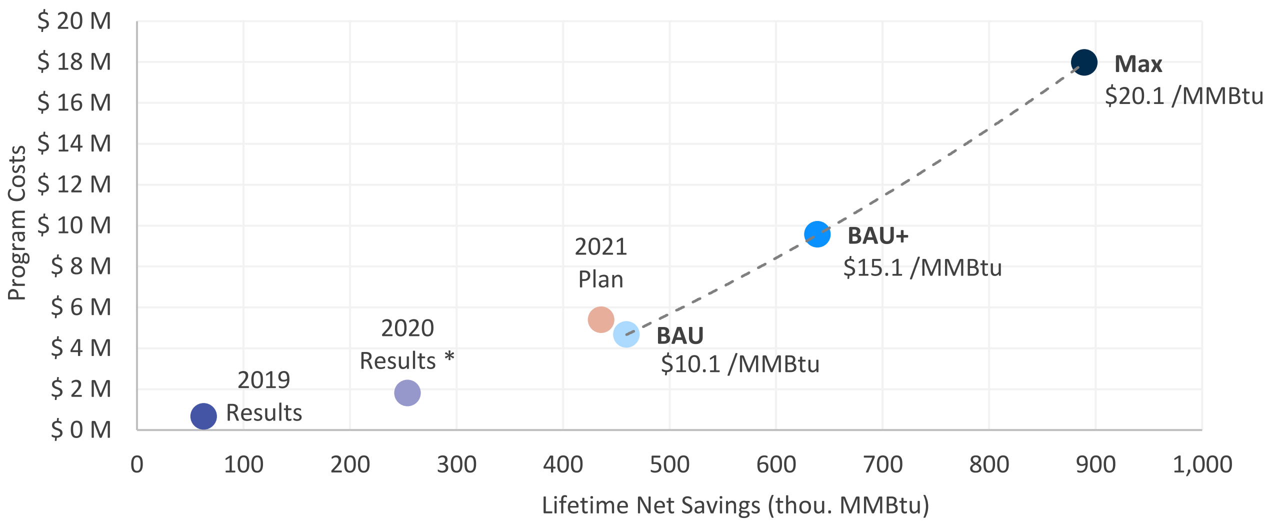
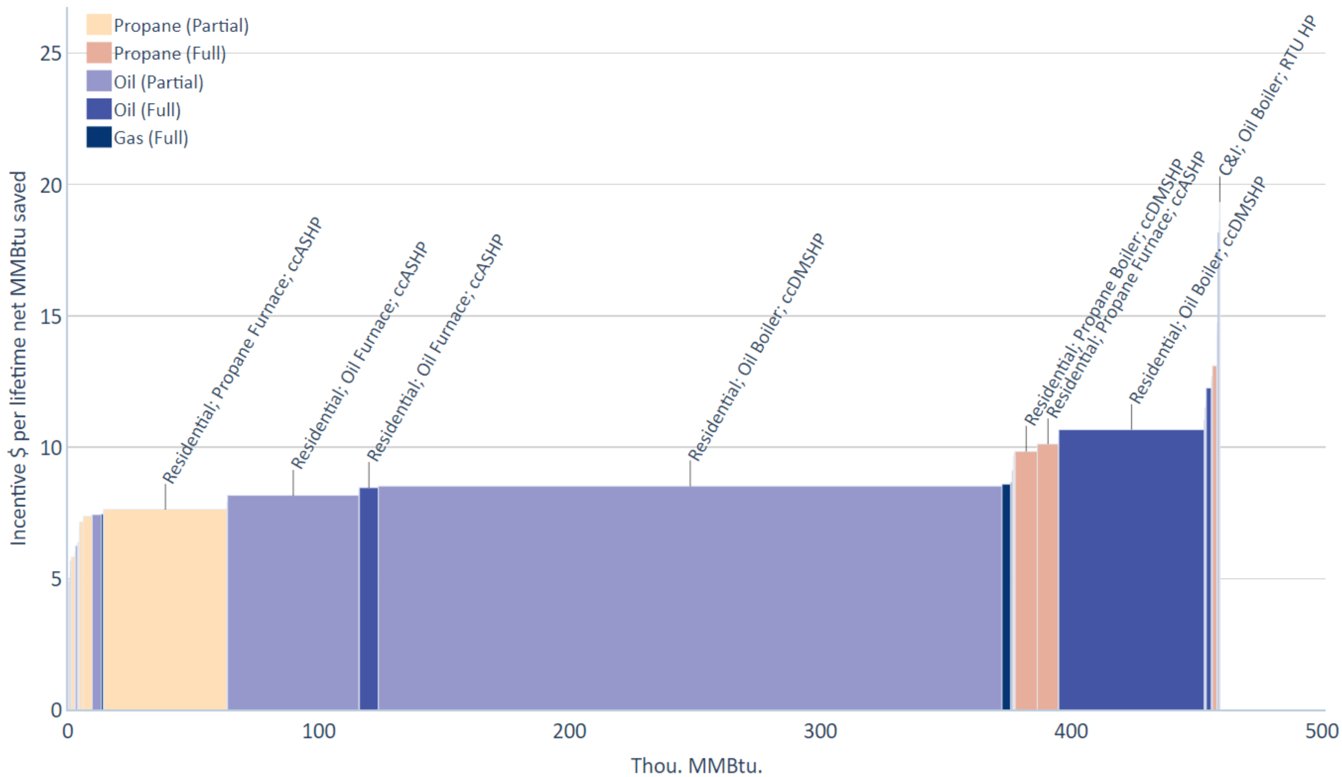


Figure 70 and Figure 71 show a net MMBtu cost abatement curve relative to program incentives for the BAU and Max scenarios, respectively.

The bulk of net MMBtu savings for the BAU scenario come at an incentive cost around $9 per net MMBtu. More than 98% of savings are in the residential sector.

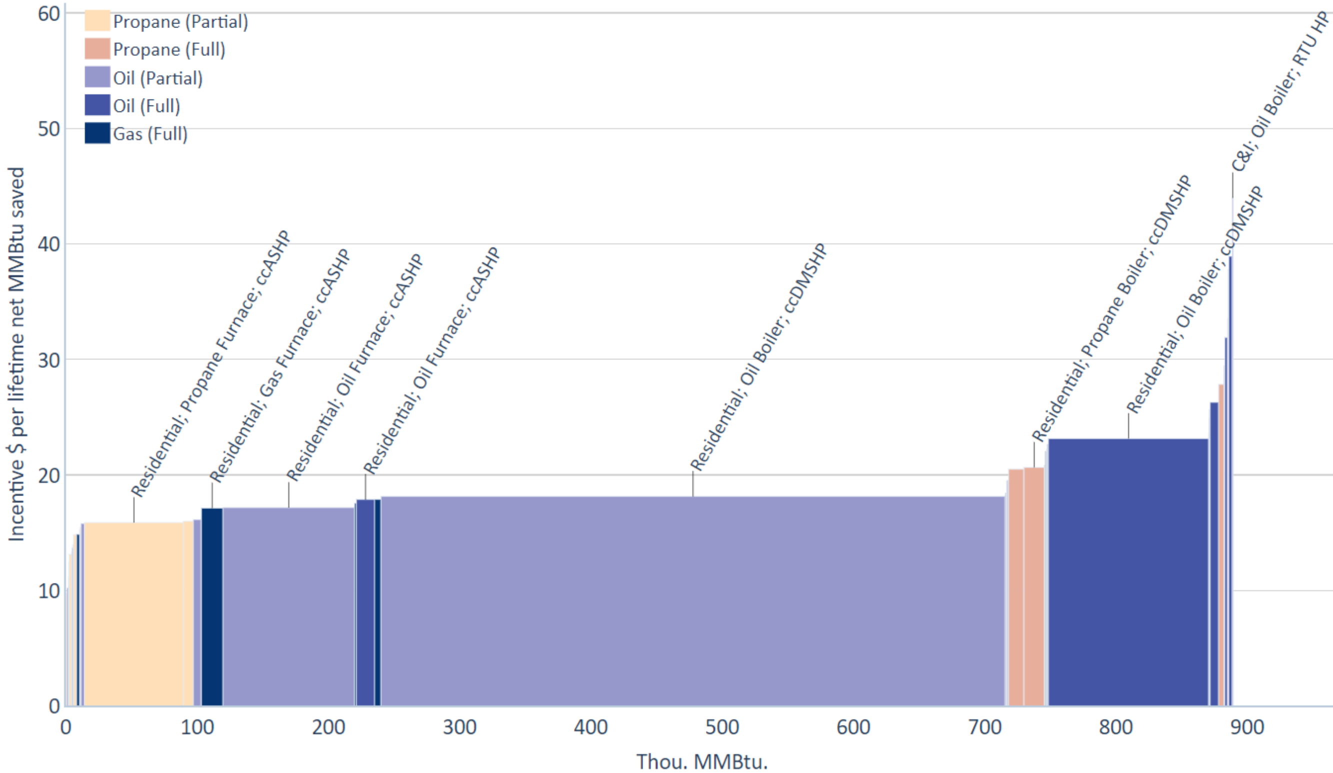
Figure 70. MMBtu Cost Abatement Curve for the BAU Scenario



Note: Lifetime net MMBtu savings, annual average over 2022–2024

The Max scenario, where incentive levels are twice the BAU levels, shows that the bulk of MMBtu savings come at an incentive cost between $16 and $18 per net MMBtu. The full replacement measures seem to provide savings at a slightly lower incentive per fuel MMBtu saved (e.g., ccDMSHPs replacing residential oil boilers). Some additional full replacement of gas heating systems are visible in Figure 71 and are from the residential sector.

Figure 71. MMBtu Cost Abatement Curve for the Max Scenario



Note: Lifetime net MMBtu savings, annual average over 2022—2024.

The program cost metrics are summarized in Table 22.

Table 22. Program Costs and Savings Comparison

Program Costs	2019 Results	2020 Results*	2021 Plan	BAU	BAU+	Max
Incentives + program admin	$0.7 M	$1.8 M	$5.4 M	$4.7 M	$9.6 M	$18 M
Per lifetime net MMBtu saved	$219	$125	$216	$163	$240	$324
Per first-year net MMBtu saved	$10.5	$7.1	$12.4	$10.2	$15.0	$20.2

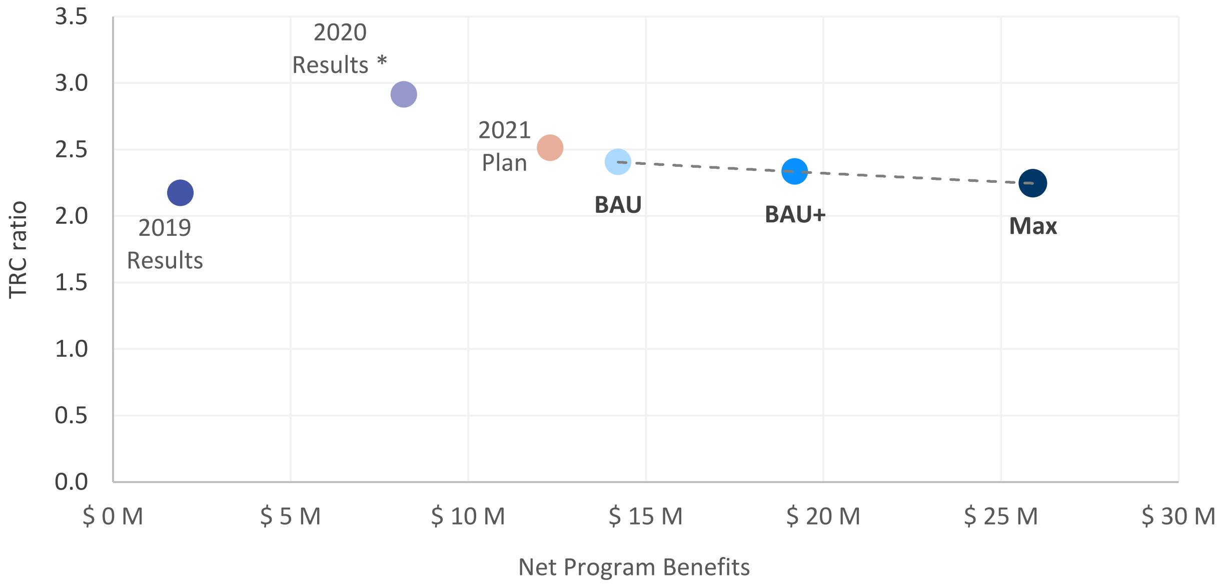
*Results for the first 10 months extrapolated to a full year

Note: 2022–2024 averages

Program Benefits

In terms of program benefits, the law of diminishing returns is visible between scenarios in Figure 72. The increased incentive levels lead to increased savings, but at the cost of a slightly lower average TRC and a higher cost per MMBtu saved.

Figure 72. Net Program Benefits Compared to TRC Ratio



Note: 2022–2024 averages

The program benefits metrics are summarized in Table 23 along with average program-level TRC ratios for all three achievable scenarios.

Table 23. Program Cost Effectiveness and Benefits Comparison

Metric	2019 Results	2020 Results *	2021 Plan	BAU	BAU+	Max
Average TRC	2.42	2.9	2.5	2.4	2.3	2.2
Net TRC Benefits	$ 1.9 M	$ 8.2 M	$ 12 M	$ 14 M	$ 19 M	$ 26 M
Net TRC benefits per first-year net MMBtu	$ 633	$ 566	$ 493	$ 496	$ 483	$ 468
Net TRC benefits per lifetime net MMBtu	$ 30	$ 32	$ 28	$ 31	$ 30	$ 29
Annual CO2 Emission Reductions (Short Tons)	247	1,295	2,237	2,376	3,294	4,588

*Results for the first 10 months extrapolated to a full year

Note: 2022–2024 averages

5.2.6 COVID sensitivity analysis

The economic uncertainty and business closures as a result of the COVID-19 pandemic are expected to have impacted overall program performance in 2020. While it is unclear what the precise economic effects from COVID-19 will be over the study period, an analysis of the impact that COVID-driven changes in market conditions may have on program savings is included.

Similar to the energy efficiency modeling, the following input parameters have been adjusted in the assessment:

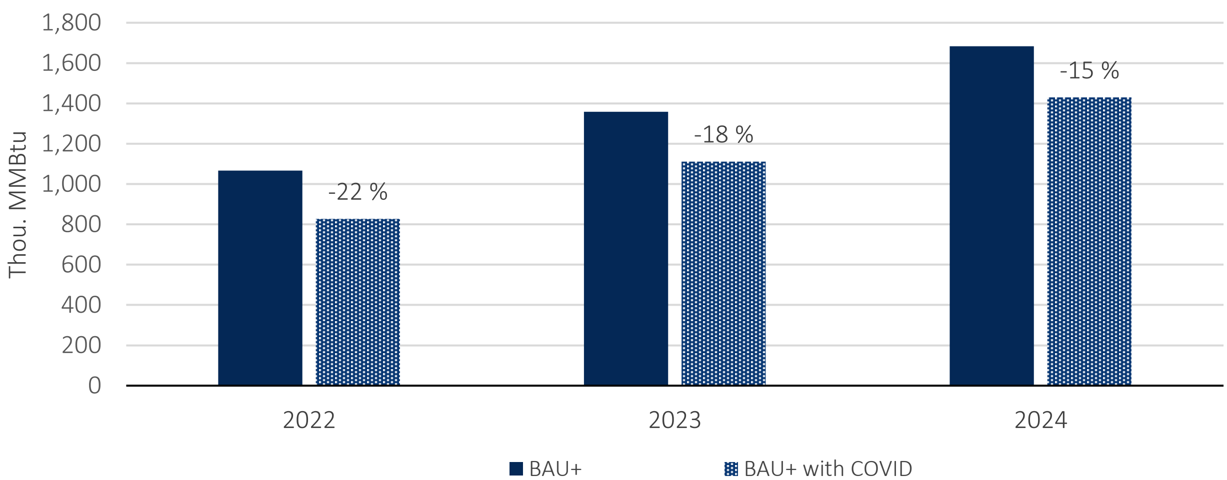
- **Market sizes** have been adjusted for some C&I segments to reflect fewer customers due to temporary or permanent business closures.
- **Barrier levels** have been increased to reflect delayed projects, increased competition for capital, decreased resources, and other impediments to energy efficiency and electrification upgrades.

Appendix B summarizes the COVID-related market and barrier parameters for each segment.

Of note, some impact of COVID-19 on the adoption curves might already be reflected in the scenario results throughout the study, due to the inclusion of actual 2020 program results (up to October) to calibrate the model's technology diffusion curves. However, 2020 program results still showed a significant annual growth when compared to 2019.

Figure 73 presents the results on the sensitivity analysis for the three years of the potential study and specifically on the BAU+ scenario, as agreed with CLC.

Figure 73. Sensitivity Analysis of COVID-19 Impacts Relative to the BAU+ Scenario



Results show a large reduction in 2022 program savings, followed by a relatively slow recovery in 2023 and 2024. Savings are not expected to reach levels estimated under the scenario without COVID-19 during the study period, even after a few years of renewed economic activity. Compared to established efficiency programs, which usually have more stable performance levels, relatively new programs like heating electrification are still ramping up, and the overall effect is likely to be a slowed rate of growth compared to a scenario without COVID-19.

The impact of the COVID-19-related temporary slowdown of the economy could therefore have lasting effects on the heating electrification adoption if it results in a delay in the technology's diffusion in the market.

5.3 Key Takeaways

Based on the results presented in this chapter, the following key take-aways emerge:

- The **technical opportunity for fuel savings through heating electrification is extremely large** when compared to other savings streams (i.e., it is nearly an order of magnitude larger than delivered fuel efficiency technical potential). The majority of this potential comes from the displacement of gas equipment (which is not considered in the EE model for delivered fuels). In addition, electrification measures can feasibly displace most, if not all, of a building's fuel consumption, while efficiency measures just reduce consumption by a portion of the current amounts.
- While most delivered fuel measures pass TRC screening, almost all gas measures do not. However, in all cases the achievable potential is *very* small relative to the economic potential because it is very **difficult to entice customers to electrify**. Poor customer economics for some measures, especially those with a gas-fired baseline system, are part of the reason customers resist electrification. The largest contributing factor, however, is the prevalence of significant market barriers that electrification measures face, largely as a result of heat pumps being a relatively new technology in Massachusetts and customers being unfamiliar with the economics of heat pumps.
- Overall, **energy optimization offerings show a continued growth in potential under all scenarios**. As heating electrification is an emerging technology, the results project large year-over-year growth that is in line with past growth witnessed in CLC's heat pump programs. This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like GSHP, the emergence of new C&I measures, and steadily improving customer economics for replacing delivered fuel heating systems.

6. Active Demand Reduction Potential Results

6.1 Overview

The Potential Study Team conducted a detailed assessment of the potential for ADR programs to reduce CLC's peak load during the 10–40 highest demand hours of the year. This represents incremental additional peak load reduction to the passive peak reductions estimated in the EE model described in Chapter 4. This chapter presents ADR program potential resulting from various strategies (ranging from equipment controls to C&I load curtailment), based on their ability to reduce loads during the ISO New England (ISO-NE) system-wide annual peak demand hours.

6.1.1 Approach

The ADR potential is assessed using Dunsky's Active Demand Reduction Optimized Potential (DROP) Model to determine potential impacts against CLC's contribution to the ISO-NE system annual peak demand. A standard peak day load curve is identified and adjusted to account for projected load growth and efficiency program impacts over the study period. Five years of historical annual hourly load data, coupled with forecasted annual peak demand provided by CLC, are used to determine the timing, duration, and magnitude of the expected annual peaks. ADR measures and programs are then applied to the projected standard peak day load curve to determine technical, economic, and achievable potential:

- **Technical potential** is estimated as the total possible coincident peak load reduction for each individual measure multiplied by the saturation of the measure or opportunity in each market segment.
- **Economic potential** is the amount of coincident peak load reduction for each individual measure that passes the TRC test. Only those measures that pass the threshold (TRC > 1.0) are included in the achievable potential scenarios.
- **Achievable potential** is assessed under three program scenarios by applying mixes of all cost-effective measures to determine the combined impact against the peak day load curve, and accounting for measure interactions.

For each year, the ADR potential is assessed, accounting for existing programs from previous years as well as increases in customer participation and new measures or programs starting in that year. Unlike many efficiency measures, ADR peak savings only persist as long as the program is offered. For new and expanded programs, ramp-up factors were applied to account for the time required to recruit participants.[30]

Consistent with how ADR cost-effectiveness is calculated in Massachusetts, the demand benefits are only considered at the identified ISO-NE peak hours and therefore do not account for possible new peaks that may result from ADR measure interactions or peak shifting impacts. As a result, the peak demand impacts in this study may somewhat overstate the true resulting incremental impact on CLC's annual peak loads.[31] Considering that CLC's service territory represents only 1% of the ISO-NE peak demand, however, it is unlikely that peak shifting could impact the timing and duration of the ISO-NE peak demand periods.

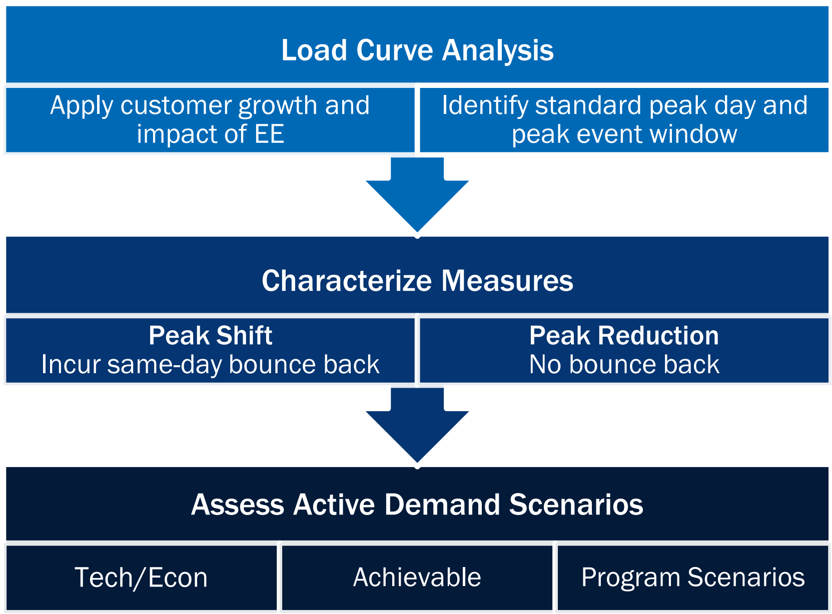
Because the technical and economic ADR potentials represent a significant portion of the overall load, they are not considered to be realistically additive across all measures. Individual measures' technical and

[30] A summary of ADR program assumptions, including ramp-up rates, is included in Appendices E and F.
[31] Demand benefits excluding peak shifting (ISO-NE) will always be equal or greater than demand benefits including peak shifting and interaction penalties.

economic potentials are provided in Appendix F. In each achievable scenario, the most cost-effective new measures were given priority in the model.

Figure 74 presents an overview of the steps applied to assess the ADR potential in this study.

Figure 74. Active Demand Reduction Potential Assessment Approach



A more detailed description of the ADR modeling approach applied in this study can be found in Appendix E.

6.1.2 Achievable Potential Scenarios

The achievable potential is assessed under three scenarios, corresponding to varied ADR program approaches and levels of investment, to determine the resulting peak demand reduction impacts and benefits (Figure 75). Further details on the specific programs and their related inputs are presented in Appendix E.

Figure 75. Active Demand Reduction Achievable Scenario Descriptions

BAU — Reflects **current ADR programs and incentives**, when applied across the full applicable market, to obtain projected equilibrium participation levels as predicted by the DROP model's propensity curves.

BAU+ — Tests the ability to **expand participation by increasing incentives** under the current ADR programs, while maintaining cost-effectiveness.

Max — Applies BAU+ scenario incentive levels, and further **expands ADR programs to include a range of new cost-effective measures.**

6.1.3 Benchmarking

The results of the study were compared to current program impacts (actual 2019 savings or 2020 preliminary savings, when available) as well as the projected impacts in the 2021 Plan. Table 24 presents current enrollment and average per participant reduction from CLC's ADR programs. The modeled achievable potentials for each program are benchmarked against current program impacts to demonstrate consistency between the study and existing ADR efforts. Apart from energy storage (both C&I targeted and daily[32] as well as residential), the modeled approach is well-aligned with the existing potential. Furthermore, current program adoption was used to calibrate the model based on the technology (measure) and sector.

Table 24 shows that the current capacity (2020) is dominated by C&I curtailment, which makes up about 50% of current demand reduction. Residential HVAC bring-your-own-device (BYOD) is also relatively well-developed accounting for more than 30% of the 2020 reduction.

Table 24. Comparison Between Existing Programs and Model in Massachusetts (CLC Territory)

Existing measures	2020 Preliminary Capacity[a] (MW)	2020 Reported Reduction (kW / participant)	Modeled Reduction (kW / participant)
C&I Curtailment	0.9	51	56
C&I Battery / Thermal Energy Storage – Daily	N/A	N/A	58
C&I Battery / Thermal Energy Storage – Targeted	0.28	280[b]	58
C&I Smart Electric Vehicle Charger (Pilot)	N/A	N/A	0.10
Residential HVAC BYOD	0.6	0.50[c]	0.51
Residential Smart Electric Vehicle Charger (Pilot)	N/A	N/A	0.39
Residential Battery Energy Storage	N/A	N/A	5.5
Total	**1.8**	**N/A**	**N/A**

[a] Because of the ADR programs' growth between 2019 and 2020, 2020 preliminary data values were used to better reflect actual program performance. Current capacity includes realization rates derived from the MA TRM.

[b] Estimated from total enrollments and average participant savings.

[c] 0.50 kW per device, some participants may have more than one device.

C&I storage programs are relatively new with only a small number of participants to date,[33] making it difficult to derive a meaningful average size of system for future applications. At the time of writing, the average battery peak reduction under the Targeted dispatch program was 280 kW, which is considered high. For assessing future potential battery sizes, the modeled average battery sizes were derived from average peak loads for medium and large buildings within each segment, resulting in an average value of 58 kW.

Residential batteries capacities were modeled at 5.5 kW and 13.5 kWh and the model assumed a 2-hour average peak event call, which is aligned with program evaluations. The Connected Solutions Home Batteries program in the rest of MA allows events of up to 3 hours which means that the average battery would not sustain a 5.5 kW discharge over 3 hours, reducing the contribution to peak ADR in the case.

[32] Targeted dispatch is limited to 8 calls per summer, Daily dispatch is 60 calls per summer. Details at: https://www.capelightcompact.org/business/commercial-connectedsolutions/

[33] At the time of this study, only 11 customers were enrolled the C&I energy storage program.

6.1.4 Load Analysis

The first step in the ADR potential analysis is to define the standard peak day (24-hour) load curve using historical CLC and ISO-NE hourly load data. The standard peak day load curve for the statewide electric system is defined by taking an average of the load shape from the top ten peak days in each of the five years of historical hourly load data provided.

The load curve analysis for ISO-NE reveals that the top 10–40 peak demand hours are within the window of 3 p.m. to 7 p.m. during high demand days in the months of June, July, August, and September[34]. For the established standard peak day based on historical load curve, the peak hour for CLC is deemed to occur near the end of the ISO-NE peak, between 6 p.m. and 7 p.m. The standard peak day load curve and the defined peak window (3 p.m. to 7 p.m.) are then used to characterize measures and assess the measure-specific peak demand reduction potentials at the technical and economic levels. Achievable peak demand reduction potentials are further verified against ISO-NE annual historical hourly load data to assess measure deployment constraints.

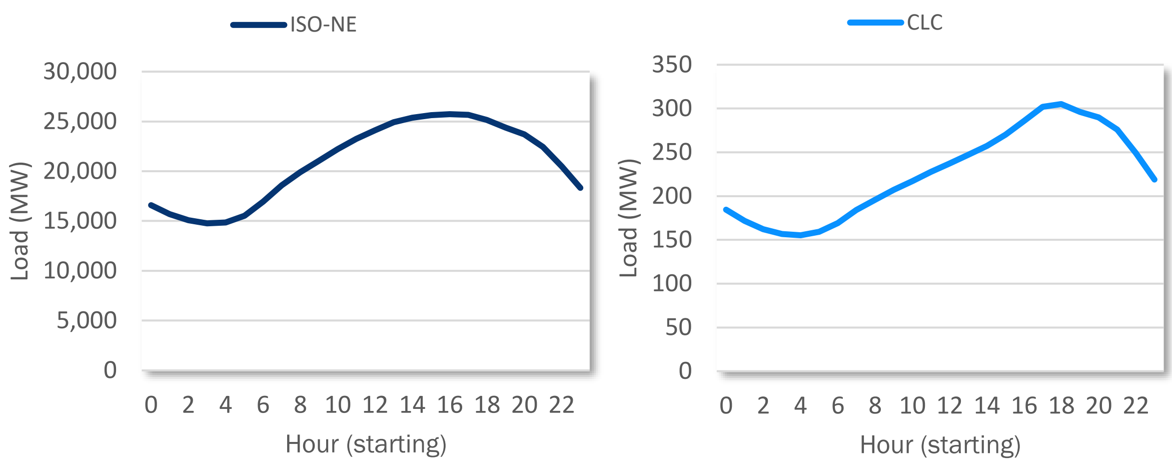
The standard peak is then forecasted in the future, considering efficiency measures and load growth forecasts from CLC's projections. Since this is a relatively short-term study, covering the years 2022–2024, the impact of load growth and efficiency programs on the peak day load curve is negligible. Further details about the standard peak day are available in Appendix E.

Figure 76 shows the resulting standard peak day load curves for the ISO-NE system, as well as CLC's territory. CLC peaks later than the ISO-NE load curve due to the higher share of residential demand. This reduces CLC's ability to coincide its demand reductions with the ISO-NE's peak.[35]

[34] The ISO-NE peak load hour in this study was derived from historical data and is between 4 p.m. and 5 p.m. (details in Appendix E). The peak hour in 2019 occurred between 5 p.m. and 6 p.m. Because ADR measures are characterized to reduce demand during the 3–7 p.m. ADR window, the shift in the timing of the ISO-NE peak from 4–5 p.m. to 5–6 p.m. would still be covered by the ADR potential analysis in this study.

[35] The peak load curve analysis reflects the impact of current solar capacity on the system but does not consider future solar adoption, which was outside the scope of the study.

Figure 76. Standard Peak Day Load for ISO-NE and CLC MA (Summer Season)



6.2 Results

The achievable potential results, by year and scenario, are presented below. These results represent the combined peak load reduction from all cost-effective programs assessed against the ISO-NE load curve, accounting for interactions among programs and ramp-up schedules for new measures and programs. A description of each measure and program along with the measure's technical and economic potentials in each market segment are provided in Appendix E.

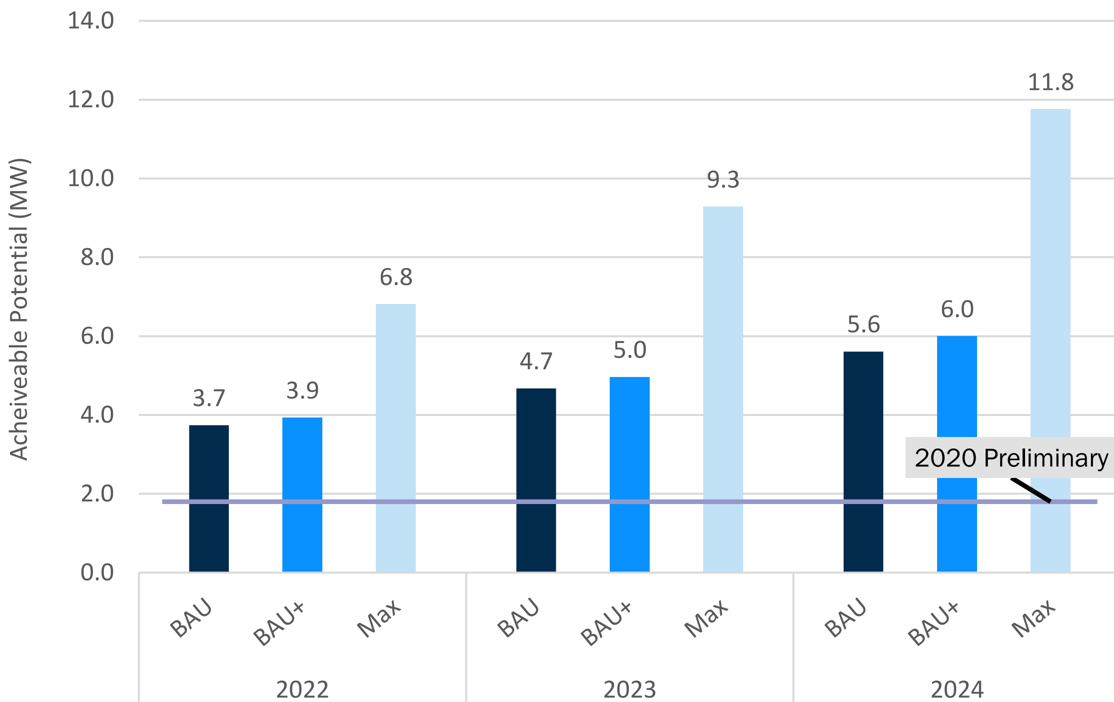
6.2.1 Achievable Potential

Under the BAU scenario—which is based on CLC's current programs[36] expanded to the full extent across applicable markets—the potential is estimated to grow from 3.7 MW in 2022 to 5.6 MW in 2024 (Figure 77), which represents approximately 1.8% of CLC's peak demand in 2024.

The BAU+ scenario applies increased incentive levels, while the Max scenario introduces new measures alongside the increased incentives from the BAU+ scenario. Both scenarios show an increase in achievable potential over the BAU levels, reaching 6 MW and 11.8 MW in 2024, respectively, representing 2.0% and 3.9% of CLC's systemwide peak demand. The scenario analysis indicates that expanding the range of ADR measures in the programs results in significantly more peak reduction potential than simply increasing incentives over CLC's current program offers.

[36] Based on the 2019 ADR programs.

Figure 77. Achievable Potential for Summer by Scenario and Year



Potential by Program

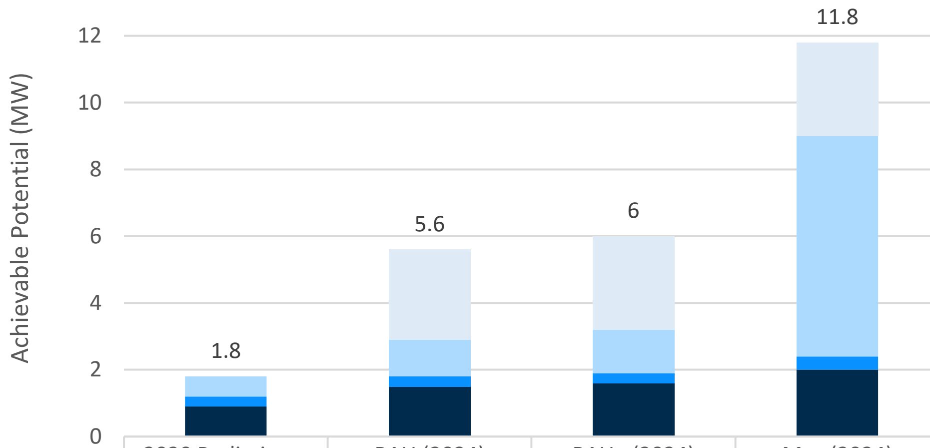
Figure 78 shows 2024 ADR achievable potential for the three scenarios, compared to 2020 preliminary results, by program. Program-level results show the following:

- In the **BAU scenario**, the ADR potential in CLC's service territory exceeds current reductions by approximately 3.8 MW by 2024. This is mainly driven by increased participation in the battery storage program in the residential sector, contributing an additional 2.7 MW of reduction. Central HVAC thermostats exhibit some growth due to the evolving market conditions for smart thermostats. C&I curtailment also exhibits some growth given that there is room left for expansion in the current market, as well as market growth.[37]
- The **BAU+ scenario** results in a 233% increase in achievable potential over current program impacts by 2024 but only a 7% increase over the BAU scenario. Some measures show modest growth, including C&I curtailment, Central HVAC BYOD, and Residential Battery Energy Storage. Overall, these results highlight that additional incentives do not significantly increase the potential under current program offerings. It should be noted, however, that modeling the effects of incentives on a small number of participants, particularly in the C&I sector, can carry with it a high level of uncertainty. For example, the addition or removal of one large commercial participant can significantly impact the overall load reduction potential.

[37] Expansion refers to possible opportunities within a given market and the market growth refers to the addition of new devices each year.

- The **Max scenario** offers an additional 10 MW of peak load reduction by 2024. Most of the gains come from the residential sector, where the potential is more than five times that of the BAU+ scenario.

Figure 78. Max Scenario Achievable Potential – Breakdown by Program



	2020 Preliminary	BAU (2024)	BAU+ (2024)	Max (2024)
Total	1.8	5.6	6	11.8
Connected Solutions - Home Batteries	0.0	2.7	2.8	2.8
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	0.6	1.1	1.3	6.6
Connected Solutions - C&I Energy Storage	0.3	0.3	0.3	0.4
Connected Solutions - C&I Curtailment	0.9	1.5	1.6	2.0

Potential by Measure

Table 25 provides the measure-level potentials for current ADR programs and new programs, modeled under the Max scenario. Measure-level results show the following:

- The **BAU scenario** shows an overall increase of 211% in demand reduction by 2024. This significant increase can be explained by the fact that many programs currently being rolled out are not captured under the 2020 preliminary results. Specifically, most of the growth in demand reduction can be attributed to residential battery energy storage, which is slated to begin in 2021. A major driver for this potential is CLC's higher market penetration of residential batteries and solar relatively to the average in MA (3 times and 2 times, respectively). This highlights the opportunity for batteries to produce significant demand reductions in the future.

  For Central HVAC BYOD measures, the program is already well-developed, capturing most of the current potential. The modest growth in this program is expected to be driven by the growing penetration of smart thermostats. The analysis suggests that the current Central HVAC BYOD program is well positioned to capture the remaining market.

- The top measures under the **BAU+ scenario** are consistent with the order observed in the BAU scenario. However, most measures show a higher potential due to increased participation resulting from the higher customer incentives.

- In the **Max scenario**, the added programs and measures generate a significant amount of additional potential, mostly concentrated in a few specific measures. Most notably, the residential Central HVAC direct load control (DLC) program applies direct-install approaches to add Smart Thermostats to air-conditioners (including heat pumps) in homes that are not expected to adopt connected thermostats for their own comfort and energy savings benefits. By overcoming this barrier, the Central HVAC BYOD measure can unlock 4 MW of additional potential. Other new measures such as residential pool pump controls also contribute significantly to the overall potential in the residential sector. The C&I sector also shows some growth in potential with the modest increase (25% relative to BAU+) coming mainly from auto-DR equipment installations.[38]

Table 25. Achievable Scenarios – Top Measures

Measures	2020 Preliminary (MW)	BAU 2024 (MW)	BAU+ 2024 (MW)	Max 2024 (MW)
Large Commercial Curtailment	0.9	1.2	1.3	1.3
Medium Commercial Curtailment		0.3	0.3	0.3
Central HVAC BYOD / DLC	0.6	0.7	0.7	4.6
Battery Energy Storage - Targeted	0.3	0.3	0.3	0.3
Residential Battery Energy Storage	-	2.6	2.7	2.7
Pool Pumps	-	-	-	0.7
Electric Vehicle Service Equipment (EVSE)	-	0.4	0.4	0.4
Behavioral	-	-	-	0.4
Smart Dehumidifier	-	-	-	0.3
Smart Clothes Dryer	-	-	-	0.2
All Other Measures[a]	-	0.1	0.2	0.7
Total	**1.8**	**5.6**	**6.0**	**11.8**

[a] Detailed breakdown available in Appendix F.

6.2.2 Residential Fuel Savings

Figure 79 provides the program costs for each scenario, by upfront costs and annual costs (both for summer and winter participation). Upfront costs include set-up costs for new programs, first-year enrollment incentives for new participants, and equipment purchase costs and incentives. Annual costs cover annual administration and customer participation or performance incentives.

[38] Auto-DR can include both a retrofit to existing Energy Management Systems (EMS), enabling utilities to control the customer's load directly; or it could also be an installation of a compatible EMS.

Figure 79. ADR Program Costs

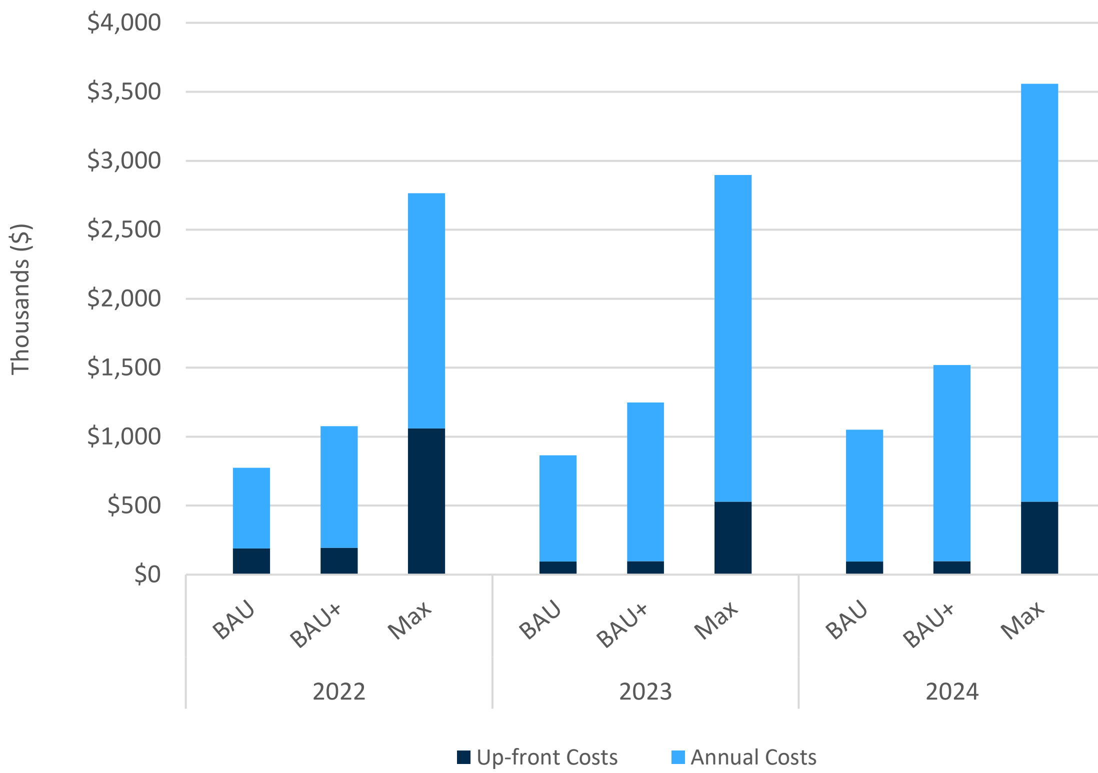


Table 26 provides the cost-effectiveness test results for each program and scenario, accounting for the costs and benefits for both existing and newly added ADR program capacity in each year.

Notable observations are:

- **The BAU scenario is the most cost-effective scenario** driven mainly by the low-cost large commercial curtailment measures.
- **The additional potential under the BAU+ incentive levels, comes at a slightly reduced overall cost-effectiveness compared to BAU.** This is due to increased incentives, which encourage more participation, but raise the cost of all peak savings reductions achieved.
- **The Max scenario has a similar cost-effectiveness to BAU+, but it includes upfront costs that can help support peak savings for years after the study period.** The equipment costs associated with the direct install measures, as well as new program set-up and enrollment costs, require a notable investment over the study period, which lowers the overall cost-effectiveness. However, the cost-effectiveness of this scenario would be expected to rise after the study period as the portion of set-up costs decreases. Additionally, the Max scenario benefits from sharing fixed costs across a larger set of participants.

Table 26. TRC Results by Program and Scenario in 2024

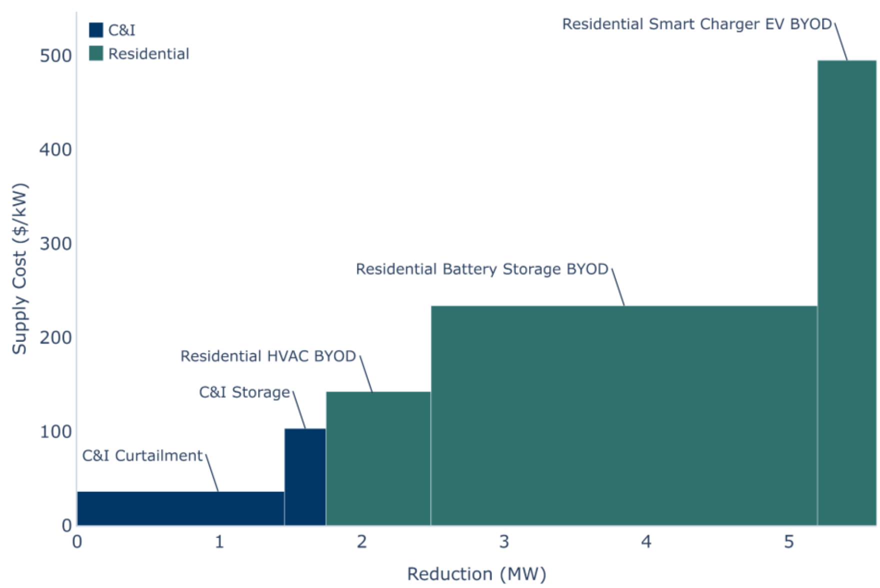
Scenario	BAU	BAU+	Max
Connected Solutions - Smart Homes (e.g., Smart Thermostat, EV Chargers, etc.)	0.8	0.8	1.1
Connected Solutions - Home Batteries	1.4	1.2	1.1
Connected Solutions - C&I Curtailment	1.6	1.5	1.1
Connected Solutions - C&I Energy Storage	0.2	0.4	0.7
Total	**1.3**	**1.1**	**1.1**

The overall TRC decreases under the BAU+ scenario with the introduction of higher incentives; however, the TRC for Residential DLC increases under the Max scenario despite the additional cost of direct install measures. This can be explained by the introduction of new, highly cost-effective residential measures in the Connection Solutions-Smart Homes category, such as pool pumps and the direct installation of smart thermostats. Under BAU+, the TRC decreases across all programs save C&I Energy Storage, mainly due as the higher incentives and modest benefits increase.

Measure Level Costs

Figure 80 shows the BAU scenario's supply cost curve which highlights the costs for realizing an increment of demand reduction (y-axis) and the cumulative achievable potential in 2024 (x-axis). Measures are bundled into categories based on sectors and technologies. Measure costs are normalized to a nine-year program life, accounting for enrollment and equipment costs, participant attrition and re-enrollment costs, and annual incentives.

Figure 80. Supply Curve – BAU Scenario



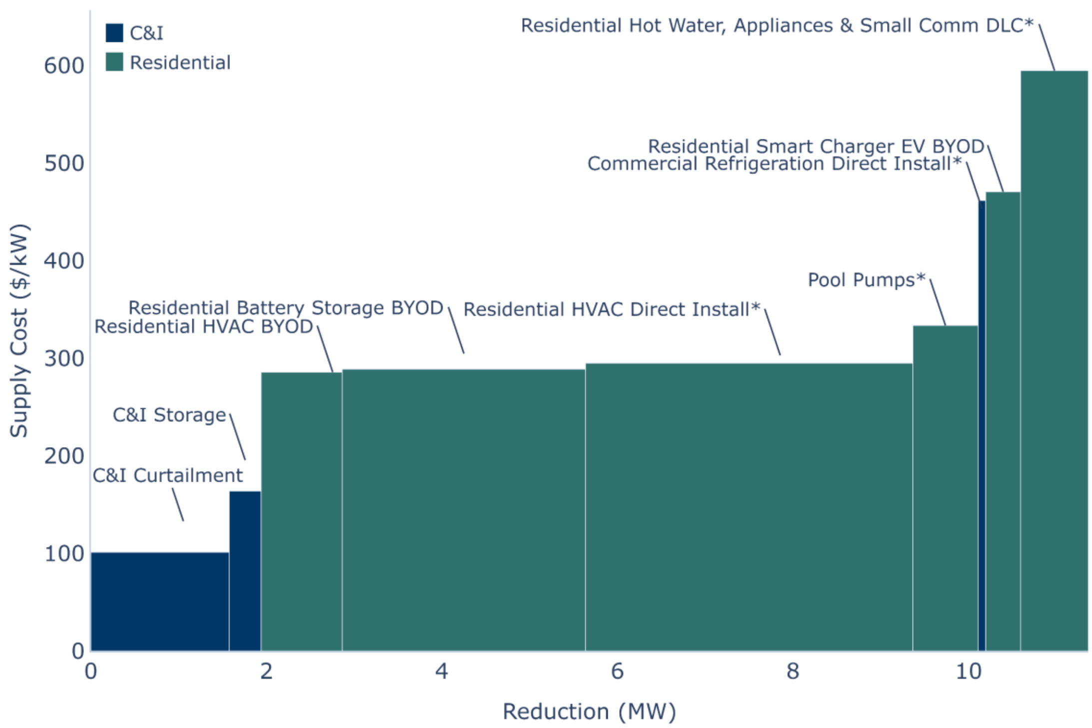
C&I Curtailment has the lowest supply cost at around $35/kW and makes up the majority of the C&I potential with 1.6 MW in 2024. C&I Storage has the second lowest cost at $105/kW, with around 0.3 MW of potential. This is due to a high participation in the Targeted dispatched measure, which was based on current enrollment. Supply costs could increase, however, if more participants join the Daily dispatch measure, which offers more generous incentives. This could bring the cost of C&I Storage above Residential HVAC BYOD ($140/kW), close to $200/kW.

As discussed before, Residential Battery Storage offers the largest potential, due to their high saturation in CLC's territory, at a cost of approximately $230/kW. Residential EV Smart Chargers have a significantly higher cost ($495/kW) due to the high incentives and relatively low benefits associated with this measure. EV charging loads primarily occur in the evening and are not expected to be coincident with the peak hour. If non-peak hour benefits, such as energy arbitrage, were accounted for, then EV smart chargers may offer improved cost-effectiveness.

Overall, the weighted average of the supply cost for the BAU scenario is around $185/kW. A detailed breakdown of the cost per measure is available in Appendix F.

Figure 81 shows the BAU+ and Max scenario's supply curve. Because BAU+ and Max apply the same incentive levels, the measure cost per kW of peak savings reduction is identical in the two scenarios. However, some measures are only applied in Max scenario's expanded programs. The new measures added under the Max scenario are grouped separately in the supply curve below and are indicated with an asterisk.

Figure 81. Supply Curve – BAU+ and Max (*) Scenarios



While C&I Curtailment BYOD remains the lowest cost category at around $100/kW, the cost for this measure in the BAU+ and Max scenarios is four times higher than under the BAU scenario, while only delivering a 0.1 MW increase in potential.

The Max scenario introduces new C&I measures, of these Curtailment Direct Install and Emergency Generation Direct Install offers no notable potential and therefore are not shown in the graph. C&I Storage on the other hand shows growth (+25%), but still only contributes 0.4 MW of the total potential. As noted earlier, the effectiveness of the C&I Battery storage under the BAU+ scenario's higher incentive levels is driven by its ability to encourage customers to purchase batteries to participate in the program.

Overall, the average supply cost for the BAU+ and Max scenarios are approximately $250/kW and $300/kW, respectively. Max scenario costs are driven by the cost associated with cost-effective measures, mainly in residential HVAC direct install measure. A detailed breakdown per measure is available in Appendix F.

6.3 Key Takeaways

Based on the results of this analysis, the achievable peak load reduction from ADR programs is projected to reach 5.6 MW under BAU and 11.8 MW under Max in 2024, representing up to 3.9% CLC's projected system-wide peak load in that year. Of this potential, 1.8 MW is currently being captured by CLC's ADR program enrollment to date, which indicates that up to 10 MW of additional potential could be achieved by expanding the range of ADR measures and increasing incentives.

The BAU scenario potential is estimated to grow from 1.8 MW in 2022 to 5.6 MW in 2024, which represents 1.8% of CLC's peak demand in 2024. This scenario focuses on CLC's current programs[39] and uses the DROP model's propensity curves to determine the maximum equilibrium participation that the program could achieve through ongoing marketing and outreach without altering incentives or measures offered. Program spending under this scenario is projected to range between $0.8 million to $1.1 million per year.

The BAU+ scenario assesses the impact of increasing incentives over the BAU scenario, and results in 6.0 MW of achievable potential in 2024. By adding new measures, while maintaining the BAU+ incentive levels for currently offered ADR programs, the Max scenario shows a further increase to 11.8 MW of achievable potential by 2024.

Table 27 details the achievable potential for each of the assessed scenarios, as well as the average portfolio cost-effectiveness results and annual program spending.

Table 27. Active Demand Reduction Potential, by Scenario (by 2024)

Scenarios	BAU	BAU+	Max
Achievable Potential (MW)	5.6 MW	6.0 MW	11.8 MW
Average Portfolio TRC	1.3	1.1	1.1
Portfolio Annual Spending	$1.1 million	$1.5 million	$3.6 million
Average Supply Cost ($/kW)	185 $/kW	250 $/kW	300 $/kW

Table 28 benchmarks the achievable ADR potential from this study against results in other relevant, recently assessed, summer peaking jurisdictions. Overall, these results show that CLC's ADR potential is in the same range of neighboring jurisdictions. It is notable that the Rhode Island and National Grid (2018) potentials were both assessed under lower avoided costs per kW of peak load reduction. The expected increase in ADR from higher avoided costs are counter balanced by the specificities of CLC's customers, namely a lower occupancy during peak periods compared to other jurisdictions. ISO-NE peaks occur during the week, while CLC's peak generally occurs on the weekend when more seasonal homes are occupied, reducing the ADR potential compared to a jurisdiction with high occupancy during ISO peak.

39 Based on the 2020 ADR programs.

Table 28. Benchmarking of the Achievable Active Demand Potential (Mid-Max Scenarios) to Other Summer Peaking Jurisdictions

	CLC (MA) (2021)	Rhode Island (2020)	National Grid (MA) (2018)	Pennsylvania (2020)
Portion of Peak Load	1.8% – 3.9% (3 years up to 2024)	3.6% – 4.5% (6-year outlook)	2.1% – 2.5% (3-year outlook)	0.75% (6-year outlook)
Avoided Costs	≈$360 / kW	$200 / kW	$290 / kW	≈$40 / kW

Based on the findings in this study, three key takeaways emerge:

- CLC's current offerings (i.e., C&I curtailment and Smart Thermostats) are effective at capturing a significant portion of the ADR potential associated with those measures; however, there remains room for further growth. The current ADR measures are capturing a large share of their existing potential (e.g., above 80% of the 2024 BAU C&I Curtailment).
- An increase in incentives (BAU+) results in a modest increase in potential. However, CLC's high peak demand avoided costs can support an expanded pool of ADR measures alongside new and increased incentives, which could increase impacts by about three folds (under the Max scenario) in 2024 in a cost-effective manner.
- **The current focus on BYOD approaches for residential HVAC measures appears to limit the program's potential.** Because residential cooling is a key driver of the ISO-NE annual peak, connected thermostats that control AC units can play an important role in curtailing the peak demand. The study shows that offering connected thermostats to customers who would not adopt these on their own could help unlock significant potential. Broadly speaking, two approaches can help improve adoption of connected thermostats and thereby expanded ADR program participation:
  - Offering smart thermostat via a Direct Install program could help overcome some market barriers to thermostat adoption and ADR program participation. Although this unlocks the potential quickly, it does carry notable upfront cost, and there is some uncertainty as to the how long customers will remain with the program if they are not required to sign a multi-year participation contract.
  - Further thermostat adoption can also be encouraged by integrating marketing and incentive offers between ADR and efficiency programs. This approach may lead to a slower penetration rate, but it would likely be more cost-effective overall.
- **Battery storage offers a large swath of cost-effective ADR potential.** The analysis indicates that there is significant room to grow these programs, particularly in the Residential sector. Compared to the rest of Massachusetts, CLC has three times more batteries per residential customer. Leveraging these batteries can lead to important ADR savings. This trend is expected to gain further momentum beyond the study period, in both the residential and C&I sectors, as battery costs continue to decrease each year.

Overall, these finding indicate that offering new measures and adding and increasing incentives can play an important role in growing ADR potential in CLC's service territory.

7. Combined System Impacts and Results

To understand the overall effect of CLC's full range of DSM programs, this section presents their combined impacts on energy consumption and electric peak demand (based on the estimates in the preceding chapters). We first present the 2024 cumulative impacts on energy consumption and electric peak demand to provide a sense of each saving stream's contribution. We then compare net source MMBtu equivalent lifetime program savings from EE and HE to understand the system-level energy impacts of HE relative to traditional efficiency opportunities. Finally, we present the combined costs and benefits of each savings stream.

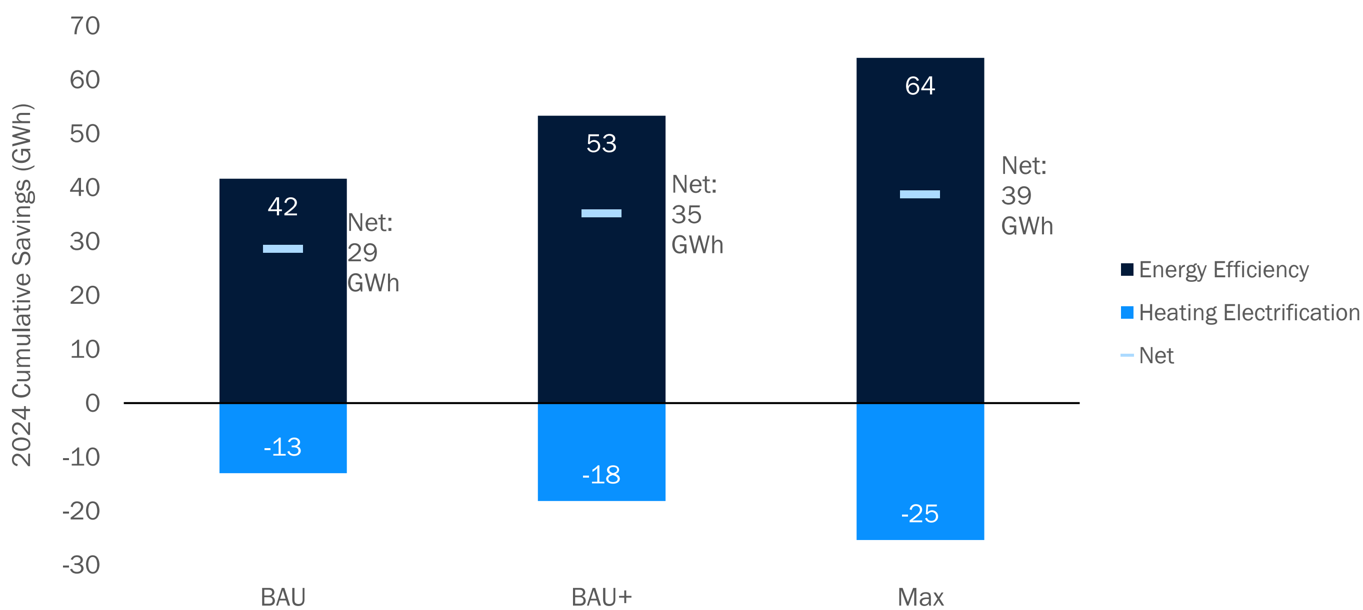
7.1 Combined Impacts in 2024

The EE, ADR, and HE savings opportunity potentials assessed over the study period (2022-2024) will have cumulative effects on the energy consumption and electric peak demand impacts of CLC's customer base. The following results combine the 2024 cumulative impacts of CLC's EE, DR, and HE programs over the study period under each achievable scenario to provide a sense of each saving stream's contribution to these overall impacts.

7.1.1 Electricity Consumption

Figure 82 shows cumulative electric energy savings in 2024 from EE and HE measures. For HE measures, impacts are expressed as negative savings values since these measure result in increased electricity consumption.

Figure 82. 2024 Cumulative Electric Energy Savings (EE and HE)

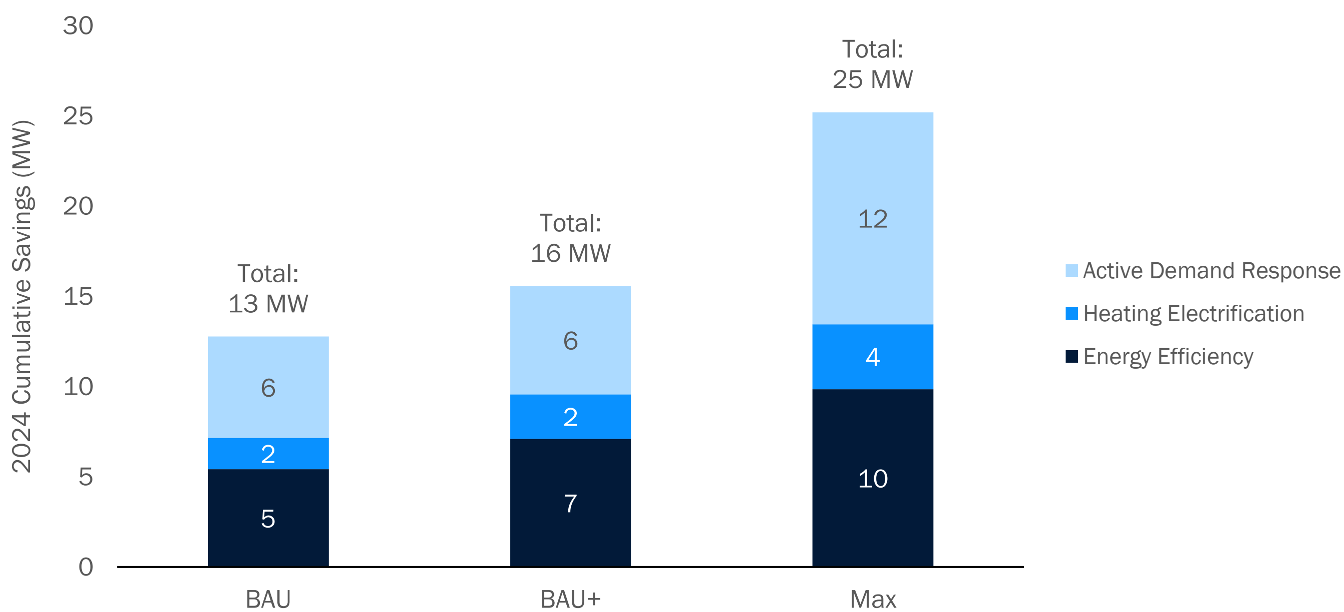


As can be seen, the cumulative impact of EE savings is expected to outpace the increase in electricity consumption resulting from heating electrification measures under all scenarios although heating electrification will increase electricity consumption for some customers. Under each scenario, the added electricity consumption resulting from HE measure adoption is approximately 30% to 40% of the savings expected from EE measures.

7.1.2 Electric Peak Demand

All three savings streams (EE, ADR, and HE) will contribute to reduction in the system-wide electric peak demand. As shown in Figure 83, EE and ADR measures provide the vast majority of peak demand savings across all scenarios, with similar proportions of the total potential. Under each scenario, ADR measures represent between 39% to 47% of cumulative peak demand reductions in 2024—despite ADR programs being relatively new within CLC's portfolio.

Figure 83. 2024 Cumulative Electric Peak Demand Savings (EE, ADR, and HE)

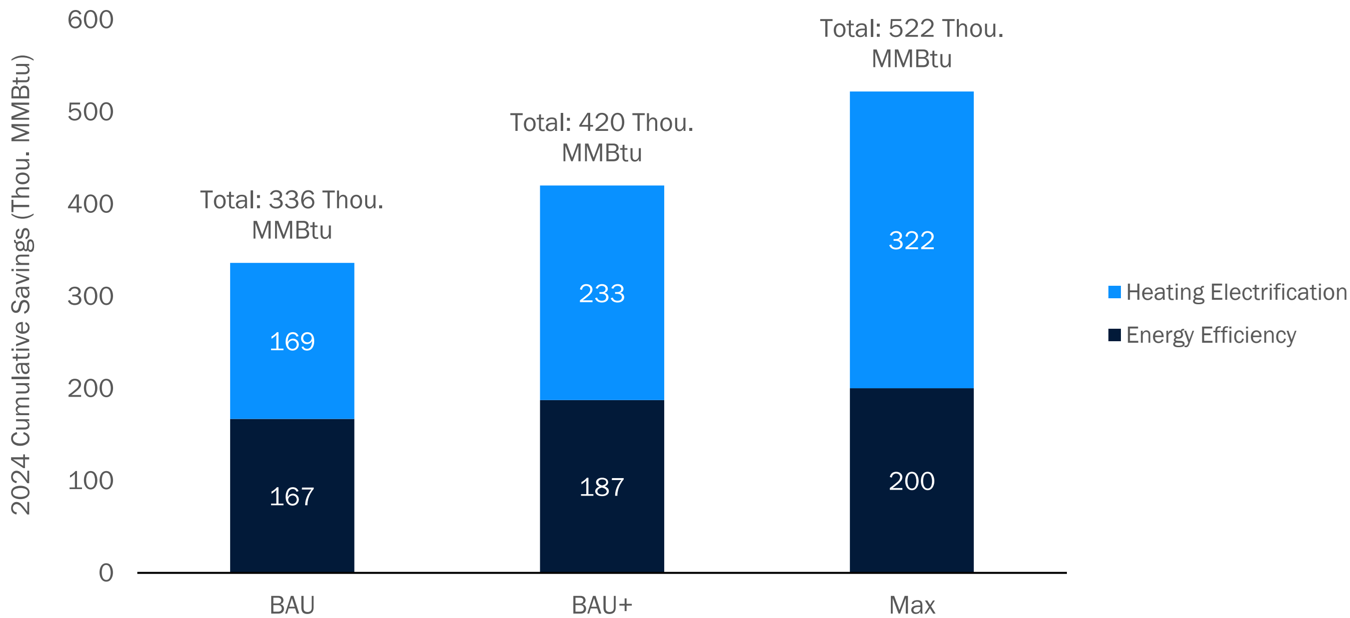


This trend reflects the growing importance of ADR measures in terms of managing peak electricity demand. In the past, EE measures have been the main contributor to peak reduction through passive electric demand savings. However, as ADR programs continue to expand and electric savings become harder to capture with the loss of lighting opportunities, ADR measures will take a more prominent role.

7.1.3 Delivered Fuel

Figure 84 shows cumulative delivered fuel savings in 2024 from EE and HE measures.

Figure 84. 2024 Cumulative Delivered Fuel Savings (EE and HE)



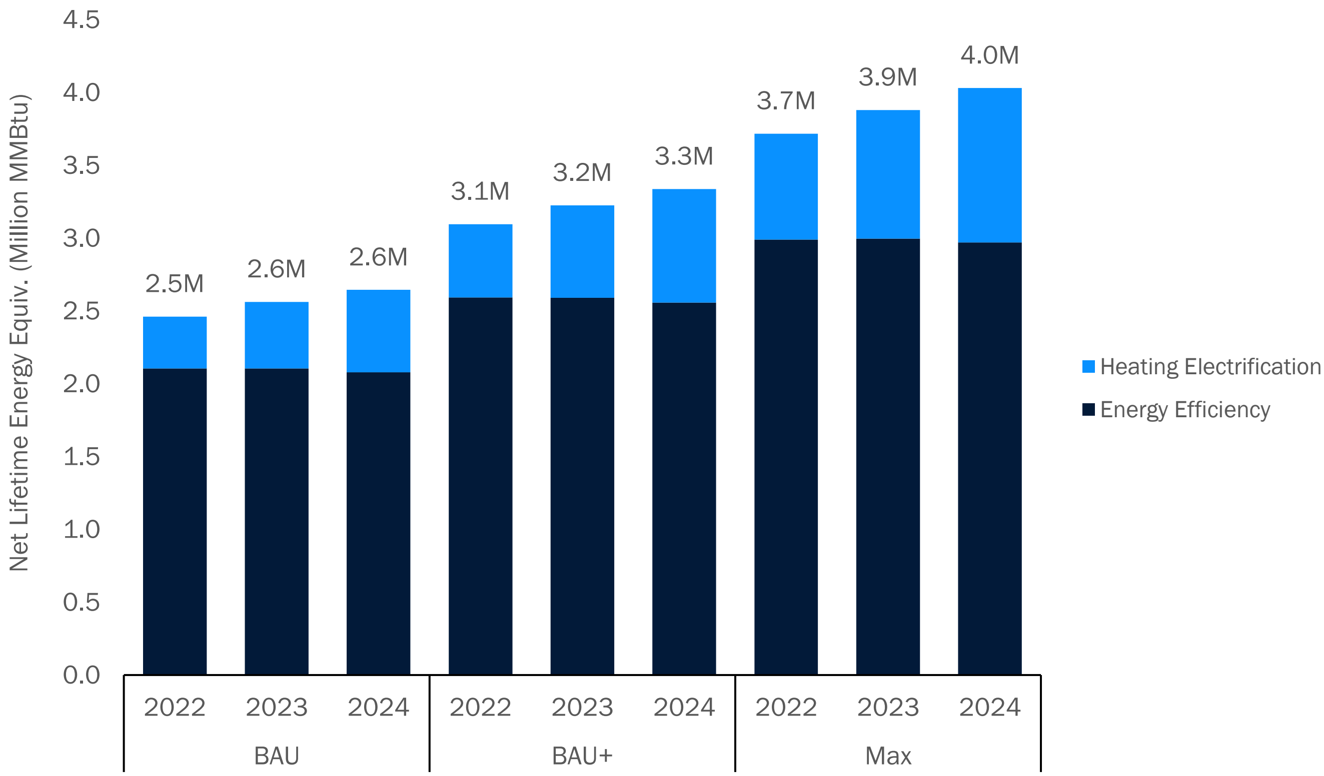
HE measures will contribute the majority of delivered fuel savings under all scenarios. Under the BAU scenario, HE measures contribute 50% of overall delivered fuel savings. This proportion increases under the higher incentive levels up to 62% of overall delivered fuel savings under the Max scenario.

7.2 Net Source MMBtu Lifetime Program Savings

Figure 85 shows net source MMBtu lifetime program savings for EE and HE measures, by year, for each scenario.[40]

[40] Net source MMBtu lifetime program savings account for the increase in electric consumption resulting from HE measures and convert site electricity savings (in kWh) to source fuel savings (in MMBtu) based on the heat rate of the average generation mix of the ISO New England region. HE savings are net of the increased electric consumption resulting from electrifying space and water heating end-uses. Site-to-source factors are sourced from the MA MMBtu Factors Study as cited in the 2019 PYR BCR Excel workbook.

Figure 85. Net Source MMBtu Lifetime Program Savings by Year (EE and HE)

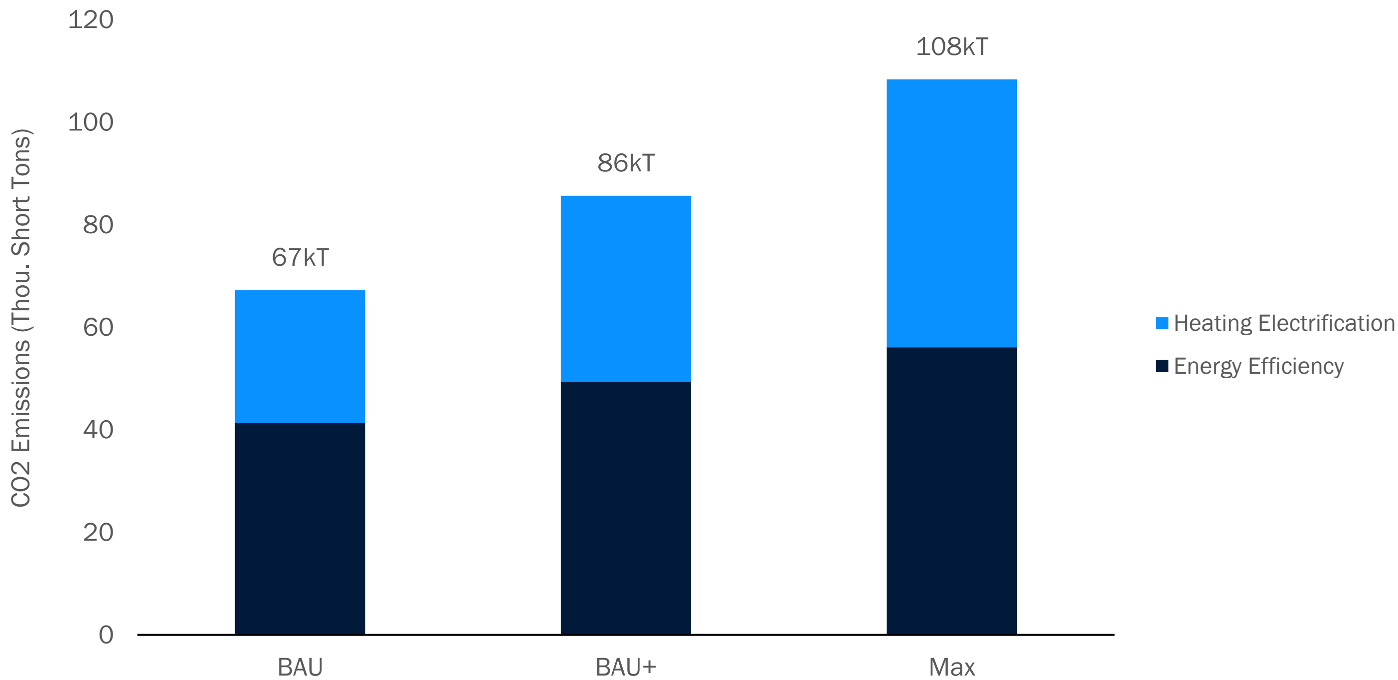


When viewed in equivalent energy units that account for the heat rate of power generators and after accounting for the impacts of increased electricity consumption from HE measures, the majority of energy savings come from EE measures. The relative proportion of savings are similar under each scenario with EE measures accounting for approximately 75 to 85% of net MMBtu equivalent lifetime savings. In 2022, HE measures represent 14% to 20% of savings; this share increases to approximately 21% to 26% of savings in 2024.

The low proportion of savings from HE measures is expected for multiple reasons. First, HE measures target only a subset of energy end-use (space and water heating) while EE measures target the full range of building-level energy end-uses. Second, while HE measures reduce fuel consumption, they result in additional electricity consumption. With New England's current generation mix, the marginal generator is generally a natural gas-fired power plant, which consumes fuel to produce electricity. Accounting for this energy consumption from HE measures reduces their net energy savings. Finally, HE measures are still expanding as heat pumps become a more accepted technology among customers and installers and programs continue to improve their outreach. As these measures increase in adoption, they will be expected to provide a greater share of energy savings.

In terms of emission reductions, CLC's EE and HE programs have the potential to reduce CO_2 emissions by over 100 kilotons (kT) of carbon dioxide by the end of the study period, as shown in Figure 86. While not quantified in this study, ADR measures could contribute to further emissions reductions by shifting electric consumption from periods with higher marginal emission rates to periods with lower emission rates.

Figure 86. Cumulative Annual Emission Reductions (EE and HE)



Emission reductions are split fairly evenly between EE and HE measures, with EE providing the slight majority of savings in all scenarios (62% in BAU, 52% in Max). The ability of HE measures to reduce emissions from the consumption of heating fuels is tempered by the increase in electricity consumption, which increases emissions from this energy source. As the electric grid continues to decarbonize (as is expected in New England), the emission benefits of heating electrification will increase—including for heating electrification measures installed during the study period as these heat pump systems will last far beyond the end of the study period.

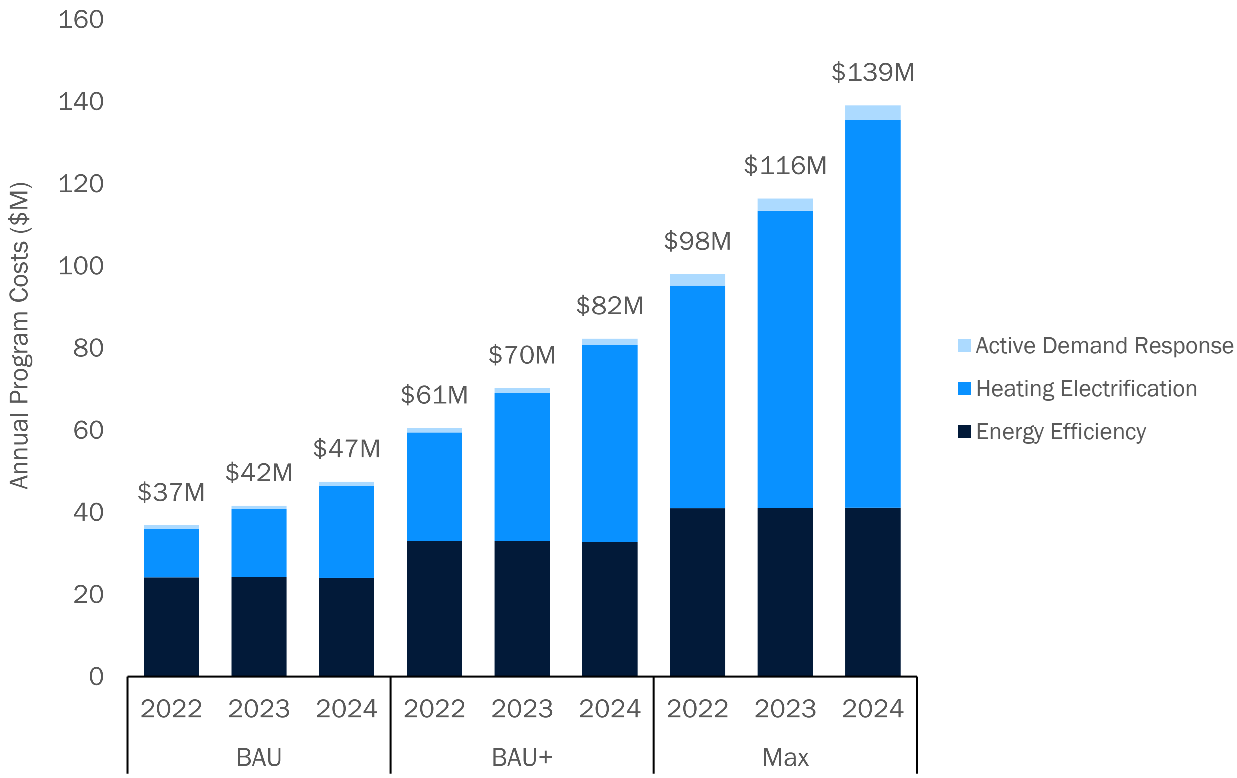
7.3 Portfolio Metrics

The following section presents combined estimates of portfolio metrics including overall program costs and program benefits.

7.3.1 Program Costs

Figure 87 shows the combined annual estimated program costs for all EE, HE, and ADR programs modeled in this study.

Figure 87. Combined Annual Program Costs (EE, HE, and ADR)



EE programs account for the majority of costs under the BAU scenario, even though costs are significantly reduced (compared to 2019 results and the 2021 plan) due to the reduction in lighting measures moving through programs. Under the BAU+ and Max scenarios, HE costs grow significantly more than EE.

Annual costs increase year-over-year under each scenario primarily due to cost increases in HE and ADR programs as these programs continue to ramp up. Under the BAU scenario, HE and ADR programs represent approximately 34% of the combined costs in 2024, increasing to 49% in 2024.

In terms of program costs per net unit of energy saved, EE savings opportunities are generally less costly than HE. As shown in Table 29, the program cost per lifetime and first-year net source MMBtu saved is lower than HE for existing efficiency programs in all cases other than BAU on a dollar per lifetime saving basis.

For all measures, the unit cost of savings increases under the BAU+ and Max scenarios as incentive levels are increased. This increase in particularly pronounced for HE measures where the cost more than doubles between the BAU and Max scenarios.

Table 29. Program Cost per Lifetime and First-Year Source MMBtu Program Savings (2022-24 Average)

	$ per source MMBtu Lifetime Savings			$ per source MMBtu First-Year Savings		
	BAU	BAU+	Max	BAU	BAU+	Max
Energy Efficiency	$11.51	$12.77	$13.75	$138	$158	$173
Heating Electrification	$9.96	$15.39	$20.25	$161	$249	$339

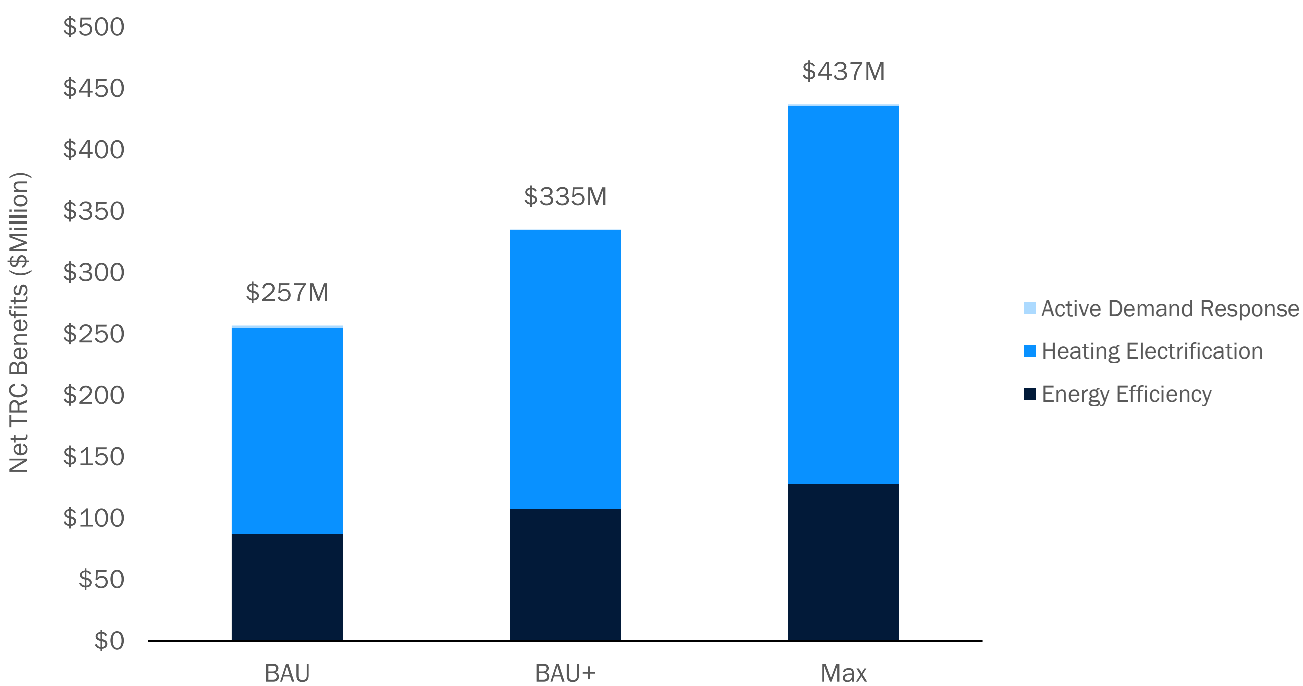
7.3.2 Program Benefits

Together, CLC's EE, HE, and ADR programs have the potential to create significant benefits as measured by the TRC.

Figure 88 shows the total net TRC benefits for each savings stream. Under each scenario, CLC's EE, HE, and ADR programs will generate hundreds of millions of dollars of net benefits over the study period with up to $437 million in net benefits captured under the Max scenario.

The majority of these benefits are a result of HE measures representing over 65% of net TRC benefits under each scenario. EE measures also create significant benefits: under BAU, these measures generate over $87M in benefits increasing to nearly $130M under the Max scenario. ADR programs provide a very small component of the overall TRC benefits ($1-2M), aligning with their small contribution to overall program costs.

Figure 88. Total 2022-2024 Net TRC Benefits (EE, HE, and ADR)



7.3.3 Key Takeaways

Based on the combined EE, HE and ADR achievable potential results presented in this chapter, the following key takeaways emerge:

- **The combined impact of EE, HE, and ADR measures will drive significant savings and benefits for CLC's customers.** As measured by the TRC test, the measures incentivized through CLC's EE, HE, and ADR programs during the study period have the potential to create hundreds of millions of dollars' worth of net benefits for CLC's customers. In addition to these benefits, CLC's programs can reduce CO_2 emissions by an additional hundred thousand tons over the study period—contributing to Massachusetts's climate goals.
- **The importance of heating electrification is growing.** Heating electrification is projected to form the majority of net TRC benefits and total delivered fuel savings. Despite being a relatively new component to CLC's programs, the potential for heating electrification is significant in the 2022-24 period.
- **Increasing incentives drives greater savings, but at notably higher costs.** For each study component, increasing incentives boosts savings captured by CLC's programs but increases costs at a faster rate. While raising incentives can lead to increased program participation, particularly in the short-term, opportunities may exist to leverage program enhancements that further reduce market barriers for efficient technologies over the long-term. While these strategies take time to implement and can have uncertain impacts, they could offer a lower cost opportunity to drive higher savings, where successful, compared to simply increasing incentives. CLC and the state of Massachusetts as a whole have consistently achieved success reducing market barriers as shown by the state's consistent top rank ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near complete transformation of the Massachusetts lighting market. Moreover, the recently enacted climate bill ("An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy") may provide a framework to drive savings through statewide policies that can work in conjunction with CLC's programs to help transform the market for other technologies.

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Cape Light Compact 2022-2024 Potential Study

Volume II: Appendices

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Subcontractor(s)

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Appendix A. Baseline Market Characterization

Residential and Low Income Market Metrics

To develop the Residential, Multi-family, and Low Income market metrics,[1] Opinion Dynamics and Dunsky Energy Consulting ("the Potential Study Team") reviewed multiple sources of data and selected, in consultation with the Cape Light Compact ("the Compact" or "CLC"), the best source for each metric. We relied on the following sources:

- 2019 Massachusetts Residential Baseline Study
- Baseline data collected as part of Opinion Dynamics' 2014 Cape Light Compact Potential Study
- Other Sources
  - 2017 American Community Survey Public Use Microdata (ACS PUMs) for Barnstable and Dukes counties
  - 2020 Cape Light Compact Customer Data

In general, we prioritized recent, Compact-specific data from the 2019 Massachusetts Residential Baseline Study. Where the 2019 Massachusetts Residential Baseline Study did not have enough sample points to develop rigorous Compact-specific estimates (e.g., for equipment characteristics), we relied on either statewide estimates from that study or on the 2014 Cape Light Compact Potential Study.

The following sections include a short description of the data sources utilized and the data leveraged for this study.

2019 Massachusetts Residential Baseline Study

The 2019 Massachusetts Residential Baseline Study (led by Guidehouse) is a continuation of a study initiated in 2016. The 2019 phase included a follow-up survey with prior respondents and a new survey to replenish lost sample. The 2019 follow-up survey achieved 3,985 completes, 1,145 of which provided detailed additional information on new equipment analogous to what would have been collected in an onsite visit. The replenishing survey targeted subpopulations that were underrepresented by the follow-up survey respondents. This survey achieved 2,528 completes with a response rate of 6.3%. In all, the 2019 study included 275 responses from customers in the Compact's service territory (225 Single Family, 42 Low Income, and 8 Multi-family).

This study was the primary source for penetration and saturation metrics. We analyzed the survey data and recalculated penetration and saturation rates, replicating Guidehouse's approach of applying weights and onsite adjustment factors, but using Compact-specific weights (rather than statewide weights) that better reflect education levels and building types of residents in the Compact's service territory.[2]

Since some model inputs benefit from additional granularity, we first developed penetration and saturation values—separately for the residential and the low income sectors—for the three building types defined by the Guidehouse study: single family attached, single family detached, and multi-family. We

[1] We calculated 134 select penetration, saturation, and equipment characteristics to support potential modeling in all end-uses except lighting. Through the PA coordination process all lighting metrics were defined at a statewide level and calculated for all MA PAs by a third-party vendor.

[2] To develop Compact-specific weights, we estimated the percentage of CLC households by education level (college degree vs. no college degree) and building type (single family attached, single family detached, and multi-family) based on 2017 ACS PUMs data.

calculated sector-level results as the weighted average of the building type-level results, based on the proportion of each building type in the Compact's service territory (developed from the ACS PUMs data). For the Multi-family segment, where the data lacked sufficient Compact-specific sample sizes, we either relied on statewide results, Single Family results, or triangulated results considering all available data, including results from the 2014 Cape Light Compact Potential Study.

2014 Cape Light Compact Potential Study

The primary data collection activities for the 2014 Cape Light Compact Potential Study included a mail survey with 2,785 residential customers and on-site visits at 169 homes within the Compact's service territory. The mail survey gathered high-level penetration information on electricity-using equipment and information on barriers to energy efficiency and participation in the Compact's programs. On-site visits collected detailed information on homes and energy-using equipment. The 2014 Potential Study report[3] contains a detailed description of the methodology and results of the primary data collection activities for the residential and low income sectors.

Due to the large sample size and scope of the study, this data continues to be the most robust source for detailed, Compact-specific characteristics, which could not be developed from the 2019 Massachusetts Residential Baseline Study due to a lack of responses. We also relied on this data for a few specific penetrations and saturation metrics not covered in the 2019 Massachusetts Residential Baseline Study. Finally, although six years old, the data also provides a useful check on penetrations and saturations we developed from more recent sources.

Other Sources

We relied on the 2020 Cape Light Compact Customer Data, received from the Compact in support of this study, to define the number of electric customers, the number of gas customers, and the average electric consumption per customer. The ACS PUMs data was used to estimate other detailed home characteristics and to develop the analysis weights discussed above.

C&I Baseline Market Metrics

To develop the C&I governing metrics,[4] we reviewed multiple sources of data and selected, in consultation with the Compact, the best source for each metric. We relied on the following sources:

- Baseline data collected as part of Opinion Dynamics' 2014 Cape Light Compact Potential Study
- 2020 Cape Light Compact Customer Data
- The National Commercial Building Energy Consumption Survey (CBECS)

Other data sources considered, but ultimately not used, included the following:

- The 2020 update of the DNV GL Statewide Commercial Baseline Study
- The 2017/2018 C&I Customer Profile

In general, we found that older, but Compact-specific estimates (i.e., those available from the 2014 Potential Study) better represent the Compact's unique customer base than more recent, but statewide

[3] Cape Light Compact 2014 Penetration, Potential and Program Opportunity Study, available online at: https://www.capelightcompact.org/potentialstudy/

[4] Governing metrics include square footage distributions, heating and water heating fuel penetrations, customer counts and average usage by fuel type (including delivered fuels), usage distributions, lighting saturations, and others. Through the PA coordination process all lighting metrics were defined at a statewide level and calculated for all MA PAs by a third-party vendor.

estimates[5]—particularly for metrics such as building square footage and space and water heating fuel penetrations, which are not expected to vary significantly over a few years. Where older data was used, however, we calibrated those values against current/more recent totals, thus ensuring that overall metrics such as total customer counts and total usage are correctly reflected in our study.

Table 1 summarizes the data sources used in the 2020 Potential Study and the governing metric groups they informed (indicated by ✓).

Table 1. Final Baseline Metric Characterization Sources

Source	Metric Group				
			Customer Counts and Average Usage		
	Square Footage	Fuel/End-use Penetrations	Electric	Natural Gas	Delivered Fuels
2014 Cape Light Compact Potential Study	✓	✓	✓	✓	✓
2020 Cape Light Compact Customer Data			✓	✓	
CBECS					✓

Key

Available	Partially Available	Not Available

The following sections include a short description of the data sources utilized and the data leveraged for this study.

2014 Cape Light Compact Potential Study

The primary data collection activities for the 2014 Cape Light Compact Potential Study included a telephone survey with 448 CLC C&I customers and on-site visits at 150 businesses within CLC's service territory. The telephone survey gathered high-level penetration information on electricity-using equipment and information on barriers to energy efficiency and participation in the Compact's programs. The 2014 Potential Study report[6] contains a detailed description of the methodology and results of the primary data collection activities for the C&I sector. Due to the large sample size of the study, this data continues to be the most robust source for market characteristics of the Compact's C&I population.

We relied on this data for square footage, electric usage distributions, and heating and water heating fuel penetrations. In addition, this data informed segment specific customer count and usage metrics (see Table 1).

2020 Cape Light Compact Customer Data

The 2020 Cape Light Compact Customer Data, received from the Compact in support of this study, contains two distinct datasets: (1) Detailed, customer-level data for all Cape Light Compact electric customers and (2) summary tables of all natural gas establishments in Cape Light Compact's service territory. The detailed electric dataset includes establishment IDs, business segments, annual usage,

[5] While the 2020 update of the DNV GL Statewide Commercial Baseline Study is recent and covers all key equipment penetrations, it only included 24 sample points in the Compact's service territory, insufficient for developing segment-level metrics. The C&I Customer Profiles are also relatively recent (2017 and 2018 data are available) and have some Compact-specific data, they do not use the same business segments as the 2020 Potential study (and many customers do not have a segment assignment at all). In addition, data are defined at the account or premise level, but not at the establishment level.

[6] Cape Light Compact 2014 Penetration, Potential and Program Opportunity Study, available online at: https://www.capelightcompact.org/potentialstudy/

peak demand, rate code, and square footage estimates for all Cape Light Compact customers.[7] The natural gas dataset includes only a summary of these customer counts, usage, and natural gas heating penetration by segment.

We relied on the 2020 Cape Light Compact Customer Data to define electric and gas customer metrics at the overall C&I level. We did not use the data to develop segment-level metrics because review of the top 100 establishments (by electric usage) showed a high degree of segment misclassification. To develop segment-level metrics, we applied the distribution of C&I segments from the 2014 Cape Light Compact Potential Study to the 2020 total C&I customer counts, essentially assuming no shifts in the distribution of customer counts by segment. The 2014 Cape Light Compact Potential Study involved extensive segmentation, supplemented by respondent self-reported verification through the baseline survey. We took a similar approach to calculate average electric usage per establishment.

Commercial Building Energy Consumption Survey

CBECS is a national sample survey that collects information on U.S. commercial buildings, including their energy-related building characteristics and energy usage. The study covers all sources of building energy consumptions, and therefore can provide insight into delivered fuel consumption, which are important metrics not covered by any other source.

We relied on CBECS to inform average usage of delivered fuels.

[7] Square footage information is only available for some establishments.

Appendix B. General Inputs, Assumptions, and Methods

Overview

This appendix describes the general inputs, assumptions, and methods common across all components of the 2022–2024 Cape Light Compact Potential Study.

Inputs, assumptions, and methods specific to the energy efficiency (EE), heating electrification (HE), and demand response (DR) components of the study are provided in Appendix C, Appendix D, and Appendix E, respectively.

Economic Cost-Effectiveness

Savings potential is assessed for economic cost-effectiveness using the Total Resource Cost (TRC) test that measures all benefits and costs associated with each measure and program. The TRC test considers the benefits and costs experienced by both the utility system and the program participant.[8] For this study, the quantified costs and benefits used for the TRC test include the avoided costs of energy supply, the incremental costs of distributed energy resources, program implementation costs, and non-energy benefits.

For avoided energy supply costs, the study applies the results of the *Avoided Energy Supply Components of New England: 2021 Report* ("2021 AESC Study")[9] and other avoided cost assumptions within the Compact's Benefit-Cost Ratio (BCR) model. The 2021 AESC Study produces "cost streams of marginal energy supply components that can be avoided in future years due to reductions in the use of electricity, natural gas, and other fuels as a result of program-based energy efficiency or other demand-side measures across all six New England states."[10] It includes estimates of the avoided costs of energy, capacity, natural gas, water, fuel oil, other fuels, other environmental costs, and demand reduction inducted price effects (DRIPE). For a complete description of how these costs are estimated and what is contained within them, please refer to the full 2021 AESC Study.

Table 2 lists the avoided cost components used in this study along with brief descriptions and sources.

Table 2. Avoided Cost Component Descriptions and Sources

Value	Description and Source
Electric energy ($/kWh)	The study uses the retail cost of electric energy for the Massachusetts zone from Appendix B of the AESC Study. It assumes a wholesale risk premium of 8.0% and electrical distribution loss factor of 8.0% consistent with the CLC BCR model. The electric energy avoided cost is broken down into winter on-peak, winter off-peak, summer on-peak, and summer off-peak components.
Electric energy DRIPE ($/kWh)	The study uses intrastate wholesale electric energy DRIPE values and wholesale cross-DRIPE values for the Massachusetts zone from Appendix B of the AESC Study. The wholesale risk premium and distribution loss factors are applied to the electric energy DRIPE values consistent with the CLC BCR model.
Electric environmental compliance cost ($/kWh)	The study uses the retail incremental Global Warming Solutions Act (GWSA) cost of compliance values from the avoided cost worksheet within the CLC BCR model for the avoided cost of electric environment compliance values. The electric environmental compliance cost

[8] National Energy Screening Project. *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources.* August 2020.
[9] Synapse Energy Economics, et al. *Avoided Energy Supply Components in New England: 2021 Report.* March 15, 2021.
[10] Ibid, page 1.

Value	Description and Source
	is broken down into winter on-peak, winter off-peak, summer on-peak, and summer off-peak components.
Capacity ($/kW)	The study uses the retail cost of electric capacity for the Massachusetts zone from Appendix B of the AESC Study. It assumes the same wholesale risk premium and distribution loss factor cited previously. It also assumes pooled transmission facility (PTF) losses of 1.6% for the uncleared resources. For energy efficiency measures, the study assumes the percent of capacity bid into the forward capacity market (FCM) is 85%, which is consistent with the CLC BCR model. For demand response measures, the study assumes 0% of resources are bid into the FCM.
Capacity DRIPE ($/kW)	The study uses the retail capacity DRIPE values for the Massachusetts zone from Appendix B of the AESC Study. It assumes the same wholesale risk premium, distribution loss factor, PTF losses, and percent capacity bid into the FCM as cited previously.
Reliability ($/kW)	The study uses the wholesale reliability 2021 values for the Massachusetts zone from Appendix B of the AESC Study. It assumes the same wholesale risk premium, distribution loss factor, and percent capacity bid into the FCM as cited previously.
Transmission & distribution ($/kW)	The study uses avoided transmission and distribution costs for the Massachusetts zones from Appendix B of the AESC Study and the CLC BCR model, respectively.
Natural gas ($/MMBtu)	The study uses the avoided cost of gas to retail customers for Southern New England (SNE) assuming some avoided retail margin from Appendix C of the AESC Study. The natural gas avoided cost is broken down into values that vary by sector and end-use.
Natural gas DRIPE ($/MMBtu)	The study uses gas supply DRIPE and gas cross-DRIPE avoided cost values for Massachusetts from Appendix C of the AESC Study.
Natural gas environmental compliance cost ($/MMBtu)	The study uses the retail incremental GWSA cost of compliance values from the avoided cost worksheet within the CLC BCR model for the avoided cost of natural gas environment compliance values.
Fuel oil ($/MMBtu)	The study uses the weighted average avoided costs of petroleum fuels from Table 130 of Appendix D of the AESC Study.
Fuel oil DRIPE ($/MMBtu)	The study uses the zone-on-zone diesel fuel DRIPE values for Massachusetts from Table 132 of Appendix D of the AESC Study.
Fuel oil environmental compliance cost ($/MMBtu)	The study uses the retail incremental GWSA cost of compliance values from the avoided cost worksheet within the CLC BCR model for the avoided cost of fuel oil environment compliance values.
Propane ($/MMBtu)	The study uses the weighted average avoided costs of propane from Table 130 of Appendix D of the AESC Study.
Propane environmental compliance cost ($/MMBtu)	The study uses the retail incremental GWSA cost of compliance values from the avoided cost worksheet within the CLC BCR model for the avoided cost of propane environment compliance values.
Water ($/gallon)	The study uses the avoided cost of water consumption from the CLC BCR model.

To apply the AESC Study results to the architecture of the models used in this study, the Potential Study Team adapted several value streams to conform to model input requirements. Specifically, several of the avoided cost value streams in the AESC Study are dependent on the measure's year of installation. These value streams include energy (including electric, natural gas, and oil) DRIPE values, uncleared capacity values, capacity DRIPE values, wholesale cross-DRIPE values, and capacity-based reliability benefit values. The models do not incorporate specific vintage year avoided cost value streams. Therefore, these value streams were converted into a single value stream by taking an average of the values for measures installed in each year weighted by the proportion of each study year's savings persisting in each year to approximate an aggregated value regardless of measure installation year.

The 2021 AESC Study provides projected values out to 2050, while this potential study calculates benefits and costs for the full life of all measures requiring projected values beyond the last year of the AESC Study. For years beyond those included in the 2021 AESC Study, we extrapolated values using a simple linear forecast.

Future TRC benefits and cost streams are discounted using a nominal discount rate of 2.82%, which assumes a real discount rate of 0.81% and an inflation rate of 2.00%.[11] These discount rate assumptions are sourced from the Program Administrators' (PAs)[12] BCR model Excel workbooks at the direction of the PAs. All TRC values are expressed in 2021 real-dollar terms.

Customer Cost-Effectiveness

Customer cost-effectiveness is a key driver of achievable potential. In general, customer cost-effectiveness is a function of the incremental costs borne by the customer, the future stream of bill impacts, the monetary value of any non-energy benefits (e.g., increased comfort), and customer discount rates. Incremental costs and non-energy benefits are developed as part of the measure characterization process described in Appendix C, Appendix D, and Appendix E.

To determine bill impacts, marginal retail rates are developed for each customer segment.

For electric rates, this study uses CLC's 2020 generation and demand rates. Residential rates are further weighted by consumption dependent on the heating season and income classification (i.e., market rate and low income). Commercial rates are weighted by load factor and size. Rates are then escalated proportionally to the avoided costs. The supply services component of retail rates is escalated using the energy avoided costs, and the distribution and transmission energy charges are escalated with the electric capacity avoided costs.

For natural gas rates, this study uses 2020 Colonial Gas[13] distribution rates, and costs of gas from Summer 2020 (off-peak) and Winter 2019 (peak). Rate components related to gas supply are escalated proportionally to the avoided costs. Other rate components remain fixed (in real dollars) throughout the project period. Residential rates are weighted by consumption, dependent on the heating season and income classification (i.e., market and low income). Commercial rates are weighted by load factor and size. Finally, rates are inflated by one year to approximate 2021 dollars.

The approach is similar for the other fuel rates, with rates escalated proportionally to the relevant avoided cost rates. Oil, propane, and water customer rates are assumed to be identical to their corresponding avoided costs.

The study assumes a participant discount rate 5.1% in real terms based on the weighted average cost of capital across all commercial sectors.[14]

[11] 1 + Real Discount Rate = (1 + Nominal Discount Rate) / (1 + Inflation Rate)
[12] Massachusetts' natural gas and electric utilities and energy efficiency service providers, including Berkshire Gas, Blackstone Gas Company, Cape Light Compact, Columbia Gas of Massachusetts, Eversource, Liberty Utilities, National Grid, and Unitil are collectively referred to as the Program Administrators.
[13] Colonial Gas is a legacy local distribution company doing business as National Grid on Cape Cod
[14] Aswath Damodaran. *Cost of Capital by Sector (US).* January 2020. Accessible at: http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm

Emission Factors

Emission impacts are estimated by multiplying energy savings by static marginal emission factors on a per kWh or per MMBtu basis. Table 3 lists the emission factors used in this study, which are taken from the PAs' BCR model.

Table 3. Marginal Emission Factors

Fuel	Marginal Emission Factor
Electricity	0.49400 tons CO2 per MWh
Natural Gas	0.00585 tons CO2 per therm
Oil	0.08069 tons CO2 per MMBtu
Propane	0.06959 tons CO2 per MMBtu

Seasonality

The seasonality of the Compact's customer base has a significant impact on the EE, HE, and DR potentials.[15] More than 30% of residential customers, as well as many C&I customers (especially in the restaurant and lodging/hospitality segments), show reduced occupancy or hours of operation, especially during the winter. Some C&I customers even shut down completely during that period. Reduced activity is also observed during the spring and autumn seasons.

For this study, we adjusted measure savings and markets to account for seasonality using data from the surveys and onsite visits conducted for the 2014 Potential Study. A similar approach as was used for the 2014 and 2017 Potential Studies. Reduced savings due to seasonality impact cost-effectiveness of measures, thus screening out some measures for specific segments and reducing adoption rates of remaining measures in segments with a strong seasonal profile.

Growth Factors

Growth factors are based on the Compact's projected customer account growth over the study period. Table 4 provides the customer growth factors used in this study.

Table 4. Customer Growth Factors

Sector	Growth Factor
Residential – Market Rate	0.30%
Residential – Low Income	0.20%
C&I	0.25%

COVID Sensitivity

As noted in the workplan, there is a high degree of uncertainty surrounding the short and long-term impacts of the pandemic. We note that this analysis did not attempt to predict what is likely to happen in the future. Instead, this analysis provides information about the sensitivity of modeled savings to changes in market conditions that may plausibly be expected as a result of the pandemic—increased business closures and increased market barriers to measure adoption. It should be noted that our analysis is

[15] Jake Millette and Martin Poirier, *Understanding Your Customers: The Effects of Seasonality on Energy Savings on Cape Cod and Martha's Vineyard*, 2015. Accessible at: https://www.iepec.org/wp-content/uploads/2015/papers/023.pdf

limited to impacts on energy efficiency programs; it did not include impacts on demand response programs.

Within the potential model, the following input parameters were adjusted to assess the sensitivity of savings potential to the impacts of the COVID-19 pandemic:

- **Market size:** The market size was adjusted to reflect a decrease in the number of customers within a given segment due to temporary or permanent business closures. Note that this adjustment applies to the C&I sector only; no market size adjustments are assumed for the residential sector.
- **Barrier levels:** Barrier levels were increased to reflect increased competition for capital, decreased resources, and other impediments to energy efficiency upgrades.

We completed the following analysis to develop the sensitivity analysis model setting inputs for these two parameters.

Methodology

Our methodology consists of three steps, which are described in the following subsections.

1. Categorize C&I segments into impact categories
2. Define sensitivity settings for each C&I category and the residential sector
3. Model sensitivity of achievable potential savings

Categorize C&I Segments into Impact Categories

In recognition of the heterogeneous impact of the pandemic on different types of businesses, we categorize each modeled segment into one of three impact categories:

- **Low**: No anticipated closures, small market barrier increase
- **Moderate**: Anticipated short-term closures, moderate market barrier increase
- **High**: Anticipated long-term closures, large market barrier increase

To categorize C&I segments, the Potential Study team reviewed available data sources for insights on COVID impact by business type.

We relied on the US Census Small Business Pulse Survey (SBPS) as the main source of impact insight by industry as it is public, recent (December 2020), and has a significant number of respondents nationally (n = 24,800) and statewide (n=550).[16] We started with the Massachusetts (MA)-specific data and validated the results with the national averages; in all cases the rounded results aligned.[17]

The SBPS is targeted at small businesses (<500 employees). Where relevant, we made adjustments to categorizations based on professional judgement and additional research.

[16] The United States Census has completed the Small Business Pulse Survey since Spring 2020, measuring the changes in business conditions during the pandemic. The data from the latest week of the survey available (12/14-12/20) was used for the analysis.

[17] The MA-specific data did not have any respondents for the campus/education segment, so the national average was used for this value.

Additionally, a Cape-specific publication, the Cape Cod Business Impact Survey,[18] was used to inform categorization of the segments.

United States Census Small Business Pulse Survey

The analysis leverages the following Pulse survey question:

1. Overall, how has this business been affected by the COVID-19 pandemic?
   a. Large negative impact
   b. Moderate negative impact
   c. Little or no effect
   d. Moderate positive effect
   e. Large positive effect

The Pulse survey collected data at the NAICS code level across the United States. The NAICS codes are mapped to the potential study segments (see Segment Mapping section). An average response is determined for each segment based on the 5-point Likert scale responses (see "Rounded Score" column in Table 5). The values shown below are based on the national averages due to data gaps in the MA-specific responses (e.g., no campus/education segment responses). However, the same analysis was conducted for MA-specific responses and the segment-level rounded values (where available) do not differ from the national responses.

Table 5. Pulse Survey Responses (National Average)

Segment [A]	Large Negative Effect (Score=1)	Moderate Negative Effect (Score=2)	Little to no Effect (Score=3)	Moderate Positive Effect (Score=4)	Large Positive Effect (Score=5)	Average Score	Rounded Score
Campus/ Education	58%	32%	6%	2%	1%	1.55	2
Food Service; Lodging	67%	24%	6%	2%	1%	1.46	1
Healthcare/ Hospitals	31%	56%	9%	3%	1%	1.85	2
Manufacturing/ Industrial	30%	42%	22%	6%	2%	2.13	2
Office	24%	42%	28%	5%	1%	2.18	2
Retail; Food Sales	24%	41%	17%	13%	5%	2.33	2
Warehouse	32%	42%	19%	5%	2%	2.02	2
Other	31%	39%	26%	4%	1%	2.09	2

[A] Some segments are grouped due to NAICS code mapping; see Table 9 for more details.

Based on this assessment, every segment except for the food service and lodging segments show a "moderate negative effect" from the COVID-19 pandemic. The average response score for the food service and lodging segments indicates a "large negative effect."

[18] *Cape Cod COVID-19 Business Economic Impact Survey*, Cape Code Commission, Oct 2020. A detailed breakdown of the results was provided to us directly. https://datacapecod.com/second-business-impact-survey/

Cape-specific Analysis

Using results from the Cape Cod Commission Economic Survey, we reviewed the segment-level change in business revenue to gauge the impact of COVID on Cape businesses and compared this to the results from the Pulse survey. Much of the data were not directly comparable due to either small sample sizes or non-equivalent industry definitions, but insights could be developed for the Food Service/Lodging and Retail sectors. Table 6 shows this analysis, highlighting that Retail businesses on the Cape are more consistently impacted than the national average.

Table 6. Cape-specific Segment Analysis

	Weighted score		Percentage of businesses indicating negative impact		Comments
Segment	Pulse Survey (USA)	Cape Cod Commission [A]	Pulse Survey (USA)	Cape Cod Commission	
Food Service; Lodging	**1.46**	**1.81**	91%	88%	The two studies are broadly consistent, though the weighted value for Cape businesses rounds to 2 instead of 1.
Retail	2.33	1.92	**65%**	**85%**	Cape Cod businesses have more consistently negative impacts.

[A] Cape Cod Commission responses of -100% to +100% year-on-year change in revenue were converted to the 5-point Likert scale, with Don't Know excluded.

Using the Rounded Scores (1-5) as a starting point, we made further modifications where warranted based on professional judgement and Cape-specific data. The final categorization and rationale for modifications are laid out in Table 7.

Table 7. Assessment Category Assignment

Segment	Pulse Survey – Overall Score Category	Impact Category	Modification Rationale
Campus/ Education	2 – Moderate negative effect	Moderate	
Food Service; Lodging	1 – Large negative effect	High	We retain the High categorization for Cape businesses despite the Cape-specific weighted score being somewhat higher, as other research suggests these are some of the hardest-hit businesses. [A]
Healthcare/ Hospitals	2 – Moderate negative effect	Moderate	
Manufacturing / Industrial	2 – Moderate negative effect	Moderate	
Office	2 – Moderate negative effect	High	While the Pulse Survey suggests moderate negative effects for commercial entities within the office segment, this does not necessarily reflect office building use impacts as many functions have shifted to remote work. Research suggests that office use has been significantly impacted and may not bounce back until roughly 2025.[A]
Food Sales	2 – Moderate negative effect	Low	Research suggests that grocery stores have not been experiencing significant negative impacts. [B]
Retail	2 – Moderate negative effect	Moderate	Research suggests impacts on retail businesses are not homogenous.[B] However, as noted above, the Retail segment is more consistently negatively impacted in the Cape region, so this segment retains a Moderate categorization.
Warehouse	2 – Moderate negative effect	Low	Many warehouses would not typically fall within the "small business" classification of the Pulse Survey, and research suggests

			increased demand for some warehouses particularly for e-commerce services.[C]
Other	2 – Moderate negative effect	Moderate	

[A] Global Office Impact Study & Recovery Timing Report, Cushman and Wakefield, Sept 2020 https://www.cushmanwakefield.com/en/insights/covid-19/global-office-impact-study-and-recovery-timing-report
[B] Top Performing and Hardest Hit Industries, Vertical IQ, Sept 2020 https://verticaliq.com/covid-19-most-impacted-industries/
[C] How the e-commerce boom during COVID-19 is changing industrial real estate, JLL, June 2020 https://www.us.jll.com/en/trends-and-insights/investor/how-the-e-commerce-boom-during-covid-19-is-changing-industrial-real-estate

Define Sensitivity Input Settings for Each of the Three C&I Categories and the Residential Sector

Table 8 summarizes the market size and adoption barrier input settings for each C&I impact category. A single setting was used for the residential sector.

Market size adjustments were limited to C&I segments in the moderate and high impact categories under the assumption that low impacted segments will retain pre-COVID levels of businesses and that the pandemic will not influence the number of residential customers. For moderate impact segments, the sensitivity analysis assumes market size reductions of 25% for the first year and return to pre-COVID levels in years 2 and 3. For high impact segments, the analysis assumes of 25% for all three years of the study. It should be noted that these are highly uncertain assumptions, used for purposes of testing the sensitivity of results to impacts from the COVID pandemic. The true impacts on market size may be higher or lower.

Numerically, **barrier levels** in the DEEP model range from 0 (no barrier) to 4 (extreme barriers). Barrier settings are based on interpreting past barrier research for each measure and adjustments made at the segment level to account for segment-specific characteristics. For this sensitivity, a “small” barrier level increase (applied to low impact C&I segments and the residential sector) denotes a 0.5 step increase in segment-level market barrier levels, a “moderate” increase (applied to moderate impact C&I segments) denotes a 0.7 step increase, and a “large” increase (applied to high impact C&I segments) denotes a 1.0 step increase.

Table 8. Sensitivity Settings by Category

Sector	Category	Segments	Impact on Savings Scenario
C&I	Low	Food Sales Warehouse	▪ **Market size:** No change ▪ **Barriers:** Small barrier level increase for all study years
	Moderate	Retail Campus/Education Healthcare/Hospitals Manufacturing/Industrial Other	▪ **Market size:** Reduce 1st-year market size by 25%, return 2nd and 3rd-year markets to baseline size ▪ **Barriers:** Moderate barrier level increase for all study years
	High	Food Service Lodging Office	▪ **Market size:** Reduce market size by 25% for all three study years ▪ **Barriers:** Large barrier level increase for all study years
Residential	N/A	N/A	▪ **Market size:** No change ▪ **Barriers:** Small barrier level increase for all study years

Model Sensitivity of Achievable Potential Savings

The next step in the sensitivity analysis is to apply the above input settings to the model. The Potential Study team modeled each of the settings, providing sensitivity around the BAU+ achievable potential scenario.

Segment Mapping

The mapping of NAICS codes included in the Pulse survey to potential study segments is included below.

Table 9. Pulse Survey NAICS Codes to Potential Study Segment Mapping

NAICS Code	Industry	Potential Study Segment
21	Mining, Quarrying, Oil and Gas Extraction	Manufacturing/Industrial
22	Utilities	Other
23	Construction	Other
31	Manufacturing	Manufacturing/Industrial
42	Wholesale Trade	Warehouse
44	Retail Trade	Retail; Food Sales
48	Transportation and Warehousing	Warehouse
51	Information	Office
52	Finance and Insurance	Office
53	Real Estate and Rental and Leasing	Office
54	Professional, Scientific, and Technical Services	Office
55	Management of Companies and Enterprises	Office
56	Administrative and Support and Waste Management and Remediation Services	Manufacturing/Industrial
61	Educational Services	Campus/Education
62	Healthcare and Social Assistance	Healthcare/Hospitals
71	Arts, Entertainment, and Recreation	Other
72	Accommodation and Food Services	Food Service; Lodging
81	Other Services (except Public Administration)	Other

It should be noted that NAICS Codes 44 (Retail Trade) and 72 (Accommodation and Food Services) cover multiple potential study segments (Retail and Food Sales, and Food Service and Lodging, respectively). These segments are broken out separately in our modeling and reporting; they are only combined here for their initial categorization into low/moderate/high COVID impact segments using the Pulse survey.

Study Component Integration

While the EE, HE, and DR components of this study are modeled separately, the study considers possible interactive effects between study components, and we adjust relevant model parameters to account for any material impacts. The potential interactive effects include inter-model measure competition, peak demand and load curve impacts, market size impacts, and additive incentive adoption effects.

The remainder of this section describes these interactive effects and details whether the effects are expected to be significant and if/how the study accounts for them. Interactions are grouped by whether they primarily impact the EE or DR models. In general, potential impacts are evaluated against model results under BAU+ scenarios to serve as an anchoring point between the BAU and Max scenario results.

DR Model Interactions

Dunsky's Demand Response Optimized Potential (DROP) model uses annual peak demand projections as well as the peak day load curve to determine the potential for DR programs and measures. EE programs encourage the adoption of electricity-using equipment that typically reduces the connected demand, and the resulting peak demand draw, when compared to standard efficiency or existing equipment. Moreover, Dunsky's Heating Electrification Adoption (HEAT™) model projects the uptake of electric heating equipment to replace combustion heating equipment. In each case, these projections are expected to impact the annual utility peak load and peak day load shape, which in turn can impact the DR potential.

- **Peak Demand Projection Adjustments:** The annual overall peak demand impact from measure adoption in the other models is first applied to adjust the annual peak load forecast provided by the utility.
- **Peak Day Load Curve Adjustments:** Next an adjustment to the hourly peak day load curve is made by assessing peak demand impacts as a portion of the overall peak demand contributions for each market segment at the end-use level. These proportional adjustments are then applied to each market segment and end-use's contribution to the overall demand in each hour of the peak day.
- **BYOD Market Adjustments:** Finally, the markets for bring-your-own-device (BYOD) measures in the DROP model are updated to account for adoption in other models. Examples include Wi-Fi thermostats and heat pumps.
- **Additive Incentives:** In cases where equipment carries both EE and DR program benefits, the available incentives may be combined to drive increased adoption. In this study, this impact is limited to Wi-Fi thermostats where a customer who is receiving an incentive under the efficiency program may also be encouraged to adopt the measure by the opportunity to participate in the DR program and receive additional annual participation incentives. In this study, however, the evaluated impact of the dual EE + DR incentive was found to have a minimal affect on Wi-Fi thermostat adoption (less than 1% increase in adoption), and thus this interaction was considered to be negligible.

Collectively, these adjustments ensure that the DROP model provides an accurate assessment of DR potential, accounting for the impacts of efficiency and heating electrification.

EE Model Interactions

Adjustments are made where appropriate to account for potential measure competition between the Dunsky Energy Efficiency Potential (DEEP) and HEAT models. In some cases, mutually exclusive measures may share the same replacement opportunity (e.g., replacing a failed furnace with a heat pump as opposed to a high-efficiency furnace) which results in measure competition. In other cases, measures may not share the same opportunity but the adoption of one measure may limit opportunities for another measure in the future. For example, the adoption of a heat pump to partially offset the heating load of an existing boiler may reduce the cost-effectiveness (both from a TRC and customer standpoint) of a future EE opportunity to replace the boiler with a more efficient version due to a much lower heating load served by the boiler.

In this study, the impact of inter-model measure competition and interactions is considered limited for three key reasons:

2. **Model calibration to recent efficiency and heating electrification program performance inherently accounts for competition at current adoption rates.** By calibrating to existing programs, the implicit competition between each program is captured for existing levels of program participation. Therefore, any possible inter-model competition would only impact measure adoption that is significantly higher

than current program uptake levels. In this study, incremental growth in programs under the BAU scenario is generally limited to HE measures for which adoption is expected to continue to grow as the opportunity for heat pumps becomes increasingly recognized in the market.

3. **The magnitude of most measure competition and interaction between DEEP and HEAT is insignificantly small.** The adoption of HE measures over the study period is extremely small relative to the overall size of the market, and thus the potential impact of competition between EE and HE measures is considered to have an insignificant impact on the study results in most cases. The primary exception is the interaction between adoption of heat pumps and high-efficiency AC units. These measures share the same upgrade opportunity (i.e., burn out of the existing AC unit) and show significant adoption rates in both models. For other measures such as high-efficiency heating systems, the overlap of upgrade opportunities is limited. For example, full replacement heating electrification adoption represents less than 1% of furnace/boiler burn out opportunities under BAU; as such it is assumed that the overlapping opportunity with high-efficiency furnace and boiler measures is insignificant (i.e., well within the range of uncertainty of the DEEP model results).
4. **The market drivers for heating electrification are expected to differ sufficiently that they will not directly compete in all cases.** Measure competition hinges on the fact that competing measures are almost identical beyond incremental costs and energy savings and assumes that a customer—once they have decided to participate in a program—must make a choice between two (or more) similar measures. Potentially competing EE and HE measures represent different value propositions for customers beyond just cost and bill savings (e.g., improved comfort from upgraded heating system), however, which could lead to different customer bases participating in an EE program versus an HE program. Therefore, to avoid overestimating the overlap between HE and EE measures, where notable overlap is identified, the market availability for high-efficiency measures is reduced to account for heat pump adoption, rather than reducing the number of efficiency measures adopted by the number of heat pumps adopted.

<u>Study adjustments</u>**: Adjust EE air conditioning measure adoption.** Considering the above rationale, an adjustment was made to the EE market opportunities for high-efficiency AC units to account for competition with heat pump adoption from the HE projections. For residential and C&I EE air conditioning measures, achievable adoption is reduced by the relative proportion of overlapping opportunities represented by the incremental growth in HE measure adoption relative to 2019 results. For example, if HE measure growth results in an additional 2% of opportunities being captured by HE programs, achievable adoption for overlapping EE measures is reduced by 2%.

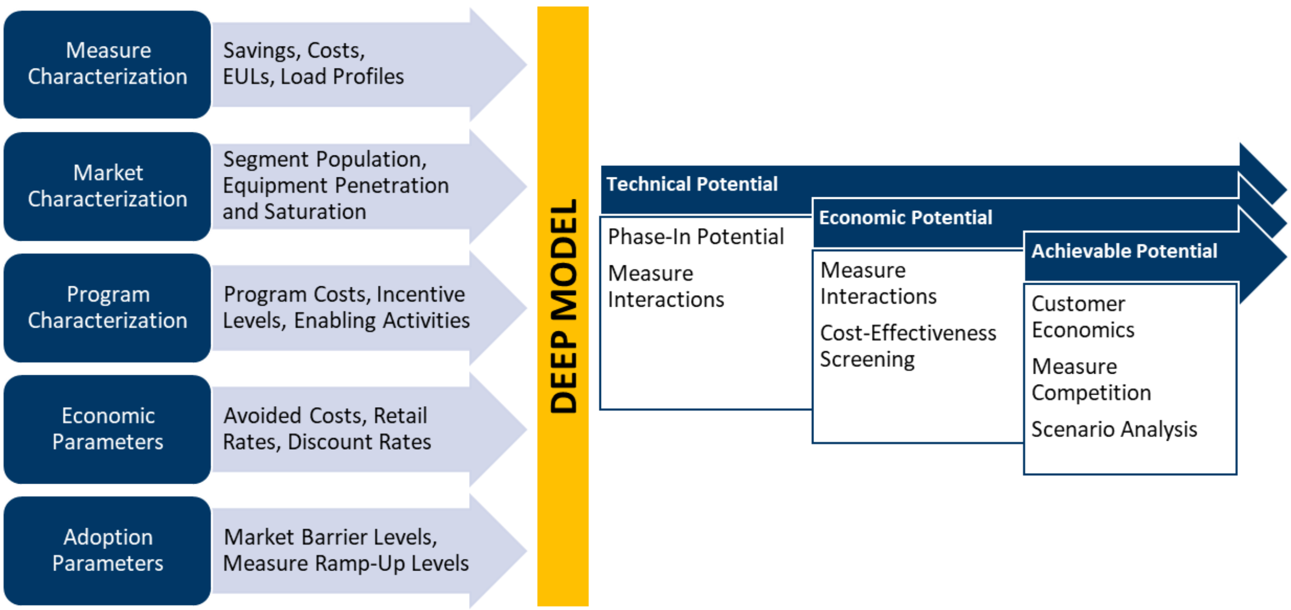
Appendix C. Energy Efficiency Methodology

Overview

The following sections outline the EE modeling methodology, used to assess the technical, economic, and achievable savings from efficiency programs. This section begins with a general discussion of the modeling approach, and then provides details on the specific assumptions and inputs made in this study.

The market potential for energy efficiency is estimated using the DEEP model (Figure 1). DEEP employs a multi-step process to develop a bottom-up assessment of technical, economic, and achievable potential. This appendix describes DEEP's modeling approach, the process of developing DEEP model inputs, and the underlying calculations employed to assess energy efficiency potential.

Figure 1. DEEP Model



The DEEP Model

DEEP's bottom-up modeling approach assesses thousands of "measure-market" combinations, applying program impacts (e.g., incentives and barrier reducing enabling activities) to assess energy savings potentials across multiple scenarios. Rather than estimating potentials based on the portion of each end-use that can be reduced by energy saving measures and strategies (often referred to as a "top-down" analysis), the DEEP approach applies a highly granular calculation methodology to assess the energy savings opportunity for each measure-market segment opportunity in each year. Key features of this assessment include:

- **Measure-Market Combinations:** Energy saving measures are applied on a segment-by-segment basis using segment-specific equipment saturations, customer counts, and demographic data to create unique segment-specific "markets" for each individual measure. The measure's impact and market size are unique for each measure-market segment combination, which increases the accuracy of the results.
- **Phase-In Potential:** DEEP assesses the phase-in technical, economic, and achievable potential by applying a measure's expected useful life (EUL) and market growth factors to determine the number of energy savings opportunities for each measure-market combination in each year. This

provides an important time series for each energy savings measure upon which estimated annual achievable program volumes (measure counts and savings) can be calculated in the model as well as phase-in technical and economic potentials.

- **Annual, Lifetime, and Cumulative Savings:** For each measure-market combination in each year, DEEP calculates the annual, lifetime, and cumulative savings accounting for mid-life baseline adjustments and program re-participation where appropriate.[19] This provides an assessment of the cumulative savings (above and beyond natural uptake) as well as the annual and lifetime savings that will pass through the Compact's portfolios.

DEEP Model Inputs

DEEP requires an extensive set of model inputs related to energy savings measures, markets, economic factors, and adoption parameters to accurately assess EE potential. These inputs are developed through several concurrent processes that include measure characterization, market characterization, program characterization, economic parameter development, and adoption parameter development. The remainder of this section outlines each process.

Measure Characterization

Measure characterization is the process of determining the costs, savings, and lifetimes of potential energy-saving technologies and services and their baseline equivalents that will then be used as inputs to the DEEP model. The measure characterization process begins by developing a comprehensive list of energy saving measures.

For this study, we proposed an initial measure list based on the full range of measures offered in the PAs' existing programs as well as emerging opportunity measures. Measures were limited to currently commercially viable measures and measures that may become commercially viable over the study period (based upon the Potential Study Team's professional judgement) and included measures that cumulatively accounted for more than 95% of the Compact's savings in previous years.

The measure list was vetted and approved by the Compact and finalized prior to measure characterization. The final measure list represents more than 1,600 measure-market combinations—representing the full range of commercially available energy saving technologies (current and emerging).

Measure characterization is accomplished by compiling primary and secondary data (as available) on the efficient and baseline (i.e., inefficient) energy-consuming equipment available in the jurisdiction. Measures are characterized using segment-specific inputs when available, yielding segment-specific characterizations for each measure-market combination.

Measures are characterized in terms of their market unit such as savings per widget, savings per square foot, or savings per ton of cooling capacity. Each measure in the measure list was characterized by defining a range of specific parameters. Table 10 describes these parameters.

Table 10. DEEP Measure Characterization Parameters

Parameter	Description
Market unit	The unit in which the measure is characterized and applied to the market (e.g., per widget, per building, per square foot, etc.)

[19] Mid-life baseline adjustments are required for early retirement measures after the useful life of the existing equipment expires and new equipment (at a more efficient baseline) would have been purchased. Program re-participation occurs when a customer may receive an incentive for a new efficient measure to replace an efficient measure previously received through the program at the end of its life, which results in *program* savings but no additional *cumulative* savings.

Parameter	Description
Measure type	The measure type, which can be at least one of the following: ▪ Replace on Burnout (i.e., replace on failure) ▪ Early Replacement ▪ Addition (e.g., retrofit/discretionary measures) ▪ New Construction/Installation
Annual gross savings	The annual gross savings of the measure per market unit in terms of energy (e.g., kWh, MMBtu), demand (e.g., kW), and other factors (e.g., water) as applicable
Measure costs	The incremental cost of the measure (e.g., the difference in cost between the baseline technology and the efficient technology)
Measure life	The EUL and/or remaining useful life (RUL) of both the efficient measure and the baseline technology
Impact factors	Any factors affecting the attribution of gross savings including net-to-gross adjustments, in-service factors, persistence factors, and realization rates.
Load factors	Any factors affecting modulating gross savings including summer and winter peak coincidence factors as well as seasonal savings distributions.
Program allocation	The program(s) to which the measure applies—in some instances, measures will be allocated to multiple programs on a prorated basis if the measure is offered through multiple programs.

This study characterized measures using inputs from the Massachusetts Technical Resource Manual (TRM) 2019 Plan-Year Report Version (May 2020) when supporting entries were present and deemed applicable to the study. In cases where MA TRM entries were not available or for measures that do not form a meaningful proportion of overall historical results, measures were characterized using other best-in-class TRMs from other jurisdictions.

Measure Types

DEEP incorporates four types of measures types: replace on burnout (ROB), early replacement (ER), addition (ADD), and new construction/installation (NEW). DEEP treats each of these measure types differently when determining the maximum annual market available for phase-in potential. Table 11 provides a guide as to how each measure type is defined and how the replacement or installation schedule is applied within the study to assess the phase-in potentials each year.

Table 11. DEEP Measure Type Descriptions

Measure Type	Description	Yearly Units Calculation
ROB	An existing unit is replaced by an efficient unit after the existing unit fails. *Example: Replacing burned out bulbs with LEDs*	The eligible market is the number of existing units divided by EUL.
ER[20]	An existing unit is replaced by an efficient unit before the existing unit fails. These measures are generally limited to measures where savings are large enough to motivate a customer to replace existing equipment earlier than its expected lifespan. *Example: Replacing a functional, but inefficient, furnace*	The eligible market is assumed to be a subset of the number of existing units based on a function of the equipment's EUL and RUL

[20] Early replacement measures are limited to measures where energy savings are sufficient to motivate a customer to replace existing equipment prior to the end of its expected lifespan.

Measure Type	Description	Yearly Units Calculation
ADD	A measure is applied to existing equipment or structures and treated as a discretionary decision that can be implemented at any moment in time. *Example: Adding controls to existing lighting systems, adding insulation to existing buildings*	The eligible market is distributed over the estimated useful life of the measure using an S-curve function.
NEW	A measure that is not related to existing equipment. *Example: Installing a heat-pump in a newly constructed building.*	The eligible market is measure-specific and defined as new units per year.

In this study, only a small number of measures were characterized as ER measures. In general, ER measures are limited to those where energy savings are sufficient to motivate a customer to replace existing equipment significantly before the end of its EUL. This is generally limited to measures with long EULs and a large difference between existing installed efficiency and baseline efficiencies for new equipment (e.g., furnaces and boilers) as the ER of these measures will create significant additional savings through the early retirement of particularly inefficient equipment.

Measure Characterization Inputs

The following tables list key measure characterization inputs used to estimate measure savings used in this study.

Table 12. Measure Characterization Inputs

Sector	Variable	Segment	Value	Units	Description	Source
Residential	EFLH_heat	Single Family	1,200	hours	Heating mode equivalent full load hours	MA TRM, May 2020; pg. 66, 151.
		Multi-family	1,158.5	hours	Heating mode equivalent full load hours	Average of single family and low income
		Low Income	1,117	hours	Heating mode equivalent full load hours	MA TRM, May 2020; pg. 325.
Residential	EFLH_cool	Single Family	419	hours	Cooling mode equivalent full load hours	MA TRM, May 2020; pg. 66, 151, 72.
		Multi-family	218	hours	Cooling mode equivalent full load hours	MA TRM, May 2020; pg. 120, 125, 325.
		Low Income	200	hours	Cooling mode equivalent full load hours	MA TRM, May 2020; pg. 347.
Residential	AHL_kWh	Single Family	20,046.1	kWh	Annual heating load in kWh	MA TRM, May 2020; pg. 300. Converted 68.4 MMBtu to kWh with a conversion factor of 293.071 kWh/MMBtu.
		Multi-family	12,974.8	kWh	Annual heating load in kWh	Scaled annual heating load of single family using the ratio of floor area.
		Low Income	15,655.2	kWh	Annual heating load in kWh	Scaled annual heating load of single family using the ratio of floor area.
Residential	ACL_kWh	Single Family	3,839.2	kWh	Annual cooling load in kWh	MA TRM, May 2020; pg. 300. Converted 13.1 MMBtu to kWh with a conversion factor of 293.071 kWh/MMBtu.
		Multi-family	2,484.9	kWh	Annual cooling load in kWh	Scaled annual cooling load of single family using the ratio of floor area.
		Low Income	2,998.3	kWh	Annual cooling load in kWh	Scaled annual cooling load of single family using the ratio of floor area.
Residential	Annual_energy_use	Single Family	26,333.1	kWh	Annual electricity used in kWh	Internal calculation sheet; Added median electricity consumption to AHL_kWh
		Multi-family	17,273.8	kWh	Annual electricity used in kWh	Internal calculation sheet; Added median electricity consumption to AHL_kWh

Sector	Variable	Segment	Value	Units	Description	Source
		Low Income	20,967.2	kWh	Annual electricity used in kWh	Internal calculation sheet; Added median electricity consumption to AHL_kWh
C&I	EFLH_heat	All	530	hours	Heating mode equivalent full load hours	MA TRM, May 2020; pg. 676.
C&I	EFLH_cool	All	1,172	hours	Cooling mode equivalent full load hours	MA TRM, May 2020; pg. 676.
C&I	HOU_lighting	Office	4,181	hours	Hours of use for the Office segment	MA TRM, May 2020; pg. 607, 608, 675
		Retail	4,939	hours	Hours of use for the Retail segment	MA TRM, May 2020, pdf pg. 607, 608, 676
		Food Service	5,018	hours	Hours of use for the Food Service segment	MA TRM, May 2020, pdf pg. 607, 608, 677
		Healthcare/ Hospitals	4,543	hours	Hours of use for the Healthcare/Hospitals segment	MA TRM, May 2020, pdf pg. 607, 608, 678
		Campus/ Education	3,814	hours	Hours of use for the Campus/Education segment	MA TRM, May 2020, pdf pg. 607, 608, 679
		Warehouse	6,512	hours	Hours of use for the Warehouse segment	MA TRM, May 2020, pdf pg. 607, 608, 680
		Lodging	4,026	hours	Hours of use for the Lodging segment	MA TRM, May 2020, pdf pg. 607, 608, 681
		Other Commercial	4,332	hours	Hours of use for the Other Commercial segment	MA TRM, May 2020, pdf pg. 607, 608, 682
		Food Sales	5,468	hours	Hours of use for the Food Sales segment	MA TRM, May 2020, pdf pg. 607, 608, 683
		Manufacturing/ Industrial	4,988	hours	Hours of use for the Manufacturing/Industrial segment	MA TRM, May 2020, pdf pg. 607, 608, 684
C&I	HOU_compressor	Office	1,976	hours	Hours of use for the Office segment	Internal calculation sheet
		Retail	1,222	hours	Hours of use for the Retail segment	Internal calculation sheet
		Food Service	1,976	hours	Hours of use for the Food Service segment	Internal calculation sheet

Sector	Variable	Segment	Value	Units	Description	Source
		Healthcare/ Hospitals	485	hours	Hours of use for the Healthcare/Hospitals segment	Internal calculation sheet
		Campus/ Education	520	hours	Hours of use for the Campus/Education segment	Internal calculation sheet
		Warehouse	1,324	hours	Hours of use for the Warehouse segment	Internal calculation sheet
		Lodging	1,976	hours	Hours of use for the Lodging segment	Internal calculation sheet
		Other Commercial	2,199	hours	Hours of use for the Other Commercial segment	Internal calculation sheet
		Food Sales	1,630	hours	Hours of use for the Food Sales segment	Internal calculation sheet
		Manufacturing/ Industrial	1,630	hours	Hours of use for the Manufacturing/Industrial segment	Internal calculation sheet

Table 13. Degree Days

Variable	°C days	Description	Source
HDD_15.6C	1,849.1	Heating degree days (°C days) with a set point of 15.6 °C (60°F)	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)
CDD_23.9C	43.9	Cooling degree days (°C days) with a set point of 23.9 °C (75°F)	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)
HDD_18.3C	2,498.0	Heating degree days (°C days) with a set point of 18.3 °C (65°F).	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)
CDD_18.3C	317.8	Cooling degree days (°C days) with a set point of 18.3 °C (65°F).	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)
HDD_10C	1,301.8	Heating degree days (°C days) with a set point of 10 °C (50°F)	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)
CDD_10C	1,420.8	Cooling degree days (°C days) with a set point of 10 °C (50°F)	Internal calculation sheet: applied a weighted average based on population in CLC's jurisdiction to HDD values provided in MA TRM (38% Otis, 53% Barnstable, 9% Provincetown)

Lighting Characterization

Due to the significant contribution lighting measures have historically made to efficiency portfolio savings and the rapidly transforming lighting market, the Potential Study Team directed additional attention to characterizing lighting measures and markets. This section documents the measure and market inputs and assumptions used to estimate EE potential from lighting measures in this study.

Residential Lighting

The study includes residential interior LED bulbs in the following categories:

- LED A-Lamps
- LED Specialty – Reflectors
- LED Specialty – Candelabras, Globes

The study separately considers lighting measures delivered via upstream and direct install (DI) delivery channels:

- For the upstream delivery channel, the study assumes 100% naturally occurring market adoption (NOMAD) by 2022, which eliminates all economic and achievable savings from this delivery channel.
- DI Lighting measures are characterized according to the MA TRM, which calculates savings as a function of (1) the difference between the inefficient and efficient lighting technology's wattage (i.e., the "delta watts") and (2) the hours of use (HOU). Claimable savings from residential bulbs are assumed to last for one year (i.e., an adjusted measure life [AML] of one year).

Table 14 lists the measure inputs used to characterize the residential lighting measures.

Table 14. Residential Lighting Measure Inputs

Input	Market Rate	Low Income
Delta watts	2019 TRM values	
HOU	▪ 2.6 hours/day for DI and Turn-in (949 hours/year)[a] ▪ 3.0 for Upstream	
Measure Life	▪ 1 year for DI / ER ▪ 2 years for upstream	
Incremental Costs	DI lighting costs (see Table 15)	
Interactive Effects	Apply fossil fuel heating penalty of 2,295 Btu/kWh as per 2019 TRM	
Non-Energy Impacts (NEIs)	Assume no NEIs	Assume low income NEIs (as per 2019 TRM)
Net-to-Gross (NTG)	▪ DI: 0.55 NTG for 2022[b] ▪ Upstream: 0.0 NTG	Assume 1.0 NTG
Program eligibility	Assume measures only offered in 2022	Assume measures offered in all three study years

[a] Consensus recommendation for inefficient DI lamps resulting from Residential Lighting Hours-of-Use Quick Hit Study (MA20R21-E) published March 31, 2020.

[b] The NTG factor for market-rate DI lighting measures assumes NTG factors continue to decline in a linear fashion based on the decline between 2019 and 2021.

Table 15 lists the DI bulb costs assumed in this study, which include the installation costs making incremental costs higher than typical measures.[21] Bulb costs are assumed to be the same for all market-rate and low income segments.

Table 15. Residential DI Bulb Costs

Bulb Type	Cost
LED Bulb	$7.76
LED Bulb - Specialty	$8.65
LED Bulb - Reflectors	$8.45

The markets for residential lighting measures are characterized using lighting saturation data from the recent residential lighting market assessment study and inefficient lighting socket saturation assumptions agreed to by all PAs through their coordination efforts.[22] Table 16 lists the lighting sockets per household assumptions used in this study (i.e., lighting saturation). The study assumes the socket saturation of non-efficient light bulbs to be 20% for all bulb types in the residential sector in 2022.[23] Both saturation and socket saturation assumptions are based on statewide data. The market split between upstream and DI programs is assumed to be the observed split in the 2019 program year.[24]

Table 16. Residential Lighting Sockets per Household Assumptions by Bulb Type and Segment (Sockets per Household)

Bulb Type	Single Family	Multi-Family	Low Income
A-Lamps	35	14	28
Specialty – Reflectors	15	8	6
Specialty – Candelabras, Globes	12	4	8

Note: sockets per home include both interior and exterior sockets.

C&I Lighting

The study includes the non-residential lighting measures listed in Table 17. To ensure coordination between the PA studies, the Potential Study Team team—in collaboration with the PAs—mapped the CLC C&I lighting measure list to the proposed list for the National Grid potential study. Table 17 presents this mapping.

Table 17. Non-residential lighting measures

CLC Measure	National Grid Measure
LED Bulbs / Lamps	Indoor LED Lamp - PAR/BR/MR/A
LED Linear Tubes (T8 and T12)	Indoor LED Linear Lamp
LED Linear Luminaires (T8 and T12)	Indoor LED Linear Fixture/Retrofit Kit
LED High Bays (HID)	Indoor LED Fixture - High/Low Bay
LED Exit Signs	Indoor LED Fixture - Other

[21] Residential DI bulb costs were aligned with the Eversource study.
[22] 2018–19 Residential Lighting Market Assessment Study (RLPNC Study 18–10).
[23] This assumption is based on a residential lighting stock turnover model that estimates efficient lighting saturation.
[24] We use this approach based on the assumption that DI programs are limited by delivery capacity (e.g., number of technicians) and customer willingness (e.g., not every customer wants a technician entering their home) that is reflected in past DI program activity.

CLC Measure	National Grid Measure
LED Parking Garage (exterior)	Exterior LED fixture
LED Pole Mounted (exterior)	Exterior LED fixture
Lighting Controls – Daylighting	Controls
Lighting Controls – Occupancy	Controls
Lighting Controls – Network	Controls

Lighting measures are characterized according to the MA TRM, which calculates savings as a function of the difference between the inefficient and efficient lighting technology's wattage and HOU. Table 18 lists the measure inputs used to characterize C&I lighting measures.

- For C&I LED bulbs and lamps (i.e., screw-based lighting), the study assumes 100% NOMAD by 2022, which eliminates all economic and achievable savings for this measure.
- For linear lighting, the study separately models T8 and T12 baselines and evaluates both as replace on failure (ROF) and ER measure types. The study assumes that linear tubes are treated as ROF and linear luminaires are treated as ER. The study assumes approximately 29% of remaining non-LED tubes and fixtures will be ROF with the rest being ER.[25] The study assumes that approximately 54% of remaining lighting opportunities are T8s and the remaining 46% are T12s.[26]
  - For ER measures, the study assumes claimable savings for the RUL of the replaced fixture and no claimable savings after the RUL, under the assumption an efficient measure would be adopted as baseline. The study assumes ER occurs at two-thirds of the existing equipment's life and that no residual value for the existing equipment remains upon replacement.
- For all other C&I lighting technologies, the input assumption sources are listed in Table 18 below.

Table 18. Non-Residential Lighting Measure Inputs

Input	Input/Source
Delta watts	2019 TRM
HOU	2019 TRM
EUL	For ROF linear lighting and non-linear lighting measures: EUL for inefficient equipment is calculated from TRM lifetime hours and adjusted based on segment specific HOU to derive EUL in years. For ER linear lighting measures: the study assumes an RUL of 5 years (one-third of ballast EUL).
Interactive Effects	Apply fossil fuel heating penalties as per 2019 TRM
NEIs	2019 TRM
NTG	Assume declining NTG factor (see Table 19)
Program eligibility	Assume measures offered in all three study years

[25] This assumption is based on the finding that 29% of lighting installations are considered ROF in the 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14).
[26] This assumption is based on the modeled forecasted saturation of ambient linear technologies under the program scenario in 2020 in the 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14); see Figure 3-4. In 2022, approximately 6% of remaining inefficient bulbs will be T12s and 7% will be T8s.

Table 19 lists the NTG factors for non-residential lighting measures used in this study.

Table 19. Non-Residential Lighting NTG Factors

Segment	2022	2023	2024
Bulbs / Lamps	0.00	0.00	0.00
Linear Lighting (ROF)	0.25	0.25	0.25
Linear Lighting (ER)	0.75	0.75	0.75
High Bays	0.40	0.38	0.35
Exterior Lighting	0.35	0.31	0.28

The markets for non-residential lighting measures are characterized using lighting saturation data from the 2016 C&I Market Characterization Study and inefficient lighting socket saturation assumptions based on the 2019 C&I Lighting Inventory and Market Model Updates final report and agreed to by all PAs through their coordination efforts.[27,28] Table 20 lists the inefficient lighting socket saturation assumptions used in the study. This is based on the inefficient lighting socket saturation listed in the source documentation, then adding 10 percentage points to inefficient lamp socket saturation to each segment to account for expected slowdowns in efficient lighting installations in 2020 and 2021 due to COVID.

Table 20. Non-Residential 2022 Inefficient Lighting Socket Saturation Assumptions

Segment	Inefficient Lighting Socket Saturation
Bulbs / Lamps	10%
Linear Lighting	23%
High/low Bays	27%
Exterior Lighting	34%
Other / Exit Signs [a]	41%

[a] Inefficient lighting saturation for exit signs / other lighting was not included in the C&I Lighting Inventory and Market Model Update. Instead, this study uses recent baseline data from a neighboring jurisdiction to estimate exit signs / other inefficient lighting saturation.

Lighting Controls

Occupancy and daylighting controls are characterized according to the MA TRM, which calculates savings as a function of (1) the controlled fixture's wattage, (2) HOU prior to control installation, and (3) a deemed savings factor.[29] Networked luminaire level controls are characterized according to the WI TRM, which also calculates savings as a function of the controlled fixture's wattage, HOU prior to control installation, and a deemed savings factor.[30] Table 21 lists the savings factor assumptions used in this study.

Table 21. Lighting Controls Savings Factors

Measure	Savings Factor	Source
Occupancy	24%	MA TRM
Daylighting	28%	MA TRM

[27] MA C&I Market Characterization On-site Assessments and Market Share and Sales Trend Study: Volume I – Main Report. November 2016. Accessible at: http://ma-eeac.org/wordpress/wp-content/uploads/MA-CI-Market-Characterization-Study.pdf
[28] 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14)
[29] 2019 Energy Efficiency Plan-Year Report, Appendix 3, Technical Reference Manual. Page 593.
[30] Wisconsin Focus on Energy 2020 Technical Reference Manual. Page 448.

Measure	Savings Factor	Source
Networked	47%	WI TRM

The study accounts for measure interactions resulting from the combined installation of efficient LED lighting and lighting control measures through the DEEP model's chaining algorithm as described in the "Measure Chaining

" subsection.

Home Energy Report Characterization

Home Energy Reports are new within the Compact's 2019–2021 programming, and evaluated savings in 2019 were minimal. To account for the growth of this program over the 2019-2021 timeframe we have aligned the number of participating customers to the 2021 Plan. Considering the HER program's performance in 2019, we have taken a conservative approach to the potential claimable savings from home energy reports in the 2022-24 study period, and derated per-customer savings by 50% compared to the 2021 Plan assumptions.

Market Characterization

Market characterization is the process of defining the size of the market available for each characterized measure. Primary and secondary data are compiled to establish a market multiplier, which is an assessment of the market baseline that details the current saturation of energy-using equipment (e.g., the number of light bulbs per home or business) and proportion of those widgets which are already energy efficient (e.g., the percentage of lightbulbs that are LEDs) in each market sector and segment. The market multiplier is applied to each market segment's population to establish each measure's market.

This study characterized markets by leveraging the Compact's customer data to establish segment populations and baseline data from relevant sources to establish market multipliers. Where possible, baseline data is CLC- or Massachusetts-specific. See Appendix A for a description of baseline market characterization methodology.

Program Characterization

Program characterization is the process of estimating the average administrative program costs—in terms of fixed and variable costs and incentive levels—of existing programs. Inputs generated through the program characterization process include:

- **Fixed costs** are the portion of non-incentive administrative costs that are independent of the amount of savings attributable to the program.

- **Variable costs** are the portion of non-incentive administrative costs that change in magnitude with the amount of savings attributable to the program.
- **Incentives** are the portion of the measure's incremental costs that are covered by the program. Incentive levels vary by program scenario.

This study characterized programs by reviewing the Compact's evaluated 2019 program investments and savings, as well as planned savings and investments in the 2019–2021 EE Plan. For additional context, these were then compared to Dunsky's internal database of program incentive levels and costs from other potential studies and program design work. Only programs with reported savings are included within the model (i.e., Hard-to-Measure initiatives are excluded).[31]

Fixed and variable costs are estimated based on non-incentive costs (i.e., program planning and administration; marketing and advertising; sales, technical assistance & training; evaluation and market research; and performance incentives) reported for modeled programs in 2019. The exception to this is A2d – Residential Behavior, which uses 2021 fixed/variable costs since 2019 was a ramp-up year for this program.

Average BAU incentive levels are estimated based on actual incentives paid in 2019 weighted by savings achieved. BAU+ incentives are determined by increasing BAU incentives by 50% to a maximum of 90% of incremental costs—except for weatherization measures where incentive levels are set to 90%. Incentive levels that exceed 90% under BAU remain unchanged. Max scenario incentives are set at 100% of incremental costs for all measures. Incentives are generally applied at the program level. In cases where average incentive levels for measures at the end-use level differ significantly within a program, sub-program incentive levels are used.

Table 22 shows the average incentive level across all end-uses for each modeled program. Detailed measure-level incentives are available within the detailed data tables in Appendix F.

Table 22. Energy Efficiency Program Characterization Parameters

Program	Fixed Costs	Variable Costs[a]	Average Incentive Level[b]		
			BAU	BAU+	Max
A1a - Residential New Homes & Renovations	$148,348	$15.00	37%	90%	100%
A2a - Residential Coordinated Delivery	$2,085,472	$92.40	85%	93%	100%
A2c - Residential Retail	$853,570	$10.34	67%	84%	100%
A2d - Residential Behavior	$39,185	$1.10	100%	100%	100%
B1a - Income Eligible Coordinated Delivery	$592,456	$255.53	100%	100%	100%
C1a - C&I New Buildings & Major Renovations	$108,388	$18.48	71%	85%	100%
C2a - C&I Existing Building Retrofit	$1,094,484	$24.72	65%	84%	100%
C2b - C&I New & Replacement Equipment	$196,818	$11.36	60%	74%	100%

[a] Variable costs are expressed in terms of dollars ($) per annual GJ saved.

[31] Hard-to-Measure initiatives do not have immediate energy savings, or their energy savings may be difficult to quantify. Examples include demonstration projects, educational programs and Evaluation, Measurement, and Verification.

[b] Incentive levels are expressed in terms of percentage of incremental cost. The values presented here are simple averages for each program across end uses; in cases where incentives are broken down by end use for modeling, the specific incentive levels used are available in the detailed data tables.

Economic Parameters

DEEP harnesses key economic parameters such as avoided costs, retail energy and demand rates, and discount rates to assess measure cost-effectiveness and customer adoption. Appendix A outlines the development of these inputs, which were used across all modules of this study.

Adoption Parameters

DEEP requires several key inputs to determine achievable measure adoption including market barrier levels and measure ramp-up levels.

- **Market barrier levels** define maximum adoption rates and are assigned for each measure-market combination based on market research, professional experience, and evidence of participation in existing programs. Different end-uses and segments exhibit different barriers. Barrier levels may change over time if market transformation effects are anticipated.
- **Measure ramp-up levels** modify the initial uptake of measures not offered by existing programs and/or offered at lower levels than expected given the market context to account for ramping up new programs and measure marketing. In this study, measures that represent significant savings and are not currently offered by existing programs have ramp-up rates of 33%, 66%, and 100% applied in the first three years of the study, respectively. For measures that are currently offered but at levels lower than expected, ramp-up rates of 50%, 75%, 100% were applied in the first three years, respectively.

Assess Potential

Using the comprehensive set of model inputs, DEEP assesses three levels of energy savings potential: technical, economic, and achievable. In each case, these levels are defined based on the governing regulations and practice in the modeled jurisdiction, such as applying the appropriate cost-effectiveness tests, and applying the relevant benefit streams and NTG ratios to ensure consistency with evaluated past program performance. Table 23 provides a summary of how DEEP treats each potential type.

Table 23. DEEP Treatment of Technical, Economic, and Achievable Potential

Applied Calculation	Technical Potential	Economic Potential	Achievable Potential
Cost-Effectiveness	No screen	TRC	Participant Cost Test
Market Barriers	No barriers (100% Inclusion)	No barriers (100% Inclusion)	Market barriers (Adoption Curves)
Competing Measures	Winner takes all	Winner takes all	Competition groups applied
Measure Interactions	Chaining adjustment	Chaining adjustment	Chaining adjustment
Net Savings	Not considered	Program Net-to-Gross Ratios (NTGRs)	NTGRs

For each level of potential, DEEP calculates annual and cumulative potential:

- **Annual potential** is the incremental savings attributable to program activities in the study year. It includes re-participation in programs (e.g., when a customer may receive an incentive for a new heat pump to replace a heat pump previously received through the program).[32] DEEP expresses annual potential both in terms of incremental lifetime savings and incremental annual savings. This is the most appropriate measure for annual program planning and budgeting.
- **Cumulative potential** is the total savings attributable to program activities from the beginning of the study period to the relevant study year. It accounts for mid-life baseline adjustments to measures implemented in previous years, as well as the retirement of savings for measures reaching their end of life. As such it does not include new savings for re-participation in programs, thereby providing an assessment of the cumulative impact of the measure/program (e.g., the reduction in energy sales). This is the most appropriate measure for resource planning.

Technical and Economic Potential

Technical potential is all theoretically possible energy savings stemming from the applied measures. Technical potential is assessed by combining measure and market characterizations to determine the maximum amount of savings possible for each measure-market combination without any constraints such as cost-effectiveness screening, market barriers, or customer economics. This excludes early replacement and retirement opportunities, which are to be addressed in the subsequent achievable potential analysis. Technical potential is calculated for each year in the study period.

DEEP's calculation of technical potential accounts for markets where multiple measures compete. In these instances, the measure procuring the greatest energy savings is selected while all other measures are excluded to avoid double counting energy savings while maximizing overall technical energy savings (see description of measure competition below for additional detail).

Additionally, the calculation of technical potential also accounts for measures that interact and impact the savings potential of other measures (see description of measure interactions below for additional detail).

EXAMPLE

Mid-Life Baseline Adjustments

Where a new standard may alter the baseline of a measure before the end of its EUL, the model removes a portion of the savings for previously installed measures from the cumulative savings for that measure. The amount removed is equivalent to the difference between the baselines, which may represent all or just a portion of the previously installed measure's cumulative savings.

Economic potential is a subset of technical potential that only includes measures that pass cost-effectiveness screening. Economic screening is performed at the measure level and only includes costs related to the measure. All benefits and costs applied in the cost-effectiveness screening are multiplied by their corresponding cumulative discounted avoided costs to derive a present value ($) of lifetime benefits. All benefits and costs are adjusted to real dollars expressed in the first year of the

[32] Because this study covers only three program years, program re-participation has a negligible impact on savings.

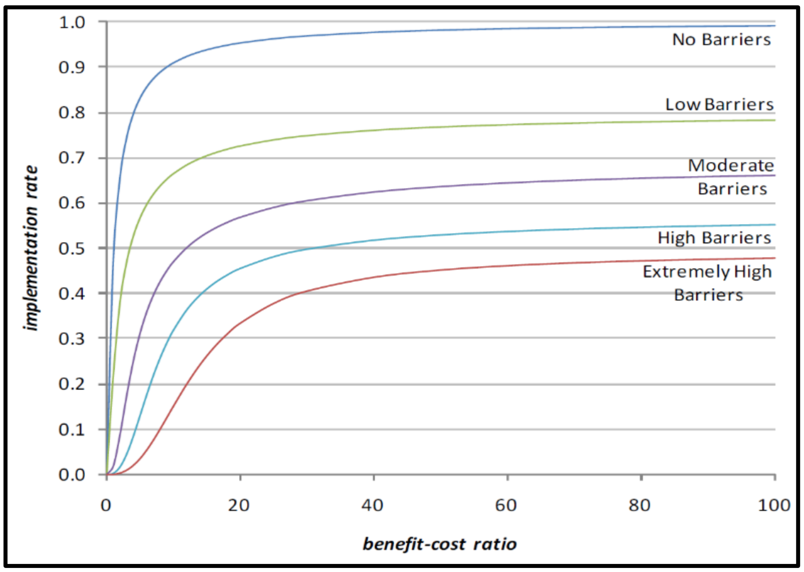
study. Economic screening does not include general program costs. Like technical potential, the calculation of economic potential also accounts for measure competition and interaction.

This study screens measures based on the TRC. Measures with a benefit-cost ratio below 1.0 are excluded from economic potential.

Achievable Potential and Scenario Modeling

Achievable potential is the energy savings stemming from the customer adoption of energy-savings measures. Rooted in the United States Department of Energy (DOE) adoption curves,[33] DEEP defines annual adoption rates based on a combination of customer cost-effectiveness and market barrier levels. Customer cost-effectiveness is calculated within the model based on inputs from measure and program characterization as well as economic and adoption parameters. Figure 2 presents a representative example of the resulting adoption curves.

Figure 2. Representative Example of Adoption Curves



While this methodology is rooted in DOE's extensive work on adoption curves, it applies two important refinements as described below:

- **Refinement #1: Choice of the cost-benefit criteria.** The DOE model assumes that participants make their decisions based on a benefit-cost ratio calculated using discounted values. While this may be true for some non-residential customers, experience shows that most consumers, especially residential ones, use simpler estimates, including simple payback periods. This has implications for the choice and adoption of measures since payback period ignores the time value of money as well as savings after the break-even point. The model converts DOE's discount rate-driven curves to equivalent curves for payback periods and applies simple and discounted payback periods based on sector. Generally, DEEP assumes residential customers assess cost-effectiveness by considering a measure's simple payback period, but all commercial customers assess cost-effectiveness by considering a discounted payback period.

[33] The US DOE uses this model in several regulatory impact analyses. An example can be found in http://www.regulations.gov/contentStreamer?objectId=090000648106c003&disposition=attachment&contentType=pdf, section 17-A.4.

- **Refinement #2: Ramp-up.** Two key factors—measure awareness and program delivery structure—can limit program participation, especially during the first few years after a program's launch or redesign, and result in lower participation than DOE's achievable rates would suggest. For example, a new home retrofit program that requires the enrollment and training of skilled auditors and contractors by program vendors could take some time to achieve the uptake assumed using DOE's curves. As described under adoption parameter development, this study applies ramp-up assumptions but then adjusts adoption rates on a case-by-base basis where appropriate.

Scenario Modeling

Multiple levels of achievable potential (i.e., BAU, BAU+, and Max) are modeled within DEEP by applying varying incentive and market barrier levels, which impact the degree of customer adoption. Additional details on parameters for each scenario can be found in the "Program Characterization

" subection. Varying levels of achievable adoption will also impact program spending by modulating incentive payments and variable program costs. As part of program characterization, variable program costs may be adjusted between scenarios to account for increased program expenses for providing additional enabling activities above current program levels.

It is important to note that program cost estimates are based on historical costs and DEEP does not consider dynamic impacts on program budgets resulting from internal (to the program) and external factors impacting program and incremental costs. For example, the variable cost of delivering programs may decline over time as program learnings are applied to future administrative and delivery practices within a program, or incentive costs may decline if incremental costs decline over time. Likewise, program costs may increase if factors lead to increasing measure costs; for example, the lack of enough contractors to deploy high adoption measures leading to an increase in overall labor costs.

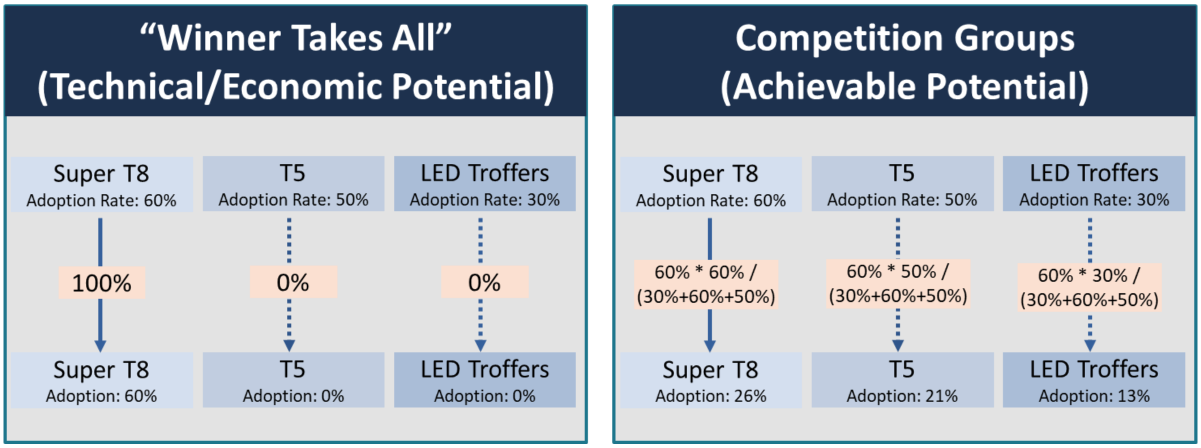
Measure Competition

Measure competition occurs when measures share the same market opportunity but are mutually exclusive. For example, LED troffers, T5 lamps, and Super T8 lamps can all serve the same market opportunity but will not be simultaneously adopted. In these cases, DEEP assesses the market potential for each measure as follows:

- **Technical Potential**: 100% of the market is applied to the measure with the highest savings.
- **Economic Potential:** 100% of the market is applied to the measure with the highest savings that passes cost-effectiveness screening.
- **Achievable Potential**: The market is split between all cost-effective measures by prorating the achievable adoption rate based on the maximum adoption rate and each of the measures' respective adoption rates.

Figure 3 presents an example where three measures compete: LED troffers, Super T8, and T5 lamps. First, the adoption rate is calculated for each measure independent of any competing measures, as outlined in the figure below. Based on this assessment, the maximum adoption rate is 60%, corresponding to the measure with the highest potential adoption. Next, the adoption of each measure is prorated based on their relative adoption rates to arrive at each measure's share of the 60% total adoption rate. As a result, the total adoption rate is still 60%, but it is shared by three different measures.

Figure 3. Example of DEEP Measure Competition

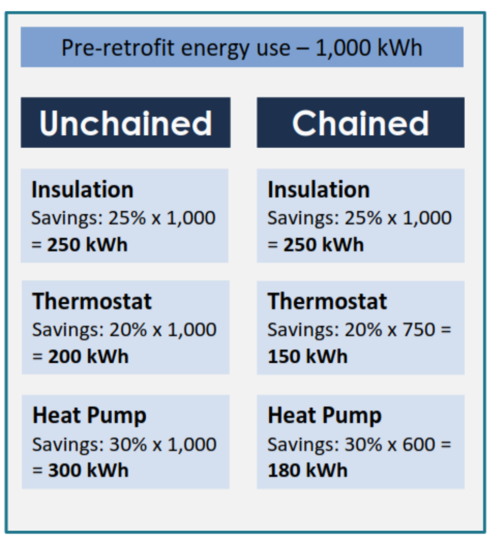


Measure Chaining

Measure interactions occur when the installation of one measure will impact the savings of another measure. For example, the installation of more efficient insulation will reduce the savings potential of subsequently installing a smart thermostat. In DEEP, measures that interact are "chained" together and their savings are adjusted when other chained measures are adopted in the same segment. Chaining is applied at all potential levels, and these interactive effects are automatically calculated according to measure screening and uptake at each potential level.

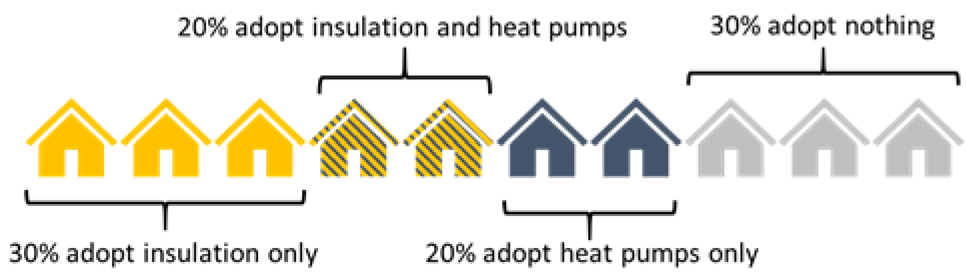
DEEP applies a hierarchy of measures in the chain, reducing the savings from each measure that is lower down the chain. The model adjusts the chained measures' savings for each individual measure, with the final adjustment calculated based on the likelihood that measures will be chained together (determined by their respective adoption rates) and the collective interactive effects of all measures higher in the chain. Figure 4 provides an example of the calculations used to determine the interactive savings effects for a customer where insulation is added in addition to a smart thermostat and a heat pump.

Figure 4. Example of Savings Calculation for DEEP Chained Measures



The model estimates the number of customers adopting chained measures based on the relative adoption rates of each measure. In an example where insulation has a 50% adoption rate and heat pumps have a 40% adoption rate in isolation, when chaining is considered, the model might assume 40% of customers adopting insulation will also install a heat pump, which means 50% of customers adopting a heat pump will also improve their installation levels. This segments the market into customers adopting only one of the measures, customers adopting both measures, and customers adopting none of the measures as shown in Figure 5.

Figure 5. Representative Example of Adoption for DEEP Chained Measures



Note: The above figure is representative of the DEEP model's treatment of chained measures only and not representative of any actual program or measure inputs. In many cases, efficiency programs require weatherization prior to the incentivization of a heat pump.

Appendix D. Heating Electrification Methodology

Overview

The HE potential analysis estimates the market opportunity for electrifying existing and yet-to-be-built natural gas, oil, and propane primary space and water heating systems for CLC's residential and commercial electric customers. The potential is estimated using Dunsky's HEAT™ model, a highly granular bottom-up model.

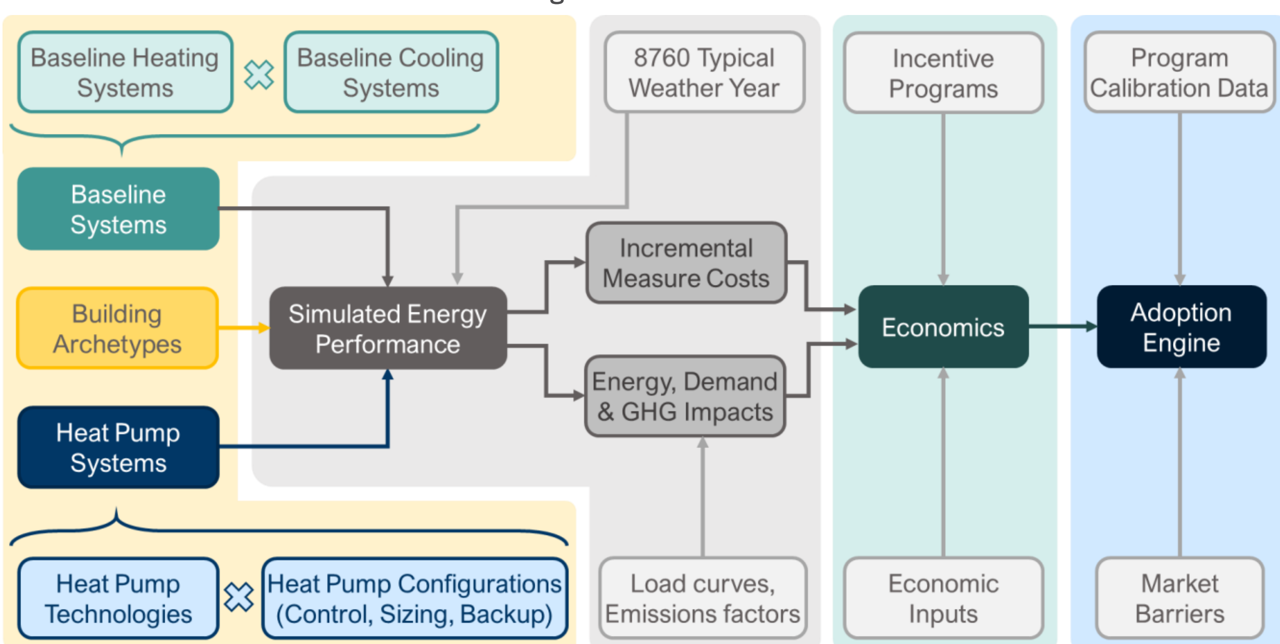
The following sections describe the HEAT™ model, modeling steps, and model inputs and sources used for this study.

HEAT Model

The costs and benefits of heating electrification are highly dependent not only on the baseline systems and their potential electrified replacements but also on the remaining useful lives of both heating and cooling systems, partial vs. full replacements, heat pump sizing, and control strategies. Moreover, the heat pump's performance (capacity as well as efficiency) varies according to the outdoor air (or ground) temperature.

To account for this, HEAT was designed to model multiple permutations of replacement cases, sizing strategies, and control strategies for each combination of baseline heating system, baseline cooling system, and heat pump technology. HEAT simulates the baseline and heat pump cases to calculate their energy performance and full cost, which allows HEAT to yield the incremental costs and savings for thousands of modeled cases.

Figure 6. HEAT Model Flow



HEAT Modeling Steps

As outlined in Figure 6, the general approach for estimating heating electrification potential consists of defining building archetypes; defining baseline heating and cooling system configuration; defining valid heat pump systems for each baseline configuration; modeling the heat pump's performance given prevailing climatic conditions; calculating incremental costs and energy/demand impacts, and using those results to calculate measure cost-effectiveness and customer economics; and assessing customer adoption under various achievable scenarios.

The remainder of this section outlines each of these modeling steps.

Building Archetypes

The first step is to define a building archetype which represents each market segment, including its heating, cooling, and domestic hot water loads. Each archetype is then equipped with many possible configurations of baseline heating and baseline cooling systems, as described in the "Baseline Systems" subsection below.

Market Segments

Table 24 lists the market segments, for which a building archetype is defined.

Table 24. Building Segments

Residential Segments	C&I Segments
Single Family (furnace)	Office
Single Family (boiler)	Retail
Multi-family	Food Service
Low Income	Healthcare/Hospitals
	Campus/Education
	Warehouse
	Lodging
	Other Commercial
	Food Sales
	Manufacturing/Industrial

Building Vintage

Each building segment is modeled both as an average existing building archetype and as a new construction/major renovation building archetype.

Heating & Cooling Loads

Instead of modeling the energy consumption of each equipment independently, space heating and cooling loads are derived for each archetype in terms of annual loads and distributed hourly based on the outdoor air temperature, similar to a temperature-bin model. Each heating and cooling system, therefore, must meet these building loads. Water heating loads are assessed separately from space heating loads.

Baseline Systems

For each building archetype, several heating and cooling systems exist, which could be replaced, partially or fully, with a heat pump system, both in existing buildings and new construction. These heating and cooling systems are the baseline systems.

Baseline Space Heating System

As shown in Table 25, each building archetype can have multiple combinations of heating fuel and baseline heating equipment. The modeled baseline heating equipment types are furnaces, boilers, and packaged rooftop units (RTU). Each of these heating equipment types can be fired by three fuels modeled through HEAT: natural gas, fuel oil, and propane.

Note that replacing electric resistance heat with heat pumps is considered an energy efficiency measure instead of an electrification opportunity and is therefore included in the results of the DEEP model (Appendix C).

Baseline Cooling System

Buildings using each of these baseline heating equipment types and heating fuels can be combined with various cooling systems. For the residential sector, HEAT models central air conditioners and room air conditioners. For C&I buildings, chillers and central package air conditioners are also included.

For the Room Air Conditioner space cooling baseline, this study uses window AC units for residential buildings[34] and a blend of window and ductless mini-split AC units for commercial buildings.

Table 25 lists the baseline heating fuel, heating equipment, and cooling system baselines considered in this study.

Table 25. Baseline Systems

Sector	Baseline Fuel	Baseline Space Heating Equipment	Baseline Space Cooling System
Residential	▪ Natural gas ▪ Fuel oil ▪ Propane	▪ Boiler ▪ Furnace	▪ Central Air Conditioner ▪ Room Air Conditioner ▪ No Air Conditioning
C&I	▪ Natural gas ▪ Fuel oil ▪ Propane	▪ Boiler ▪ Furnace ▪ Packaged Rooftop Unit (RTU)	▪ Chiller ▪ Central Package Air Conditioner ▪ Central Split Air Conditioner ▪ Room Air Conditioner Blend ▪ No Air Conditioning

[34] Assumption from RES21 Energy Optimization Study

Customers without Air Conditioning

The study includes buildings without any air conditioning (AC). For this space cooling baseline, the study assumes that a portion of these customers would have adopted AC in the absence of adopting a heat pump, and a portion who would not have adopted AC. For residential customers, this study uses a 50/50 split of customers without AC who would / would not have adopted AC, while for C&I it is assumed that customers without AC would not have adopted AC.

For customers without AC who would not have adopted AC, since the counterfactual is no space cooling at all, the incremental cost of space heating electrification is the full incremental cost of the heat pump, and electric energy and demand used for space cooling are treated as negative savings (i.e., increased consumption vs baseline).

For the remainder of customers—without AC, but who would have adopted AC—the incremental cost of space heating electrification will be reduced, and measure adoption will result in energy and demand savings from space cooling as the heat pump will provide more efficient space cooling than the counterfactual baseline AC equipment. The counterfactual cooling equipment is assumed to be central AC where customers have a furnace, and a room AC where they have a boiler.

Baseline Water Heating System

While many hot water systems can be electrified through a custom project, this study focuses on storage water heaters, which can be replaced on a one-for-one basis with electric heat pump water heaters. This is summarized in Table 26.

Table 26. Baseline Water Heaters

Market	Baseline Water Heater	Included in Study
Residential	Storage Water Heater	✓
	Tankless Water Heater	✓
	Combination Boiler	×
C&I	Storage Water Heater	✓
	Tankless Water Heater	×
	Indirect Water Heater	×
	Volume Water Heater	×

Heat Pump Systems

Each combination of baseline heating system and baseline cooling systems can be replaced partially (resulting in a dual-fuel or hybrid system) or fully (resulting in an all-electric system) using various heat pump technologies.

Heat Pump Technologies

Table 27 summarizes the heating electrification technologies considered in this study.

Table 27. Heating Electrification Technologies

Sector	End-use	Heat Pump Technology
Residential	Space heating	▪ Cold climate ductless mini-split heat pump (ccDMSHP) [a] ▪ Cold climate central ducted air source heat pump (ccASHP) [a] ▪ Water-to-air ground-source heat pump (GSHP) ▪ Water-to-water ground source heat pump (GSHP)
	Water heating	▪ Heat pump storage water heaters (HPWH)
C&I	Space heating	▪ Cold climate ductless mini-split heat pump (ccDMSHP) [a] ▪ Cold climate central ducted air source heat pump (ccASHP) [a] ▪ Packaged rooftop cold climate air source heat pump (RTU ccHP) ▪ Variable refrigerant flow heat pump (VRF) ▪ Air-to-water heat pump (ATWHP) ▪ Water-to-air ground source heat pump (GSHP) ▪ Water-to-water ground source heat pump (GSHP)
	Water heating	▪ Heat pump storage water heaters (HPWH)

[a] It is assumed that all heat pumps that go through Mass Save's Fuel Optimization program are cold climate models, as the models in the Heat Pump Qualified Product List (HPQPL) are at or above the NEEP definitions for cold-climate, and while the HPQPL does not include NEEP's COP requirement at 5 °F, it does require a level of cold climate performance through a minimum capacity degradation requirement at 17 °F.

Each of the heat pump technologies can be sized and controlled in different ways and can have different backup systems. The backup, sizing, and control options included in the model are described below.

Heat Pump Backup

A heat pump's backup system serves both as supplementary heat source when using the heat pump is not optimal (e.g., when the heat pump's output capacity does not meet demand, or when the cost of heating with the heat pump exceeds the cost of heating with the backup), and as a source of emergency heat in the case of heat pump failure. The backup can either be the existing fuel-fired heating system, or a dedicated system, such as an electric resistance coil built into the air handling unit.

HEAT models both a full replacement case, where the baseline heating system and cooling system are removed and replaced by a heat pump with an electric resistance backup system, and a partial replacement case, where the cooling system is removed, but the baseline heating system remains in place to act as the heat pump backup, resulting in a dual-fuel or hybrid system.

Heat Pump Sizing

Heat pumps lose some capacity as outdoor temperatures drop. Consequently, sizing strategies aim to determine the right balance to leverage the heat pump's high efficiency while limiting costly oversizing. The optimal sizing strategies can differ between partial replacements (dual fuel) and full replacements (all electric), where the backup heating equipment has various installation and energy cost considerations.

Where needed, HEAT can simulate multiple competing sizing strategies for each heat pump.

Heat Pump Controls

Similar to heat pump sizing, multiple control strategies can offer various levels of system performance for the same installed equipment. These control strategies can be split into two categories:

- **Switchover temperature**: The heat pump runs only above a pre-defined outdoor air temperature, and the backup system—whether electric or fuel-based—supplies the full heating load under that switchover temperature. Optimal switchover temperatures can vary based on the difference in rates and equipment efficiency (electric heat pump vs. fuel-based heating equipment).
- **Run together**: The heat pump supplies the heat it can at specific outdoor air temperatures, and the backup system—whether electric of fuel-based—supplies the remaining heat to match the building's heating load.

HEAT can simulate multiple competing control strategies for each heat pump measure.

Matching Heat Pump Technologies to Baseline Systems

Not all heat pump technologies are applicable to all baseline systems. In general, the type of existing distribution system (hydronic pipes, ventilation ducts, refrigerant piping) defines the valid heat pump technology for a specific baseline system. Baseline cooling systems are also an important consideration since heat pumps may replace the existing AC equipment and will also provide space cooling services. In HEAT, valid baseline configurations are constrained to include only commercially viable and non-deep-retrofit options. For example, the study does not consider replacing a hydronic-only system (e.g., gas-fired boiler) with a forced-air heat pump system (e.g., central ducted ASHP) due to the high cost of these types of deep retrofits. Table 28 summarizes the valid applications of the different heat pump technology mapping used in the study.

Table 28. Valid Heat Pump Applications

Sector	Heat Pump Measure	Baseline Configurations
Residential	ccASHP	Furnaces; Boilers with central ducted AC units
	ccDMSHP	Boilers only
	Water-to-air GSHP	Furnaces; Boilers with central ducted AC units
	Water-to-water GSHP	Boilers only
C&I	ccDMSHP	Boilers with room AC or no AC
	ccASHP	Furnaces; Boilers with central ducted AC units
	RTU ccHP	Packaged rooftop units; Boilers with central packaged units
	VRF	New construction & Major renovations only
	Air-to-water HP (ATWHP)	All boiler-based systems
	Water-to-air GSHP	All duct-based systems (furnaces, RTUs)
	Water-to-water GSHP	All boiler-based systems

Simulated Energy Performance

A heat pump's performance (capacity as well as efficiency) varies according to the outdoor air (or ground) temperature. For each combination of baseline heating system, baseline cooling system, and heat pump technology, HEAT is designed to model multiple permutations of replacement case (partial vs. full), sizing strategy and control strategy, and simulates both the baseline and heat pump cases to calculate their energy performance. The model combines hourly temperature data, building heating and cooling loads, floor areas, and sizing strategies to compute the required heat pump size, hourly heat pump efficiency, and hourly heat pump output capacity.

Hourly Simulation

The heating and cooling loads for each building archetype are simulated in HEAT using an approach similar to a temperature-bin model, but where every hour of the year (8,760) is simulated. That enables heat pumps to be assessed precisely, based on their outdoor air temperature-based capacity and efficiency curves, and also captures the impact on a customer's electricity bill more precisely for rates which include a demand charge ($ per kW).

For each heating electrification measure, HEAT computes the required system size and energy performance of both the baseline system and the heat pump plus backup system based on hourly temperature data, building heating/cooling load, floor area, sizing strategy, and control strategy. Where the heat pump is sized based on heating demand, HEAT sizes the heat pump based on its capacity at the design outdoor air temperature, rather than by using its nominal capacity.

Energy, Demand, and Greenhouse Gas Impacts

To determine the energy and demand impacts of a partial or full retrofit, both the baseline case and the heat pump case are simulated as described above. The difference between the baseline and heat pump simulations yields the hourly energy savings, and therefore the demand savings.

For the summer and winter utility peak impacts, the hottest and coldest hour within the peak window is identified prior to the model run, so that the peak impact at those two specific hours can be assessed from the hourly simulations.

For building-level peak impacts, the hourly heating and cooling demand is added to the building's 8,760 load profile for other end uses. The monthly maximum demand is calculated and compared between the baseline and the retrofitted case. This approach allows HEAT to account for shifts in the timing of the peak due to electrification of the heating system.

Greenhouse gas (GHG) impacts are determined by multiplying average annual emissions factors by the fuel-specific energy savings (or increase).

Economics

The model combines the incremental measure costs with energy and maintenance savings to produce customer, utility, and societal financial metrics.

Cost Streams

The incremental measure costs are defined as the difference between the expected full cost streams of the baseline case (replacing each equipment at the end of its useful life) and the altered cost streams after installing heat pumps, accounting for the avoided cost of the replaced heating and/or cooling system, where applicable. A discount rate is applied to these future cost streams to get the present value of both the baseline and the retrofit cases, which are compared to yield the incremental measure cost.

This approach allows for the computation of tens of thousands of combinations of baseline heating and cooling systems, heat pump technologies, heat pump sizing strategies, control strategies, and backup equipment.

Assessment of Equipment Installed Costs

Measure capital and maintenance costs are computed with a bottom-up approach based on equipment capacity within the HEAT model.

For each heat pump and baseline technology, we determine a fixed and variable cost for the assumed efficiency of equipment so that the equipment costs are closer to reality, where a 2-ton unit is less than twice the cost of a single-ton unit—in other words, using a single dollar per ton cost would underestimate the cost of a small unit and/or overestimate the cost of larger units.

Early Replacement Opportunities

HEAT includes both the heating system burnout and cooling system burnout as replacement opportunities, as well as some ER opportunities. Since most baseline heating and cooling equipment will likely not reach their end of life at the same time, at least one of them might be replaced early with the installation of heat pumps. Moreover, the economics for the ER of both heating and cooling equipment with a heat pumps can be compelling in some cases.

Therefore, HEAT includes some ER opportunities every year. Figure 7 shows a representation of replacement opportunities for a hypothetical case where the baseline cooling system has an EUL of 9 years and the heating system has an EUL of 6 years (simplified for representation purposes).

Based on input from the PAs, the cooling system threshold for early replacement is set at two-thirds of useful life (i.e., if the cooling system is above that age threshold, the customer is considered as an opportunity for heating electrification). The PAs are not targeting heating system ER, so only heating systems that are at their end of life are considered a trigger for a heating electrification opportunity. As the economics might not be favorable for a certain ER case, those who do not adopt a heating electrification measure are simply considered again the next year, when the economics are likely more favorable than the previous year as the equipment ages. This continues until either the cooling or heating equipment reaches its end of life, which is then considered a ROB case.

Figure 7. Early replacement and replace on burnout (ROB) opportunities

		Age of the cooling system								
		1	2	3	4	5	6	7	8	9
Age of the heating system	1	(not yet eligible for replacement)						Eligible for ER		Cooling system ROB
	2	(not yet eligible for replacement)						Eligible for ER		Cooling system ROB
	3	(not yet eligible for replacement)						Eligible for ER		Cooling system ROB
	4	(not yet eligible for replacement)						Eligible for ER		Cooling system ROB
	5	(not yet eligible for replacement)						Eligible for ER		Cooling system ROB
	6	Heating system ROB								Both ROB

Cost-Effectiveness

HEAT computes financial metrics that highlight the measure's cost-effectiveness from a customer's perspective: simple payback (years), Internal Rate of Return (IRR), and Net Present Value (NPV). The model also computes various cost-effectiveness test ratios (PCT, PACT, TRC, SCT[35]) from their applicable costs and benefits.

These cost-effectiveness metrics are leveraged for economic screening, economics-driven adoption, or reporting purposes. Screening takes place at the most granular level (e.g., Single Family home with an oil boiler and a room AC at the end of its useful life, partially replaced with a ccDMSHP sized for cooling with a switchover temperature of 30°F, in 2022).

Adoption Engine

The final step in the modeling is the adoption engine, which involves the calibration of diffusion curves to historical program uptake and the forecast of heat pump adoption based on customer economics, technology diffusion, and competition between measures.

Assess Potential

In addition to the technical and economic potential, multiple achievable scenarios can be forecasted based on incentive levels, energy rates, the rate of cost decline, barrier levels, and heat pump availability. The three achievable scenarios for the heating electrification module of this study are BAU, BAU+, and Max. Details for these scenarios are listed in Table 42 in the "Jurisdictional Inputs" subsection below.

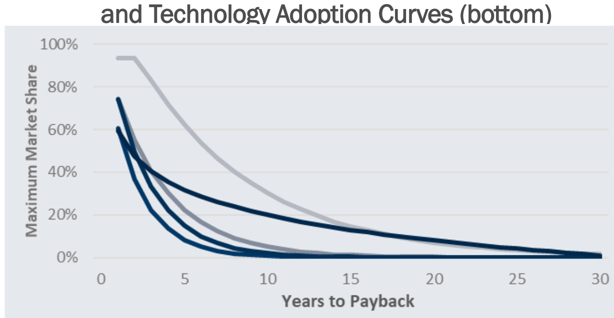
Technology Diffusion

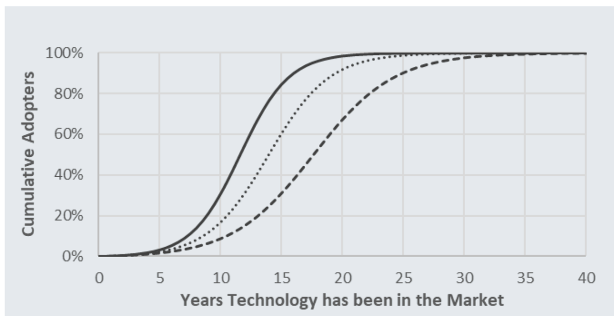
As heating electrification is an emerging trend in energy efficiency programs, HEAT's adoption engine is built on two factors:

- **Customer Economic Potential**: The expected uptake driven by customer economics and willingness-to-pay for heat pumps. Decision-making is assumed to be based on simple payback (years) for residential customers and on IRR for commercial customers. Sample willingness-to-pay curves are shown in Figure 8.
- **Technology adoption**: The rate of adoption of heat pumps over time, considering local barriers and market characteristics, is captured through Bass Diffusion curves, where new adopters are classified as either innovators or imitators. Key model parameters are calibrated using historical uptake trends from programs.

[35] Defined as the Participant Cost Test, Program Administrator Cost Test, Total Resource Cost Test, and Societal Cost Test, respectively.

Figure 8. Customer Economics Curves (top) and Technology Adoption Curves (bottom)





Measure Competition

The model accounts for competing measures available to potential adopters to estimate the proportion of customers that will opt for a given measure given the economics and barriers they face. A specific building archetype with specific baseline heating and cooling equipment can be electrified through several combinations of heat pump technologies, heat pump sizing strategies, backup equipment, and control strategies; these combinations are all modeled and put in competition by the HEAT model.

- **Technical Potential**: 100% of the market is applied to the measure with the highest savings.
- **Economic Potential:** 100% of the market is applied to the measure with the highest savings that passes cost-effectiveness screening.
- **Achievable Potential**: The market is split between all cost-effective measures by prorating the adoption rate based on the maximum adoption rate and each of the measures' adoption rates.

HEAT Model Inputs

HEAT requires an extensive set of model inputs related to heating and cooling technologies, markets, economic factors, and adoption parameters to accurately assess heating electrification potential.

This section presents details on the inputs used in this potential study, starting with measure inputs (equipment costs and efficiencies), followed by heat pump sizing and control inputs, market inputs (populations and market shares), and concluding with jurisdictional inputs (economic inputs and weather data).

Table 29 lists the sources and references used, following the same format as the equivalent table from the EE module in Appendix C.

Table 29. HEAT Measure Input Sources

Key	Source
MA-2	Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2019–2021: Plan Version.
MA-3	MA RES21, Energy Optimization Study
MA-4	MA RES19 Water Heating, Boiler, and Furnace Cost Study
MA-5	MA RES23 Cost Study of Heat Pump Installations for Dual Fuel Operation
MA-6	MA RES28 Ductless Mini-Split Heat Pump Cost Study
ASHRAE	ASHRAE Journal Article, Long-Term Commercial GSHP Performance, Part 4: Installation Costs, 2012
NY-1	Energy + Environmental Economics New York Heat Pump Potential Model Overview, 2019
RI-4	Brattle Group Heating Sector Transformation, and Heating Sector Transformation in Rhode Island: Technical Support Document
PSEG-LI	PSEG Long Island Technical Reference Manual – 2019
EIA	EIA, Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, 2018

Measure Inputs

This section provides detail on the measure inputs used in the HEAT model, in particular the capital costs, maintenance costs, and EUL of various heating and cooling technologies and heat pumps.

Note that the costs are calculated in HEAT based on a combination of fixed and variable costs depending on equipment size. For reporting purposes, existing Single Family Homes are used as reference size for residential equipment, while existing Office Buildings are used as reference size for commercial equipment.

Measure-level inputs and results are provided in the detailed results workbooks, found in Appendix F in Excel Workbook format.

Baseline Space Heating Equipment

Residential

Table 30. Residential Baseline Space Heating Equipment Specifications (existing Single-Family Home)

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	AFUE	EUL
Gas Boiler	110	$6,000	$90	79%	20
Oil Boiler	110	$4,600	$140	75%	20
Propane Boiler	110	$6,600	$90	75%	20
Gas Furnace	80	$4,900	$40	85%	17
Oil Furnace	80	$6,600	$70	79%	18
Propane Furnace	80	$4,900	$40	79%	18

Commercial

Table 31. Commercial Baseline Space Heating Equipment Specifications (existing Office Building)

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	AFUE	EUL
Gas Boiler	300	$11,500	$340	79%	20
Oil Boiler	300	$12,500	$340	75%	20
Propane Boiler	300	$12,500	$340	75%	20
Gas Furnace	300	$8,900	$420	85%	18
Oil Furnace	300	$9,500	$420	79%	17
Gas RTU	300	$0 [a]	$0 [a]	85%	17

[a] Costs accounted for on the cooling baseline side (Central Package Air Conditioner)

Baseline Space Cooling Equipment

Residential

Table 32. Residential Baseline Space Cooling Equipment Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	SEER	EUL
Central Split AC	2.5	$3,400	$70	10	14
Room AC (window AC)	2.5	$750	$40	8	8

Commercial

Table 33. Commercial Baseline Space Cooling Equipment Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	SEER	EUL
Chiller	15	$58,100	$800	16	23
Central Package Air Conditioner	15	$28,300	$660	12	17
Central Split Air Conditioner	15	$11,900	$360	10	14
Room AC Blend [a]	15	$10,700	$180	8	8

[a] 50/50 split of window air-conditioners and ductless mini-split air-conditioners.

Heat Pump Equipment

Heat pump installed costs include costs for controls, integration, and electrician costs. The costs used here are based primarily on Massachusetts-specific studies and are higher than costs typically seen in other studies. The prefix “cc” refers to cold climate heat pumps (refer to note to Table 27 on page 39). Measure applicability is summarized in Table 28.

Residential

Table 34. Residential Heat Pump Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	EUL	COP [a]	SEER
ccDMSHP (multihead)	2.5	$11,600	$90	18	-	20
ccASHP (central ducted)	2.5	$13,000	$90	17	-	18
GSHP (Water-to-Air)	2.5	$22,800	$90	25	-	17
GSHP (Water-to-Water)	2.5	$26,700	$90	25	-	N/A

[a] Refer to Figure 9 for heat pump COP relative to outdoor air temperature.

Commercial

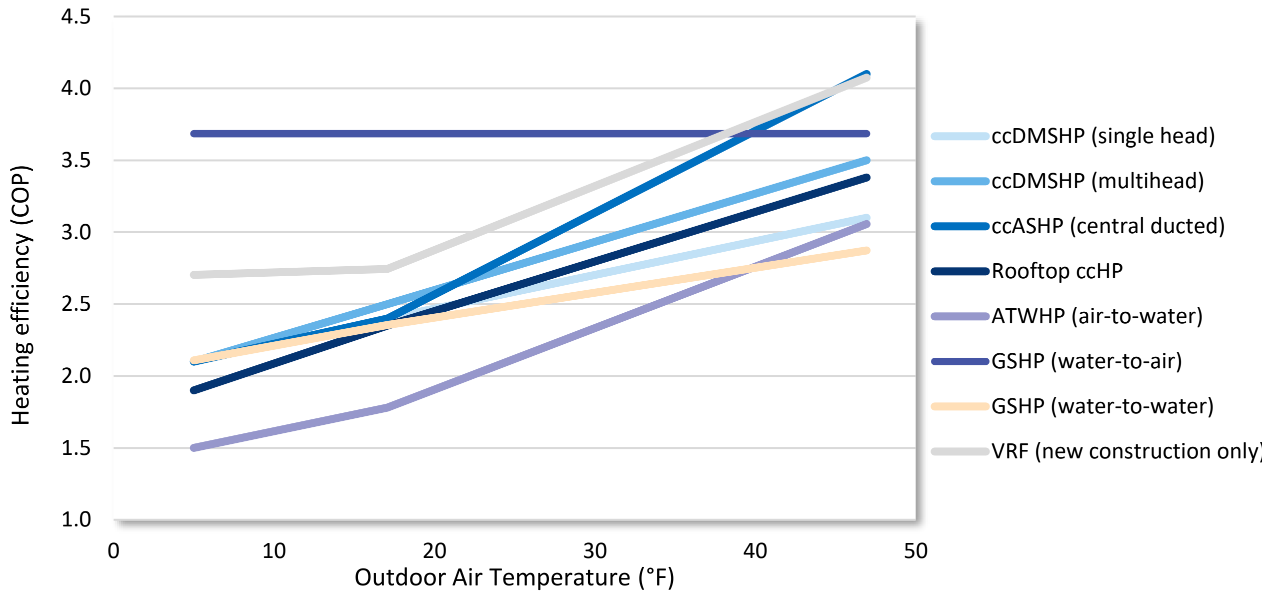
Table 35. Commercial Heat Pump Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	EUL	COP [a]	SEER
ccDMSHP (multihead)	15	$67,600	$450	18	-	20
ccASHP (central ducted)	15	$74,600	$450	17	-	18
RTU ccHP	15	$55,100	$620	17	-	18
GSHP (Water-to-Air)	15	$97,400	$560	25	-	17
GSHP (Water-to-Water)	15	$97,400	$520	25	-	N/A
ccATWHP (Air-to-Water)	15	$76,100	$690	17	-	N/A
VRF	15	$66,100	$620	17	-	18

[a] Refer to Figure 9 for heat pump COP relative to outdoor air temperature.

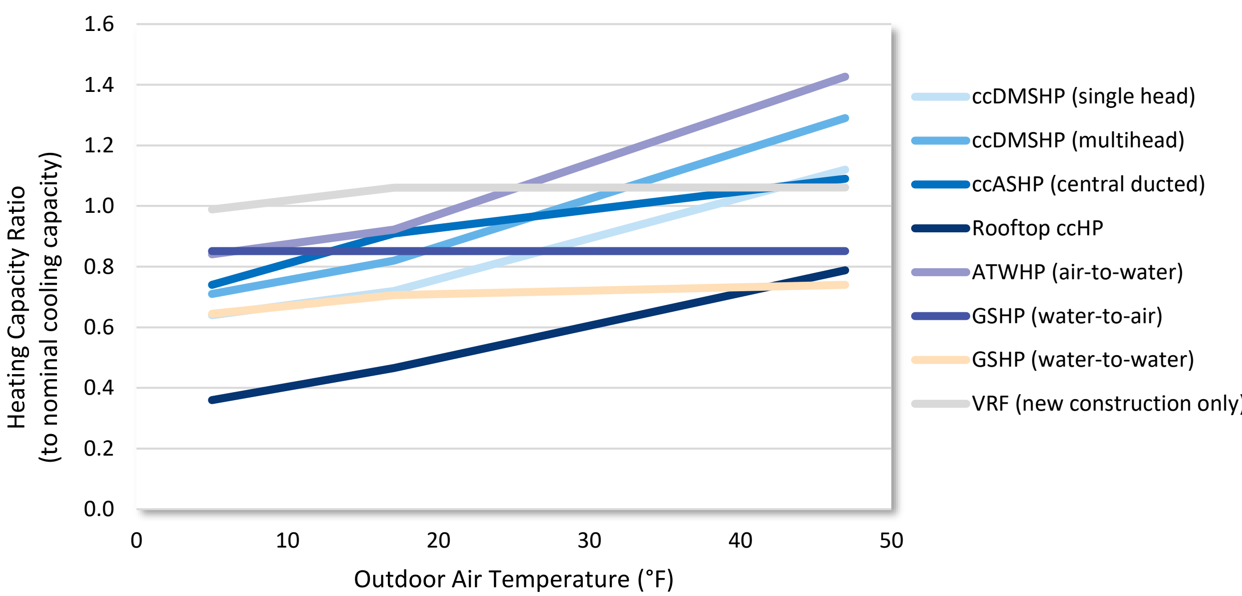
Performance

Figure 9. Heat Pump Efficiency vs. Outdoor Air Temperature



Note: Water-loop heat pump (GSHP water-to-water and ATWHP) efficiency varies indirectly to outdoor air temperatures through the heating loop's outdoor reset control.

Figure 10. Heat Pump Heating Capacity vs Outdoor Air Temperature



Backup Heating Equipment

The capital cost and maintenance cost for backup heating equipment, for the residential and commercial sectors, are provided below.

Residential

Table 36. Residential Backup Heating Equipment Specifications

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	EUL
Electric Baseboards	40	$3,200	$0 [a]	18
Electric Resistance Coil	40	$1,100	$0 [a]	17
Buffer Tank Electric Boiler	40	$3,500	$80	20

[a] No additional maintenance costs over heat pump/primary heating systems.

Commercial

Table 37. Commercial Backup Heating Equipment Specifications

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	EUL
Electric Baseboards	200	$12,400	$0 [a]	25
Electric Resistance Coil	200	$10,900	$0 [a]	18
Buffer Tank Electric Boiler	200	$8,400	$30	25

[a] No additional maintenance costs over heat pump/primary heating systems.

Baseline Domestic Hot Water Equipment

The capital cost and maintenance cost for the baseline domestic hot water equipment is assumed to be the same for residential and commercial.

Table 38. Baseline Domestic Hot Water Equipment Specifications

Equipment	Installed Cost	Maintenance Cost (annual)	EUL
Gas Storage Water Heater	$1,600	$0 [a]	15
Oil Storage Water Heater	$2,200	$180	13
Propane Storage Water Heater	$1,700	$0 [a]	13

[a] Maintenance costs are considered negligible.

Efficient Domestic Hot Water Equipment

The capital cost and maintenance cost for a heat pump water heater is assumed to be the same for residential and commercial.

Table 39. Efficient Domestic Hot Water Equipment Specifications

Equipment	Installed Cost	Maintenance Cost (annual)	EUL
Heat Pump Water Heater	$2,100	$20	13

Heat Pump Sizing and Controls

This section summarizes the sizing and control strategies used in this potential study.

Heat Pump Sizing

Heat pump sizing strategies try to find the optimal balance between an additional size increase, with the incremental savings provided by that size increase.

In general, for partial replacements the heat pumps are sized for cooling, and for full replacements they are sized to meet the full building heating demand, taking into account the heat pump technology's capacity at that design outdoor air temperature. It should be noted that a less aggressive heat pump sizing strategy for full replacements would likely result in better customer and societal cost-effectiveness by reaching closer to the optimal sizing balance referenced above.

Table 40 below provides an example of how heat pump sizing can vary depending on its level of replacement (partial/full) for single family homes. The most common archetype single family home was used for reference.

Table 40. Heat Pump Sizing by Level of Replacement

Segment	Equipment	Partial replacement (tons)	Full replacement (tons)
Single Family (Boiler)	ccDMSHP (ductless)	1.0 or 2.5	3.7 [a]
	GSHP (Water-to-Water)	N/A	4.0
Single Family (Furnace)	ccASHP (central ducted)	2.5	3.4
	GSHP (Water-to-Air)	N/A	3.1

[a] While full replacement measures with ductless heat pumps assume that the indoor heads will only cover 90% of floor area in heating (based on the assumption that some very small rooms such as bathrooms will have electric baseboards instead), the main difference in size between heat pump types is related to their relative capacity performance curves, as shown in Figure 10. Note that the *Single Family (Boiler)* segment is assumed to have a larger heating load than the *Furnace* equivalent, so larger heat pumps are required for full replacement in these homes.

Additional examples and details are provided in the detailed results workbooks, found in Appendix F in Excel Workbook format.

Heat Pump Controls

As with heat pump sizing, different control strategies result in different system performance for the same installed equipment. These control strategies can be split into two categories: run together or switchover temperature (see also "Heat Pump Systems" subsection above). The control strategy assumptions detailed below were provided by the PAs.

For partial replacements, it is assumed that the control strategy is a fixed switchover temperature, determined based on the customer's energy rates and the equipment efficiencies. The heat pump would switch to the backup technology at a certain outdoor air temperature (OAT) as follows:

- Propane systems: 15°F (source: MA-2)
- Oil systems: 30°F (source: MA-2)
- Gas systems: 50°F (source: MA-3)

For full replacements, it is assumed that the electric resistance backup runs in parallel with the heat pump when the heat pump's output capacity is insufficient to meet the building's heating demand. As explained above, however, since the heat pump is sized to match the building's design heating demand, the electric resistance backup is hardly used.

Market Inputs

Building Archetypes

Floor Area

The floor area for the various segments within residential and business archetypes were determined from penetration and saturation baseline study market data described in Appendix A . It was assumed that new and existing buildings have the same average floor area. Table 41 lists these average floor areas.

Heating & Cooling Loads

For existing buildings, residential annual heating loads come from reference MA-2, while commercial annual heating loads are derived from equipment sizing from DOE archetypes and effective full load hours (EFLH) come from MA-2.

Table 41 provides a reference summary of the heating and cooling loads for existing buildings in the residential and commercial segments for non-seasonal customers in the Compact's service territory.

Table 41. Building Archetype Summary

Sector	Segment	Floor Area (sq ft)	Annual Heating Load (MMBtu)	Annual Cooling Load (MMBtu)
Residential	Single Family (furnace)	1,830	62	8
	Single Family (boiler)	1,830	70	8
	Multi-family	1,180	40	6
	Low Income	1,430	48	6
C&I	Office	3,000	72	50
	Retail	2,520	60	22
	Food Service	2,150	86	56
	Healthcare/Hospitals	6,350	202	120
	Campus/Education	18,990	454	208
	Warehouse	3,900	62	28
	Lodging	3,060	98	58
	Other Commercial	2,430	78	18
	Food Sales	9,300	222	244
	Manufacturing/Industrial	4,150	66	46

For new buildings, a simple scaling factor derived from the New Buildings Institute report (*Moving Energy Codes Forward: A Guide for Cities and States*) is used to account for the improvement in envelope and HVAC distribution and efficiency compared to the average existing building. For residential seasonal buildings, a heating load scaling factor that is half of what it is for non-seasonal buildings is used to account for the lower occupancy of seasonal buildings. As discussed below, commercial seasonal buildings are excluded from the HE analysis.

Water Heating Load

For consistency between the various parts of this potential study, the water heating load uses the same approach as the efficiency measure's characterization.

Seasonality

The seasonality of CLC's customer base has a significant impact on the potential across EE, DR, and HE. The earlier "Seasonality

" subsection describes the overall methodology to account for the fact that more than 30% of residential customers, as well as many C&I customers (especially in the restaurant and lodging/hospitality segments), show reduced occupancy or hours of operation, especially during the winter.

Market Size

Population

Applicable markets are estimated using CLC customer population counts and baseline data on existing space and water heating equipment, cooling equipment, and primary heating fuel. This population data is broken down to the segment level for commercial and residential segments.

The population data for CLC is broken out to find the estimated residential population for seasonal and non-seasonal customers. This split assumes 30% of residential customers are seasonal, and the remaining 70% are non-seasonal. For commercial customers, a seasonality factor is applied to the segments to exclude all seasonal businesses.

Equipment and Fuel Shares

Equipment and fuel shares are determined from baseline study market data, which provides breakdowns for commercial and residential segments' existing space and water heating equipment, cooling, equipment, and primary heating fuel. The equipment shares are fuel- and segment-specific—for example, the proportion of single family homes with propane furnaces.

For new residential buildings, baseline configurations for new construction are based on the 2019 Residential New Construction Baseline/Compliance Study. For commercial new construction, it is assumed no oil heating would be used. The portion that would be allocated to oil heating was reallocated to propane and gas heating, following existing building proportions.

Market Applicability Factors

Three Market Applicability Factors are applied by segment to account for:

- the limiting factors of **hydronic distribution system compatibility** (0.7 to 0.8 depending on segment, mainly related to the terminal equipment's required loop temperatures or the project complexity related to the location of the building's heating plant)
- the availability of land to drill **geothermal boreholes** (0.8 to 0.9 depending on segment)

Jurisdictional Inputs

Incentive Program Scenarios

The model reads in three different incentive levels: BAU, BAU+, and Max. These incentive levels are described in Table 42.

Table 42. Achievable Program Scenarios

BAU	Applies incentives in line with CLC's 2019–2021 Energy Efficiency Plan to simulate business as usual, $1,250 a ton for air-source, $3,000 a ton for ground-source HPs: ▪ Incentive levels are capped at 90% of full heat pump installation cost. ▪ HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). ▪ Additional measures are included (e.g., natural gas displacement, units > 5.4 tons).
BAU+	Increases incentives above and beyond levels within CLC's 2019–2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: ▪ $1,875 a ton for air-source, $4,500 a ton for ground-source HPs. ▪ Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives above and beyond levels within CLC's 2019–2021 Energy Efficiency Plan. Incentives are twice the BAU levels: ▪ $2,500 a ton for air-source, $6,000 a ton for ground-source HPs. ▪ Incentive levels are capped at 90% of full heat pump installation cost.

Typical Meteorological Data

The HEAT model imports climate data for the typical meteorological year (TMY) from NREL's National Solar Radiation database. TMY datasets contain one year of hourly data that best represents the median weather conditions of a typical year from a multiyear period. Table 43 shows key weather metrics for the climate zone.

Table 43. Climate Zone Summary

Climate Zone	Weather file	Heating degree-days (60°F)	Cooling degree-days (65°F)	Heating Design OAT (°F)
Cape Cod	Martha's Vineyard	4,222	486	10.4

Economic Inputs

HEAT harnesses key economic parameters such as avoided costs, retail energy rates, and discount rates to assess measure cost-effectiveness and customer adoption. Appendix B outlines the development of these inputs, which are used across all modules of this study.

Net-to-Gross

Net-to-Gross ratios are taken from MA-2. The ratios used are 0.9 for residential measures, and 1.0 for income-eligible measures. Where the measure was not detailed in the TRM, the most similar measure is chosen, except for GSHPs where a value of 0.77 is used to account for increased free-ridership.[36]

For commercial segments, the NTG is assumed to be 1.0 for all measures.

[36] Source: Connecticut Ground Source Heat Pump Impact Evaluation & Market Assessment https://www.energizect.com/sites/default/files/CT%20GSHP%20Impact%20Eval%20and%20Market%20Assessment%20%28R7%29%20-%20final%20report.pdf

Market Barriers

As explained in the “Adoption Engine

" subsection above, HEAT’s adoption engine involves the calibration of market barriers to historical program uptake. The Compact's 2019 and 2020 results (up to October 2020) were leveraged for this calibration exercise.

Appendix E. Demand Response Methodology

Overview

The following sections outline the Potential Study Team's Demand Response Model methodology, used to assess the technical, economic, and achievable peak-hour demand savings from electric demand response programs. The strength of our approach to analyzing demand response (DR) potential, is that it takes into account two specific considerations that differentiate it from energy efficiency potential assessments: the time-sensitive nature of DR potential and that many DR measures offer little to no direct economic benefit to customers. This section begins with a general discussion of the modeling approach, and then provides details on the specific assumptions and inputs made in this study.

DR Potential is Time-Sensitive

- DR measures are often subject to constraints based on when the affected demand can be reduced and for how long.
- DR measure “bounce-back” effects (caused by shifting loads to another time) can be significant, creating new peaks that limit the achievable potential.
- DR measures impact one another by modifying the System Load Shape. Therefore, the entire pool of measures (at all sites) must be assessed together to capture these interactive effects and provide a true estimate of the achievable potential impact on the system peak.

Many DR Measures Offer Little to no Direct Economic Benefits to Customers

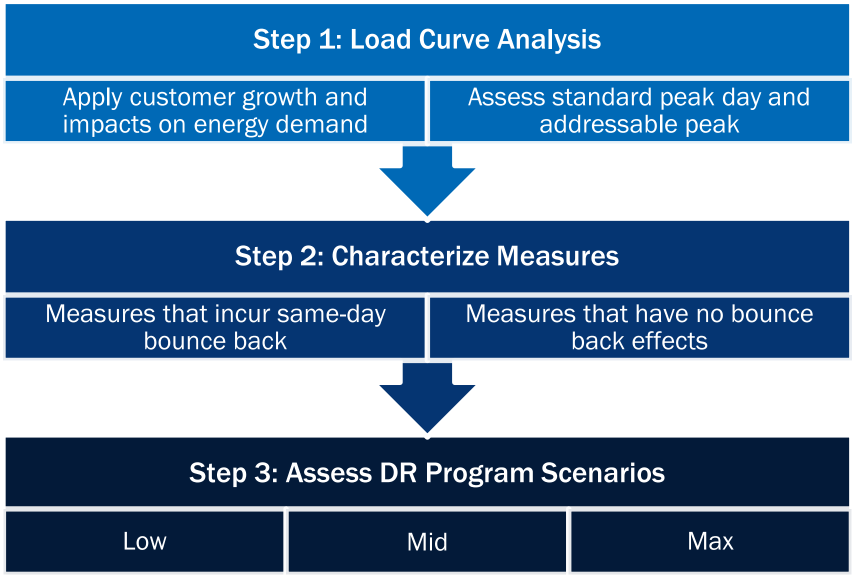
- Participants must receive an incentive over and above simply covering the incremental cost associated with installing the DR equipment.[37]
- Incentives can be based on an annual payment basis, a rebate/reduced rate based on a participant agreement to curtail load, or through time-dependent rates that send a price signal encouraging load reduction during anticipated system peak hours.
- Savings are expected to persist only as long as programs remain active.

A limitation of the methodology is that it may not be consistent with how PAs quantify their DR impacts, which may focus on reducing demand only at certain pre-determined peak hours, regardless of how load may vary at other hours, or if a new peak emerges outside of the targeted hours.

Figure 11 presents an overview of the analysis steps applied to assess the DR potential in this study. For each step, detailed below, system-specific inputs are identified and incorporated into the model.

[37] This study did not account for reductions in customer peak demand charges that may arise from DR program participation. Since DR events are typically called for a small number of days each month, the impact on commercial monthly peak demand charges is assumed to be minimal.

Figure 11. Demand Response Potential Assessment Steps



Load Curve Analysis

The first modeling step of our approach is to define the baseline load forecast and determine the key parameters of the utility load curve that influence the DR potential (Figure 12). The process begins by conducting a statistical analysis of historical utility data to determine the 24-hour load curve for the "Standard Peak Day" against which DR measure impacts are assessed. The utility peak demand forecast period is then applied to adjust the amplitude of the standard peak day curve over the study period. Finally, relative market sector growth factors and efficiency and heating electrification program savings (as well as solar PV, where relevant)[38] are applied to further adjust the peak day load curve (growth factors used in the study can be referenced in Appendix B).

Figure 12. Load Curve Analysis Tasks

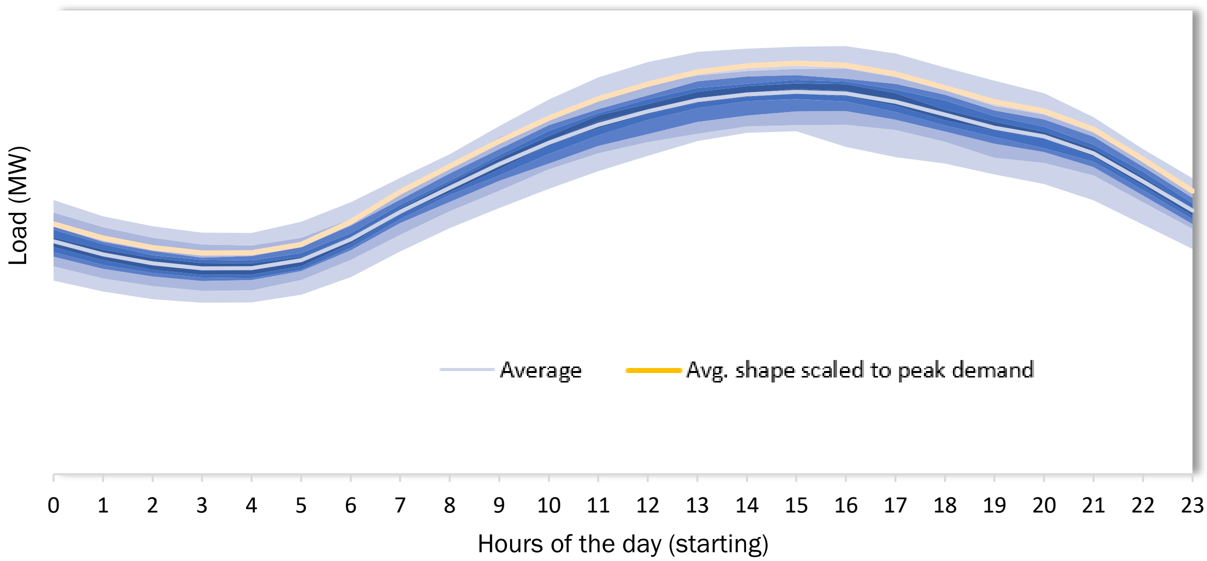
Once complete, the load curve analysis provides a tool which can assess the individual measure, and combined program impacts against a valid utility peak baseline curve that evolves to reflect market changes over the study period.

[38] Mid-scenario results for EE, HE, and solar PV savings were applied to adjust the load curve.

Identify Standard Peak Day

The **Standard Peak Day** is assessed through an analysis of historical hourly annual load curves. For each year, a sample of the peak days are identified (e.g., top 10 peak demand days in each year where historical data is available) and a pool of peak days is established. The average peak day shape is established from this pool of peak day hourly shapes. The standard peak day load curve is then defined by raising the average peak day load curve such that the peak moment matches the projected annual peak demand (keeping the shape consistent with the average curve), as shown in Figure 13.

Figure 13. Example of a Standard Peak Day Curve



Note: Each blue shading area represents a 10-percentile gradient.

From the standard peak day curve, a DR window is identified which represent the time period that capture the highest demand hours. These are assessed against the historical annual curves to ensure that 90% of DR peak events within a given year fall within the defined DR windows. These are used to characterize certain DR measures, providing guidance on which hours to target for time-of-use (TOU) high-rate tiers, customer-driven curtailment periods, and to create pre-charge/reduction/re-charge curves for equipment control measures, as described in the next step.

DR Measures Characterization

DR potential is assessed drawing on our database of specific demand reducing measures developed from a review of commonly applied approaches in DR programs across North America, as well as other emerging opportunities such as battery storage.[39] Measures are characterized with respect to the local customer load profiles,[40] and the technical and economic DR potentials are assessed for each individual measure (Figure 14).

[39] A detailed list of measures applied in this study is provided in Appendix F.

[40] When local profiles are not available, profiles from similar jurisdictions are used.

Figure 14. DR Measure Characterization Tasks

Once complete, the measure-specific economic potential is loaded into the model to assess the achievable potential scenarios when all interactive load curve effects are considered.

Measure Specific Model Inputs

Measures are developed covering all customer segments and end-uses, and can be broadly categorized into two groups:

- **Type 1 DR Measures** (typically constrained by demand bounce-back and/or pre-charging):
  - These measures exhibit notable pre-charging or bounce-back demand profiles within the same day as the DR event is called. This can create new peaks outside of the DR window and may lead to significant interaction effects among measures when their combined impact on the utility peak day curve is assessed.
  - Typically, Type 1 measures can only be engaged for a limited number of hours before causing participant discomfort or inconvenience. This is reflected in the DR measure load curves developed for each measure-segment combination (e.g., direct load control of a residential water heater).
- **Type 2 DR Measures** (unconstrained by load curve):
  - These measures do not exhibit a demand bounce-back and are therefore not constrained by the addressable peak.
  - Some of them can be engaged at any time, for an extended duration (e.g., back-up generator at a commercial facility)

Our existing library of applicable DR measure characterizations was applied and adjusted to reflect hourly end-use energy profiles for each applicable segment. Key metrics of the characterization are:

- **Load Shape:** Each measure characterization relies on defined 24-hour load shape both before and after the demand response event. The load shapes are based on the population of measures within each market segment and are defined as the average aggregate load in each hour across the segment.
- **Effective Useful Life (EUL):** The measure EUL is either the EUL of the installed equipment/control device, or, for behavioural measures with no equipment, a one-year EUL is applied.
- **Costs:** At measure level, the costs include the initial cost of the installed equipment (i.e., controls devices and telemetry) and the annual operational cost (program administration, customer incentives, etc.).

- **Constraints:** Some measures are subject to specific constraints such as the number of hours per day or year, maximum number of events per year, and event durations.

Once the measures are adapted to the utility customer load profiles and markets, the technical and economic potentials are assessed for each measure independently as outlined below. Because these are assessed independently (i.e., not considering interactions among measures), the technical and economic potentials are not considered to be additive, but instead provide important measure characterization inputs to assess the collective achievable potential when measures are analyzed together.

Technical Potential (Measure Specific)

The technical potential represents a theoretical assessment of the total universe of controllable loads that could be applicable to a DR program. It is defined as the technically feasible load (kW) impact for each DR measure considering the impact on the controlled equipment power draw coincident with the utility annual peak.

More specifically, the technical potential is calculated from the maximum hourly load impact during a DR event multiplied by the applicable market of the given measure.[41] It is important to note that the technical potential assessment does not consider the utility load curve constraints, such as the impact that shifting load to another hour may have on the overall annual peak.

Economic Potential (Measure Specific)

The assessment of each measure's economic potential is conducted in three key steps: adjustment of the technical potential, screening for cost-effectiveness, and adjusting for market adoption limitations.

1. **Technical Potential Adjustment:** The measure's hourly load curve impact is applied to the utility standard peak day load curve, to assess the impact. For each individual measure, an optimization algorithm that assesses various control schemes and market portions is applied to arrive at the maximum number of participants and impact for the given measure, either during the standard peak day, or over the sample annual hourly load profile.

2. **Cost-Effectiveness Screening:** Once each measure's impact on the peak is assessed, measures are screened using the applicable cost-effectiveness test, considering installation costs and baseline incentive costs.[42] It is important to note the customer incentives are not treated as a pass through cost for DR programs because they typically do not cover a portion of the customers' own equipment incremental costs (i.e., customers typically have no direct equipment costs, unlike in efficiency programs where the incentives provided cover a portion of the participant's incremental costs for the efficiency upgrade).

   For measures that pass the cost-effectiveness screening, program incentives can then be set either as a fixed portion of the avoided costs net of measure costs (i.e., 50%) or at the level that maximizes the cost-effectiveness test value for the measure in question.

[41] For thermostats, electric vehicles, and heat pumps, the applicable markets were defined using outputs from the BAU+ scenarios in the relevant study component (i.e., energy efficiency and heating electrification).

[42] Any measure that cannot achieve a cost-effectiveness test < 1.0 is not retained for further consideration in the model. For customer curtailment measures, cost-effectiveness test screening may be assessed under a baseline incentive level. For equipment control measures, the baseline incentive can be set to zero and then adjusted for measures that return net benefits to the utility.

Table 44. DR Benefits and Costs Included in Determination of the TRC

Benefits	Costs
Avoided Capacity Costs Other ancillary benefits (as applicable)	▪ Controls equipment installation ▪ Controls equipment Operations and Maintenance (O&M) (if required) ▪ Annual incentives ($/ participant) ▪ Peak reduction incentives ($/kW contracted)

3. **Market Adoption Adjustment:** The market for a given DR program or measure may be constrained either by the impact on the load curve, or by the expected participation (or adoption) among utility customers.

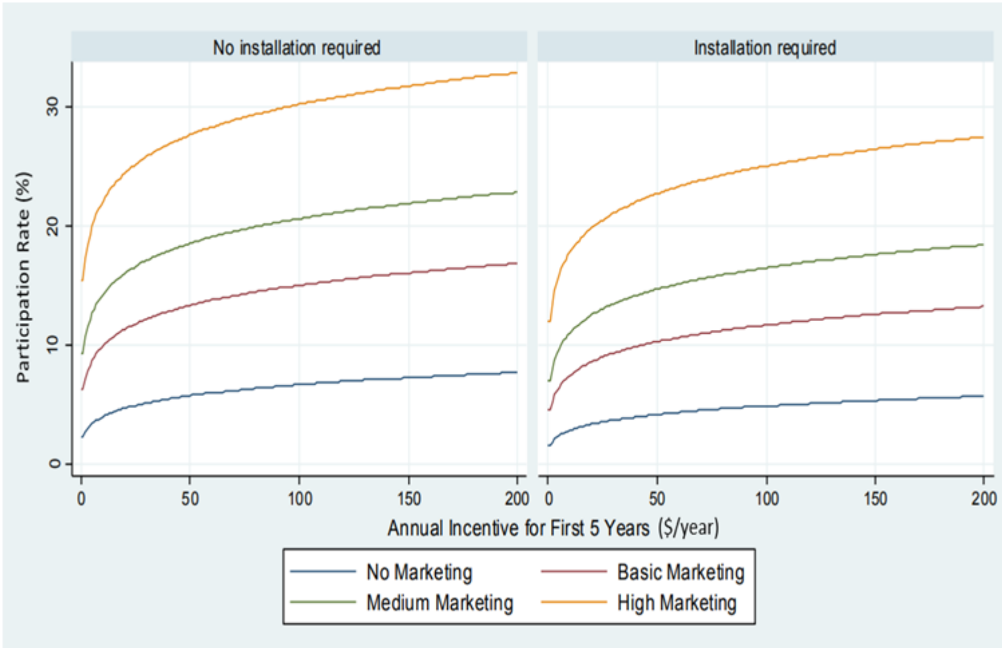
   In the first case, the economic potential assessment (described above) determines the number of devices needed to achieve the measure's maximum impact on the utility peak load. Adding any further participation will come at a cost to the utility, but with little or no DR impact benefits.

   In the second case, the model determines the expected maximum program participation based on the incentive offered, the need to install controls equipment, the level of marketing, and the total number of eligible customers, by applying DR program propensity curves (described in the call out box below) developed by the Lawrence Berkeley National Laboratory.[43]

The DR model assesses both the utility curve economic potential market and the maximum adoption at the resulting incentive levels, then constrains the market (maximum number of participants) to the lower of the two. This is then applied as a measure input for the achievable potential assessment described in the Assessment of Achievable Potential Scenarios section below.

[43] Lawrence Berkeley National Laboratory, March 2017. 2025 California Demand Study Potential Study, Phase 2 Appendix F. Retrieved at: http://www.cpuc.ca.gov/General.aspx?id=10622

Figure 15. Residential Adoption Curves Used in the Study



Demand Response Propensity Curves

For each measure the propensity curve methodology, as developed by the Lawrence Berkeley National Laboratory to assess market adoption under various program conditions, is applied. The curves represent achievable enrollment rates as a function of incentive levels, marketing strategy, number of DR calls per year, and the need for controls equipment. Their development is based on empirical studies, calibrated to actual enrollment from utility customer data. Specific curves are available for each sector.

Assessment of Achievable Potential Scenarios

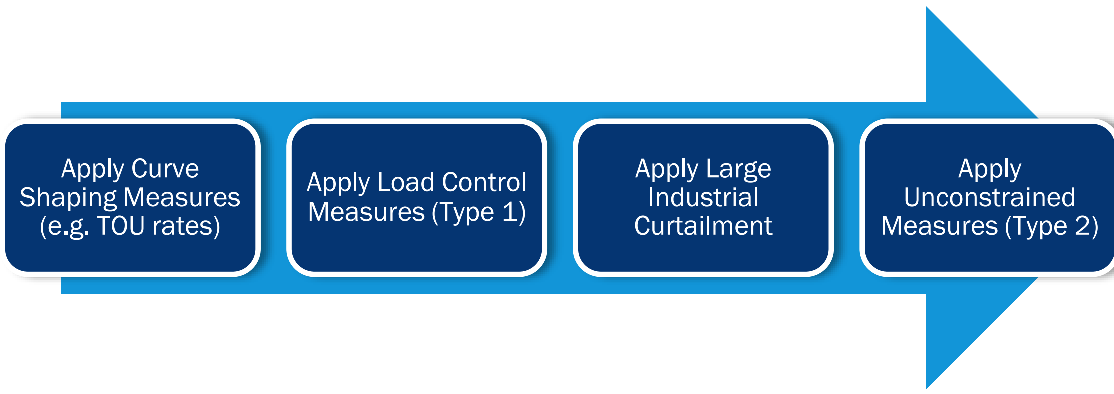
The achievable potential is determined through an optimization process that considers market adoption constraints, individual measure constraints, and the combined inter-measure impacts on the utility load curve.

Scenarios are developed to assess the combined impact of selected programs and measures. For example, one scenario may assess the achievable potential of the impact of applying TOU rates and industrial curtailment, while another may assess the combined potential from direct load control of customer equipment and industrial curtailment. This approach recognizes that there can be various strategies to access the DR potentials from the same pool of equipment (i.e., TOU rates can exert a reduction in residential water heating peak demand, thereby reducing or eliminating the potential from a water heater DLC program). The scenarios are assembled from logical combinations of programs and measures designed to test various strategies to maximize the achievable peak load reduction.

Assessing Achievable Potential

For each scenario, measures are applied in groups and in order starting with the least flexible/most constrained measures and progressing to the measures/groups that are less and less constrained, as per the order illustrated in Figure 16.

Figure 16. Achievable Potential Assessment Tasks



- **Curve Shaping:** Rates-Based Measures (such as time-of-use rates) are typically applied first as these are designed to alter customer behaviour with time, and are considered the least flexible (i.e., with the exception of critical peak pricing, they cannot be engaged by the utility to respond to a specific DR event but must be set in place and exert a prolonged effect on the utility load curve shape). Curve shaping can also include passive demand reduction via increased adoption of efficiency measures.
- **Type 1 – Load Control Measures:** Direct control of connected loads such as water heaters and thermostats, and customer controlled shut-off or ramp down of commercial HVAC loads are applied next. These are typically constrained to specific times of day based on the utility peak load shape, and the controlled equipment load shape (i.e., turning of residential water heaters at midday may be feasible but deliver next to no savings as there is minimal hot water demand at that hour). These are assessed against the load curve altered by any shaping measures, and measures that may double count savings are eliminated. A new aggregate utility load curve is then created, applying the achievable load control peak reductions, and bounce-back effect.
- **Industrial / Commercial Curtailment:** Next customer curtailment is applied, which typically carries constraints related to the number of curtailment hours per day (consecutive and total), the number of events per year, and in some cases the time of day that curtailment can be applied (but does not carry same-day bounce-back effects). These are applied to the adjusted load curve to assess the potential impact of large industrial and commercial curtailment measures on the magnitude and timing of the overall annual peak.
- **Type 2 – Unconstrained Measures:** Finally, the remaining Type 2 measures that have no constraints on the duration, frequency or timing of their application are applied. These may include measures such as dual-fuel heating and back-up generators which can be engaged as needed and whose potential is not impacted by the shape of the utility load curve.

DR Programs and Scenarios

We have developed a set of best-in-class program archetypes based on a review of programs in other jurisdictions. For each program, development, marketing, and operating costs are estimated and applicable measures are mapped to the corresponding program, applying key features from the program archetypes, and considering current programs offered by the utility.

The model first determines the achievable DR potential of the combined measures within all programs, and then assesses the program level cost-effectiveness, summing all program and measure costs, as well as applicable measure benefits. A specific delivery period is assumed for each program, except where the program is based on control devices with a longer EUL, in which case the program is assumed to cover the entire device life. In cases where DR device EULs are shorter than the delivery period, preparticipation/re-installation costs are applied. This approach allows the model to fairly assess the programs costs and benefits for an on-going program.

New Measure and Program Ramp-Up

Where applicable, new programs and measures can be ramped up accounting for the time needed to enroll customers and install controls equipment to reach the full achievable potential. Ramp up trajectories applied to the achievable potential markets after all interactive effects (i.e., new peaks created or program interactions that affect the net impact of any other program) have been assessed. Typically, it is assumed that it takes three years for a new or expanded program or measure to reach full participation and roll out (i.e., a ramp rate of 33% per year was applied for adding new programs).

Based on these steps the Achievable DR potential for each measure, program, and scenario are developed, along with an appropriate assessment of the measure, program, and scenario level cost-effectiveness.

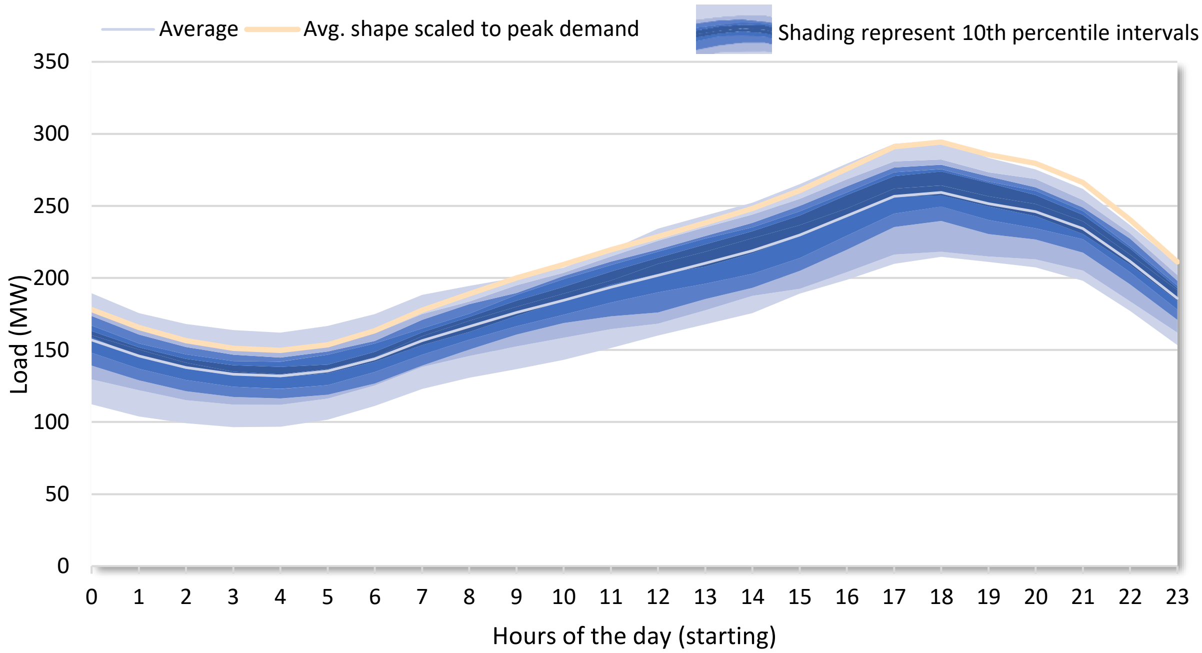
Demand Response Input

In addition to data described in this appendix, a number of other inputs were used in the demand response potential assessment.

Standard Peak Day

The Compact provided hourly historical load data covering January 1, 2015 to December 31, 2019 (43,819 data points). This historical data was used to create standard peak days for the system.

Figure 17. Standard Summer Peak Day – CLC, Massachusetts



End-Use Breakdowns

The Potential Study Team developed end-use load curves for each market sector and end-use and where relevant, for individual segments. **Note that these breakdowns are for the electric consumption only, not the whole building (all fuel) energy use.** The load shapes were used to:

- Assess standard peak day adjustments for DR addressable peak.
- Characterize measures when local load curves were not available.
- Benchmark savings when calibrating the model.

The end-use load curves were developed from the following sources:

- DOE published load curves, taken from buildings in the Massachusetts climate zones, and adjusted to account for heating energy source.
- Engineered load profiles and our in-house developed sample consumption profiles.

In this study, the industrial sector was grouped into one segment "Manufacturing / Industrial." The segment was modeled using one industrial end-use ("Industrial").

Using this breakdown, an annual (hourly—8670 hours) building energy consumption simulation from DOE (*Commercial Reference Buildings & Building America House Simulation Protocols*) allowed for the recreation of the end-use breakdown for a standard peak day. The figures below present the end-use and sector breakdown of the electric system.

Figure 18. Summer Standard Peak Day – Sector Breakdown

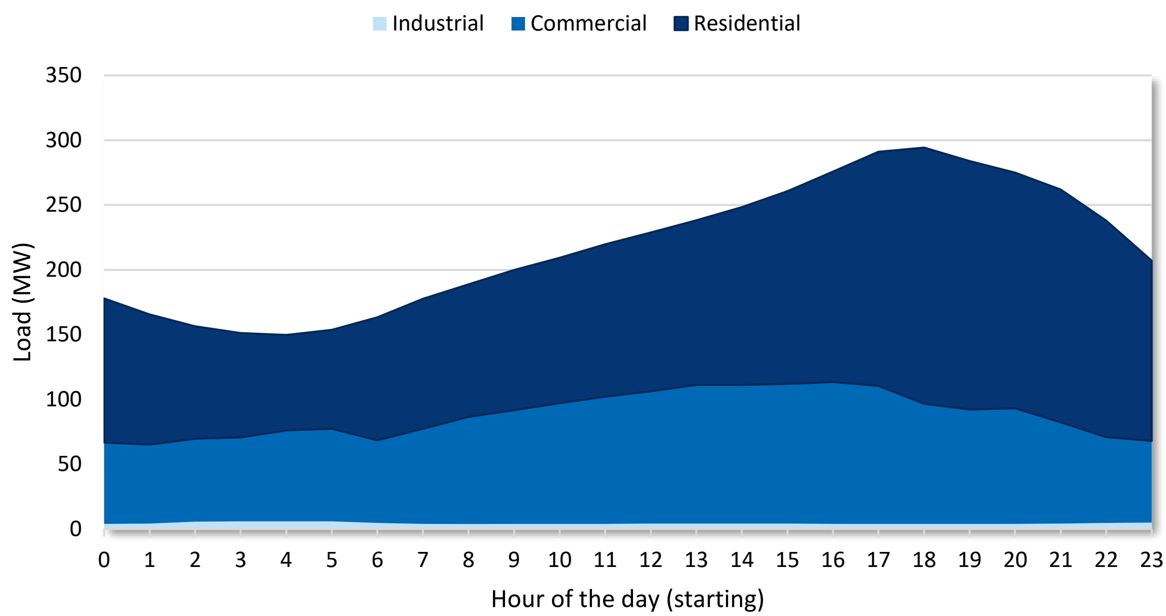
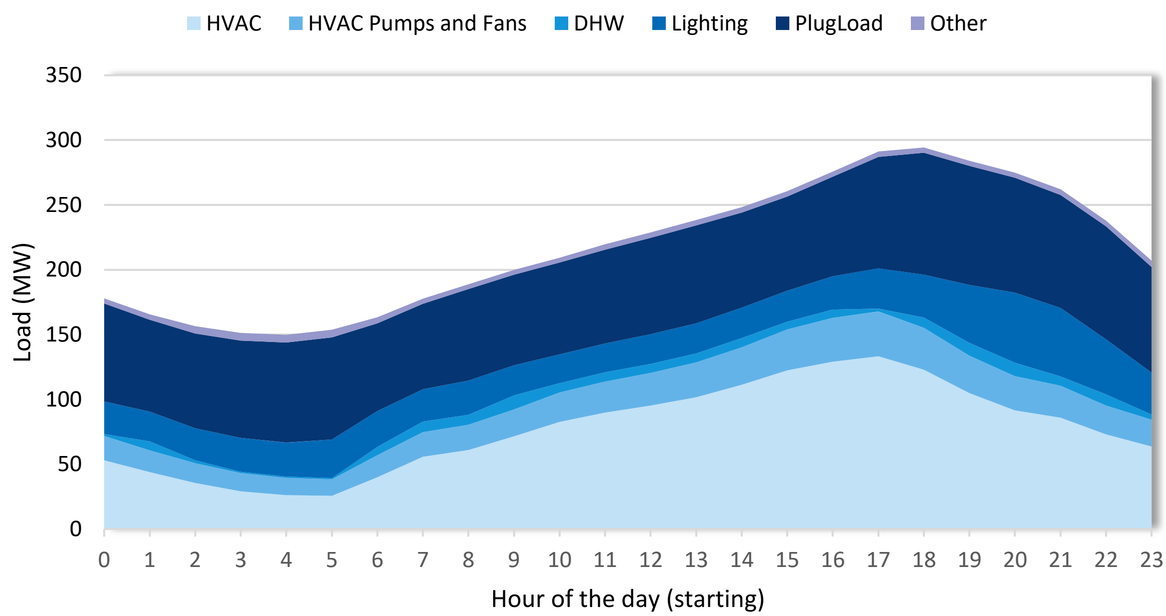


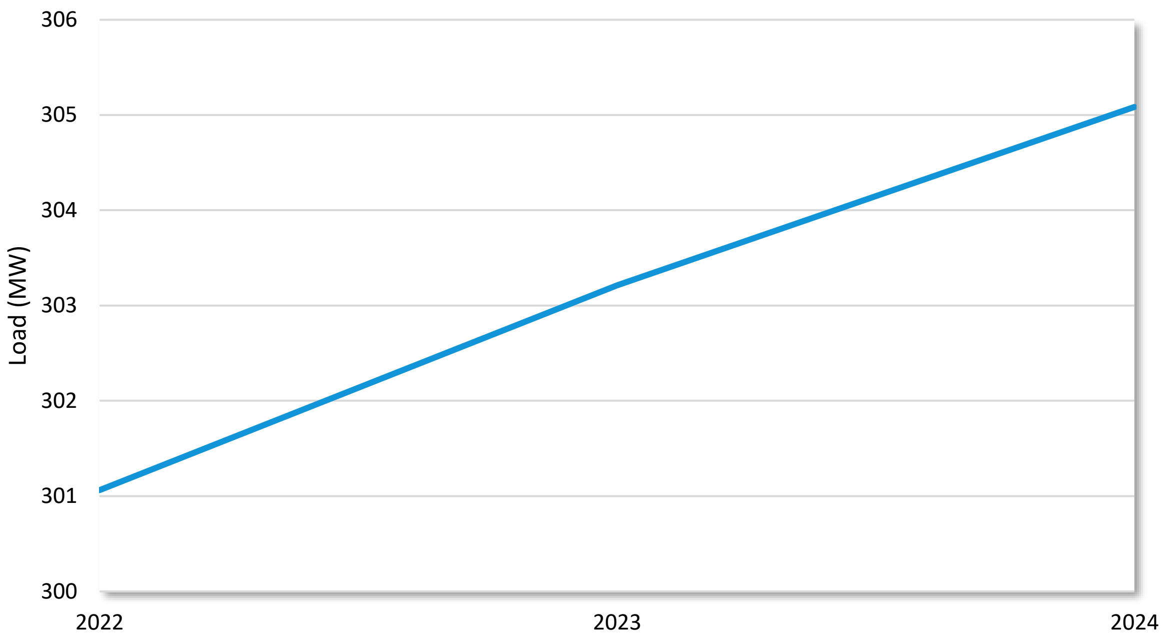
Figure 19. Summer Standard Peak Day – End-use Breakdown



Future impacts

The standard peak day was forecasted using the same peak demand forecast as the rest of the potential study. It is presented in the figure below.

Figure 20. Load forecasting (before EE/HE impacts)



Furthermore, results (baseline scenarios) for energy efficiency and heating electrification were combined with the load forecast in order to have a better grasp at the future load shape.

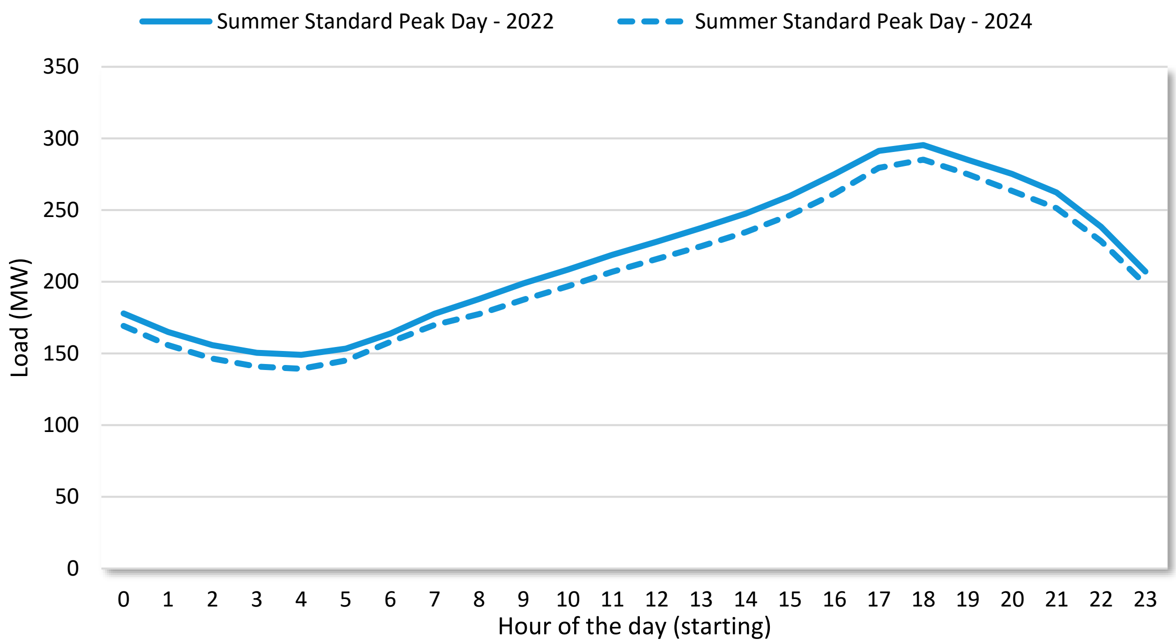
Table 45. Impact of Energy Efficiency and Heating Electrification on Key Demand Response Factors (2024)

Season	Average hourly reduction	Peak reduction	Peak-to-average difference
Summer	18.7 MW	19.8 MW	-1.2 MW

Note: Negative savings represent an increase in peak demand.

When considering as load growth in combination to energy efficiency and heating electrification, in Table 45 the combined effects are notable. Even if the period covered in the study is three years, the impact of such measures on the peak shape can be seen in summer, as shown in Figure 21.

Figure 21. Evolution of the Standard Peak Day



Measures

To assess the DR potential in the jurisdiction, the Potential Study Team characterized over 25 demand reducing measures, based on commonly applied approaches in DR programs across North America, and emerging opportunities such as battery storage. As defined in Appendix E, the measures are covering all customer segments and can be categorized into two groups: type 1 (constrained by the addressable peak) and type 2 (unconstrained by the addressable peak). Measures of all types have the following key metrics:

- Load shape of the measure
- Constraints
- Measure Effective Useful Life (EUL)
- Costs

We applied our existing library of applicable DR measure characterizations and adjusted them to reflect end-use energy use profiles in Massachusetts' climate. Each measure was evaluated independently for each segment of the study. Table 46 and Table 47 provide an overview of each measure characterization and approach.

Table 46. Residential Demand Response Measures

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit [b]
Appliances						
Clothes Dryer - DLC	Appliance shut off during event	Smart Plug	Number of non-smart clothes dryers in the jurisdiction	Smart Plug	Fail	Not cost-effective
Clothes Dryer - BYOD	Appliance shut off during event	Smart Appliance	Number of smart clothes dryers in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives [c]
Dehumidifier - BYOD	Appliance shut off during event	Smart Appliance	Number of smart dehumidifiers in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives
Pool Pumps – Timer or Smart Switch – DLC	Postponing filtering and cleaning work of the pump	Simple Timer Switch or Smart Switch	Number of non-smart pool pumps in the jurisdiction	Timer or Smart Switch	Pass	Market size & Incentives
Pool Pumps – BYOD	Postponing filtering and cleaning work of the pump	Smart Appliance	Number of smart pool pumps in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives
Hot Water						
Resistance Storage Water Heater - DLC	Appliance shut off during event	Smart Switch	Non-smart electric water heater (excl. heat pump water heater)	Smart Switch	Fail	Not cost-effective
Resistance Storage Water Heater - BYOD	Appliance shut off during event	Smart Water Heater	Smart electric water heater (excl. heat pump water heater)	Incentive upon program inscription	Pass	Market size & Incentives
Heat Pump Storage Water Heater – BYOD	Appliance shut off during event	Smart Heat Pump Water Heater	Smart heat pump water heater	Incentive upon program inscription	Pass	Market size & Incentives
HVAC						
Central Air Conditioner (AC) – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with central AC and with manual or programmable thermostat	Installation of a Wi-Fi thermostat	Pass	Market size & Incentives

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit [b]
Central Air Conditioner – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with central AC and with Wi-Fi Thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Ductless HP/AC – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with a Ductless HP/AC	Installation of a Wi-Fi thermostat	Pass	Market size & Incentives
Ductless HP/AC – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with a Ductless HP/AC a smart thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Room AC – BYOD	Temperature setback (including pre-cooling strategies)	Smart Appliance	Smart room AC in the jurisdiction	Incentive upon program inscription	Fail	Not cost-effective
Other						
Electrical Vehicle (EV) - DLC	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug (such as FloCarma Plug)	Number of EVs in the jurisdiction x % charged at home using new smart charger	Smart EVSE or Smart Plug	Pass	Market size & Incentives
Electrical Vehicle (EV) - BOYD	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug (such as FloCarma Plug)	Number of EVs in the jurisdiction x % charged at home using existing smart charger	Smart EVSE or Smart Plug	Fail	Not cost-effective
Battery Energy Storage – With Solar - BYOD	Battery discharges during event and extra power is send back into the grid	Battery	Households with solar panels and battery	None	Pass	Market size & Incentives
Battery Energy Storage – Without Solar - BYOD	Battery discharges during event to cover the house loads only	Battery	All households with a battery, excluding households with solar panels	None	Pass	Market size & Incentives

[a] Main results from cost-effectiveness (CE) test: Some specific segments in a given measure may present different results.

[b] Main limiting factor: Some specific segments could have different adoption limits.

[c] The number of participants is a function of both market size and incentives. Increasing any of them could enhance adoption, as long as the new potential is not in competition with another measure.

Table 47. Non-Residential Demand Response Measures

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit b
Appliances						
Commercial Refrigeration	Refrigeration loads shed	Auto-DR	Refrigeration load per building with low-temperature cases x number of buildings (Grocery only)	Automated demand response	Pass	Market size & Incentives
Hot Water						
Resistance Storage Water Heater - DLC	Appliance shut off during event	Smart Switch	Non-smart electric water heaters (excl. heat pump water heater)	Smart Switch	Fail	Not cost-effective
Resistance Storage Water Heater - BYOD	Appliance shut off during event	Smart Water Heater	Smart electric water heaters (excl. heat pump water heater)	Incentive upon program inscription	Fail	Not cost-effective
HVAC						
Wi-Fi Thermostat – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Small C&I buildings with central AC and with manual or programmable thermostat	Wi-Fi Thermostat	Pass	Market size & Incentives
Wi-Fi Thermostat – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Small C&I buildings with central AC and with Wi-Fi thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Other - Curtailment						
Medium Commercial & Institutional	Turning off some of the fixtures, HVAC demand (fresh airflow reduction, temperature adjustment, interruption of dehumidification, etc.), devices,	Manual or existing BAS system not optimized	All medium-sized C&I buildings	None	Pass	Market size & Incentives

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit b
	appliances, or processes					
Large Commercial & Institutional	Turning off some of the fixtures, HVAC demand (fresh airflow reduction, temperature adjustment, interruption of dehumidification, etc.), devices, appliances, or processes	Manual or existing BAS system not optimized	All large-sized C&I buildings	None	Pass	Market size & Incentives
Medium (Auto-DR) Commercial & Institutional	Reduce level by 30% during peak events	Upgrade to a DR-optimized BMS system or installation of new equipment.	All medium-sized C&I buildings	Auto-DR system	Pass	Market size & Incentives
Large (Auto-DR) Commercial & Institutional	Reduce level by 30% during peak events	Upgrade to a DR-optimized BMS system or installation of new equipment.	All large-sized C&I buildings	Auto-DR system	Pass	Market size & Incentives
Large Industrial Curtailment	Load shifting with no intraday rebound, via expansion of existing programs or interruptible rates	Manual, BAS or Auto-DR	All large-sized Industrial buildings	None	Pass	Market size & Incentives
Medium Industrial Curtailment	Load shifting with no intraday rebound, via expansion of existing programs or interruptible rates	Manual, BAS or Auto-DR	All medium-sized Industrial buildings	None	Pass	Market size & Incentives
Other						
Electrical Vehicle (EV)	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug	Number of EVs in the jurisdiction x % charged at the office	Smart EVSE or Smart Plug	Fail	Not cost-effective

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit b
Emergency Generator (Gas)	Use of emergency generator during event	Manual, BAS or Auto-DR	Number of gas emergency generator in the jurisdiction	Costs of EPA stationary nonemergency compliance	Pass	Market size & Incentives
Combined Heat and Power	Use of CHP system during event	Manual, BAS or Auto-DR	Number of CHPs in the jurisdiction (not already involved with C&I program)	None	Pass	Market size & Incentives
Battery Energy Storage – With Solar (Small C&I)	Battery discharges during event and extra power is send back into the grid	Battery	Small C&I buildings with solar panels and battery	None	Pass	Market size & Incentives
Battery Energy Storage – Without Solar (Small C&I)	Battery discharges during event to cover the building loads only	Battery	Small C&I buildings with a battery, excluding households with solar panels	None	Pass	Market size & Incentives
Medium Battery Energy Storage - Daily	Battery Energy Storage discharges during event	Battery	Medium C&I buildings with a battery	None	Pass	Market size & Incentives
Large Battery Energy Storage - Daily	Battery Energy Storage discharges during event	Battery	Large C&I buildings with a battery	None	Pass	Market size & Incentives
Medium Battery Energy Storage - Targeted	Battery Energy Storage discharges during event	Battery	Medium C&I buildings with a battery	None	Pass	Market size & Incentives
Large Battery Energy Storage - Targeted	Battery Energy Storage discharges during event	Battery	Large C&I buildings with a battery	None	Pass	Market size & Incentives
Medium Thermal Energy Storage - Daily	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Medium C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives
Large Thermal Energy Storage - Daily	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Large C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives

Measure by End Use	Demand Response Strategy	Enabling Device	Market Size	Initial Measure Cost	Ce Test [a]	Adoption Limit b
Medium Thermal Energy Storage - Targeted	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Medium C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives
Large Thermal Energy Storage - Targeted	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Large C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives

[a] Main results from cost-effectiveness (CE) test: Some specific segments in a given measure may present different results.

[b] Main limiting factor: Some specific segments could have different adoption limits

Programs

Table 48 below presents the program costs for each major program type applied in the DR potential model, which were developed based on historical program information provided by the Compact. Program costs account for program development (set up), annual management costs, and customer engagement costs. These are added to equipment installation and customer incentive costs to assess the overall program cost-effectiveness. In some cases, a program's constituent measures may be cost-effective, but the program may not pass cost-effectiveness testing due to the additional program costs. Under those scenarios, the measures in the underperforming program are eliminated from the achievable potential measure mix, and the DR potential steps are recalculated to reassess the potential and cost-effectiveness of each measure and program.

Table 48. DR Program Administration Costs Applied in Study (excluding DR equipment costs)

Program Name	Development Costs (High Scenario)	Program Fixed Annual Costs	Other Costs ($/customers) for Marketing, IT, Admin
Residential DLC	$150,000	$25,000	$40
Residential Energy Storage	$150,000	$25,000	$40
Commercial Curtailment	$150,000	$25,000	$30
Commercial Energy Storage	$150,000	$5,000	$30

Appendix F. Detailed Results Tables

Appendix F contains additional detailed inputs and results tables for each component of the study and is provided in an Excel workbook format.

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Dunsky provides strategic analysis and counsel in the areas of energy efficiency, renewable energy and clean mobility. We support our clients – governments, utilities and others – through three key services: we **assess** opportunities (technical, economic, market); **design** strategies (programs, plans, policies); and **evaluate** performance (with a view to continuous improvement).

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List of Acronyms

ADR	Active demand reduction
AESC	Avoided energy supply costs
ASHP	Air source heat pump
ATWHP	Air-to-water heat pump
BAU	Business-as-usual
CHP	Combined heat and power
CMA	Columbia Gas of Massachusetts
DEEP	Dunsky's Demand and Energy Efficiency Potential Model
DMSHP	Ductless mini-split heat pump
DR	Demand response
DROP	Dunsky's Demand Response Optimized Potential Model
DSM	Demand-side management
EE	Energy efficiency
EGMA	Eversource Gas Company of Massachusetts
EMS	Energy management system
EUL	Effective useful life
EVSE	Electric vehicle service equipment
GHG	Greenhouse gas
GSHP	Ground source heat pump
GWh	Gigawatt-hour
HE	Heating electrification
HEAT	Dunsky's Heating Electrification Adoption Model
HER	Home Energy Report
HPWH	Heat pump water heater
ICR	Installed capacity requirement
ISO-NE	ISO New England
MMBtu	One million British thermal units
MW	Megawatt
PA	Program administrator
PCT	Participant cost test
TRC	Total resource cost
VRF	Variable refrigerant flow

Definitions

Term	Definition
Achievable potential	The net savings from cost-effective opportunities once market barriers have been applied, resulting in an estimate of net savings that can be achieved through demand-side management programs attributed to the program administrator. For each study component, three achievable potential scenarios (BAU, BAU+, and Max) are modeled to examine how varying factors such as incentive levels and market barrier reductions impact uptake.
Cumulative savings	A rolling sum of all new savings that will affect energy sales, cumulative savings exclude measure re-participation (i.e., savings toward a measure are counted only once, even if customers can participate again after the measure has reached the end of its useful life) and provide total expected grid-level savings.
Economic potential	The savings opportunities available should customers adopt all cost-effective savings, as established by screening measures against the Total Resource Cost (TRC) Test without consideration of market barriers or adoption limitations.
Energy end-use	In this study, energy end-uses refer to a grouping of energy-saving measures related to specific building components (i.e., water heating, HVAC, lighting, etc.).
First-year savings	Savings from measures incentivized through programs in a given year expressed in terms of savings in the first year of each measure's life. First-year savings include savings attributable to measure re-participation (i.e., when a customer is incentivized to participate in a program again after the original measure has reached the end of its useful life).
Lifetime savings	Savings from measures incentivized through programs in a given year expressed in terms of savings expected over the lifetime of each measure. Lifetime savings include savings attributable to measure re-participation (i.e., when a customer is incentivized to participate in a program again after the original measure has reached the end of its useful life).
Market segment	Within each sector, market segments are defined to capture key differences in energy use and savings opportunities that are governed by building use and configuration.
Measure re-participation	The re-participation of a customer in a program after the original incentivized measure has reached the end of its useful life. Re-participation is counted in program savings (i.e., lifetime savings and first-year savings), but it does not impact cumulative savings since the customer's net consumption is not impacted by replacing an efficient technology with an equally efficient technology.
Program Savings	Savings from measures incentivized through programs in a given year. Program savings include measure re-participation and are generally expressed in terms of lifetime savings or first-year savings.
Source MMBtu Savings	Source MMBtu savings convert site savings of electricity (in kWh) into source fuel savings (in MMBtu).

Executive Summary

E.1 Introduction

The following executive summary provides high-level results and key takeaways of the 2022-2024 Eversource MA Potential Study. A detailed discussion of the results is provided in the main body of the report. Volume II of this report contains appendices that outline the methodological approach and data inputs utilized in this study.

Study Overview

The 2022-2024 Eversource MA Potential Study quantifies the savings potential from utility demand-side management (DSM) programs and includes three components covering the following savings streams:

- Energy efficiency (EE),
- Electric demand response (DR), and
- Heating electrification (HE).[1]

The study covers the three years spanning calendar years 2022 to 2024 and includes electricity, natural gas, oil, and propane energy savings; passive and active electric demand reduction savings; and the costs and benefits associated with the measures providing these savings. Inputs and assumptions are based on the best available information at the time of the study and account for current evaluation factors (e.g., net-to-gross ratios, realization rates, etc.) wherever possible. Where these factors are not available, the study makes reasonable assumptions as appropriate but does not try to forecast future evaluation factors based on potential program changes.

In addition to results for Eversource's electric and gas programs, this report also includes energy efficiency potential results for the service territory formerly served by Columbia Gas (CMA). Throughout the study, the results for the former CMA territory are referred to as the EGMA ("Eversource Gas Company of MA") results.

The study explores three program achievable scenarios to determine how incentive levels can impact achievable savings:

- A **BAU** (business-as-usual) scenario emulating existing incentive levels and program configurations,
- A **BAU+** scenario that increases incentives above BAU levels, and
- A **Max** scenario that represents the highest feasible achievable potentials.

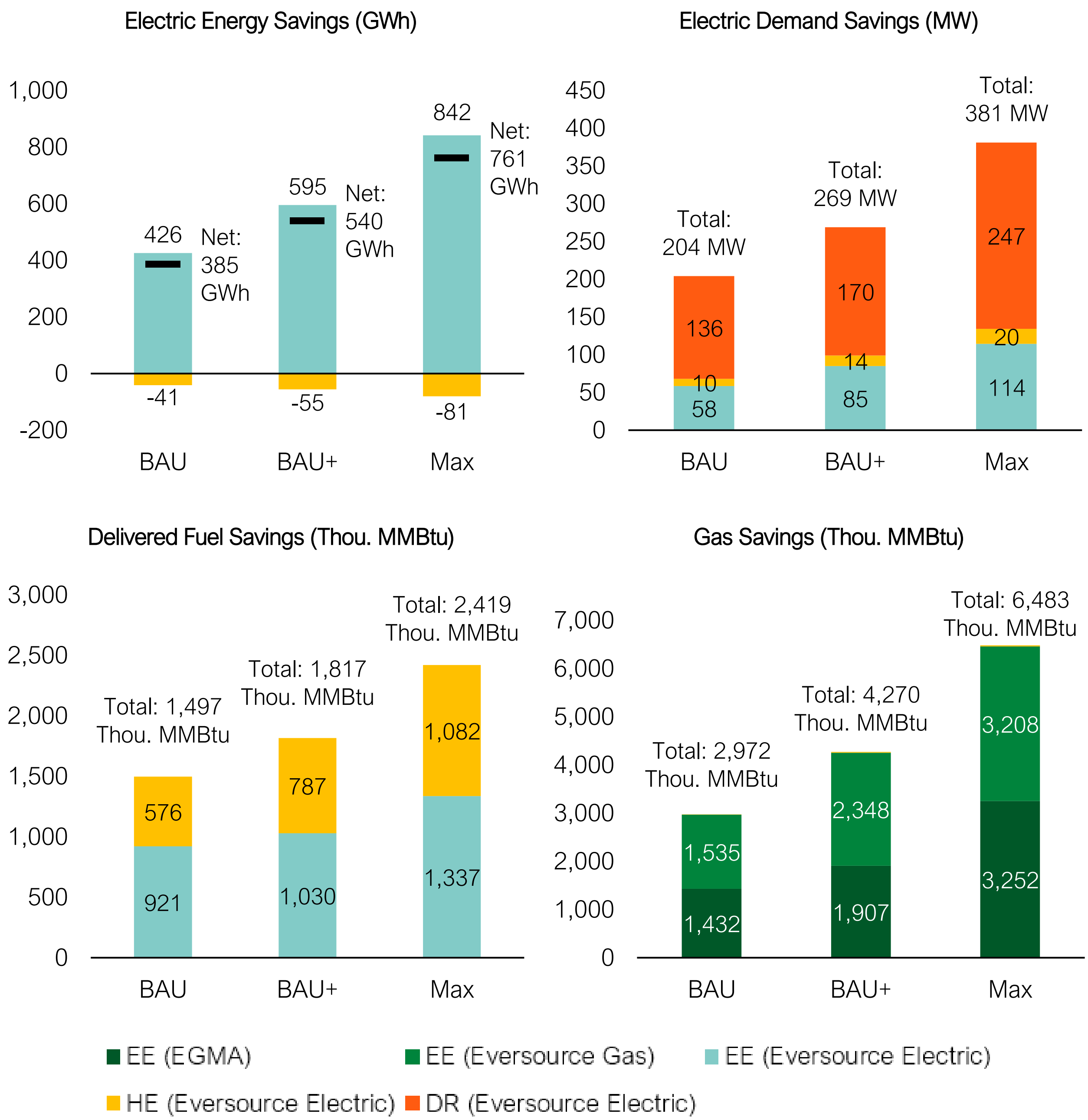
The specific incentive parameters employed for each study component are described in more detail in their respective chapters.

[1] This study does not include an assessment of savings from combined heat and power (CHP) and other distributed energy resources such as distributed generation.

Results Overview

The study finds that Eversource's EE, DR, and HE programs can continue to generate substantial savings throughout the study period and that increasing incentives would likely drive significant savings increases relative to the BAU scenario. Over the three-year study period, the combined impact of these programs will reduce Eversource customers' consumption of electricity, gas, and delivered fuels and reduce their contribution to peak electric demand as summarized in Figure E-1 below.

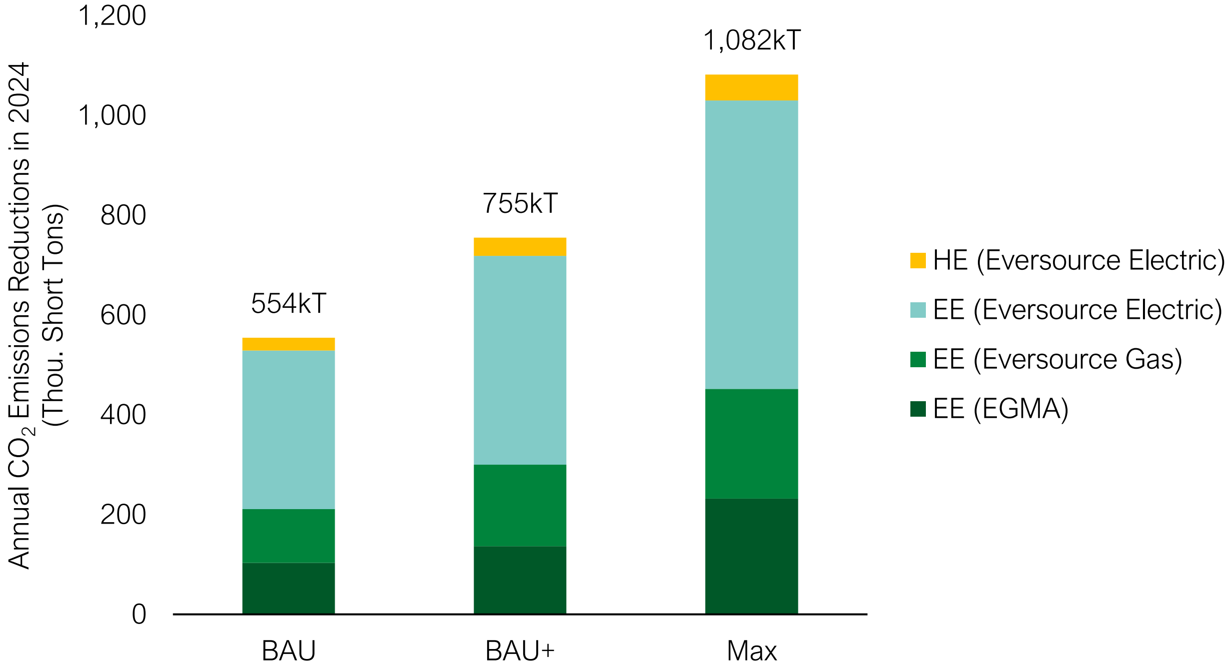
Figure E-1. 2024 Combined Cumulative Savings (EE, HE, and DR)



Note: Results in the above figure represent the combined 2024 cumulative impact of modeled EE, HE, and DR programs over the study period (2022-2024) under each achievable scenario.

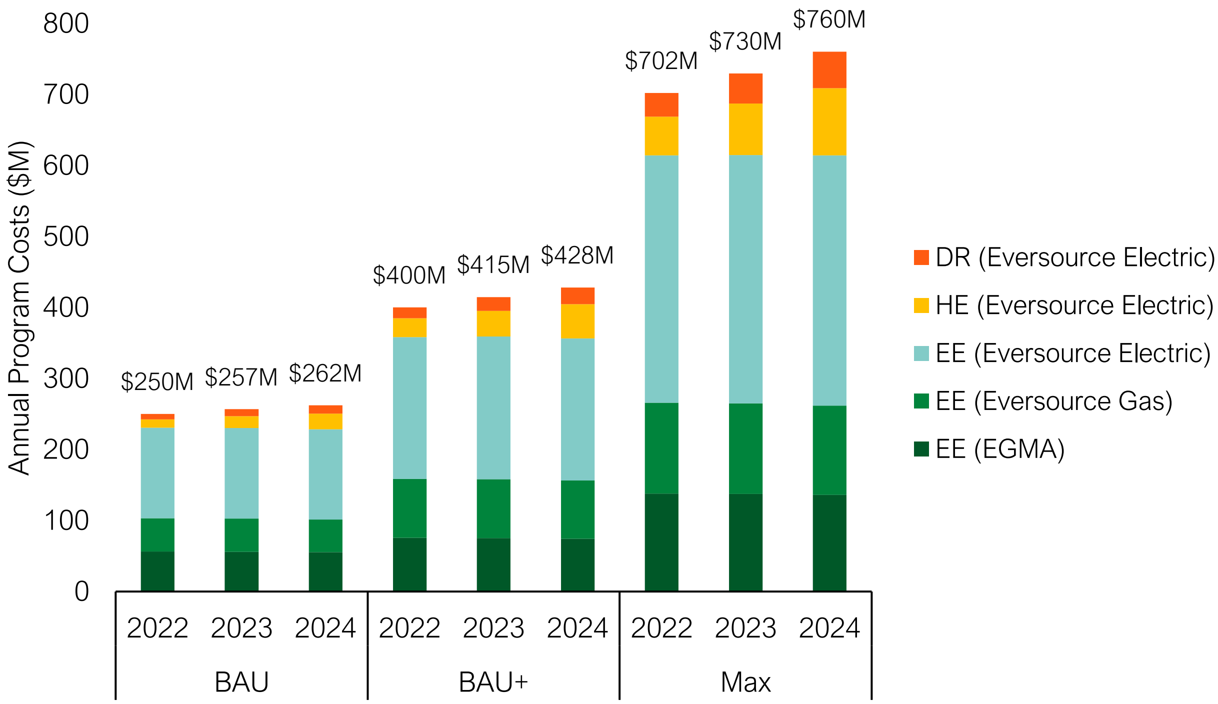
When savings are viewed in terms of annual emission reductions, Eversource's EE and HE programs have the potential to reduce annual CO_2 emissions by a half-million to a million tons by the end of the study period in 2024 as shown in Figure E-2. The majority of emission reductions come from EE measures – with Eversource's Electric Programs contributing over half of all emission reductions under each scenario. HE measures, conversely, represent approximately 5% of emission reductions under all scenarios.

Figure E-2. 2024 Cumulative Annual Emission Reductions (EE and HE)



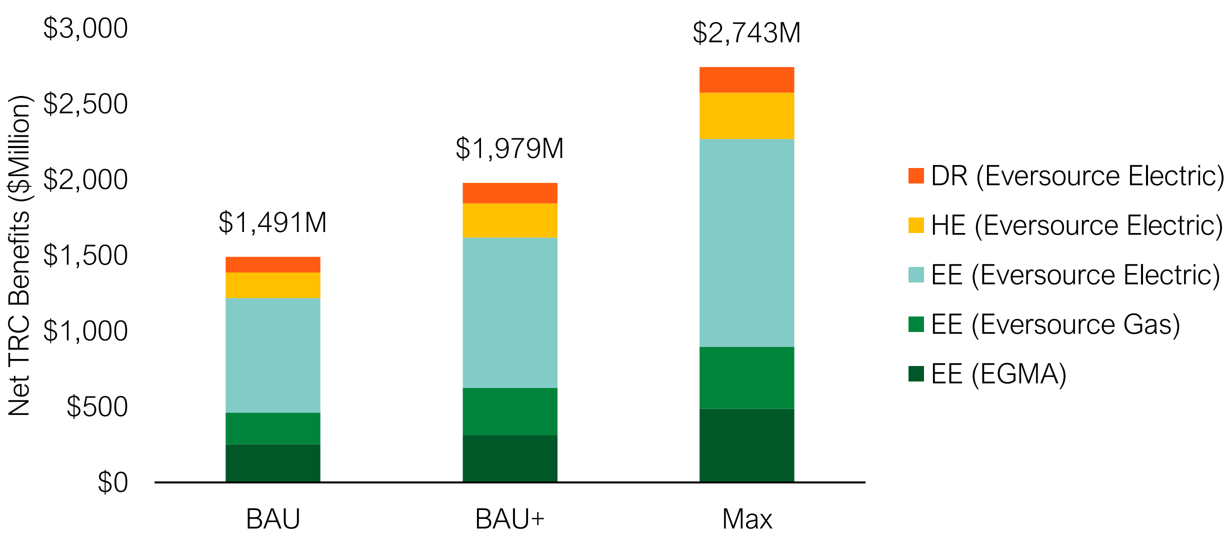
The combined estimated program costs (including incentives and non-incentive administrative program costs) to achieve these savings are presented in Figure E-3. As expected, increasing incentive levels increases overall costs as participation increases and the incentives per participant increase. Under all scenarios, costs increase each year primarily due to year-over-year growth in HE and DR measure adoption. Under BAU conditions, costs top out at $262 million in 2024. Under the Max scenario, costs nearly triple relative to BAU to $760 million in 2024.

Figure E-3. Combined Annual Program Costs (EE, HE, and DR)



While the modeled programs will require significant expenditures, these costs will be outweighed by the benefits as measured by the total resource cost test (TRC) results. Over the three-year study period, the total estimated combined net TRC benefits range from nearly $1.5 billion under the BAU scenario to $2.7 billion under the Max scenario as shown in Figure E-4. The reduction in energy consumption from EE and HE measures will also drive significant greenhouse gas (GHG) emission reductions – reducing annual CO_2 emissions by 554 thousand tons in 2024 under the BAU scenario and up to 1 million tons under the Max scenario as previously discussed.

Figure E-4. Total 2022-2024 Net TRC Benefits (EE, HE, and DR)



Finally, while raising incentives can lead to increased program participation and increased costs, particularly in the short-term, opportunities may exist to leverage program enhancements that further reduce market barriers for efficient technologies over the long term. While these strategies take time to implement and their impacts can be uncertain, they could offer a lower-cost opportunity to drive higher savings, where successful, when compared to simply increasing incentives. Eversource and the state of Massachusetts as a whole have consistently achieved success reducing market barriers as shown by the state's consistent top ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near-complete transformation of the Massachusetts residential lighting market. Moreover, the recently enacted state climate bill ("An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy") may provide a framework to drive savings through statewide policies that can work in conjunction with Eversource's programs to help transform the market for other technologies.

E.2 Energy Efficiency Potential

Energy efficiency potential is assessed for Eversource Electric, Eversource Gas, and EGMA's energy efficiency programs. The analysis explores three achievable program scenarios as described in Table E-1. The BAU scenario is designed to emulate savings that can be achieved under existing program structures and incentive levels albeit with measures and technologies that may not be currently offered by existing programs. The BAU+ and Max scenarios demonstrate what is possible with increased incentive levels.

Table E-1. Energy Efficiency Achievable Program Scenario Descriptions

BAU	Applies incentives and program configurations in line with the PA's incentives paid in 2019 to simulate **business as usual**. Additional prescriptive measures beyond those currently offered may be included.
BAU+	Increases incentives **above and beyond** BAU levels. Specifically, weatherization measure incentives are set at 90% of incremental costs and all other incentives are set 50% higher than BAU levels with a maximum of 90% of incremental costs unless BAU scenarios already exceed this threshold).
Max	Completely **eliminates incremental customer costs** associated with installing efficiency measures (all incentives set to cover 100% of the efficiency measure incremental cost).

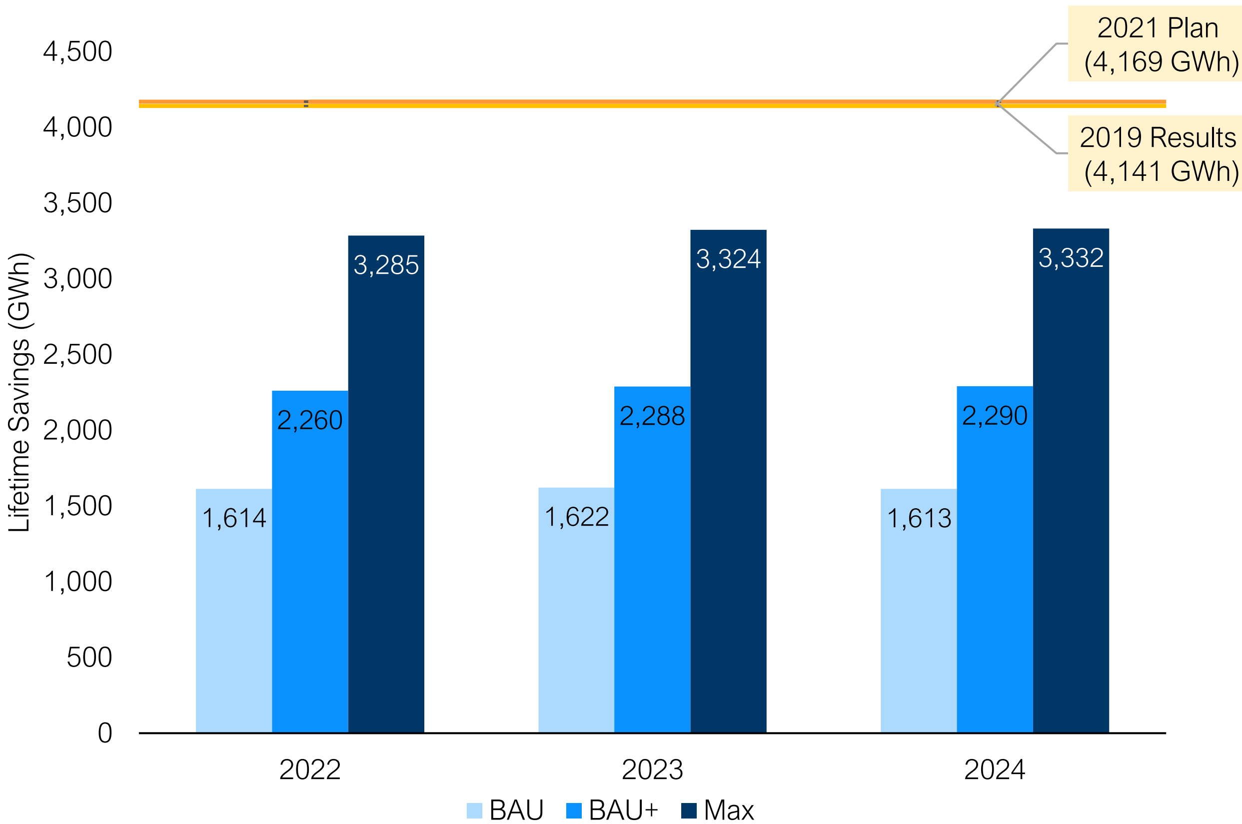
Results are presented by program administrator (PA) in the following order:

- Eversource Electric Program Results (including electric and delivered fuel savings)
- Eversource Gas Program results
- EGMA Gas Program results

Eversource Electric EE Program Results

The study finds that achievable lifetime electric savings for Eversource Electric's efficiency programs will decline relative to savings achieved in the past under all scenarios as shown in Figure E-5.

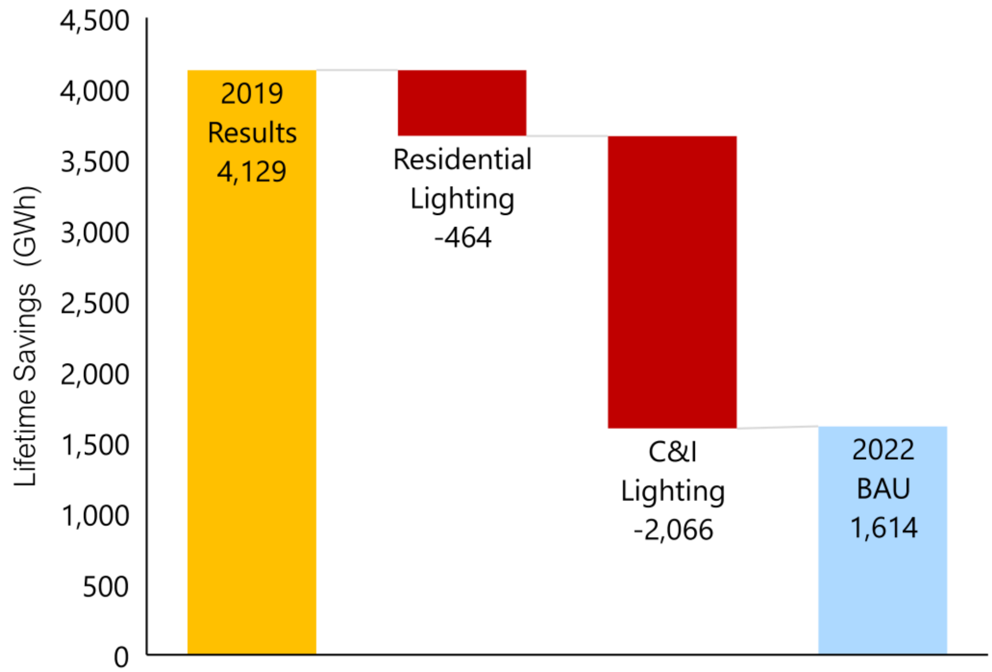
Figure E-5. Eversource Electric Programs, Electric EE Lifetime Savings by Year



Compared to Eversource's 2019 program results and the 2021 Plan savings, achievable lifetime electric savings are expected to decline precipitously. Under BAU incentive levels, 2022-24 average lifetime savings are approximately 61% lower than past program savings. While modest increases in some measures are expected as heat pump markets grow – primarily impacting residential HVAC savings – the difference between the BAU scenario and recent electric savings achievements is almost entirely attributable to reductions in lighting savings from both the residential and C&I sectors as shown in Figure E-6.[2]

[2] While the reduction in lighting savings explains most of the difference between 2019 Results and 2022 BAU, it should be noted there are other differences that result in both increases and decreases in savings, but these largely offset each other (i.e., reductions in home energy report savings and increases in HVAC savings).

Figure E-6. Eversource Electric Programs, Electric EE 2022 BAU Lifetime Savings vs. 2019 Results

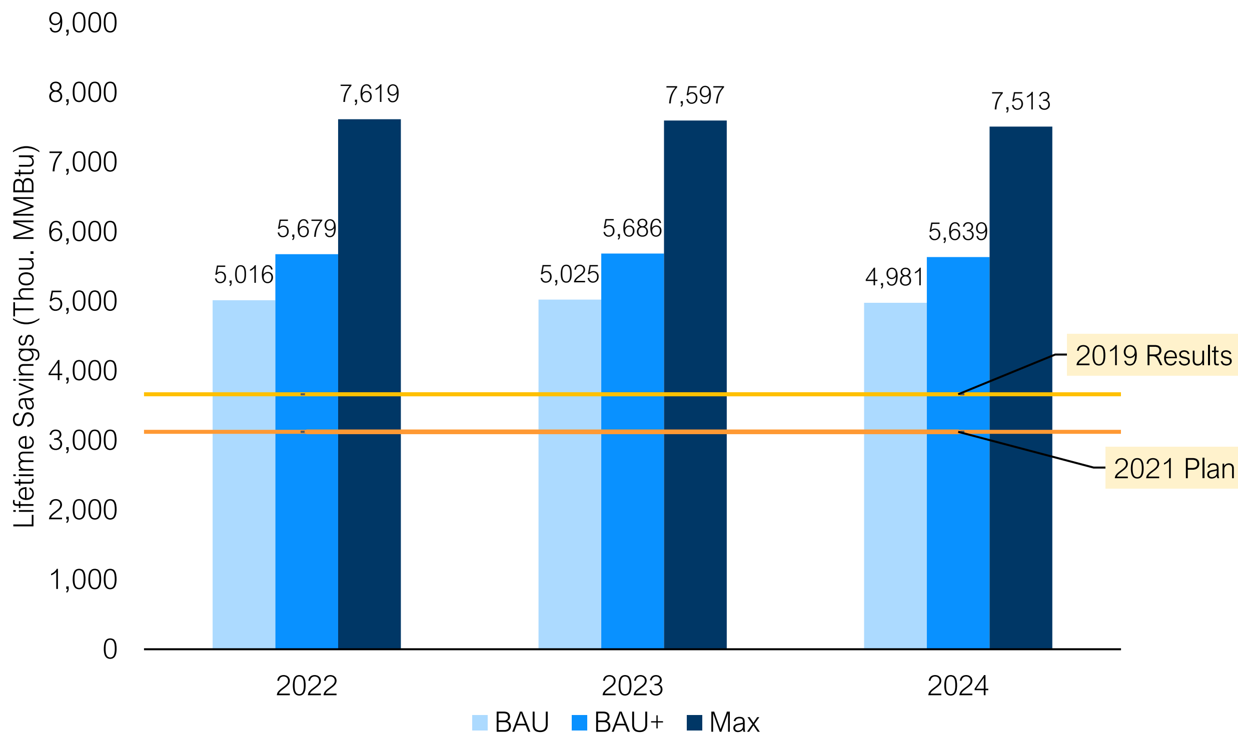


The reduction in lighting savings is significant enough that even under Max incentive levels, savings do not reach levels achieved in the past. Under the BAU+ and Max scenarios, 2022-24 average lifetime savings increase by 41% and 105% relative to BAU, respectively, yet still fall short of past achievements. This suggests that maintaining electric savings at historical levels will not be possible even if the programs offer incentives to customers that offset 100% of the incremental costs associated with efficient technologies.

Delivered Fuel Savings from Eversource Electric Programs

Eversource Electric's efficiency programs also offer measures targeted at delivered fuels (oil and propane) savings. The achievable delivered fuel savings are assessed to exceed past program savings as shown in Figure E-7.

Figure E-7. Eversource Electric Programs, Delivered Fuels EE Lifetime Savings by Year



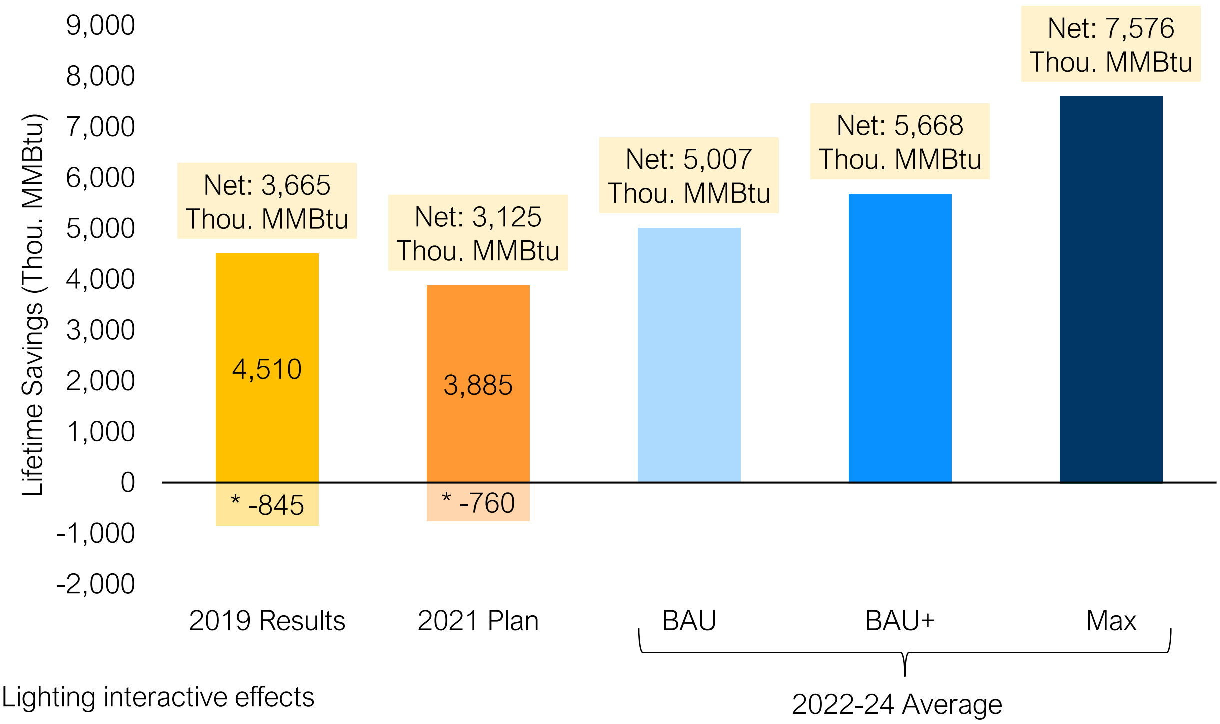
The increase in savings relative to past achievements is attributable to two main factors:

- First, the study includes prescriptive C&I delivered fuels measures that are not currently part of Eversource's programs.
- Second, the delivered fuels savings in Eversource's 2019 Results and 2021 Plan were reduced due to a significant amount of indirect negative savings from lighting measure interactive effects.[3] With reduced lighting savings in the study period, negative savings stemming from lighting interactive effects are reduced, thereby increasing overall net delivered fuel savings.

When lighting interactive effects are removed as shown in Figure E-8, the study estimates that residential savings will continue at levels achieved in 2019 with the remaining increase in savings driven by the prescriptive C&I measures. With increased incentives under the BAU+ and Max scenarios, 2022-24 average lifetime savings increase by 13% and 51% relative to BAU, respectively.

[3] LED lighting produces less waste heat than inefficient lighting equipment requiring heating systems to consume additional energy to maintain the same indoor temperature.

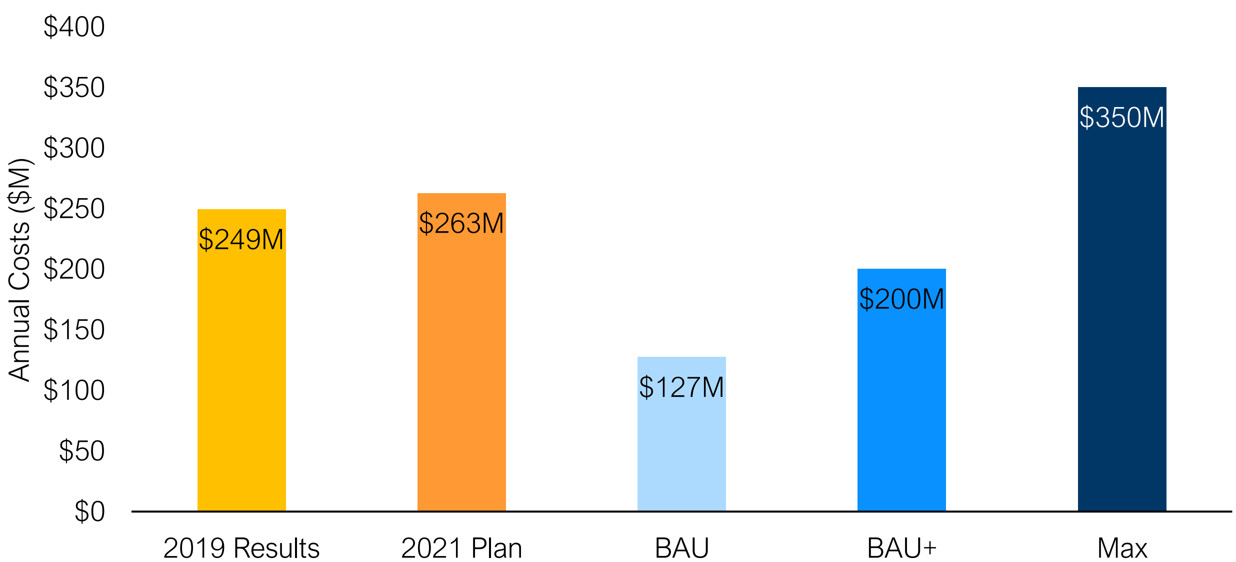
Figure E-8. Eversource Electric Programs, Delivered Fuels EE Lifetime Savings with Lighting Interactive Effects Removed



Portfolio Metrics

Figure E-9 presents the estimated 2022-24 average annual cost of administering Eversource's electric programs (including electric and delivered fuel measures) under each achievable scenario.

Figure E-9. Eversource Electric Programs, EE Program Costs



In the BAU and BAU+ scenarios, electric program costs are significantly below 2019 Results and the 2021 Plan, which is commensurate with the decline in overall electric savings. With significant reductions in the incentives paid for lighting measures, overall costs are reduced by 49% under the BAU scenario relative to 2019 Results and 52% relative to the 2021 Plan. Under the Max scenario, overall costs eclipse 2019 Results and the 2021 Plan even though achievable electric lifetime savings do not reach 2019/2021 levels. Under the Max scenario, average annual costs are 41% higher than in 2019, while achieved electric lifetime savings are still 20% below 2019 achievements.

The higher budgets coupled with lower electric savings increase the cost per kWh of savings relative to past years. This is partly driven by a larger portion of program budgets going towards delivered fuels measures as diminishing lighting savings reduce overall electric savings. As diminishing lighting savings reduce overall electric savings, the relative portion of budgets going towards delivered fuels measures are expected to increase. This increases the program cost per unit of electric savings as more program dollars go towards measures that do not procure significant amounts of electric savings. This trend increases the study's estimated program cost per unit of electric savings, but it does not explain the entire difference.

Even when delivered fuel incentive costs are excluded, the cost to deliver electric savings is still higher than in the past as shown in Table E-2, where **program costs per lifetime kWh under the BAU scenario are 37% greater than in 2019**. This difference is driven by the programs capturing more higher-cost savings opportunities to replace lost lighting savings, which tend to be among the lowest-cost opportunities. Therefore, as lighting savings decrease in the portfolio, the average program cost per unit of electric savings should be expected to increase.

Table E-2. Eversource Electric Programs, EE Program Costs with and without Delivered Fuels Incentive Costs

	With delivered fuels incentive costs			Without delivered fuels incentive costs		
	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per First-Year kWh	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per First-Year kWh
2019 Results	$249	$0.055	$0.48	$226	$0.050	$0.43
2021 Plan	$263	$0.049	$0.53	$239	$0.044	$0.48
BAU	$127	$0.079	$0.84	$110	$0.068	$0.73
BAU+	$200	$0.088	$0.97	$177	$0.078	$0.85
Max	$350	$0.106	$1.21	$308	$0.093	$1.06

Overall, Eversource's electric efficiency programs have the potential to continue to generate significant benefits as measured by the TRC as well as emission reductions. Table E-3 displays the overall TRC ratio, net TRC benefits, and net benefits per lifetime and first-year kWh saved. Under the BAU scenario, the portfolio-wide TRC ratio declines slightly compared to 2019 but is higher than the 2021 plan. While electric avoided costs used in this study (AESC 2021 values) are generally lower than the avoided costs used to estimate TRC values in the 2019 Results and 2021 Plan (AESC 2018 values), the higher proportion of savings from delivered fuels measures, which generally have higher net TRC benefits, helps counteract lower electric avoided costs.[4] Additionally, the TRC ratio across scenarios only varies slightly as incentive levels do not impact measure benefit-cost ratios.

Table E-3. Eversource Electric Programs, EE TRC Benefits, and CO2 Emission Reductions (2022-24 Average)

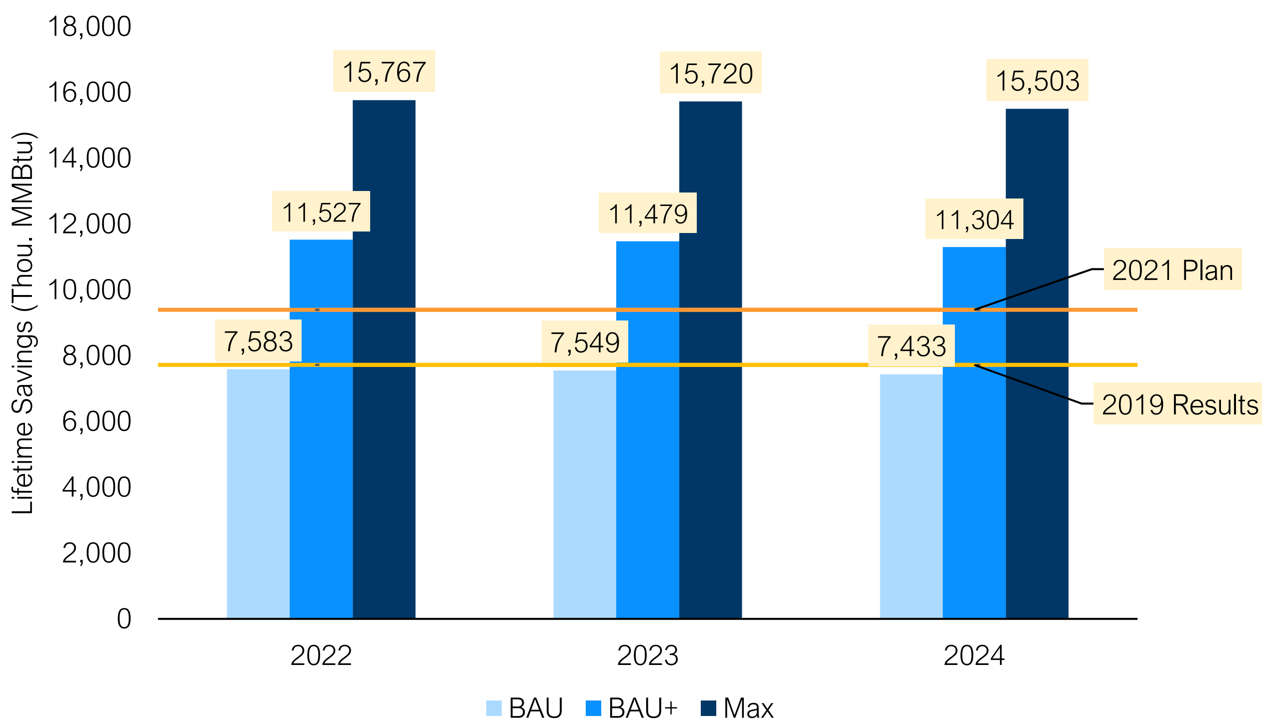
	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime kWh	Net TRC Benefits per First-year kWh	CO_2 Annual Emission Reductions (Short Tons)
2019 Results	2.6	$600M	$0.13	$1.15	334,000
2021 Plan	2.3	$584M	$0.11	$1.18	274,000
BAU	2.6	$252M	$0.16	$1.67	106,000
BAU+	2.7	$331M	$0.15	$1.60	140,000
Max	2.6	$457M	$0.14	$1.58	193,000

Note: TRC values for 2019/2021 benchmarks are derived using 2018 AESC values while modeled TRC values are derived using 2021 AESC values.

Eversource Gas EE Program Results

The study finds that gas achievable lifetime savings for Eversource Gas's efficiency programs are projected to be similar to past program performance under the BAU scenario with the potential to increase savings by increasing incentive levels as shown in Figure E-10.

Figure E-10. Eversource Gas Programs, EE Gas Lifetime Savings by Year

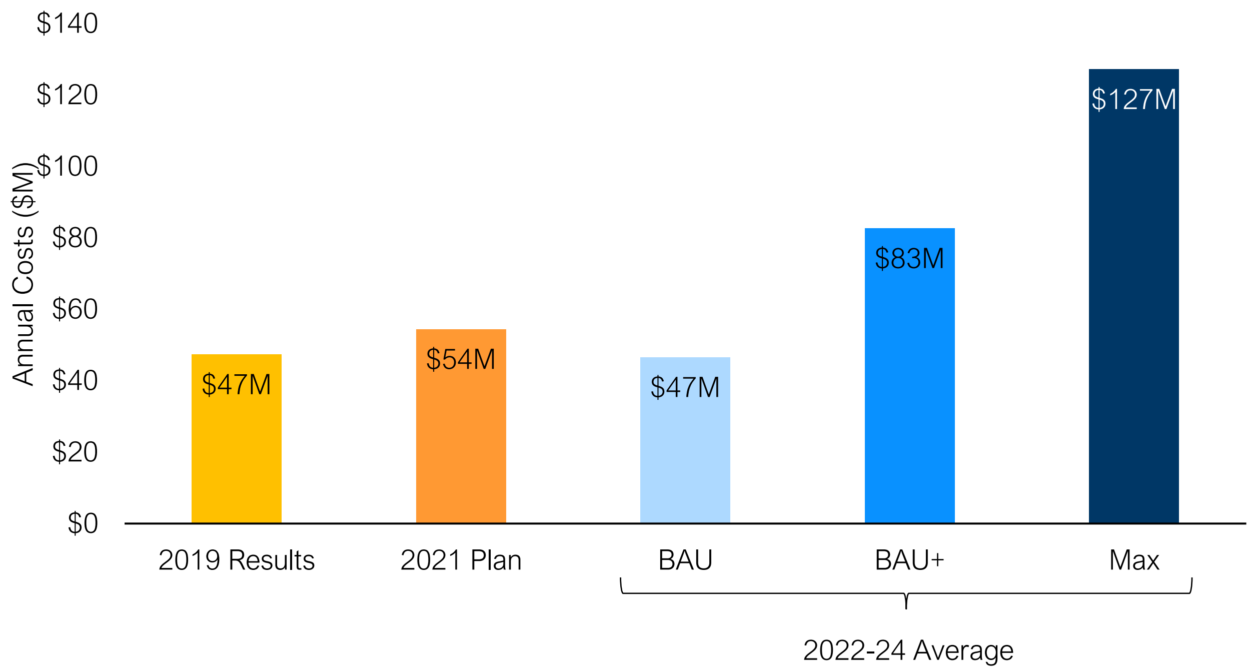


[4] For more information on differences between AESC 2018 and AESC 2021 values, see page 2 of the *Avoided Energy Supply Components in New England: 2021 Report*. Accessible at: https://www.synapse-energy.com/sites/default/files/AESC_2021_.pdf

Portfolio Metrics

Under BAU conditions, program costs are expected to remain at expenditure levels observed in 2019 commensurate with the similar level of gas savings as shown in Figure E-11. With increased incentives, costs will be expected to increase faster than savings. Under the BAU+ scenario, costs increase by 77% over the BAU scenario, while average lifetime savings only increase by 52%. A similar trend is observed in the jump from BAU+ to Max.

Figure E-11. Eversource Gas Programs, EE Program Costs



In terms of program cost per MMBtu of gas saved, the unit cost to deliver savings is commensurate with costs in the 2019 Results, but savings under the BAU+ and Max scenarios cost one to two programs dollars more per lifetime MMBtu saved as shown in Table E-4.

Table E-4. Eversource Gas Programs, EE Program Costs per Unit of Savings

	Program $ per Lifetime MMBtu	Program $ per First-Year MMBtu
2019 Results	$6.13	$85
2021 Plan	$5.79	$74
BAU	$6.21	$89
BAU+	$7.25	$104
Max	$8.16	$119

Overall, Eversource's gas efficiency programs have the potential to continue to create significant benefits as measured by the TRC as well as GHG emission reductions. Table E-5 displays the overall TRC ratio, net

TRC benefits, net benefits per lifetime and first-year MMBtu saved, and average annual CO_2 emission reductions achieved each program year.

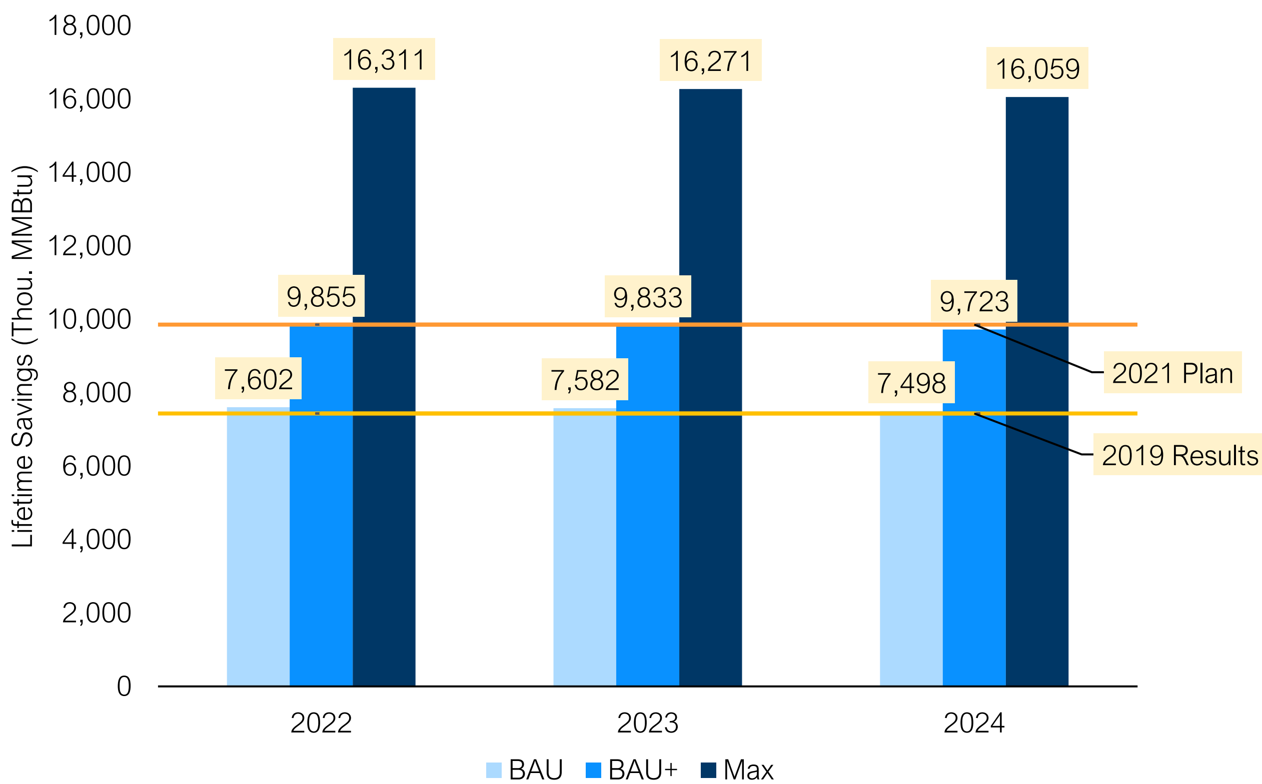
Table E-5. Eversource Gas Programs, EE TRC Benefits, and CO_2 Emission Reductions (2022-24 Average)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime MMBtu	Net TRC Benefits per First-Year MMBtu	Annual CO2 Emission Reductions (Short Tons)
2019 Results	2.1	$76M	$9.78	$136	37,700
2021 Plan	2.3	$98M	$10.44	$133	50,100
BAU	2.2	$70M	$9.87	$133	36,000
BAU+	2.1	$103M	$9.57	$130	54,000
Max	2.2	$137M	$9.29	$128	73,000

EGMA Gas EE Program Results

Similar to the Eversource Gas results, the study finds that gas achievable lifetime savings for EGMA's efficiency programs under the BAU scenario will continue at similar levels to past program performance, with the potential to increase savings by increasing incentive levels as shown in Figure E-12.

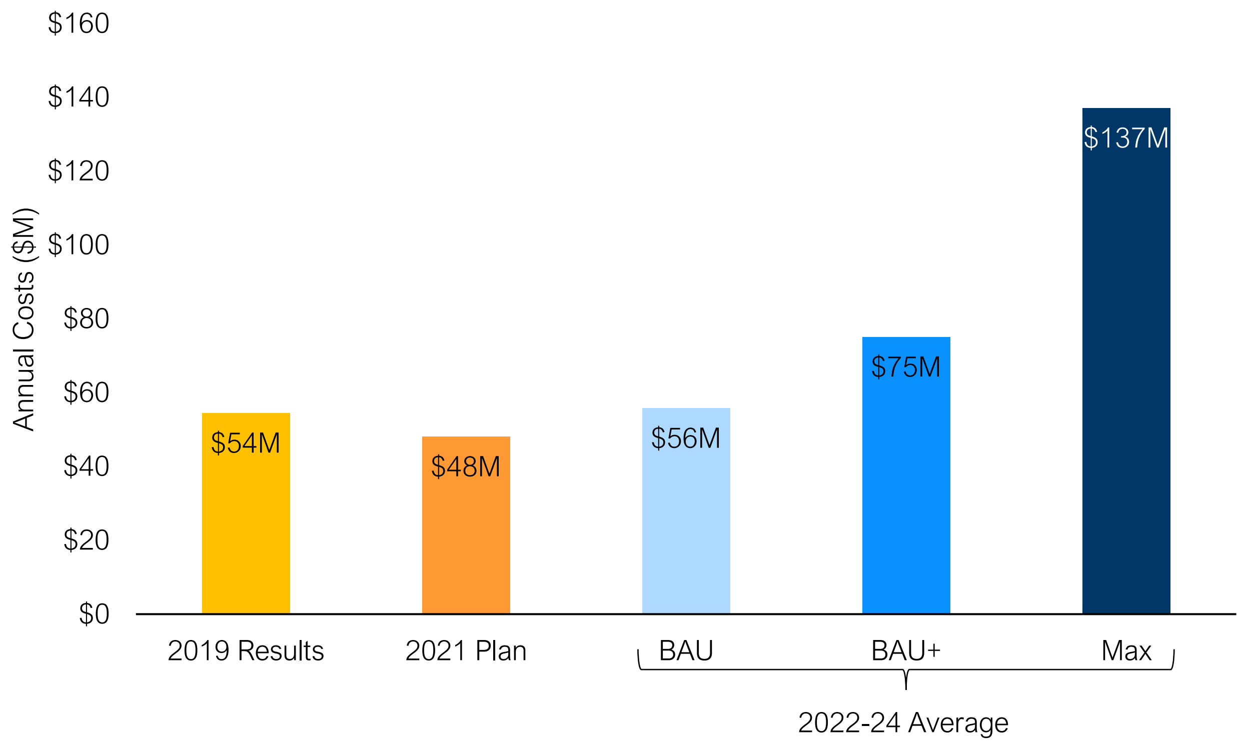
Figure E-12. EGMA Programs, EE Gas Lifetime Savings by Year



Portfolio Metrics

Under BAU conditions, program costs are expected to remain at expenditure levels observed in 2019 commensurate with the similar level of gas savings as shown in Figure E-13. With increased incentives, costs will be expected to increase more rapidly than savings. Under the BAU+ scenario, costs increase by 35% over the BAU scenario, while average lifetime savings only increase by 30%. A similar trend is observed in the jump from BAU+ to Max.

Figure E-13. EGMA Programs, EE Program Costs



In terms of program cost per MMBtu of gas saved, the unit cost to deliver savings is commensurate with costs in the 2019 Results, but savings under the BAU+ and Max scenarios more programs dollars per lifetime MMBtu saved as shown in Table E-6.

Table E-6. EGMA Programs, EE Program Costs per Unit of Savings

	Program $ per Lifetime MMBtu	Program $ per First-Year MMBtu
2019 Results	$7.33	$131
2021 Plan	$4.88	$69
BAU	$7.38	$112
BAU+	$7.66	$115
Max	$8.46	$124

Overall, EGMA's gas efficiency programs have the potential to continue to create significant benefits as measured by the TRC as well as emission reductions. Table E-7 displays the overall TRC ratio, net TRC benefits, net benefits per lifetime and first-year MMBtu saved, and average annual CO_2 emission reductions achieved each program year.

Table E-7. EGMA Programs, EE TRC Benefits, and CO_2 Emission Reductions (2022-24 Average)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime MMBtu	Net TRC Benefits per First-Year MMBtu	Annual CO2 Emission Reductions (Short Tons)
2019 Results	2.1	$77M	$10.32	$184	26,600
2021 Plan	2.8	$121M	$12.32	$175	46,900
BAU	2.2	$84M	$11.66	$168	34,000
BAU+	2.2	$104M	$11.24	$159	46,000
Max	2.3	$162M	$10.53	$147	77,000

Key Takeaways

Based on the results of this study, the following key take-aways emerge for EE:

- Under **BAU incentive levels** and current program configurations, electric and delivered fuels savings levels are projected to vary significantly from past program results:
  - **Electric savings** will decline sharply as lighting savings continue to drop due to the rapid transformation of Massachusetts's lighting markets, despite increased opportunities from growing heat pump penetrations.
  - **Delivered fuels savings** could increase with the inclusion of new prescriptive C&I measures in existing programs while residential savings continue at past levels, and
  - **Gas savings** are expected to stay relatively stable as exogenous factors are not expected to significantly change savings opportunities or markets.[5]

- **By increasing incentives**, programs can obtain substantially more savings albeit with significant increases in program costs. Under the Max scenario:
  - **Electric savings** increase by 105% relative to the BAU scenario. Yet, while this is a substantial increase, it is still not sufficient to replace the declining lighting opportunities, and as a result, overall electric savings will still be lower than past program achievements.
  - **Delivered fuels savings** increase by 51% over the BAU scenario projections. Relative to electric and gas savings, raising incentives offers a relatively smaller incremental increase in delivered fuels savings. Existing programs already capture a large portion of net economic potential and due to the relatively high cost of delivered fuels in Massachusetts, customers are already highly incentivized to use these fuels efficiently. Thus, providing greater upfront incentives has less of an impact on customer decision-making.

[5] Toward the end of the study, the PAs elaborated plans to restrict propane and gas heating equipment replacements to only replace non-condensing equipment with condensing equipment. In addition, the PAs planned to eliminate incentives for high efficiency oil boilers and instead offer incentives to replace oil boilers with heat pumps. If these changes take place, residential gas and delivered fuel savings would be expected to decline relative to past program performance and the achievable potential savings results presented in this report.

  - **Gas savings** increase by 108% relative to the BAU scenario for Eversource's gas programs and 114% for EGMA's gas programs, showing that there is substantial room to grow gas savings by offering higher customer incentives.
  - Importantly, in all cases, **costs increase at a faster rate than savings** with Eversource Electric costs (for electric and delivered fuel savings) increasing by 176%, Eversource Gas costs increasing by 170%, and EGMA costs increasing by 144% relative to the BAU scenario.

- **Program Enhancements:** Raising incentives can lead to increased program savings, but for some measures and end-uses, even at the Max scenario incentive levels a substantial portion of the net economic savings remain untapped. These uncaptured savings represent cost-effective opportunities that are inhibited for reasons beyond customer economics. For example, under the Max scenario:
  - 38% of 2024 cumulative net economic **electric savings** are not captured by programs,
  - 35% of 2024 cumulative net economic **delivered fuels savings** are not captured by programs, and
  - 29% and 32% of 2024 cumulative net economic **gas savings** are not captured by Eversource and EGMA programs, respectively.

  While *completely* eliminating all market barriers for all efficient technologies is not feasible, (particularly in just the next three years), uncaptured economic savings may represent opportunities for enabling program strategies and market transformation approaches to further reduce market barriers and increase savings. Examples could include changes in program requirements, updating program delivery mechanisms and marketing, offering new financing options to support energy efficiency upgrades, additional investments in workforce training and contractor outreach, and new feedback mechanisms such as home and building energy reporting and disclosure that help to value energy efficiency in the marketplace. However, these strategies take time to implement, and their impacts are more uncertain than increasing incentive levels.

E.3 Demand Response

Electric demand response potential is assessed for Eversource Electric's Active Demand Reduction (ADR) programs to reduce Eversource's peak load during the 10-40 highest demand hours of the year. This represents incremental additional peak load reduction to the passive peak demand reductions resulting from energy efficiency measures. The analysis explores three achievable program scenarios as described in Table E-8.

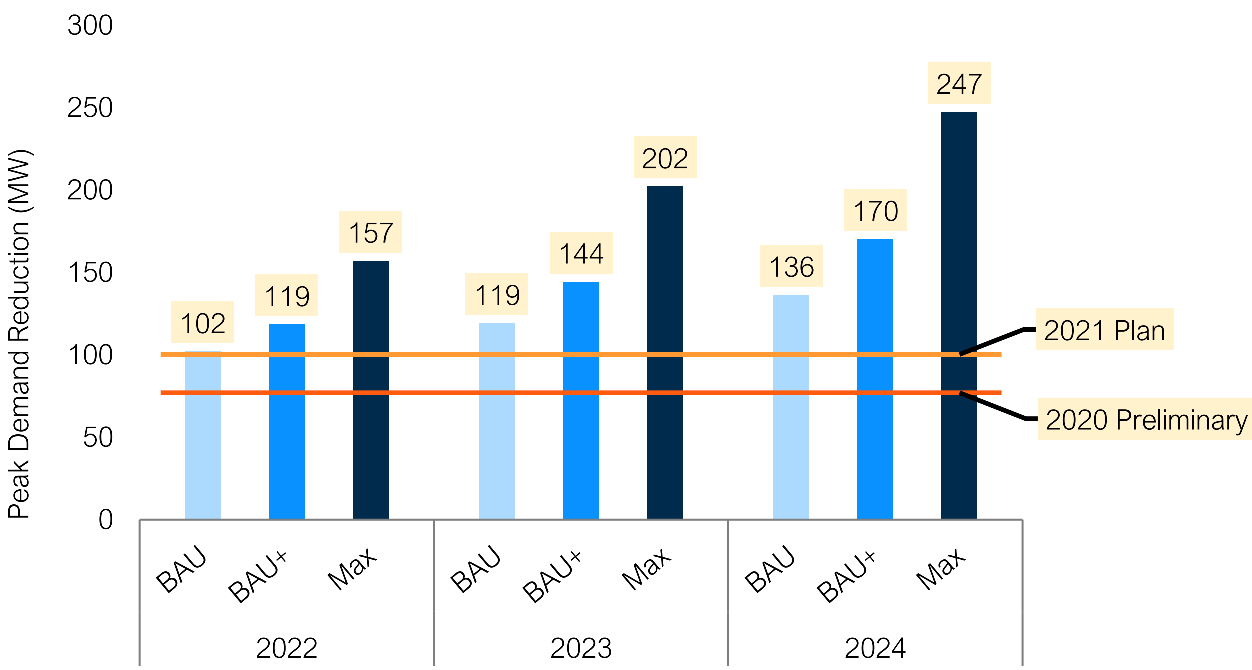
Table E-8. Demand Response Achievable Program Scenario Descriptions

BAU	**Current ADR programs and incentives**, when applied across the full applicable market, to obtain projected equilibrium participation levels as predicted by the DROP model's propensity curves[6] under evolving market conditions and through ongoing marketing and outreach without altering incentives or measures offered.
BAU+	Tests the ability to **expand participation by increasing incentives** under the current ADR programs, while maintaining cost-effectiveness.
Max	Applies BAU+ scenario incentive levels, and further **expands ADR programs to include a range of new cost-effective measures**.

ADR Program Results

The study finds that achievable peak load reduction from Eversource's ADR programs can reach 136 MW under BAU conditions and up to 247 MW under the Max scenario as shown in Figure E-14. 77 MW of this potential is currently being captured by Eversource's ADR program enrollment to date, which indicates that up to 170 MW of additional potential could be achieved by expanding the range of ADR measures and increasing incentives.

Figure E-14. Achievable ADR Potential by Year



[6] Propensity curves available in Appendix D.

Table E-9 summarizes the achievable potential in 2024 for each of the assessed scenarios, as well as the average portfolio TRC ratio results and annual program costs. Annual costs increase over the study period as ADR programs continue to grow to amount to $11.6 million in 2024 under BAU conditions and $51.5 million under the Max scenario. While achievable potential under all scenarios is cost-effective, the benefit-cost ratio, as measured by the TRC, declines under the BAU+ and Max scenarios, which is in contrast with the modeled EE TRC ratios. This is due to the inclusion of DR incentive costs in the TRC calculation because they typically do not cover a portion of the customers' equipment incremental costs.

Table E-9. ADR Achievable Potential, TRC Ratio, and Annual Spending in 2024 by Scenario

Scenarios	BAU	BAU+	Max
Achievable Potential (2024)	136 MW	170 MW	247 MW
Average Portfolio TRC (2024)	2.7	2.3	1.7
Portfolio Annual Spending (2024)	$11.6 million	$23.5 million	$51.5 million
Average Supply Cost (2024)	$90/kW	$140/kW	$210/kW

Key Takeaways

Based on these finds, three key takeaways emerge:

- **Eversource's current programs are effective at capturing a significant portion of the ADR potential; however, there remains room for further growth.** The current ADR measures are capturing a large share of their existing potential (about 60% of the 2024 BAU potential). However, through increased incentives and an expanded pool of ADR measures, Eversource could increase impacts by 200% in 2024 (under the Max scenario) in a cost-effective manner. The bulk of this growth in potential can be attributed to residential DLC programs, C&I energy storage, and C&I curtailment.

- **The current focus on BYOD approaches for residential HVAC measures appears to limit the program's potential.** Because residential cooling is a key driver of the ISO-NE annual peak, connected thermostats that control AC units can play an important role in curtailing the peak demand. The study shows that offering connected thermostats to customers who would not adopt these on their own could help unlock significant potential. Broadly speaking, two approaches can help improve the adoption of connected thermostats and thereby expand ADR program participation:

    - Offering to provide smart thermostats to customers specifically to encourage ADR program participation could help overcome some market barriers to thermostat adoption, as has been witnessed in recent programs in a handful of other states. Although this unlocks the potential quickly, it does carry notable upfront costs, and there is some uncertainty as to how long customers will remain with the program if they are not required to enter into a multi-year participation contract.

- Further thermostat adoption can also be encouraged by integrating marketing and incentive offers between ADR and efficiency programs. This approach may lead to a slower penetration rate, but it would likely result in a higher benefit-cost ratio overall.

- **Battery storage offers a large swath of cost-effective ADR potential.** While C&I curtailment has the highest benefit-cost ratio, it cannot be applied in all cases. The analysis indicates that there is significant room for batteries to grow particularly in the C&I sector. Moreover, by offering higher ADR incentives to C&I customers, Eversource may encourage further adoption of battery technologies among its C&I customers, which can further expand the program potential. This trend is expected to gain further momentum beyond the study period as battery costs continue to decrease each year.

Overall, these findings indicate that both expanding to new measures and increasing incentives can play an important role in increasing active demand reduction potential in Eversource's Massachusetts service territory.

E.4 Heating Electrification

Heating electrification (HE) potential is assessed for electrifying existing buildings that contain gas, oil, and propane-fired primary space and water heating systems among Eversource's residential and commercial electric customers. It also includes an assessment of the potential to encourage electric heating systems to be installed in newly constructed buildings. The analysis explores three achievable program scenarios as described in Table E-10.

Table E-10. Heating Electrification Achievable Program Scenario Descriptions

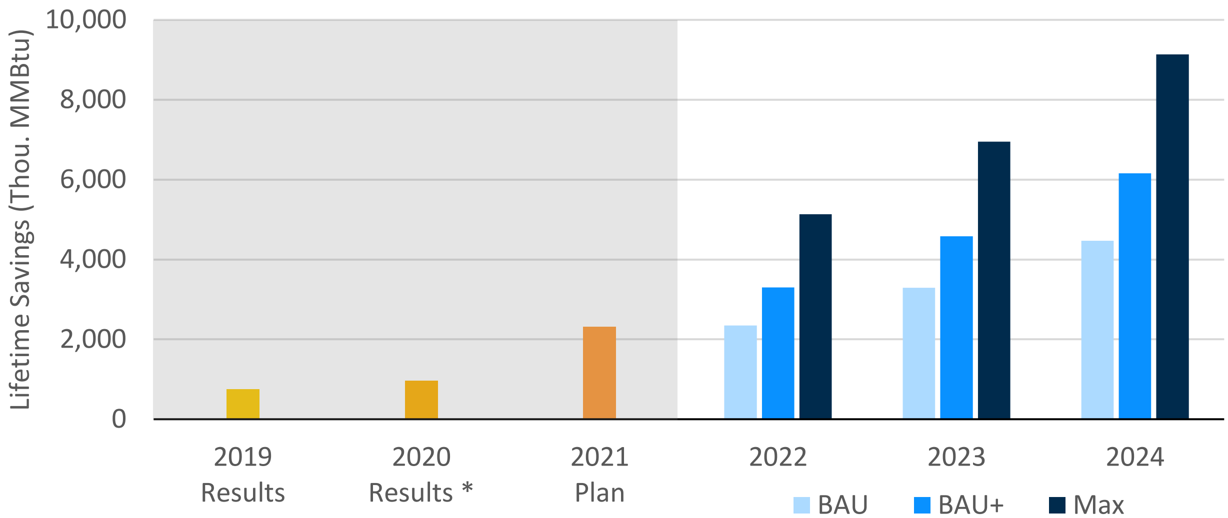
BAU	Applies incentives **in line with Eversource's 2019-2021 Energy Efficiency Plan** to simulate business as usual: • $1,250 a ton for air-source, $3,000 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost.[7] • HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). • Measures not currently offered within programs are also included (gas, units > 5.4 tons).
BAU+	Increases incentives **above and beyond** levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: • $1,875 a ton for air-source, $4,500 a ton for ground-source HPs. • Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives further above and beyond levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives **are twice the BAU levels**: • $2,500 a ton for air-source, $6,000 a ton for ground-source HPs. • Incentive levels are capped at 90% of full heat pump installation cost.

[7] Current programs provide incentives as a function of heat pump capacity and not incremental cost. Moreover, incremental costs are highly variable from case to case due to the combination of heating *and* cooling system replacements. Incentives could therefore exceed the incremental cost, depending on the baseline.

HE Program Results

The study finds that energy optimization offerings will exhibit continued growth in potential under all scenarios as shown in Figure E-15. As heating electrification is an emerging technology, the analysis projects large year-over-year growth that is in line with the planned expansion in Eversource's programs in the years preceding the study period.

Figure E-15. HE Lifetime Building-level Fuel Savings

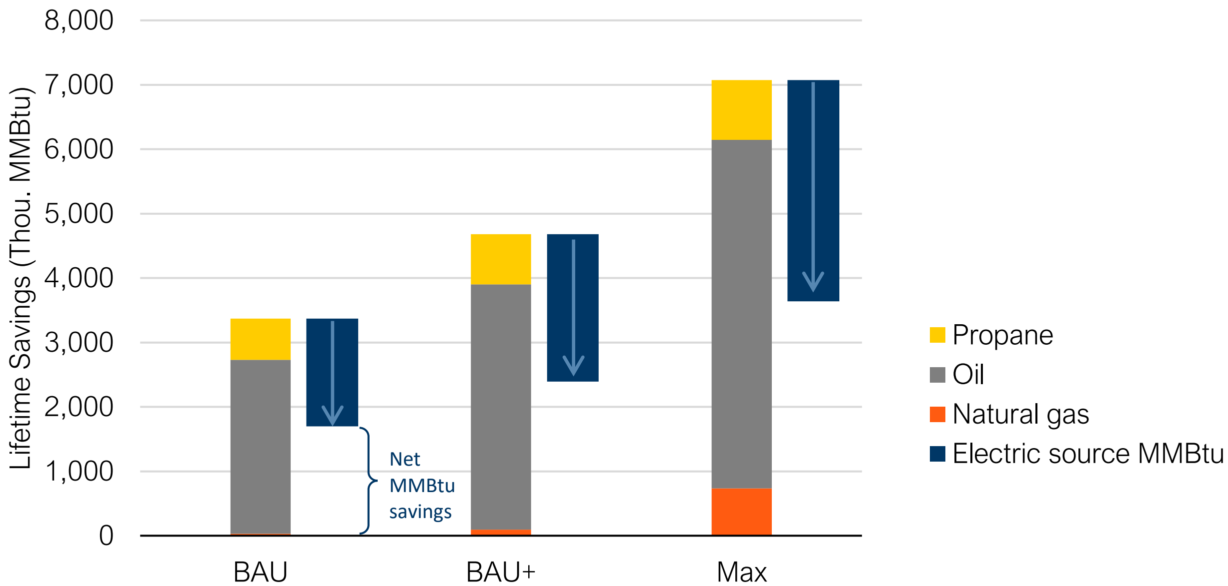


Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

These measures will result in significant reductions in building-level fuel consumption throughout the lifetime of the installed heat pump equipment. Under BAU conditions, the study estimates HE measures installed in 2022 will result in 2,300 thousand lifetime MMBtu building-level fuel savings. By 2024, achieved fuel savings will increase to 4,500 thousand lifetime MMBtu under BAU. For the Max scenario, these fuel savings estimates increase to 5,100 and 9,100 thousand MMBtu, respectively.

Figure E-16 shows 2022-24 average lifetime fuel savings broken down by fuel type. As can be seen, the potential in all three achievable scenarios is dominated by oil, which is driven by the high penetration of oil boilers among residential customers and the relatively favorable economics of replacing oil-fired heating systems with heat pumps. Propane customers are disproportionately represented in the achievable potential due to favorable customer economics. Because the customer economics are already strong under the BAU scenario, increasing the incentive levels in BAU+ and Max has a limited effect on propane adoption. Despite gas being the most widely used heating fuel among Eversource's customers, heat pump adoption in gas-heated buildings remains limited due to poor customer economics.

Figure E-16. Lifetime MMBtu Savings and Electric Source MMBtu Increases (2022-24 Average)



While HE measures will have significant impacts on building-level fuel use, they will also drive an increase in electricity consumption. Figure E-16 also illustrates the impact of this electricity consumption increase in MMBtu equivalent units based on the fuel consumed by electric generators in New England by showing the negative electric source MMBtu savings. As can be seen, the anticipated increase in electric generation fuel consumption is less than half the decrease in building-level heating fuel consumption due to the high efficiency of heat pump technologies.

Table E-11 summarizes the estimated program costs, TRC benefits, and CO_2 reductions resulting from HE measures under each scenario. As HE measure adoption continues to grow, costs are expected to increase relative to past program costs. At the same time, net TRC and emission benefits will increase as well.

Table E-11. HE Program Costs, Net TRC Benefits, and CO_2 Reductions (2022-2024 Average)

	2019 Results	2020 Results*	2021 Plan	BAU	BAU+	Max
Program Costs	$ 4.2 M	$ 4.8 M	$ 9.3 M	$ 17 M	$ 37 M	$ 74 M
Program Costs per first-year net source MMBtu saved	$ 278	$ 211	$ 129	$ 161	$ 249	$ 339
Program Costs per lifetime net source MMBtu saved	$ 13.6	$ 11.9	$ 7.6	$ 10.0	$ 15.4	$ 20.2
Average TRC Ratio	2.1	2.1	3.4	2.6	2.5	2.3
Net TRC Benefits	$ 9.2 M	$ 11.8 M	$ 46 M	$ 56 M	$ 76 M	$ 103 M
Annual CO_2 Emission Reductions (Short Tons)	1,637	2,080	5,947	8,616	12,104	17,414

Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

Key Takeaways

Based on these results, the following takeaways emerge:

- Overall, **energy optimization offerings show continued growth in potential under all scenarios.** As heating electrification is an emerging technology, the results project large year-over-year growth that is in line with the planned expansion in Eversource's heat pump programs in the years preceding the study period.

  This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like ground source heat pumps (GSHP), and the emergence of new C&I measures.

- Most delivered fuel (oil and propane) replacement measures pass TRC screening and provide customer bill savings, but almost all gas replacement measures either do not pass TRC screening and/or do not provide customer bill savings. For all fuels, the achievable potential is *very* small relative to the economic potential because it is very **difficult to entice customers to electrify.**

  For gas customers, the main reason is related to poor customer economics, as adopting most heat pumps will lead to bill increases given current gas and electricity rates. For delivered fuels, it is mostly caused by the significant market barriers that electrification measures face, largely as a result of cold climate heat pumps being a relatively new technology in Massachusetts - customers and contractors are still unaware or unfamiliar with the technology.

- Finally, **heating electrification is expected to drive a net reduction in overall energy consumption** (i.e., net MMBtu savings) when including all energy sources and accounting for the associated increase in electricity consumption.

1 Introduction

1.1 Study Overview

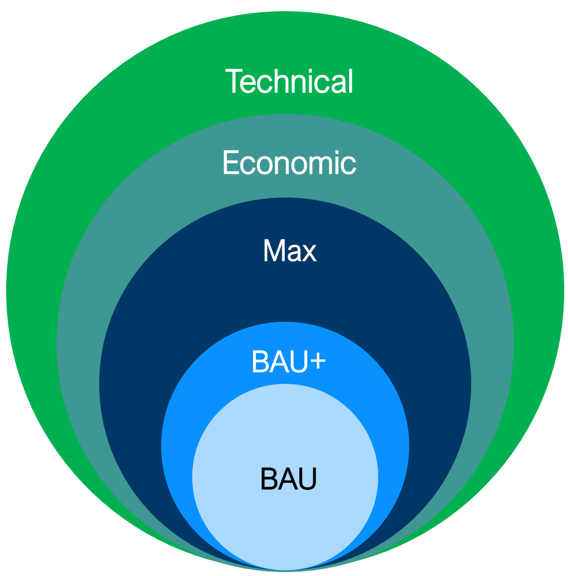
This report volume presents the results of the 2022-2024 Eversource MA Potential Study. The study quantifies the savings potential from utility demand-side management (DSM) programs and includes three components covering the following savings streams:

- Energy efficiency (EE),
- Electric demand response (DR), and
- Heating electrification (HE).

The study covers the three years spanning calendar years 2022 to 2024 and includes electricity, natural gas (referred to as "gas" in the remainder of the report), oil, and propane energy savings; passive and active electric demand reduction savings; and the costs and benefits associated with these savings.

In addition to potential results for Eversource's electric and gas programs, this report also includes gas energy efficiency potential results for the service territory formerly served by Columbia Gas (CMA). Throughout the study, the results for the former CMA territory are referred to as the EGMA ("Eversource Gas Company of MA") results.

1.2 Assessment of Potential



As is standard practice in potential studies, the study assesses potential at the technical, economic, and program achievable levels for each study component (EE, HE, and DR).

The study explores three program achievable scenarios to determine how incentive levels can impact achievable savings:

- A **BAU** (business-as-usual) scenario emulating existing incentive levels and program configurations,
- A **BAU+** scenario that increases incentives above BAU levels, and
- A **Max** scenario that represents the highest feasible achievable potentials

The specific incentive parameters employed for each study component are described in more detail in their respective chapters, and the description and methodological approaches for determining technical, economic, and achievable potential are described in Volume II of this report.

1.3 Study Scope and Exclusions

This study is a high-level assessment of electric, gas, and delivered fuels savings opportunities in Eversource's Massachusetts territories for the three-year period between 2022 and 2024. The main purpose of this study is to quantify the cost-effective savings opportunities for energy efficiency, electric demand response, and heating electrification. In addition to this objective, the study can also support:

- Resource planning,
- Program planning, and
- State policy and strategies.

While the study provides granular information such as savings for specific measures in specific building segments, the study is not a program design document meant to accurately forecast and optimize savings and spending through utility programs in a given future year. The study is meant to quantify the potential opportunities that exist under specific parameters as defined under each scenario.

The study does not include an assessment of energy savings from combined heat and power (CHP). CHP is an energy efficiency technology that simultaneously generates electricity and useful heat that would otherwise be wasted, and Eversource provides technical assistance and incentives for eligible CHP systems in its territory. Investments in these systems tend to be "lumpy", i.e., savings come from relatively few projects with large variances between project sizes and lead times, which limits the value of projecting the achievable potential for this technology – particularly over short study periods.

The study also does not include other distributed energy resources such as distributed generation.

1.4 Savings Terminology

This study expresses savings in terms of **program savings** and **cumulative savings**.

The primary focus of this report is on **program savings**, which represent the savings from measures that are incentivized by utility programs *in a given year*. Program savings are expressed in terms of first-year savings and lifetime savings. **First-year program savings** are expressed in terms of savings achieved in the first year of measures incentivized through efficiency programs. **Lifetime program savings** are expressed in terms of savings expected over the entire useful lives of measures incentivized through efficiency programs.

Cumulative savings are a rolling sum of all *new* savings from measures incentivized by utility programs. Cumulative savings provide the total expected impact of incentivized measures on energy consumption and peak demand. Where applicable, cumulative savings are modified to account for mid-life baseline adjustments and the retirement of equipment that has reached the end of its effective useful life (EUL). For this reason, cumulative savings are not simply the addition of all program savings over a given period. However, for short-duration studies such as this one, cumulative savings and the sum of program savings across years will not diverge significantly.

Unless otherwise noted, all program savings are expressed in terms of **net program savings**, which accounts for free ridership and spillover effects attributable to the modeled programs.

1.5 Report Structure

This report is structured into two volumes. This volume (Volume I) focuses on presenting the potential study results, while Volume II presents outlines the study's supporting data, inputs, and methodological approach.

In Volume I, each study component's results are presented in individual chapters. For each component, results are broken down by sector, segment, and end-use. Portfolio metrics including benefits and costs are also presented within each chapter. The final chapter of Volume I provides a high-level combined savings overview from all study components.

In Volume II, general study inputs and methodological approaches are presented along with specific information for each study component. Volume II also includes detailed results and inputs data tables in Excel workbook format.

2 Energy Efficiency

2.1 Overview

The following chapter presents an assessment of the energy savings potential from electric, natural gas, and delivered fuels (oil and propane) measures as well as the peak demand savings (i.e., passive demand reductions) associated with electric efficiency measures. It does *not* include savings or consumption impacts from heating electrification (HE) or demand response (DR), which are discussed in subsequent chapters.[8]

The chapter first briefly summarizes the methodological approach used to estimate EE potential. A full description of the methodology can be found in Appendix B of Volume II of this report. Results are then presented by program administrator (PA) in the following order:

- Eversource Electric Program Results (including electric and delivered fuel savings)
- Eversource Gas Program Results
- EGMA Gas Program Results

Approach

The market potential for EE is assessed using Dunsky's Demand and Energy Efficiency Potential (DEEP) model. DEEP employs a bottom-up modeling approach that assesses thousands of "measure-market" combinations, applying program impacts (e.g., incentives and enabling activities that help address market barriers) to assess energy savings potentials across multiple scenarios. Rather than estimating potential based on the portion of each end-use that can be reduced by energy-saving measures and strategies (often referred to as a "top-down" analysis), the DEEP's approach applies a highly granular calculation methodology to assess the energy savings opportunity for each measure-market segment opportunity in each year.

Achievable Scenarios

The EE component explores three achievable program scenarios as described in Table 2-1. The BAU scenario is designed to emulate savings that can be achieved under existing program structures and incentive levels albeit with measures and technologies that may not be currently offered by existing programs. The BAU+ and Max scenarios demonstrate what is possible with increased incentive levels.

[8] HE and DR savings are estimated with separate models as described in Volume II of this report and thus are presented separately. Adjustments are made for interactive effects between study components. These adjustments are described in Appendix A.

Table 2-1. Energy Efficiency Achievable Program Scenario Descriptions

BAU	Applies incentives and program configurations in line with the PA's incentives paid in 2019 to simulate **business as usual**. Additional prescriptive measures beyond those currently offered may be included.
BAU+	Increases incentives **above and beyond** BAU levels. Specifically, weatherization measure incentives are set at 90% incremental costs, and all other incentives are set 50% higher than BAU levels with a maximum of 90% of incremental cost unless BAU scenarios already exceed this threshold).
Max	Completely **eliminates incremental customer costs** associated with installing efficiency measures (all incentives set to cover 100% of the efficiency measure incremental cost).

Program Enhancements and Measure Adoption

Energy efficiency programs typically combine incentives (or rebates) to improve customer cost-effectiveness, along with enabling strategies, such as contractor training, marketing and education, and other approaches that can help reduce market barriers to widespread adoption of efficient technologies.

There is a substantial body of empirical evidence available to help quantify customers' willingness to pay for an efficiency upgrade, which is captured in the adoption curves applied in this study to predict the impact of varying incentive levels on the achievable potentials. Conversely, assessing the impact of specific enabling strategies can be more difficult to quantify, and there is little empirical data available on how specific strategies may impact program performance.

Considering these factors, this study focuses on the achievable potential scenarios on varied incentive levels but does not account for changes to other program features or enabling strategies. Instead, for each savings stream and sector, the end-uses that show a significant amount of untapped economic potential are identified as opportunities where further enabling strategies and market transformation approaches to help grow the program impacts. However, while these approaches may help increase savings over the long term, they may struggle to achieve demonstrable savings that can be claimed by the PAs over the near-term period covered by this study (2022-2024) as market transformation strategies require more complex and coordinated implementation/evaluation strategies and can take years to show impacts.

Benchmarking of Inputs and Results

Throughout this chapter, results are benchmarked to evaluated savings from Eversource and CMA's 2019 Plan-Year Report ("2019 Results") as well as the savings indicated for 2021 in their 2019-2021 Energy Efficiency Plans ("2021 Plan"). To enable commensurable comparisons, the benchmark metrics remove savings attributable to measures outside the scope of the EE analysis including combined heat and power savings (out of scope for this study) and heating electrification savings (presented separately in this report).

2019 Results benchmarks are derived from the detailed workbooks provided with each utility's 2019 Energy Efficiency Plan-Year Report. 2021 Plan benchmarks are derived from the BCR model workbooks provided with each utility's 2019-2021 Electric and Gas Three-Year Energy Efficiency Plan.

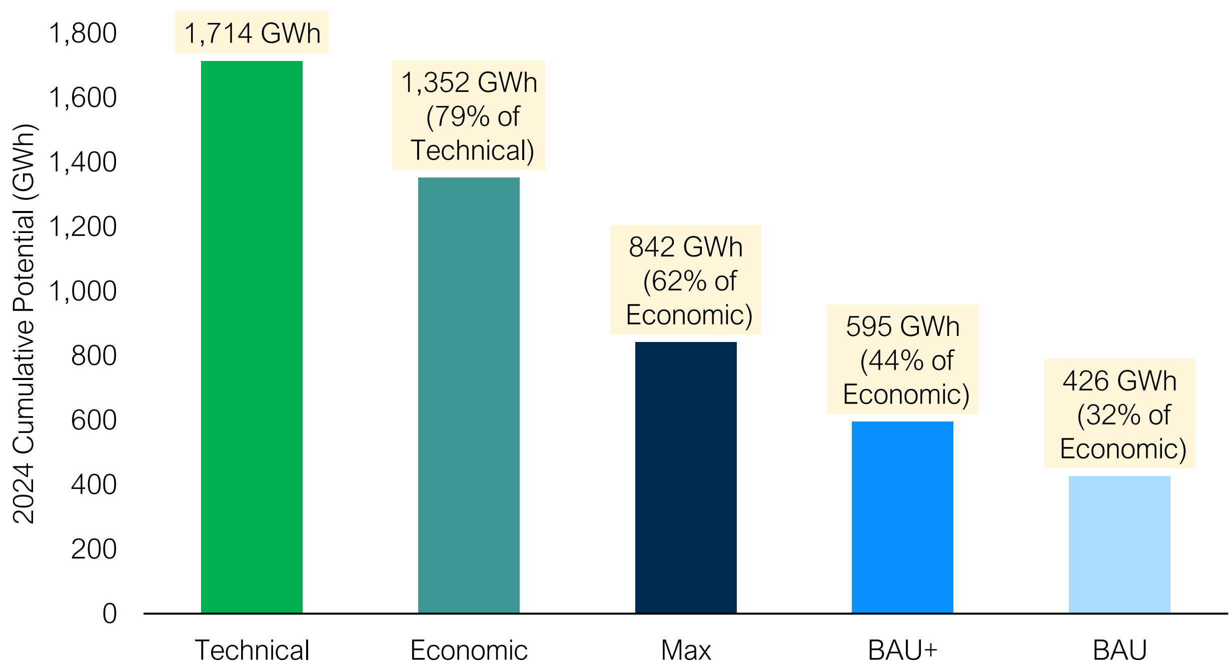
2.2 Eversource Electric Program Results

The following section presents results for Eversource's electric program savings potential. The results focus on electric energy, passive electric demand, and delivered fuels savings as these are the primary focus of Eversource's electric programs.[9] Electric savings results are presented first, followed by gas savings, and then delivered fuels savings.

Electric Savings

Figure 2-1 presents technical, economic, and achievable electric energy savings potential in terms of cumulative annual impacts in 2024 from measures installed during the 2022-24 study period.

Figure 2-1. Eversource Electric Programs, Electric EE 2024 Cumulative Technical, Economic, and Achievable Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

Compared to Eversource's previous potential study, electric technical potential has declined significantly.[10] The previous study estimated 3,455 GWh of cumulative annual impacts over the three-year study period (2019-21). In this study, the three-year cumulative technical potential is estimated at 1,714 GWh – approximately 50% lower than the previous study.

[9] Active electric demand response potential is discussed in the DR chapter.
[10] *Eversource (MA) Electric & Gas Efficiency Potential Study Report – Volume 1.* Dunsky Energy Consulting. June 2018.

This difference is primarily driven by a reduction in lighting savings potential. Over the last three years, the lighting market in Eversource's territory has continued to transform and a significant portion of lighting equipment has been replaced with efficient products. By the first year of the study period (2022), this study assumes most existing lighting equipment is efficient. For example, the study assumes only 20% of residential bulbs and 10% of C&I screw-based bulbs will have not been replaced with efficient products by 2022.[11] With such a high penetration of efficient lighting, there is significantly less technical potential for electric savings from lighting improvements.

Most electric savings pass economic screening. While net economic potential is 362 GWh less than technical potential, roughly 22% of this difference is due to measures failing the TRC test. In total, 96% of technical electric savings pass economic screening.[12] The remaining difference is due to net-to-gross adjustments, which generally reduce net electric savings due to large free ridership effects for many electric measures.

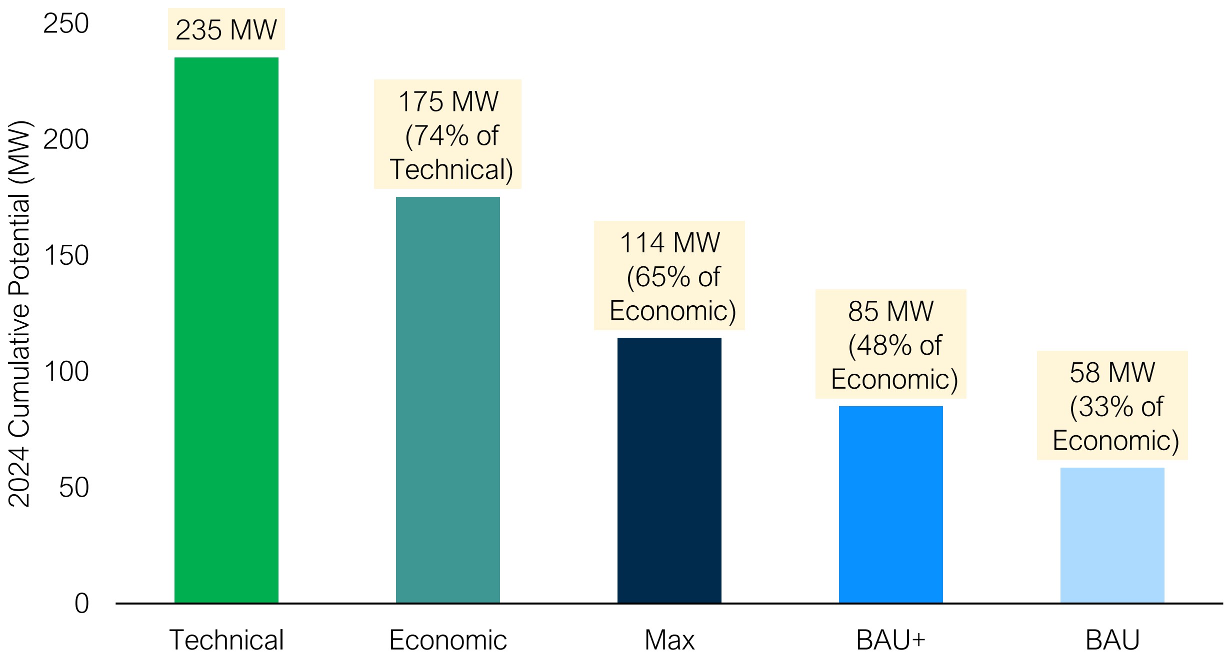
The BAU scenario captures less than one-third of economic savings. Under current incentive levels, only 32% of net economic savings are captured suggesting there is significant room to grow electric savings with increased incentives and enhanced program designs.

Increasing incentives can more than double savings. Under the Max scenario, the portion of net economic savings captured increases by 30 percentage points relative to the BAU scenario. When 100% of customers' incremental costs are covered, Eversource's electric programs have the potential to capture slightly over half of the net economic electric potential but at a significantly higher program cost per kWh saved as discussed in the program costs section below.

Figure 2-2 presents the technical, economic, and achievable **passive electric demand savings** potential in terms of cumulative annual impacts in 2024 from measures installed during the 2022-24 study period.

[11] For additional detail on the specific assumptions regarding lighting penetration, see Appendix B.
[12] Gross economic potential nears technical potential for two primary reasons. First, the study employs a phased-in potential assessment approach that accounts for expected market turnover in the study period. Second, the study focusses on measures that are commercially viable, and thus measures that may offer technical potential, but are not expected to be cost-effective were largely omitted from the study.

Figure 2-2. Eversource Electric Programs, Electric Demand 2024 Cumulative Technical, Economic, and Achievable Potential

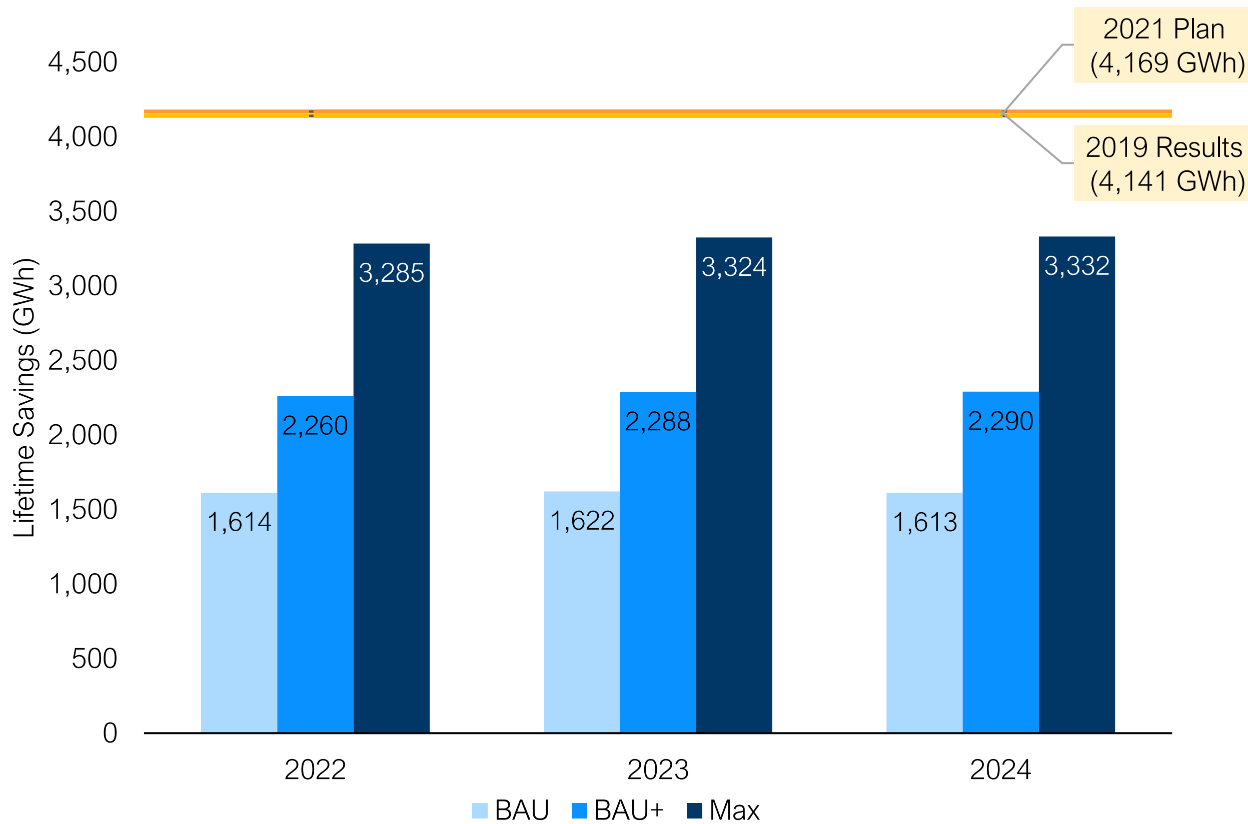


Potential for passive electric demand savings mostly mirrors electric energy savings with economic potential representing 74% of technical potential and the achievable potential scenarios capturing between 33% and 65% of net economic potential.

Overall Program Savings

Figure 2-3 presents lifetime electric savings derived from measures installed in each year under the various achievable scenarios.

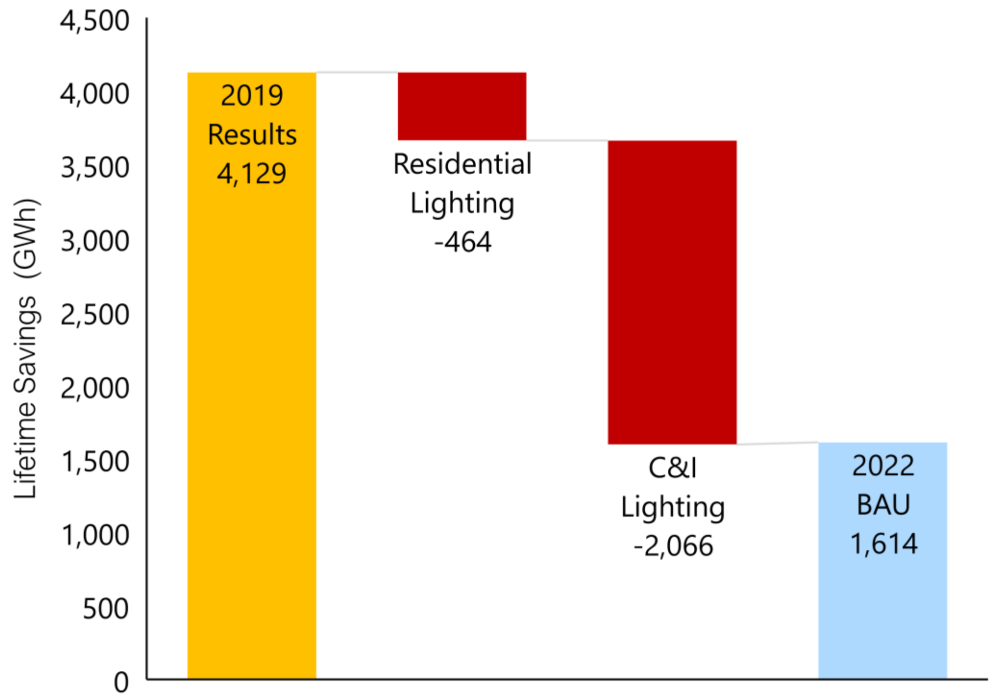
Figure 2-3. Eversource Electric Programs, Electric Lifetime Savings by Year



Compared to Eversource's 2019 program results and the 2021 Plan savings, achievable lifetime electric savings are expected to decline precipitously. Under BAU incentive levels, 2022-24 average lifetime savings are approximately 61% below past program savings. The decline is almost entirely attributable to reductions in lighting savings from both the residential and C&I sectors. As shown in Figure 2-4, reductions in residential and C&I lighting savings reduce lifetime savings in 2022 by 2,530 GWh compared to 2019 results, which accounts for much of the difference between the two years. As previously described, this reduction in lighting savings is driven by the rapid transformation of lighting markets, which is demonstrated by the high penetrations of efficient lighting in both the residential and C&I markets and growing free ridership within Eversource's lighting programs as efficient lighting becomes the default choice for the majority of customers.[13]

[13] For additional detail on the specific assumptions regarding lighting net-to-gross factors, see Appendix B.

Figure 2-4. Eversource Electric Programs, Electric 2022 BAU Lifetime Savings vs. 2019 Results



While the reduction in lighting savings explains most of the difference between 2019 Results and 2022 BAU in Figure 2-4, it should be noted there are additional differences between the two years that result in both increases and decreases in savings – albeit in magnitudes that largely offset each other (i.e., reductions in home energy report savings and increases in HVAC measure savings). These differences are discussed later in the chapter.

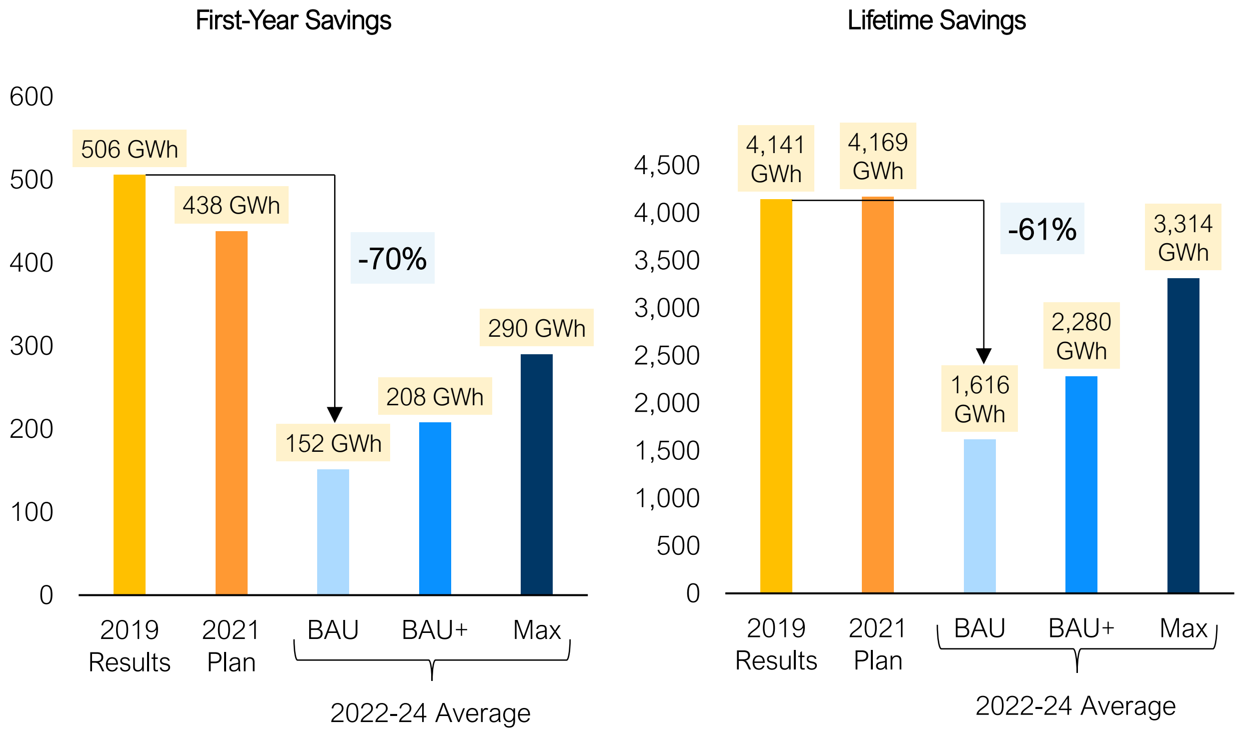
The reduction in lighting savings is significant enough that even under Max incentive levels, savings do not reach levels achieved in the past. Under the BAU+ and Max scenarios, 2022-24 average lifetime savings increase by 41% and 105% relative to BAU, respectively, yet still fall short of past achievements. This suggests that maintaining electric savings at historical levels will not be possible even with 100% incentives.

A final observation is that savings are stable across study years. Slight year-over-year differences are due to general market growth, changing baseline standards, and the plateauing of some discretionary measures with significant historical uptake. Overall, these impacts are small and counteract each other resulting in year-over-year fluctuations of less than 1.5% under every scenario. Due to this stability, the remainder of this section expresses savings as the 2022-24 average.

First-year versus Lifetime Electric Savings

Figure 2-5 compares first-year and lifetime electric savings. Relative to 2019 Results, the observed reduction in electric savings potential from recent program savings levels is starker when measured in first-year savings than it is when considered on a lifetime savings basis. In first-year terms, BAU savings are 70% below 2019 Results levels compared to the 61% drop when measured in lifetime savings.

Figure 2-5. Eversource Electric Programs, Electric First-Year vs. Lifetime Savings Comparison



This difference is driven by two primary factors.

Lighting measures have short EULs: First, the reduction in lighting savings has a greater proportional impact on first-year savings relative to lifetime savings due to the generally short savings persistence of many lighting measures. In particular, savings from efficient LED bulb measures within the 2019 Results and 2021 Plan persist for under 5 years as these measures generally replace baseline lighting equipment with short EULs (e.g., halogen bulbs). Thus, these measures have lower lifetime savings relative to first-year savings, when compared to measures with longer EULs. This effect is particularly pronounced in Eversource's 2019 Results due to the larger amount of residential lighting savings in this program year relative to the 2021 Plan.

Home Energy Report (HER) savings have a short persistence: Second, assumptions regarding changes in Eversource's HER measure have a much greater impact on first-year savings than lifetime savings. Program changes are expected to reduce the per participant claimable savings attributable to behavioral changes from HERs during the study period. This study assumes HER savings persist for a single year (i.e., EUL of 1 as specified in the MA TRM), which significantly reduces the measure's lifetime savings metric.[14]

Savings by Sector

At the sector level, while both the residential and C&I sectors show reductions in savings compared to 2019 Results and the 2021 Plan, but nonetheless, the **bulk of electric savings opportunities continue to be found in the C&I sector** as shown in Figure 2-6.

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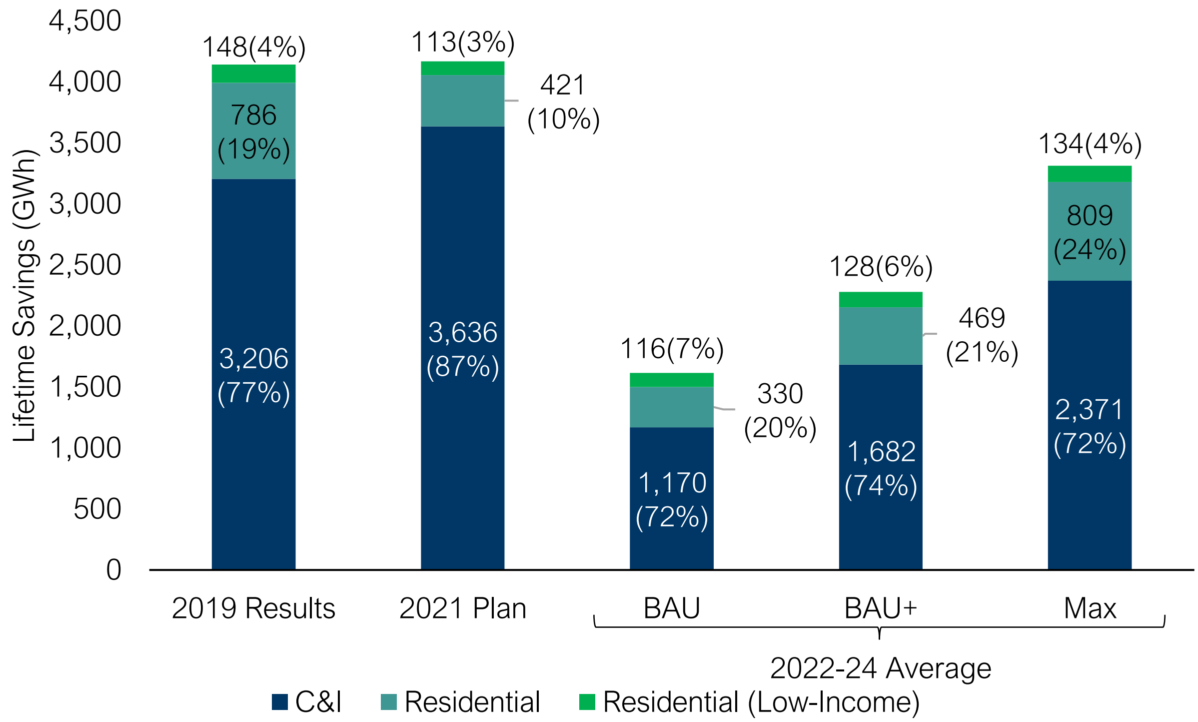
[14] This assumption is consistent with the MA TRM, which also assumes HER savings persist for a single year.

Figure 2-6. Eversource Electric Programs, Electric Lifetime Savings by Sector



Both the residential and C&I sectors show similar proportional growth under higher incentive scenarios. Across all three achievable scenarios, the proportion of overall savings from each sector remains similar suggesting that increasing incentive levels have similar proportional impacts on savings in each sector.

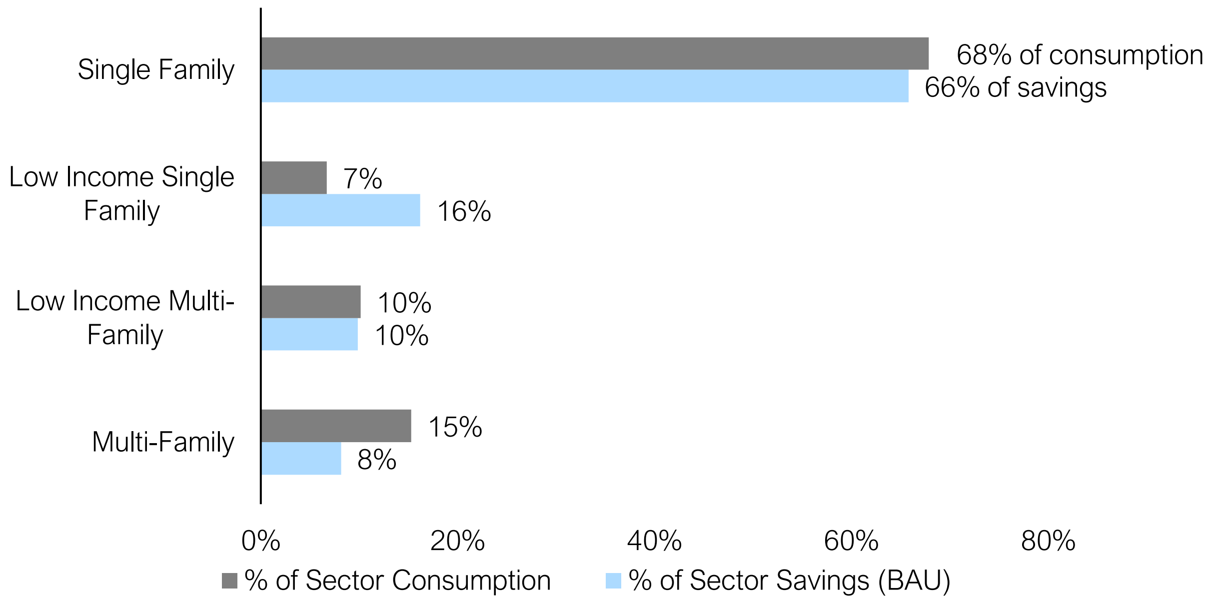
Residential Savings

Savings by Market Segment

In the residential market, the bulk of savings resides in the market-rate single family segment as shown in Figure 2-7. However, when compared to the portion of electric consumption within each segment, the low-income segments claim a greater share of savings, while the market-rate multi-family segment's portion of savings is significantly less than its portion of consumption.[15] This is indicative of the success of Eversource's existing low-income programs as well as the specific barriers inherent to reaching multi-family customers.

[15] Multi-family market segment savings include savings from large master-metered buildings and multi-family common areas. For modeling purposes, these savings are modeled in the C&I sector and apportioned to the residential sector outside of the model. See Appendix A (Customer Population) for more detail.

Figure 2-7. Eversource Electric Programs, Percent of Electric Residential Lifetime Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

As incentives increase, the relative portion of savings in the single-family segment increases from 66% to 76%, while the portion of multi-family savings stays relatively constant only increasing by two percentage points, and the portion of savings in both low-income segments decreases as shown in Table 2-2.

The growth in single-family savings juxtaposed with the nearly constant proportion of savings from the market-rate multi-family segment shows that, while increased incentives can capture additional savings in the multi-family segment, other market barriers remain that limit the growth of these savings.

The proportion of residential savings from the low-income market segments decreases since incentives are already at 100% under the BAU scenario. Savings in the other segments grow under increased incentives in BAU+ and Max while low-income savings remain constant, leading to a decline in the relative portion of residential savings that the low-income segment represents.[16]

[16] Low-income multi-family savings increase slightly (in absolute terms) under the BAU+ and Max scenarios due to a modeling artifact resulting in a portion of low-income savings being captured with the C&I multi-family segment, which is modeled in the C&I sector with C&I program incentive levels.

Table 2-2. Eversource Electric Programs, Electric Residential Lifetime Savings by Market Segment

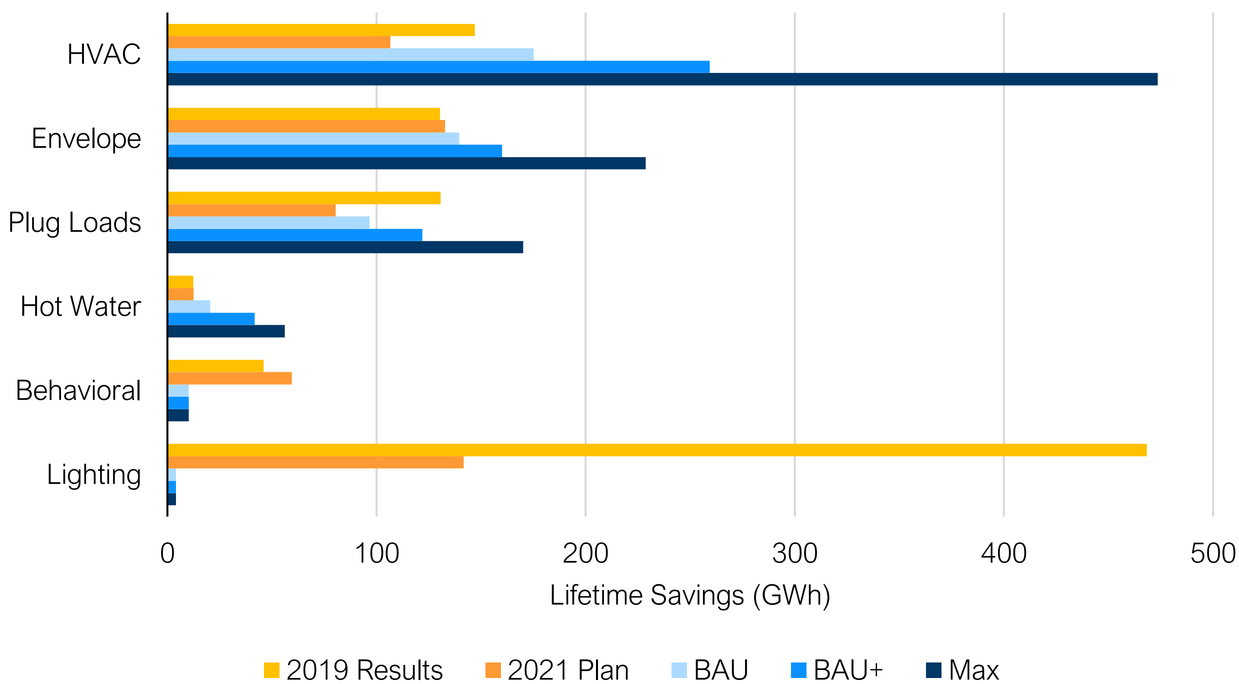
Segment	2022-24 Average Lifetime GWh (% of Total)		
	BAU	BAU+	Max
Single Family	294 (66%)	415 (69%)	712 (76%)
Low Income Single Family	72 (16%)	72 (12%)	72 (8%)
Low Income Multi-Family	44 (10%)	55 (9%)	62 (7%)
Multi-Family	36 (8%)	55 (9%)	97 (10%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

Figure 2-8 shows residential market lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

Figure 2-8. Eversource Electric Programs, Electric Residential Lifetime Savings by End-use



Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include savings for both market-rate and low-income customers.

When viewed at the end-use level, several key trends emerge.

Lighting savings are eliminated for all but the low-income customers: The decline in residential lighting savings is stark – transitioning from the most prominent end-use category to the least. Under BAU conditions, lighting savings become less than 1% of overall residential lifetime electric savings compared to 50% in 2019 Results and 27% in the 2021 Plan. Within the study, the only remaining lighting savings come from low-income direct install programs, which is why lighting savings remain static between achievable scenarios.

HER savings are assumed to drop: Behavioral savings, which consist entirely of HER savings, also are assumed to decline significantly compared to 2019 Results and the 2021 Plan due to the anticipated changes in Eversource's HER program. Eversource discontinued its existing HER program in October 2019 and has initiated an alternative program called "Delivered Energy Insights".[17] The Delivered Energy Insights program delivers energy savings suggestions via email to residential customers. In addition, the program provides targeted messaging about other Eversource programs. As such, the program is intended to achieve direct savings through behavioral change, and cross-participation savings via other energy efficiency programs. Savings associated with cross-participation are not counted towards behavioral program savings.

At the time of this study, evaluated savings results for the program were not available so the study makes a broad assumption that the average per customer behavioral savings of the new program will be 50% of the per-customer savings experienced under the previous HER program to account for the above-described factors.[18] Additionally, the study assumes a smaller portion of Eversource's residential customers will participate in DEI during the study period due to factors such as non-e-mailable customers and the need for a control group to evaluate the program's impacts. For both of these reasons, residential behavioral savings decline. Behavioral savings do not increase between achievable scenarios as the HER measure does not include a traditional incentive that can be changed between scenarios.

Other end-uses remain largely consistent between past results and the BAU projections: The remaining end-use categories closely mirror 2019 Results and 2021 Plans under BAU conditions as assumptions regarding exogenous factors (e.g., standards updates, market transformations) do not change significantly between 2019 Results, the 2021 Plan, and the study. One exception is HVAC savings, which exhibit an increase in savings in the BAU scenario due to general growth in heat pump adoption as this market becomes more mature. This growth in heat pump adoption and EE savings is distinct from additional growth expected through Eversource's heating electrification programs (described in the HE chapter).

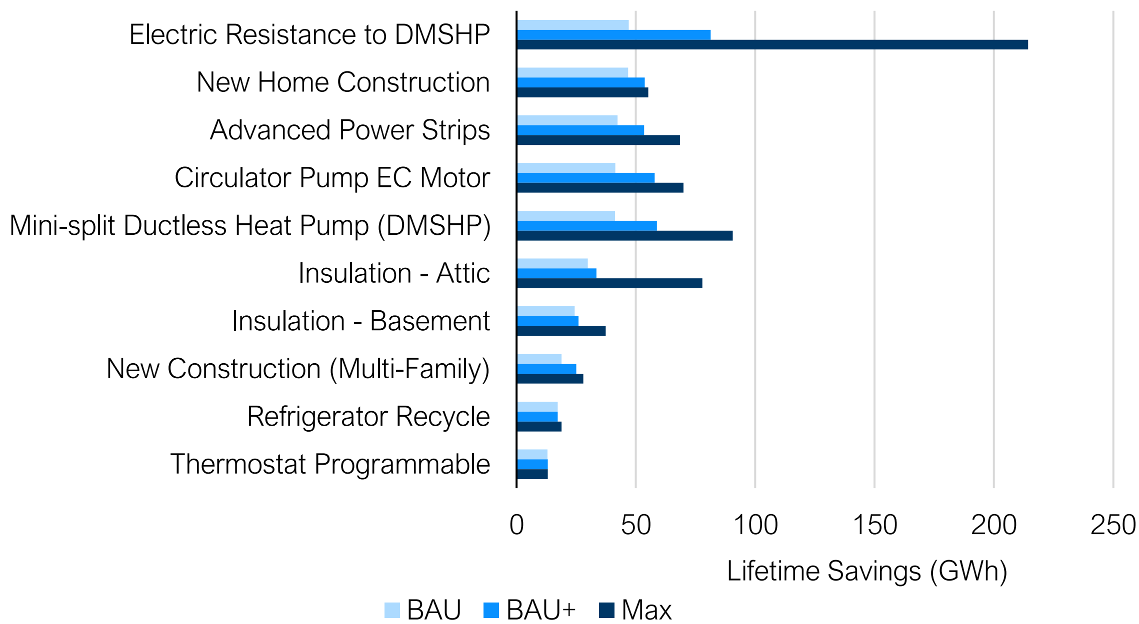
With increasing incentives, most end uses see growth in savings, except behavior and lighting as noted above. In the BAU+ scenario, savings from hot water measures are particularly responsive – more than doubling relative to the BAU scenario. HVAC measures display the biggest absolute jump in savings increasing by 84 lifetime GWh under the BAU+ scenario – a 48% increase. When customers' incremental costs are eliminated under the Max scenario, HVAC savings grow significantly increasing by 170% relative to BAU savings.

[17] While the name of Eversource's program is changing, this study continues to refer to the measure representing Delivered Energy Insights as a home energy report (HER).
[18] This study does not explicitly attribute savings related to increasing program participation to the HER measure to avoided double-counting savings estimated in other programs. This aligns with the MA TRM and evaluations of MA's behavior programs, which account for and "remove savings co-generated by behavioral and standard programs to order to avoid double counting savings." See "*Massachusetts Cross-Cutting Behavioral Program Evaluation Opower Results*". Navigant Consulting, Inc. and Illume Advising, LLC. March 2015.

Top Measures

With the loss of residential lighting savings, the most prominent end-use categories become envelope, HVAC, and appliance measures. As shown in Figure 2-9, most of the top measures for lifetime savings fall into these categories.

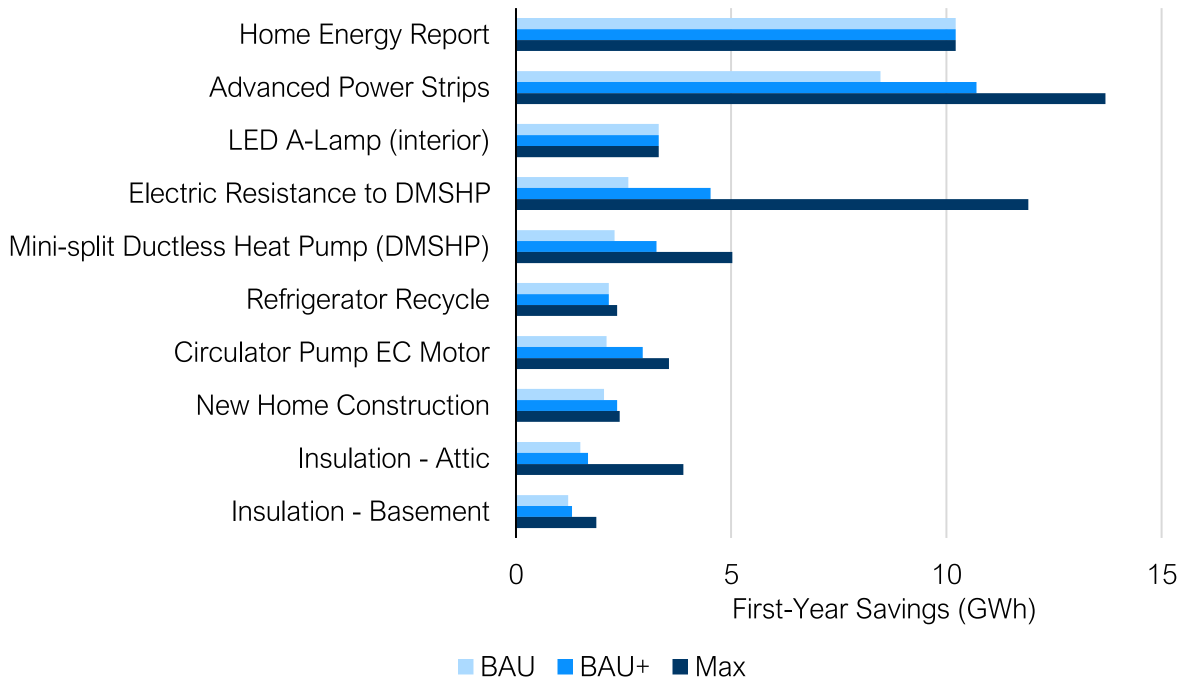
Figure 2-9. Eversource Electric Programs, Electric Top 10 Residential Measures by Lifetime Savings



Note: Measures are selected and arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include both market-rate and low-income savings. The top measure list contains New Home Construction and New Construction (Multi-Family) measures, which represent savings from single-family and large multi-family new construction opportunities, respectively.

In terms of first-year savings, several other measures are found in the top 10 list. HERs become the most prominent measure on a first-year savings basis, as shown in Figure 2-10, despite the anticipated changes to this measure. This shows that a sustained behavioral program will likely have a significant impact on residential savings in any given year. Additionally, LED A-Lamps are the third most significant measure in first-year savings terms as well showing that efficient lighting can continue to play an important role in Eversource's low-income programs.

Figure 2-10. Eversource Electric Programs, Electric Top 10 Residential Measures by First-Year Savings



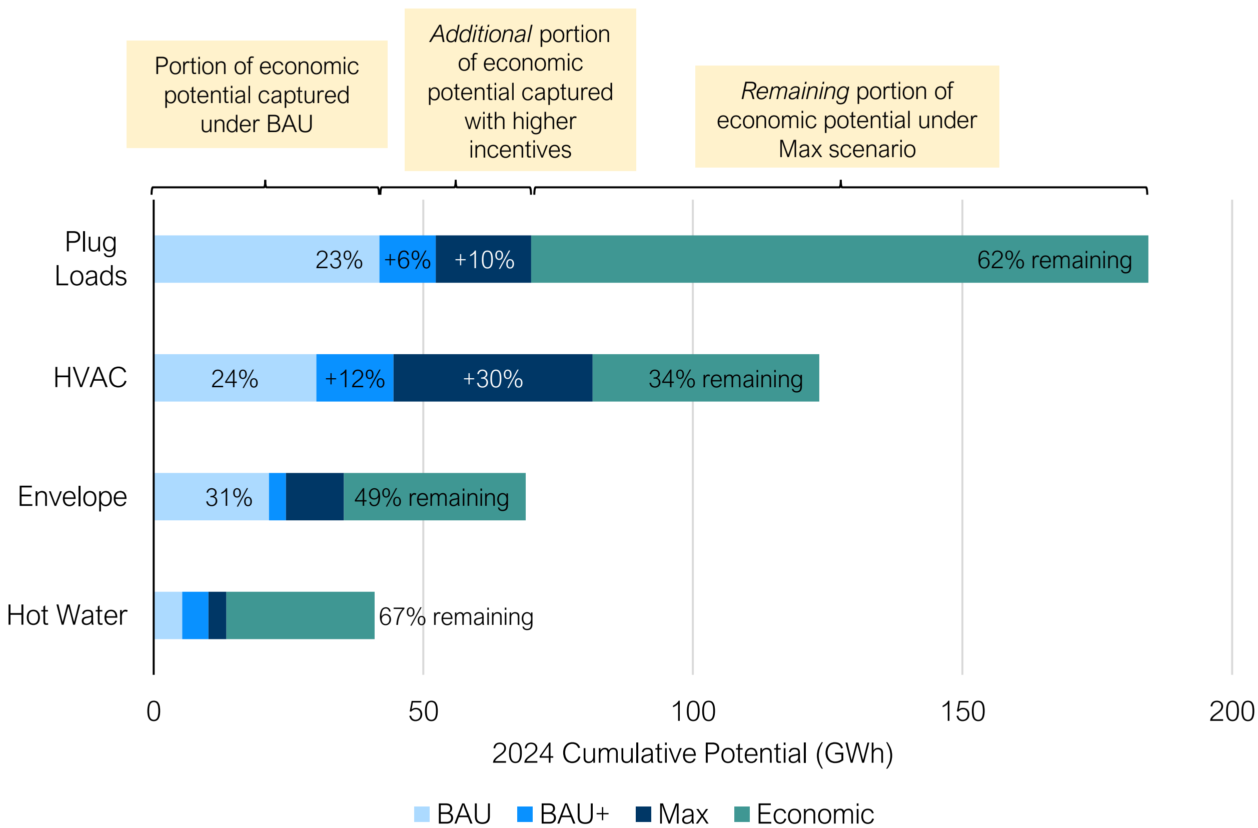
Note: Measures are selected and arranged by relative contribution to 2022-24 average first-year savings under the BAU scenario. Results in the figure include both market-rate and low-income savings.

A final observation to note is the relative absence of thermostat measures from the top 10 residential electric measures list – except for programmable thermostats, which ranked number 10 in terms of lifetime savings. For delivered fuels and gas savings, both programmable and wi-fi thermostat measures feature prominently in the top measure lists. A driving factor for their relatively lower importance to residential electric savings is thermostat savings assumptions. This study uses the deemed savings values for thermostats in accordance with the MA TRM. However, these deemed values are significantly lower than savings assumptions made in other jurisdictions, which may warrant further evaluation to determine if electric thermostat savings are being underestimated in MA.

Potential Growth Opportunities

Figure 2-11 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-11. Eversource Electric Programs, Electric Residential Growth Opportunities



Note: Residential behavioral and lighting savings represent <5% of residential 2024 cumulative economic potential and are excluded from the above figure.

Under BAU incentives, only a small portion of economic potential is captured across all end-use categories with the greatest portion being captured among envelope measures at only 31%. Higher incentives increase the portion of captured economic savings at varying rates across end-uses. HVAC measures appear the most responsive to increased incentives – capturing an additional 42% of economic savings under the Max scenario relative to BAU. This suggests that HVAC measures are primarily limited by customer cost-effectiveness.

For other end-uses, a significant portion of economic savings remains across all end-uses even when incentives cover the full incremental cost, as is the case under the Max scenario. Plug load and hot water measures achieve less than 40% of the estimated economic potential under the Max scenario suggesting that barriers beyond customer economics are inhibiting the adoption of these measures. For these measures, alternative program approaches and market transformation strategies may be more effective at increasing savings rather than simply raising incentive levels.

For plug load measures, the gap between max achievable and economic potential is driven by significant estimated economic savings from household appliances and discretionary measures such as advanced power strips. For household appliances (e.g., refrigerators, washers, and dryers), the large gap can be explained by consumer behavior that prioritizes appliance characteristics (e.g., special features, aesthetics) other than energy efficiency, which makes it difficult to capture customers with program offerings. For advanced power strips, the model assumes a large portion of households offers cost-effective opportunities. However, real-world consumer behavior again limits achievable potential as many consumers face significant barriers such as unfamiliarity with technology.

Electric Efficiency Programs in a Post-Lighting World

As lighting savings fade from Eversource's residential programs, strategies to encourage the adoption of a more diverse mix of efficiency opportunities become essential. The remaining untapped economic potentials identified in this study may in many cases lend themselves more to market transformation approaches – training, qualifications, financing, new business models (e.g., efficiency-as-a-service solutions), regulation – rather than the traditionally successful "resource acquisition" strategies that rely on rebates and similar tools. This is particularly relevant for securing deep savings opportunities in the envelope and HVAC categories – ones that typically require more capital and increasingly skilled labor across multiple trades.

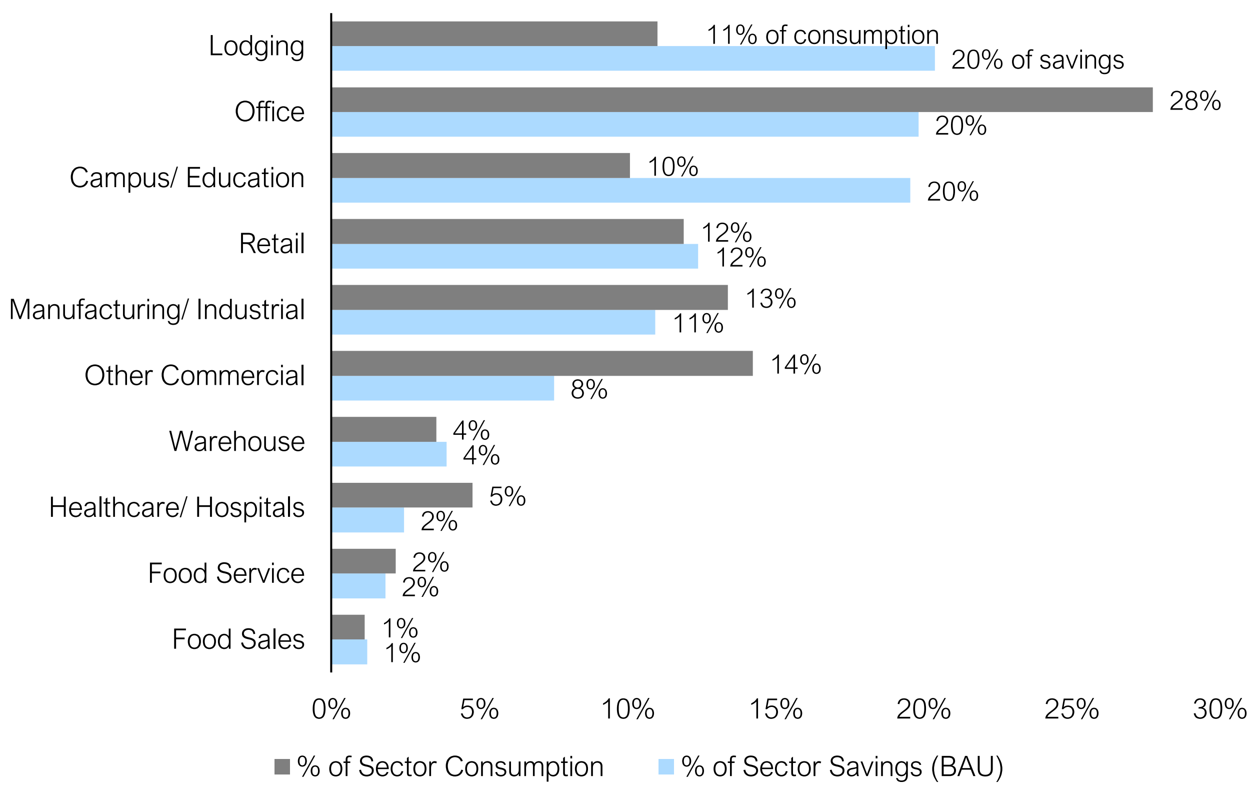
While the transformation of the lighting market in Massachusetts should be viewed as a success, it does pose a challenge for the next phase of efficiency programs, as the state strives to meet historically high savings targets. The value of accessing new and deeper savings opportunities is apparent, given the increasing demand for electricity, coupled with the significant remaining efficiency opportunities that remain more cost-effective than the cost of electricity supply. A partial pivot toward longer-term market transformation strategies could successfully replace more of the lost lighting savings but may also run up against the limitations of the current regulatory framework. Moreover, market transformation strategies can take years to show impacts and may pose attribution challenges, which could limit their demonstrable impacts over the study period.

C&I Savings

Savings by Market Segment

The C&I sector is split into ten market segments with each segment representing a pool of savings opportunities based on expected building configurations and operations across the segment. Under the BAU scenario, the lodging, campus & education, and office segments deliver the largest portion of savings, with each representing 20% or more of overall C&I lifetime electric savings as shown in Figure 2-12.

Figure 2-12. Eversource Electric Programs, Percent of Electric C&I Lifetime Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

There are a few segments for which their portion of electric savings is not aligned with their portion of sector-wide electricity consumption. Notable among these are the lodging and campus & education segments, where savings are significantly higher than the segments' portion of consumption, suggesting that savings opportunities are relatively abundant in these segments. On the other hand, office savings represent a substantial 20% of overall C&I savings, yet the segment's portion of consumption is higher at 28% suggesting relatively fewer remaining savings opportunities even though there is significant electricity consumption.

While these results are indicative of which segments hold the greatest potential for savings, they should be interpreted with the following caveats.

First, due to the COVID-19 pandemic, updated baseline data collection for C&I customers was limited, thereby requiring the use of recent data that was not segment-specific (due to lack of sufficient observations), from the previous baseline study in 2016, or from nearby jurisdictions. While not ideal, the use of alternative data sources still provides reasonable estimates of C&I potential at the aggregate sector-wide level, but the uncertainty at the segment level is somewhat increased.

Second, past program data is not broken down by segment making it not possible to calibrate modeled savings on a segment-by-segment basis. This may introduce some uncertainty in the distribution of savings among the various segments.

Table 2-3 shows the savings by segment across the different achievable potential scenarios. Segment breakdowns do not change significantly across scenarios, but several segments show quicker proportional growth with increased incentives including the manufacturing & industrial market segment and the other commercial market segment.

Table 2-3. Eversource Electric Programs, Electric C&I Lifetime Savings by Market Segment

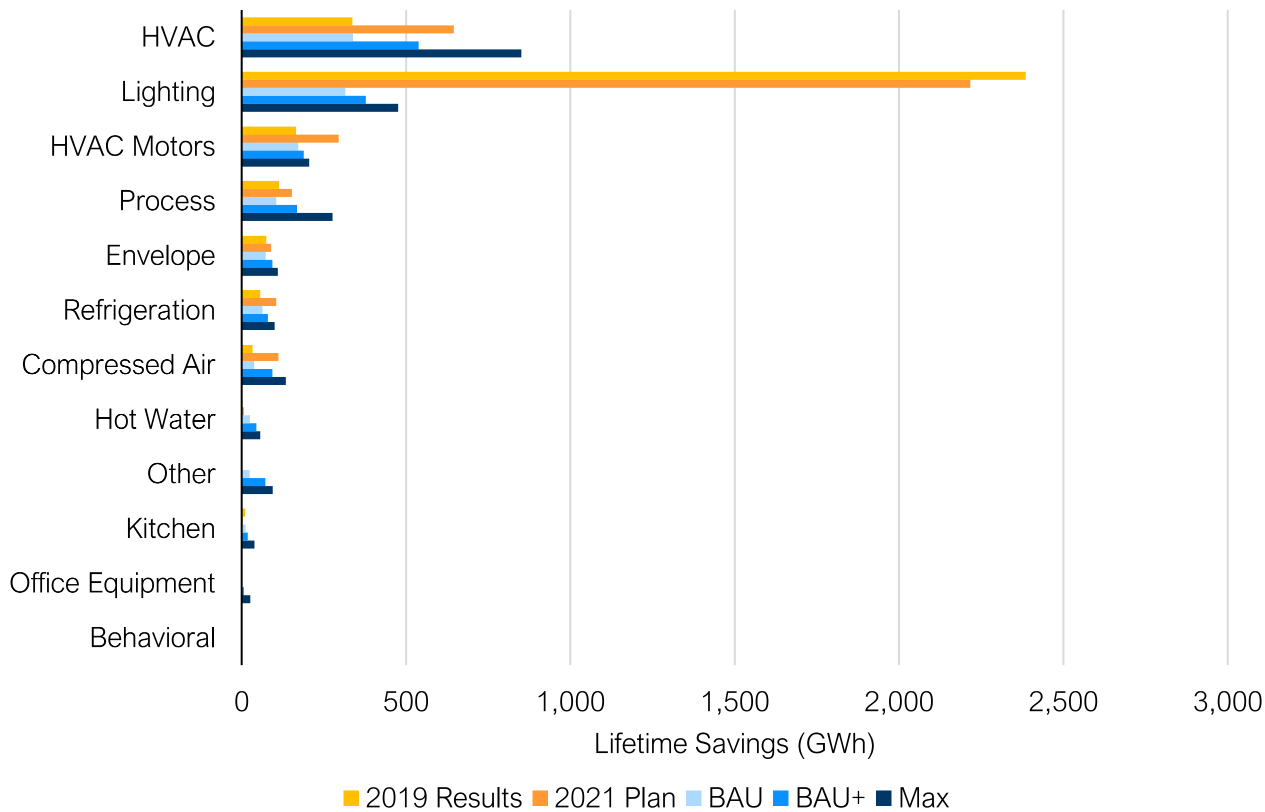
Segment	2022-24 Average Lifetime GWh (% of total)		
	BAU	BAU+	Max
Lodging	238 (20%)	308 (18%)	381 (16%)
Office	232 (20%)	333 (20%)	488 (21%)
Campus/ Education	229 (20%)	307 (18%)	414 (17%)
Retail	145 (12%)	182 (11%)	235 (10%)
Manufacturing/ Industrial	128 (11%)	233 (14%)	374 (16%)
Other Commercial	88 (8%)	171 (10%)	262 (11%)
Warehouse	46 (4%)	55 (3%)	68 (3%)
Healthcare/ Hospitals	29 (2%)	48 (3%)	86 (4%)
Food Service	21 (2%)	28 (2%)	40 (2%)
Food Sales	14 (1%)	18 (1%)	24 (1%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

Figure 2-13 shows C&I lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

Figure 2-13. Eversource Electric Programs, Electric C&I Lifetime Savings by End-use



Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario.

Similar to the residential sector, the C&I results show a significant decline in lighting savings with 2022-24 average lifetime savings being approximately 13% of savings achieved in 2019 and 14% of savings planned for 2021. While the model included C&I program support for efficient lighting measures, the ongoing transformation of the C&I lighting market is projected to lead to reduced NTG ratios for these measures over time and an increasing penetration of efficient lighting products.[19] Together these factors lead to a steady decline in C&I lighting savings, despite the increasing lighting controls savings.

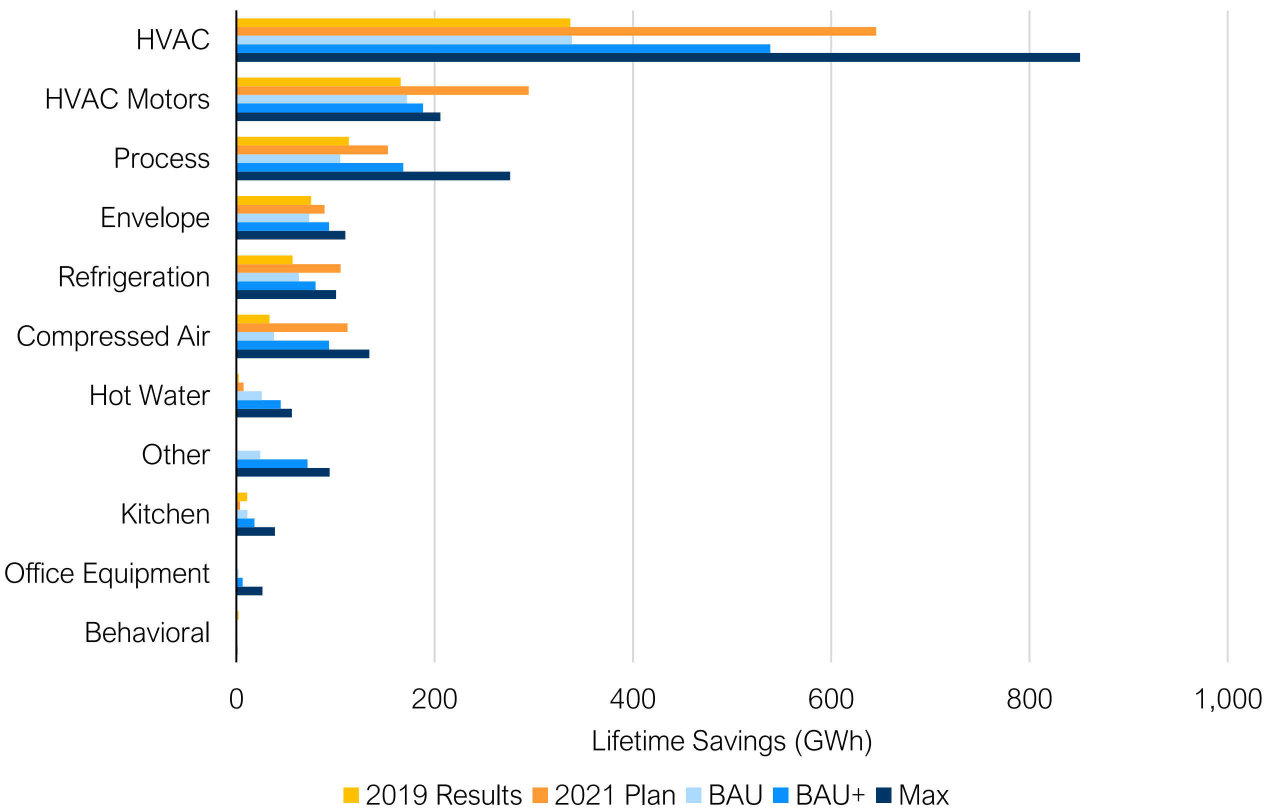
It is important to note that the projected transformation of the C&I lighting market is not as extensive as is the case in the residential sector. As a result, C&I lighting savings are the second most prominent C&I end-use category (compared to residential where it becomes the least prominent). However, C&I lighting savings are significantly lower than historical program savings for this end-use category, driven by the projected saturation of efficient lighting (the study assumes that 77% of C&I linear lighting will be efficient by 2022), and declining lighting program NTGs (e.g., the study applies an NTG factor of 0.25 for ROF linear lighting and 75% for early retirement or a combined NTG for linear lighting of approximately 60%).[20]

[19] For specific details on the lighting assumptions employed in this study, see Appendix B.
[20] Additional uncertainty is inherent in the lighting saturation assumptions due the impacts of COVID-19. As described in Appendix B, high-level adjustments are made to C&I lighting saturation levels in recognition of the

While these point to decreasing market opportunities for linear lighting, the measures remain cost-effective and the sheer amount of linear lighting in the C&I sector results in a notable volume of achievable lighting savings throughout the study period.

Figure 2-14 shows C&I lifetime savings broken down by end-use with lighting excluded. Beyond lighting, C&I savings in other end-use categories closely mirror savings achieved in 2019 as there is little reason to expect these savings to deviate significantly under existing incentive levels and program structures. HVAC and HVAC motor savings are the most prominent opportunities for C&I electric savings with significant savings seen in many other categories as well.

Figure 2-14. Eversource Electric Programs, Electric C&I Lifetime Savings by End-use (Excluding Lighting)

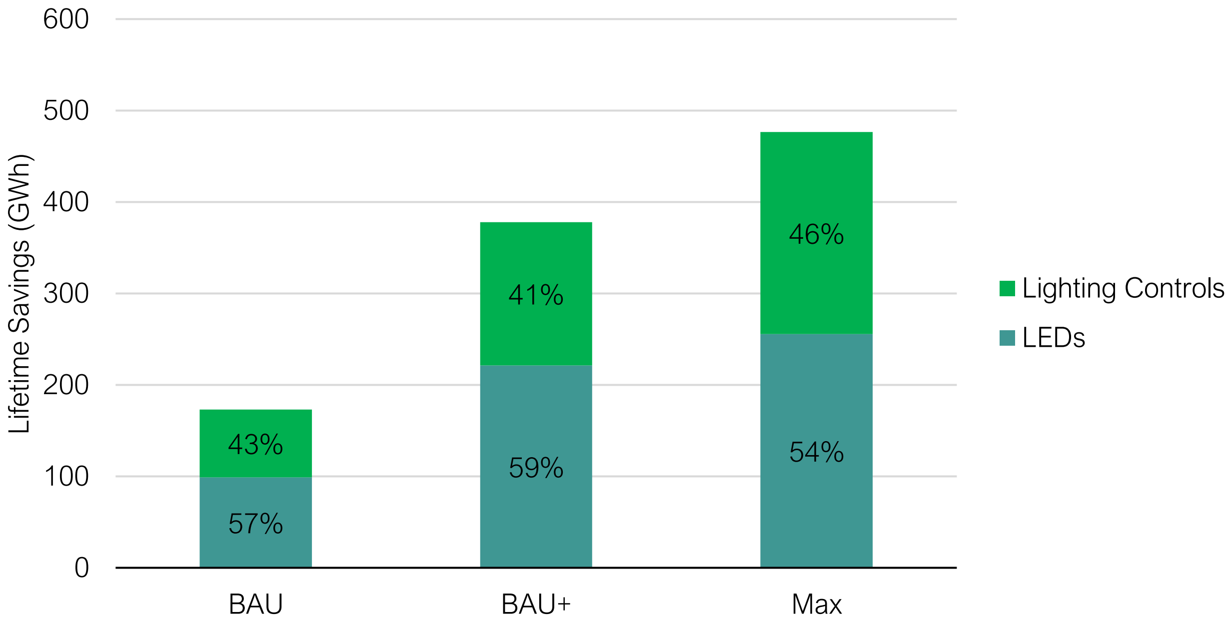


C&I end-use categories show varying responses to elevated incentives under the BAU+ and Max scenarios. HVAC, lighting, and process savings increase significantly as incentives increase – more than doubling savings under the Max scenario relative to BAU. Envelope and HVAC Motors savings, on the other hand, have more muted responses – increasing only 50% and 19%, respectively, when all customer incremental costs are eliminated under the Max scenario.

slowdown in programs during the pandemic, but specific data to inform these adjustments was not available at the time of the study.

As shown in Figure 2-15, lighting controls are a substantial portion of the remaining C&I lighting potential. Under the achievable scenarios, lighting controls contribute 41% to 46% of overall 2022-24 average C&I lighting lifetime savings.

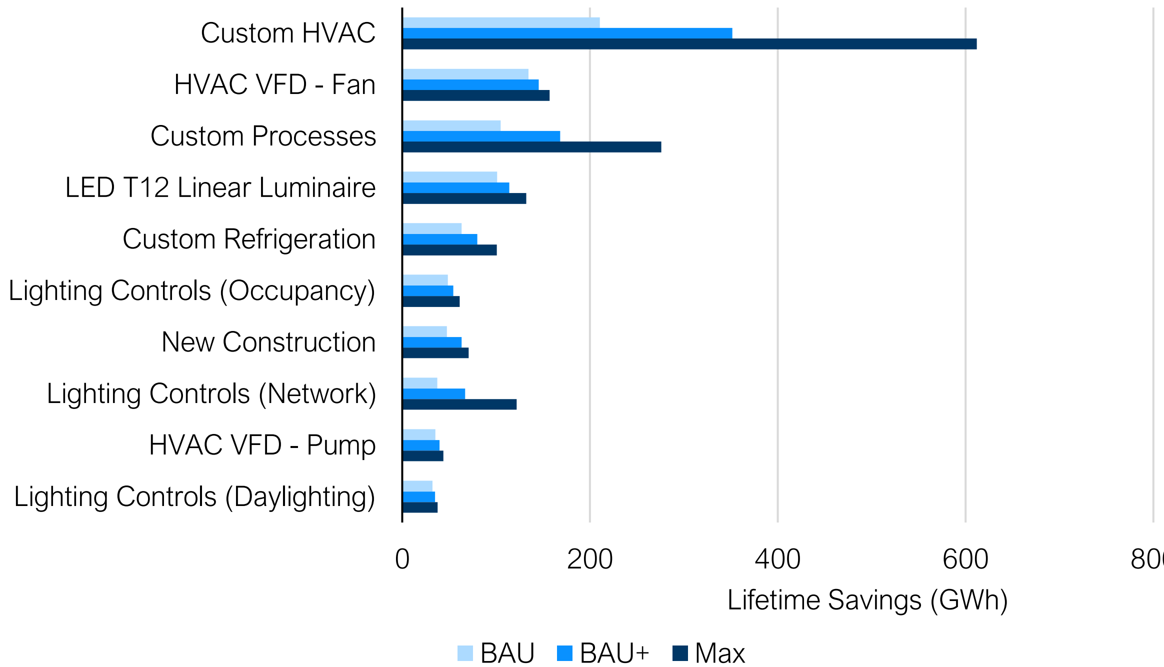
Figure 2-15. Eversource Electric Programs, Electric C&I Lifetime Lighting Savings, LEDs vs. Lighting Controls



Top Measures

The top 10 C&I electric measures in terms of lifetime savings are shown in Figure 2-16. Custom measures feature prominently in this list, highlighting the importance of taking facility-specific approaches and considering savings from deeper reconfigurations of the building systems in the C&I sector. Additionally, even though overall lighting savings are reduced, lighting measures still feature prominently in the top electric measures.

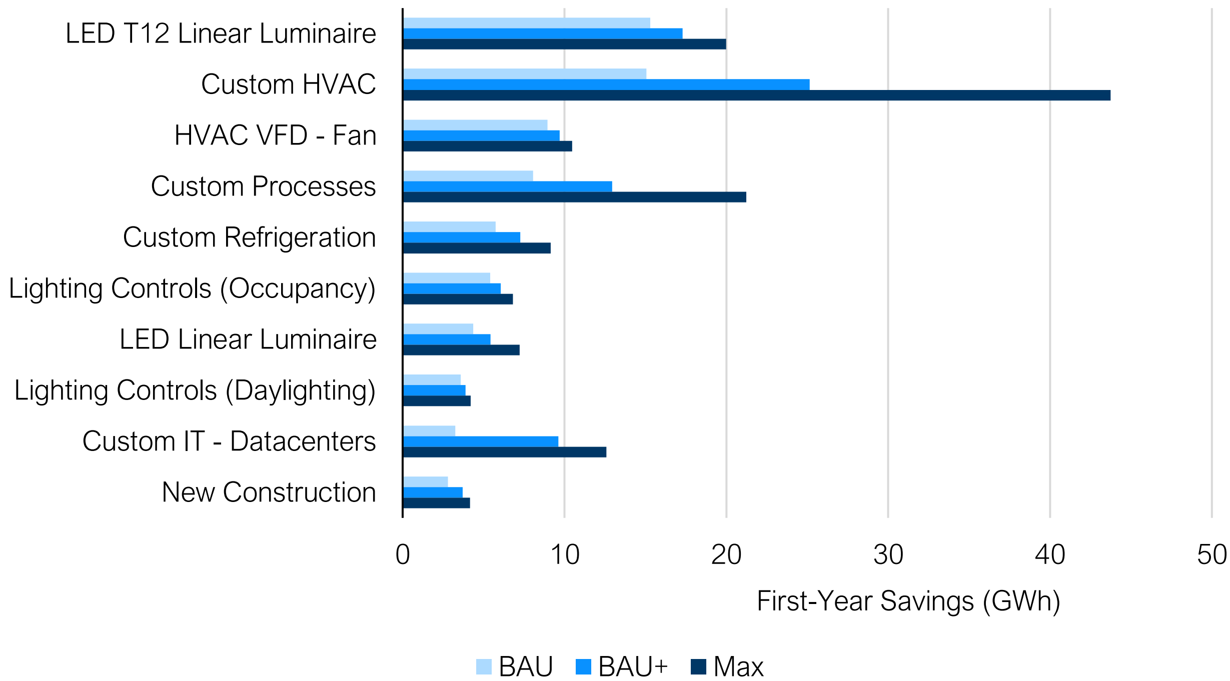
Figure 2-16. Eversource Electric Programs, Electric Top 10 C&I Measures by Lifetime Savings



Note: Measures are selected and arranged by relative contribution to 2022-24 average first-year savings under the BAU scenario.

In terms of first-year savings, the top C&I measures are mostly the same as shown in Figure 2-17. One exception is the custom IT (data centers) measure, which is the 9th most prominent electric C&I measure in first-year savings terms but does not show up in the top ten measures on a lifetime savings basis. Data centers offer a significant opportunity for electric savings due to their high levels of electric consumption, but the persistence of savings is relatively short due to the high turnover of energy-consuming equipment in these facilities.

Figure 2-17. Eversource Electric Programs, Electric Top 10 C&I Measures by First-Year Savings

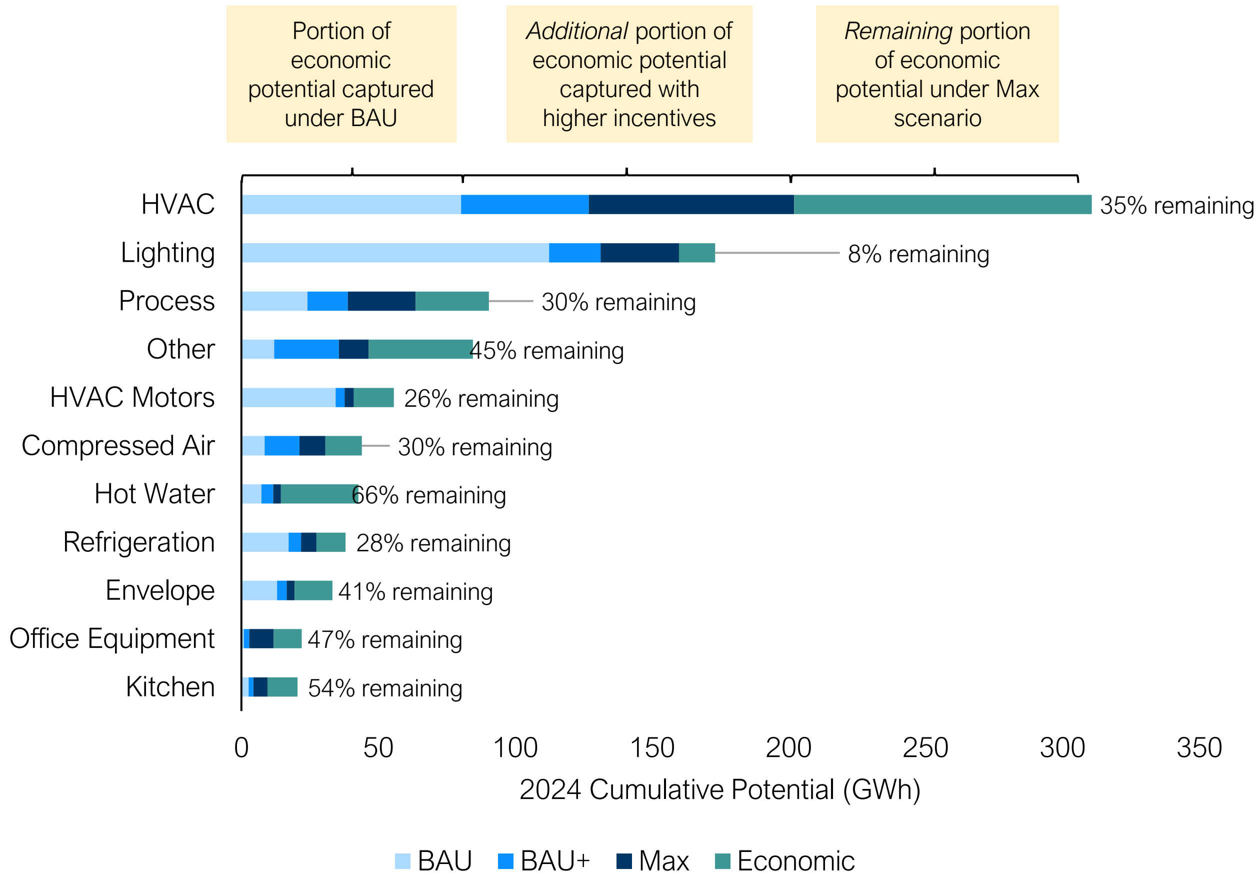


Note: Measures are selected and arranged by relative contribution to 2022-24 average first-year savings under the BAU scenario.

Potential Growth Opportunities

Figure 2-18 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-18. Eversource Electric Programs, Electric C&I Growth Opportunities



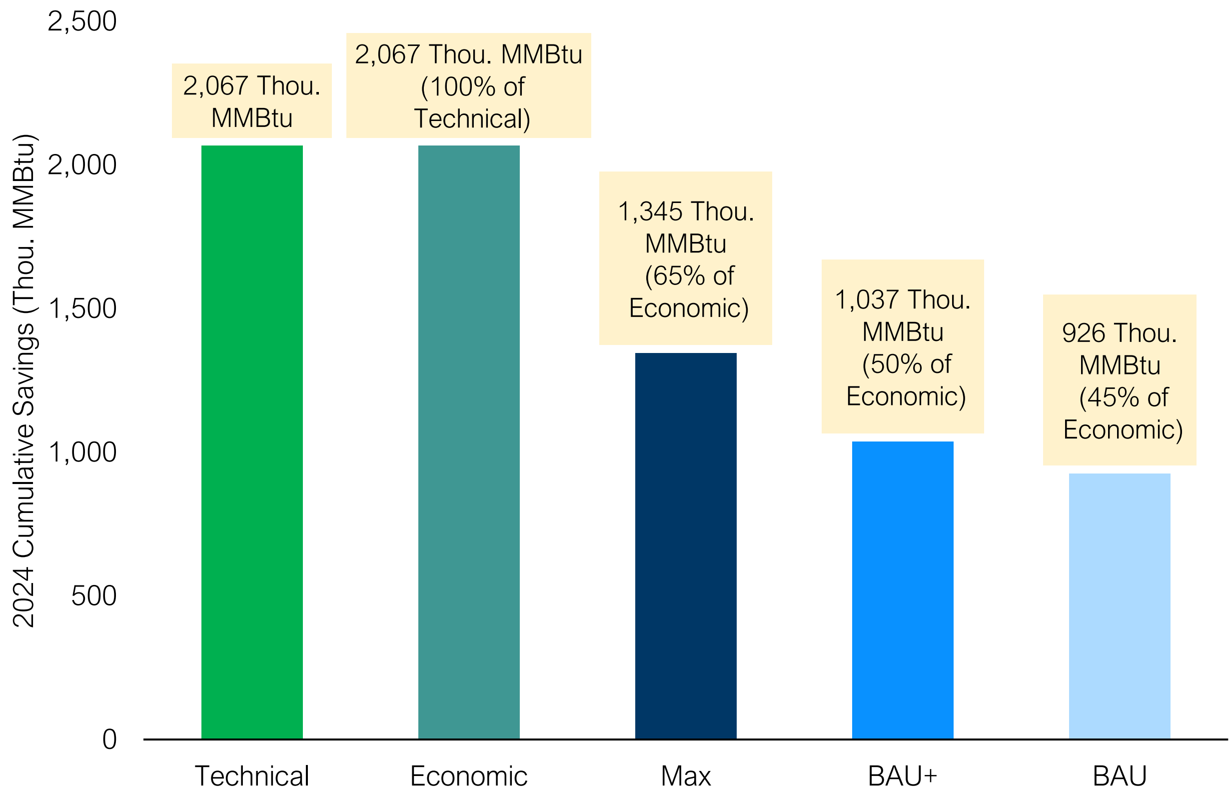
With maximum incentives, programs can capture over 50% of economic potential for most end-use categories. Notably, a significant portion (65%) of economic lighting savings are captured under the BAU scenario, and Max incentives increase this portion to 92% of net economic savings, which illustrates the efficacy of Eversource's existing programs for capturing C&I lighting savings.

For other end-uses, the results suggest that HVAC, Hot Water, Other (Data centers and Agriculture measures) Envelope, Kitchen and Office Equipment all offer notable room to grow savings via a combination of increased incentives and enabling strategies.

Delivered Fuels Savings

Figure 2-19 presents technical, economic, and achievable **delivered fuels savings potential** for Eversource's electric efficiency programs in terms of cumulative annual impacts in 2024 from measures installed during the 2022-24 study period.

Figure 2-19. Eversource Electric Programs, Delivered Fuels 2024 Cumulative Technical, Economic, and Achievable Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

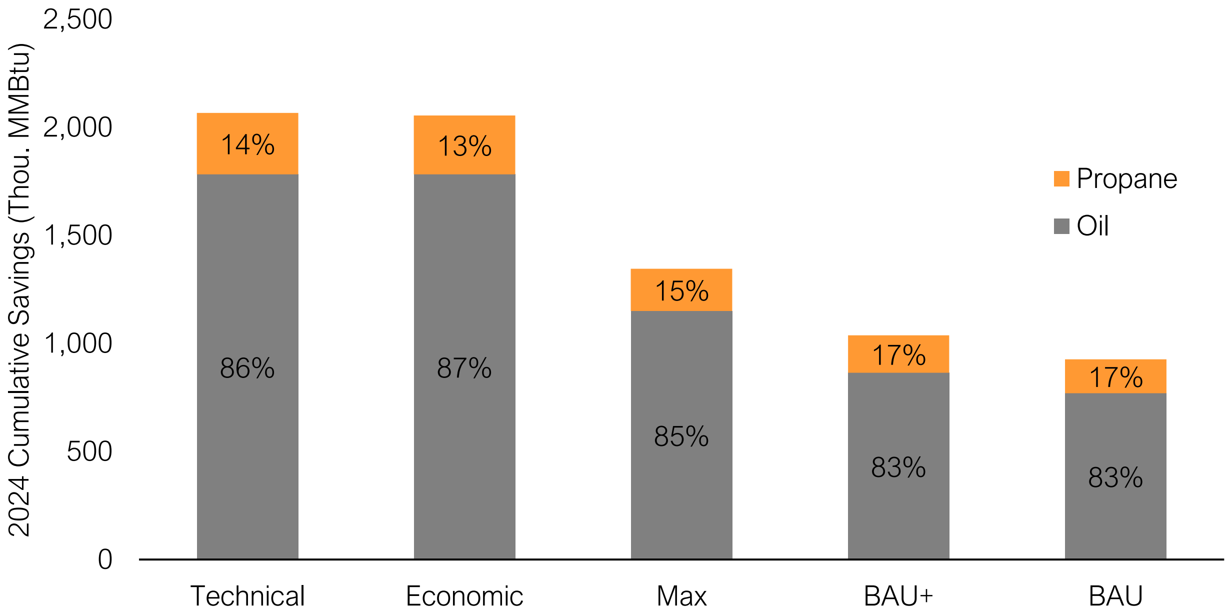
Net economic potential is the same as technical potential. Two factors are driving this observation. First, delivered fuels have relatively high avoided costs resulting in all measures passing the TRC. Second, there is significant economic savings potential from measures with NTGs greater than 1.0 indicating measures with large participant spillover effects (e.g., insulation and air sealing measures). The additional spillover savings from these measures more than counteract reduced savings from measures with NTGs less than 1.0 resulting in net economic potential that equals technical potential.

Relative to electric potential, the BAU achievable scenario captures a larger portion of net economic savings (45% vs. 32%). This illustrates the relatively better economic proposition of delivered fuels efficiency measures for customers due to the high costs of these fuels, which makes customers more likely to participate in fuel savings programs.

Savings by fuel type

Figure 2-20 technical, economic, and achievable delivered fuels savings potential broken down by fuel type (oil and propane).

Figure 2-20. Eversource Electric Programs, Delivered Fuels 2024 Cumulative Technical, Economic, and Achievable Potential by Fuel Type

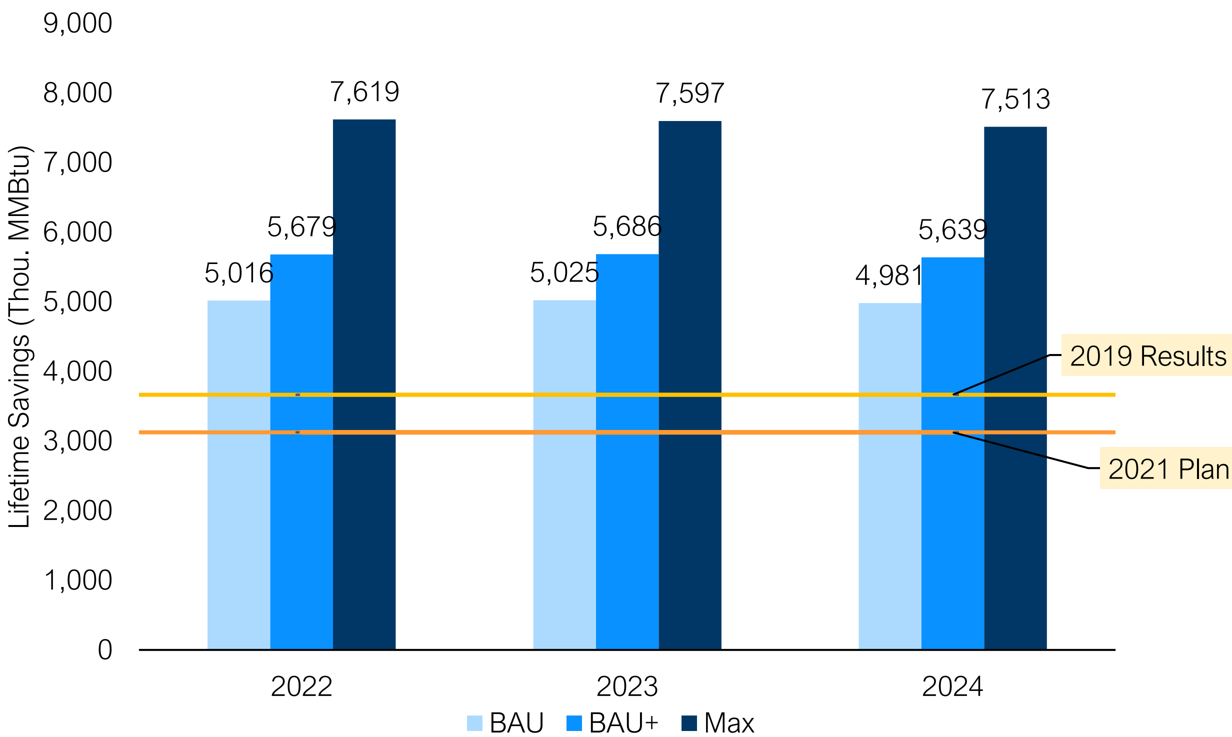


The majority of delivered fuels savings come from oil measures, but propane savings are still a substantial component, making up slightly over 14% of technical savings potential. For achievable potential, propane savings compose a slightly larger share of savings (15% to 17%) driven by the higher customer cost of propane relative to oil, which makes these measures somewhat more attractive to customers (*ceteris paribus*).

Overall Program Savings

Figure 2-21 presents lifetime savings derived from measures installed in each year under the achievable scenarios.

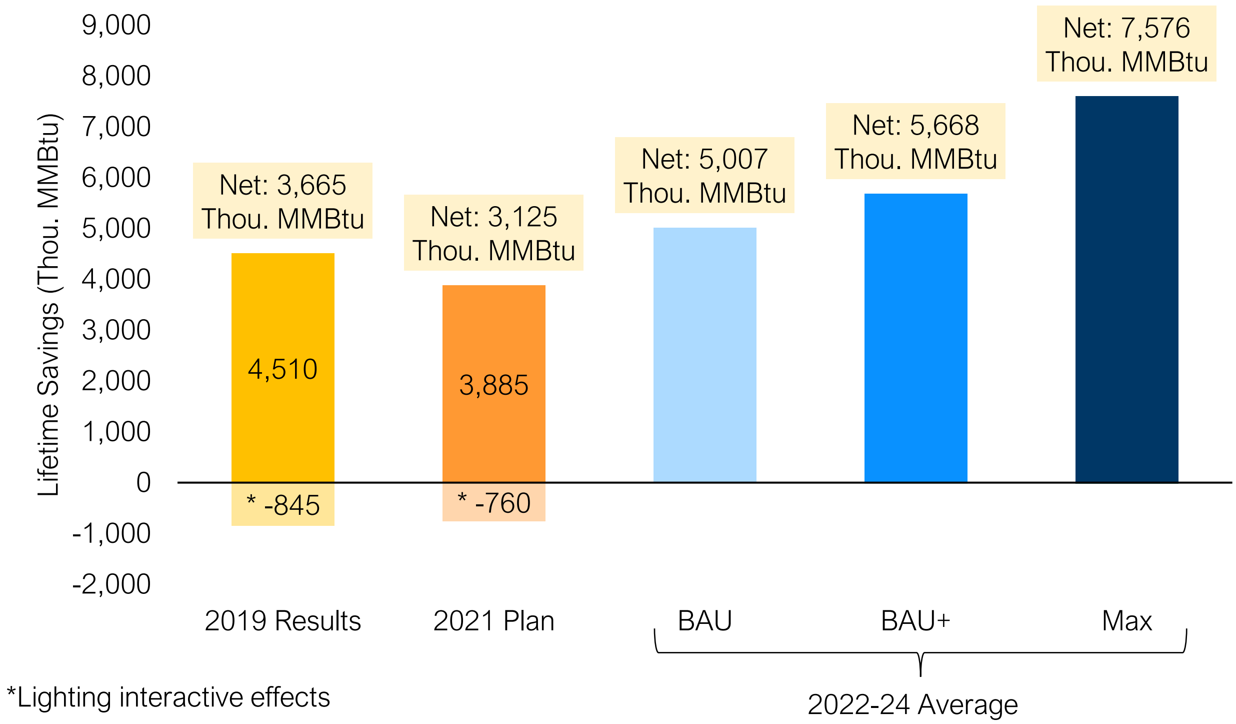
Figure 2-21. Eversource Electric Programs, Delivered Fuels Lifetime Savings by Year



Compared to 2019 Results and the 2021 Plan, achievable lifetime savings for delivered fuels are higher under all scenarios including BAU. Under the BAU scenario, the higher savings estimate is due to two factors. First, this study includes prescriptive C&I delivered fuels measures that are not currently part of Eversource's programs. And second, delivered fuels savings in 2019 Results and 2021 Plan are reduced due to a significant amount of indirect negative savings from lighting measures.[21] With reduced lighting savings in the study period, negative savings stemming from interactive effects are reduced. Figure 2-22 shows lifetime savings with negative indirect savings displayed separately.

[21] LED lighting produces less waste heat than inefficient lighting equipment requiring heating systems to consume additional energy to maintain the same indoor temperature.

Figure 2-22. Eversource Electric Programs, Delivered Fuels Lifetime Savings with Lighting Interactive Effects Removed

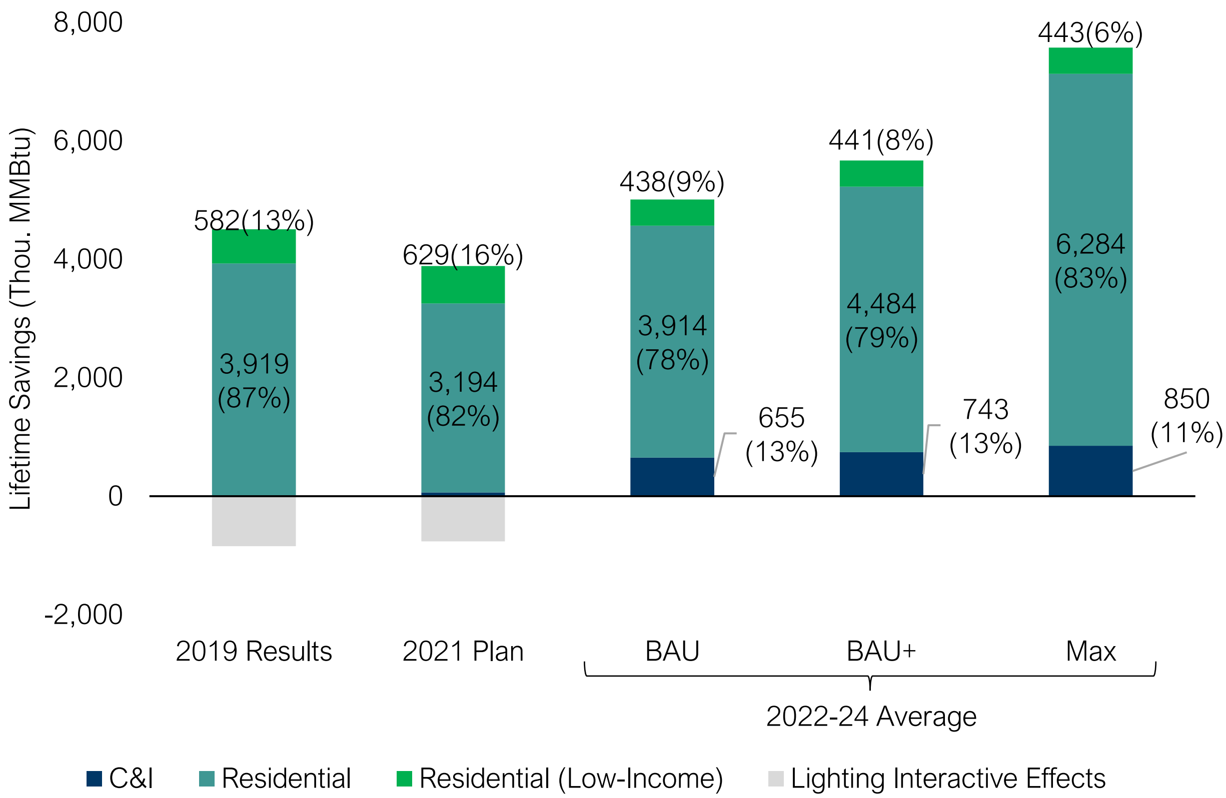


With lighting interactive effects removed, delivered fuels savings under the BAU scenario are approximately 37% above 2019 Results due to the inclusion of new prescriptive C&I measures.

Savings by Sector

At the sector level, most savings come from the residential sectors as shown in Figure 2-23.

Figure 2-23. Eversource Electric Programs, Delivered Fuels Lifetime Savings by Sector



As can be seen, little to no C&I delivered fuels savings are claimed by past programs while the study finds C&I savings can contribute a small, but significant, amount of delivered fuels savings.

Residential Savings

Savings by Market Segment

The vast majority of residential delivered fuels savings resides in the market-rate single family segment as shown in Table 2-4.[22]

[22] Low-income multi-family savings increase slightly under in absolute terms the BAU+ and Max scenarios due to a modeling artifact resulting in a portion of low-income savings being captured with the C&I multi-family segment, which is modeled in the C&I sector with C&I program incentive levels.

Table 2-4. Eversource Electric Programs, Delivered Fuels Residential Lifetime Savings by Market Segment

Segment	2022-24 Average Lifetime Thou. MMBtu (% of Total)		
	BAU	BAU+	Max
Single Family	3,868 (89%)	4,434 (90%)	6,229 (93%)
Low Income Single Family	331 (8%)	331 (7%)	331 (5%)
Low Income Multi-Family	108 (2%)	110 (2%)	112 (2%)
Multi-Family	46 (1%)	50 (1%)	54 (1%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

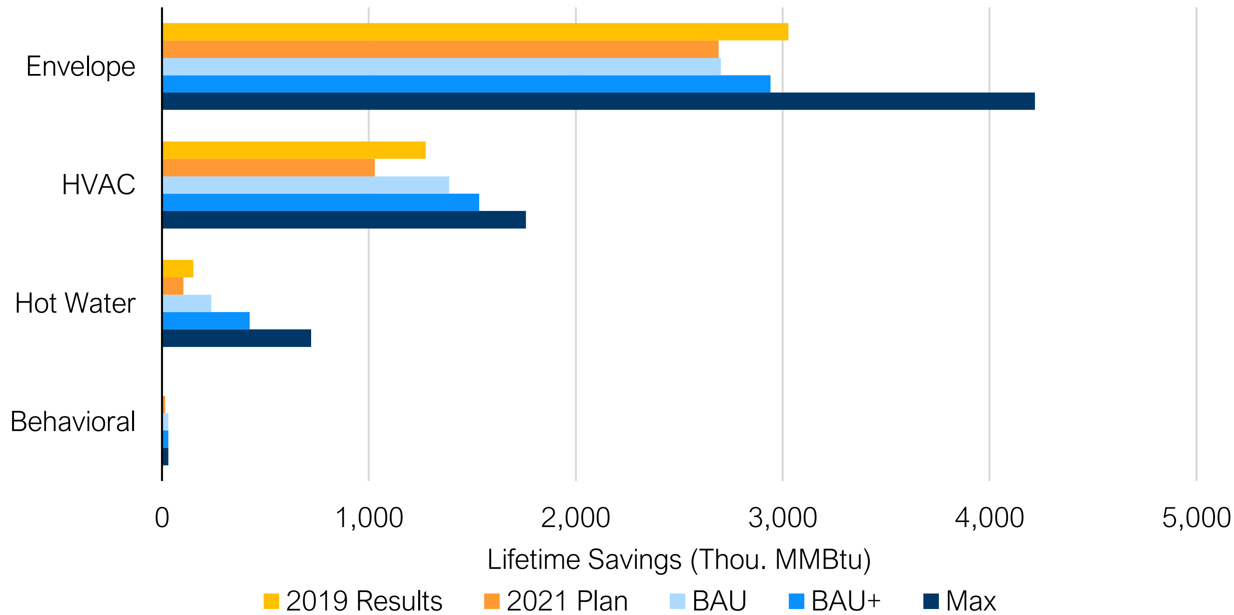
Very few savings are found in the multi-family segment primarily due to the small number of these customers who primarily heat with oil or propane. For example, according to baseline data, approximately 1% of multi-family customers primarily heat with fuel oil compared to 27% of single-family customers.[23] Delivered fuels savings are driven by envelope and HVAC measures (see Figure 2-24.) making divergences in heating fuel type a significant influence on savings potential among building segments.

Savings by End-use

Residential delivered fuels savings are mostly distributed across envelope, HVAC, and hot water measures. The study assumes some delivered fuels savings from Eversource's HER program, but due to the one-year EUL assumption, this measure contributes relatively little to the lifetime savings. In first-year savings terms, delivered fuels behavioral measures account for approximately 8% of all first-year residential delivered fuels savings.

[23] Estimate is based on Eversource-specific residential baseline data from the 2020 Residential Baseline Study. (Guidehouse. *Massachusetts Residential Baseline Study.* March 31, 2020. Accessible at: https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf)

Figure 2-24. Eversource Electric Programs, Delivered Fuels Residential Lifetime Savings by End-use



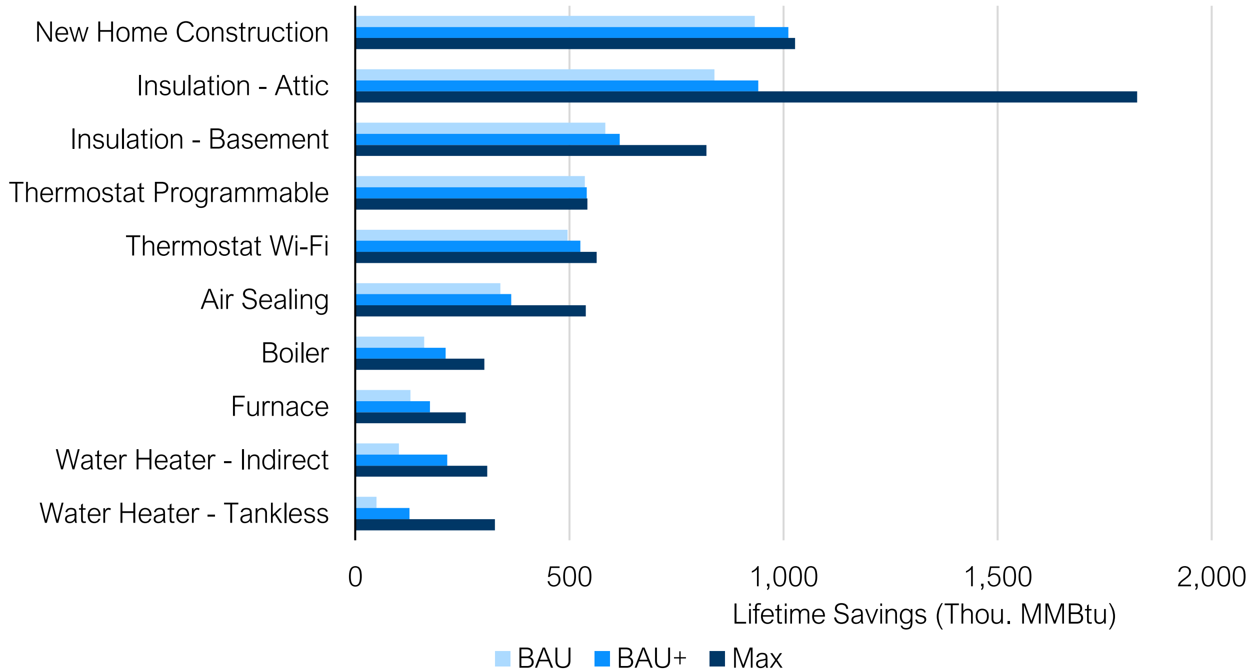
Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include savings for both market-rate and low-income customers.

The most significant growth opportunity in absolute terms through increased incentives is with envelope measures. Under the Max scenario, envelope savings increase by over 1.5 million lifetime MMBtu compared to the BAU scenario. Hot water measures also show significant potential for growth – increasing by over 200% under the Max scenario relative to BAU, however, they do not represent a very large portion of overall residential delivered fuels savings.

Top Measures

Envelope and HVAC measures compose most of the top residential delivered fuels measures as shown in Figure 2-25. Notably, programmable and wi-fi thermostats are the fourth and fifth most prominent measures – highlighting the ability of this equipment to help reduce space heating energy consumption.

Figure 2-25. Eversource Electric Programs, Delivered Fuels Top 10 Residential Measures by Lifetime Savings

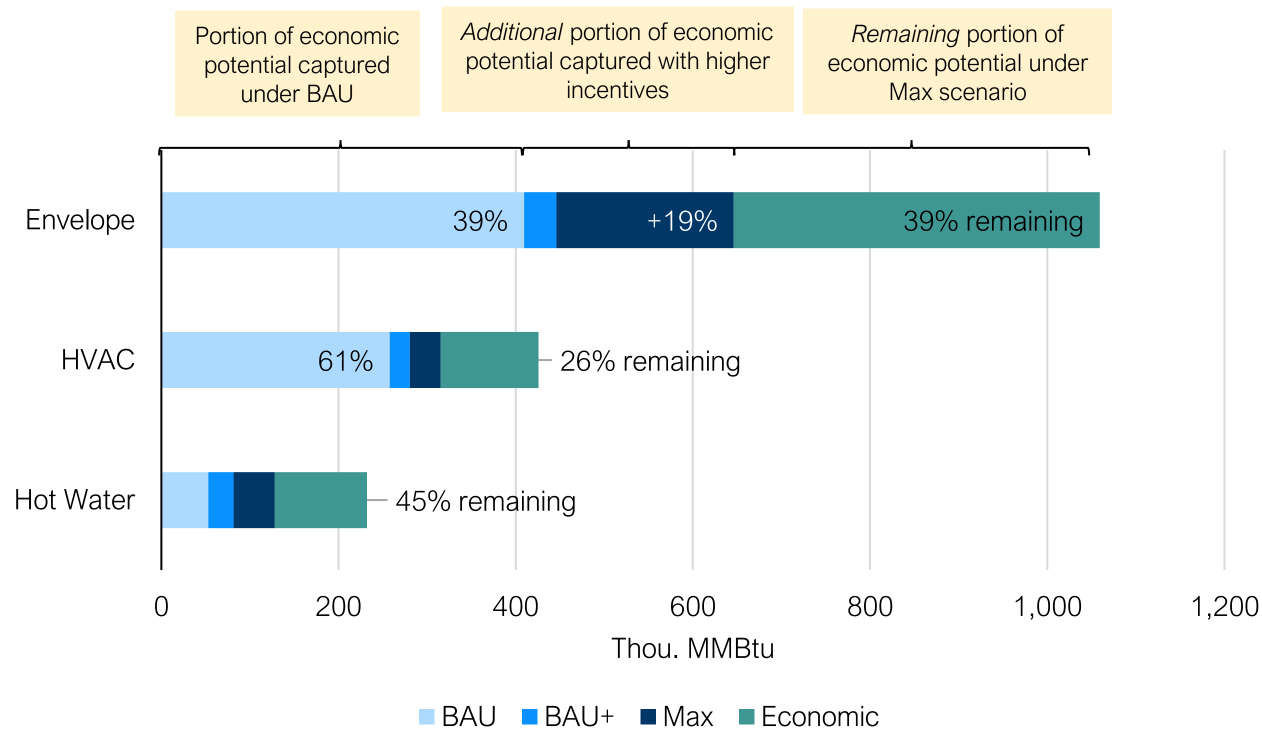


Note: Measures are selected and arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include both market-rate and low-income savings.

Potential Growth Opportunities

Figure 2-26 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-26. Eversource Electric Programs, Delivered Fuels Residential Growth Opportunities



Note: Residential behavioral savings represent <5% of residential 2024 cumulative economic potential and are excluded from the above figure.

Under BAU incentives, over 60% of HVAC savings are captured indicating effective existing programs. Increasing incentives only capture an additional 13% of economic savings suggesting customer economics is not a limiting factor for these measures. In each end-use category, the Max scenario captures over 50% of economic savings. Similar to the electric savings analysis, the Envelope and Hot Water measures may lend themselves to further program enhancements beyond incentive increases that can help unlock a higher proportion of the economic potentials by addressing market barriers.

C&I Savings

Savings by Segment

C&I delivered fuels savings are split among the ten market segments with the lodging and office segments comprising over 50% of 2022-24 average lifetime savings under all scenarios as shown in Table 2-5.

Table 2-5. Eversource Electric Programs, Delivered Fuels C&I Lifetime Savings by Segment

Segment	2022-24 Average Lifetime Thou. MMBtu (% of total)		
	BAU	BAU+	Max
Lodging	237 (36%)	246 (33%)	254 (30%)
Office	133 (20%)	156 (21%)	186 (22%)
Manufacturing/ Industrial	75 (11%)	97 (13%)	125 (15%)
Retail	72 (11%)	83 (11%)	96 (11%)
Other Commercial	45 (7%)	53 (7%)	61 (7%)
Warehouse	42 (6%)	47 (6%)	52 (6%)
Healthcare/ Hospitals	21 (3%)	26 (4%)	32 (4%)
Campus/ Education	20 (3%)	24 (3%)	30 (4%)
Food Service	6 (1%)	6 (1%)	8 (1%)
Food Sales	4 (1%)	4 (1%)	5 (1%)

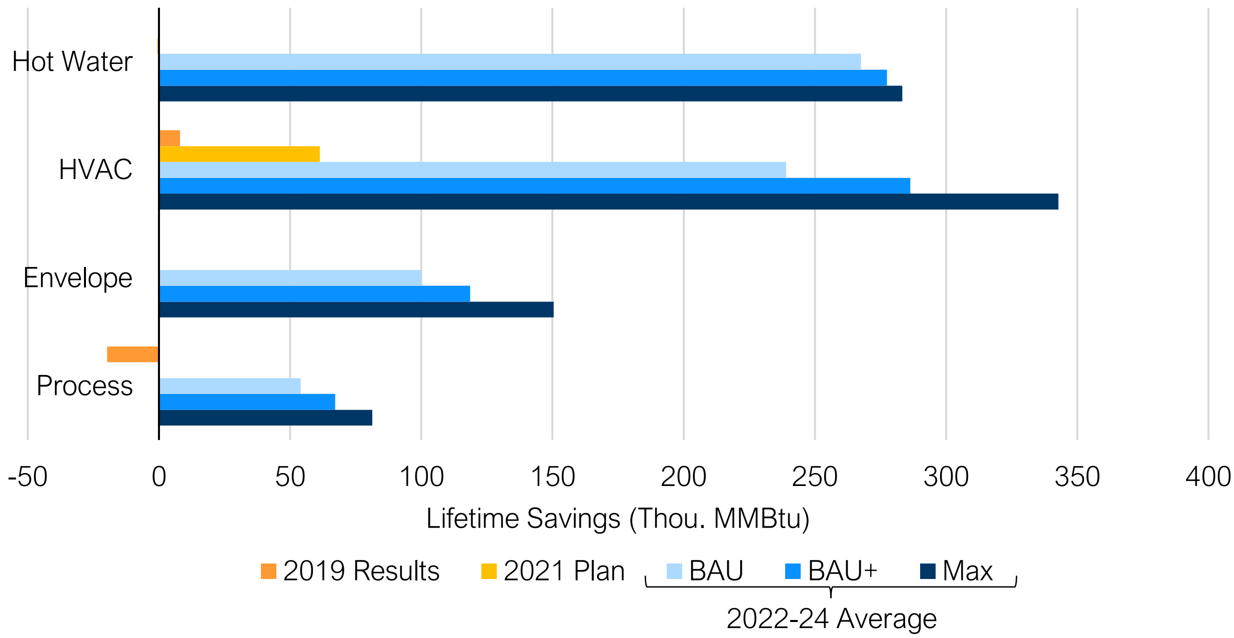
Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

At the end-use level, most C&I delivered fuels savings come from hot water, HVAC, and envelope measures though there is potential for some process-related delivered fuels savings as well. Notably, the most prominent end-use category under BAU incentives is hot water, which differs from residential savings where hot water measures are much less significant than HVAC and envelope measures, reflecting the generally lower heating requirements per square footage in C&I buildings relative to residential buildings. Increasing incentives do not increase hot water savings by very much, however, and HVAC measures become the most prominent end-use category under the BAU+ and Max scenarios.

The absence of prescriptive C&I delivered fuels measures in Eversource's existing programs is also evident in Figure 2-27 as the 2019 Results and 2021 Plan benchmarks show little to no savings by end-use. The only savings shown are associated with custom measures targeting electric savings, including a small amount of HVAC savings associated with custom HVAC measures that provide significant electric savings. Eversource also reported an increase in propane consumption associated with electric custom process measures in 2019, resulting in negative delivered fuels savings for this end-use.

Figure 2-27. Eversource Electric Programs, Delivered Fuels C&I Lifetime Savings by End-use

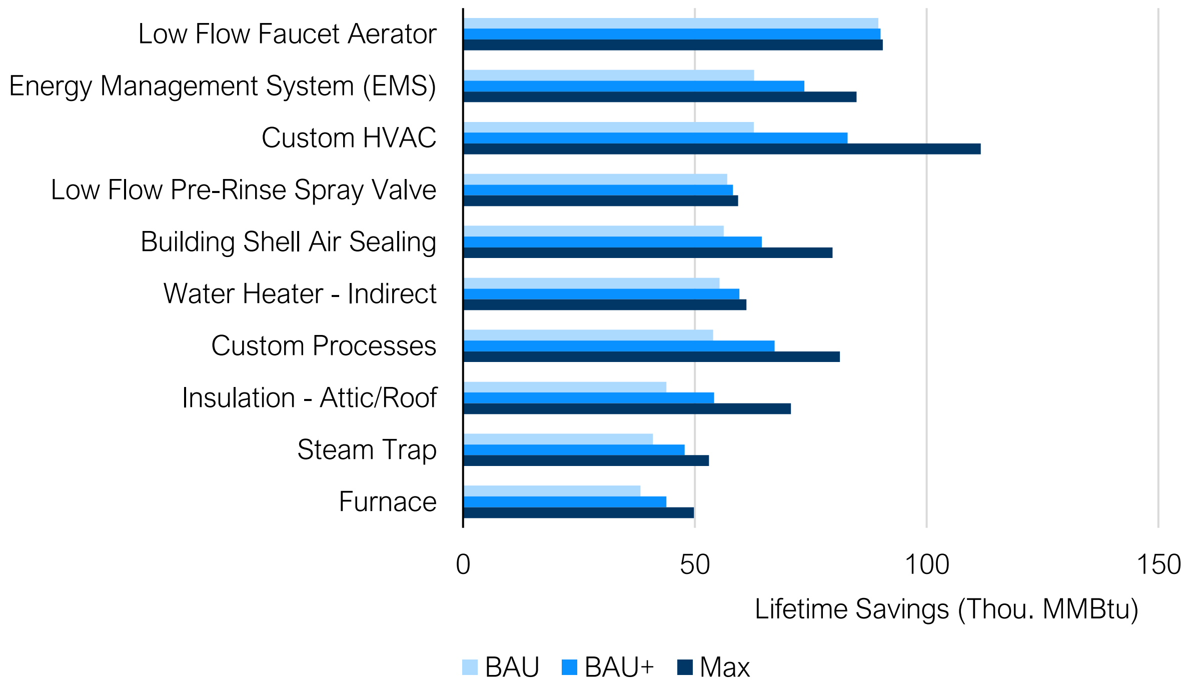


Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario.

Top measures

The significant amount of hot water savings is primarily driven by water consumption reducing measures such as low flow faucet aerators and low flow pre-rinse spray valves as shown in Figure 2-28.

Figure 2-28. Eversource Electric Programs, Delivered Fuels Top 10 C&I Measures (2022-24 Average Lifetime Savings)



Note: Measures are selected and arranged by relative contribution to 2022-24 average first-year savings under the BAU scenario.

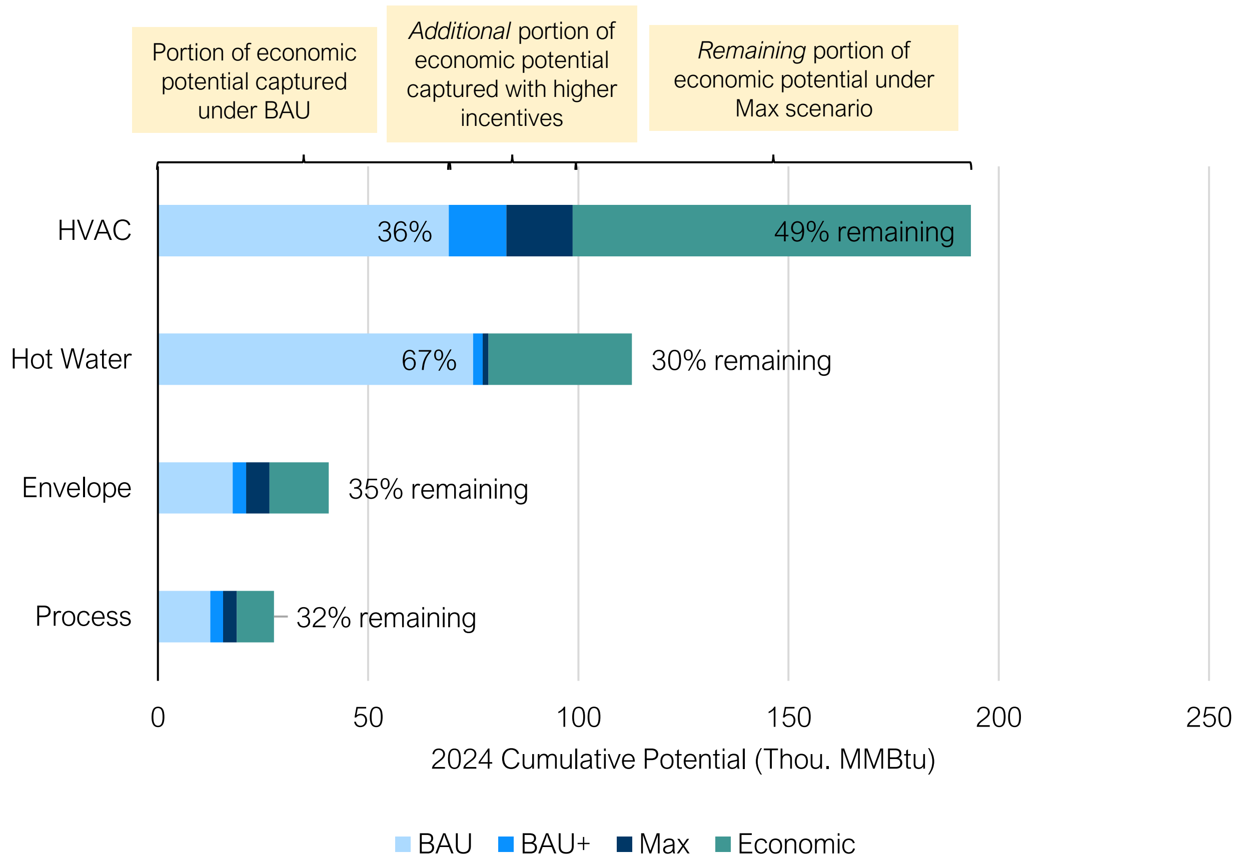
Energy Management Systems (EMS) are a significant source of C&I delivered fuels savings but are highly dependent on the savings assumptions. In the absence of an analogous MA TRM entry, this study assumes EMS can help reduce delivered fuels consumption by 10% when applied to buildings without an existing EMS, however establishing the precise level of EMS savings across all facilities and evaluating these savings can pose challenges for program administrators.[24]

Potential Growth Opportunities

Figure 2-29 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

[24] As EMS measures are highly custom per facility, this high-level assumption is derived from Dunsky's internal engineering expertise. Additionally, the challenges inherent with estimating and evaluating EMS savings can impact the ability of programs to claim savings. For additional information on this topic, see, for example, "*P73B - Energy Management System Baseline Opinion Memo*" accessible at: https://ma-eeac.org/wp-content/uploads/MA_CIEC_P73B_EMS_OpinionMemo_FINAL_190215.pdf

Figure 2-29. Eversource Electric Programs, Delivered Fuels C&I Potential Growth Opportunities



The results suggest the greatest cumulative economic potential resides in HVAC measures, but only 36% of these savings are captured under BAU incentive levels. With increased incentives under the Max scenario, slightly over half of the economic HVAC savings are captured suggesting other market barriers inhibiting adoption of these measures.

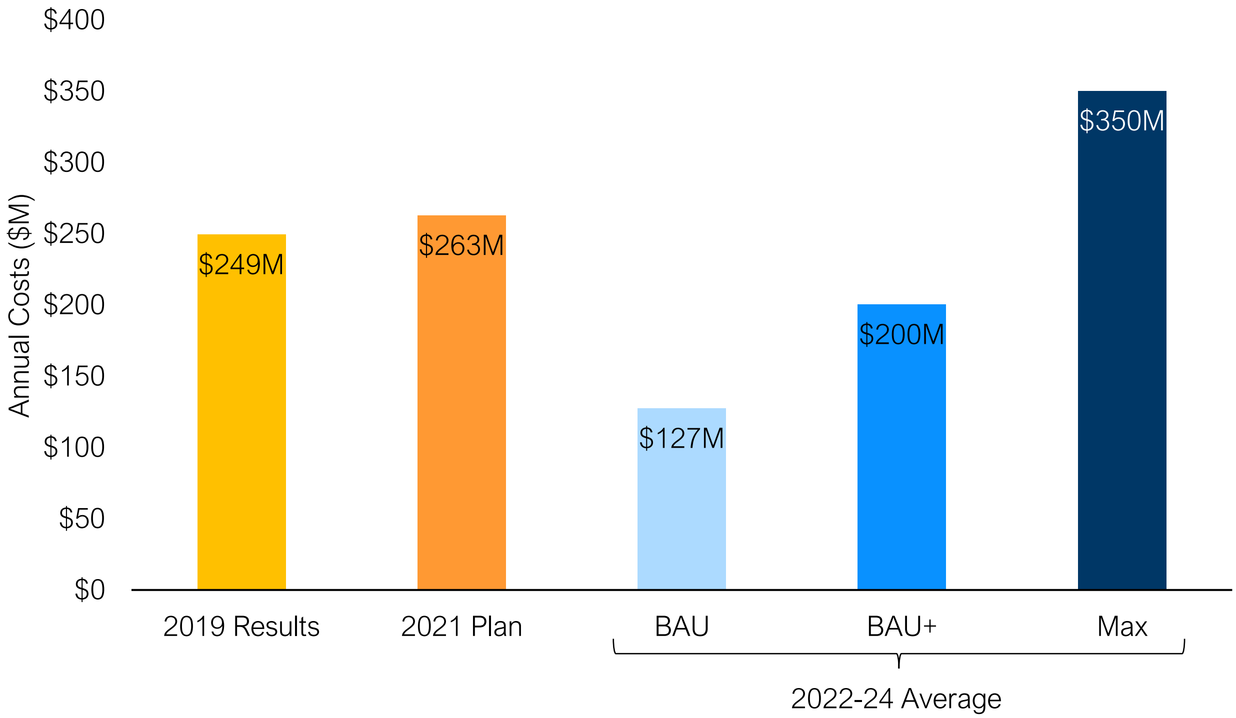
Portfolio Metrics

The following section presents portfolio-level metrics for the Eversource Electric Program results including program costs, TRC results, and emission benefits.

Program Costs

Figure 2-30 presents the estimated 2022-24 average annual cost of administering Eversource's electric programs under each achievable scenario.

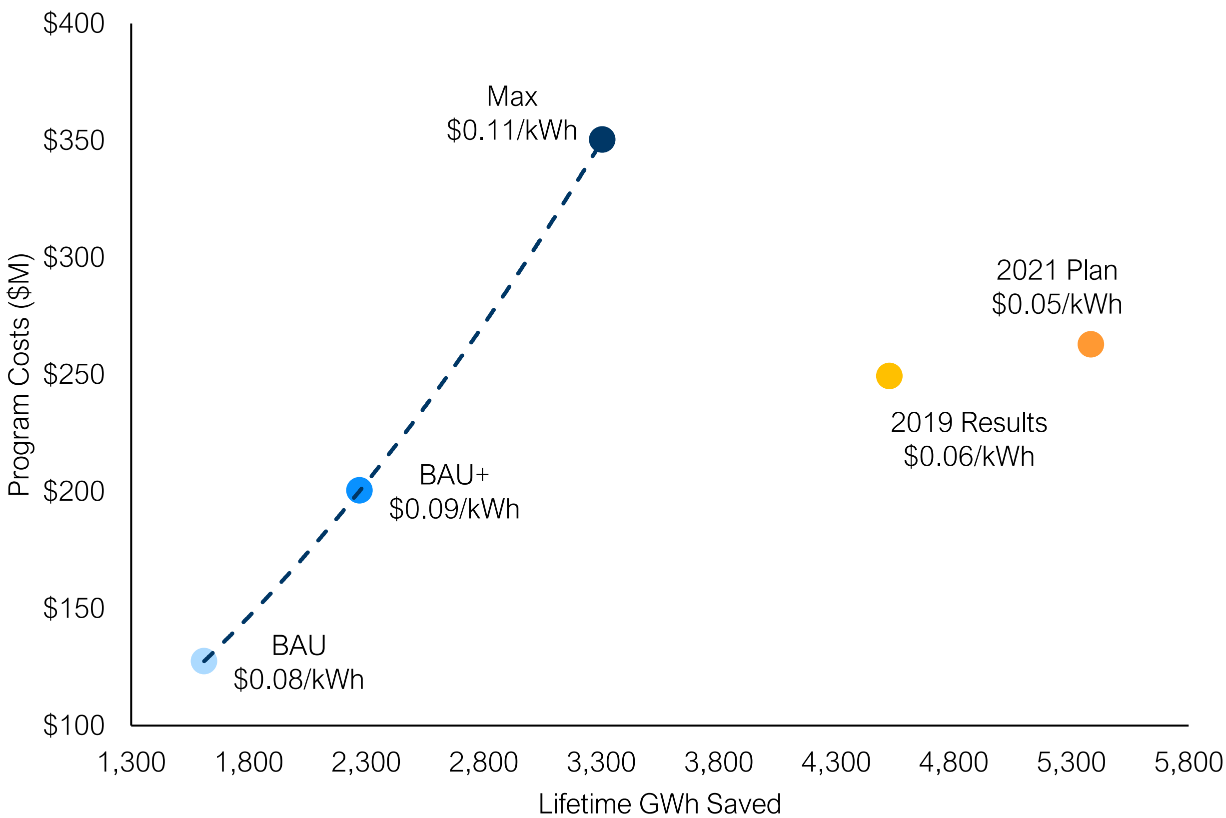
Figure 2-30. Eversource Electric Programs, Program Costs



Commensurate with the decline in overall electric savings, overall electric program costs are significantly below 2019 Results and the 2021 Plan. With significant reductions in the incentives paid for lighting measures, overall costs are reduced by 49 to 52% under BAU incentive levels relative to 2019 Results and the 2021 Plan, respectively. Under the Max scenario, overall costs eclipse 2019 Results and the 2021 Plan even though achieved electric lifetime savings do not even reach 2019/2021 levels. Under the Max scenario, average annual costs are 41% higher than in 2019, while achieved electric lifetime savings are still 20% below 2019 achievements.

While program costs may decline under the BAU scenario relative to 2019 Results and the 2021 Plan, the cost to deliver electric savings is higher than in the past as shown in Figure 2-31. This is driven by two factors.

Figure 2-31. Eversource Electric Programs, Program Costs vs. Lifetime GWh Saved



First, as diminishing lighting savings reduce overall electric savings, the relative portion of budgets going towards delivered fuels measures are expected to increase. This will also increase program cost per unit of electric savings as more program dollars go towards measures that do not procure significant amounts of electric savings. This trend increases the study's estimated program cost per unit of electric savings, but it does not explain the entire difference. Table 2-6 shows program costs with and without delivered fuels incentive costs. **Even after removing delivered fuels incentives, the program cost per lifetime kWh under the BAU scenario is 37% greater than in 2019.** As an illustrative example of this increase in costs, if the programs had spent the cost per lifetime kWh projected for the BAU scenario to actual lifetime kWh saved in 2019, the program would have spent a total of $308M instead of the actual spend of $225M (after removing delivered fuel incentives). Similarly, if the program had spent the cost per lifetime kWh projected for the Max scenario, the cost would have been $421M.

Table 2-6. Eversource Electric Programs, Program Costs with and without Delivered Fuels Incentive Costs

	With delivered fuels incentive costs			Without delivered fuels incentive costs		
	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per First-Year kWh	Annual Cost ($M)	Program $ per Lifetime kWh	Program $ per First-Year kWh
2019 Results	$249	$0.055	$0.48	$226	$0.050	$0.43
2021 Plan	$263	$0.049	$0.53	$239	$0.044	$0.48
BAU	$127	$0.079	$0.84	$110	$0.068	$0.73
BAU+	$200	$0.088	$0.97	$177	$0.078	$0.85
Max	$350	$0.106	$1.21	$308	$0.093	$1.06

The remainder of this cost difference is again driven by the loss of lighting savings – this time because lighting savings tend to be less expensive per kWh than other measures. Therefore, as lighting savings decrease in the portfolio, the average program cost per unit of electric savings should be expected to increase.

A final observation regarding costs is that under higher incentive levels, costs increase faster than savings. As shown in Figure 2-31, the slope of average annual program costs plotted against average incremental lifetime savings achieved steepens as incentives are increased. This result is to be expected as raising incentives increases the cost not just for newly acquired savings but for savings that would have been obtained under lower incentive levels as well. Increased incentives will also tend to drive greater adoption of measures with higher unit savings costs as these measures will also tend to have smaller customer benefits (e.g., bill savings). With increased incentives, these measures become more attractive to customers and thus are adopted at greater levels.

Cost Estimate Considerations

While the per-unit acquisition costs of savings should be expected to increase with increased incentive levels, the precise magnitude of these cost increases presented in this study should be interpreted with the following caveats.

First, costs are estimated based on historical cost data. Fixed and variable program costs are based on historical spending data for Eversource's 2019 efficiency programs. These inputs do not vary over the study period to account for factors that may increase (e.g., higher labor or technology costs as programs increase demand for specific services and/or equipment) or decrease costs (e.g., lower program implementation costs as programs mature and become more efficient or employ new delivery strategies).

Second, program scenarios are not optimized for program spending. For each achievable scenario, incentive levels are set at the program level as a portion of incremental costs for all measures in the program. However, a real-world program design would likely set specific incentive levels for each measure, applying higher incentive levels for measures that may have had limited uptake in the past and maintaining or lowering incentive levels for measures that meet their expected adoption. Such an optimized program design approach would help avoid paying significantly higher acquisition costs for measures where increased incentives do not lead to significantly increased savings.

Program Benefits

Overall, Eversource's electric efficiency programs have the potential to continue to generate significant benefits as measured by the TRC as well as emission reductions. Table 2-7 displays the overall TRC ratio, net TRC benefits, net benefits per lifetime and first-year kWh saved, and average annual CO_2 emission reductions achieved each program year.

Table 2-7. Eversource Electric Programs, TRC Benefits and CO2 Emission Reductions (2022-24 Average)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime kWh	Net TRC Benefits per First-year kWh	CO_2 Annual Emission Reductions (Short Tons)
2019 Results	2.6	$600M	$0.13	$1.15	334,000
2021 Plan	2.3	$584M	$0.11	$1.18	274,000
BAU	2.6	$252M	$0.16	$1.67	106,000
BAU+	2.7	$331M	$0.15	$1.60	140,000
Max	2.6	$457M	$0.14	$1.58	193,000

Note: TRC values for 2019/2021 benchmarks are derived using 2018 AESC values while modeled TRC values are derived using 2021 AESC values.

As expected, net TRC benefits decline in accordance with the reduction in overall electric program savings. Despite this decline, Eversource's electric programs are projected to generate over $200 million of net benefits for the utility's ratepayers each year of the study.

Under the BAU scenario, the portfolio-wide TRC ratio declines slightly compared to 2019 but is higher than the 2021 plan. While electric avoided costs used in this study (AESC 2021 values) are generally lower than the avoided costs used to estimate TRC values in the 2019 Results and 2021 Plan (AESC 2018 values), the higher proportion of savings from delivered fuels measures, which generally have higher net TRC benefits, helps counteract lower electric avoided costs.[25] Net benefits per kWh savings are higher than benchmarks for the same reason.

In terms of annual CO_2 emission reductions, while these will also drop compared to past programs, Eversource's electric programs will still have the potential to produce slightly more than 100,000 short tons of CO_2 reductions each year during the study period under BAU conditions.

Sensitivity Analyses

COVID-19

As the COVID-19 pandemic has led to economic uncertainty and business closures, it may have some impact on the achievable potential within the study period (2022-24). It is unclear what precise economic effects will be caused by COVID, how they will be distributed across the market, and how long these effects will persist; however, this analysis performs a high-level assessment of how COVID-driven changes in market conditions may impact achievable program savings.

As the energy efficiency potential study results are calibrated to program results before the pandemic started (2019), they do not implicitly account for the impacts of COVID.

To test the sensitivity of model results to long-lasting COVID-19 impacts, this analysis adjusts the following input parameters to reflect possible economic impacts of COVID lasting through the study period:

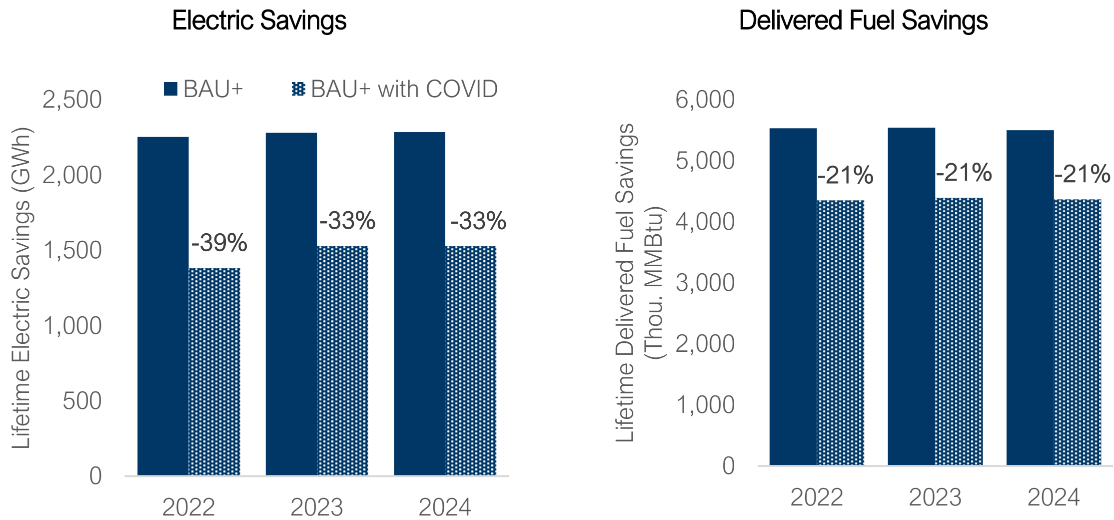
- **Market sizes** have been adjusted in the C&I sector to reflect fewer customers within a given segment due to temporary or permanent business closures.
- **Barrier levels** have been increased to reflect delayed projects, increased competition for capital, decreased resources, and other impediments to energy efficiency and electrification upgrades.

Appendix A summarizes the methodology including market and barrier parameters used for each segment. It should be noted that the sensitivity parameter adjustments were selected before the rapid rollout of COVID-19 vaccinations in the spring of 2021 and that this sensitivity should be interpreted as an upper-bound worst-case scenario (e.g., the emergence of vaccine-resistant COVID variants). The analysis is performed on the BAU+ scenario.

[25] For more information on differences between AESC 2018 and AESC 2021 values, see page 2 of the *Avoided Energy Supply Components in New England: 2021 Report*. Accessible at: https://www.synapse-energy.com/sites/default/files/AESC_2021_.pdf

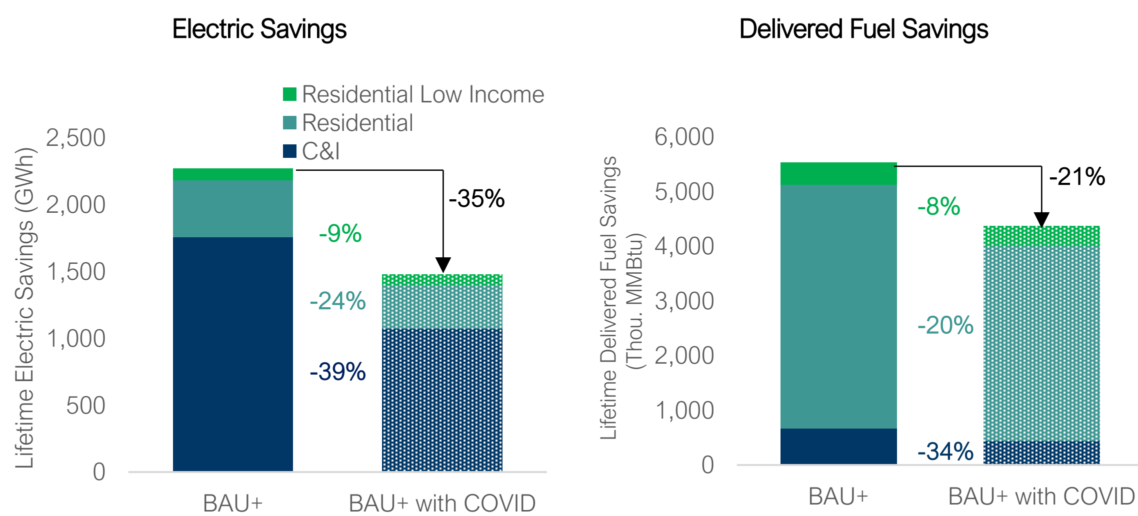
Figure 2-32 presents the results of the sensitivity analysis for the three years of the potential study compared to the BAU+ scenario.

Figure 2-32. Eversource Electric Programs, COVID Sensitivity - Impact on Lifetime Achievable Savings



In our modeling, COVID-19 impacts reduce the achievable electric savings by around a third compared to the BAU+ scenario, with this impact less pronounced after the first year when some temporarily closed businesses reopen. On the delivered fuel side, a reduction of 21% is seen across all years. Delivered fuel savings are impacted less than electric savings due to the relative portion of savings coming from the residential sector as shown in Figure 2-33 and discussed below.

Figure 2-33. Eversource Electric Programs, COVID Sensitivity - Impact by Sector (2022-24 Average)



The C&I sector shows a larger reduction in savings than the residential sectors, which is to be expected since this sector sees market size adjustments as well as barrier level increases. Both delivered fuels and electric savings demonstrate this trend.

Overall, our analysis suggests that the COVID-related impacts to the economy could result in reduced achievable savings for efficiency programs through the study period if economic impacts persist. These savings reductions are significant in both the C&I and residential sectors, with businesses hit harder than households in terms of achievable potential.

State Codes and Standards

On March 26, 2021, Governor Baker signed "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy" into law. One of the (many) provisions of this law updates energy and water efficiency standards for common household and commercial appliances included in this study. By increasing baseline efficiency standards, the law will reduce technical, economic, and claimable achievable savings potential estimates for affected measures in this study.

This analysis looks at the group of achievable savings that could be impacted by this law. It is unclear to what degree *claimable* savings for the PAs will be impacted as ongoing discussions will determine whether and to what degree the PAs can claim credit for the strengthening of these standards.

The following electric and delivered fuels measures included in this study are also included in the appliance standards included in the bill:

- Commercial hot food holding cabinets
- Commercial dishwashers
- Commercial fryers
- Commercial ovens
- Commercial steam cookers
- Low-flow showerheads
- Low-flow faucets
- T12 linear lighting

Under the BAU+ scenario, these measures account for approximately 6.7% of 2022-24 average lifetime electric savings and 3.0% of 2022-24 average lifetime delivered fuels savings. As shown in Table 2-8 and Table 2-9, the impact is not spread evenly across sectors. Overall, the C&I sector could experience a much bigger impact on savings than the residential sector, primarily due to the possible impact on claimable savings from T12 linear lighting measures.[26] Claimable C&I delivered fuels savings, in particular, could potentially decline by nearly 17% due to a large amount of savings from low-flow water measures.

[26] The precise impact on claimable savings – and for T12 linear lighting in particular – will depend on how savings from replace-on-failure (ROF) and early replacement (ER) measures are treated in light of the new standards. This analysis includes savings from both measure types to present an upper bound of the savings that may be impacted.

Table 2-8. Eversource Electric Programs, Electric Lifetime Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted by C&S (Lifetime GWh)	% Impacted
C&I	150	8.9%
Residential	3.1	0.7%
Residential Low Income	0.4	0.3%

Table 2-9. Eversource Electric Programs, Delivered Fuels Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted by C&S (Lifetime Thou. MMBtu)	% Reduction
C&I	118.8	16.0%
Residential	45.9	1.0%
Residential Low Income	5.1	1.2%

In addition to these appliance standards, the law also requires the state to develop a voluntary specialized stretch code for "net-zero energy" buildings. Depending on requirements, net-zero buildings either emit no greenhouse gases or generate their own renewable energy to offset any emissions. These codes are often designed to be flexible and performance-based making, and at the time of writing the impact of the proposed stretch code on New Construction savings in this study is unclear.

Overall, a number of measures are likely to be impacted by the new law, and at the time of writing, the exact impact of measures, and what (if any) portion may still be claimable by the efficiency program administrators under the law, is uncertain.

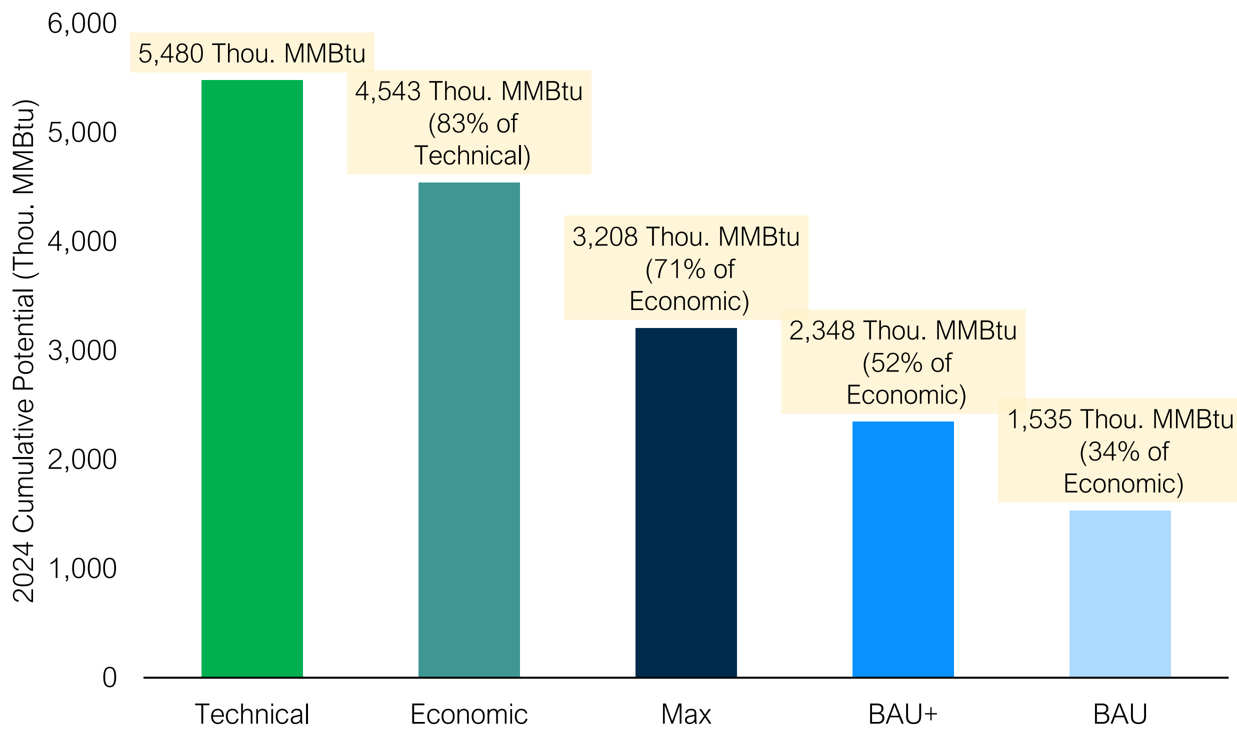
2.3 Eversource Gas Program Results

The following section presents results for Eversource's Gas Program savings potential. These results cover Eversource's existing gas territory prior to the acquisition of CMA. Potential results for EGMA (formerly CMA) are presented separately in the following section.

Gas Savings

Figure 2-34 presents technical, economic, and achievable **gas savings potential** in terms of cumulative annual impacts in 2024 from measures installed during the 2022-24 study period.

Figure 2-34. Eversource Gas Programs, 2024 Cumulative Technical, Economic, and Achievable Gas Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

Most gas savings pass economic screening. Only 3.5% of technical gas potential fails the TRC cost-effectiveness screening.[27] The remaining difference between technical and net economic potential is due to net-to-gross adjustments, which generally reduce net gas savings due to large free ridership effects for many gas measures.

The BAU scenario captures slightly over one-third of economic savings. Under current incentive levels, only 34% of net economic savings are captured suggesting there could be significant room to grow gas savings with increased incentives and enhanced program designs.

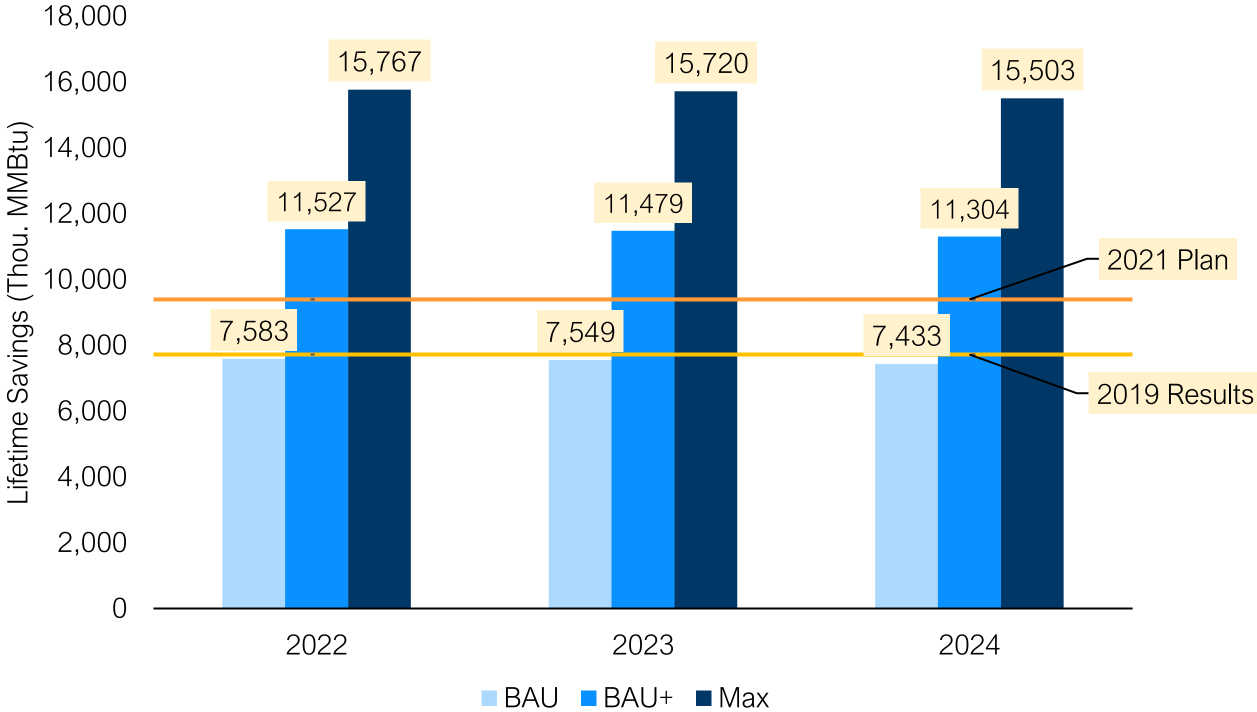
Increasing incentives double savings. Under the Max scenario, the portion of net economic savings captured increases by 37 percentage points relative to the BAU scenario. When 100% of customers' incremental costs are covered, Eversource's gas programs have the potential to capture nearly three-quarters of net economic potential for gas savings.

Overall Program Savings

Figure 2-35 presents lifetime gas savings derived from measures installed in each year under the various achievable scenarios.

[27] Gross economic potential nears technical potential for two primary reasons. First, the study employs a phased-in potential assessment approach that accounts for expected market turnover in the study period. Second, the study focusses on measures that are commercially viable, and thus measures that may offer technical potential, but are not expected to be cost-effective were largely omitted from the study.

Figure 2-35. Eversource Gas Programs, Gas Lifetime Savings by Year



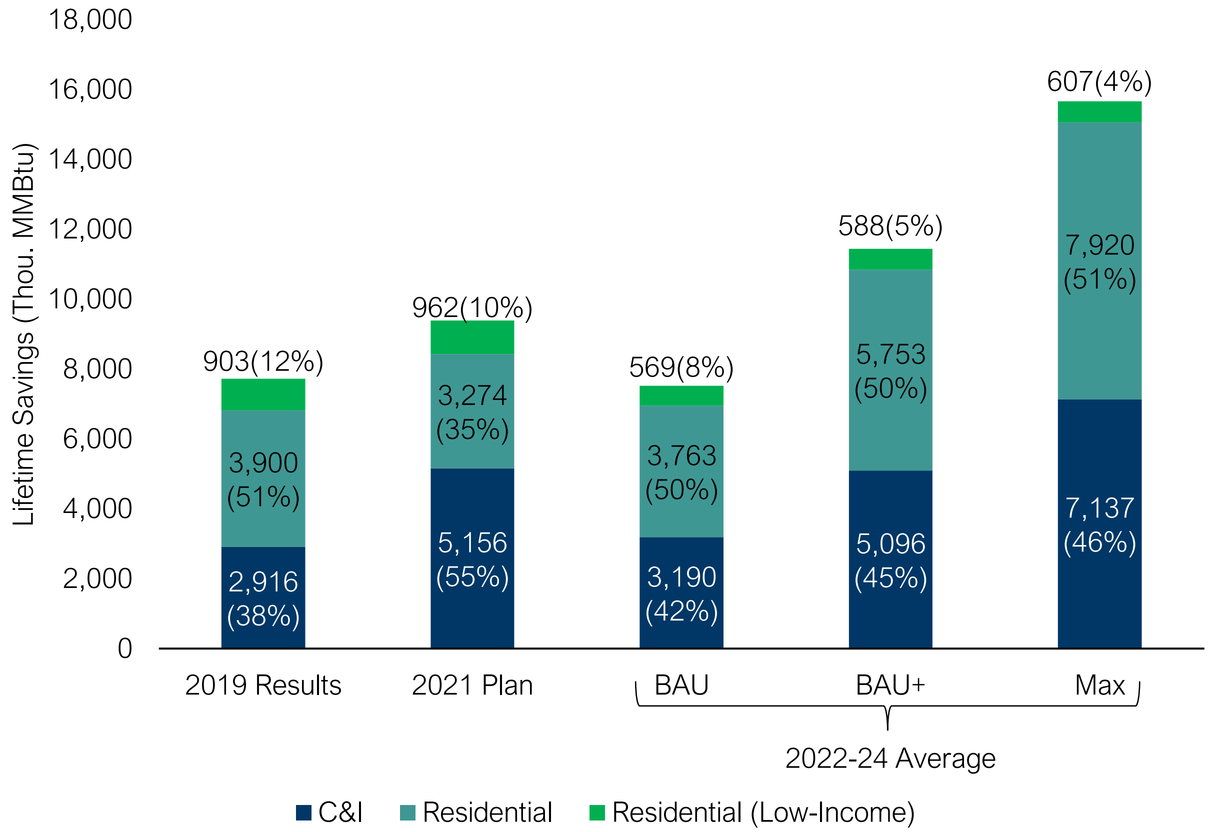
Compared to Eversource's 2019 Program results, the achievable lifetime gas savings are expected to continue at similar levels under BAU incentives. Increasing incentives under the BAU+ and Max scenarios has the potential to increase gas savings above and beyond savings achieved and planned in the past. Under the BAU+ scenario, lifetime savings are 48% and 22% above Eversource's 2019 Results and 2021 Plan savings, respectively. Under the Max scenario, savings jump even higher increasing by 103% and 67% above Eversource's 2019 Results and 2021 Plan savings, respectively.

Savings are generally stable year over year over the study period. Slight year-over-year differences are due to general market growth and the plateauing of some discretionary measures with significant historical uptake. Overall, these impacts are small and counteract each other resulting in year-over-year fluctuations of less than 2% under the BAU scenario. Due to this stability, the remainder of this section expresses savings as the 2022-24 average.

Savings by Sector

A majority of lifetime gas savings are found in the residential sectors, which mirrors Eversource 2019 Program Results as shown in Figure 2-36.

Figure 2-36. Eversource Gas Programs, Gas Lifetime Savings by Sector



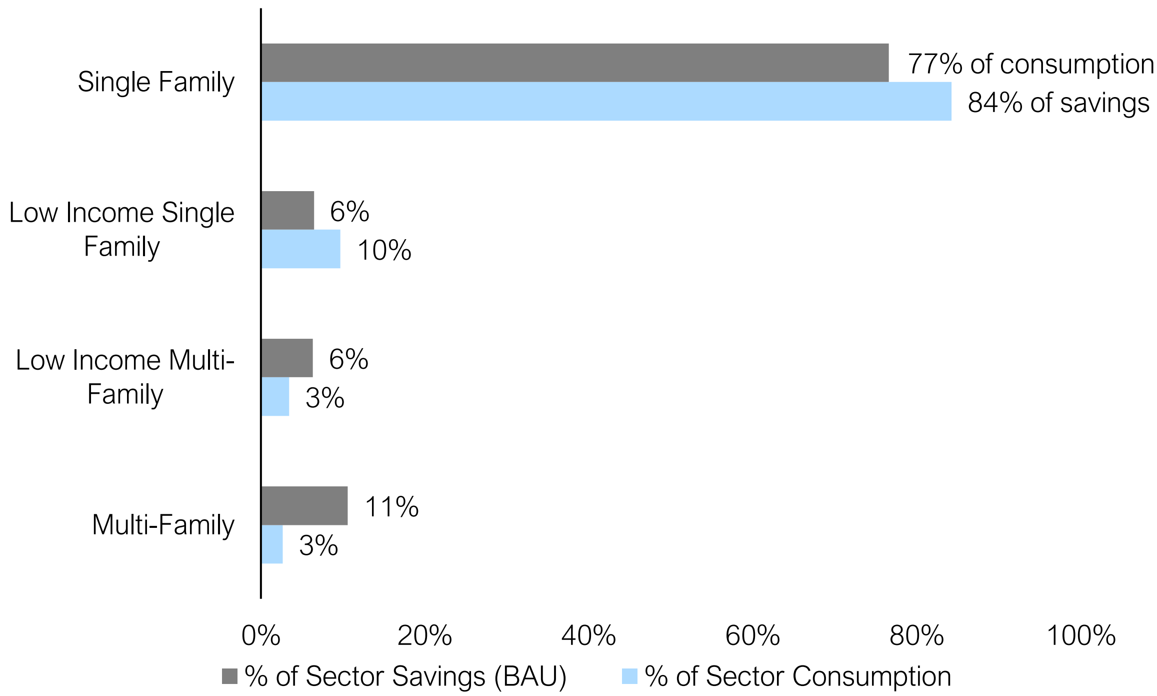
As incentives are increased under the BAU+ and Max scenarios, the C&I sector shows slightly faster proportional growth compared to the residential sectors – slightly increasing the sector's share of overall savings from 42% under BAU to 46% under the Max scenario.

Residential Savings

Savings by Segment

In the residential market, the bulk of savings reside in the market-rate single family segment as shown in Figure 2-37. When compared to the portion of gas consumption within each segment, the single family segments (both market-rate and low-income) claim a slightly greater share of savings relative to consumption. The market-rate multi-family segment, in particular, comprises only 3% of residential gas savings under BAU while accounting for 14% of consumption. This discrepancy is more pronounced than electric savings and reflects the generally higher barriers to adoption for gas measures within multi-family buildings both in absolute terms and relative to electric measures. Most gas measures relate to the building's envelope, HVAC, and domestic hot water systems, which are commonly not within the multi-family customers' full control or are subject to the split-incentive barrier. Conversely, many electric measures – particularly appliances and formerly lighting – are not impacted by these barriers to the same degree.

Figure 2-37. Eversource Gas Programs, Percent of Residential Lifetime Gas Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

As incentives increase, the relative portion of savings in the single-family segment increases from 84% to 91%, while the other market segments' share of savings slightly decreases as shown in Table 2-10.

The growth in single-family savings juxtaposed with the nearly constant proportion of savings from the multi-family segment shows that, while increased incentives do lead to further savings in the multi-family segment, other market barriers likely limit the growth of these savings.

The proportion of residential savings from the low-income market segments decreases since incentives are already at 100% under the BAU scenario. Savings in the other segments grow under increased incentives in BAU+ and Max while low-income savings remain constant, leading to a decline in the relative portion of residential savings that the low-income segment represents.[28]

[28] Low-income multi-family savings increase slightly under in absolute terms the BAU+ and Max scenarios due to a modeling artifact resulting in a portion of low-income savings being captured with the C&I multi-family segment, which is modeled in the C&I sector with C&I program incentive levels.

Table 2-10. Eversource Gas Programs, Residential Lifetime Gas Savings by Market Segment

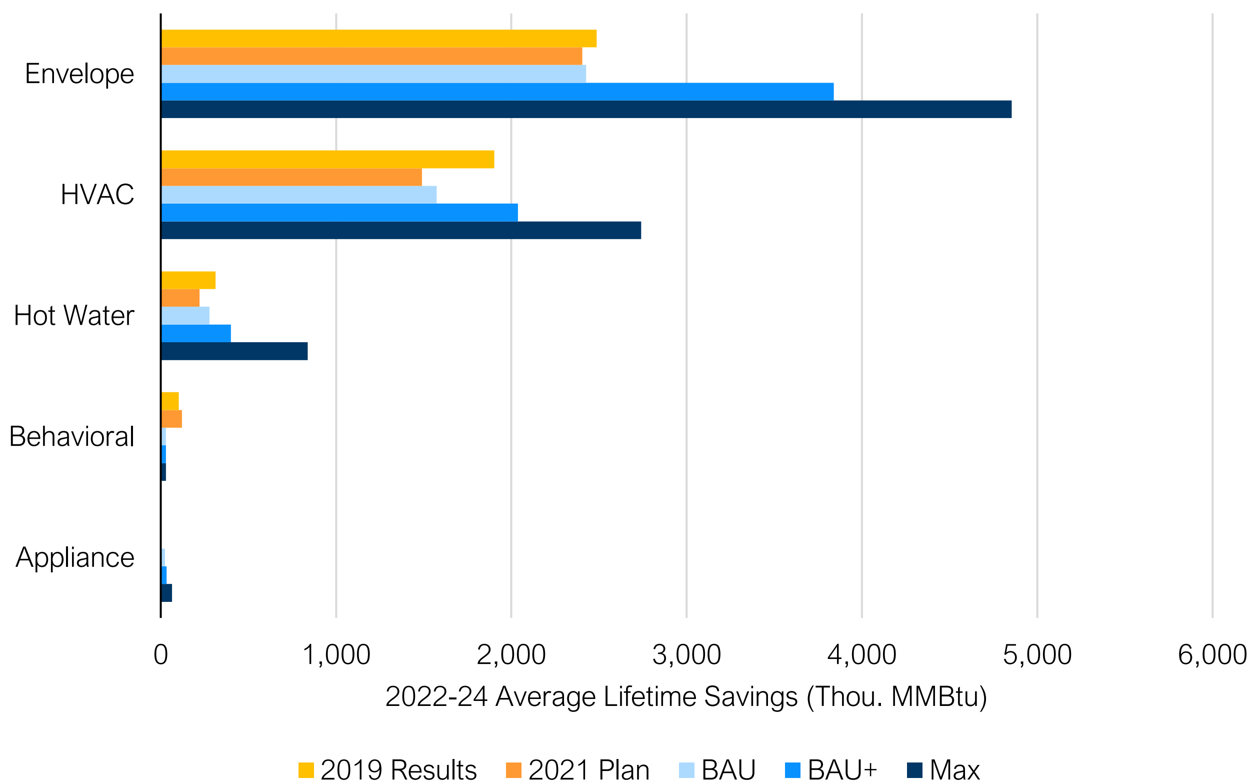
Segment	2022-24 Average Lifetime Thou. MMBtu (% of Total)		
	BAU	BAU+	BAU
Single Family	3,649 (84%)	5,611 (88%)	7,722 (91%)
Low Income Single Family	420 (10%)	420 (7%)	420 (5%)
Low Income Multi-Family	148 (3%)	168 (3%)	187 (2%)
Multi-Family	115 (3%)	142 (2%)	198 (2%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

Figure 2-38 shows residential market lifetime savings broken down by end-use, comparing recent program savings to the three achievable scenarios (expressed as the average lifetime savings achieved per year).

Figure 2-38. Eversource Gas Programs, Residential Gas Lifetime Savings by End-use



Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include savings for both market-rate and low-income customers.

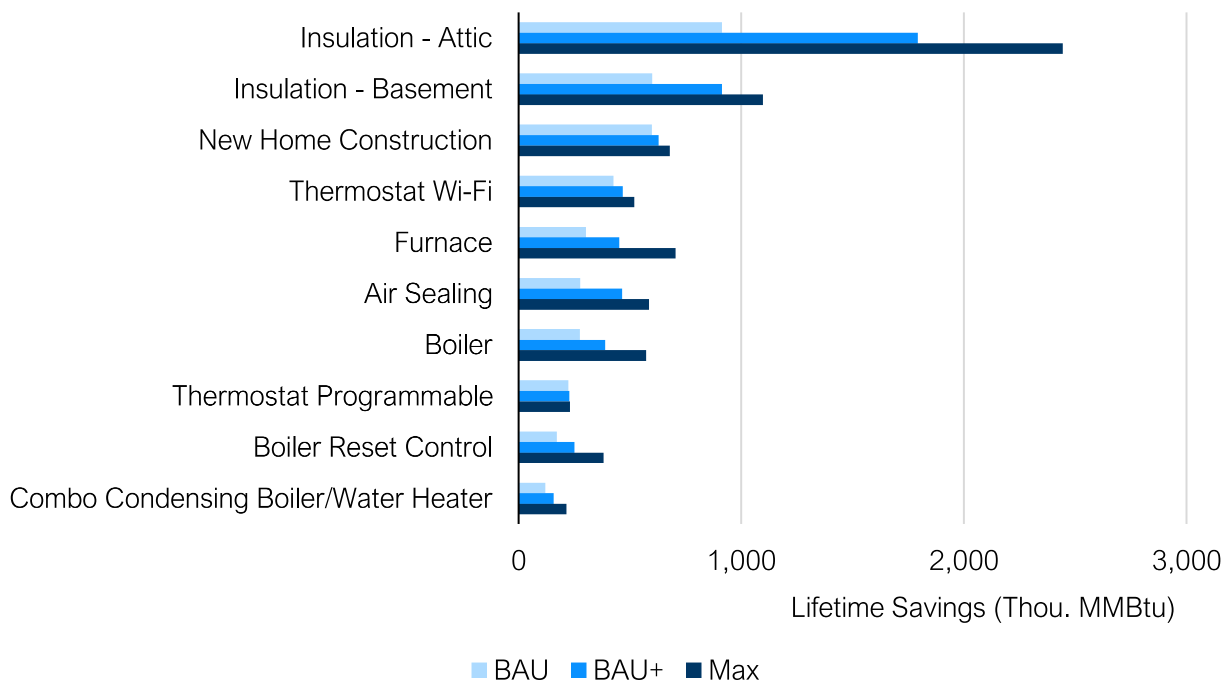
Similar to historical and planned savings, modeled residential gas lifetime savings are concentrated primarily in the envelope and HVAC end-use categories. Across all top end-use categories, savings are expected to remain at levels similar to 2019 Results and the 2021 Plan under BAU incentive levels.

Behavioral savings are assumed to drop compared to past results due to changes to Eversource's HER measure as previously described in the electric program results section.

Top Measures

Envelope and HVAC measures compose most of the top measures as shown in Figure 2-39.

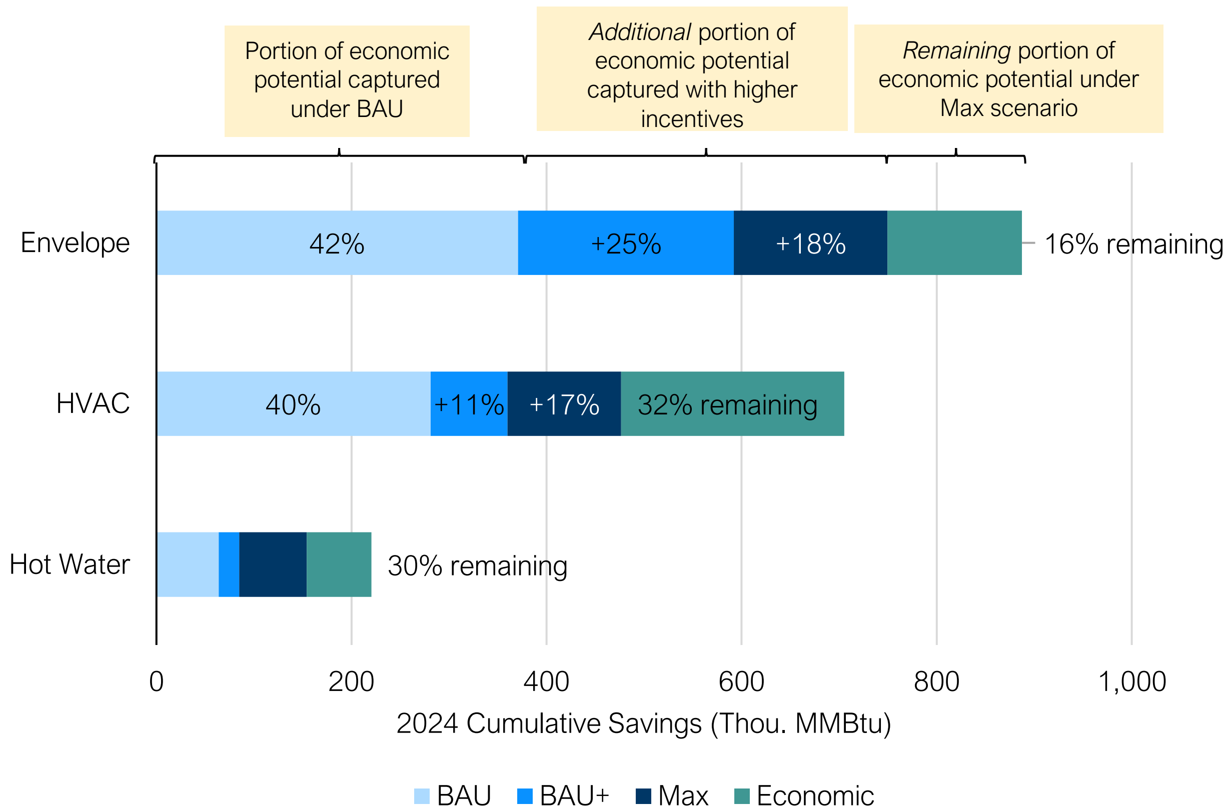
Figure 2-39. Eversource Gas Programs, Top 10 Gas Residential Measures by Lifetime Savings (2022-24 Average)



Potential Growth Opportunities

Figure 2-40 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-40. Eversource Gas Programs, Residential Gas Growth Opportunities



Note: Residential behavioral and appliance savings represent <5% of residential 2024 cumulative economic potential and are excluded from the above figure.

Notably, envelope measures experience a significant jump in savings between the BAU and Max scenarios – doubling the share of economic savings captured and leaving only 16% of economic potential remaining. The large proportion of gas savings captured is driven in part by the assumptions behind the study's retrofit envelope measures, which assume measures are only applied to buildings where weatherization can be conducted cost-effectively.[29] In many buildings, envelope measures are not cost-effective due to extensive costs resulting from the unique characteristics of the structure. For example, the costs for removing and re-installing exterior cladding and/or drilling and patching drywall to install insulation in limited areas are significant and, in many cases, undermine the cost-effectiveness of many insulation retrofits. In these cases, the study assumes these opportunities *within the study's included measures* are not available to the model to ensure the subset of cost-effective opportunities is not removed from economic potential. This reduces the estimate of technical and economic potential for envelope measures while enabling reasonable achievable potentials, which ultimately results in a large share of economic potential being captured.

[29] This methodological choice is made to ensure retrofit weatherization measures pass cost-effectiveness in the study under the assumption programs will effectively screen weatherization candidates for cost-effective opportunities. Including all weatherization opportunities – including buildings with extensive retrofit costs – would risk screening the entire measure from economic and achievable potential despite the existing of cost-effective savings within a subset of the opportunities.

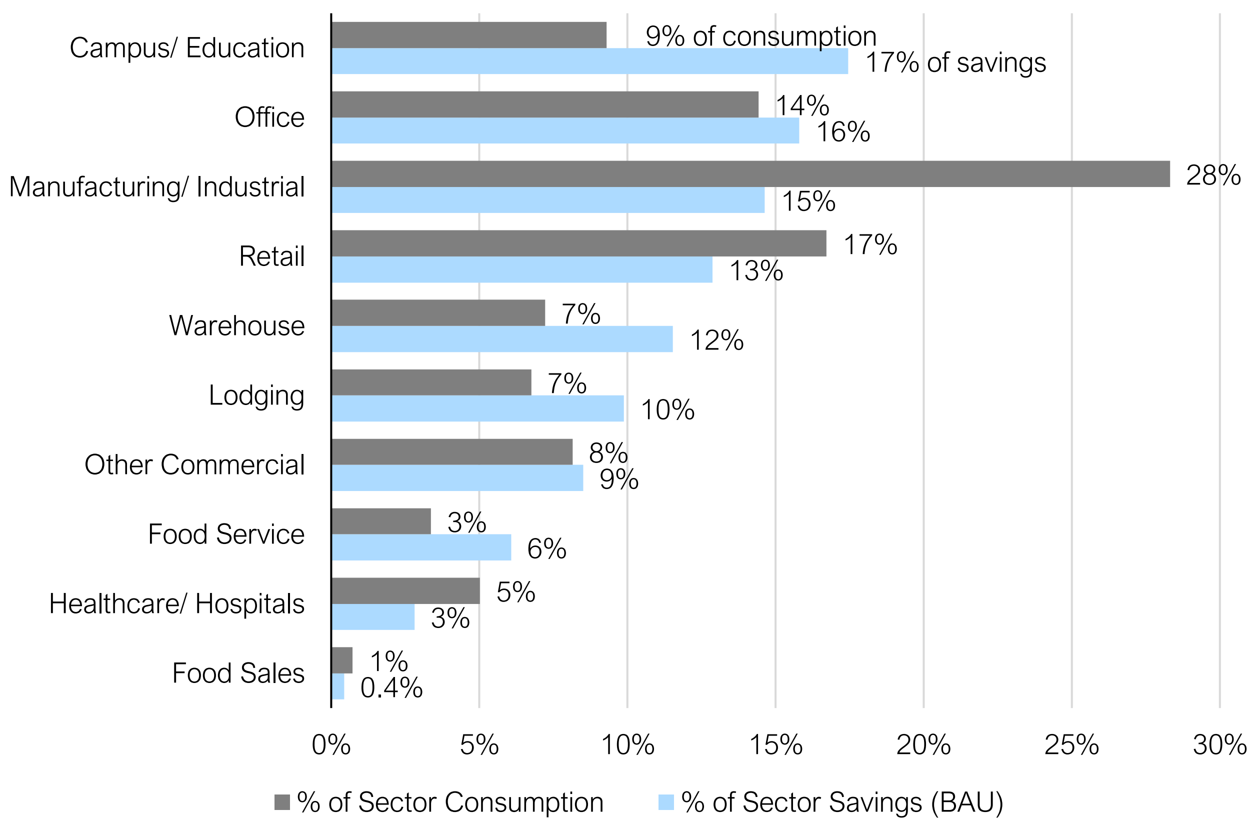
This share of economic gas envelope savings captured is also in contrast with electric envelope savings where approximately half of the economic savings are captured under the Max scenario (see Figure 2-11). This divergence is likely explained by differences in customer demographics between electrically heated homes and gas heated homes. Customers in electrically heated homes, particularly with baseboard heating, are more likely to be renters and harder to engage due to split incentives and other market barriers despite cost-effective envelope opportunities, which in turn reduces the achievable portion of economic potential.

C&I Savings

Savings by Segment

Under the BAU scenario, nearly half of C&I lifetime gas savings come from the campus & education, office, and manufacturing & industrial market segments as shown in Figure 2-41.

Figure 2-41. Eversource Gas Programs, Percent of C&I Lifetime Gas Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

There are a few segments for which their portion of gas savings is not aligned with their portion of sector-wide gas consumption. Notable among these are the campus & education and manufacturing & industrial segments where savings are significantly higher and lower, respectively, than the segments' portion of consumption.

While the same caveats described in the electric program C&I market segment savings section apply to C&I market segment gas savings here, the results may still be indicative of existing trends.

For manufacturing & industrial market segment savings, in particular, the low proportion of savings relative to consumption is likely indicative of the general challenge and cost of improving efficiency for highly varied industrial processes. As can be seen in Table 2-11, savings from the manufacturing & industrial market segment grow a proportionally faster rate than the sector as a whole – increasing from 15% of savings under the BAU scenario to 21% of savings under the Max scenario indicating customer economics particularly hamper measure adoption in this segment.

For campus & education savings, the high proportion of savings relative to consumption is driven by significant savings from custom HVAC measures, which is a result of this market being characterized by a relatively high proportion of large facilities. From Table 2-11 below it can be seen that the proportion of overall C&I program savings captured in this segment diminishes as incentives increase under the BAU+ and Max scenarios, indicating that the large proportion of savings in the campus and education segment under the BAU scenario is also driven by the relatively preferential conditions for custom measure savings within this market segment under BAU incentive levels and that opportunities for growth via increased incentives are fewer relative to other market segments.

Table 2-11. Eversource Gas Programs, C&I Lifetime Gas Savings by Market Segment

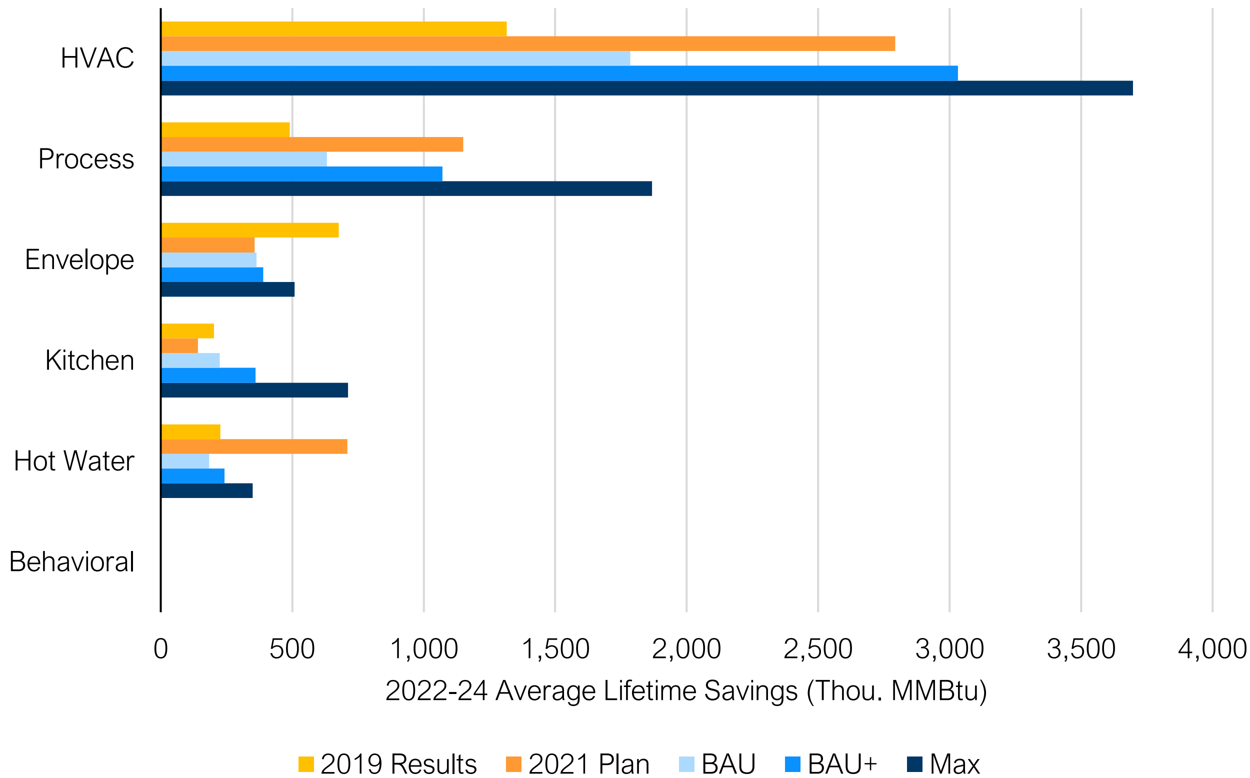
Segment	2022-24 Average Lifetime Thou. MMBtu (% of total)		
	BAU	BAU+	Max
Campus/ Education	557 (17%)	750 (15%)	941 (13%)
Office	504 (16%)	785 (15%)	1,064 (15%)
Manufacturing/ Industrial	467 (15%)	1,000 (20%)	1,529 (21%)
Retail	410 (13%)	645 (13%)	885 (12%)
Warehouse	368 (12%)	481 (9%)	584 (8%)
Lodging	315 (10%)	417 (8%)	554 (8%)
Other Commercial	271 (9%)	534 (10%)	846 (12%)
Food Service	194 (6%)	273 (5%)	409 (6%)
Healthcare/ Hospitals	90 (3%)	184 (4%)	280 (4%)
Food Sales	14 (<1%)	28 (1%)	44 (1%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

Figure 2-42 shows C&I lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

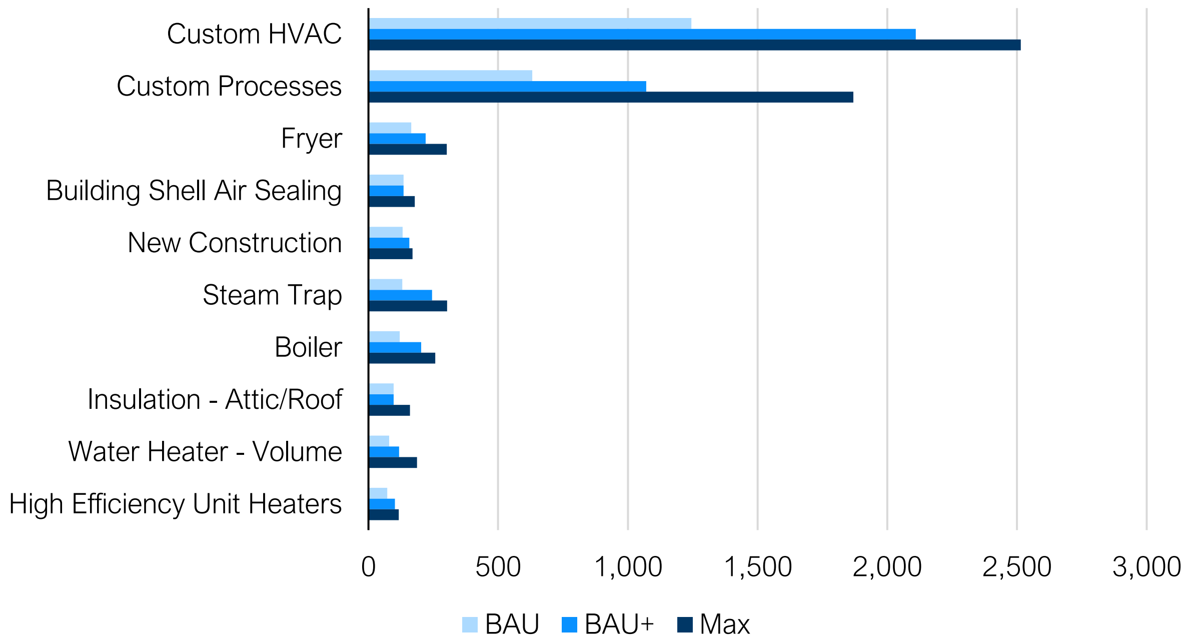
Figure 2-42. Eversource Gas Programs, C&I Gas Lifetime Savings by End-use



Top Measures

As shown in Figure 2-43, custom HVAC and custom process savings are, by far, the most prominent C&I gas measures highlighting the non-standard nature of many savings opportunities within the C&I sector. These measures compose over 50% of C&I gas savings under all scenarios.

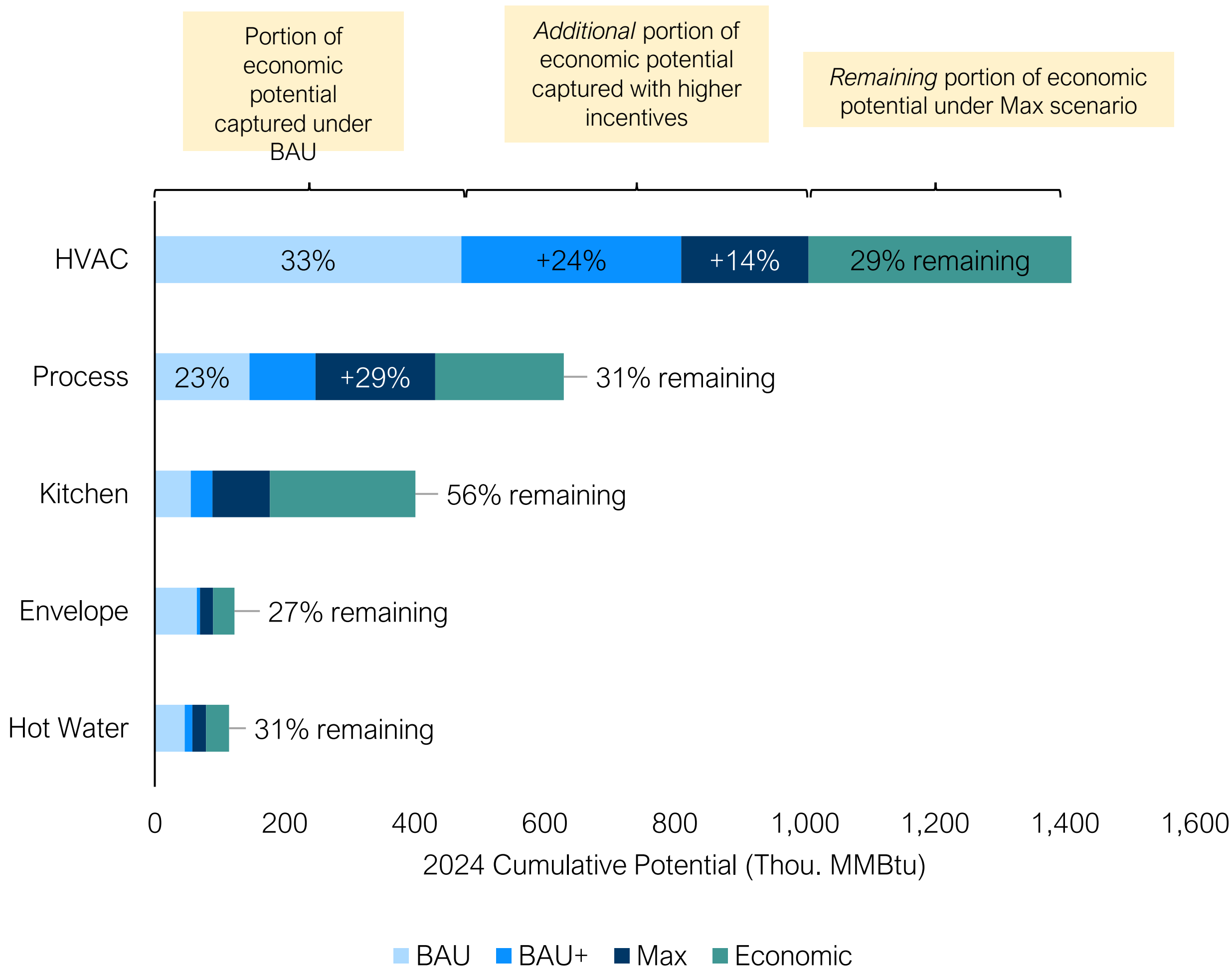
Figure 2-43. Eversource Gas Programs, C&I Top Measures (2022-24 Average Lifetime Savings)



Potential Growth Opportunities

Figure 2-44 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-44. Eversource Gas Programs, C&I Gas Growth Opportunities



With maximum incentives, programs can capture over 50% of economic potential for most end-use categories. The one notable exception is kitchen measures, where only 44% of economic potential is captured under the Max scenario indicating additional factors beyond customer economics inhibiting savings in this category.

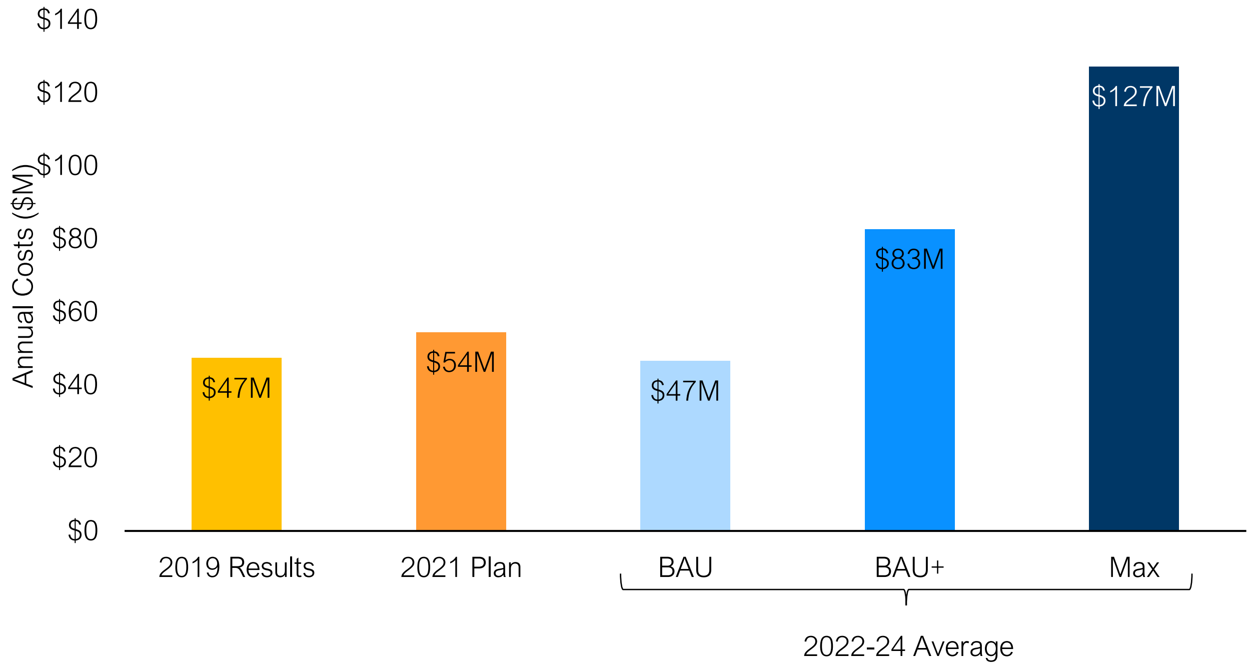
Portfolio Metrics

The following section presents portfolio-level metrics for the Eversource Gas Program results including program costs, TRC results, and emission benefits.

Program Costs

Figure 2-45 shows the estimated 2022-24 average annual cost of administering Eversource's gas programs under each achievable scenario.

Figure 2-45. Eversource Gas Programs, Program Costs

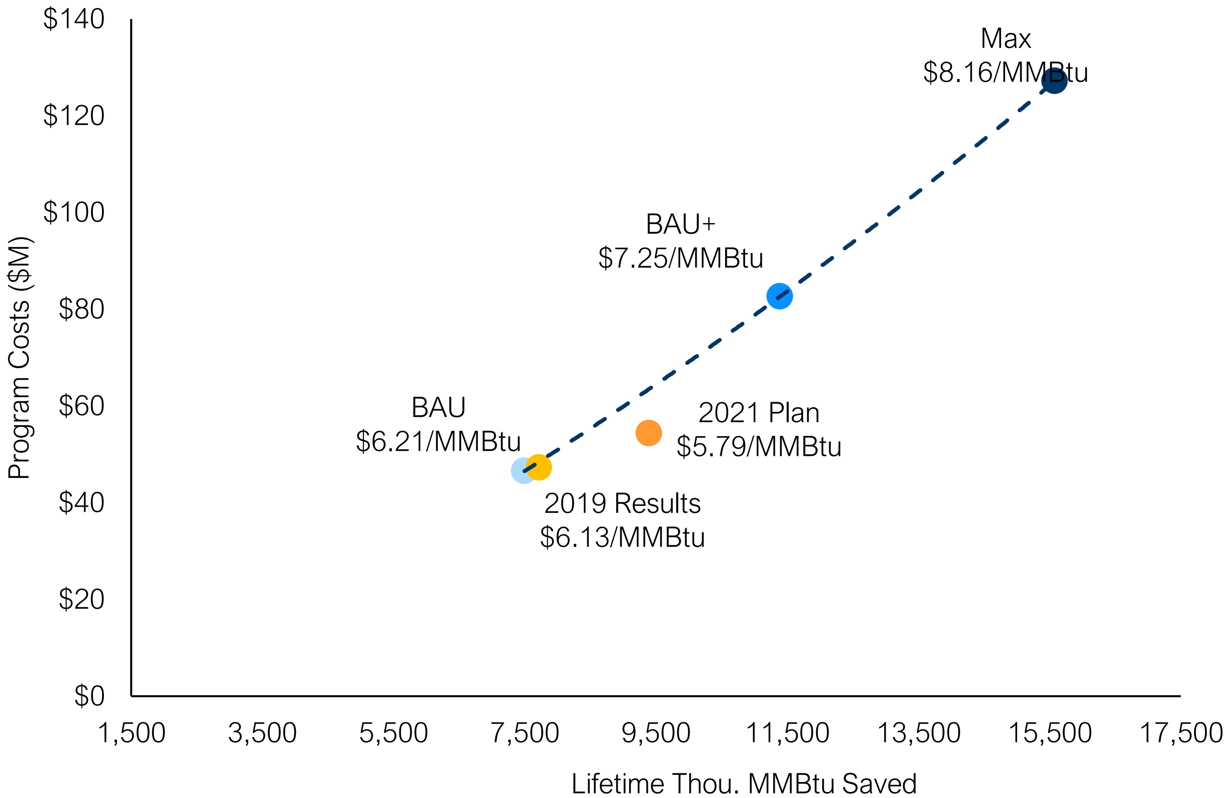


As would be expected, average annual costs under the BAU scenario closely mirror 2019 Results at approximately $47 million. With increased incentives and savings, costs increase at a faster rate than savings under the BAU+ and Max scenarios. Under the BAU+ scenario, costs increase by 77% over the BAU scenario, while average lifetime savings only increase by 52%. A similar trend is observed in the jump from BAU+ to Max.

The larger proportional increase in costs relative to savings results in higher unit costs to deliver gas savings under the BAU+ and Max scenarios as shown in Figure 2-46. Under the BAU scenario, the unit cost to deliver savings is commensurate with costs in the 2019 Results, but savings under the BAU+ and Max scenarios cost one to two programs dollars more per lifetime MMBtu saved.

This result is to be expected as raising incentives increases the cost not just for newly acquired savings but for savings that would have been obtained under lower incentive levels as well – and thus at a lower unit cost. Increased incentives will also tend to drive greater adoption of measures with higher unit savings costs as these measures will also tend to have smaller customer benefits (e.g., bill savings). With increased incentives, these measures become more attractive to customers and thus are adopted at greater levels.

Figure 2-46. Eversource Gas Programs, Program Costs vs. Lifetime MMBtu Saved



Cost Estimate Considerations

While the per-unit acquisition costs of savings should be expected to increase with increased incentive levels, the precise magnitude of these cost increases presented in this study should be interpreted with the following caveats.

First, costs are estimated based on historical cost data. Fixed and variable program costs are based on historical spending data for Eversource's 2019 efficiency programs. These inputs do not vary over the study period to account for factors that may increase (e.g., higher labor or technology costs as programs increase demand for specific services and/or equipment) or decrease costs (e.g., lower program implementation costs as programs mature and become more efficient or employ new delivery strategies).

Second, program scenarios are not optimized for program spending. For each achievable scenario, incentive levels are set at the program level as a portion of incremental costs for all measures in the program. However, a real-world program design would likely set specific incentive levels for each measure applying higher incentive levels for measures that may have had limited uptake in the past and maintaining or lowering incentive levels for measures that meet their expected adoption. Such an optimized program design approach would help avoid paying significantly higher acquisition costs for measures where increased incentives do not lead to significantly increased savings.

Program Benefits

Overall, Eversource's gas efficiency programs have the potential to continue to create significant benefits as measured by the TRC as well as emission reductions. Table 2-12 displays the overall TRC ratio, net TRC benefits, net benefits per lifetime and first-year MMBtu saved, and average annual CO_2 emission reductions achieved each program year.

Table 2-12. Eversource Gas Programs, TRC Benefits, and CO_2 Emission Reductions (2022-24 Average)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime MMBtu	Net TRC Benefits per First-Year MMBtu	Annual CO2 Emission Reductions (Short Tons)
2019 Results	2.1	$76M	$9.78	$136	37,700
2021 Plan	2.3	$98M	$10.44	$133	50,100
BAU	2.2	$70M	$9.87	$133	36,000
BAU+	2.1	$103M	$9.57	$130	54,000
Max	2.2	$137M	$9.29	$128	73,000

Note: TRC values for 2019/2021 benchmarks are derived using 2018 AESC values while modeled TRC values are derived using 2021 AESC values.

Benefit metrics under the BAU scenario closely mirror 2019 Results as expected. Under higher incentive scenarios, net TRC benefits increase though the average net TRC benefit per unit of savings declines.

In terms of emission reductions, Eversource's gas programs will continue to produce thousands of tons of CO_2 reductions each year during the study period under BAU conditions.

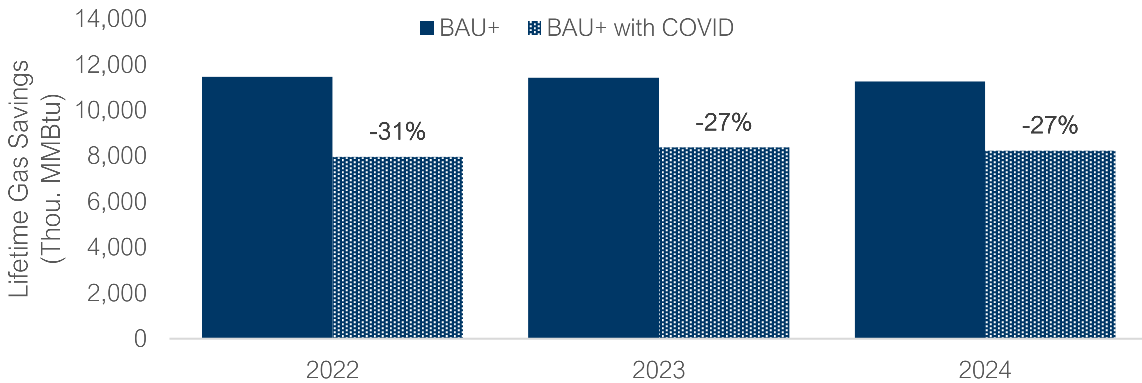
Sensitivity Analyses

COVID-19

As described previously in the Eversource Electric Program Results section, the COVID-19 pandemic has led to economic uncertainty and business closures, it may have some impact on the achievable potential within the study period (2022-24). It is unclear what precise economic effects will be caused by COVID, how they will be distributed across the market, and how long these effects will persist; however, this analysis performs a high-level assessment of how COVID-driven changes in market conditions may impact achievable program savings.[30]

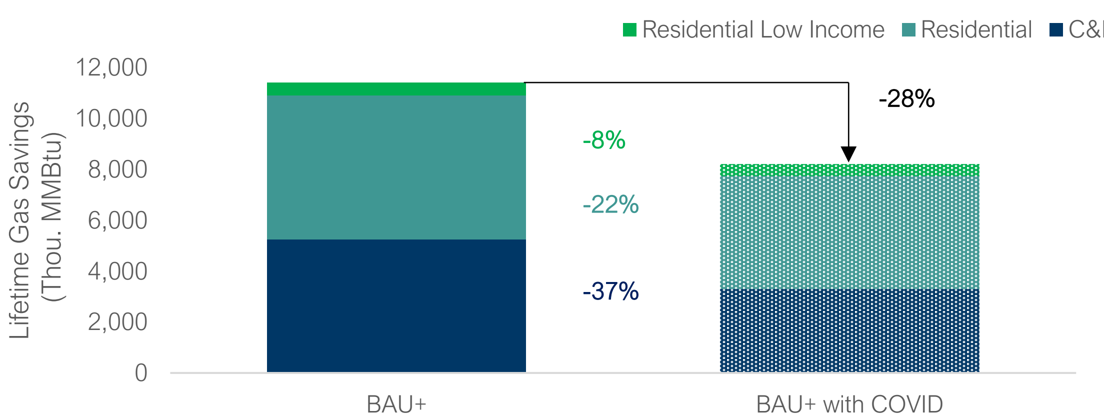
Figure 2-47 presents the results of the sensitivity analysis for the three years of the potential study compared to the BAU+ scenario.

Figure 2-47. Eversource Gas Programs, COVID Sensitivity - Impact on Lifetime Savings (BAU+ Scenario)



In our modeling, COVID-19 impacts reduce the total achievable electric savings by around 30% compared to the BAU+ scenario, with this impact less pronounced after the first year when some temporarily closed businesses reopen. Figure 2-48 presents the sector breakdown of the COVID sensitivity as an average across the study period.

Figure 2-48. Eversource Gas Programs, COVID Sensitivity - Impact by Sector (2022-24 Average, BAU+ Scenario)



[30] It should be noted that the sensitivity parameter adjustments were selected prior to the rapid rollout of COVID-19 vaccinations in the spring of 2021 and that this sensitivity should be interpreted as an upper-bound worst-case scenario (e.g., the emergence of vaccine-resistant COVID variants).

The C&I sector shows a larger reduction in savings than residential since this sector sees market size adjustments as well as barrier level increases.

Overall, our analysis suggests that the COVID-related impacts to the economy could result in reduced achievable savings for efficiency programs through the study period if economic impacts persist. These savings reductions are significant in both the C&I and residential sectors, with businesses hit harder than households in terms of achievable potential.

State Codes and Standards

On March 26, 2021, Governor Baker signed “An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy” into law. One of the (many) provisions of this law updates energy and water efficiency standards for common household and commercial appliances included in this study. By increasing baseline efficiency standards, the law will reduce technical, economic, and claimable achievable savings potential estimates for affected measures in this study.

This analysis looks at the group of achievable savings that could be impacted by this law. It is unclear to what degree *claimable* achievable savings for the PAs will be impacted as ongoing discussions will determine whether the PAs can claim at least partial credit for the strengthening of these standards. The following gas measures included in this study are also included in the appliance standards included in the bill:

- Commercial dishwashers
- Commercial fryers
- Commercial ovens
- Commercial steam cookers
- Low-flow showerheads
- Low-flow faucets

Under the BAU+ scenario, these measures account for approximately 4.2% of 2022-24 average lifetime gas savings. As shown in Table 2-13, the impact is not spread evenly across sectors. Overall, the C&I sector would experience a bigger impact on savings due to the reduction in savings opportunities from commercial kitchen equipment. Claimable C&I gas savings could potentially decline by over 8%.

Table 2-13. Eversource Gas Programs, Gas Lifetime Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted by C&S (Lifetime Thou. MMBtu)	% Reduction
C&I	416.1	8.2%
Residential	61.5	1.1%
Residential Low Income	5.3	0.9%

In addition to these appliance standards, the law also requires the state to develop a voluntary specialized stretch code for “net-zero energy” buildings. Depending on requirements, net-zero buildings either emit no greenhouse gases or generate their own renewable energy to offset any emissions. These codes are often designed to be flexible and performance-based making it difficult to ascertain the impact it could have on future claimable program savings, but they could ostensibly reduce new construction opportunities as well as new market opportunities for other equipment-related measures (e.g., furnaces, boilers) once implemented.

Overall, a number of measures are likely to be impacted by the new law, and at the time of writing, the exact impact of measures, and what (if any) portion may still be claimable by the efficiency program administrators under the law, is uncertain.

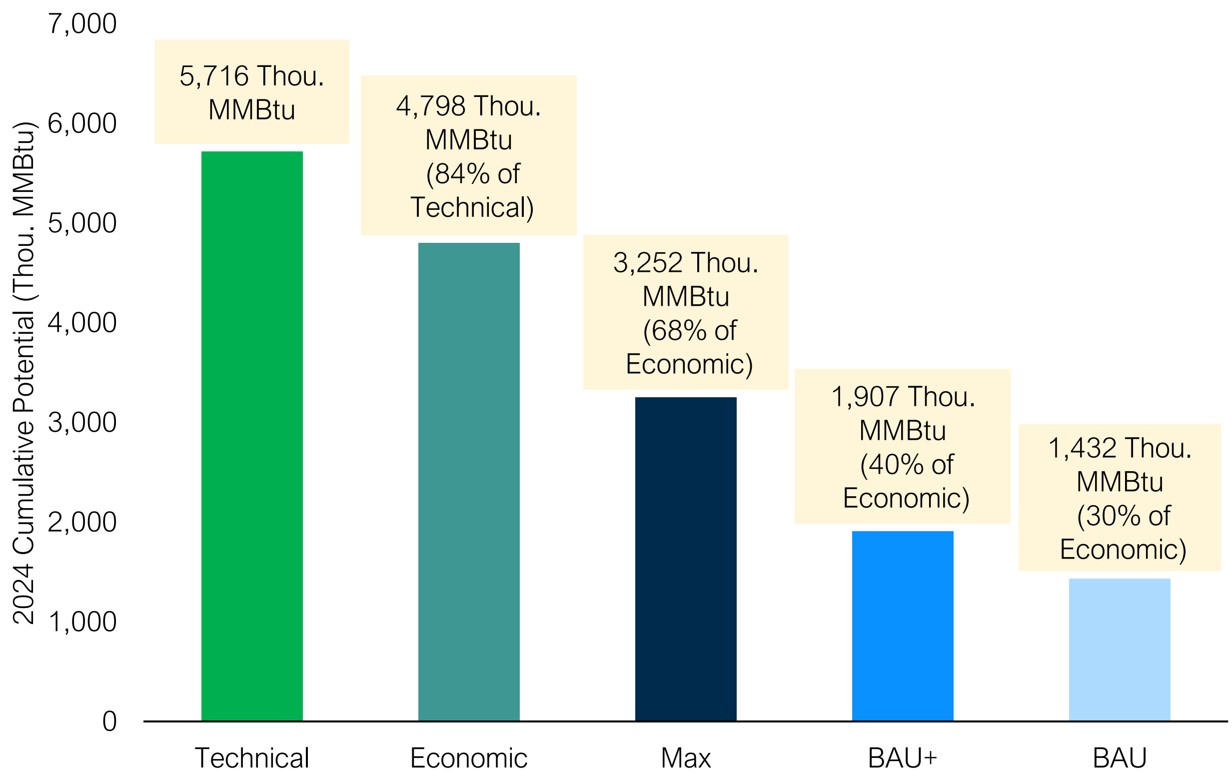
2.4 EGMA Gas Program Results

The following section presents results for EGMA's Gas Program savings potential. As previously described, these results cover CMA's gas territory prior to the acquisition of Eversource. Results for Eversource's Gas Program savings potential are presented separately in the preceding section.

Gas Savings

Figure 2-49 presents technical, economic, and achievable **gas savings potential** in terms of cumulative annual impacts in 2024 from measures installed during the 2022-24 study period.

Figure 2-49. EGMA Programs, 2024 Cumulative Technical, Economic, and Achievable Gas Potential



Note: Economic and achievable potentials (Max, BAU+, BAU) are presented in terms of net savings.

Most gas savings pass economic screening. Only 3.3% of technical gas potential fails the TRC cost-effectiveness screening.[31] The remaining difference between technical and net economic potential is due to net-to-gross adjustments, which generally reduce net gas savings due to large free ridership effects for many gas measures.

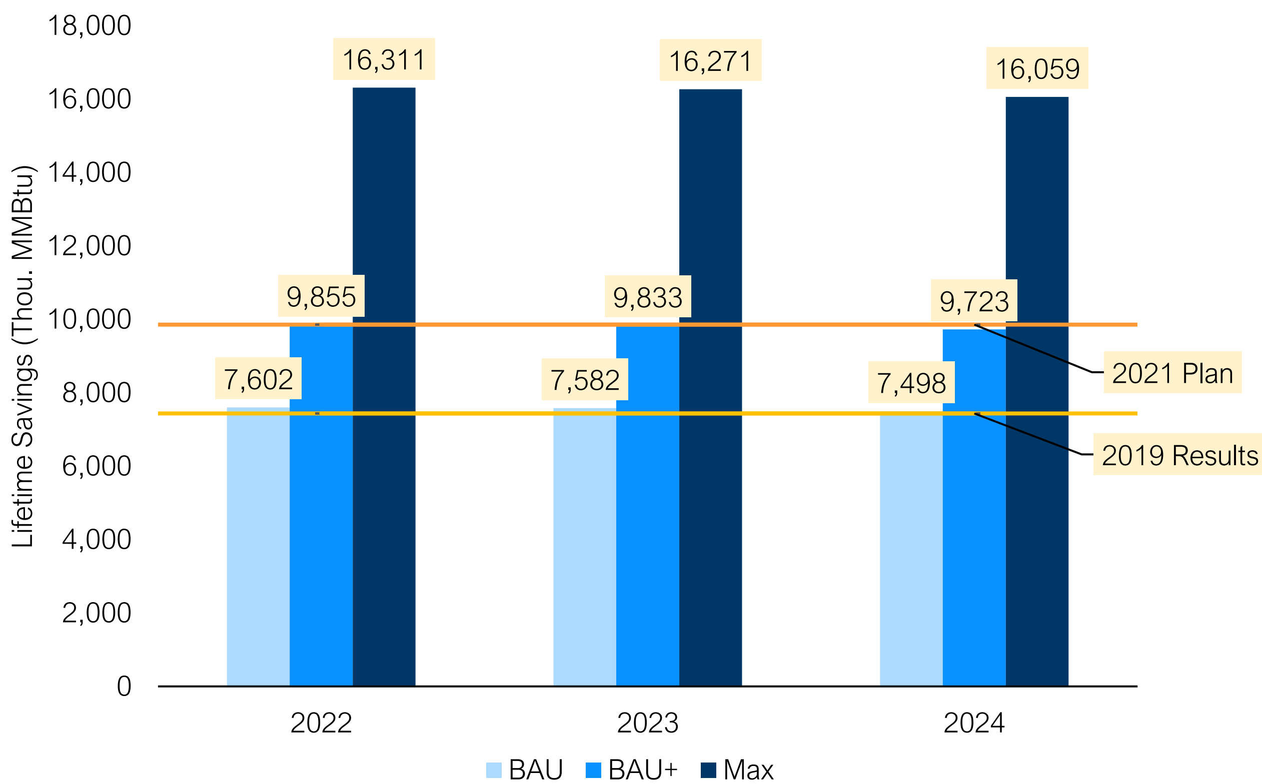
The BAU scenario captures slightly over one-third of economic savings. Under current incentive levels, only 30% of net economic savings are captured suggesting there is significant room to grow gas savings with increased incentives and enhanced program designs.

Increasing incentives double savings. Under the Max scenario, the portion of net economic savings captured increases by 38 percentage points relative to the BAU scenario. When 100% of customers' incremental costs are covered, EGMA's gas programs have the potential to capture nearly 70% of net economic gas potential.

Overall Program Savings

Figure 2-50 presents lifetime gas savings derived from measures installed in each year under the various achievable scenarios.

Figure 2-50. EGMA Programs, Gas Lifetime Savings by Year



[31] Gross economic potential nears technical potential for two primary reasons. First, the study employs a phased-in potential assessment approach that accounts for expected market turnover in the study period. Second, the study focusses on measures that are commercially viable, and thus measures that may offer technical potential, but are not expected to be cost-effective were largely omitted from the study.

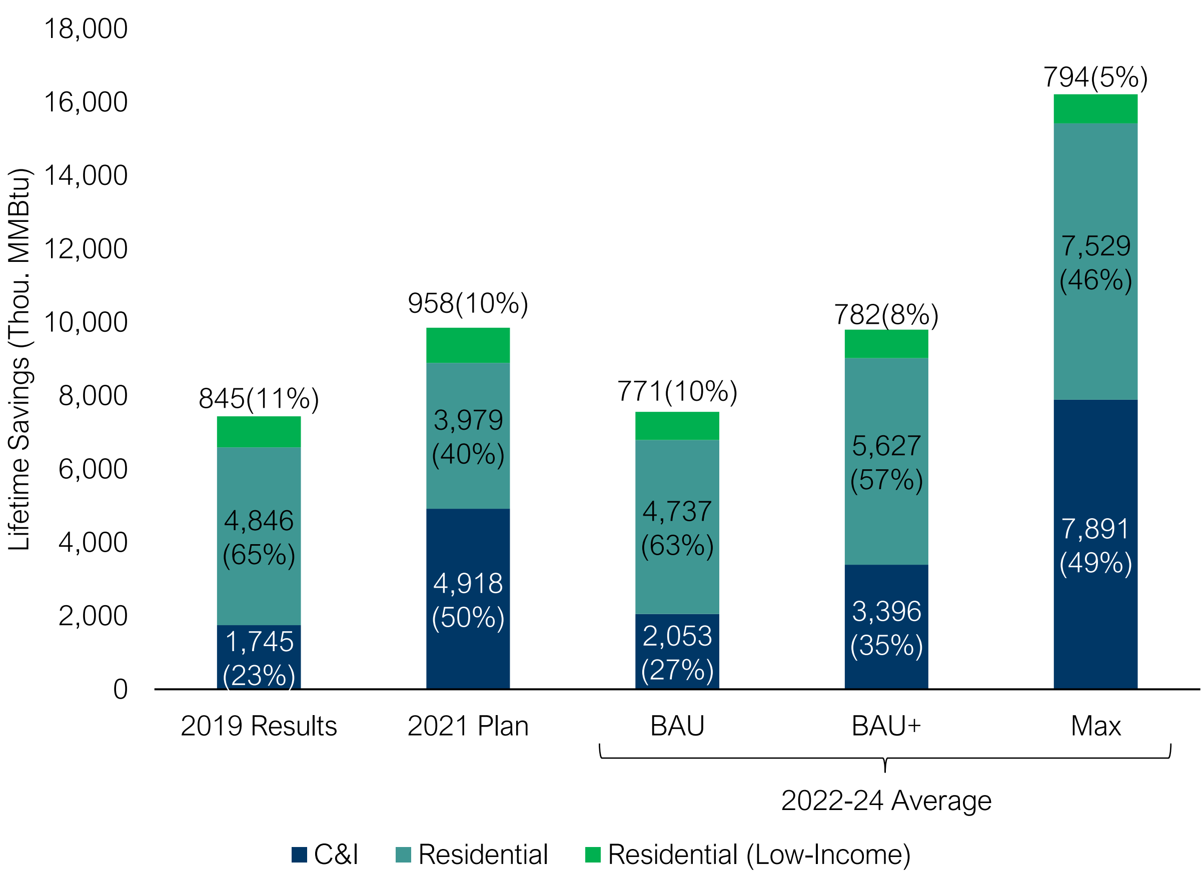
Compared to EGMA's 2019 Results, the achievable lifetime gas savings are expected to continue at similar levels under BAU incentives. Increasing incentives under the BAU+ and Max scenarios has the potential to increase gas savings above and beyond savings achieved in the past. Under the BAU+ scenario, lifetime savings are 31% above EGMA's 2019 Results and similar to 2021 Plan savings. Under the Max scenario, savings increase further to 118% and 65% above EGMA's 2019 Results and 2021 Plan savings, respectively.

Savings are stable across study years. Slight year-over-year differences are due to general market growth and the plateauing of some discretionary measures with significant historical uptake. Overall, these impacts are small and counteract each other resulting in year-over-year fluctuations of less than 2% under the BAU scenario. Due to this stability, the remainder of this section expresses savings as the 2022-24 average.

Savings by Sector

A majority of lifetime gas savings are found in the residential sectors, which mirrors EGMA 2019 Program Results but deviates from the 2021 Plan savings as shown in Figure 2-51.

Figure 2-51. EGMA Programs, Gas Lifetime Savings by Sector

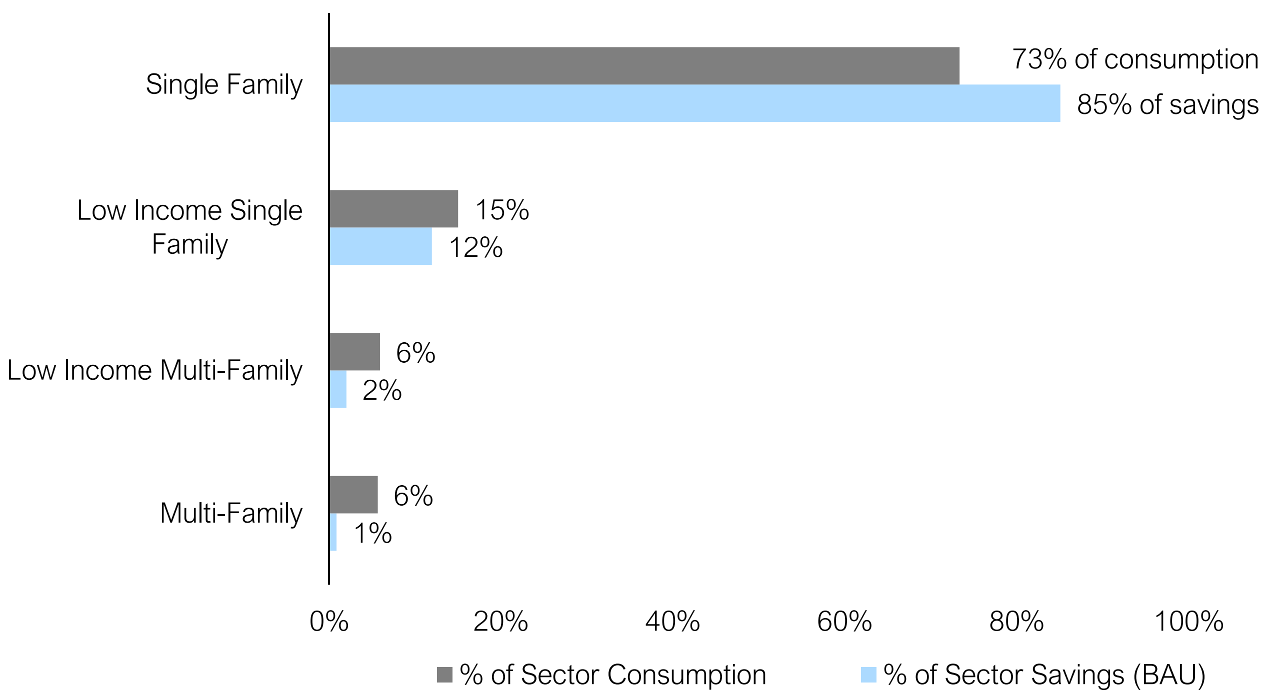


As incentives are increased under the BAU+ and Max scenarios, the C&I sector shows more proportional growth compared to the residential sectors – increasing the sector's share of overall savings from 27% under BAU to 49% under the Max scenario.

Savings by Segment

In the residential market, the bulk of savings reside in the market-rate single family segment as shown in Figure 2-52. When compared to the portion of gas consumption within each segment, the single-family market segment claims a higher share of savings than other segments. This discrepancy reflects the fact that barriers to adoption for gas measures within both low-income and multi-family segments tend to be higher than for single-family. Gas measures typically relate to a building's envelope, HVAC, and domestic hot water systems, and the ownership and control over these are commonly not within the multi-family / low-income customers' full control. This result is also in contrast to the Eversource Gas results, which show low-income single-family savings slightly higher than their proportion of consumption, which suggests EGMA's existing low-income programs have additional room for growth relative to Eversource.

Figure 2-52. EGMA Programs, Percent of Residential Lifetime Gas Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

As incentives increase, the relative portion of savings in the single family segment increases from 85% to 89%, while the other market segments' share of savings stays static or slightly decreases as shown in Table 2-14.

The growth in single-family savings juxtaposed with the nearly constant proportion of savings from the multi-family segment shows that, while increased incentives do lead to further savings in the multi-family segment, other market barriers remain that limit the growth of these savings.

The proportion of residential savings from the low-income market segments decreases since incentives are already at 100% under the BAU scenario. Savings in the other segments grow under increased incentives in BAU+ and Max while low-income savings remain constant, leading to a decline in the relative portion of residential savings that the low-income segment represents.[32]

Table 2-14. EGMA Programs, Residential Lifetime Gas Savings by Market Segment

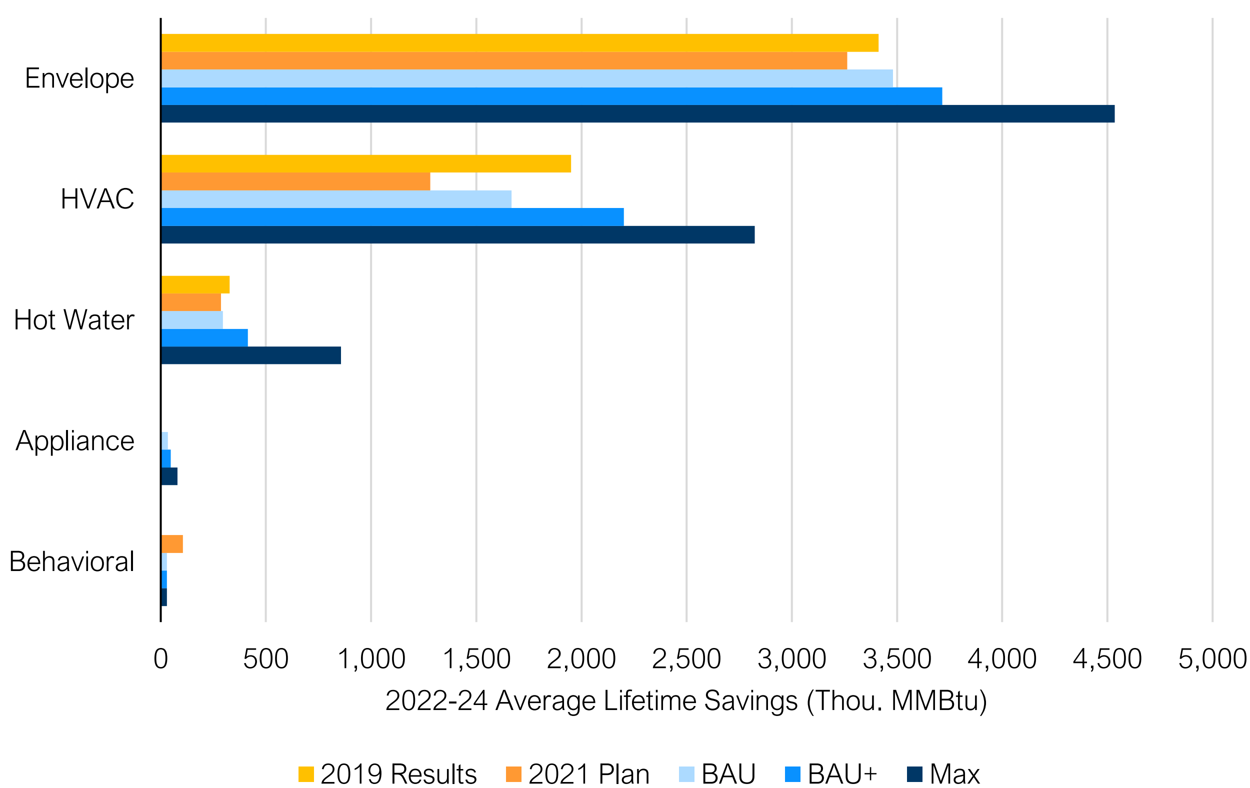
Segment	2022-24 Average Lifetime Thou. MMBtu (% of Total)		
	BAU	BAU+	BAU
Single Family	4,688 (85%)	5,563 (87%)	7,439 (89%)
Low Income Single Family	658 (12%)	658 (10%)	658 (8%)
Low Income Multi-Family	112 (2%)	123 (2%)	135 (2%)
Multi-Family	49 (1%)	64 (1%)	90 (1%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-use

Figure 2-53 shows residential market lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year).

Figure 2-53. EGMA Programs, Residential Gas Lifetime Savings by End-use



[32] Low-income multi-family savings increase slightly under in absolute terms the BAU+ and Max scenarios due to a modeling artifact resulting in a portion of low-income savings being captured with the C&I multi-family segment, which is modeled in the C&I sector with C&I program incentive levels.

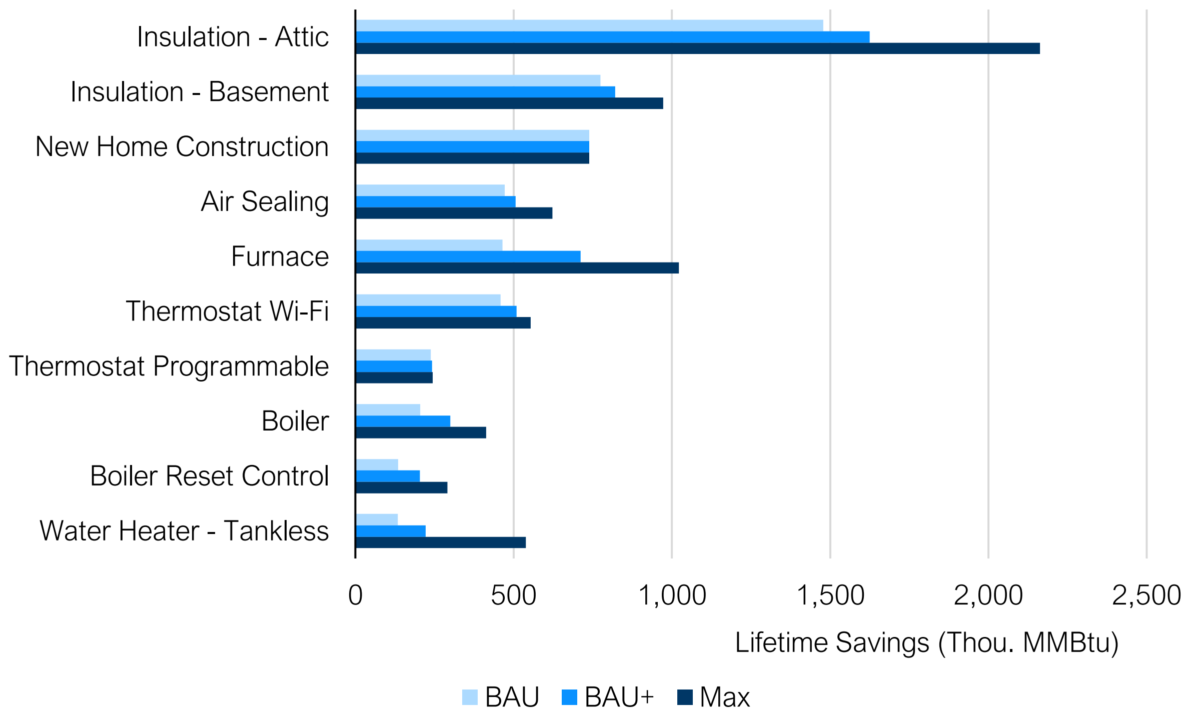
Note: Categories are arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario. Results in the figure include savings for both market-rate and low-income customers.

Similar to historical and planned savings, modeled residential lifetime gas savings are concentrated primarily in the envelope and HVAC end-use categories. Across all top end-use categories, savings are expected to remain at levels similar to 2019 Results and the 2021 Plan under BAU incentive levels. Behavioral savings are expected to drop relative to EGMA's 2021 Plan (note: EGMA did not claim HER savings in 2019) due to changes to EGMA's HER measure, which is assumed to mirror the changes anticipated for Eversource as previously described in the Eversource electric program results section.

Top Measures

Envelope and HVAC measures compose most of the top measures as shown in Figure 2-54.

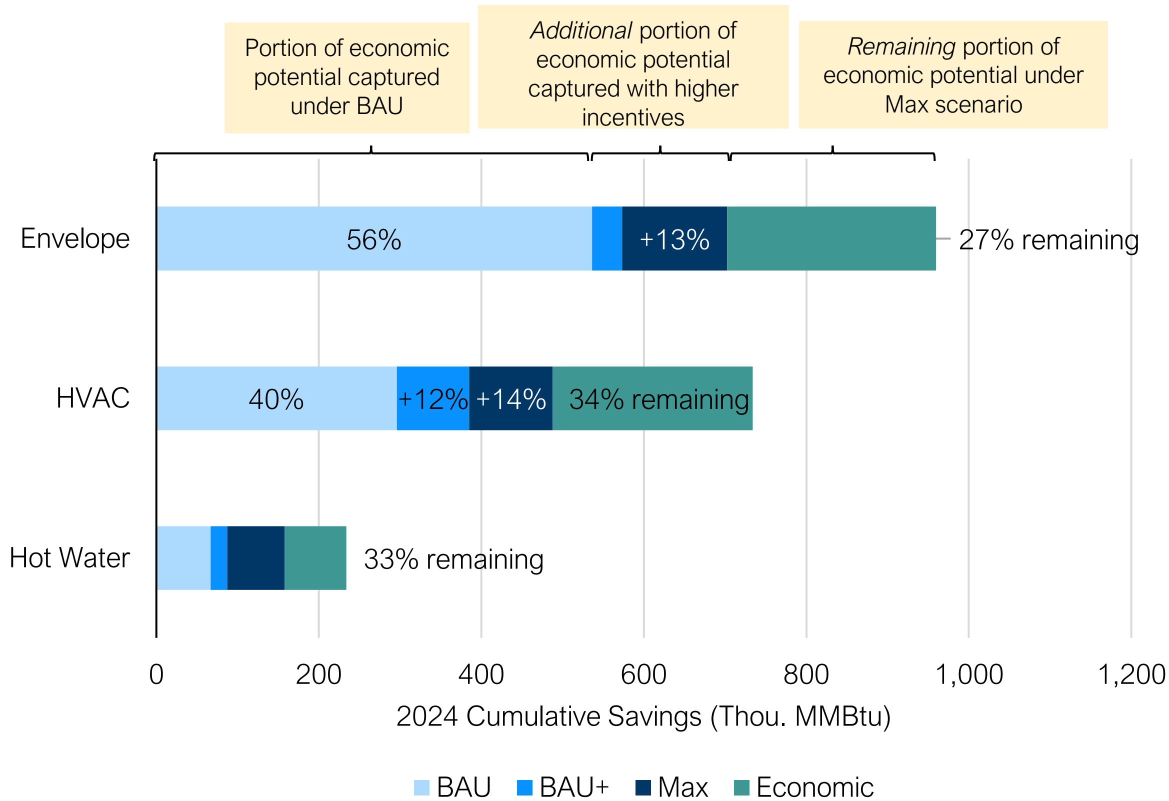
Figure 2-54. EGMA Programs, Top 10 Gas Residential Measures by Lifetime Savings (2022-24 Average)



Potential Growth Opportunities

Figure 2-55 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-55. EGMA Programs, Residential Gas Growth Opportunities



Note: Residential behavioral and appliance savings represent <5% of residential 2024 cumulative economic potential and are excluded from the above figure.

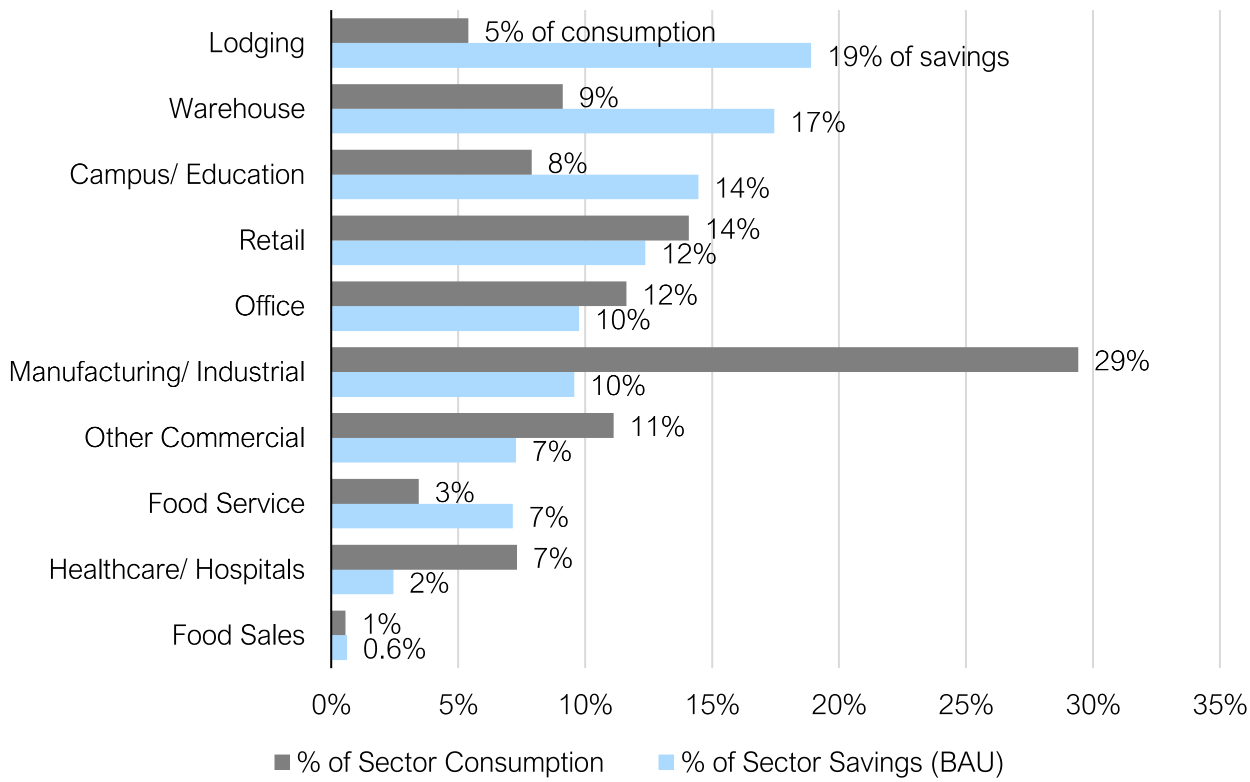
Similar to the results observed for Eversource Gas, only a small portion of economic envelope measure savings goes uncaptured under the Max scenario. The large proportion of gas savings captured is driven in part by the assumptions behind the study's retrofit envelope measures, which assume measures are only applied to buildings where weatherization can be conducted cost-effectively.[33] In many buildings, envelope measures are not cost-effective due to extensive costs resulting from the unique characteristics of the structure. For example, the costs for removing and re-installing exterior cladding and/or drilling and patching drywall to install insulation in limited areas are significant and, in many cases, undermine the cost-effectiveness of many insulation retrofits. In these cases, the study assumes these opportunities are not available to the model to ensure the subset of cost-effective opportunities is not removed from economic potential. This reduces the estimate of technical and economic potential for envelope measures while enabling reasonable achievable potentials, which ultimately results in a large share of economic potential being captured.

[33] This methodological choice is made to ensure retrofit weatherization measures pass cost-effectiveness in the study under the assumption programs will effectively screen weatherization candidates for cost-effective opportunities. Including all weatherization opportunities – including buildings with extensive retrofit costs – would risk screening the entire measure from economic and achievable potential despite the existing of cost-effective savings within a subset of the opportunities.

Savings by Segment

Under the BAU scenario, half of C&I lifetime gas savings come from the lodging, warehouse, and campus & education market segments as shown in Figure 2-56.

Figure 2-56. EGMA Programs, Percent of C&I Lifetime Gas Savings vs. Consumption by Market Segment



Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

There are a few segments for which their portion of gas savings is not aligned with their portion of sector-wide gas consumption. Notable among these are the lodging, warehouse, and campus & education segments (higher savings than consumption) and manufacturing & industrial segment (lower savings than consumption).

While the same caveats described in the Eversource electric program C&I market segment savings section apply to C&I market segment gas savings here, the results may still be indicative of existing trends. For manufacturing & industrial market segment savings, in particular, the low proportion of savings relative to consumption is likely indicative of the general challenge and cost of improving efficiency for highly varied industrial processes. As can be seen in Table 2-15, savings from the manufacturing & industrial market segment grow a proportionally faster rate than the sector as a whole – increasing from 10% of savings under the BAU scenario to 18% of savings under the Max scenario indicating customer economics particularly hamper measure adoption in this segment.

For the segments with outsized savings opportunities compared to their consumption, similar factors likely explain this observation as for the Eversource Gas results, namely custom HVAC savings from segments such as campus and education with a relatively high proportion of large facilities.

Table 2-15. EGMA Programs, C&I Lifetime Gas Savings by Market Segment

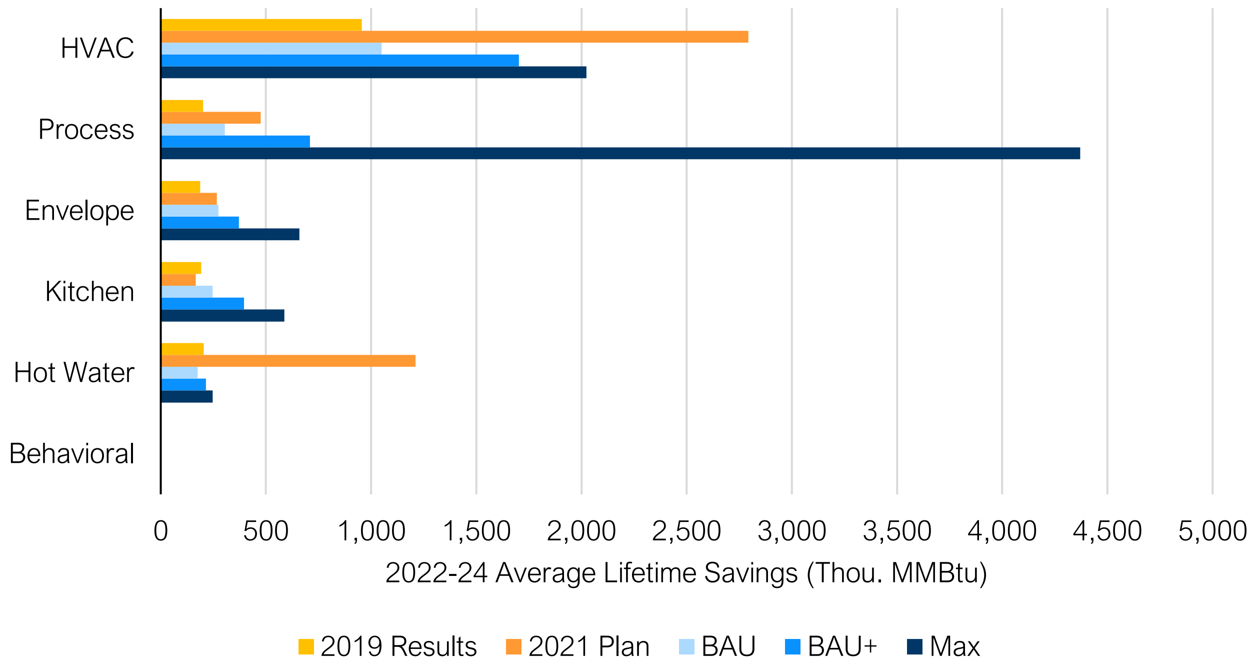
Segment	2022-24 Average Lifetime Thou. MMBtu (% of total)		
	BAU	BAU+	Max
Lodging	388 (19%)	579 (17%)	1,123 (14%)
Warehouse	358 (17%)	539 (16%)	1,023 (13%)
Campus/ Education	297 (14%)	461 (14%)	929 (12%)
Retail	254 (12%)	443 (13%)	1,087 (14%)
Office	200 (10%)	351 (10%)	908 (12%)
Manufacturing/ Industrial	196 (10%)	403 (12%)	1,453 (18%)
Other Commercial	149 (7%)	282 (8%)	644 (8%)
Food Service	147 (7%)	217 (6%)	344 (4%)
Healthcare/ Hospitals	50 (2%)	95 (3%)	281 (4%)
Food Sales	13 (1%)	27 (1%)	99 (1%)

Note: Market segments are arranged by relative contribution to the sector's 2022-24 average lifetime savings under the BAU scenario.

Savings by End-Use

Figure 2-57 shows C&I lifetime savings broken down by end-use comparing recent program savings to the three potential scenarios (expressed as the average lifetime savings achieved per year). HVAC represents over half of savings within the BAU scenario with a fairly even spread of savings from the other end uses other than behavioral savings.

Figure 2-57. EGMA Programs, C&I Gas Lifetime Savings by End-use

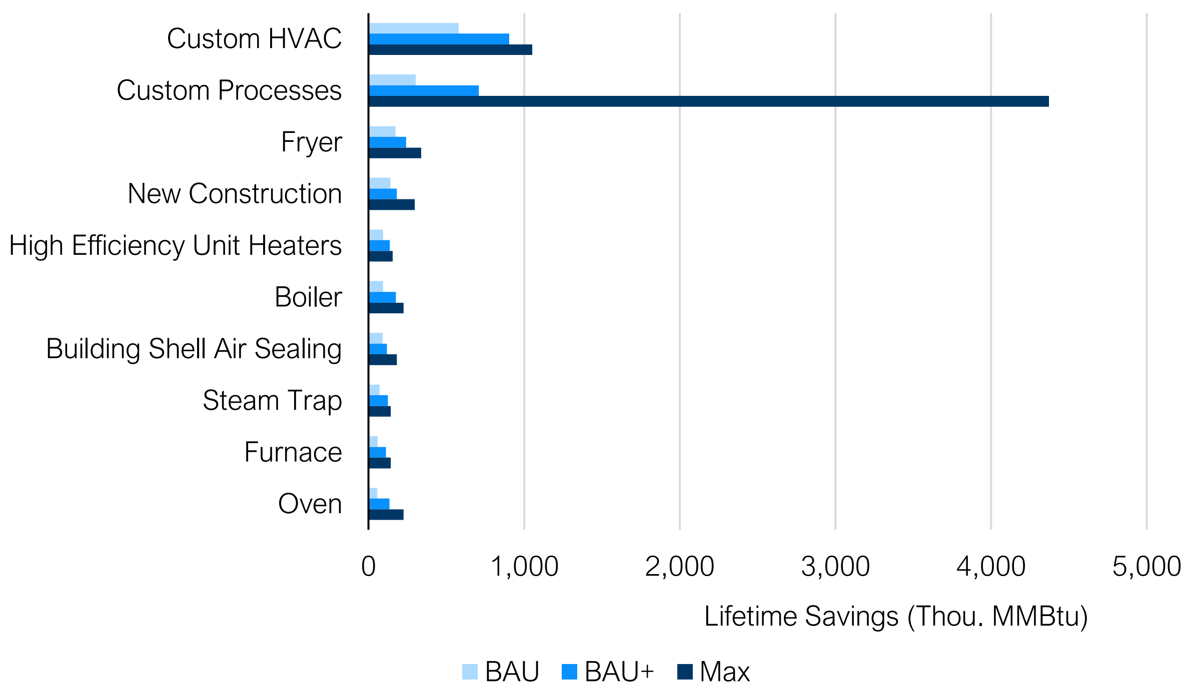


The significant increase in process savings under the Max scenario is driven by relatively lower incentive levels under the BAU scenario, which are 20% of incremental costs. When incentives are increased to five times their current level (i.e., 100% of incremental costs), the customer economics for process savings reaches a tipping point which drives much greater customer adoption than seen in past programs. Much of this increase is observed in the manufacturing and industrial segment, which represents a large portion of C&I gas consumption. As previously described, the share of savings from this market segment nearly doubles between the BAU and Max scenarios as more process-related savings are achieved.

Top Measures

As shown in Figure 2-58, custom HVAC and custom process savings are, by far, the most prominent C&I gas measures highlighting the non-standard nature of many savings opportunities within the C&I sector. These measures compose over 50% of C&I gas savings under all scenarios.

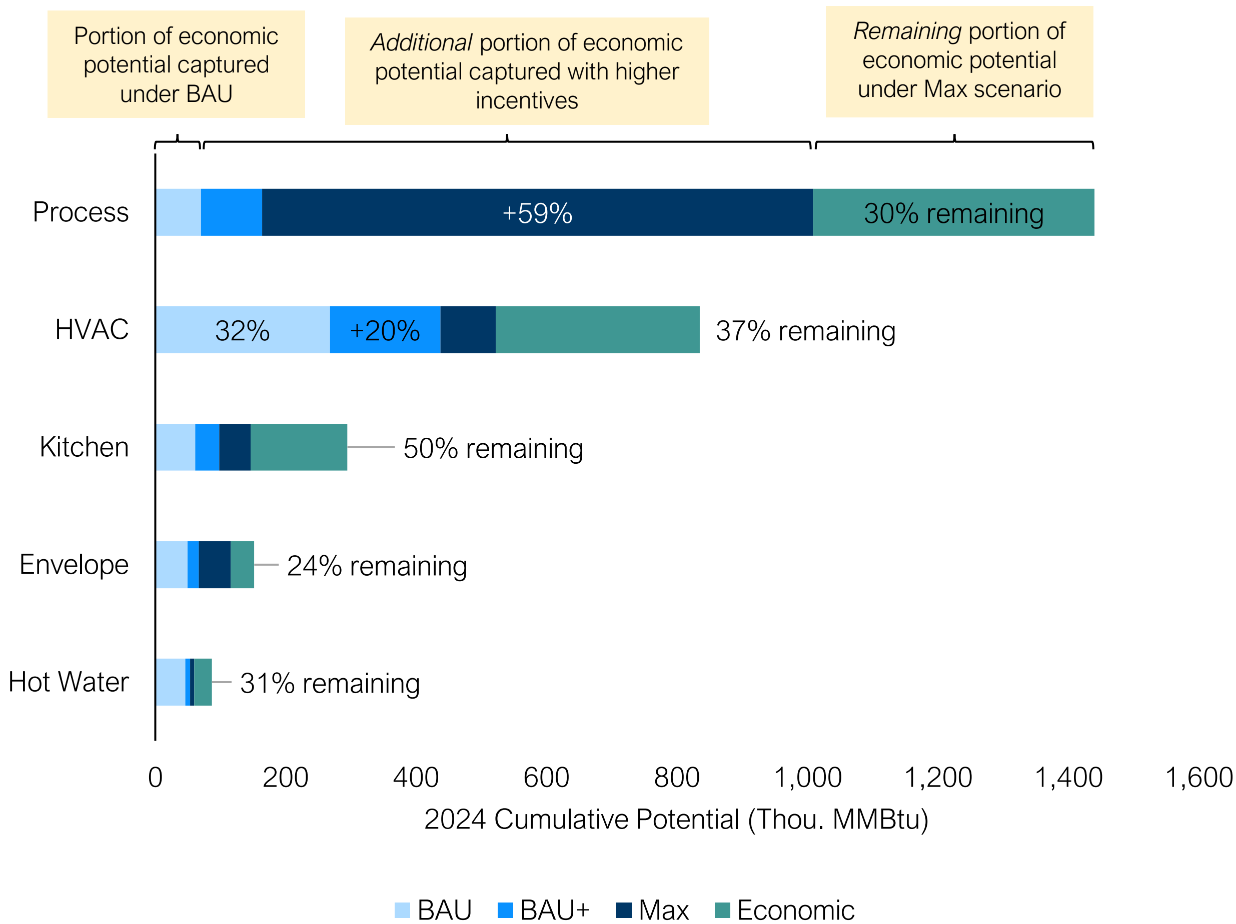
Figure 2-58. EGMA Programs, C&I Top Measures (2022-24 Average Lifetime Savings)



Potential Growth Opportunities

Figure 2-59 illustrates the portion of 2024 cumulative economic potential captured under each achievable scenario. The end-uses that exhibit a significant spread between the economic and achievable potentials may represent opportunities for future program growth via strategic program adaptations.

Figure 2-59. EGMA Programs, C&I Gas Growth Opportunities



With maximum incentives, programs can capture over 60% of economic potential for most end-use categories. The one notable exception is kitchen measures, where half of the economic potential is captured under the Max scenario indicating additional factors beyond customer economics inhibiting savings in this category. The large jump in captured process savings between BAU+ and Max is driven by the low historical performance under low BAU incentive levels (as previously discussed). Incentives increase from ~40% under BAU+ to 100% under Max.

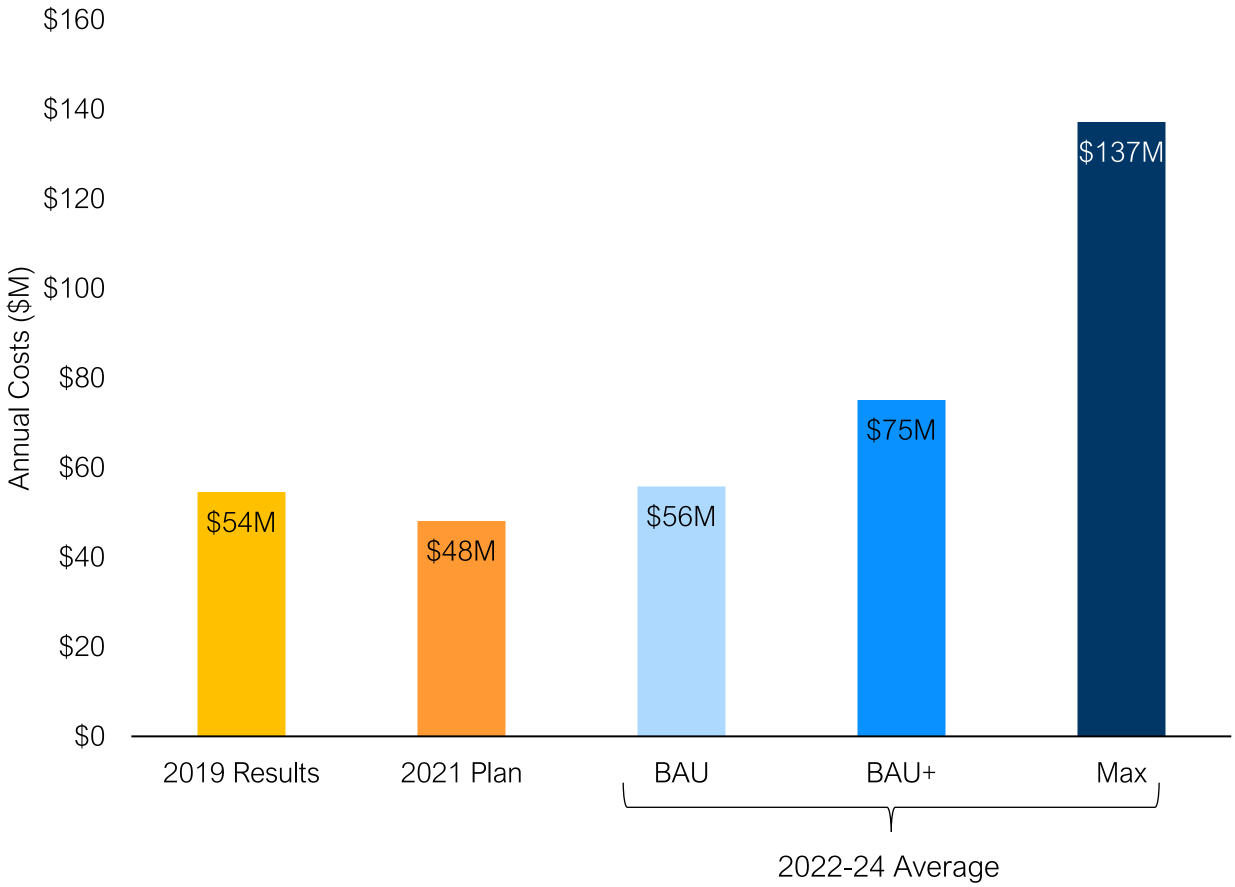
Portfolio Metrics

The following section presents portfolio-level metrics for the EGMA Program results including program costs, TRC results, and emission benefits.

Program Costs

Figure 2-60 shows the estimated 2022-24 average annual cost of administering EGMA's gas programs under each achievable scenario.

Figure 2-60. EGMA Programs, Program Costs

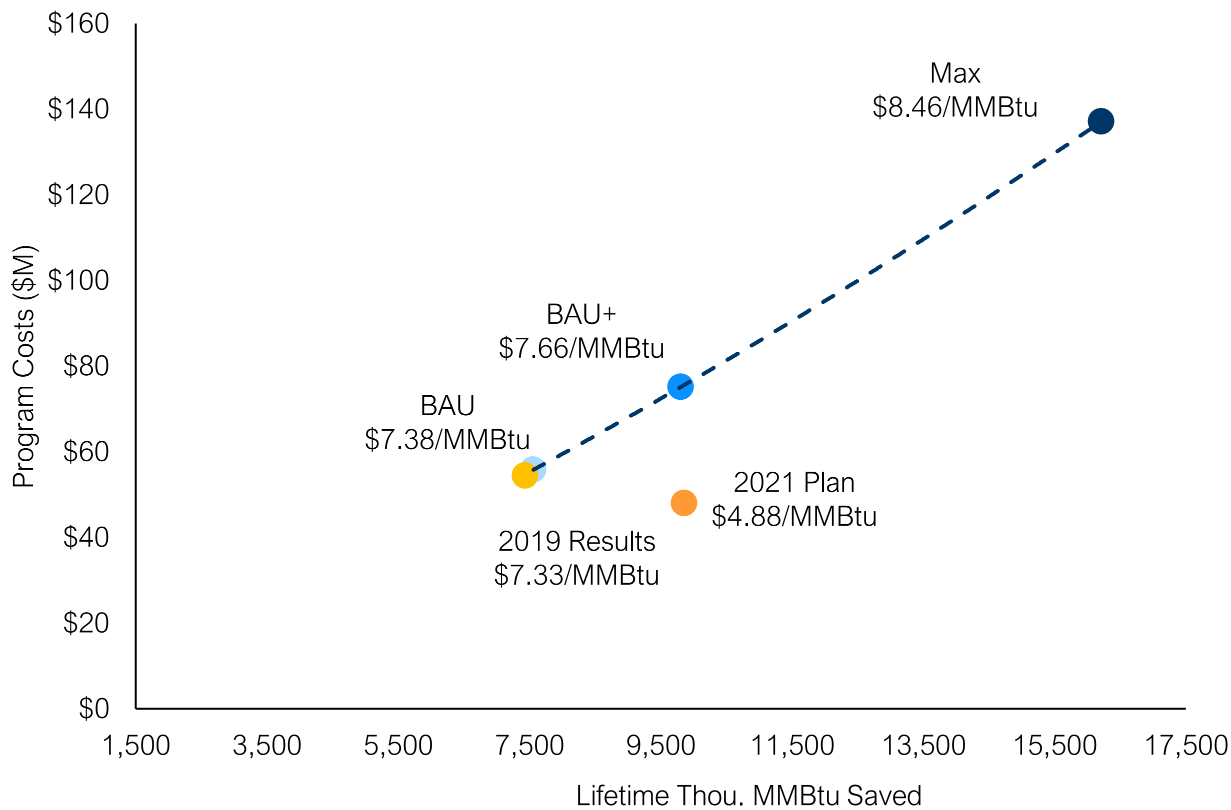


As would be expected, average annual costs under the BAU scenario closely mirror 2019 Results at approximately $56 million. With increased incentives and savings, costs increase at a faster rate than savings under the BAU+ and Max scenarios. Under the BAU+ scenario, costs increase by 35% over the BAU scenario, while average lifetime savings only increase by 30%. A similar trend is observed in the jump from BAU+ to Max.

The larger proportional increase in costs relative to savings results in higher unit costs to deliver gas savings under the BAU+ and Max scenarios as shown in Figure 2-61. Under BAU, the unit cost to deliver savings is commensurate with costs in the 2019 Results, but savings under the BAU+ and Max scenarios cost a higher program dollar per lifetime MMBtu saved.

This result is to be expected as raising incentives increases the cost not just for newly acquired savings but for savings that would have been obtained under lower incentive levels as well – and thus at a lower unit cost. Increased incentives will also tend to drive greater adoption of measures with higher unit savings costs as these measures will also tend to have smaller customer benefits (e.g., bill savings). With increased incentives, these measures become more attractive to customers and thus are adopted at greater levels.

Figure 2-61. EGMA Programs, Program Costs vs. Lifetime MMBtu Saved



Program Benefits

Overall, EGMA's gas efficiency programs have the potential to continue to create significant benefits as measured by the TRC as well as emission reductions. Table 2-16 displays the overall TRC ratio, net TRC benefits, net benefits per lifetime and first-year MMBtu saved, and average annual CO_2 emission reductions achieved each program year.

Table 2-16. EGMA Programs, TRC Benefits, and CO_2 Emission Reductions (2022-24 Average)

	TRC Ratio	Net TRC Benefits	Net TRC Benefits per Lifetime MMBtu	Net TRC Benefits per First-Year MMBtu	Annual CO2 Emission Reductions (Short Tons)
2019 Results	2.1	$77M	$10.32	$184	26,600
2021 Plan	2.8	$121M	$12.32	$175	46,900
BAU	2.2	$84M	$11.66	$168	34,000
BAU+	2.2	$104M	$11.24	$159	46,000
Max	2.3	$162M	$10.53	$147	77,000

Note: TRC values for 2019/2021 benchmarks are derived using 2018 AESC values while modeled TRC values are derived using 2021 AESC values.

Overall, benefit metrics under the BAU scenario closely mirror 2019 Results as expected. Under higher incentive scenarios, net TRC benefits increase though the average net TRC benefit per unit of savings declines.

In terms of emission reductions, EGMA's gas programs will continue to produce thousands of tons of CO_2 reductions each year during the study period under BAU conditions. Emissions reductions under BAU are greater than emission reductions claimed for 2019 even though lifetime savings are similar primarily due to the lack of HER savings in EGMA's 2019 results.

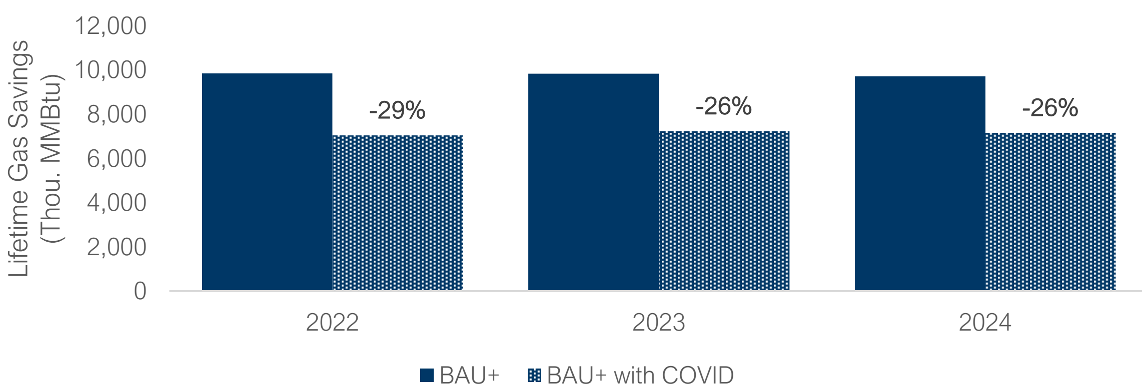
Sensitivity Analyses

COVID-19

As described previously in the Eversource Electric Program Results section, the COVID-19 pandemic has led to economic uncertainty and business closures, it may have some impact on the achievable potential within the study period (2022-24). It is unclear what precise economic effects will be caused by COVID, how they will be distributed across the market, and how long these effects will persist; however, this analysis performs a high-level assessment of how COVID-driven changes in market conditions may impact achievable program savings.[34]

Figure 2-62 presents the results of the sensitivity analysis for the three years of the potential study compared to the BAU+ scenario.

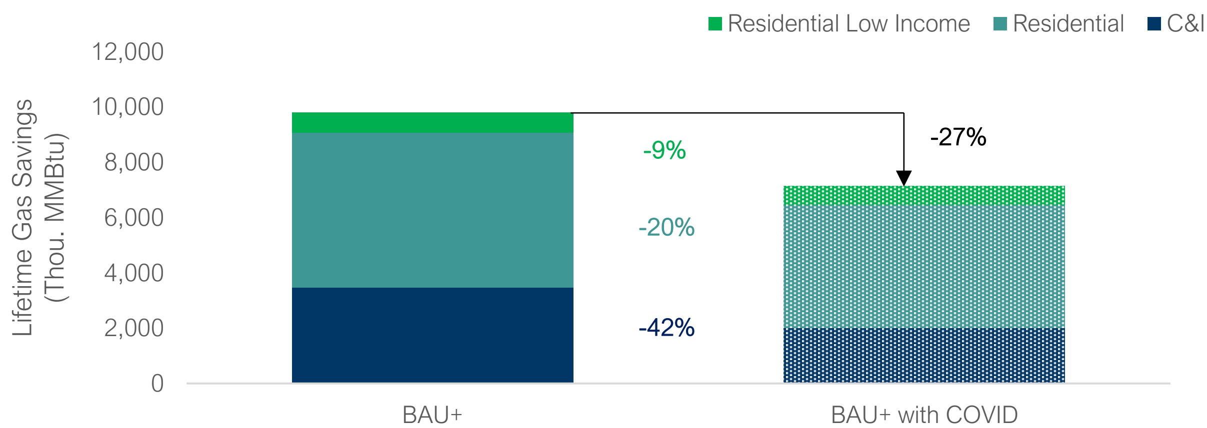
Figure 2-62. CMA Programs, COVID Sensitivity - Impact on Lifetime Savings



In our modeling, COVID-19 impacts reduce the total achievable electric savings by 26-29% compared to the BAU+ scenario, with this impact less pronounced after the first year when some temporarily closed businesses reopen. Figure 2-63 presents the sector breakdown of the COVID sensitivity as an average across the study period.

[34] It should be noted that the sensitivity parameter adjustments were selected prior to the rapid rollout of COVID-19 vaccinations in the spring of 2021 and that this sensitivity should be interpreted as an upper-bound worst-case scenario (e.g., the emergence of vaccine-resistant COVID variants).

Figure 2-63. CMA Programs, COVID Sensitivity - Impact by Sector (2022-24 Average)



The C&I sector shows a larger reduction in savings than residential, which is to be expected since this sector sees market size adjustments as well as barrier level increases.

Overall, our analysis suggests that the COVID-related impacts to the economy could result in reduced achievable savings for efficiency programs through the study period if economic impacts persist. These savings reductions are significant in both the C&I and residential sectors, with businesses hit harder than households in terms of achievable potential.

State Codes and Standards

On March 26, 2021, Governor Baker signed "An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy" into law. One of the (many) provisions of this law updates energy and water efficiency standards for common household and commercial appliances included in this study. By increasing baseline efficiency standards, the law will reduce technical, economic, and claimable achievable savings potential estimates for affected measures in this study.

This analysis looks at the group of achievable savings that could be impacted by this law. It is unclear to what degree *claimable* achievable savings for the PAs will be impacted as ongoing discussions will determine whether the PAs can claim at least partial credit for the strengthening of these standards.

The following gas measures included in this study are also included in the appliance standards included in the bill:

- Commercial dishwashers
- Commercial fryers
- Commercial ovens
- Commercial steam cookers
- Low-flow showerheads
- Low-flow faucets

Under the BAU+ scenario, these measures account for approximately 4.2% of 2022-24 average lifetime gas savings. As shown in Table 2-13, the impact is not spread evenly across sectors. Overall, the C&I

sector would experience a bigger impact on savings due to the reduction in savings opportunities from commercial kitchen equipment. Claimable C&I gas savings could potentially decline by over 13%.

Table 2-17. EGMA Programs, Gas Lifetime Savings Impacted by Potential Codes and Standards Updates (BAU+ Scenario)

Sector	Savings Impacted by C&S (Lifetime Thou. MMBtu)	% Reduction
C&I	461.8	13.6%
Residential	63.6	1.1%
Residential Low Income	8.6	1.1%

In addition to these appliance standards, the law also requires the state to develop a voluntary specialized stretch code for "net-zero energy" buildings. Depending on requirements, net-zero buildings either emit no greenhouse gases or generate their own renewable energy to offset any emissions. These codes are often designed to be flexible and performance-based making it difficult to ascertain the impact it could have on future claimable program savings, but they could ostensibly reduce new construction opportunities as well as new market opportunities for other equipment-related measures (e.g., furnaces, boilers) once implemented.

Overall, a number of measures are likely to be impacted by the new law, and at the time of writing, the exact impact of measures, and what (if any) portion may still be claimable by the efficiency program administrators under the law, is uncertain.

2.5 Key Takeaways

Based on the results presented in this chapter, the following key takeaways emerge:

- Under **BAU incentive level**s and current program configurations, electric and delivered fuels savings levels will vary significantly from past program results:
    - **Electric savings** will decline sharply as lighting savings continue to drop due to the rapid transformation of Massachusetts's lighting markets, despite increased opportunities from growing heat pump penetrations.
    - **Delivered fuels savings** could increase with the inclusion of new prescriptive C&I measures in existing programs while residential savings continue at past levels, and
    - **Gas savings** are expected to stay relatively stable as exogenous factors are not expected to significantly change savings opportunities or markets.

- **By increasing incentives**, programs can obtain substantially more savings albeit with significant increases in program costs. Under the Max scenario:
    - **Electric savings** increase by 105% relative to the BAU scenario. Yet, while this is a substantial increase, it is still not sufficient to replace the declining lighting opportunities, and as a result, overall electric savings will still be lower than past program achievements.

- **Delivered fuels savings** increase by 51% over the BAU scenario projections. Relative to electric and gas savings, raising incentives offers a relatively smaller incremental increase in delivered fuels savings. Existing programs already capture a large portion of net economic potential and due to the relatively high cost of delivered fuels in Massachusetts, customers are already highly incentivized to use these fuels efficiently. Thus, providing greater upfront incentives has less of an impact on customer decision-making.
- **Gas savings** increase by 108% relative to the BAU scenario for Eversource's gas programs and 114% for EGMA's gas programs, showing that there is substantial room to grow gas savings by offering higher customer incentives.

- **Program Enhancements:** Raising incentives can lead to increased program savings, but for some measures and end-uses, even at the Max scenario incentive levels a substantial portion of the net economic savings remain untapped. These uncaptured savings represent cost-effective opportunities that are inhibited for reasons beyond customer economics. For example, under the Max scenario:

  - 38% of 2024 cumulative net economic **electric savings** are not captured by programs,
  - 35% of 2024 cumulative net economic **delivered fuels savings** are not captured by programs, and
    29% and 32% of 2024 cumulative net economic **gas savings** are not captured by Eversource and EGMA programs, respectively.

While *completely* eliminating all market barriers for all efficient technologies is likely not feasible, (particularly in just the next three years), uncaptured economic savings may represent opportunities for enabling program strategies and market transformation approaches to further reduce market barriers and increase savings. While these strategies take time to implement and their impacts are more uncertain than increasing incentive levels, Eversource and the state of Massachusetts as a whole have consistently achieved success reducing market barriers as shown by the state's consistent top rank ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near-complete transformation of the Massachusetts lighting market.

3 Demand Response

3.1 Overview

A detailed assessment of the potential for active demand reduction (ADR) programs to reduce Eversource's peak load during the 10-40 highest demand hours of the year was conducted. This represents incremental additional peak load reduction to the passive peak reductions resulting from energy efficiency described in the other chapters of this study. The following chapter presents ADR program potential resulting from a range of equipment controls, and load curtailment strategies applied in industrial and commercial facilities, based on their ability to reduce loads during the ISO New England (ISO-NE) system-wide annual peak demand[35] hours.

Approach

The ADR potential is assessed using Dunsky's Demand Response Optimized Potential (DROP) Model to determine potential impacts against Eversource's contribution to the ISO NE system annual peak demand. A standard peak day load curve is identified and adjusted to account for projected load growth and efficiency program impacts over the study period. Five years of historical annual hourly load data, coupled with forecasted annual peak demand provided by Eversource, are used to determine the timing, duration, and magnitude of the expected annual peaks.

The ADR measures and programs are then applied to the projected standard peak day load curve to determine the following:

Technical potential is estimated as the total possible coincident peak load reduction for each individual measure multiplied by the saturation of the measure or opportunity in each market segment.

Economic potential is the amount of coincident peak load reduction for each individual measure that passes the Total Resource Cost Test. Only those measures that pass the threshold (TRC > 1.0) are included in the achievable potential scenarios.

Achievable potential is assessed under three program scenarios by applying mixes of all cost-effective measures, to determine the combined impact against the peak day load curve, and accounting for measure interactions.

For each year, the active demand reduction potential is assessed, accounting for existing programs from previous years as well as increases in customer participation, new measures or programs starting in that year. Unlike many efficiency measures, active demand reduction peak savings only persist as long as the

[35] The system-wide annual peak demand refers to the hour in the year that exhibits the highest system peak demand in MW. It is assessed on a system-wide basis, not accounting for local constraints across the transmission and distribution system.

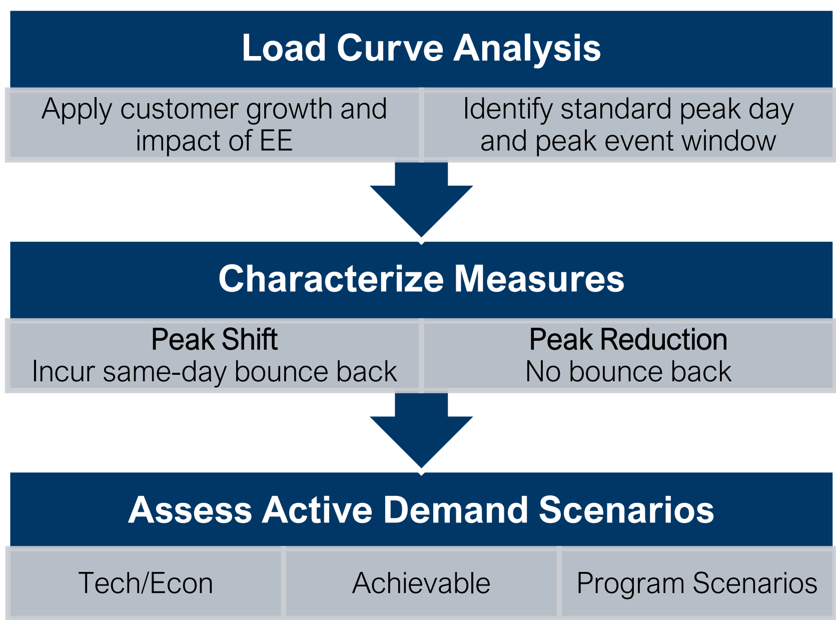
program is offered. For new and expanded programs, ramp-up factors were applied to account for the time required to recruit participants[36].

According to how ADR cost-effectiveness is calculated in Massachusetts, the demand benefits are only considered at the identified ISO-NE peak hours and therefore do not account for possible new peaks that may result from ADR measure interactions or peak shifting impacts. This analysis aims to capture the impact at the hours used by ISO-NE to determine the installed capacity requirement (ICR) while assuming there is no load shifting impact across the ISO-NE load curve.[37] As a result, the peak demand impacts in this study may somewhat overstate the true resulting incremental impact on Eversource's annual peak loads. Moreover, considering that Eversource MA represents 20% of the ISO-NE peak demand and other utilities will likely engage in similar ADR strategies, there is a chance that peak shifting could impact the timing and duration of the ISO-NE peak demand periods.

The technical and economic ADR potentials represent a significant portion of the overall load; however, they are not considered to be realistically additive across all measures since some measures can target the same end-use. For example, using a smart thermostat to control a central HVAC system and using an energy storage device can both target the same cooling load. Technical and economic potentials for individual measures are provided in Appendix E.

Figure 3-1 below presents an overview of the steps applied to assess the ADR potential in this study.

Figure 3-1. ADR Potential Assessment Approach



A more detailed description of the active demand reduction modeling approach applied in this study can be found in Appendix D.

[36] A summary of ADR program assumptions, including ramp up rates, is included in Appendices D and E.
[37] To date, these hours are almost entirely in July and August.

Achievable Potential Scenarios

The achievable potential is assessed under three scenarios, corresponding to varied active demand reduction program approaches and levels of investment, to determine the resulting peak demand reduction impacts and benefits. Further details on the specific programs and their related inputs are presented in Appendix D.

Table 3-1: Active Demand Reduction Achievable Scenario Descriptions

BAU	**Current ADR programs and incentives**, when applied across the full applicable market, to obtain projected equilibrium participation levels as predicted by the DROP model's propensity curves[38] under evolving market conditions and through ongoing marketing and outreach without altering incentives or measures offered.
BAU+	Tests the ability to **expand participation by increasing incentives** under the current ADR programs while maintaining cost-effectiveness.
Max	Applies BAU+ scenario incentive levels and further **expands ADR programs to include a range of new cost-effective measures**.

Benchmarking

The results of the study are compared to current program impacts as well as the projected impacts in the 2021 plan.[39] Table 3-2 presents current enrollment and averaged per participant reduction from Eversource's active demand reduction programs. The modeled achievable potentials for each program are benchmarked against current program impacts to demonstrate consistency between the study and existing active demand reduction efforts. Apart from C&I daily energy storage, the modeled reduction per participant is well aligned with the existing potential. Furthermore, current program adoption was used to calibrate the model based on the technology (measure) and sector.

Table 3-2 shows that the current capacity (2020) is around 80% of the 2021 planned capacity, indicating that Eversource is well-positioned to achieve its planned target. Particularly, C&I curtailment and Residential HVAC BYOD programs are nearing or exceeding planned capacity which indicates a keen interest by participants.

[38] Propensity curves available in Appendix D.
[39] Current program impacts are derived from either the actual 2019 savings or 2020 preliminary savings (when available).

Table 3-2. Comparison Between Existing Programs and Model in Eversource Territory (Massachusetts)

Existing measures	2020 Preliminary Capacity[40] (MW)	2021 Planned Capacity (MW)	2020 Reported Reduction (kW / participant)	Modeled Reduction (kW / participant)
C&I Curtailment	69	76	264	271
C&I Battery / Thermal Energy Storage – Daily	2.8	10	350[41]	121
C&I Battery / Thermal Energy Storage – Targeted	0.41	10	136[41]	121
C&I Smart Electric Vehicle Charger (Pilot)	N/A	N/A	N/A	0.10
Residential HVAC BOYD	4.2	4.0	0.6	0.6
Residential Smart Electric Vehicle Charger (Pilot)	0.09	N/A	0.40[42]	0.39
Residential Battery Energy Storage	0.41[43]	0.25	5.5[44]	5.5
Total	77	100	N/A	N/A

C&I storage programs are relatively new with only a small number of participants to date[45], making it difficult to derive a meaningful average size of system for future applications. For assessing future potential battery sizes the modeled average battery sizes were derived from average peak loads for medium and large buildings within each segment. Residential battery capacities were modeled at 5.5kW and 13.5kWh, and the model assumed a 2-hour average peak event call, which is aligned with program evaluations. Note that the Connected Solutions Home Batteries program allows calls for up to 3 hours and that the average battery could not sustain a 5.5kW discharge over 3 hours, reducing the contribution to peak active demand reduction when calling them for 3 hours.

Load Analysis

The first step in the active demand reduction potential analysis is to define the standard peak day (24-hour) load curve using historical Eversource and ISO-NE hourly load data. The standard peak day load curve for the statewide electric system is defined by taking an average of the load shape from the top ten peak days in each of the five years of historical hourly load data provided (Figure 3-2).

The load curve analysis reveals that the top 10-40 peak demand hours peaks within the window of 3pm to 7pm during high demand days in June, July, August, and September. For the established standard peak

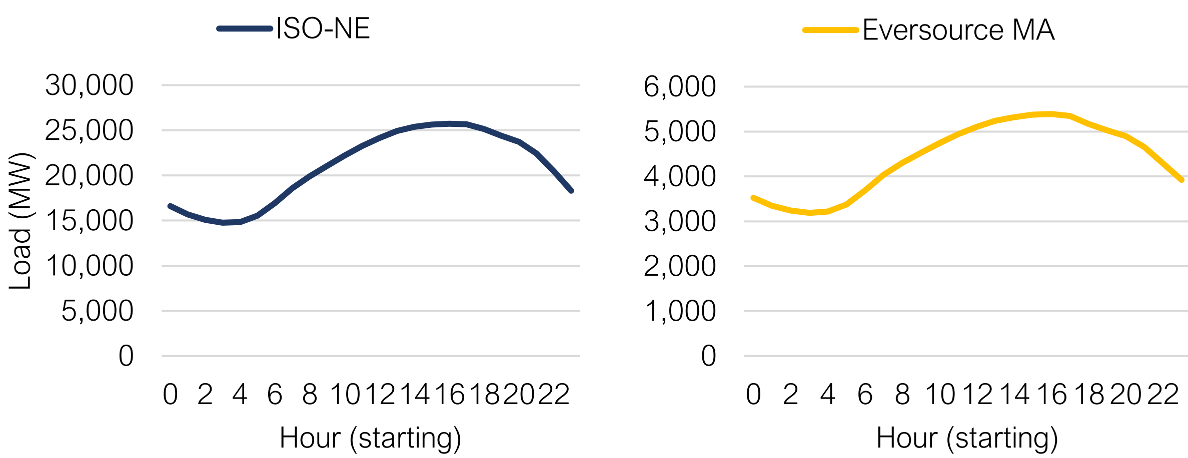
[40] Because of the ADR programs growth between 2020 and 2019, 2020 preliminary data values were used to better reflect actual program state. Current capacity includes realisation rates derived from MA TRM.
[41] Average is derived from a very small number of participants and is therefore not statistically significant. Averages are provided for information purposes only.
[42] Numbers for Massachusetts were derived from total Eversource territory.
[43] Estimated from total enrollments and average participant savings.
[44] Corresponding to the average battery output capacity of currently enrolled participants for a two-hour active demand reduction event.
[45] At the time this study was produced, only 11 customers were enrolled in all the C&I energy storage program.

day based on the historical load curve, the peak hour is deemed to occur between 4pm to 5pm.[46] The standard peak day load curve and Eversource's defined peak window (3pm to 7pm) are then used to characterize measures and assess the measure-specific peak demand reduction potentials at the technical and economic levels. Achievable peak demand reduction potentials are further verified against ISO-NE annual historical hourly load data to assess measure deployment constraints.

The standard peak is then forecasted in the future, considering efficiency measures and load growth forecasts from Eversource's projections. Since this is a relatively short-term study covering three years (2022-2024), the impact of load growth and efficiency programs on the peak day load curve is negligible. Further details about the standard peak day are available in Appendix D.

Figure 3-2 shows the resulting standard peak day load curves for the ISO-NE system, as well as Eversource's Massachusetts territory. As can be seen, Eversource's peak day load curve largely follows the same shape as the ISO-NE curve but accounts for just 20% of the peak load.[47]

Figure 3-2. Standard Peak Day Load for ISO-NE and Eversource MA (Summer Season)



3.2 Results

The achievable potential results in each year for each scenario are presented below. These results represent the combined peak load reduction from all cost-effective programs assessed against the ISO-NE load curve, accounting for interactions among programs and ramp-up schedules for new measures and programs. A description of each measure and program along with the measure's technical and economic potentials in each market segment are provided in Appendix D.

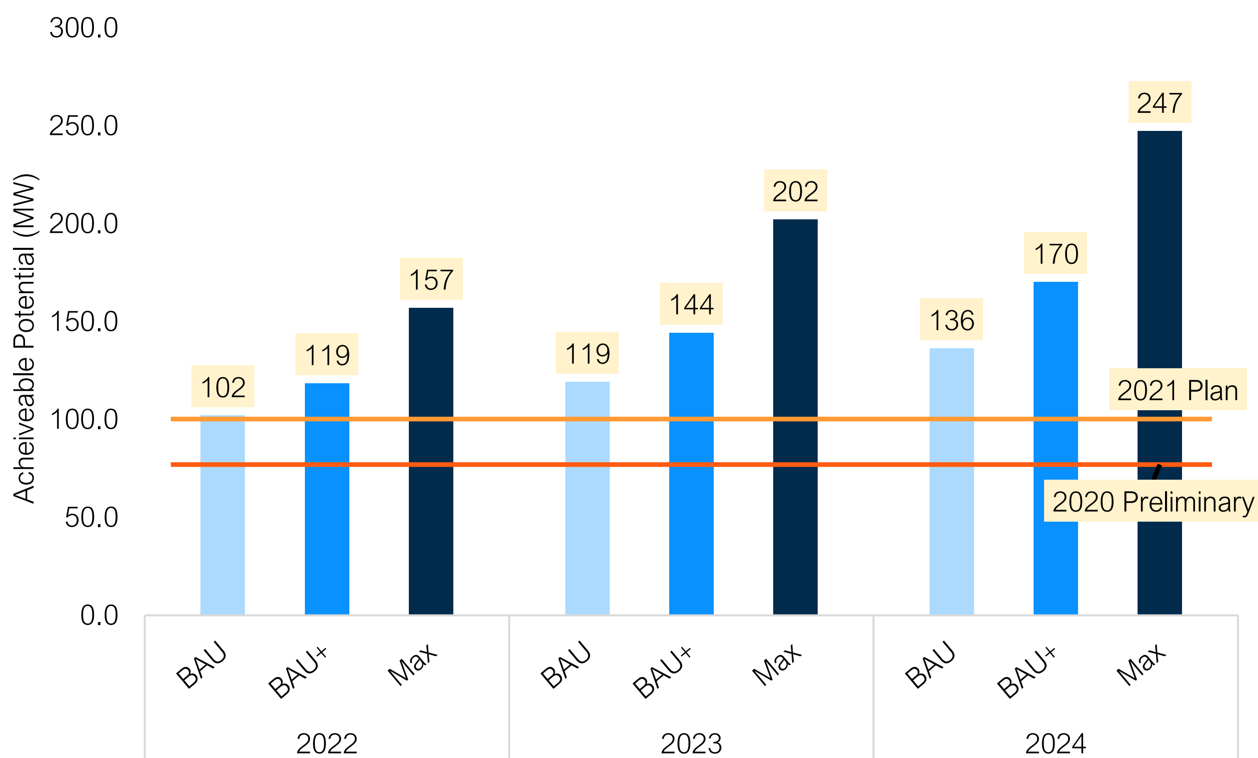
[46] The peak hour in 2019 occurred between 5pm to 6pm. However, because ADR measures are characterized to reduce demand during 3-7 PM ADR window, the shift in the timing of the peak from 4pm-5pm to 5pm-6pm would still be covered by the ADR potential analysis in this study.
[47] The peak load curve analysis reflects the impact of current solar capacity on the system but does not consider future solar adoption, which was outside the scope of the study.

Achievable Potential

Under the BAU scenario, which is based on Eversource's current programs[48] expanded to the full extent across applicable markets, the potential is estimated to grow from 102 MW in 2022 to 136 MW in 2024 (Figure 3-3), which represents approximately 2.5% of Eversource's statewide peak demand in 2024.

The BAU+ scenario applies increased incentive levels, while the Max scenario introduces new measures alongside the increased incentives from the BAU+ scenario. Both scenarios show an increase in achievable potential over the BAU levels reaching 170 MW and 247 MW in 2024, respectively, which represents 3.2% and 4.6% of Eversource's systemwide peak demand. The scenario analysis indicates that expanding the range of ADR measures in the programs results in significantly more peak reduction potential than simply increasing incentives over Eversource's current program offers.

Figure 3-3. ADR Achievable Potential by Scenario and Year



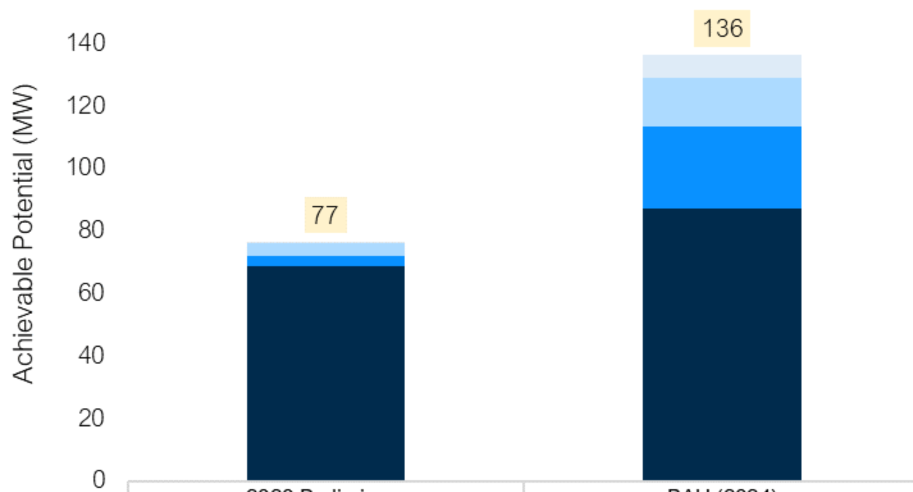
BAU Scenario

The BAU scenario focuses on Eversource's current programs and uses the DROP model's propensity curves to determine the maximum equilibrium participation that the program can achieve under evolving market conditions and through ongoing marketing and outreach without altering incentives or the measures offered.

[48] Based on the 2019 ADR programs.

Figure 3-4 shows that the ADR potential by 2024 in Eversource's Massachusetts service territory can exceed current reductions by approximately 60 MW. This is due to the growing participation in commercial and industrial curtailment programs which are expected to see an increase of 20 MW by 2024. Particularly, the modeling highlights the untapped potential within the medium C&I segment. Other factors also include an increase in both commercial and residential energy storage measures.

Figure 3-4. ADR BAU Scenario Achievable Potential – Breakdown by Measure Categories



	2020 Preliminary	BAU (2024)
Total	77	136
Connected Solutions - Home Batteries	0.4	7.3
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	4.3	15.5
Connected Solutions - C&I Energy Storage	3.3	26
Connected Solutions - C&I Curtailment	69	87

Table 3-3 provides the measure-level savings for current ADR programs, presented alongside the achievable potential in 2024. Results show an overall increase of 76% in demand reduction by 2024. The Connected Solutions C&I Curtailment program, which was the program providing most of the active demand reduction in 2020, is still the key contributor in 2024. The current average enrolled curtailment capacity of 264 kW/participant indicates that the C&I curtailment program is dominated by large customers. Our findings suggest that there is room for growth, particularly for medium C&I curtailment. However, capturing medium C&I participants comes at a higher cost, but it remains highly cost-effective.

Table 3-3. ADR BAU Scenario – Top Measures

Measures	2020 Preliminary (MW)	Achievable Potential 2024 (MW)
Large Commercial Curtailment	69	61.4
Medium Commercial Curtailment		12.4
Large Industrial Curtailment		11.8
Medium Industrial Curtailment		1.6
Large Battery Energy Storage - Daily	2.8	16.4
Residential HVAC DLC (BYOD only)	4.2	11.0
Large Battery Energy Storage - Targeted	0.41	7.9
Residential Battery Energy Storage	0.41	7.3
Electric Vehicle Service Equipment (EVSE)	0.09	4.2
All Other Measures[49]	-	2.4
Total	77	136

Battery storage measures (residential and commercial), electric vehicle service equipment (EVSE) measures (residential), and Residential HVAC BYOD measures, show a significant increase relative to current programs. For batteries, the program is relatively new and current battery penetration indicates that the program should have room to grow to capture more of the available market. For EVSE measures, the projected increase in potential is linked primarily to the increasing uptake of EVs in the market. For Residential HVAC BYOD measures, the program is already well-developed, capturing most of the current potential, and the growth in this program is expected to be driven by the growing penetration of smart thermostats driven in part by incentives from EE programs which are increasing the adoption of the technology. The analysis suggests that the current Connected Solution Smart Thermostat program is well-positioned to capture this growing opportunity.

BAU+ Scenario

The BAU+ scenario tests the ability to expand participation in current ADR programs through increased customer incentives while still ensuring that measures are cost-effective.[50]

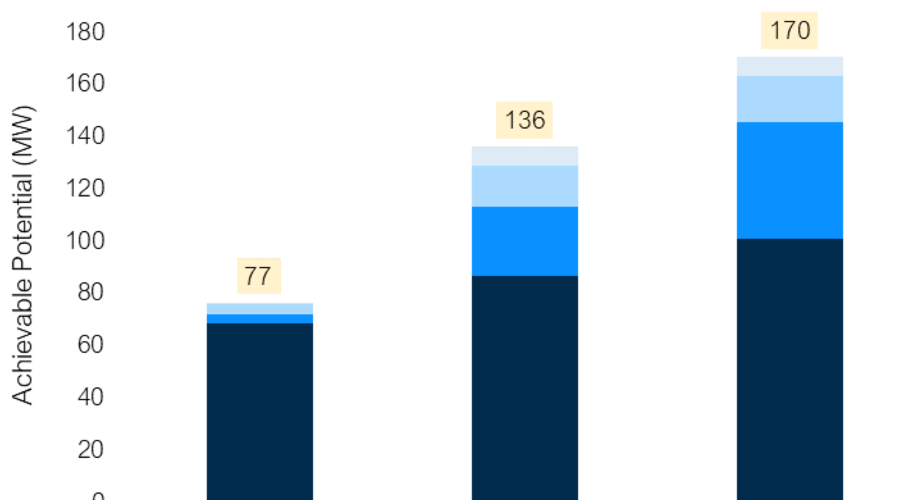
The BAU+ scenario shows an achievable potential increase of around 220% over current program impacts by 2024. Specifically, the Commercial Energy Storage program shows the most growth relative to both current program impacts and the projected BAU scenario results. This can be explained by the impact that the higher ADR incentives would have to improve the customer cost-effectiveness for battery storage. This is projected to help increase the adoption of battery storage systems among C&I

[49] Detailed breakdown available in Appendix E.
[50] Because active demand reduction program incentives do not cover an incremental cost of equipment they are captured as a participation bonus in the TRC calculation, rather than a pass through. Thus, unlike in the EE and HE analysis, incentive levels do impact DR measure-level cost-effectiveness results.

customers, and thereby grow participation in the Commercial Energy Storage program, relative to the BAU scenario levels.

For the Residential Energy Storage program, increased incentives do not result in a notable increase in potential. This indicates that the current incentive offered by Eversource for the measure is sufficiently generous and an increase would not likely increase participation in the program to a significant degree.

Figure 3-5. ADR BAU+ Scenario Achievable Potential – Breakdown by Program



	2020 Preliminary	BAU (2024)	BAU+ (2024)
Total	77	136	170
Connected Solutions - Home Batteries	0.4	7.3	7.4
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	4.3	15.5	17.9
Connected Solutions - C&I Energy Storage	3.3	26	44
Connected Solutions - C&I Curtailment	69	87	101

The resulting top 10 measures under the BAU+ scenario are consistent with the order observed in the BAU scenario as presented in Table 3-4. However, all measures show a higher potential due to increased participation resulting from the higher customer incentives.

Table 3-4. ADR BAU+ Scenario – Top 10 Measures

Measures	2020 Preliminary (MW)	Achievable Potential 2024 (MW)
Large Commercial Curtailment	69	70.1
Medium Commercial Curtailment		10.8
Large Industrial Curtailment		17.8
Medium Industrial Curtailment		1.8
Large Battery Energy Storage - Daily	2.8	22.1
Residential HVAC DLC (BYOD only)	4.2	13.4
Large Battery Energy Storage - Targeted	0.41	19.1
Medium Battery Energy Storage - Targeted		1.4
Residential Battery Energy Storage	0.41	7.4
Electric Vehicle Service Equipment	0.09	4.2
All Other Measures[51]	-	2.1
Total	77	170

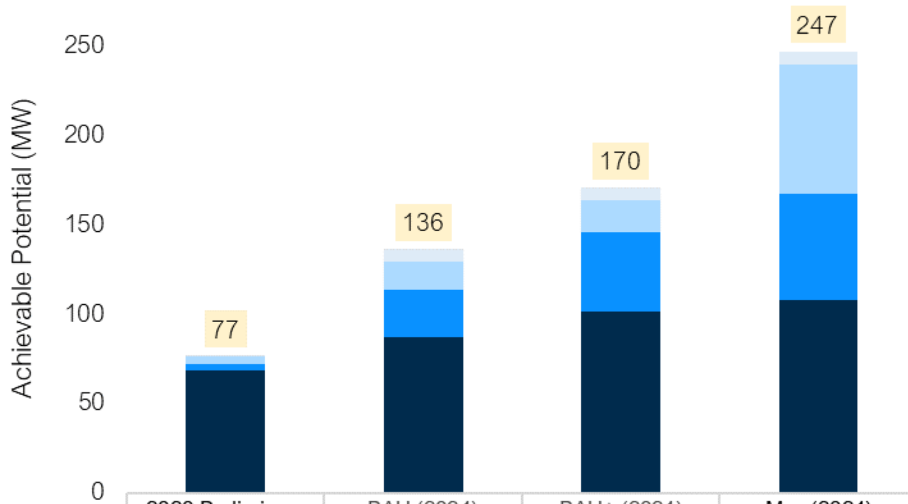
Max Scenario

The Max scenario expands the programs with new measures while maintaining the same level of incentives assessed under the BAU+ scenario.

When compared to the BAU+ scenario, the Max scenario results in a further increase in the ADR potential, as shown in Figure 3-6, offering an additional 77 MW of peak load reduction by 2024. Most of the gains come from the residential sector, where the potential is more than triple that of the BAU+ scenario.

[51] Detailed breakdown available in Appendix E.

Figure 3-6. ADR Max Scenario Achievable Potential – Breakdown by Program



	2020 Preliminary	BAU (2024)	BAU+ (2024)	Max (2024)
Total	77	136	170	247
Connected Solutions - Home Batteries	0.4	7.3	7.4	7.4
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	4.3	15.5	17.9	72
Connected Solutions - C&I Energy Storage	3.3	26	44	59
Connected Solutions - C&I Curtailment	68.6	87	101	108

The achievable potential for the top 10 measures under the Max scenario is provided in Table 3-5. The added programs and measures in this scenario generate a significant amount of additional potential, mostly concentrated in a few specific measures. Most notably, the Residential HVAC DLC program applies direct-install[52] approaches to add WiFi Thermostats to air-conditioners (including heat pumps) in homes that are not expected to install WiFi Thermostats – either on their own through natural adoption of the technology or a BYOD DR or EE program. By overcoming this barrier, the Residential HVAC DLC measure can unlock over 20 MW of additional potential. Other new measures such as residential pool pump control also contribute significantly to the overall potential in the residential sector. On the other hand, the C&I sector shows limited growth in potential with the modest increase (+15% relative to BAU+) coming from mainly auto-DR equipment installations. [53]

[52] It should be noted that this measure applies to the wider market and is not limited to the current Home Audit Program.
[53] Auto-DR can include both a retrofit to existing Energy Management Systems (EMS), enabling utilities to control the customer's load directly; or it could also be an installation of a compatible EMS.

Examples of Other Programs Offering Support for ADR Equipment

There is a growing number of examples where ADR program administrators have successfully expanded their pool of participants by providing the needed control equipment and devices within the ADR program offers:

- Baltimore Gas & Electric (BG&E) in Maryland conducts a successful demand response program targeting air conditioners (PeakRewards DLC program). As part of the program, BG&E installed a large number of smart thermostats and one-way switches on outdoor air conditioning units while maintaining program cost-effectiveness by balancing earlier investments with new installations.
- Arizona Public Service (APS) offers free Google Nest thermostats through their APS marketplace to customers enrolling in their demand response program (APS Cool Rewards program). They are also exploring ways to work with manufacturers to install new custom rate-enabled, TOU-compatible smart t-stats. Events would be triggered by thermostat settings provided by the thermostat manufacturer and defined to coincide with peak utility rate schedules.
- California Automated Demand Response programs (PG&E, SCE, and SDG&E) offer a combination of innovative rates, programs, and technology solutions where customers may choose among different options designed to fit their needs. As part of the programs, customers receive a large incentive to install the technology and receive technical support, but they need to agree to enroll in one of the utilities' ADR program options.

Table 3-5. ADR Max Scenario – Top 10 Measures[54]

Measures	2020 Preliminary (MW)	Achievable Potential 2024 (MW)
Large Commercial Curtailment	69	70.1
Medium Commercial Curtailment		10.8
Large Industrial Curtailment		17.8
Residential HVAC DLC (BYOD and Direct Install)	4.2	46.0
Large Battery Energy Storage - Daily	42.8	21.0
Large Thermal Energy Storage - Daily		8.0
Large Battery Energy Storage – Targeted	0.41	18.0
Large Thermal Energy Storage – Targeted		4.7
Pool Pumps	-	9.7
Residential Battery Energy Storage	0.41	7.4
All Other Measures[55]	0.09	33.8
Total	**77**	**247**

[54] The sum of top 10 measures will not match total program demand reduction since a large sway of measures are under "All Other Measures" (e.g., C&I Curtailment account for 108 MW, but only 99 MW is in the top 10 measures).
[55] Detailed breakdown available in Appendix E.

Portfolio Metrics

Figure 3-7 below provides the program costs for each scenario, broken down between upfront costs and annual running costs (both for summer and winter participation). Upfront costs include set-up costs for new programs, first-year enrollment incentives for new participants, and equipment purchase costs and incentives. Annual running costs cover annual administration and customer participation or performance incentives.

Figure 3-7. ADR Program Costs

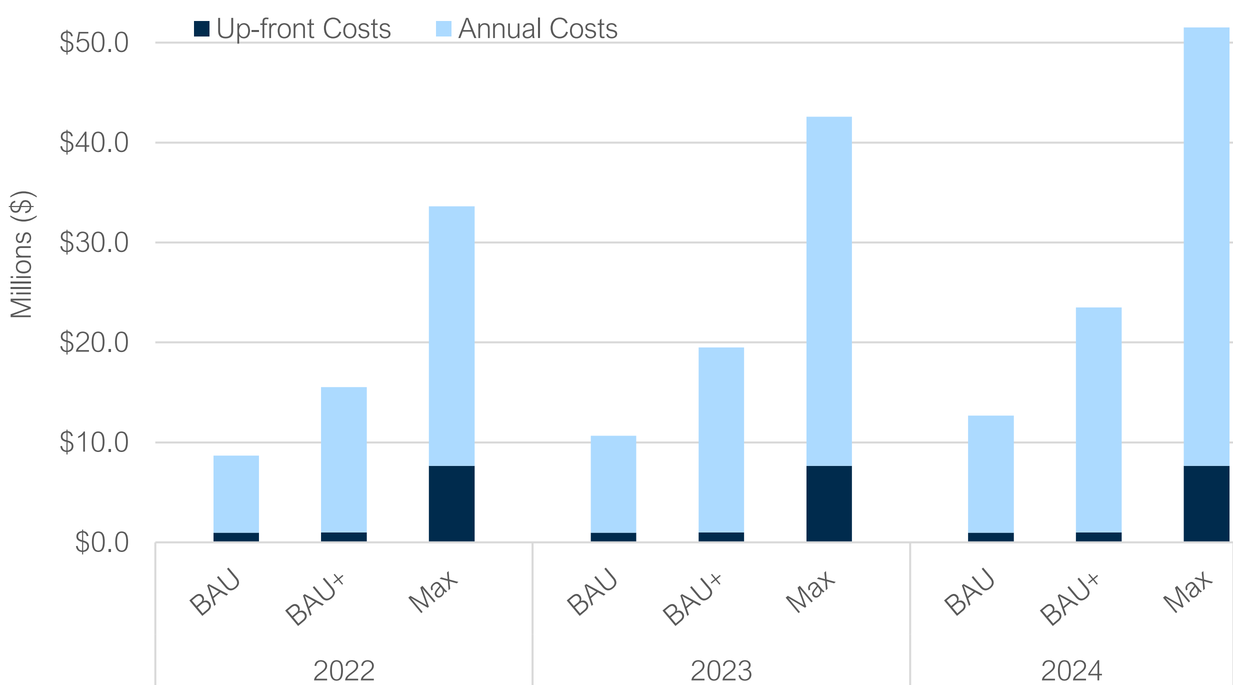


Table 3-6 provides the cost-effectiveness test results for each program and scenario accounting for the costs and benefits for both existing and newly added ADR program capacity in each year. Overall, these indicate that while the Max scenario provides the most peak reduction potential, the BAU and BAU+ scenarios have higher benefit-cost ratios.

A few further observations to note are:

- **The BAU scenario maintains the highest benefit-cost ratio** driven mainly by the low-cost large commercial curtailment measures.

- **The additional potential under the BAU+ incentive levels comes at a somewhat reduced overall benefit-cost ratio compared to BAU.** This is due to increased incentives, which encourage more participation but raise the cost of all peak savings reductions achieved.

- **The Max scenario has the lowest benefit-cost ratio, but it includes upfront costs that can help support peak savings for years after the study period.** The equipment costs associated with the direct install measures[56] as well as new program set-up and enrollment costs require a notable investment over the study period, which lowers the overall cost-effectiveness. However, the benefit-cost ratio of this scenario would be expected to rise after the study period as the portion of set-up costs decreases.

Table 3-6. TRC Results by Program and Scenario in 2024

Scenario	BAU	BAU+	Max
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	1.2	1.0	1.2
Connected Solutions - Home Batteries	1.2	1.1	1.1
Connected Solutions - C&I Curtailment	6.6	3.3	3.1
Connected Solutions - C&I Energy Storage	2.5	2.0	2.0
Portfolio	**2.6**	**2.1**	**1.7**

The Max scenario shows a potential of 247 MW of annual peak reduction by 2024, which is a threefold increase from 2020 through current active demand reduction programs.

The TRC decreases under the BAU+ scenario with the introduction of higher incentives; however, the TRC for Residential DLC increases under the Max scenario despite the additional cost of direct install measures. This can be explained by the introduction of new highly cost-effective residential measures in the Connection Solutions-Smart Homes category, such as pool pumps and the direct installation of smart thermostats.

C&I Curtailment shows the biggest drop in TRC across scenarios. Under BAU+, the TRC decreases by around 40%, mainly due to the higher incentives weigh on the TRC.

The Max scenario also results in a significant decrease in the TRC driven mainly by the additional equipment cost associated with new direct install measures. However, these investments can be leveraged for many years by maintaining program participation incentives after 2024. Therefore, up-front costs will diminish once the program has reached equilibrium participation levels (i.e. after the ramp-up phase), and it would be expected that the overall TRC in the Max Scenario would increase in the post-2024 period as a result.

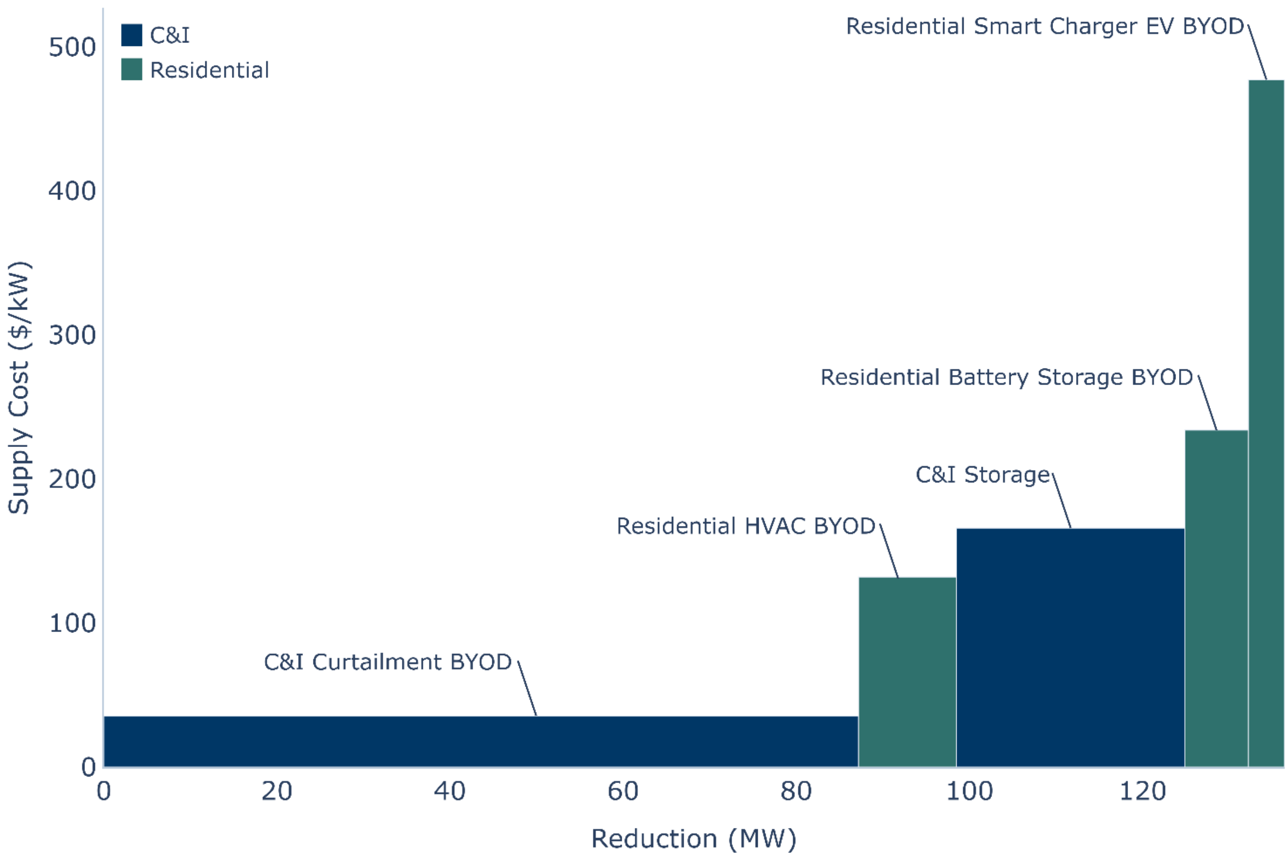
Measure Level Costs

Figure 3-8 shows the BAU scenario's supply cost curve which highlights the costs for realizing an increment of demand reduction (y-axis) and the cumulative achievable potential in 2024 (x-axis). Measures are bundled into categories based on corresponding sectors and technologies. The measures

[56] Detail results, per measure, is available in Appendix E.

costs are normalized to 9-year program life, accounting for enrollment and equipment costs, participant attrition and re-enrollment costs, and annual incentives.

Figure 3-8. ADR Supply Cost Curve – BAU Scenario



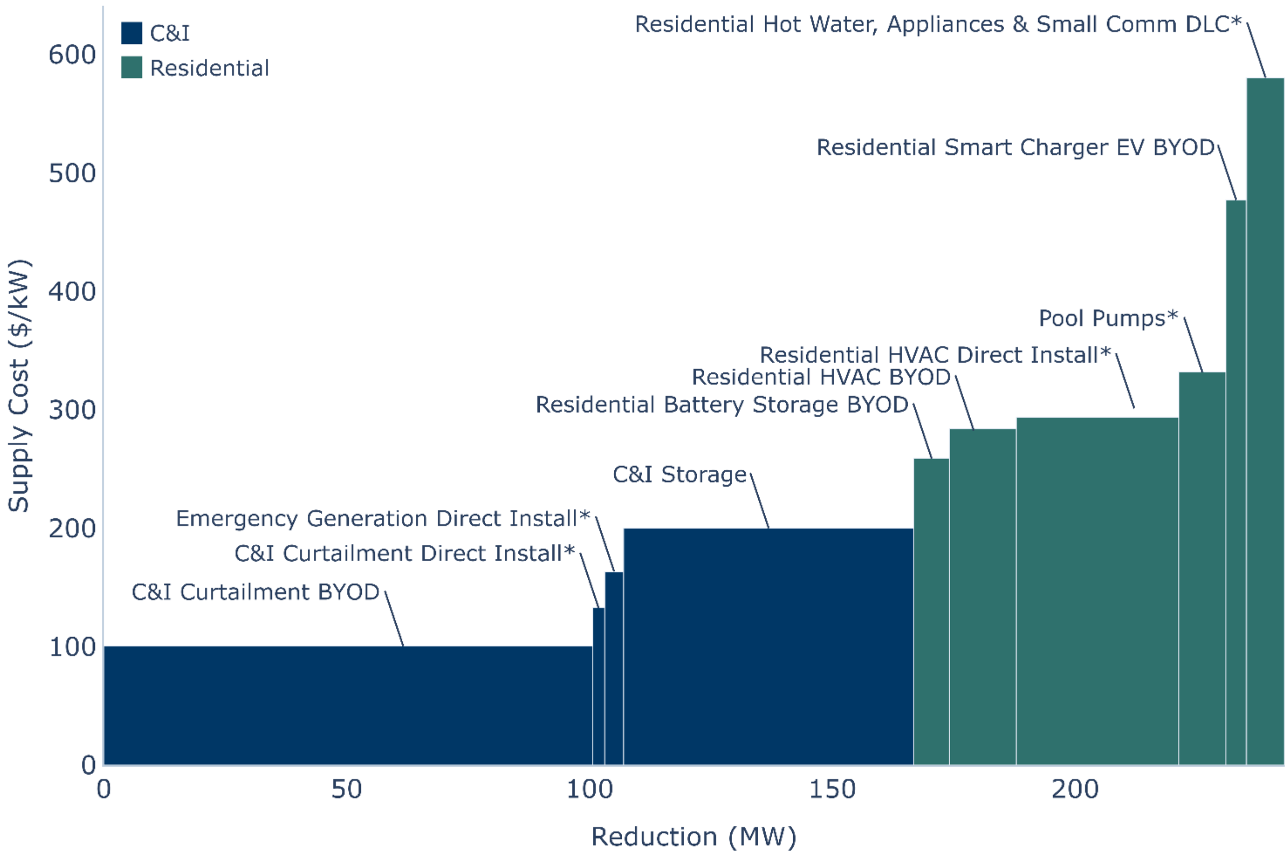
C&I Curtailment has the lowest supply cost at around $35/kW and makes up the majority of the potential with around 90 MW in 2024. Residential HVAC BYOD has the second-lowest cost at around $130/kW with a potential of around 11 MW. While C&I Storage has a higher cost at $165/kW, it has the second-highest potential at 26 MW.

Residential EV Smart Chargers have a significantly higher cost ($475/kW) due to the high incentives and relatively low benefits associated with this measure. EV charging loads primarily occur in the evening and are not expected to be coincident with the peak hour. If non-peak hour benefits, such as energy arbitrage, were accounted for, then EV smart chargers may offer improved cost-effectiveness.

Overall, the weighted average of the supply cost for the BAU scenario is around $90/kW driven by a handful of highly cost-effective measures such as C&I curtailment. A detailed breakdown of the cost per measure is available in Appendix E.

Figure 3-9 shows the BAU+ and Max scenario's supply curve. Because BAU+ and Max apply the same incentive levels, the measure cost per kW of peak savings reduction is identical in the two scenarios. However, some measures are only applied in Max scenario's expanded programs. The new measures added under the Max scenario are grouped separately in the supply curve below and are indicated with an asterisk.

Figure 3-9. ADR Supply Cost Curve – BAU+ and Max Scenarios



Note: Measures indicated by an asterisk (*) are measures introduced in the Max scenario.

While C&I Curtailment BYOD remains the lowest cost category at around $100/kW, the cost for this measure in the BAU+ and Max scenarios is four times higher than under the BAU scenario, while only delivering an additional 10MW of potential.

The Max scenario introduces new C&I measures such as Curtailment Direct Install and Emergency Generation Direct Install. Both measures have low supply costs, however, only add around 6 MW in potential to the C&I sector. C&I Storage on the other hand significantly contributes to the overall potential, doubling from the BAU scenario with only a modest increase (20%) in the supply cost. As mentioned earlier in this analysis, the effectiveness of the C&I Battery storage under the BAU+ scenario's higher incentive levels is driven by its ability to encourage customers to purchase batteries to participate in the program.

Overall, the average supply cost for the BAU+ and Max scenarios are around $140/kW and $210/kW, respectively. Max scenario costs are driven by the cost associated with cost-effective measures in the C&I sector and residential HVAC direct install measures. A detailed breakdown per measure is available in Appendix E.

3.3 Key Takeaways

Based on the results of this analysis, the achievable peak load reduction from ADR programs is projected to reach 136 MW to 247 MW (BAU to Max scenario range) in 2024, representing up to 4.6% of Eversource's projected system-wide peak load in that year. 77 MW of this potential is currently being captured by Eversource's ADR program enrollment to date, which indicates that up to 170 MW of additional potential could be achieved by expanding the range of ADR measures and increasing incentives.

The BAU scenario potential is estimated to grow from 102 MW in 2022 to 136 MW in 2024, which represents 2.5% of Eversource's statewide peak demand in 2024. This scenario focuses on Eversource's current programs[57] and uses the DROP model's propensity curves to determine the maximum equilibrium participation that the program could achieve through ongoing marketing and outreach without altering incentives or measures offered. Program spending under this scenario is projected to increase from $8.6 million in 2022 to $12.6 million in 2024.

The BAU+ scenario assesses the impact of increasing incentives over the BAU scenario, reaching 170 MW in 2024. By adding new measures, while maintaining the BAU+ incentive levels for currently offered ADR programs, the Max scenario shows a further increase to 247MW of achievable potential by 2024.

Table 3-7 details the achievable potential in 2024 for each of the assessed scenarios, as well as the average portfolio TRC ratio results and annual program costs.

Table 3-7. ADR Potential, TRC Ratio, and Annual Spending in 2024 by Scenario

Scenarios	BAU	BAU+	Max
Achievable Potential (2024)	136 MW	170 MW	247 MW
Average Portfolio TRC (2024)	2.6	2.1	1.7
Portfolio Annual Spending (2024)	$12.6 million	$23.5 million	$51.5 million

[57] Based on the 2020 active demand reduction programs

Sensitivity to Electric Capacity Related Avoided Costs

When interpreting the achievable potential results presented here, it is important to note that the ADR potential is highly sensitive to changes in the avoided costs, much more so than efficiency or heating electrification potentials. This is largely driven by two factors.

First, the capacity-related avoided costs are essentially the only value stream included in the assessment of ADR cost-effectiveness under the TRC in Massachusetts. Conversely energy efficiency and heating electrification deliver both energy and capacity savings benefits, as well as substantial non-energy impacts in many cases that can buffer TRC results against a change in any single avoided cost category. As a result, minor changes or uncertainty in the capacity-related avoided costs may cause some ADR measure TRC values to fall below or increase above 1.0.

The second reason is that in this study ADR measure incentive levels under the BAU+ and MAX scenarios are set based on the avoided capacity cost-related benefits. Thus, changes to the avoided costs would lead to adjustments in the ADR incentive levels, which could increase or decrease program participation accordingly. For efficiency and heating electrification, the incentive levels are set as a portion of the equipment's incremental costs and therefore are not impacted by changes to avoided costs.

Table 3-8 below benchmarks the achievable ADR potential relative to this study against results in other relevant summer peaking jurisdictions. Overall, these results show that Eversource's ADR potential is similar to that assessed recently for Rhode Island, albeit under a shorter time frame. Notably, the Rhode Island potential was assessed under lower avoided costs per kW of peak load reduction. The 2021 Avoided Energy Supply Costs (AESC) for Massachusetts (≈$360/kW) appear to drive a notable increase in ADR potential relative to the other benchmarks, which, as seen below, all have avoided costs below ≈$300/kW.

Table 3-8. Benchmarking of the Achievable ADR Potential (Mid-Max Scenarios) to Other Summer Peaking Jurisdictions

	Eversource (MA) (2021)	Rhode Island (2020)	National Grid (MA) (2018)	Pennsylvania (2020)
Portion of Peak Load	2.5% - 4.6% (3 years up to 2024)	3.6% - 4.5% (6-year outlook)	2.1% - 2.5% (3-year outlook)	0.75% (6-year outlook)
Avoided Costs	≈$360 / kW	≈$200 / kW	≈$290 / kW	≈$40 / kW

Based on the findings in this study, three key takeaways emerge:

- **Eversource's current programs are effective at capturing a significant portion of the ADR potential, however, there remains room for further growth.** The current ADR measures are capturing a large share of their existing potential (about 60% of the 2024 BAU potential). However, through increased incentives and an expanded pool of ADR measures, Eversource could increase impacts by 200% in 2024 (under the Max scenario) in a cost-effective manner. The bulk of this growth in potential can be attributed to residential DLC programs, C&I energy storage, and C&I curtailment.

- **The current focus on BYOD approaches for residential HVAC measures appears to limit the program's potential.** Because residential cooling is a key driver of the ISO-NE annual peak, connected thermostats that control AC units can play an important role in curtailing the peak demand. The study shows that offering connected thermostats to customers who would not adopt these on their own could help unlock significant potential. Broadly speaking, two approaches can help improve the adoption of connected thermostats and thereby expand ADR program participation:
    - Offering smart thermostats via a Direct Install program specifically for ADR programs could help overcome some market barriers to thermostat adoption and ADR program participation. Although this unlocks the potential quickly, it does carry notable upfront costs, and there is some uncertainty as to how long customers will remain with the program if they are not required to enter into a multi-year participation contract.
    - Further thermostat adoption can also be encouraged by integrating marketing and incentive offers between ADR and efficiency programs. This approach may lead to a slower penetration rate, but it would likely result in a higher benefit-cost ratio overall.
- **Battery storage offers a large swath of cost-effective ADR potential.** The analysis indicates that there is significant room to grow these programs, particularly in the C&I sector. Moreover, by offering higher ADR incentives to C&I customers, Eversource may encourage further adoption of battery technologies among its C&I customers, which can further expand the program potential. This trend is expected to gain further momentum beyond the study period as battery costs continue to decrease each year.

Overall, these findings indicate that both expanding to new measures and increasing incentives can play an important role in increasing active demand reduction potential in Eversource's Massachusetts service territory.

4 Heating Electrification

4.1 Overview

The heating electrification (HE) component of this potential study provides an assessment of the market opportunity for electrifying existing buildings that contain gas, oil, and propane-fired primary space and water heating systems among Eversource's residential and commercial electric customers. It also includes an assessment of the potential to encourage electric heating systems to be installed in newly constructed buildings.

The analysis focuses on the ability of heat pump technologies to displace combustion-fired heating systems. Heat pump adoption in place of existing electric resistance heating systems is considered an efficiency measure and is therefore assessed within the energy efficiency (EE) chapter of this report.

Approach

The costs and benefits (from both the TRC and customer's perspective) of heating electrification are not only dependent on the baseline heating equipment, the heat pump's costs, and the difference in energy rates and avoided costs, but also on:

- The decision to choose a **dual fuel** (hybrid) or **all-electric** system;
- The **baseline cooling system** - which may be the only equipment being replaced;
- The **size of the heat pump** - each additional ton increases costs but provides varying benefits;
- The **integrated control strategy** between the heat pump and its backup system (fuel or electric);
- The **remaining useful lives** of both heating and cooling systems;
- The **local climate**, which impacts the capacity and efficiency of heat pumps.

To account for this, Dunsky's Heating Electrification Adoption Model (HEAT) assesses multiple permutations of replacement case, sizing strategy, and control strategy for each combination of baseline heating system, baseline cooling system, and heat pump technology. HEAT simulates the baseline and heat pump cases to calculate the energy performance and full cost, which allows the model to yield the incremental costs and savings for thousands of modeled cases. Additional details on HEAT's modeling approach are provided in Appendix C.

Achievable Potential Scenarios

Three achievable potential scenarios are assessed to determine the impact of varied incentive levels on the adoption of heat pumps among Eversource's electric customers. Table 4-1 summarizes the BAU, BAU+, and Max scenarios as applied within the heating electrification module. It should be noted that these scenarios do not account for the impact of other possible program enhancements (e.g., increased marketing and contractor outreach) or interventions by actors other than Eversource (e.g., state-level actions to promote heat pump adoption toward the target of 1 million housing units converted to heat pump systems by 2030).[58]

Table 4-1. Heating Electrification Achievable Program Scenario Descriptions

BAU	Applies incentives **in line with Eversource's 2019-2021 Energy Efficiency Plan** to simulate business as usual: • $1,250 a ton for air-source, $3,000 a ton for ground-source heat pumps. Incentive levels are capped at 90% of full heat pump installation cost.[59] • HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). • Measures not currently offered within programs are also included (gas, units > 5.4 tons).
BAU+	Increases incentives **above and beyond** levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: • $1,875 a ton for air-source, $4,500 a ton for ground-source HPs. • Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives further above and beyond levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives **are twice the BAU levels**: • $2,500 a ton for air-source, $6,000 a ton for ground-source HPs. • Incentive levels are capped at 90% of full heat pump installation cost.

[58] "*1,000,000 housing units are converted to heat pump system for heating and cooling, mostly from fuel oil but some from natural gas*", from GWSA Implementation Advisory Committee Meeting, August 7, 2020. Source: https://www.mass.gov/doc/presentation-slide-deck/download

[59] Current programs provide incentives as a function of heat pump capacity and not incremental cost. Moreover, incremental costs are highly variable from case to case due to the combination of heating *and* cooling system replacements. Incentives could therefore exceed the incremental cost, depending on the baseline.

Program Enhancements and Measure Adoption

Energy efficiency programs typically combine incentives (or rebates) to improve customer cost-effectiveness, along with enabling strategies, such as contractor training, marketing and education, and other approaches that can help reduce market barriers to widespread adoption of efficient technologies.

There is a substantial body of empirical evidence available to help quantify customers' willingness to pay for an efficiency upgrade, which is captured in the adoption curves applied in this study to predict the impact of varying incentive levels on the achievable potentials. Conversely, assessing the impact of specific enabling strategies can be more difficult to quantify, and there is little empirical data available on how specific strategies may impact program performance.

The rate of adoption of heat pumps over time considering local barriers and market characteristics is captured through Bass diffusion curves, where new adopters are classified as either innovators or imitators. Key model parameters are calibrated using historical uptake trends from programs. Evolving market barriers are therefore implicitly captured through these adoption curves.

Considering these factors, this study focuses on the achievable potential scenarios on varied incentive levels but does not account for changes to other program features or enabling strategies.

Benchmarking of Inputs and Results

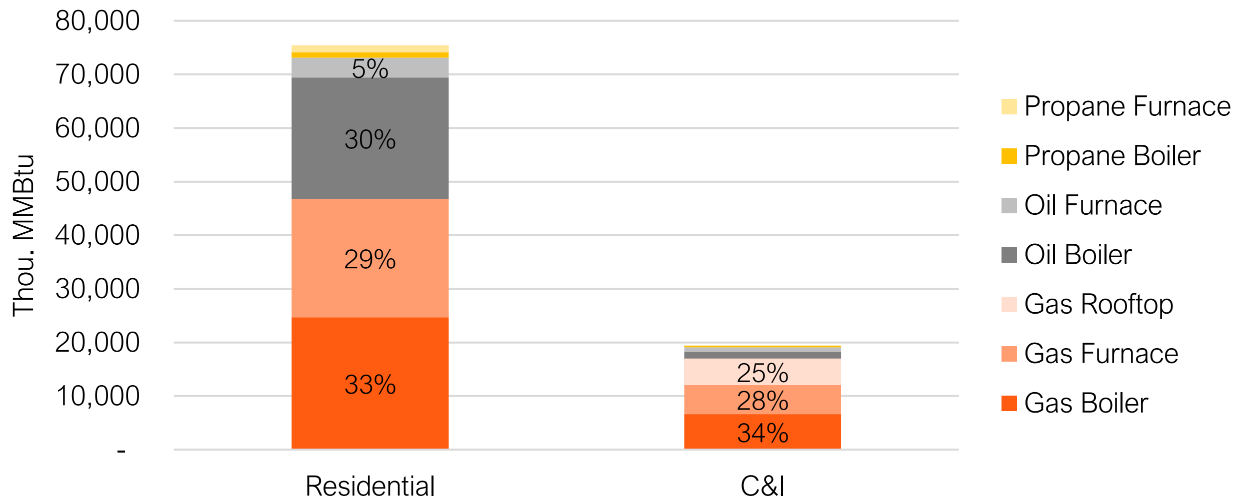
Throughout this chapter, results are benchmarked to evaluated savings from Eversource 2019 and 2020 (up to October) Plan-Year Report ("2019 Results", "2020 Results") as well as the savings planned for 2021 in their 2019-2021 Energy Efficiency Plans ("2021 Plan").

2019 and 2020 Results benchmarks are derived from the detailed workbooks provided with each utility's 2019 and 2020 Energy Efficiency Plan-Year Report. 2021 Plan benchmarks are derived from the BCR model workbooks provided with each utility's 2019-2021 Electric Three-Year Energy Efficiency Plan.

4.2 Results

To provide context for our results, Figure 4-1 presents the estimated fuel consumption for space heating by fuel and baseline heating equipment. The technical potential for heating electrification will be closely related to these shares of fuel, heating equipment, and sector.

Figure 4-1. Estimated Annual Space Heating Energy Consumption by Fuel and Baseline Heating Equipment



Note: Estimates are based on the baseline data regarding fuel penetration and average floor areas for the modeled archetypes, as well as the heating loads and baseline heating equipment efficiencies as detailed in the methodology appendix.

The estimated annual consumption is dominated by residential customers. While C&I buildings are larger and thus have higher heating loads per customer, this factor is outweighed by the number of residential customers. The majority of residential heating is provided by gas (62%), but oil boilers also provide a significant portion (30%). Gas heating (i.e., boilers, furnaces, and rooftop units) completely dominates C&I, providing 87% of estimated total space heating.

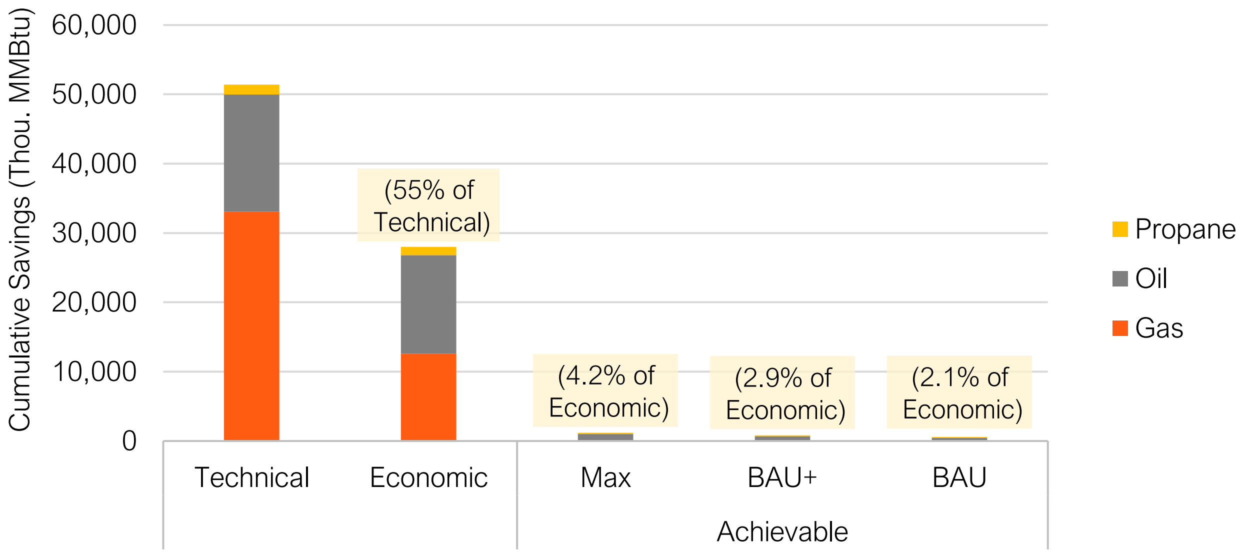
Figure 4-2 presents the technical, economic, and achievable potentials for heating electrification, expressed in terms of cumulative 2024 building-level fossil fuel savings.

The technical opportunity for fuel savings through heating electrification is extremely large when compared to other savings streams. It is nearly an order of magnitude larger than gas and delivered fuel energy efficiency technical potential. This is primarily driven by the fact that electrification measures can feasibly displace most, if not all, of a building's fuel consumption, while efficiency measures only reduce consumption by a portion of the current amounts. However, it should be noted that heating fuel is displaced with electricity which is itself partly generated by natural gas.

The technical potential includes opportunities related to end-of-life replacements of existing heating and cooling equipment, as well as some early replacement opportunities for cooling equipment (mostly related to existing AC units being replaced by heat pump equivalents). It also includes the potential to avoid installing combustion heating systems in newly constructed buildings or reduce their consumption through partial electrification. Additional detail is provided in section C.3.5 of the appendix.

The economic potential is defined as the sum of all opportunities that yield a TRC greater than 1.0, and it represents 55% of the technical potential. Gas replacements account for almost all of the difference between the technical and economic potential, as they do not typically pass the TRC cost-effectiveness screening. As will be shown throughout this analysis, the few gas measures that do pass the TRC screen *and* also prove cost-effective for customers are found in C&I buildings.

Figure 4-2. HE 2024 Cumulative Technical, Economic and Achievable Potential



The achievable potential is very small relative to the economic potential because it is very difficult to entice customers to electrify. A portion of the drop between economic and achievable potential is related to poor customer economics for some measures, especially those with a gas-fired baseline system since gas is a relatively cheap heating fuel. In other words, given current fuel and electric prices, customers heating with gas would pay more to heat their homes with electricity under most conditions. However, in addition to cost-effectiveness challenges for gas baseline measures, market barriers to heating electrification are also very high for all fuels, and adoption is limited due to the following factors:

- Heat pumps are a relatively new technology in Massachusetts – especially cold-climate units.[60] Many contractors have little experience installing them and may be reluctant to recommend them.[61]
- Customers are inexperienced in using heat pumps efficiently.
- Integrated controls are a new and still developing technology.
- Customers are unfamiliar with the economics of heat pumps.

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[60] "Cold climate" refers to air-source heat pumps which are designed to provide efficient heating at low outdoor air temperatures – even below 5°F. NEEP created a cold climate heat pump specification and product list which is usually used to define cold climate heat pumps: https://neep.org/high-performance-air-source-heat-pumps/ccashp-specification-product-list

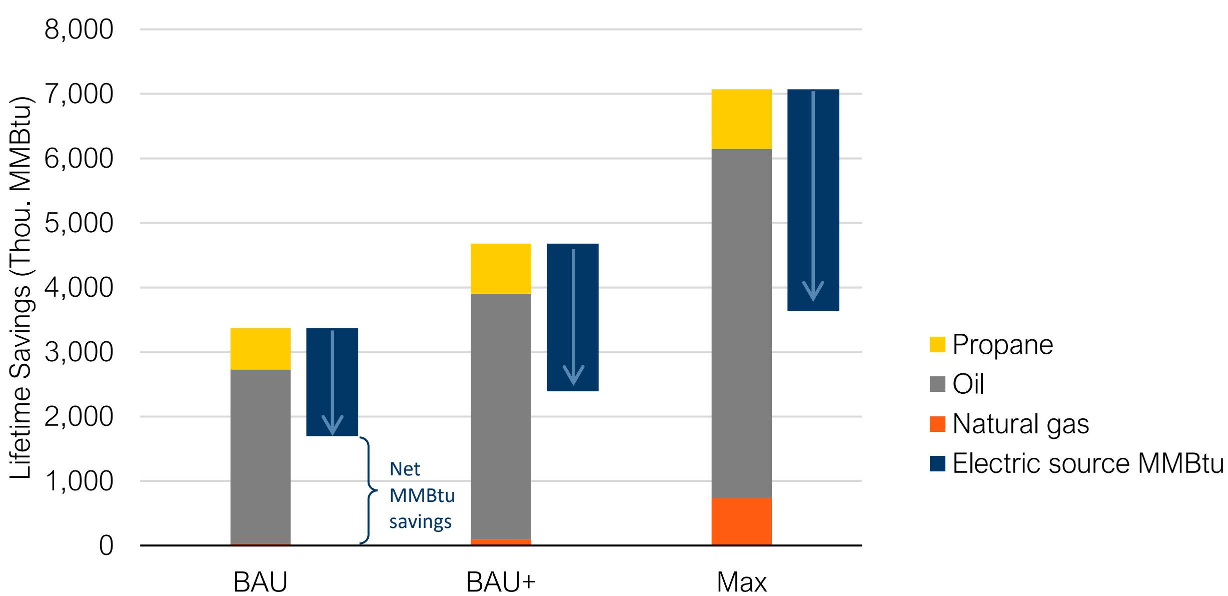
[61] NMR & DNV GL, *Evidence for Market Effects from Support for Ductless Mini-split Heat Pump Integrated Controls*, April 15, 2020. https://ma-eeac.org/wp-content/uploads/MA-19X09-B-INTCTRME_Evidence-for-MEs-from-DMSHP-ICs-Report_Final_2020.4.15.pdf

The HEAT model's adoption engine is driven both by customer economics and market barriers. The change in market barriers over time is represented using a Bass diffusion curve which is calibrated to 2019 and 2020 program results (additional methodological detail is provided in Appendix C). Results show that even in cases where heating electrification is economically beneficial to customers, the influence of market barriers restricts adoption.

Overall Program Savings

Figure 4-3 provides a closer view of the three achievable potential scenarios and presents the 2022-24 average lifetime building-level fuel savings achieved each year along with the electric source MMBtu equivalent of the increased electric consumption resulting from electrification.

Figure 4-3. Lifetime MMBtu Savings and Electric Source MMBtu Increases (2022-24 Average)



The potential in all three achievable scenarios is dominated by oil, which is driven by the high penetration of oil boilers among residential customers and the relatively favorable economics of replacing oil-fired heating systems. Propane customers are disproportionately represented in achievable potential due to favorable customer economics and because the customer economics are already strong under the BAU scenario. Increasing the incentive levels in BAU+ and Max has a limited effect on propane adoption for this reason. Despite gas being the most widely used heating fuel among Eversource's customers, heat pump adoption in gas-heated buildings remains limited due to poor customer economics.

Figure 4-3 also shows that heating electrification is expected to drive a net reduction in source energy consumption when accounting for the associated increase in fuel consumption required to supply the additional electric demand (i.e., electric source MMBtu). Under each scenario, the anticipated increase in electric generation fuel consumption is less than half the decrease in building-level heating fuel consumption.

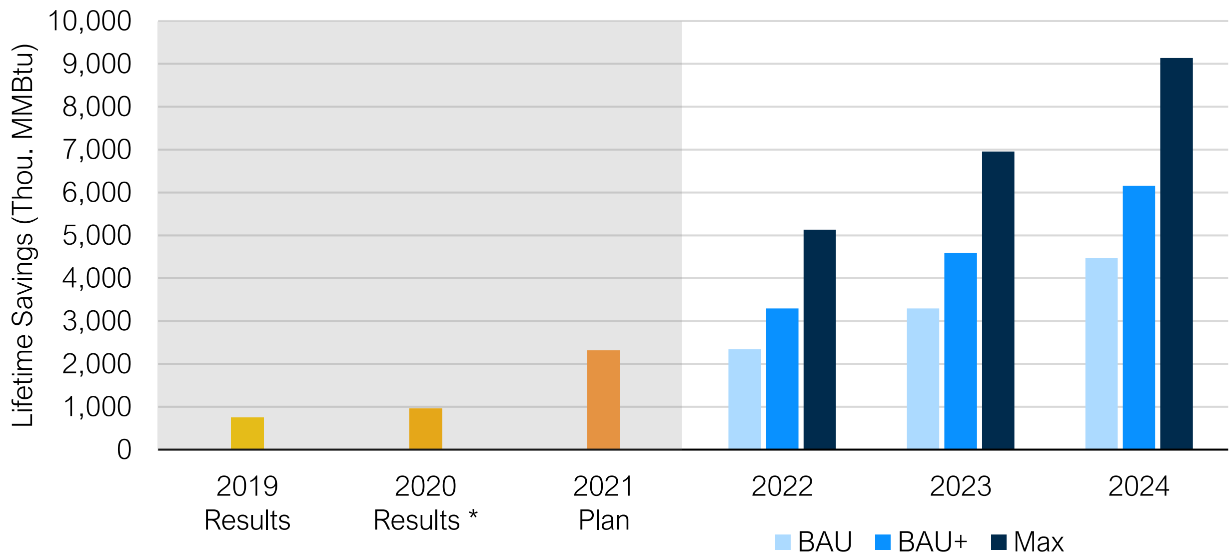
The site-to-source conversion factor of electricity is based on the energy consumed at the generation source (generally gas-fired power plants). Overall, because of the high efficiency of heat pumps, net MMBtus are reduced through heating electrification.

Building-level vs. Net Source MMBtu Savings

The analysis for the remainder of this chapter focuses on program savings expressed as **building-level fuel savings**, excluding the increase in energy consumption related to additional electricity generation from heating electrification apart from the portfolio metrics which include costs and benefits per **net source MMBtu savings.** Grid impacts (in kWh terms) from heating electrification are presented later in this chapter as well.

Figure 4-4 shows a comparison of annual results for all three years of the potential study and all three scenarios, compared to program benchmarks.

Figure 4-4. Lifetime Building-level Fuel Savings by Year



Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

One key insight is that energy optimization offerings show continued growth in potential under all scenarios. As heating electrification is an emerging technology, the model projects large year-over-year growth that is in line with that witnessed in Eversource's programs. This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like ground source heat pumps (GSHP), the emergence of new C&I measures, and steadily improving customer economics for delivered fuels.

The model has been calibrated to past program results, as well as the annual program growth rates. The resulting BAU achievable potential for 2022 is significantly larger than 2019 and 2020 results, but falls slightly short of the 2021 Plan for two reasons:

- 2020 program results show a slower growth rate from 2019 results when compared to Eversource's 2019-2021 Energy Efficiency Plan, which might be the effects of the COVID-19 pandemic. Since the 2020 program results are included in the calibration of our market barriers, it does impact the 2022 to 2024 results. A sensitivity analysis around COVID-19 is presented on page 130.

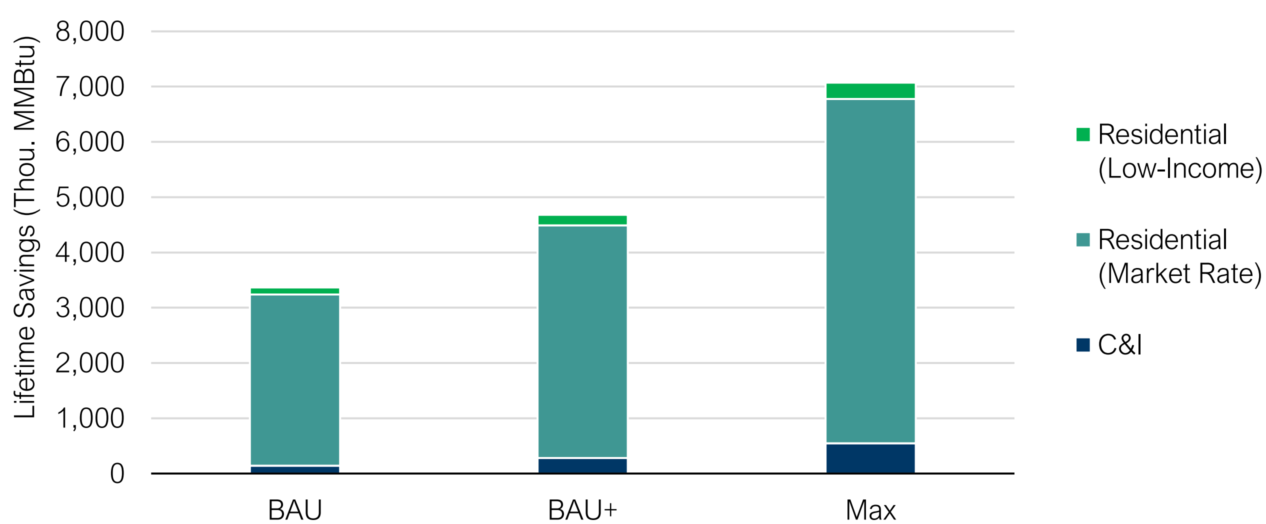
- As presented in the next sections, the ductless mini-split heat pump (DMSHP) is a top measure and while the TRM uses an average 2.5-ton unit for partial replacements, we have modeled both single-head units (1-ton) and multi-head units (2.5-ton), which lowers the average savings per unit compared to the TRM. The analysis assumes one outdoor unit per household.

Overall, regardless of the scenario and associated incentive levels, the results show that steady growth in heating electrification will likely occur over the study period, which is consistent with observed program trends in recent years. However, like any emerging technology, there is inherent uncertainty in projecting the future growth of heating electrification. That uncertainty was addressed, to the degree possible, by calibrating the model to account for the growth between 2019 and 2020 program results. Moreover, the relatively short potential study period of only three years limits the impact of market growth uncertainty on the savings potentials.

Savings by Sector

Residential market-rate customers present the largest electrification opportunity as shown in Figure 4-5, which corresponds with the customer base and heating fuel consumption breakdown. While the C&I sector represents an expansion opportunity for the program, the residential sector produces 96% of achievable savings under the BAU scenario.

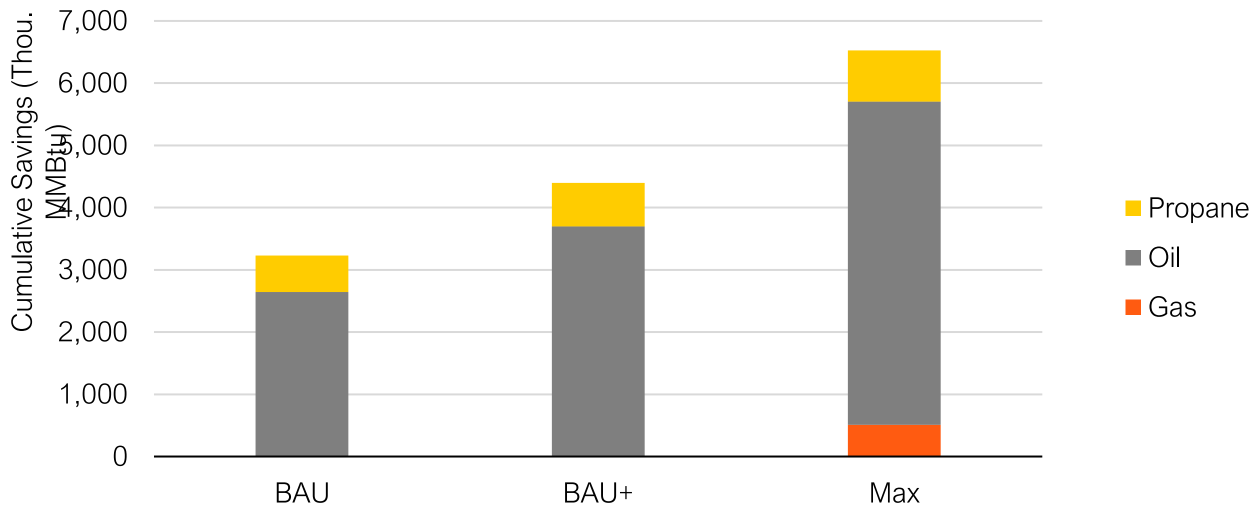
Figure 4-5. Lifetime Building-level Fuel Savings by Sector (2022-24 Average)



Residential Savings

Figure 4-6 presents residential 2022-24 average lifetime fuel savings from heating electrification broken down by fuel type.

Figure 4-6. Lifetime Residential Building-level Fuel Savings (2022-24 Average)

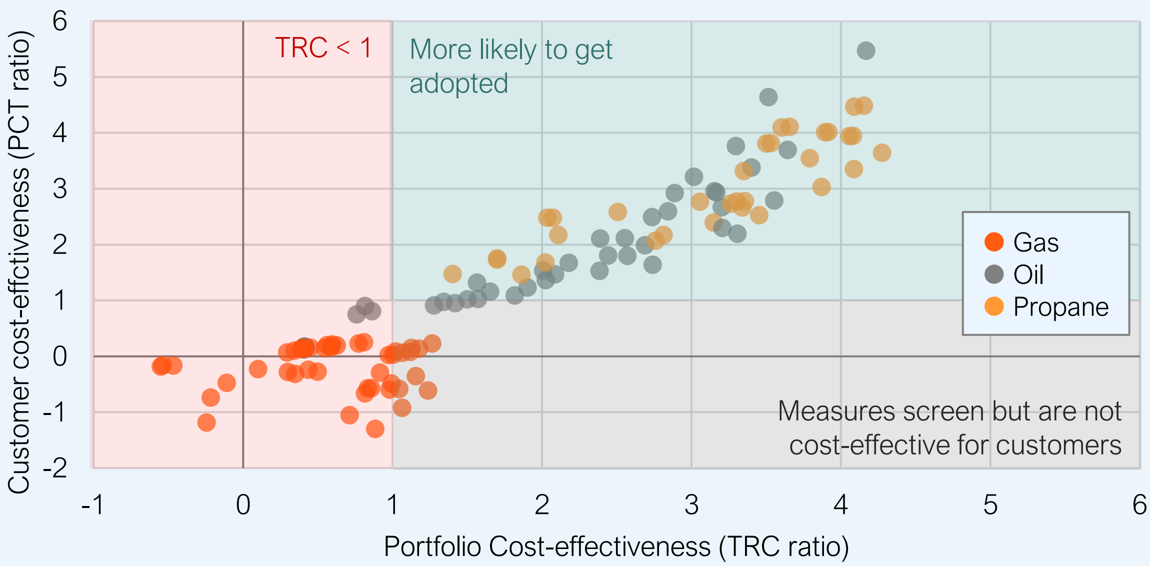


The results show that oil savings dominate under all achievable scenarios. Conversely, gas replacement measures only see adoption in the Max scenario, where incentive levels are high enough to support customer adoption of GSHP replacements of gas furnaces. Oil savings potential increases with additional incentives, while propane savings remain relatively flat because customer economics are quite favorable even under BAU incentive levels.

Customer vs. Portfolio Cost-Effectiveness

Figure 4-7 highlights the relationship among customer economics, portfolio cost-effectiveness, and base system fuel type. It includes the full set of heating electrification measures applied under the BAU scenario to an archetypal existing Eastern MA single family home in 2022. Customer economics are expressed by the Participant Cost Test (PCT), which compares the costs and benefits of the customer installing the measure. Three regions in the chart are highlighted: measures that do not pass TRC cost-effectiveness in red, measures that screen but whose adoption is hampered by their low customer cost-effectiveness in grey, and measures more likely to get adopted in green.

Figure 4-7. Cost-effectiveness results from every measure case in existing single-family homes in the East Massachusetts region.



Overall, the results demonstrate the following trends which are reflected in the adoption breakdowns across the residential sector:

1. **Gas measures:** Most do not pass the TRC screen, and those which do show low customer cost-effectiveness – many even providing a net increase in customer bills (negative benefits). As a result, there is no residential gas measure adoption under the BAU scenario.
2. **Oil measures:** Shows a scatter with most measures passing the TRC screen, and a range of PCTs, many showing very high customer cost-effectiveness. The high PCT oil measures drive the majority of savings in this study, due to their cost-effectiveness and the high penetration of existing oil heating systems.
3. **Propane measures:** All propane measures pass the TRC screen *and* show favorable PCT values, and therefore show relatively high adoption rates. The relatively low adoption of propane-replacing heat pumps is largely a reflection of the low penetration of propane heating systems and market barrier to heat pumps in general.

Increasing the incentive levels under the BAU+ and Max scenarios would effectively drive each dot upwards, making them more attractive for customers without impacting portfolio cost-effectiveness as expressed by the TRC.

Residential Savings by Market Segment

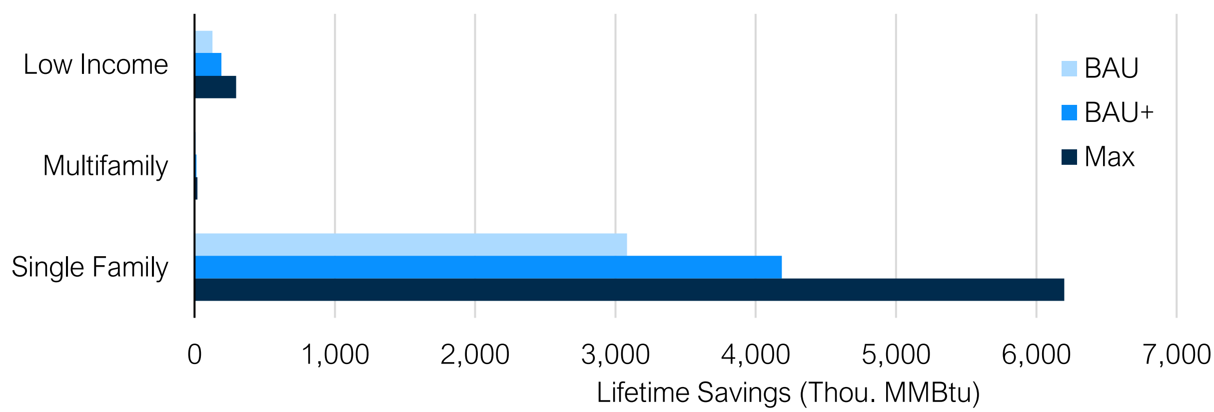
Most of the residential potential is in the single-family segment as shown in Figure 4-8. This segment is disproportionately represented due to a combination of the high penetration of delivered fuels in this market segment and the favorable customer economics for a handful of key electrification opportunities.

Multifamily buildings[62], on the other hand, show close to no potential for two main reasons:

- They are mostly dominated by gas, which shows poor customer cost-effectiveness;
- Central systems for larger multifamily buildings are modeled under the lodging C&I segment.

Low-income households also show low potential illustrating the higher barriers for this segment due to financial limitations and the generally higher prevalence of rentals among low-income customers.

Figure 4-8. Residential Lifetime Building-level Fuel Savings by Market Segment (2022-24 Average)



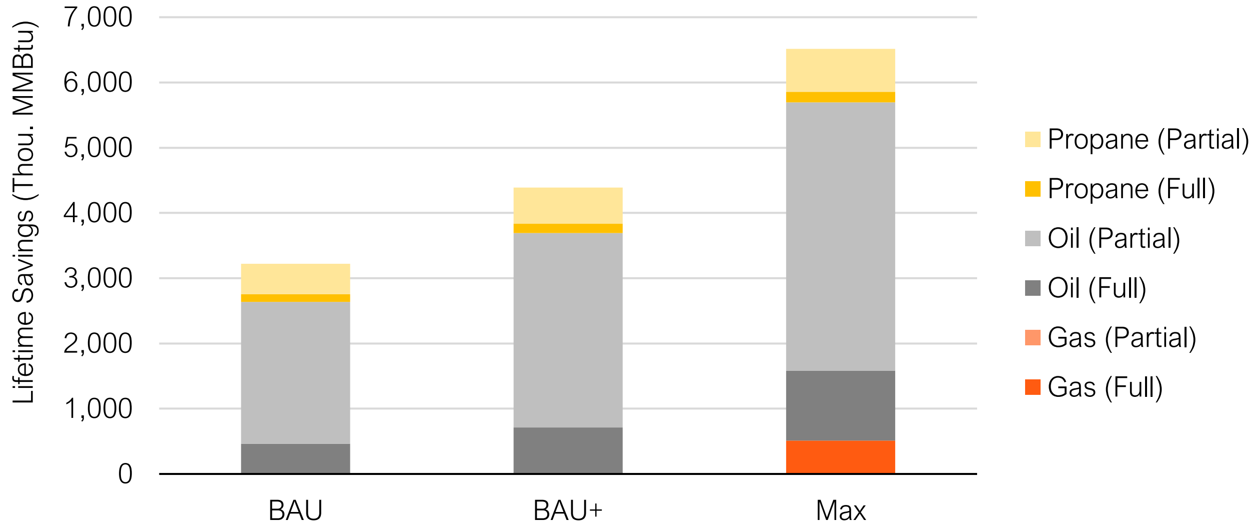
Residential Savings by Baseline Heating Equipment

Figure 4-9 presents the breakdown of fuel savings by fuel and full or partial replacements. These two competing replacement types are defined as follows:

- Partial replacements: the addition of a heat pump in a building while keeping the existing fuel-based heating equipment as a supplemental source of heat, resulting in a dual-fuel or hybrid system. A portion of the fuel consumption for heating is displaced.
- Full replacements: replacement of the existing fuel-based heating system with a heat pump and an electrical backup, resulting in an all-electric system. All of the fuel consumption for heating is displaced.

[62] As described in Appendix A, multifamily buildings represent those with 4 or more units.

Figure 4-9. Residential Lifetime Building-level Fuel Savings by Baseline Heating System and Full/Partial Replacement (2022-24 Average)



The results show that despite the ability for full replacement measures to generate higher fuel savings per participant, partial replacements far outpace full replacement measures. This is largely reflected in the 2019 and 2020 program results, which show a small but not insignificant uptake of full replacements.

While full replacements are more cost-effective than partial replacements, two main reasons explain the domination of partial replacement measures[63]:

1. The first is that partial replacements face **fewer barriers to adoption** than full replacements due to:
   - Lower project complexity (e.g., an AC unit simply being replaced by a heat pump equivalent);
   - Less resistance to change from the customer's point of view, compared to full electrification where some clients see two new heating systems (the heat pump *and* the electric backup);
   - Partial replacements have been more heavily emphasized by the program to date, which might explain part of the domination of partial measures in 2019 and 2020 actual program results. The adoption diffusion curves have been calibrated to these results.
2. The second is that we consider **early retirement opportunities** for space cooling systems in addition to cooling and heating system burnouts. A cooling system reaching two-thirds of its expected useful life (EUL) is considered a replacement opportunity in HEAT. As the economics might not be favorable for a certain early replacement case, those who do not adopt an electrification measure are simply considered again the next year by the model, when the

[63] The improved cost-effectiveness for full replacement measures is mainly due to the electric backup being cheaper than its fuel-fired equivalent, but also because of the different control strategies used for partial and full replacements which lead to the heat pumps being used more in the full replacement measure than in the partial replacement – for an equivalent installed capacity, the heat pump is not restricted to operating only above a switchover temperature in full replacement measures.

economics are likely more favorable than the last. This continues until one piece of equipment reaches its end of life, which is then considered a replace on burnout case.

Early replacement options expand the potential market for heat pump adoption every year (e.g. for a 15-year EUL for existing AC units, it is assumed that only 1/15th of the market reaches the end of life every year, but four years worth of the market (4/15th) is above two-thirds of its EUL). Results show that:

- The many early retirement opportunities for space cooling are more favorable to a partial replacement, as there is still "value" left in the existing heating system. Partial replacement measures add a heat pump but keep the fuel-fired heating system in place as a supplemental source of heat, compared to full replacements where it is replaced with an electric equivalent. In other words, the timing would need to align between cooling and heating burnout for full replacement to be preferred;
- Heating system burnouts lead to a larger share of full replacements, where the heating system has to be replaced anyway which improves the economics of an upgrade to an all-electric heating system. However, there are fewer heating system burnout opportunities than early replacement of the cooling system every year.

Notably, gas partial replacement measures do not pass the TRC screen in this study, and thus only the full replacement gas measures show any achievable potential, which is limited to the Max scenario. This is largely driven by the impact that controls strategies for partial replacement measures have on their overall ability to displace gas consumption (see text box).

Understanding Residential Gas Measure Results

This study models heat pumps whose performance levels correspond to MassSave's Heat Pump Qualified Product List (HPQPL), which only includes cold-climate models, as described in Appendix C.

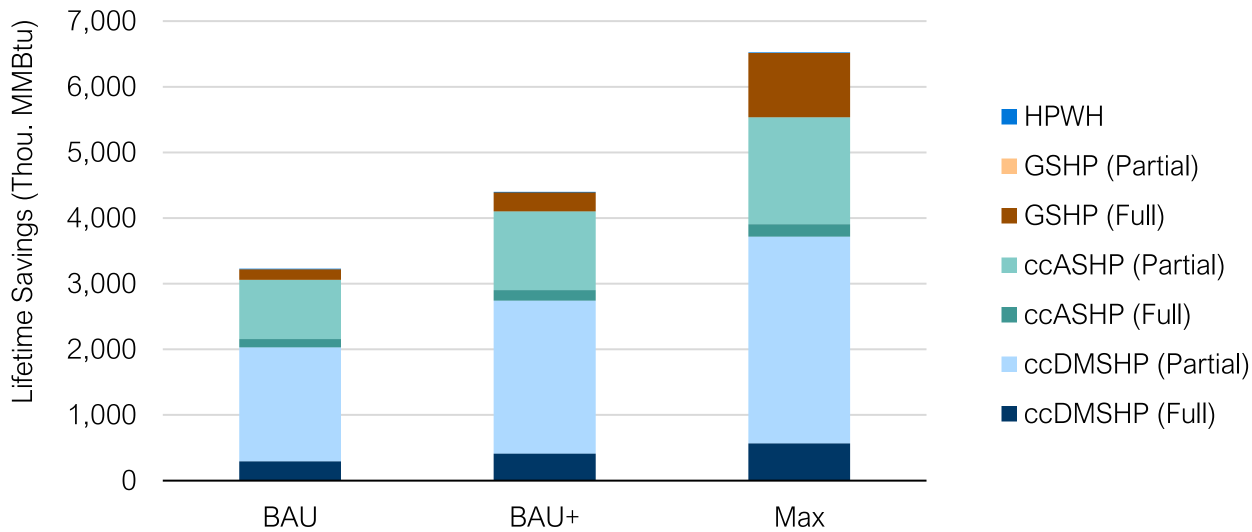
Cold climate models carry higher incremental costs as compared to standard heat pump models (i.e. not rated for cold climate operation). However, because of the high switchover temperature of partial replacement gas measures, they are generally not able to generate sufficient savings to cover the high incremental cost of cold climate heat pumps.

Cheaper non-cold-climate heat pumps may offer somewhat better economics but not at a level that would improve program and customer cost-effectiveness enough to drive adoption. Therefore, adding standard heat pump models to the assessment would not likely impact overall potential significantly.

Residential Savings by Heat Pump Type

Figure 4-10 presents residential program fuel savings split among heat pump technologies installed. Overall, the partial cold climate ductless mini-split heat pump (ccDMSHP) and partial cold climate central ducted air-source heat pump (ccASHP) replacements dominate the program uptake, which is driven by the prevalence of oil-fired boilers and furnaces, respectively, and the beneficial customer economics associated with measures that replace the existing air conditioning (AC) unit but leave the existing furnace or boiler in place as a supplemental source of heat.

Figure 4-10. Residential Lifetime Building-level Fuel Savings by Heat Pump Type and Full/Partial Replacement (2022-2024 Average)

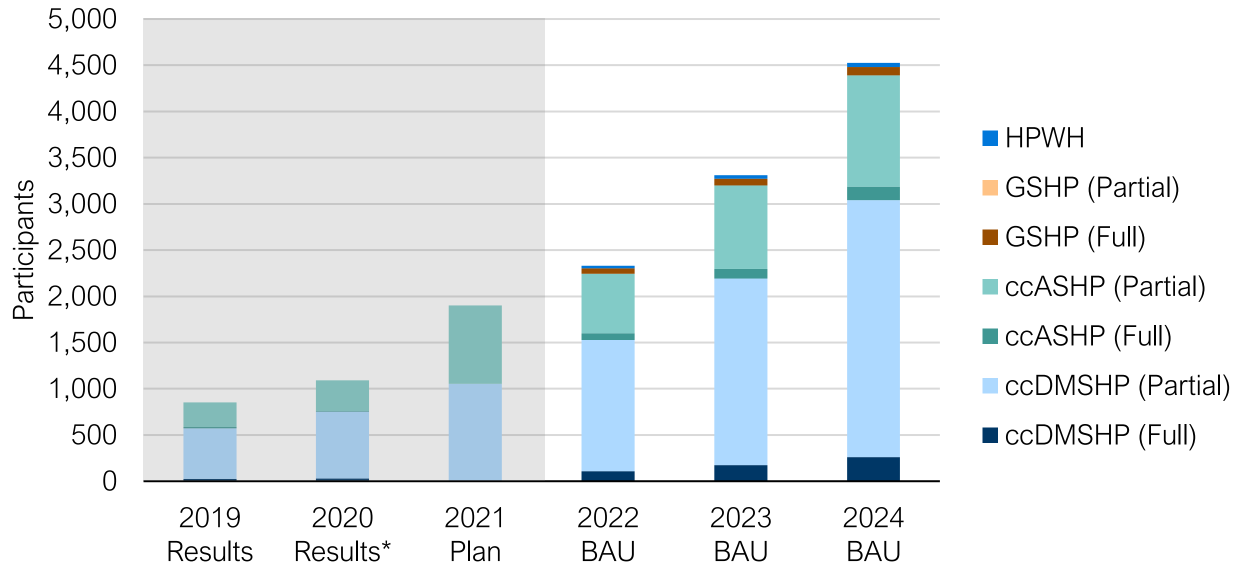


With their significant upfront cost, GSHPs see more gains from the increased incentive levels in the Max scenario, where some gas furnaces are being replaced, as discussed above.

Heat pump water heaters (HPWH) for domestic hot water do not see significant uptake under any of the scenarios. Despite the favorable customer economics of these units in many applications, the significant market barriers associated with this technology mean that it is not widely recognized in the marketplace.

Figure 4-11 compares the annual number of participants for the BAU scenario to recent program benchmarks. Overall, these show that while there is an expected growth in full system replacement measures, the ccDMSHP and ccASHP partial replacement measures account for the majority of program growth over the study period. While the 2019-2021 Plan did not expect much uptake from full replacement measures, both 2019 and 2020 program results show a small but significant uptake, which aligns with the results of the BAU scenario.

Figure 4-11. Residential Participants by Heat Pump Type and Full/Partial Replacement Compared to Benchmarks

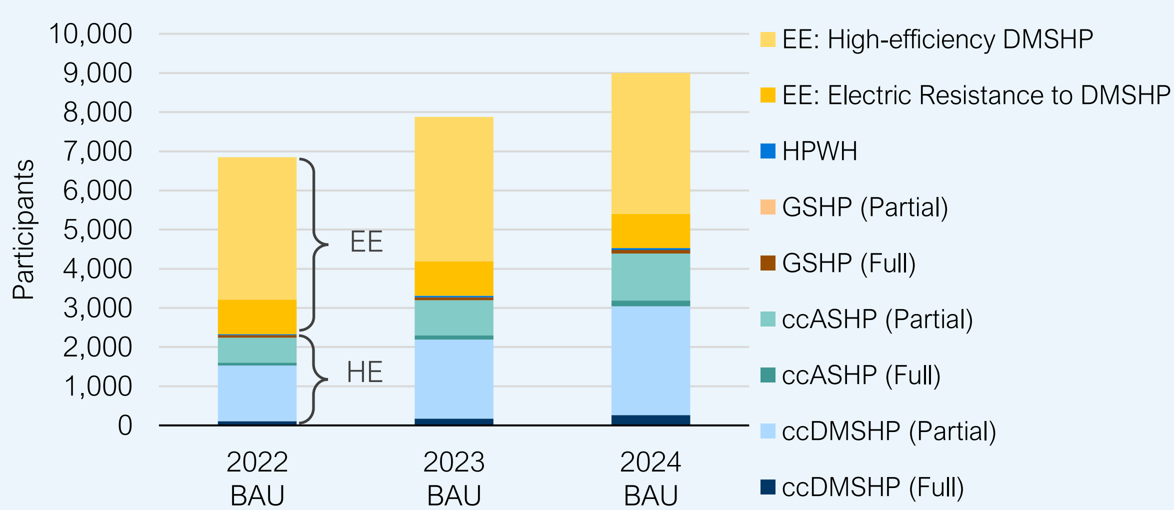


Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

Heat Pump Adoption Across EE and HE Programs

While this chapter focuses on the ability of heat pump technologies to displace combustion-fired heating systems, heat pumps also get adopted in place of existing electric resistance heating systems or to replace existing heat pumps at the end of their useful lives. These measures are assessed within the energy efficiency (EE) chapter of this report. Figure 4-12 shows the evolving share of residential heat pump adoption through EE and HE programs under BAU conditions. As can be seen, EE measure heat pumps represent roughly 66% of total residential heat pump adoption in 2022. As HE programs expand, this proportion decreases to 50% by 2024.

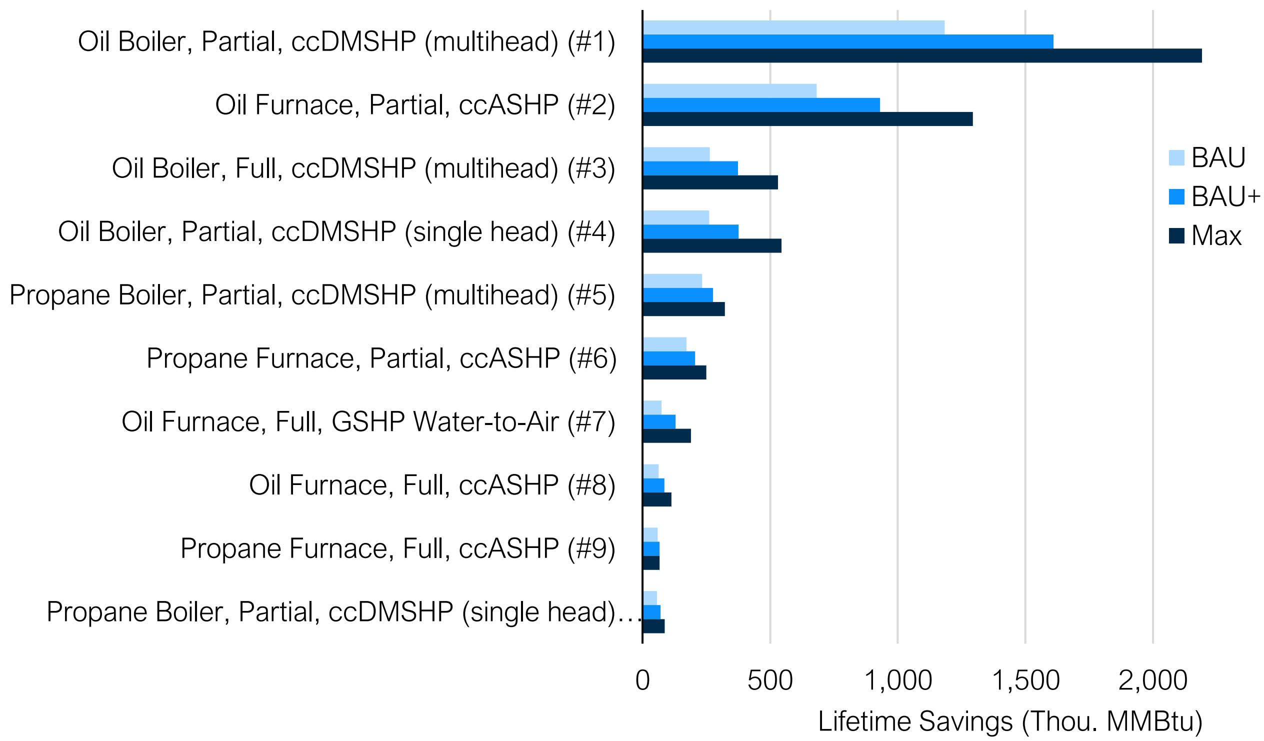
Figure 4-12. Residential Heat Pump Adoption Across EE and HE Programs (BAU Scenario)



Residential Top Savings Measures

Figure 4-13 presents the top 10 measure list sorted by lifetime fuel savings under the BAU scenario.

Figure 4-13. Top 10 Residential Measures (2022-24 Average)



Note: Measures are selected and arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario.

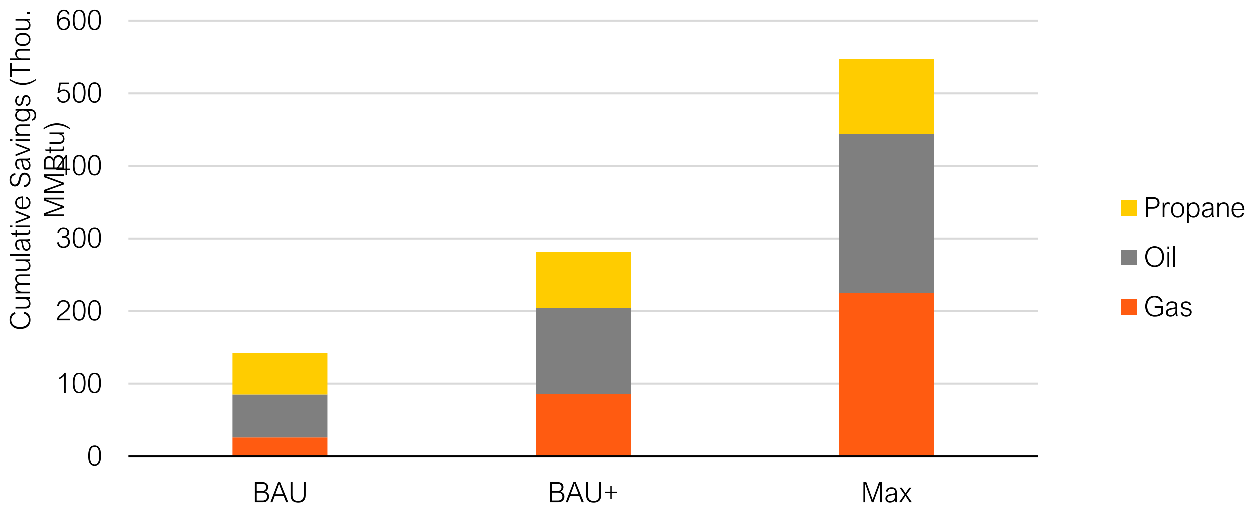
The top 10 list largely reflects the measures with the largest market base (mostly oil) and most beneficial customer cost-effectiveness (particularly high for propane and ccDMSHPs). Of note, the partial ccDMSHP measure is split into two equipment sizes: one assessing single-ton units (average of 1.0 tons), and another assessing multi-head units (average of 2.5 tons).

Figure 4-13 also shows that propane measures are less impacted by incentive levels due to their relatively favorable customer cost-effectiveness even at the BAU scenario incentive levels.

C&I Fuel Savings

Figure 4-14 presents C&I 2022-24 average lifetime fuel savings from heating electrification broken down by fuel type under each scenario. The results show a mix among the three baseline heating fuels with a notable amount of uptake for gas replacement measures, particularly under the Max scenario. Overall, this is largely a reflection of the dominance of gas as the baseline heating source in the C&I sector, representing 87% of all C&I heating consumption. And unlike residential measures, a few C&I measures both pass TRC screening *and* provide customer bill savings, due to generally lower C&I electricity consumption rates. Oil savings potential also increases with additional incentives, while the increase in propane savings is less pronounced similar to residential results.

Figure 4-14. Lifetime C&I Building-level Fuel Savings (2022-24 Average)

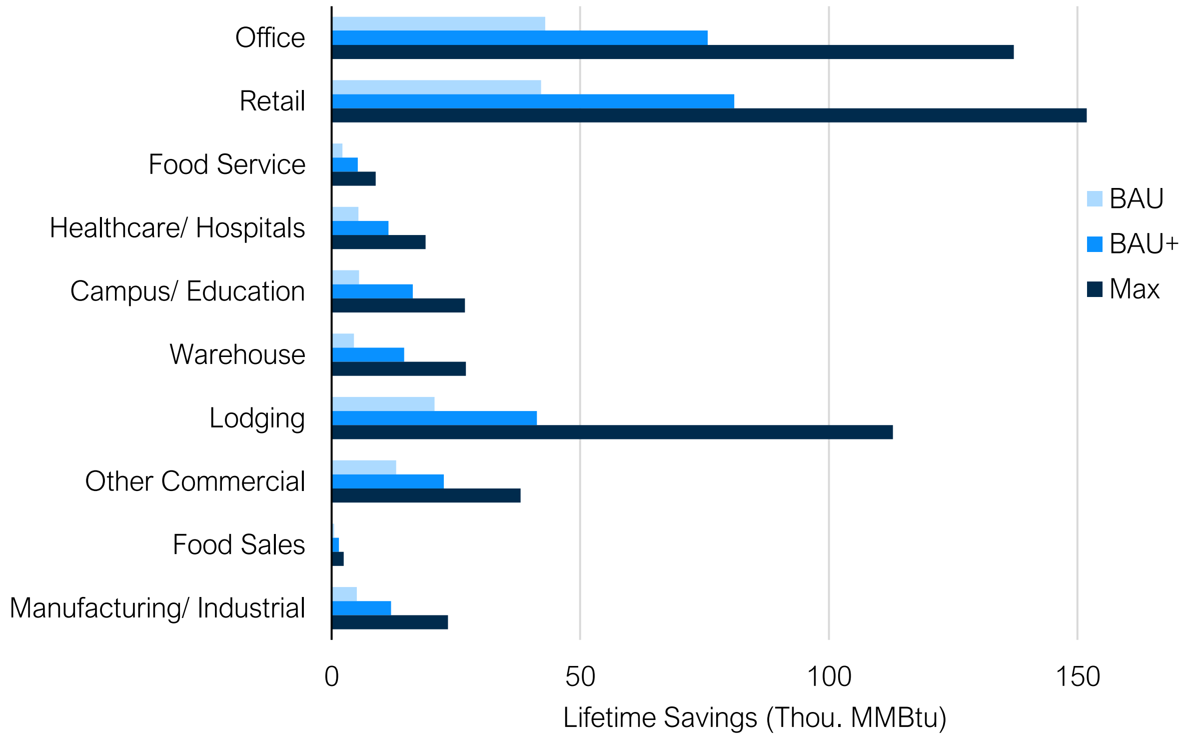


C&I Savings by Market Segment

Figure 4-15 details the achievable savings potential in each C&I market segment. The results show that the Office, Retail, and Lodging segments dominate the electrification opportunities, which reflects not only their large customer base but also their relatively larger proportion of oil and propane users, along with a few select cost-effective gas replacement measures.

Of note, the Lodging segment includes central systems from multi-family buildings, and they make up approximately 70% of that segment's population. The relatively large impact from incentive levels in that segment is explained by the packaged rooftop heat pump installations for which the incentive levels cover a larger share of the incremental cost, as discussed in the call-out box on page 123. Additionally, almost all of the achievable potential from heat pump water heaters (HPWH) is found in the Lodging segment, due to some Lodging buildings having individual storage water heaters for each unit, while the other C&I segments tend to have large combustion-fired central water heaters.

Figure 4-15. C&I Lifetime Building-level Fuel Savings by Market Segment (2022-24 Average)

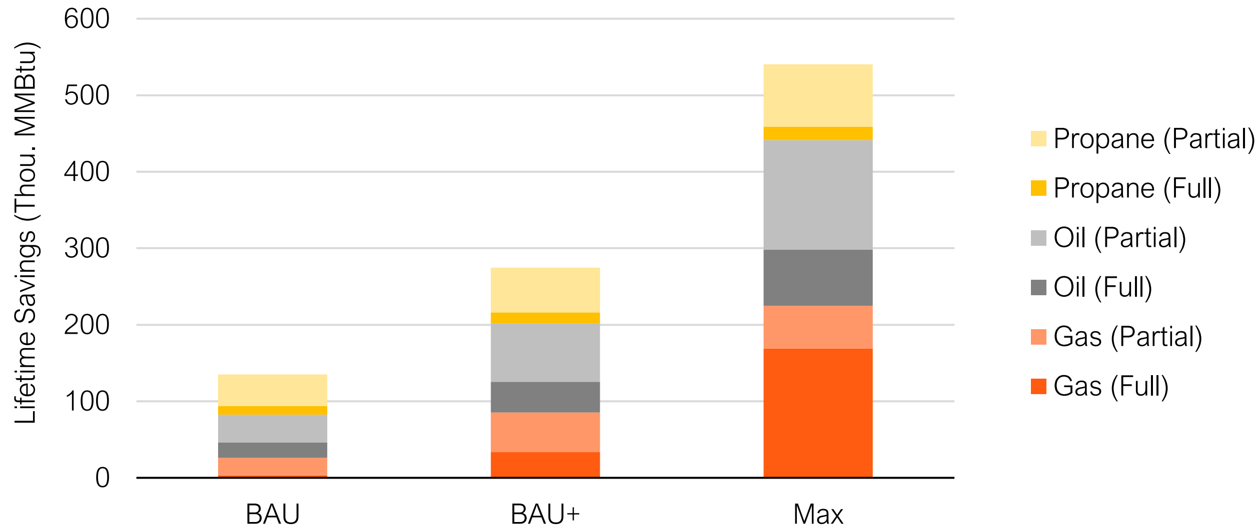


C&I Savings by Baseline Heating Equipment

Figure 4-16 shows fuel savings broken down by baseline heating system and full or partial replacement measures. While many gas measures do not pass cost-effectiveness screening, the large proportion of gas replacements in the C&I achievable results is driven primarily by cost-effective partial replacements of gas-fired packaged rooftop AC units (RTU) – refer to the textbox on page 123 for further details on this outlier measures. Increasing the incentive levels in the Max scenario leads to significant savings from gas-fired RTU replacements, particularly full replacement.

Some oil and propane measures do provide achievable savings under all three scenarios, and oil particularly benefits from increased incentive levels compared to propane which already shows convincing customer cost-effectiveness under the BAU incentive levels.

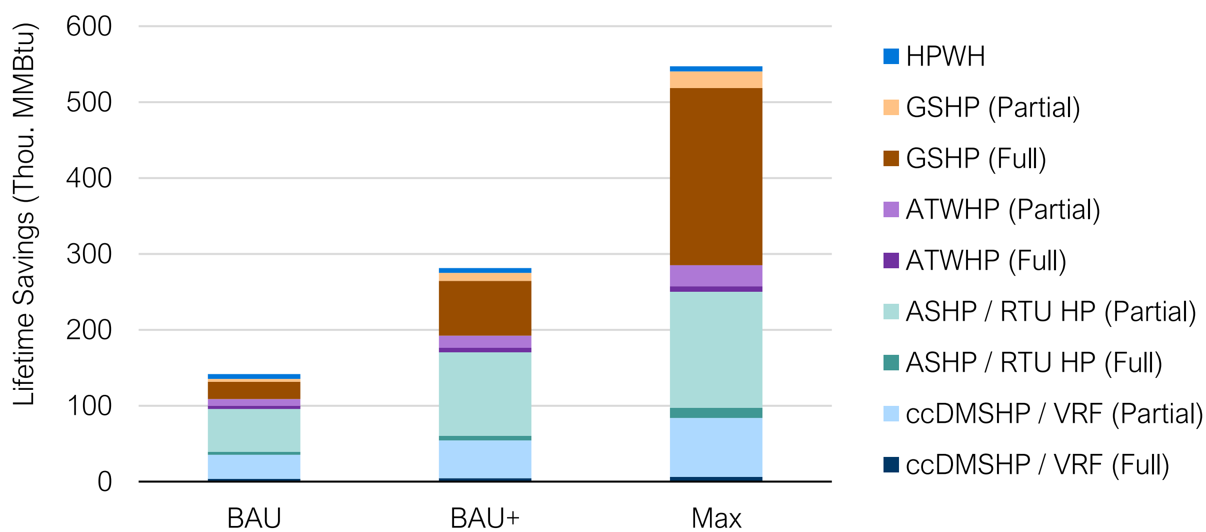
Figure 4-16. C&I Lifetime Building-level Fuel Savings by Baseline Heating System and Full/Partial Replacement (2022-24 Average)



C&I Savings by Heat Pump Type

Figure 4-17 shows the C&I savings potential by heat pump technology under each scenario. Results show that the BAU scenario is mostly driven by gas-fired RTUs being replaced upon burnout. Most other gas measures either do not pass cost-effectiveness screening or barely do but do not provide enough customer benefits to overcome the incremental cost of the heat pump, which limits adoption.

Figure 4-17. C&I Lifetime Building-level Fuel Savings by Heat Pump Type and Full/Partial Replacement (2022-24 Average)



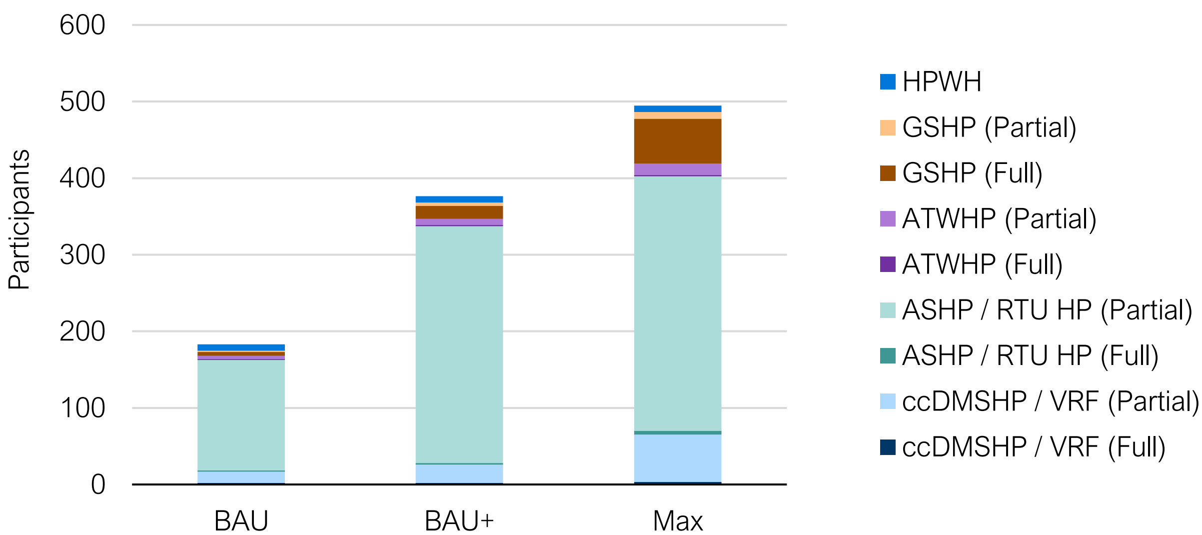
While GSHP adoption is minimal under the BAU scenario, increasing incentive levels are seen to drive higher adoption levels, as can be seen in the BAU+ and Max scenario results.

The ductless heat pump technologies are shown in blue and include both mini-split and larger variable refrigerant flow (VRF) heat pumps. To note, VRF heat pumps are only included as a measure for new construction, as they are not deemed economically feasible in existing buildings that do not go through a deep retrofit of their HVAC systems. However, air-to-water heat pumps (ATWHP) do provide a viable option to retrofit existing buildings with boilers, and some savings are seen from these measures under all scenarios.

For most measures, the partial replacement options outweigh the full replacement measures, except for the high savings driven by full heating GSHP replacement measures.

Figure 4-18 shows a representation of adoption in terms of C&I participants. As opposed to the number of participants, the large fuel displacement from full replacement measures drives the savings, as well as the presence of natural gas partial replacement measures for which the relatively high switchover temperature limits the savings potential compared to delivered fuel measures.

Figure 4-18. C&I Participants by Heat Pump Type and Full/Partial Replacement (2022-24 Average)



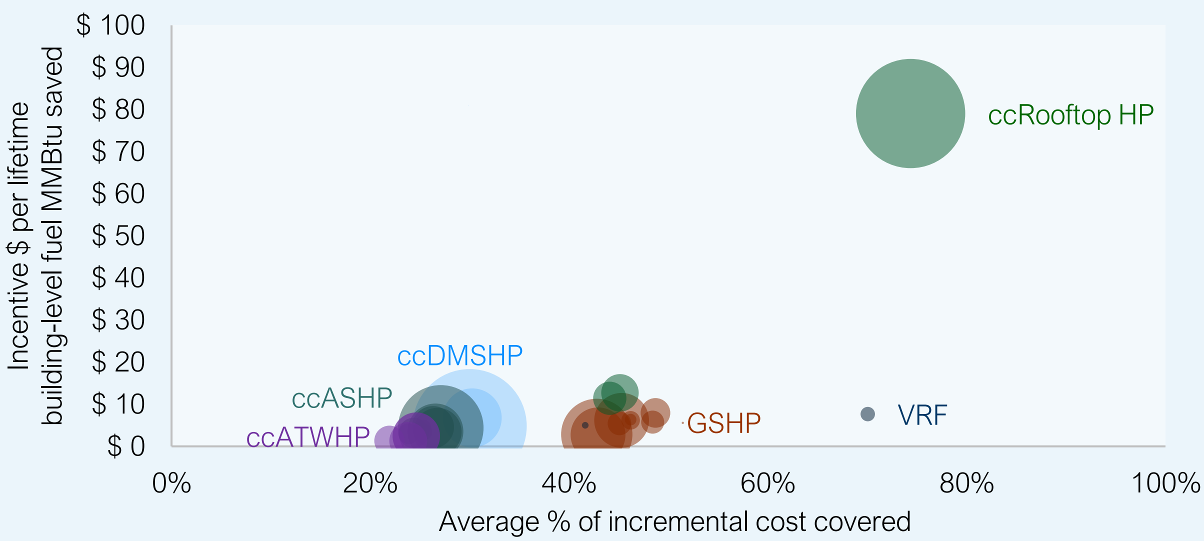
RTU replacements are the outlier opportunity in the C&I sector

The bubble chart shown in Figure 4-19 presents how BAU incentive levels for RTUs compare to other measures, on a cost per MMBTU savings basis. The top right bubble represents partial gas RTU replacements with hybrid heat pump RTUs - the large size of the bubble shows the large adoption potential of these measures. However, it can be seen that the incentive as a portion of the incremental measure cost is the highest among all C&I measures. Moreover, the cost per MMBTU savings is substantially higher for this measure than for other measures.

This is largely because most of its bill and avoided cost savings come from its increased cooling efficiency. In other words, even though it is a heating electrification measure, it mostly is a cooling efficiency measure that also provides some fuel savings in the shoulder seasons at incentive levels an order of magnitude higher than current high-efficiency packaged AC offerings. The result is a significantly larger heating electrification incentive cost per fuel savings compared to other measures.

However, even faced with a compelling business case, because of substantial market barriers, our results show that only 1 in 70 rooftop burnouts are replaced with heat pump versions under BAU.

Figure 4-19. Cost-effectiveness of the Incentive for Different C&I Measures

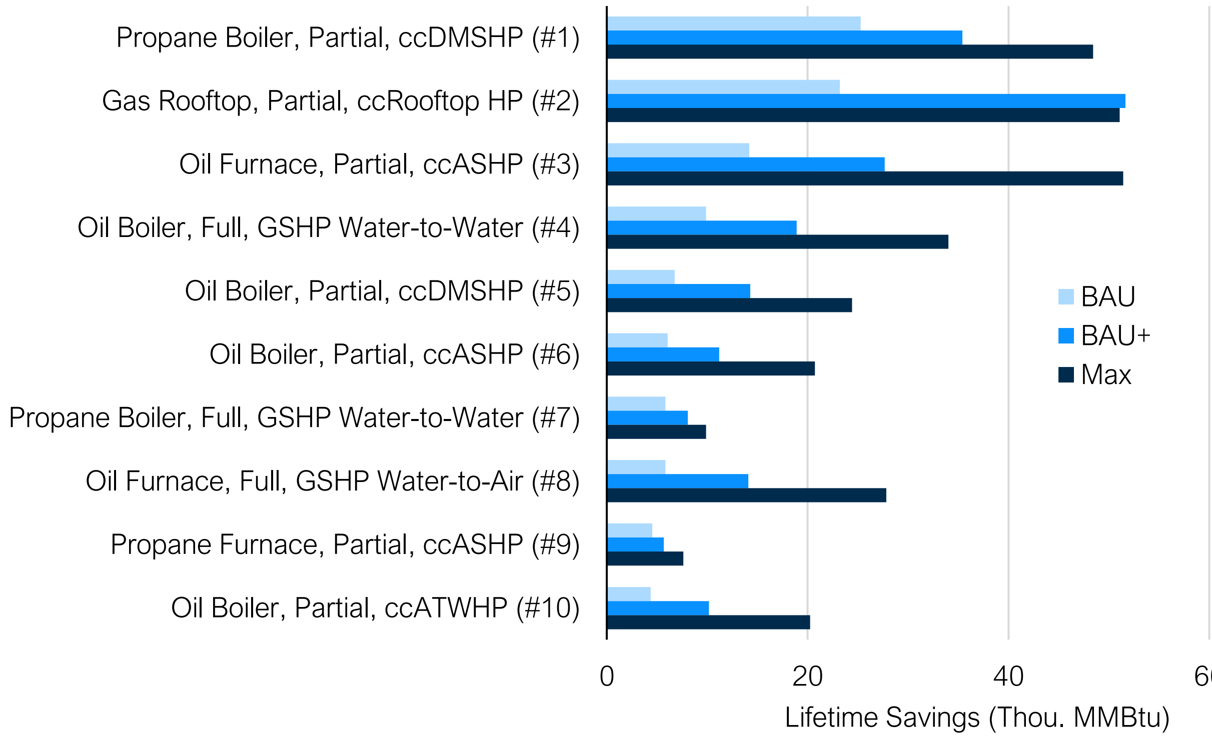


Note: Bubble size represents lifetime building-level fuel MMBtu savings.

C&I Top Savings Measures

The C&I top 10 measure list is presented in Figure 4-20. Again, the impact of gas-fired RTU replacements can be seen, as it represents the second-highest measure in terms of savings.

Figure 4-20. Top 10 C&I Measures (2022-24 Average)



Note: Measures are selected and arranged by relative contribution to 2022-24 average lifetime savings under the BAU scenario.

Most C&I top measures are partial replacements, mainly because of higher market barriers for full replacement measures. Key barriers to full replacements include the project complexity (real or perceived), equipment reliability (real or perceived), resistance to change, and risk aversion from the customer's point of view. On the contrary, partial replacement measures keep the existing fuel-based heating equipment as backup and are often simply replacing the existing AC equipment with a heat pump equivalent.

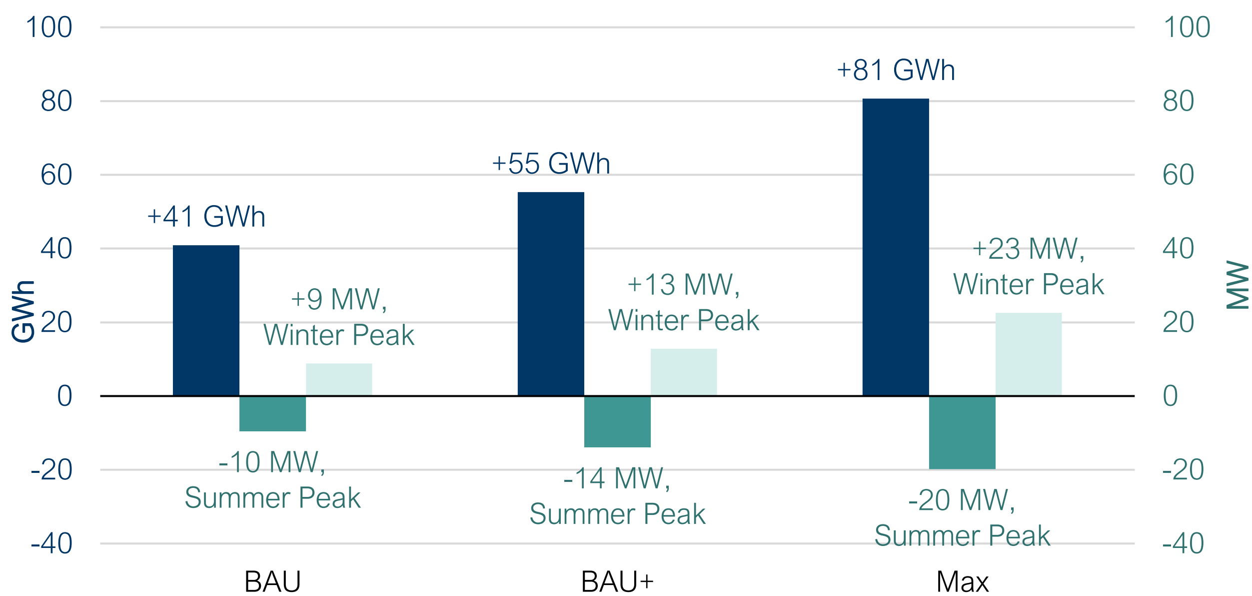
The only full replacement exceptions in the top 10 list are GSHPs, which is explained by the fact partial GSHPs typically do not pass TRC cost-effectiveness. Moreover, the electric backup systems (RTU electric heating section, buffer tank electric boiler, electric resistance coil, etc.) are comparatively cheaper than their fuel equivalents, which further improves the business case for full replacements.

Of note, the incentive levels under the BAU+ scenario cover more than the incremental cost of the RTU measure, which naturally boosts adoption. However, under the Max scenario, increasing the incentive levels does not entice more customers to adopt an already compelling offer, and other competing measures (full replacements and GSHPs) become more appealing than the partial RTU measure (#2), which slightly reduces the adoption of the partial RTU replacement.

Grid Impacts

Figure 4-21 shows the overall impact that heat pump adoption is expected to have on electricity consumption over the study period. As can be seen, heating electrification increases customer electricity consumption (kWh) and winter peak demand, while it reduces the summer peak demand as most heat pumps have higher cooling efficiency than the existing AC equipment they replace (e.g. a baseline central AC has a SEER of 13, where the ccASHP equivalent has a SEER of 18).

Figure 4-21. 2024 Cumulative Electric Grid Impacts



Both full and partial replacement measures can have an impact on the summer peak. However, partial replacement measures are not typically expected to affect the winter peak demand, as their controls will switch over to the combustion-fired backup system under the cold conditions that drive winter peak demand days.

Results show that heating electrification is not yet sufficient to significantly impact system-wide winter and summer peaks (±0.5 %). However, widespread electrification could lead to local and system-level peak demand, which in turn could change avoided cost structures. If a winter peak avoided cost should arise, it would reduce the cost-effectiveness of full air-source replacement measures, which would comparatively increase the appeal of GSHPs and partial replacements, for example, as they have limited / no impact on the winter peak.

Portfolio Metrics

Energy optimization offerings show continued growth in potential under all scenarios, which impacts program costs and benefits. As heating electrification is an emerging technology, the model projects large year-over-year growth that is in line with past growth witnessed in Eversource's programs. However, like any emerging technology, there is inherent uncertainty in projecting the future growth of heating electrification. That uncertainty was addressed, to the degree possible, by calibrating the model to account for the growth between 2019 and 2020 program results. Moreover, the relatively short potential study period of only three years limits the impact of market growth uncertainty on the savings potentials.

Program Costs

Figure 4-22 details the program costs by year and scenario. Similar to program savings, program costs are expected to follow a relatively large year-over-year growth as heat pump adoption grows across Eversource's territory.

Figure 4-22. HE Program Costs by Year and Scenario.

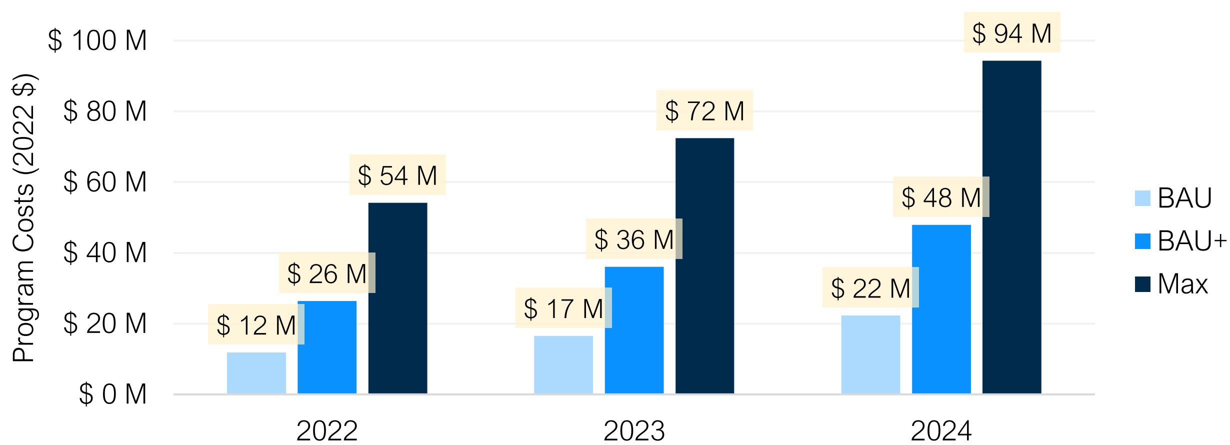
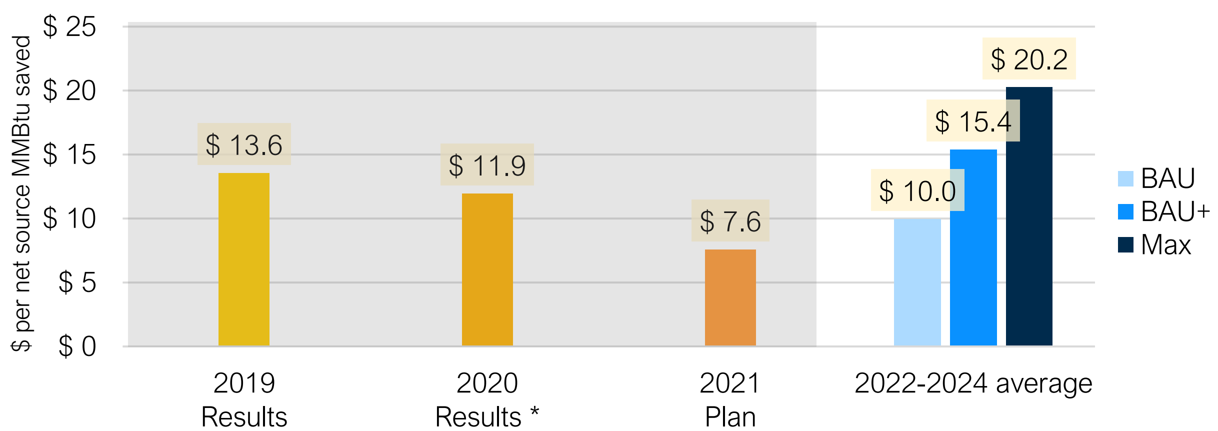


Figure 4-23 compares average program costs per lifetime net source MMBtu saved.

Figure 4-23. HE Program Costs per Lifetime Net Source MMBtu Saved



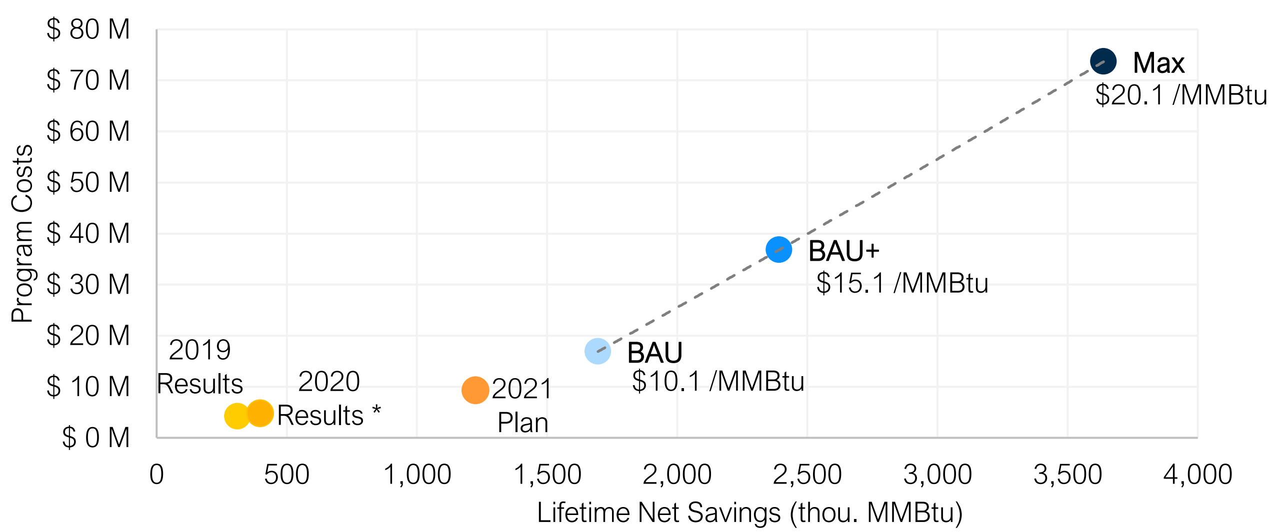
Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

Part of the reason why the cost per MMBtu is higher for the BAU compared to the 2021 Plan benchmark is related to new measures added in the modeled programs that come at somewhat higher costs than the currently offered measures:

- GSHPs were not offered in 2019 or 2020, nor included in the 2021 Plan, but are added for the 2022-2024 study period. Incentives are set at a higher level than current air-source heat pumps ($3,000 vs $1,250 per ton) incentives to account for GSHP's higher costs and savings.
- ccDMSHPs: While the TRM assumes that the average installed capacity of DMSHPs in partial replacement measures is 2.5 tons, this study includes both single-head (1.0 ton) and multi-head (2.5 tons) units for residential applications, which lowers the average savings per unit compared to the TRM.

Figure 4-24 shows lifetime net source MMBtu savings compared to program costs for all three achievable scenarios. The large year-over-year program growth is clearly visible, as well as the increasing cost per MMBtu saved as incentive levels rise with the scenarios.

Figure 4-24. HE Program Costs vs Lifetime Net Source MMBtu Saved

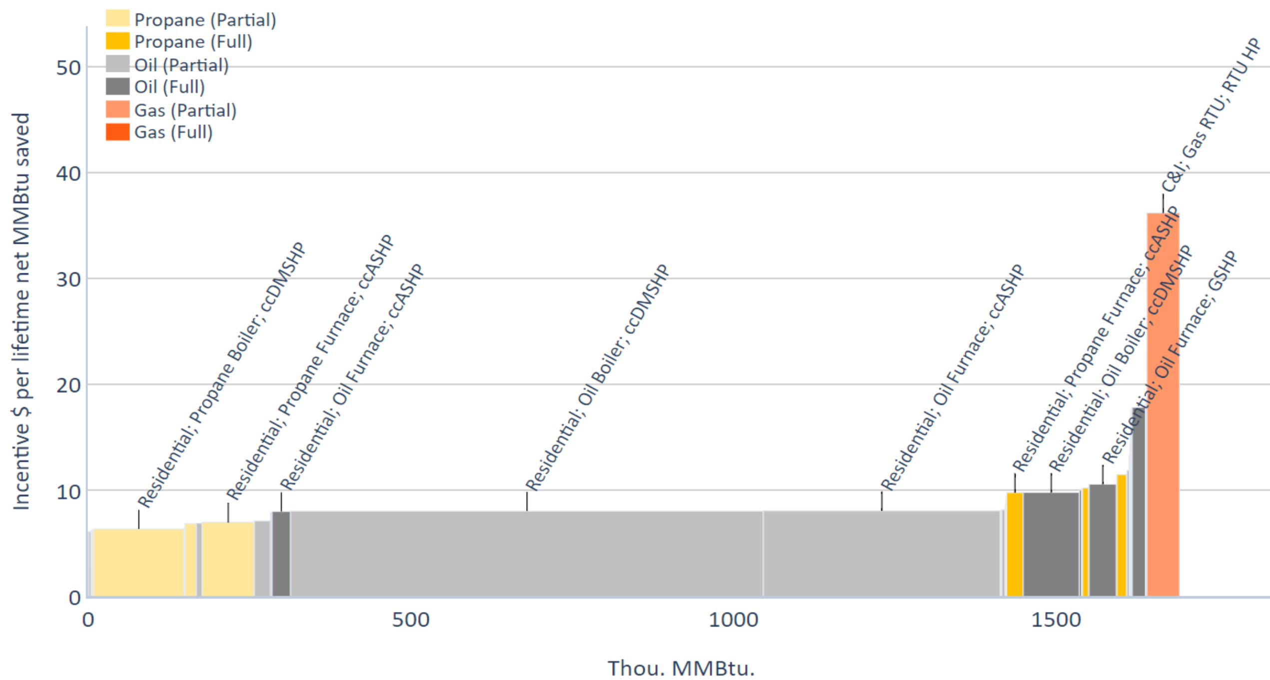


Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

Figure 4-25 and Figure 4-26 show a cost abatement curve in terms of net source MMBtu savings relative to program incentives, respectively for the BAU and Max scenarios.

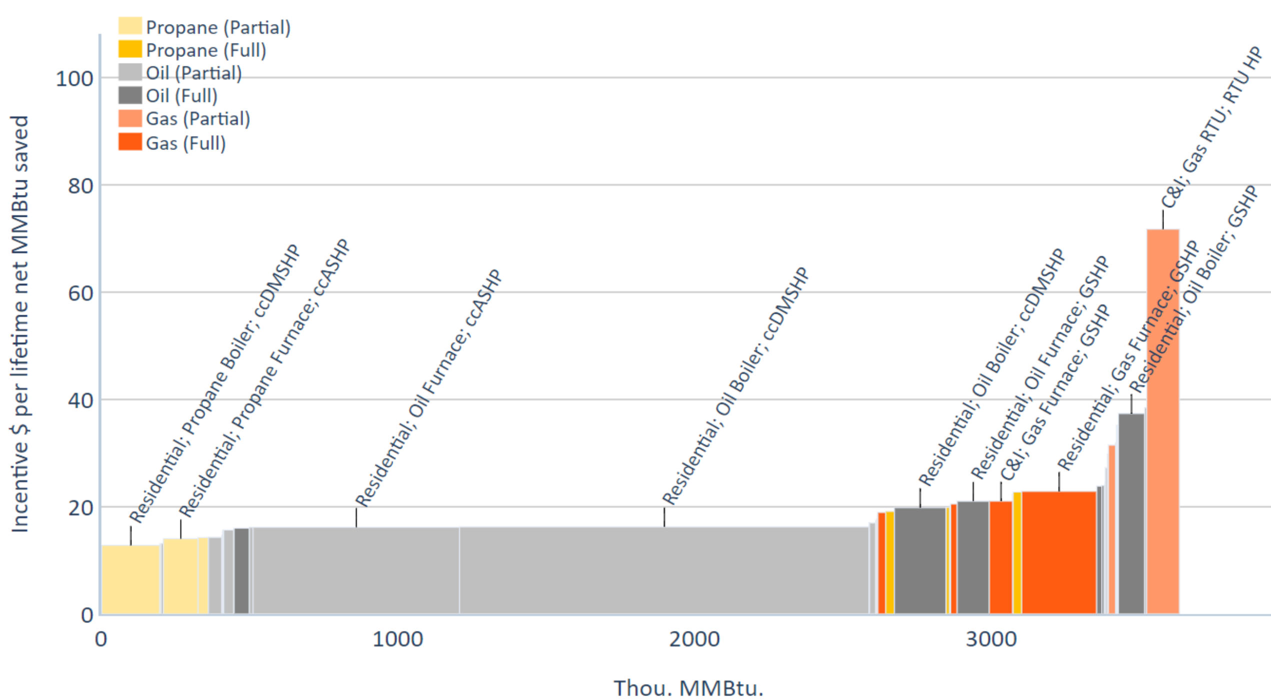
The BAU scenario shows the partial gas RTU outlier first and foremost, which is discussed in the call-out box on page 123. The bulk of net MMBtu savings are from homes with delivered fuels, with partial replacement measures at an incentive cost between 6 and 8 $ per net MMBtu saved, and full replacement measures being generally more expensive at between 10 and 19 $ per net MMBtu. More than 96% of net savings are in the residential sector.

Figure 4-25. HE MMBtu Cost Abatement Curve for the BAU Scenario (2022-2024 Average)



The Max scenario, where incentive levels are twice the BAU levels, again shows the gas partial RTU outlier, with additional gas measures now included but still at a relatively high incentive cost per MMBtu saved compared to delivered fuels. The bulk of net source MMBtu savings come at an incentive cost between 13 and 16 $ per net MMBtu. More than 92% of savings are in the residential sector.

Figure 4-26. HE MMBtu Cost Abatement Curve for the Max Scenario (2022-2024 Average)



The program cost metrics are summarized in Table 4-2.

Table 4-2. HE Program Results Summary (2022-24 Average)

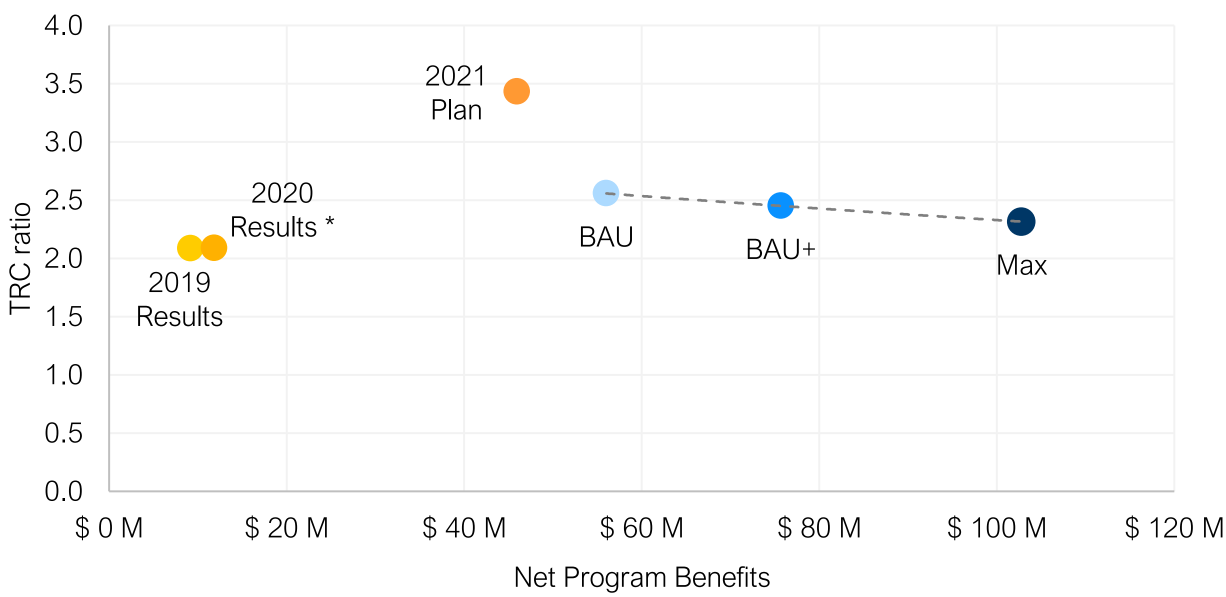
	2019 Results	2020 Results *	2021 Plan	BAU	BAU+	Max
Program Costs Incentives + program admin	$ 4.2 M	$ 4.8 M	$ 9.3 M	$ 17 M	$ 37 M	$ 74 M
Program costs per first-year net source MMBtu saved	$ 278	$ 211	$ 129	$ 161	$ 249	$ 339
Program costs per lifetime net source MMBtu saved	$ 13.6	$ 11.9	$ 7.6	$ 10.0	$ 15.4	$ 20.2

Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

Program Benefits

In terms of program benefits, the law of diminishing returns is clearly visible between scenarios in Figure 4-27 in that increased incentive levels lead to increased savings, but at the cost of a lower average TRC and a higher cost per MMBtu saved.

Figure 4-27. HE Net TRC Benefits vs. TRC ratio (2022-2024 Average)



Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

The program benefits metrics are summarized in Table 4-3 along with average program-level TRC ratios for all three achievable scenarios.

Table 4-3. HE Program Results Summary, TRC Benefits and CO2 Emission Reductions (2022-2024 Average)

	2019 Results	2020 Results *	2021 Plan	BAU	BAU+	Max
Average TRC Ratio	2.1	2.1	3.4	2.6	2.5	2.3
Net TRC Benefits	$ 9.2 M	$ 11.8 M	$ 46 M	$ 56 M	$ 76 M	$ 103 M
Net TRC benefits per first-year net source MMBtu	$ 606	$ 525	$ 638	$ 533	$ 513	$ 473
Net TRC benefits per lifetime net source MMBtu	$ 30	$ 30	$ 37	$ 33	$ 32	$ 28
Annual CO_2 Emission Reductions (Short Tons)	1,637	2,080	5,947	8,616	12,104	17,414

Note: 2020 Results are based on preliminary results from the first 10 months of the year extrapolated to a full year.

COVID-19 Sensitivity Analysis

As the COVID-19 pandemic led to economic uncertainty and business closures, it is expected to have some impact on overall program performance. While it is unclear what COVID's precise economic effects will be over the study period, an analysis of the impact that COVID-driven changes in market conditions may have on program savings is included.

Similar to the energy efficiency modeling, the following input parameters have been adjusted in the assessment:

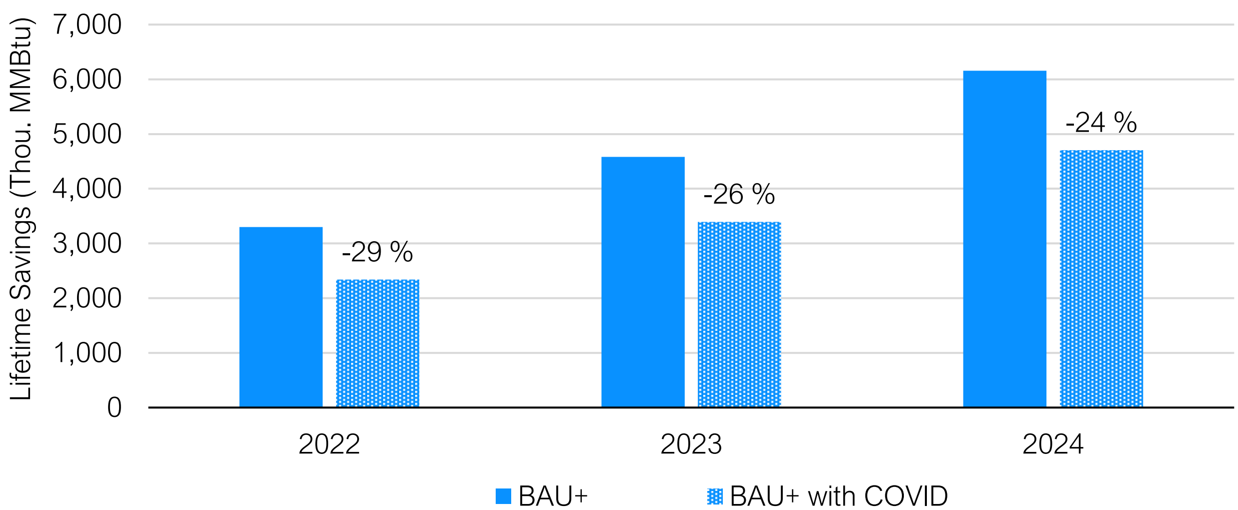
- **Market sizes** have been adjusted to reflect fewer customers within a given segment due to temporary or permanent business closures.
- **Barrier levels** have been increased to reflect delayed projects, increased competition for capital, decreased resources, and other impediments to energy efficiency and electrification upgrades.

Appendix A summarizes the market and barrier parameters for each segment. It should be noted that the sensitivity parameter adjustments were selected prior to the rapid rollout of COVID-19 vaccinations in the spring of 2021 and that this sensitivity should be interpreted as an upper-bound worst-case scenario (e.g., the emergence of vaccine-resistant COVID variants). The analysis is done on the BAU+ scenario.

Of note, some impact of COVID on the adoption curves might already be reflected in the scenario results throughout the study, as a result of including actual 2020 program results (up to October) to calibrate the model's technology diffusion curves. Overall, 2020 program results showed either a slight decrease or slowed growth trajectory when compared to 2019 program results, which may be early indications of impacts due to COVID-19.

Figure 4-28 presents the results on the sensitivity analysis for the three years of the potential study and specifically on the BAU+ scenario, as agreed with Eversource.

Figure 4-28. HE Sensitivity Analysis of COVID-19 Impacts Relative to the BAU+ Scenario.



Results show a large reduction in 2022 program savings followed by a relatively slow recovery in 2023 and 2024. Savings are not expected to reach levels under the no-COVID scenario during the study period, even after a few years of renewed economic activity. Compared to established efficiency programs which usually have more stable performance levels, relatively new programs like heating electrification are still ramping up, and the overall effect is likely to be a slowed rate of growth compared to a no-COVID scenario.

The impact of the COVID-19-related temporary slowdown of the economy could therefore have lasting effects on the heating electrification adoption if it results in a delay in the technology's diffusion in the market.

4.3 Key Takeaways

Based on the results presented in this chapter, the following key takeaways emerge:

The **technical opportunity for fuel savings through heating electrification is extremely large** when compared to other savings streams (i.e., it is nearly an order of magnitude larger than gas and delivered fuel efficiency technical potentials.) This is primarily driven by the electrification measures' ability to displace most, if not all, of a building's fuel consumption, while efficiency measures just reduce consumption by a portion of the current amounts. Moreover, heating electrification is expected to drive a net reduction in overall heating and cooling energy consumption (i.e., net MMBtu savings) when including all energy sources and accounting for the associated increase in electricity consumption.

Most delivered fuel (oil and propane) measures pass TRC screening and provide customer bill savings, but almost all gas measures either do not pass TRC screening and/or do not provide customer bill savings. For all fuels, the achievable potential is *very* small relative to the economic potential because it is very **difficult to entice customers to electrify**. For gas customers, the main reason is related to poor customer economics, as adopting most heat pumps will lead to bill increases given current gas and electricity rates. For delivered fuels, it is mostly caused by the significant market barriers that electrification measures face, largely as a result of heat pumps being a relatively new technology in Massachusetts - customers and contractors are still unaware or unfamiliar with the technology.

Overall, **energy optimization offerings show continued growth in potential under all scenarios**. As heating electrification is an emerging technology, the results project large year-over-year growth that is in line with past growth witnessed in Eversource's heat pump programs. This is largely a result of increased customer awareness of the heating electrification opportunity, additional incentivized measures like ground source heat pumps (GSHP), the emergence of new C&I measures, and steadily improving customer economics for replacing delivered fuels heating systems.

Under the BAU scenario, **heating electrification program costs could reach $22M in 2024** under the BAU scenario and $94M under the Max scenario. Program costs per net source MMBtu saved increase significantly with higher incentives – more than doubling under the Max scenario relative to BAU

5 Combined Impacts and Results

To understand the overall effect of Eversource's full range of DSM programs, their combined impacts on energy consumption and electric peak demand as projected in each of the preceding chapters is presented and the implications are discussed. We first present the 2024 cumulative impacts on energy consumption and electric peak demand to provide a sense of each saving stream's contribution. We then compare net source MMBtu equivalent lifetime program savings from EE and HE to understand the system-level energy impacts of HE relative to traditional efficiency opportunities. Finally, we present the combined costs and benefits of each savings stream.

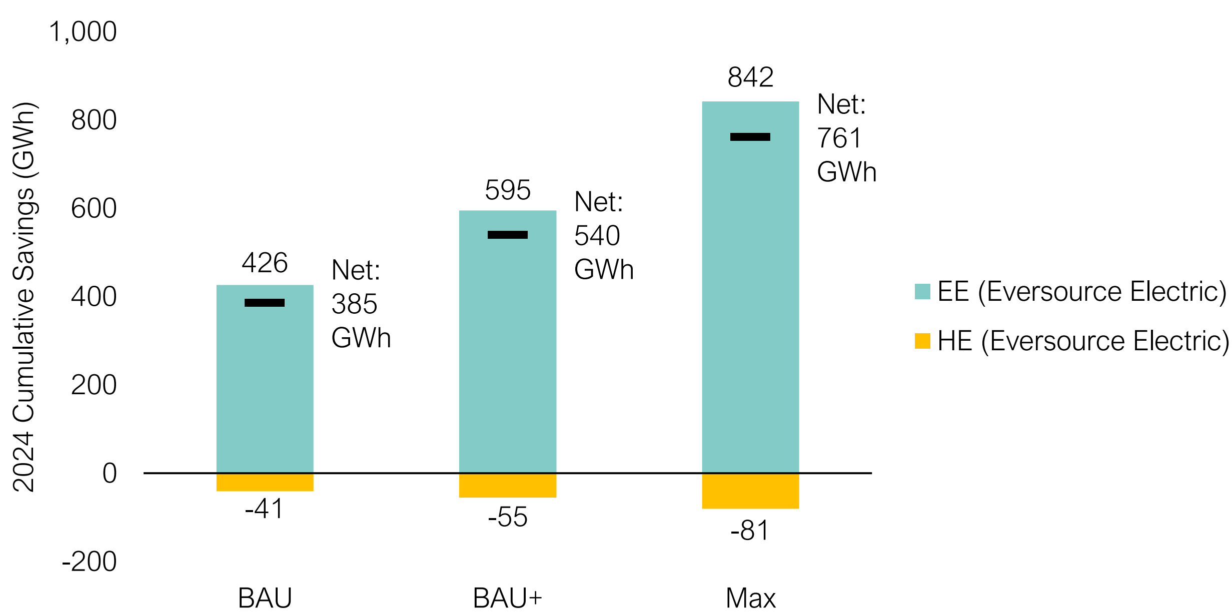
5.1 Combined Impacts in 2024

The EE, DR, and HE savings opportunity potentials assessed over the study period (2022-2024) will have additive and cumulative effects on the energy consumption and electric peak demand contribution of Eversource's customer base. The following results combine the 2024 cumulative impacts of Eversource's EE, DR, and HE programs over the study period under each achievable scenario to illustrate each saving stream's contribution to these overall impacts.

Electricity Consumption

Figure 5-1 shows cumulative electric energy savings in 2024 from EE and HE measures. For HE measures, impacts are expressed as negative savings values since these measures result in increased electricity consumption.

Figure 5-1. 2024 Cumulative Electric Energy Savings (EE and HE)

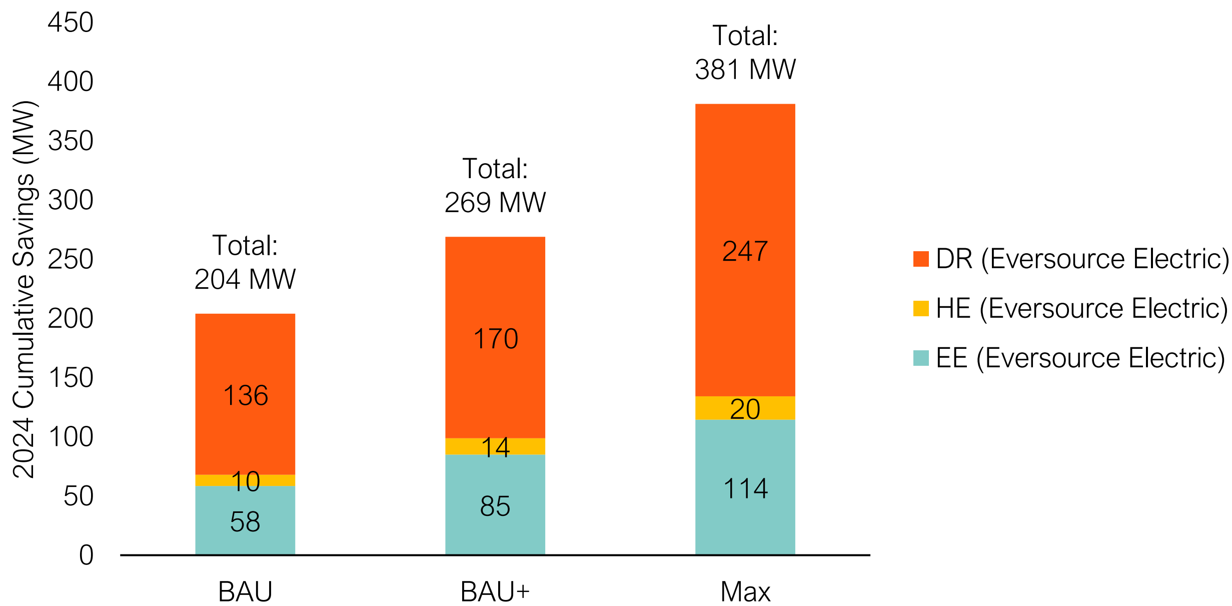


As can be seen, the cumulative impact of EE savings is expected to far outpace the increase in electricity consumption resulting from heating electrification measures under all scenarios although heating electrification will increase electricity consumption for some customers. Under each scenario, the added electricity consumption resulting from HE measure adoption is roughly 9% to 10% of the savings expected from EE measures.

Electric Peak Demand

In terms of electric peak demand, all three savings streams (EE, DR, and HE) will contribute to a reduction in the system-wide annual peak demand as shown in Figure 5-2.

Figure 5-2. 2024 Cumulative Electric Peak Demand Savings (EE, DR, and HE)



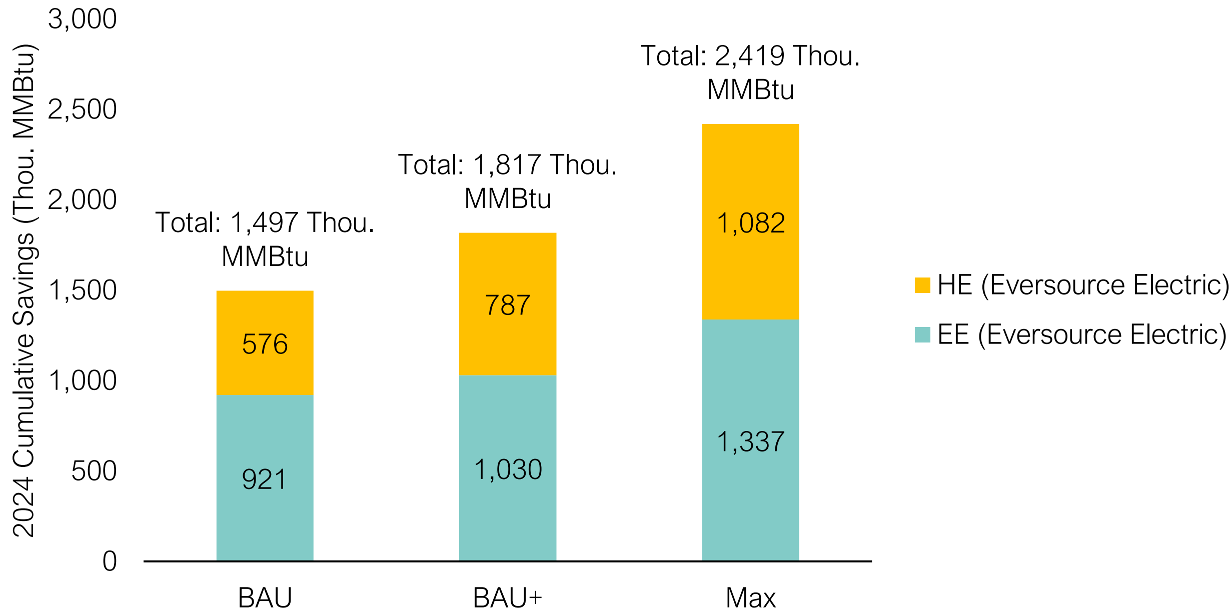
As can be seen, DR measures will provide the majority of peak demand savings across all scenarios. Under each scenario, DR measures represent between 60 to 70% of cumulative peak demand reductions in 2024.

This trend reflects the growing importance of DR measures in terms of managing peak electricity demand. In the past, EE measures have been the main contributor to peak reduction through passive electric demand savings. However, as DR programs continue to expand and electric savings become harder to capture with the loss of lighting opportunities, DR measures will take a more prominent role.

Delivered Fuel

Figure 5-3 shows cumulative delivered fuel savings in 2024 from EE and HE measures.

Figure 5-3. 2024 Cumulative Delivered Fuel Savings (EE and HE)

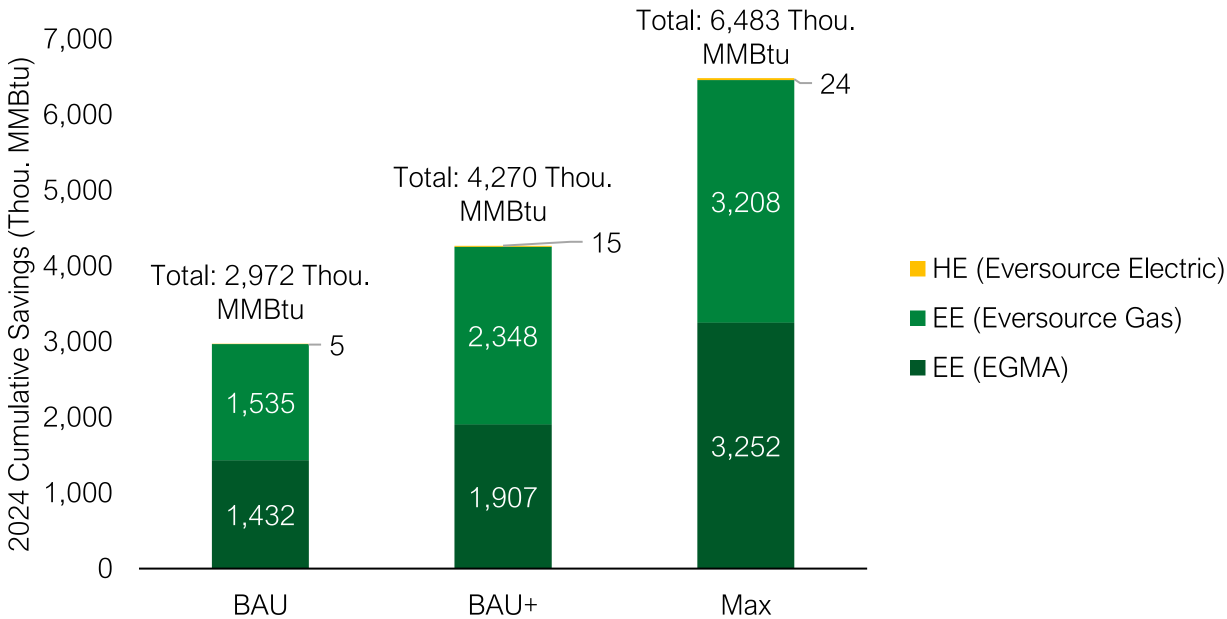


While EE measures will contribute the majority of delivered fuel savings, HE measures substantially increase overall delivered fuel savings for Eversource's electric customers. Under the BAU scenario, HE measures contribute 38% of overall delivered fuel savings. This proportion increases under the higher incentive levels up to 45% of overall delivered fuel savings under the Max scenario.

Gas

EE measures supported under Eversource's Gas Programs, EGMA's Gas Programs, as well as HE measures from Eversource's Electric Programs will all contribute to gas savings as shown in Figure 5-4.

Figure 5-4. 2024 Cumulative Gas Savings (EE and HE)



Under the BAU scenario, Eversource Gas's programs contribute slightly more than half of EE gas savings (52%). Under the Max scenario, savings from EGMA's programs increase at a slightly faster rate and become the majority contributor (50.3%) to EE gas savings between the two programs.

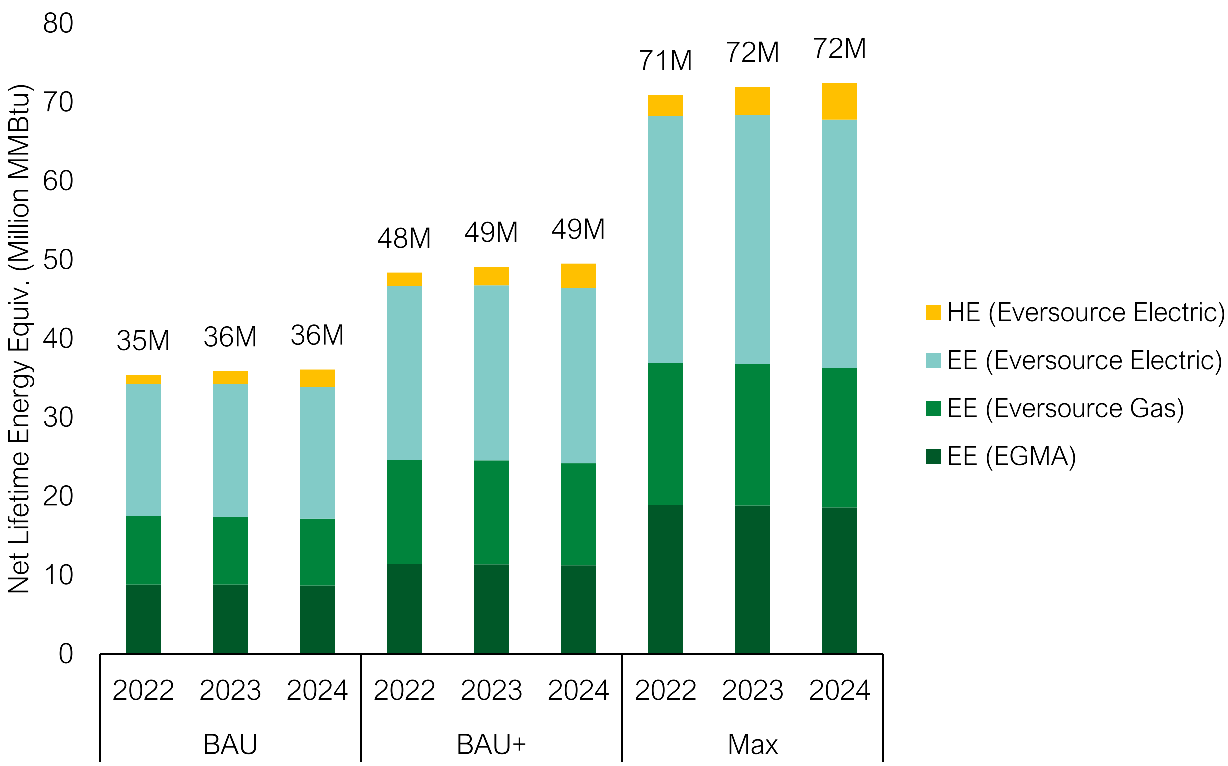
Gas savings from eligible measures under Eversource Electric's HE program are minor due to the limited economic and customer cost-effectiveness of these measures. Overall, HE measures represent less than 0.5% of cumulative 2024 gas savings under all scenarios.

5.2 Net Source MMBtu Lifetime Program Savings

Figure 5-5 shows net source MMBtu lifetime program savings for EE and HE measures by year for each scenario.[64]

[64] Net source MMBtu lifetime program savings account for the increase in electric consumption resulting from HE measures and convert site electricity savings (in kWh) to source fuel savings (in MMBtu) based on the heat rate of the average generation mix of the ISO New England region.

Figure 5-5. Net Source MMBtu Lifetime Program Savings by Year (EE and HE)



Note: Electric kWh savings are converted to MMBtu equivalent savings using site-to-source factors that account for the fuel required to generate electricity on the ISO New England grid.[65] HE savings are net of the increased electric consumption resulting from electrifying space and water heating end-uses.

When viewed in equivalent energy units that account for the heat rate of power generators and the impacts of increased electricity consumption from HE measures, the majority of energy savings come from EE measures. The relative proportion of savings are similar under each scenario with Eversource Electric EE measures accounting for approximately 45% of net source MMBtu lifetime savings, Eversource Gas and EGMA EE measures accounting for slightly more than 45% of savings, and the remainder coming from Eversource Electric HE measures. In 2022, HE measures represent 3 to 4% of savings and increase to approximately 6% of savings in 2024.

When savings are viewed in terms of emission reductions, the observations are largely the same as shown in Figure 5-6. Overall, Eversource's EE and HE programs have the potential to reduce annual CO_2 emissions by a half-million to a million tons by the end of the study periods in 2024. While not quantified in this study, DR measures could contribute to further emission reductions by shifting electric consumption from periods with higher marginal emission rates to periods with lower emission rates.

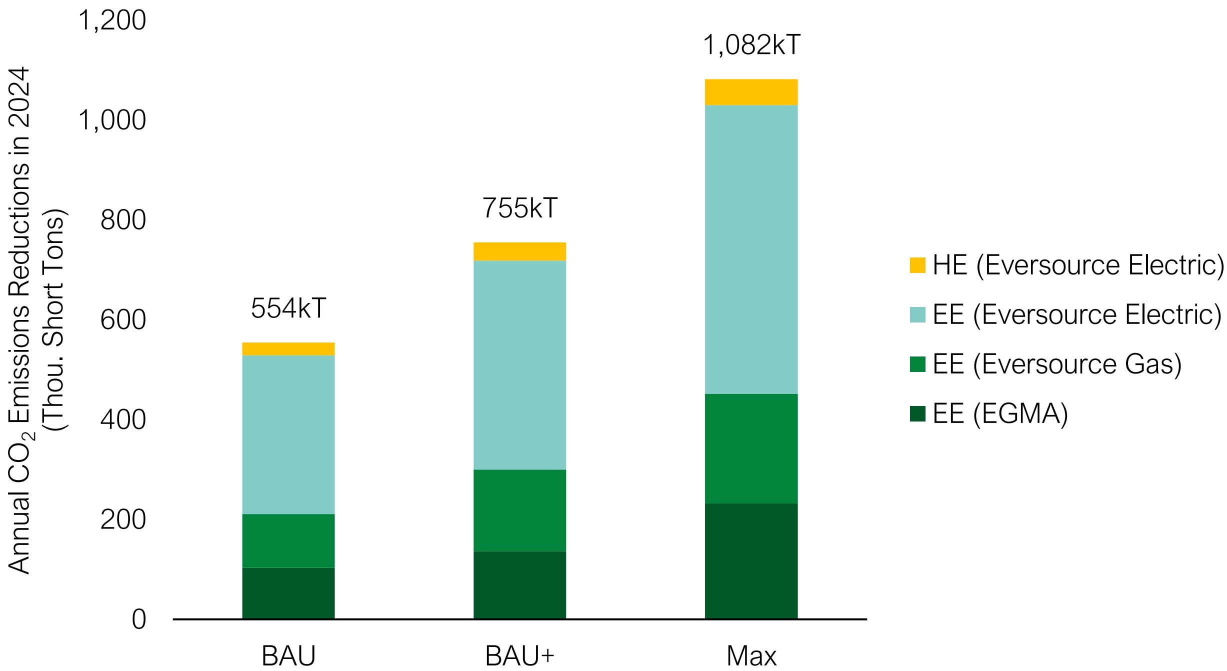
The majority of emission reductions come from EE measures – with Eversource's Electric Programs contributing over half of all emission reductions under each scenario. HE measures, conversely, only

[65] Site-to-source factors are sourced from the MA MMBtu Factors Study as cited in the 2019 PYR BCR Excel workbook.

represent approximately 5% of emission reductions under all scenarios, which is roughly the same proportion of net source MMBtu savings.

The ability of HE measures to reduce emissions from the consumption of heating fuels is tempered by the increase in electricity consumption, which increases emissions from this energy source. As the electric grid continues to decarbonize (as is expected in New England), the emission benefits of heating electrification will increase – including for heating electrification measures installed during the study period as these heat pump systems will last far beyond the end of the study period.

Figure 5-6. 2024 Cumulative Annual Emission Reductions (EE and HE)



The low proportion of savings and emission reductions from HE measures is an expected result for multiple reasons. First, HE measures target only a subset of energy end-use (space and water heating) while EE measures target the full range of building-level energy end-uses. Second, while HE measures reduce fuel consumption, they result in additional electricity consumption. With New England's current generation mix, the marginal generator is generally a natural gas-fired power plant, which consumes fuel to produce electricity. Accounting for this energy consumption from HE measures reduces their net energy savings. Finally, HE measures are still expanding as heat pumps become a more accepted technology among customers, and installers and programs continue to improve their outreach. As these measures increase in adoption, they will be expected to provide a greater share of energy savings.

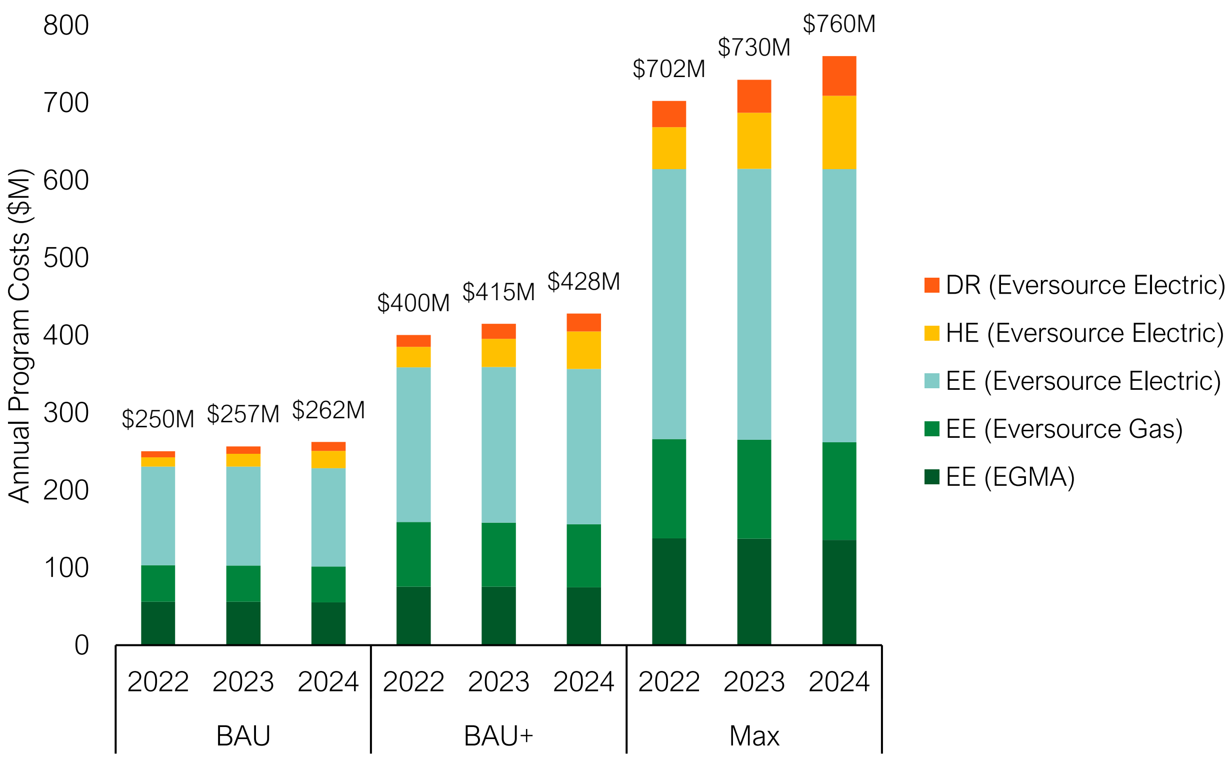
5.3 Portfolio Metrics

The following section presents combined estimates of portfolio metrics including overall program costs and program benefits.

Program Costs

Figure 5-7 shows the combined annual estimated program costs for all EE, HE, and DR programs modeled in this study.

Figure 5-7. Combined Annual Program Costs (EE, HE, and DR)



Eversource Electric EE programs compose the plurality of costs under all scenarios even though costs are significantly reduced due to the reduction in lighting measures moving through programs.

Annual costs increase year-over-year under each scenario primarily due to cost increases in HE and DR programs as these programs continue to ramp up. Under the BAU scenario, HE and DR programs represent approximately 13% of the combined costs in 2024 and increases to 19% in 2024. When compared to costs borne by Eversource Electric only, HE and DR programs represent 14% and 7% of overall costs in 2024, respectively, under the BAU scenario. Under the Max scenario, these proportions increase to 19% and 10%, respectively.

In terms of program costs per net unit of energy saved, EE measures represent the least costly savings opportunities. As shown in Table 5-1, the program cost per lifetime and first-year net source MMBtu saved is lowest for the gas efficiency programs followed by Eversource Electric (electric/delivered fuels) efficiency programs. HE measures, on the other hand, have higher costs per net source MMBtu saved relative to EE opportunities.

For all measures, the unit cost of savings increases under the BAU+ and Max scenarios as incentive levels are increased. This increase is particularly pronounced for HE measures where the cost more than doubled between the BAU and Max scenarios.

Table 5-1. Program Cost per Lifetime and First-Year Source MMBtu Program Savings (2022-24 Average)

	$ per source MMBtu Lifetime Savings			$ per source MMBtu First-Year Savings		
	BAU	BAU+	Max	BAU	BAU+	Max
EE (EGMA)	$6.38	$6.63	$7.32	$98	$100	$108
EE (Eversource Gas)	$5.49	$6.39	$7.24	$79	$92	$105
EE (Eversource Electric)	$7.69	$9.12	$11.21	$95	$113	$142
HE (Eversource Electric)	$9.96	$15.39	$20.25	$161	$249	$339

In terms of marginal program costs per lifetime source MMBtu saved, the EE gas programs exhibit the lowest values as shown in Figure 5-2. HE measures, on the other hand, tend to require substantially more program investment to drive an increase in net MMBtu savings.

Table 5-2. Marginal Program Cost per Lifetime Source MMBtu for BAU+ and Max Scenarios

	BAU → BAU+	BAU+ → Max
EE (EGMA)	$7.50	$8.36
EE (Eversource Gas)	$7.96	$9.29
EE (Eversource Electric)	$13.44	$16.11
HE (Eversource Electric)	$28.55	$29.48

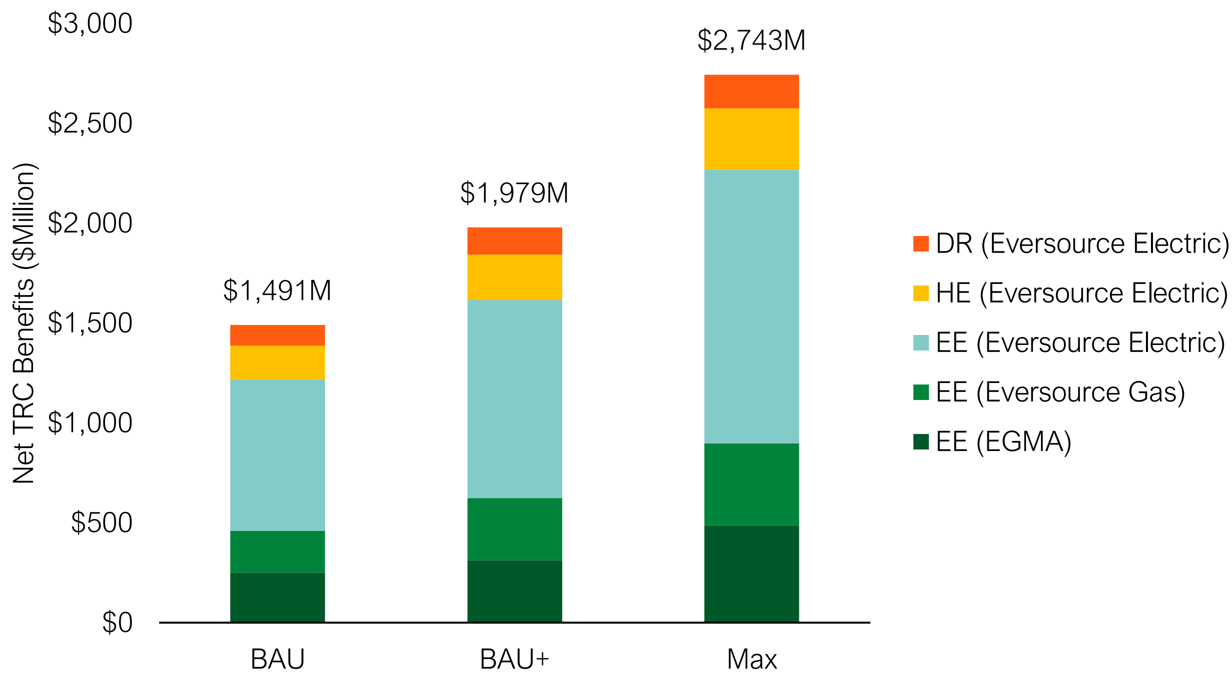
Program Benefits

Together, Eversource's EE, HE, and DR programs have the potential to create significant benefits as measured by the TRC.

Figure 5-8 shows the total accrued net TRC benefits for each savings stream. Under each scenario, Eversource's EE, HE, and DR programs will accrue billions of dollars of net benefits over the study period with up to $2.7 billion net benefits captured under the Max scenario.

The majority of these benefits are a result of EE measures representing over 80% of net TRC benefits under each scenario. Still – HE and DR measures create significant benefits. Under BAU, these measures accrue over $270M in benefits increasing to nearly half a billion under the Max scenario.

Figure 5-8. Total 2022-2024 Net TRC Benefits (EE, HE, and DR)



In terms of net TRC benefits per source MMBtu of energy saved, HE measures offer the highest value relative to EE measures as shown in Table 5-3. This difference is driven by HE measures' substitution of delivered fuels (generally high avoided costs) with electricity consumption (generally low avoided costs). It also illustrates that – while HE measures require more program investment per unit of energy saved – HE measures also return significant benefits since all measures must pass the TRC threshold and the long-lived nature of heating systems result in benefits accruing long into the future.

Table 5-3.Net TRC Benefits per Lifetime Source MMBtu Saved (EE and HE)

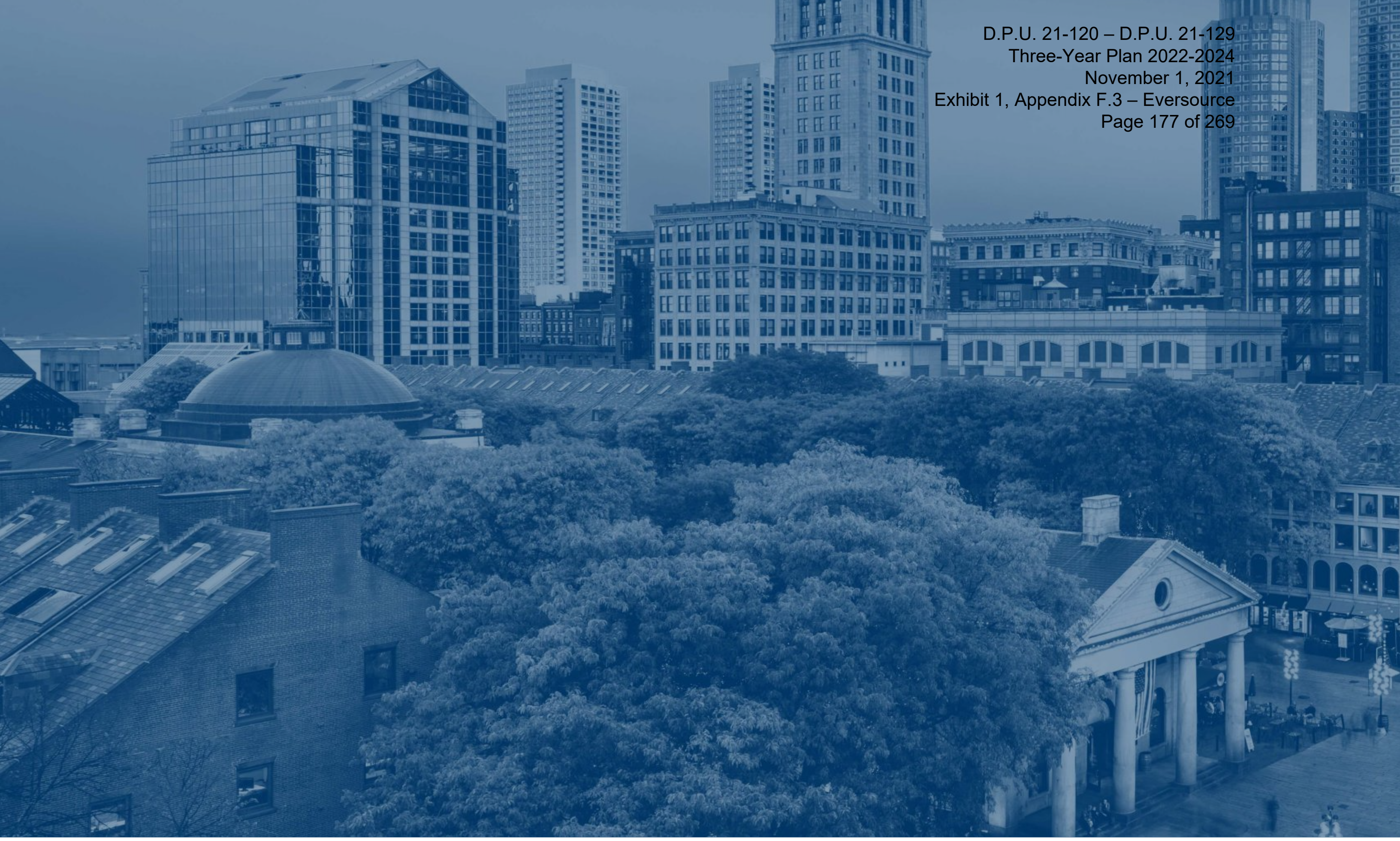
	BAU	BAU+	Max
EE (EGMA)	$9.55	$9.23	$8.64
EE (Eversource Gas)	$8.17	$7.88	$7.66
EE (Eversource Electric)	$15.08	$14.93	$14.51
HE (Eversource Electric)	$33.04	$31.64	$28.25

5.4 Key Takeaways

Based on the combined EE, HE, and DR achievable potential results presented in this chapter, the following key takeaways emerge:

- **The combined impact of EE, HE, and DR measures will drive significant savings and benefits for Eversource's customers.** As measured by the TRC test, the measures incentivized through Eversource's EE, HE, and DR programs during the study period have the potential to create billions of dollars of net benefits for Eversource's customers. In addition to these benefits, Eversource's programs can reduce CO_2 emissions by up to an additional million tons over the study period – helping contribute to Massachusetts's climate goals.

- **The importance of demand response measures for managing peak demand is growing.** For electric peak demand, DR measures are projected to have the greatest impact relative to passive demand reductions from EE and HE measures. In the past, EE measures have been the main contributor to peak reduction through passive electric demand savings. However, as DR programs continue to expand and electric savings become harder to capture with the loss of lighting opportunities, DR programs will take a more prominent role in driving future peak demand reductions.
- **In terms of energy savings, EE measures offer the least costly savings opportunities.** The overall program cost per lifetime source MMBtu saved for EE measures ranges from $5.49 to $7.69 per MMBtu relative to $9.96 per MMBtu for HE measures under BAU incentives, and this difference only grows under the higher incentive scenarios.
- **Increasing incentives drive greater savings, but at notably higher costs.** For each study component, increasing incentives boosts savings captured by Eversource's programs but increases costs at a faster rate. While raising incentives can lead to increased program participation, particularly in the short-term, opportunities may exist to leverage program enhancements that further reduce market barriers for efficient technologies over the long term. While these strategies take time to implement and their impacts can be uncertain, they could offer a lower-cost opportunity to drive higher savings, where successful, when compared to simply increasing incentives. Eversource and the state of Massachusetts as a whole have consistently achieved success reducing market barriers as shown by the state's consistent top ranking in the American Council for an Energy-Efficient Economy (ACEEE) State Energy Efficiency Scorecard, and the near-complete transformation of the Massachusetts lighting market. Moreover, the recently enacted climate bill ("An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy") may provide a framework to drive savings through statewide policies that can work in conjunction with Eversource's programs to help transform the market for other technologies.



2022-2024 Eversource MA Potential Study

(Volume II: Appendices)

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A. General Inputs, Assumptions, and Methods

A.1 Overview

The following appendix describes the general inputs, assumptions, and methods common across all components of the 2022-2024 Eversource MA Potential Study. This study includes an assessment of potential for Eversource's electric and gas programs including for the service territory formerly served by Columbia Gas (CMA). Throughout the report, the results and information pertinent to the assessment of CMA's former territory potential are referenced with EGMA ("Eversource Gas Company of MA"). Unless otherwise noted, specific inputs and assumptions apply to both the Eversource and EGMA potential assessments.

Inputs, assumptions, and methods specific to the EE, HE, and DR components of the study are provided in Sections B, C, and D, respectively.

A.2 Economic Cost-Effectiveness

Savings potential is assessed for economic cost-effectiveness using the Total Resource Cost (TRC) test that measures all benefits and costs associated with each measure and program. The TRC considers the benefits and costs experienced by both the utility system and the program participant.[1] For this study, the quantified costs and benefits used for the TRC test include the avoided costs of energy supply, the incremental costs of distributed energy resources, program implementation costs, and non-energy benefits. For all study components, measures are screened from economic potential if they have a TRC ratio below 1.0.

For avoided energy supply costs, the study applies the results of the Avoided Energy Supply Components of New England: 2021 Report ("2021 AESC Study") and other avoided cost assumptions within the utility's BCR model. The AESC Study produces "projections of marginal energy supply components that can be avoided in future years due to reductions in the use of electricity, natural gas, and other fuels as a result of program-based energy efficiency or other demand-side measures across all six New England states."[2] It includes estimates of the avoided costs of energy, capacity, natural gas, water, fuel oil, other fuels, other environmental costs, and demand reduction inducted price effects (DRIPE). For a complete description of how these costs are estimated and what is contained within them, please refer to the full 2021 AESC report.[3]

[1] National Energy Screening Project. *National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources.* August 2020.

[2] Synapse Energy Economics, et al. *Avoided Energy Supply Components in New England: 2018 Report.* March 30, 2018. Page 1.

[3] The full 2021 AESC report and supporting materials is accessible at: https://www.synapse-energy.com/project/aesc-2021-materials

Table A-1 lists the avoided cost components used in this study along with brief descriptions and sources.

Table A-1. Avoided Cost Component Descriptions and Sources

Value	Description and Source
Electric energy ($/kWh)	The study uses the retail cost of electric energy for the Massachusetts zone from Appendix B of the AESC study. It assumes a wholesale risk premium of 8.0% and an energy loss factor of 9.0% consistent with the Eversource BCR. The electric energy avoided cost is broken down into winter on-peak, winter off-peak, summer on-peak, and summer off-peak components.
Electric energy DRIPE ($/kWh)	The study uses intrastate wholesale electric energy DRIPE values and wholesale cross-DRIPE values for the Massachusetts zone from Appendix B of the AESC study. The wholesale risk premium and energy loss factors are applied to the electric energy DRIPE values and are consistent with the Eversource BCR.
Electric environmental compliance cost ($/kWh)	The study uses the retail incremental Global Warming Solutions Act (GWSA) cost of compliance values from the avoided cost worksheet within the Eversource BCR (which cites the February 19, 2019 Compliance Filing to the D.P.U.) for the avoided cost of electric environment compliance values. The electric environmental compliance cost is broken down into winter on-peak, winter off-peak, summer on-peak, and summer off-peak components.
Capacity ($/kW)	The study uses the retail cost of electric capacity for the Massachusetts zone from Appendix B of the AESC study. It assumes the same wholesale risk premium and distribution losses factor cited previously. It also assumes a peak demand loss factor of 16% for the uncleared resources. For energy efficiency measures, the study assumes the percent of capacity bid into the forward capacity market (FCM) is 85%, which is consistent with the Eversource BCR. For demand response measures, the study assumes 0% of resources are bid into the FCM.
Capacity DRIPE ($/kW)	The study uses the retail capacity DRIPE values for the Massachusetts zone from Appendix B of the AESC study. It assumes the same wholesale risk premium, peak demand losses, and percent capacity bid into the FCM as cited previously.
Reliability ($/kW)	The study uses the wholesale reliability 2021 values for the Massachusetts zone from Appendix B of the AESC study. It assumes the same wholesale risk premium, peak demand losses factor, and percent capacity bid into the FCM as cited previously.
Transmission & distribution ($/kW)	The study uses avoided transmission and distribution costs for the Massachusetts zones from Appendix B of the AESC study and the Eversource BCR, respectively. The peak demand loss factor is applied to avoided transmission costs only.
Natural gas ($/MMBtu)	The study uses the avoided cost of gas to retail customers for Southern New England (SNE) assuming some avoided retail margin from Appendix C of the AESC study. The natural gas avoided cost is broken down into values that vary by sector and end-use.
Natural gas DRIPE ($/MMBtu)	The study uses gas supply DRIPE and gas cross-DRIPE avoided cost values for Massachusetts from Appendix C of the AESC study. Avoided natural gas DRIPE costs only include zone-on-zone values (zone-on-ROP values are excluded).

Value	Description and Source
Natural gas environmental compliance cost ($/MMBtu)	The study uses the retail incremental Global Warming Solutions Act (GWSA) cost of compliance values from the avoided cost worksheet within the Eversource BCR (which cites the February 19, 2019 Compliance Filing to the D.P.U.) for the avoided cost of natural gas environment compliance values.
Fuel oil ($/MMBtu)	The study uses the weighted average avoided costs of petroleum fuels from Table 130 of Appendix D of the AESC study.
Fuel oil DRIPE ($/MMBtu)	The study uses the zone-on-zone diesel fuel DRIPE values for Massachusetts from Table 132 of Appendix D of the AESC study.
Fuel oil environmental compliance cost ($/MMBtu)	The study uses the retail incremental Global Warming Solutions Act (GWSA) cost of compliance values from the avoided cost worksheet within the Eversource BCR (which cites the February 19, 2019 Compliance Filing to the D.P.U.) for the avoided cost of fuel oil environment compliance values.
Propane ($/MMBtu)	The study uses the weighted average avoided costs of propane from Table 130 of Appendix D of the AESC study.
Propane environmental compliance cost ($/MMBtu)	The study uses the retail incremental Global Warming Solutions Act (GWSA) cost of compliance values from the avoided cost worksheet within the Eversource BCR (which cites the February 19, 2019 Compliance Filing to the D.P.U.) for the avoided cost of propane environment compliance values.
Water ($/gallon)	The study uses the avoided cost of water consumption from the Eversource BCR.

In order to apply the AESC study results to the architecture of the models used in this study, Dunsky adapted several value streams to conform to model input requirements. Specifically, several of the avoided cost value streams in the AESC study are dependent on the measure's year of installation. These value streams include energy (including electric, natural gas, and oil) DRIPE values, uncleared capacity values, capacity DRIPE values, wholesale cross-DRIPE values, and capacity-based reliability benefit values. Dunsky's models do not incorporate specific vintage year into avoided cost value streams. Therefore, these value streams were converted into a single value stream by taking an average of the values for measures installed in each study year weighted by the proportion of each study year's savings persisting in each year to approximate an aggregated value regardless of measure installation year.

The 2021 AESC Study provides projected values out to 2050, while this study calculates benefits and costs for the full life of all measures requiring projected values beyond the last year of the AESC study. For years beyond those included in the 2021 AESC Study, values were extrapolated using a simple linear forecast.

Future TRC benefits and cost streams are discounted using a nominal discount rate of 2.82%, which assumes a real discount rate of 0.81% and an inflation rate of 2.00%. These discount rate assumptions are sourced from the PA's benefit-cost ratio (BCR) model Excel workbooks at the direction of PAs. All TRC values are expressed in 2021 real-dollar terms.

A.3 Customer Cost-Effectiveness

Customer cost-effectiveness is a key driver of achievable potential. In general, customer cost-effectiveness is a function of the incremental costs borne by the customer, the future stream of bill impacts, the monetary value of any non-energy benefits (e.g., increased comfort), and customer discount rates. Incremental costs and non-energy benefits are developed as part of the measure characterization process described in Appendix B.

To determine bill impacts, marginal retail rates are developed for each customer segment.

For electric rates, this study uses Eversource's 2020 generation and demand rates weighted by consumption in five Eversource rate jurisdictions (Boston, Cambridge, South Shore, Cape Cod, and Western Mass). Residential rates are further weighted by consumption dependent on the heating season and income classification (i.e., market and low-income). Commercial rates are weighted by load factor and size. Rates are then adjusted proportionally to variations in the forecasted AESC electric avoided costs over the study period. The supply services component of retail rates is escalated using the energy avoided costs, and the distribution and transmission energy charges are escalated with the electric capacity avoided costs.

For Eversource natural gas rates, this study uses 2020 Eastern Massachusetts gas distribution rates, and costs of gas from summer 2020 (off-peak) and winter 2019 (peak). Rate components related to gas supply are escalated proportionally to the avoided costs. Other rate components (i.e., variable distribution charges) remain fixed (in real dollars) throughout the study period (2022-24). Residential rates are weighted by consumption, dependent on the heating season and income classification (i.e., market and low-income). Commercial rates are weighted by load factor and size.

Finally, electric and gas rates are inflated by one year to approximately 2021 dollars.

For EGMA natural gas rates, this study uses Columbia Gas rates in Nov 2019 for peak rates and July 2020 rates for off-peak rates. The approach for adjusting rates to the potential model structure is identical to the Eversource approach detailed in the previous paragraph.

The approach is similar for the other fuel rates with rates escalated proportionally to the relevant avoided cost rates. Oil, propane, and water customer rates are assumed to be identical to their corresponding avoided costs.

For customer discount rates, the study assumes a participant discount rate of 5.1% in real terms based on the weighted average cost of capital across all commercial sectors.[4]

A.4 Emission Factors

Emission impacts are estimated by multiplying energy savings by static marginal emission factors on a per kWh or per MMBtu basis. Table A-2 lists the emission factors used in this study, which are taken from the utility's BCR model.

[4] Aswath Damodaran. *Cost of Capital by Sector (US).* January 2020. Accessible at: http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/wacc.htm

Table A-2. Marginal Emission Factors

Fuel	Marginal Emission Factor
Electricity	0.49400 tons CO_2 per MWh
Natural Gas	0.00585 tons CO_2 per therm
Oil	0.08069 tons CO_2 per MMBtu
Propane	0.06959 tons CO_2 per MMBtu

Electricity savings in MMBtu equivalent use a weighted site-to-source conversion factor based on measure EUL to account for the anticipated declining average heat rate of generation in ISO-NE in the future. The site-to-source conversion factors are sourced from the Eversource 2019 PYR BCR workbook, which cites the MA MMBtu Factors study.[5]

[5] Navigant. *Study to Propose a More Refined Method to Account for the Conversion of Electric Savings to MMBtu Savings.* March 23, 2020. Accessible at: https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/12190546

A.5 Market Characterization

A.5.1 Customer Populations

Customer population counts at the segment level are a key parameter for defining market opportunities within each component of the study. Segment-level customer population counts were provided by the utilities.

For residential customers, the customer data was pre-segmented into the following categories:

- Non-low income and low-income customers
- Customers residing in single family buildings, multi-family buildings with 2 to 3 units, and multi-family buildings with 4 or more units

This study, however, considers any customers residing within a building with less than five units to be single-family customers in order to align with the customer segmentation definition employed in the residential baseline data used in this study. Therefore, customer data for single family customers and within multi-family buildings with 2 to 3 units are combined into a single segment with recognition this may slightly undercount single-family savings and overcount multi-family savings due to the inability to segment customers based on the baseline data's multi-family threshold. Table A-3 lists the segment-level residential customer account totals used in this study.

Table A-3. Residential Market Segment Customer Account Totals

	Single Family	Multi-Family	Low Income	Low Income Multi-Family	Total
Eversource Electric Population	995,642	163,788	91,152	28,761	**1,279,343**
Eversource Gas Population	262,387	37,043	21,395	5,360	**326,185**
EGMA Population	277,703	14,358	43,614	6,694	**342,369**

For modeling purposes, the low-income segments are grouped together. Outside the models, savings attributable to the low-income single-family and low-income multi-family segments are apportioned on a pro-rated basis according to the segment's proportion of energy consumption.

For C&I customers, the provided customer data was segmented into the following categories:

- Office
- Retail
- Food Service
- Healthcare/ Hospitals
- Campus/ Education
- Warehouse
- Lodging
- Other Commercial
- Food Sales
- Manufacturing/ Industrial
- C&I Multifamily
- Unknown

The unknown customer population is assigned to the known segment populations on a pro-rated basis based on known segment populations. Additional metrics provided with the customer data (e.g., mean consumption) are adjusted to reflect the addition of unknown accounts. Table A-4 lists the segment-level C&I population counts used in this study.

Table A-4. C&I Market Segment Customer Account Totals

Segment	Eversource Electric Population	Eversource Gas Population	EGMA Population
Office	21,812	5,111	4,915
Retail	24,606	8,128	8,836
Food Service	3,279	1,242	1,245
Healthcare/ Hospitals	1,789	546	619
Campus/ Education	2,438	1,093	796
Warehouse	6,186	2,078	3,514
Lodging	22,296	1,241	1,666
Other Commercial	10,846	2,169	2,683
Food Sales	324	132	104
Manufacturing/ Industrial	4,000	1,814	2,397
C&I Multi-Family	47,798	3,500	2,152
Total	*145,376*	*27,056*	*28,927*

For modeling purposes, the C&I multi-family segment – representing multi-family common areas and master metered multi-family buildings – is grouped with the lodging segment within each model due to the general common applicability of measures to each segment. Outside the models, savings attributable to the lodging and C&I multi-family segments are apportioned on a pro-rated basis according to the segment's proportion of energy consumption. Savings are split between market-rate and low-income multi-family market segments on an even basis (i.e., 50/50) based on guidance from Eversource regarding the proportion of C&I multi-family savings passing through existing market-rate and low-income programs.

A.5.2 Baseline Data

Where possible, this study leverages baseline data from recently conducted Massachusetts baseline studies. When MA-specific baseline data is not available (or based upon insufficient observations), the study leverages data from nearby comparable jurisdictions in the Northeast U.S.

For the residential sector, the study leverages the Massachusetts Residential Baseline Study.[6] Utility-specific baseline metrics are used where possible (e.g., sufficient number of observations).

For the C&I sector, the study leverages baseline data from the recent 2020 Massachusetts C&I Baseline Saturation Study and the 2016 Massachusetts C&I Market Characterization Study.[7] Due to data collection limitations resulting from the COVID-19 pandemic, the 2020 baseline study had limited observations – particularly for segments such as healthcare. Where possible, this study uses results from the 2020 baseline study. However, in many cases, low observation counts limited the use of this data. Data from the 2016 baseline study is leveraged where possible – particularly for variables where minimal change would be expected between 2016 and the present day (e.g., the average number of light sockets per business).

A.5.3 Growth Factors

Table A-5 lists the customer growth factors used in this study. Growth factors are based on the utility's projected customer account growth over the study period.

Table A-5. Customer Growth Factors

Sector	Growth Factor
Residential – Market Rate	0.7%
Residential – Low Income	0.6%
Commercial	0.6%
Industrial	-2.7%

A.6 Study Component Integration

While the EE, HE, and DR components of this study are modeled separately, the study considers possible interactive effects between study components and adjusts relevant model parameters to account for any material impacts. The potential interactive effects include inter-model measure competition, peak demand, and load curve impacts, market size impacts, and additive incentive adoption effects.

The remainder of this section describes these interactive effects and details whether the effects are expected to be significant and if/how the study accounts for them. Interactions are grouped by whether

[6] Guidehouse. *Massachusetts Residential Baseline Study.* March 31, 2020. Accessible at: https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf

[7] DNV-GL. *MA C&I Market Characterization On-Site Assessments and Market Share and Sales Trends Study*. November 2016. Accessible at: https://ma-eeac.org/wp-content/uploads/MA-CI-Market-Characterization-Study.pdf

they primarily impact the EE or DR models.[8] In general, potential impacts are evaluated against model results under BAU+ scenarios to serve as an anchoring point between the BAU and Max scenario results.

A.6.1 DR Model Interactions

Dunsky's Demand Response Optimization (DROP) model uses annual peak demand projections as well as the peak day load curve to determine the potential for DR programs and measures (see Appendix D for more detail on DROP). Efficiency programs encourage the adoption of electricity using equipment that typically reduces the connected demand, and the resulting peak demand draw, when compared to standard efficiency or existing equipment. Moreover, Dunsky's Heating Electrification Adoption (HEAT) model projects the uptake of electric heating equipment to replace combustion heating equipment (see Appendix C for more detail on HEAT). Lastly, Dunsky's Electric Vehicle Adoption (EVA) model projects the uptake of electric vehicles in the service territory.[9] In each case, these projections are expected to impact the annual utility peak load and peak day load shape, which in turn can impact the DR potential.

Peak Demand Projection Adjustments: The annual overall peak demand impact from measure adoption in the other models is first applied to adjust the annual peak load forecast provided by the utility.

Peak Day Load Curve Adjustments: Next an adjustment to the hourly peak day load curve is made by assessing peak demand impacts as a portion of the overall peak demand contributions for each market segment at the end-use level. These proportional adjustments are then applied to each market segment and end uses' contribution to the overall demand in each hour of the peak day.

BYOD Market Adjustments: Finally, the markets for BYOD measures in the DROP model are updated to account for adoption in other models. Examples of BYOD markets adjusted based on adoption observed in the other models include WiFi thermostats, EV smart charging, and heat pumps.

Additive Incentives: In cases where equipment carries both EE and DR program benefits, the available incentives may be combined to drive increased adoption. In this study, this impact is limited to Wi-Fi Thermostats where a customer who is receiving an incentive under the efficiency program may also be encouraged to adopt the measure by the opportunity to participate in the DR program and receive additional annual participation incentives. However, in this study, the evaluated impact of the dual EE + DR incentive was found to have a minimal effect on WiFi thermostat adoption (<1% increase in adoption), and thus this interaction was considered to be negligible.

Collectively, these adjustments ensure that the DROP model provides an accurate assessment of DR potential, accounting for the impacts of efficiency, heating electrification, and EV adoption.

A.6.2 EE Model Interactions

Adjustments are made where appropriate to account for potential measure competition between Dunsky's Demand and Energy Efficiency Potential (DEEP) model and the HEAT model. In some cases, mutually

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[8] The study's approach for model interactions assumes impacts are limited to EE and DR modeling (and excludes impacts to HE modeling) to limit the recursive process required to adjust each separate model with each iteration of results.

[9] Under a separate project, Dunsky estimated electric vehicle adoption for the Eversource electric territory. The results of that analysis were leveraged for this study.

exclusive measures may share the same replacement opportunity (e.g., replacing a failed furnace with a heat pump as opposed to a high-efficiency furnace) which results in measure competition. In other cases, measures may not share the same opportunity but the adoption of one measure may limit opportunities for another measure in the future. For example, the adoption of a heat pump to partially offset the heating load of an existing boiler may reduce the cost-effectiveness (both from a TRC and customer standpoint) of a future EE opportunity to replace the boiler with a more efficient version due to a much lower heating load served by the boiler.

In this study, the impact of inter-model measure competition and interactions is considered limited for three key reasons.

1) **Model calibration to recent efficiency and heating electrification program performance inherently accounts for competition at current adoption rates.** By calibrating to existing programs, the implicit competition between each program is captured for existing levels of program participation. Therefore, any possible inter-model competition would only impact measure adoption that is significantly higher than current program uptake levels. In this study, incremental growth in programs under the BAU scenario is generally limited to HE measures for which adoption is expected to continue to grow as the opportunity for heat pumps becomes increasingly recognized in the market.

2) **The magnitude of most measure competition and interaction between DEEP and HEAT is insignificantly small.** The adoption of HE measures over the study period is extremely small relative to the overall size of the market, and thus the potential impact of competition between EE and HE measures is considered to have an insignificant impact on the study results in most cases. The primary exception is the interaction between the adoption of heat pumps and high-efficiency AC units. These measures share the same upgrade opportunity (i.e., burnout of the existing AC unit) and show significant adoption rates in both models. For other measures such as high-efficiency heating systems, the overlap of upgrade opportunities is limited. For example, full replacement heating electrification adoption represents less than 1% of furnace/boiler burn out opportunities under BAU, and as such it is assumed that the overlapping opportunity with high-efficiency furnace and boiler measures is insignificant (i.e., well within the range of uncertainty of the DEEP model results).

3) **The market drivers for heating electrification are expected to differ sufficiently that they will not directly compete in all cases.** Measure competition hinges on the fact that competing measures are almost identical beyond incremental costs and energy savings and assumes that a customer – once they have decided to participate in a program – must choose between two (or more) similar measures. However, potentially competing EE and HE measures represent different value propositions for customers beyond just cost and bill savings (e.g., improved comfort from upgraded heating system), which could lead to different customer bases participating in an EE program versus an HE program. Therefore, to avoid overestimating the overlap between HE and EE measures, where notable overlap is identified the market availability for high-efficiency measures is reduced to account for heat pump adoption, rather than reducing the number of efficiency measures adopted by the number of heat pumps adopted.

Study adjustments: **Adjust EE air conditioning measure adoption.** Considering the above rationale, an adjustment was made to the EE market opportunities for high-efficiency AC units to account for competition with heat pump adoption from the HE projections. For residential and C&I EE air conditioning measures, achievable adoption is reduced by the relative proportion of overlapping opportunities represented by the incremental growth in HE measure adoption relative to 2019 results. For example, if HE measure growth results in an additional 2% of opportunities being captured by HE programs, achievable adoption for overlapping EE measures is reduced by 2%.

A.7 COVID-19 Sensitivity

As the COVID-19 pandemic has led to economic uncertainty and business closures, it is expected to have some impact on overall program performance. While it is unclear what the short and long-term impacts of the pandemic will be, this study includes a sensitivity analysis of the impact that COVID-driven changes in market conditions may have on program savings for the EE and HE study components.

Dunsky does not suggest that this analysis will predict what is likely to happen in the future. Instead, the hope is that it will provide information about the sensitivity of modeled savings to changes in market conditions that may plausibly be expected because of the pandemic – increased business closures and increased market barriers to measure adoption.

To model this sensitivity, the following model input parameters on a segment-by-segment basis are adjusted within each model:

- **Market size** is adjusted to reflect fewer customers within a given segment due to temporary or permanent business closures.
- **Adoption barrier levels** are increased to reflect delayed projects, increased competition for capital, decreased resources, and other impediments to energy efficiency and electrification upgrades.

In recognition of the heterogeneous impact of the pandemic on business types, the study categorizes each modeled C&I market segment into one of three impact categories:

- **Low**: No anticipated closures, small market barrier increase
- **Moderate**: Anticipated short-term closures, moderate market barrier increase
- **High**: Anticipated long-term closures, large market barrier increase

To categorize C&I market segments, the Dunsky team reviewed available data sources for insights on COVID impact by business type.

The analysis relies on the US Census Small Business Pulse Survey (SBPS) as the main source of impact insight by industry as it is public, recent (December 2020), and has a significant number of respondents nationally (n = 24,800) and state-wide (n=550). The analysis starts with the MA-specific data and validates the results with the national averages; in all cases the rounded results aligned.

The SBPS is targeted at small businesses (<500 employees). Where relevant, the analysis makes adjustments to categorizations based on professional judgment and additional research.

The Pulse survey collected data at the NAICS code level across the United States. The NAICS codes are mapped to the potential study segments. Average response is determined for each segment based on the 5-point Likert scale responses (see 'Rounded overall score' columns in Table A-6). The values shown below are based on the national averages due to data gaps in the MA-specific responses (e.g., no campus/education segment responses). However, the same analysis was conducted for MA-specific responses and the segment-level rounded values (where available) do not differ from the national responses.

Table A-6. Pulse Survey Responses: Overall, how has this business been affected by the COVID-19 pandemic? (National Average)

Segment[10]	Large negative effect (score=1)	Moderate negative effect (score=2)	Little to no effect (score=3)	Moderate positive effect (score=4)	Large positive effect (score=5)	Overall score	Rounded overall score
Campus/ Education	58%	32%	6%	2%	1%	1.55	2
Food Service; Lodging	67%	24%	6%	2%	1%	1.46	1
Healthcare /Hospitals	31%	56%	9%	3%	1%	1.85	2
Manufacturing / Industrial	30%	42%	22%	6%	2%	2.13	2
Office	24%	42%	28%	5%	1%	2.18	2
Retail; Food Sales	24%	41%	17%	13%	5%	2.33	2
Warehouse	32%	42%	19%	5%	2%	2.02	2
Other	31%	39%	26%	4%	1%	2.09	2

Based on this assessment, every segment except for the food service and lodging segments indicated a "moderate negative effect" from the COVID-19 pandemic. The average response score for the food service and lodging segments indicates a "large negative effect".

Using these rounded scores (1-5) as a starting point, we then select final impact categories for the segments and make further modifications where warranted based on professional judgement and additional data. The final categorization and rationale for modifications are laid out in Table A-7.

Table A-7. COVID-19 Impact Assessment Category Assignment

Segment	Pulse Survey – Overall Score Category	Impact Category	Modification Rationale
Campus/Education	Moderate negative effect	Moderate	

[10] Some segments are grouped due to NAICS code mapping.

Food Service; Lodging	Large negative effect	High	
Healthcare/ Hospitals	Moderate negative effect	Moderate	
Manufacturing/ Industrial	Moderate negative effect	Moderate	
Office	Moderate negative effect	High	While the Pulse Survey suggests moderate negative effects for commercial entities within the office segment, this does not necessarily reflect office building use impacts as many functions have shifted to remote work. Research suggests that office use has been significantly impacted and may not bounce back until roughly 2025.[11]
Retail; Food Sales	Moderate negative effect	Low	Research suggests impacts on retail businesses are not homogenous. While some retail businesses have been negatively affected (clothing, auto dealerships, travel agencies), others – particularly ones that may not be captured by the Pulse Survey – are seeing significant growth (big box stores, grocery, hardware).[12]
Warehouse	Moderate negative effect	Low	Many warehouses would not typically fall within the "small business" classification of the Pulse Survey, and research suggests increased demand for some warehouses particularly for e-commerce services[13].
Other	Moderate negative effect	Moderate	

Finally, sensitivity input settings are defined for each category. Table A-8 outlines the input settings for each non-residential impact category. A single setting was used for the residential sector. As previously described, two settings will be adjusted – market sizes and segment-level barrier levels.

Market size adjustments are limited to non-residential segments within the moderate and high impact categories under the assumption low impacted segments will retain pre-COVID levels of businesses and that the pandemic will not influence the number of residential customers. For moderate and high impacted segments, the sensitivity analysis assumes market size reductions of 25% for the first year and all three years of the study, respectively. Please note this assumption is highly speculative as the overall impact on business closures is still highly uncertain and the true market size impacts may be higher or lower.

[11] *Global Office Impact Study & Recovery Timing Report*, Cushman and Wakefield, Sept 2020
https://www.cushmanwakefield.com/en/insights/covid-19/global-office-impact-study-and-recovery-timing-report

[12] *Top Performing and Hardest Hit Industries*, Vertical IQ, Sept 2020
https://verticaliq.com/covid-19-most-impacted-industries/

[13] *How the e-commerce boom during COVID-19 is changing industrial real estate*, JLL, June 2020
https://www.us.jll.com/en/trends-and-insights/investor/how-the-e-commerce-boom-during-covid-19-is-changing-industrial-real-estate

Table A-8. COVID-19 Sensitivity Settings by Category

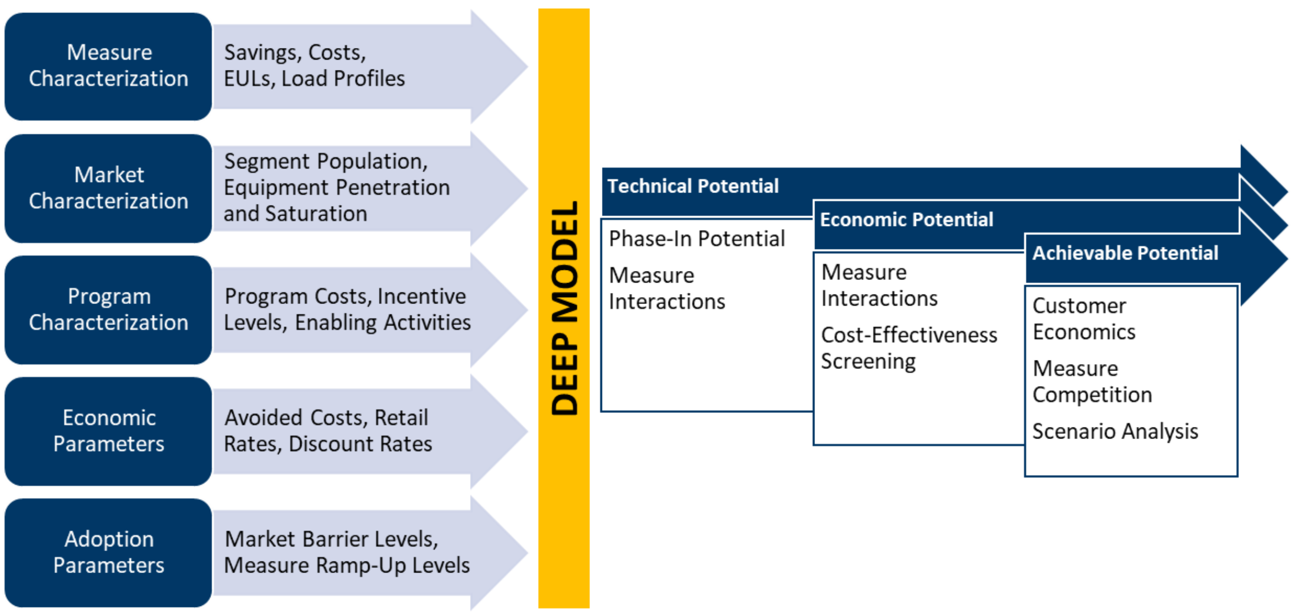
Sector	Category	Segments	Impact on Savings Scenario
Residential	Low impact	All	• Market size: No change • Barriers: small barrier level increase / technology diffusion curve slowdown
C&I	Low impact	Retail Food Sales Warehouse	• Market size: No change • Barriers: small barrier level increase / technology diffusion curve slowdown
	Moderate impact	Campus/Education Healthcare/Hospitals Manufacturing/Industrial Other	• Market size: Reduce 2022 market by 25%, return 2023-2024 markets to baseline size • Barriers: moderate barrier level increase / technology diffusion curve slowdown
	High impact	Food Service Lodging Office	• Market size: Reduce by 25% for 2022-2024 • Barriers: large barrier level increase / technology diffusion curve slowdown

B. Energy Efficiency Methodology

B.1 Overview

The following appendix outlines the energy efficiency modelling methodology used to assess the technical, economic and achievable savings from efficiency programs. This section begins with a general discussion of the Dunsky's modelling approach and then provides details on the specific assumptions and inputs made in this study.

The market potential for energy efficiency is estimated using the Dunsky's Demand and Energy Efficiency Potential (DEEP) model. DEEP employs a multi-step process to develop a bottom-up assessment of technical, economic, and achievable potential. This appendix describes DEEP's modeling approach, the process of developing DEEP model inputs and the underlying calculations employed to assess energy efficiency potential.



B.2 The Dunsky Energy Efficiency Potential Model

DEEP's bottom-up modeling approach assesses thousands of "measure-market" combinations, applying program impacts (e.g., incentives and barrier reducing enabling activities) to assess energy savings potentials across multiple scenarios. Rather than estimating potentials based on the portion of each end-use that can be reduced by energy-saving measures and strategies (often referred to as a "top-down" analysis), the DEEP's approach applies a highly granular calculation methodology to assess the energy savings opportunity for each measure-market segment opportunity in each year. Key features of this assessment include:

- **Measure-Market Combinations:** Energy saving measures are applied on a segment-by-segment basis using segment-specific equipment saturations, utility customer counts, and demographic data to create unique segment-specific "markets" for each individual measure. The measure's impact and market size are unique for each measure-market segment combination, which increases the accuracy of the results.

- **Phase-In Potential:** DEEP assesses the phase-in technical, economic, and achievable potential by applying a measure's expected useful life (EUL) and market growth factors to determine the number of energy savings opportunities for each measure-market combination in each year. This provides an important time series for each energy savings measure upon which estimated annual achievable program volumes (measure counts and savings) can be calculated in the model as well as phase-in technical and economic potentials.

- **Annual, Lifetime, and Cumulative Savings:** For each measure-market combination in each year, DEEP calculates the annual, lifetime, and cumulative savings accounting for mid-life baseline adjustments and program re-participation where appropriate.[14] This provides an assessment of the cumulative savings (above and beyond natural uptake) as well as the annual and lifetime savings that will pass through DSM portfolios.

B.3 DEEP Model Inputs

DEEP requires an extensive set of model inputs related to energy savings measures, markets, economic factors, and adoption parameters to accurately assess energy efficiency potential. These inputs are developed through several concurrent processes that include measure characterization, market characterization, program characterization, economic parameter development and adoption parameter development. The remainder of this section outlines each process.

B.3.1 Measure Characterization

Measure characterization is the process of determining the costs, savings, and lifetimes of potential energy-saving technologies and services and their baseline equivalents that will then be used as inputs to the DEEP model. The measure characterization process begins by developing a comprehensive list of energy-saving measures.

For this study, Dunsky proposed an initial measure list based on the full range of existing measures offered in the utility's existing programs as well as emerging opportunity measures. Measures were limited to currently commercially viable measures and measures that may become commercially viable over the study period based upon Dunsky's professional judgment and included measures that contributed to more than 95% of the utility's savings in previous years.

[14] Mid-life baseline adjustments are required for early retirement measures after the useful life of the existing equipment expires and new equipment (at a more efficient baseline) would have been purchased. Program re-participation occurs when a customer may receive an incentive for a new efficient measure to replace an efficient measure previously received through the program at the end of its life, which results in *program* savings but no additional *cumulative* savings.

The measure list was vetted and approved by the utility with modifications based on coordination with the other PAs and input from the EEAC and finalized prior to measure characterization. The final measure list represents more than 1,600 measure-market combinations – representing the full range of commercially available energy saving technologies (current and emerging).

Measure characterization is accomplished by compiling primary and secondary data (as available) on the efficient and baseline (i.e., inefficient) energy-consuming equipment available in the jurisdiction. Measures are characterized using segment-specific inputs when available yielding segment specific characterizations for each measure-market combination.

Measures are characterized in terms of their market unit such as savings per widget, savings per square foot, or savings per ton of cooling capacity. Each measure in the measure list was characterized by defining a range of specific parameters. Table B-1 describes these parameters.

Table B-1. DEEP Measure Characterization Parameters

Parameter	Description
Market unit	The unit in which the measure is characterized and applied to the market (e.g. per widget, per building, per square foot, etc.)
Measure type	The measure type, which can be at least one of the following: • Replace on Burnout (i.e., replace on failure) • Early Replacement • Addition (e.g., retrofit / discretionary measures) • New Construction/Installation
Annual gross savings	The annual gross savings of the measure per market unit in terms of both energy (e.g., kWh, MMBtu), demand (e.g., kW), and other factors (e.g., water) as applicable
Measure costs	The incremental cost of the measure (e.g., the difference in cost between the baseline technology and the efficient technology)
Measure life	The effective useful life (EUL) and/or remaining useful life (RUL) of both the efficient measure and the baseline technology
Impact factors	Any factors affecting the attribution of gross savings including net-to-gross adjustments, in-service factors, persistence factors, and realization rates.
Load factors	Any factors affecting modulating gross savings including summer and winter peak coincidence factors as well as seasonal savings distributions.
Program allocation	The program(s) to which the measure applies – in some instances, measures will be allocated to multiple programs on a pro-rated basis if the measure is offered through multiple programs

This study characterized measures using inputs from the Massachusetts Technical Resource Manual (TRM) 2019 Plan-Year Report Version (May 2020) when supporting entries were present and deemed applicable to the study. In cases where MA TRM entries were not available or did not account for segment-by-segment variations, measures were characterized using other best-in-class TRMs from other jurisdictions. Dunsky strived to characterize measures in accordance with the MA TRM for measures constituting more than 80% of overall savings.

Measure Types

DEEP incorporates four types of measures types – replace on burnout, early replacement, addition, and new construction/installation. DEEP treats each of these measure types differently in determining the maximum annual market available for phase-in potential. Table B-2 provides a guide as to how each measure type is defined and how the replacement or installation schedule is applied within the study to assess the phase-in potentials each year.

Table B-2. DEEP Measure Type Descriptions

Measure Type	Description	Yearly Units Calculation
Replace on Burnout (ROB)	An existing unit is replaced by an efficient unit after the existing unit fails. *Example: Replacing burned out bulbs with LEDs*	The eligible market is the number of existing units divided by EUL.
Early Replacement (ER)[15]	An existing unit is replaced by an efficient unit before the existing unit fails. These measures are generally limited to measures where savings are sufficient enough to motivate a customer to replace existing equipment earlier than its expected lifespan. *Example: Replacing a functional, but inefficient, furnace*	The eligible market is assumed to be a subset of the number of existing units based on a function of the equipment's EUL and remaining useful life (RUL)
Addition (ADD)	A measure is applied to existing equipment or structures and treated as a discretionary decision that can be implemented at any moment in time. *Example: Adding controls to existing lighting systems, adding insulation to existing buildings*	The eligible market is distributed over the estimated useful life of the measure using an S-curve function.
New Construction/ Installation (NEW)	A measure that is not related to existing equipment. *Example: Installing a heat-pump in a newly constructed building.*	The eligible market is measure-specific and defined as new units per year.

In this study, only a small number of measures were characterized as early replacement measures. In general, early replacement measures are limited to those where energy savings are sufficient to motivate a customer to replace existing equipment significantly before the end of its expected useful life. This is generally limited to measures with long EULs and a large difference between existing installed efficiency and baseline efficiencies for new equipment (e.g., furnaces and boilers) as the early replacement of these measures will create significant additional savings through the early retirement of particularly inefficient equipment.

[15] Early replacement measures are limited to measures where energy savings are sufficient to motivate a customer to replace existing equipment prior to the end of its expected lifespan.

Measure Characterization Inputs

The following tables list key measure characterization inputs used to estimate measure savings used in this study.

Table B-3. Measure Characterization Inputs

Sector	Variable	Segment	Value	Units	Description	Source
Residential	EFLH_heat	Single-family	1200	hours	Heating mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 66, 151
		Multi-family	1158.5	hours	Heating mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 120, 125, 325
		Low-income	1117	hours	Heating mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 325,
Residential	EFLH_cool	Single-family	419	hours	Cooling mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 66, 151, 72
		Multi-family	218	hours	Cooling mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 120, 125, 325
		Low-income	200	hours	Cooling mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 347
Residential	AHL_kWh	Single-family	20046.06	kWh	Annual heating load in kWh	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 300 Converted 68.4 MMBtu to kWh with a conversion factor of 293.071 kWh/MMBtu
		Multi-family	12974.78	kWh	Annual heating load in kWh	Scaled annual heating load of single family based on floor area ratio
		Low-income	15655.22	kWh	Annual heating load in kWh	Scaled annual heating load of single family based on floor area ratio
Residential	ACL_kWh	Single-family	3839.23	kWh	Annual cooling load in kWh	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 300 Converted 13.1 MMBtu to kWh with a conversion factor of 293.071 kWh/MMBtu
		Multi-family	2484.94	kWh	Annual cooling load in kWh	Scaled annual heating load of single family based on floor area ratio
		Low-income	2998.29	kWh	Annual cooling load in kWh	Scaled annual heating load of single family based on floor area ratio

Sector	Variable	Segment	Value	Units	Description	Source
C&I	EFLH_heat	All	1035.75	hours	Heating mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 676 Calculated using weighted averages based on population of MA (85% National Grid, 15% WMECO)
C&I	EFLH_cool	All	908	hours	Cooling mode equivalent full load hours	MA TRM - 2019 EE Plan-Year Report, published May 2020; pg. 676 Calculated using weighted averages based on population of MA (85% National Grid, 15% WMECO)
C&I	HOU_lighting	Office	4181	hours	Hours of use for the Office segment	MA TRM, May 2020, pdf pg 607, 608, 675
		Retail	4939	hours	Hours of use for the Retail segment	MA TRM, May 2020, pdf pg 607, 608, 676
		Food Service	5018	hours	Hours of use for the Food Service segment	MA TRM, May 2020, pdf pg 607, 608, 677
		Healthcare/ Hospitals	4543	hours	Hours of use for the Healthcare/ Hospitals segment	MA TRM, May 2020, pdf pg 607, 608, 678
		Campus/ Education	3813.5	hours	Hours of use for the Campus/ Education segment	MA TRM, May 2020, pdf pg 607, 608, 679
		Warehouse	6512	hours	Hours of use for the Warehouse segment	MA TRM, May 2020, pdf pg 607, 608, 680
		Lodging	4026	hours	Hours of use for the Lodging segment	MA TRM, May 2020, pdf pg 607, 608, 681
		Other Commercial	4332	hours	Hours of use for the Other Commercial segment	MA TRM, May 2020, pdf pg 607, 608, 682
		Food Sales	5468	hours	Hours of use for the Food Sales segment	MA TRM, May 2020, pdf pg 607, 608, 683
		Manufacturing/ Industrial	4988	hours	Hours of use for the Manufacturing/ Industrial segment	MA TRM, May 2020, pdf pg 607, 608, 684
C&I	HOU_compressor	Office	1976	hours	Hours of use for the Office segment	Internal calculation
		Retail	1222	hours	Hours of use for the Retail segment	Internal calculation

Sector	Variable	Segment	Value	Units	Description	Source
		Food Service	1976	hours	Hours of use for the Food Service segment	Internal calculation
		Healthcare/ Hospitals	485	hours	Hours of use for the Healthcare/ Hospitals segment	Internal calculation
		Campus/ Education	520	hours	Hours of use for the Campus/ Education segment	Internal calculation
		Warehouse	1324	hours	Hours of use for the Warehouse segment	Internal calculation
		Lodging	1976	hours	Hours of use for the Lodging segment	Internal calculation
		Other Commercial	2199	hours	Hours of use for the Other Commercial segment	Internal calculation
		Food Sales	1630	hours	Hours of use for the Food Sales segment	Internal calculation
		Manufacturing/ Industrial	1630	hours	Hours of use for the Manufacturing/ Industrial segment	Internal calculation

Table B-4. Degree Days

Variable	°C days	Description	Source
HDD_15.6C	1982.47	Heating degree days (°C days) with a base temperature of 15.6 °C (60°F)	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)
CDD_23.9C	99.46	Cooling degree days (°C days) with a base temperature of 23.9 °C (75°F)	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)
HDD_18.3C	2605.58	Heating degree days (°C days) with a base temperature of 18.3 °C (65°F).	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)
CDD_18.3C	440.91	Cooling degree days (°C days) with a base temperature of 18.3 °C (65°F).	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)

Variable	°C days	Description	Source
HDD_10C	1449.45	Heating degree days (°C days) with a base temperature of 10 °C (50°F)	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)
CDD_10C	1617.49	Cooling degree days (°C days) with a base temperature of 10 °C (50°F)	Internal calculation sheet; applied a weighted average based on population in the Eversource's jurisdiction to HDD values provided in MA TRM (85% Boston, 15% Chicopee)

Lighting Characterization

Due to the significant contribution lighting measures have historically made to efficiency portfolio savings and the rapidly transforming lighting market, the potential study team directed additional attention to characterizing lighting measures and markets. The following section documents the measure and market inputs and assumptions used to estimate energy efficiency potential from lighting measures in this study.

Residential Lighting

The study includes residential interior LED bulbs broken down into the following categories:

- LED A-Lamps
- LED Specialty – Reflectors
- LED Specialty – Candelabras, Globes

The study separately considers lighting measures delivered via upstream and direct install (DI) delivery channels. For the upstream delivery channel, the study assumes 100% naturally occurring market adoption (NOMAD) by 2022, which eliminates all economic and achievable savings from this measure delivery channel.[16] Lighting measures are characterized according to the MA TRM, which calculates savings as a function of the difference between the inefficient and efficient lighting technology's wattage and hours of use. Claimable savings from residential bulbs are assumed to last for one year (i.e. an adjusted measure life [AML] of one year). Table B-5 lists the measure inputs used to characterize the residential DI lighting measures.

Table B-5. Residential Lighting Measure Inputs (Direct Install)

Input	Market Rate	Low-Income
Delta watts	2019 TRM values	
Hours of use (HOU)	2.6 hours/day for DI and Turn-in (949 hours/year)[17]	
Measure Life	1 year for Direct Install / Early Replacement	
Incremental Costs	Eversource-specific DI lighting costs (see Table B-6)	
Interactive Effects	Apply fossil fuel heating penalty of 2,295 Btu/kWh as per 2019 TRM	
NEIs	Assume no NEIs	Assume low-income NEIs (as per 2019 TRM)
NTG	DI: 0.55 NTG for 2022[18]	Assume 1.0 NTG
Program eligibility	Assume measures only offered in 2022	Assume measures offered in all three study years

[16] Based on ongoing discussions between the MA PAs and DOER.

[17] Consensus recommendation for inefficient direct install lamps resulting from Residential Lighting Hours-of-Use Quick Hit Study (MA20R21-E) published March 31, 2020.

[18] The NTG factor for market-rate DI lighting measures assumes NTG factors continue to decline in a linear fashion based on the decline between 2019 and 2021.

Table B-6 lists the DI bulb costs assumed in this study, which include the installation costs making incremental costs higher than typical measures.[19] Bulb costs are assumed to be the same for all market-rate and low-income segments.

Table B-6. Residential DI Bulb Costs

Bulb Type	Cost
LED Bulb	$7.76
LED Bulb - Specialty	$8.65
LED Bulb - Reflectors	$8.45

The markets for residential lighting measures are characterized using lighting socket penetration data from the recent residential lighting market assessment study and inefficient lighting penetration assumptions agreed to by all PAs through their coordination efforts.[20] Table B-7 lists the lighting sockets per household assumptions used in this study. The study assumes the saturation of non-efficient light bulbs to be 20% for all bulb types in the residential sector in 2022.[21] Both saturation and penetration assumptions are based on statewide data. The market split between upstream and DI programs is assumed to be the observed split in the 2019 program year.[22]

Table B-7. Residential Lighting Sockets per Household Assumptions by Bulb Type and Segment (Sockets per Household)

Bulb Type	Single Family	Multi-Family	Low-Income
A-Lamps	35	14	28
Specialty – Reflectors	15	8	6
Specialty – Candelabras, Globes	12	4	8

Note: sockets per home include both interior and exterior sockets.

C&I Lighting

The study includes the non-residential lighting measures listed in Table B-8. To ensure coordination between the PA studies, the Dunsky team in collaboration with Eversource mapped the Dunsky C&I lighting measure list to the proposed list for the National Grid potential study. The table presents this mapping as well.

[19] Residential DI bulb costs were provided by Eversource and based on actual delivery prices (both equipment and labor) in 2019.

[20] 2018-19 Residential Lighting Market Assessment Study (RLPNC Study 18-10).

[21] This assumption is provided by Eversource and based on a residential lighting stock turnover model that estimates efficient lighting saturation.

[22] We use this approach based on the assumption that direct install programs are limited by delivery capacity (e.g., number of technicians) and customer willingness (e.g., not every customer wants a technician entering their home) that is reflected in past direct install program activity.

Table B-8. Non-residential lighting measures

Eversource Measure	National Grid Measure
LED Bulbs / Lamps	Indoor LED Lamp - PAR/BR/MR/A
LED Linear Tubes (T8 and T12)	Indoor LED Linear Lamp
LED Linear Luminaires (T8 and T12)	Indoor LED Linear Fixture/Retrofit Kit
LED High Bays (HID)	Indoor LED Fixture - High/Low Bay
LED Exit Signs	Indoor LED Fixture - Other
LED Parking Garage (exterior)	Exterior LED fixture
LED Pole Mounted (exterior)	Exterior LED fixture
Lighting Controls – Daylighting	Controls
Lighting Controls – Occupancy	Controls
Lighting Controls – Network	Controls

Lighting measures are characterized according to the MA TRM, which calculates savings as a function of the difference between the inefficient and efficient lighting technology's wattage and hours of use. Table B-9 lists the measure inputs used to characterize C&I lighting measures.

For C&I LED bulbs and lamps (i.e., screw-based lighting), the study assumes 100% NOMAD by 2022 (consistent with the residential assumption), which eliminates all economic and achievable savings for this measure.

For linear lighting, the study separately models T8 and T12 baselines and evaluates both as replace on failure (ROF) and early replacement (ER) measure types. The study assumes that linear tubes are treated as ROF and linear luminaires are treated as ER. The study assumes approximately 29% of the remaining non-LED tubes and fixtures will be ROF with the rest being ER.[23] The study assumes that approximately 54% of the remaining lighting opportunities are T8s and the remaining 46% are T12s.[24] For ER measures, the study assumes claimable savings for the remaining useful life (RUL) of the replaced fixture and no claimable savings after the RUL under the assumption an efficient measure would be adopted as baseline. The study assumes early replacement occurs at approximately 2/3rd of the existing equipment's life and that no residual value for the existing equipment remains upon replacement.

For all other C&I lighting technologies, the input assumption sources are listed in Table B-9 below.

[23] This assumption is based on the finding that 29% of lighting installations are considered ROF in the 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14).

[24] This assumption is based on the modeled forecasted saturation of ambient linear technologies under the program scenario in 2020 in the 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14); see Figure 3-4. In 2022, approximately 6% of remaining bulbs will be T12s and 7% will be T8s.

Table B-9. Non-Residential Lighting Measure Inputs

Input	Input/Source
Delta watts	2019 TRM
Hours of use (HOU)	2019 TRM
EUL	For ROF linear lighting and non-linear lighting measures: EUL for inefficient equipment is calculated from TRM lifetime hours and adjusted based on segment-specific HOU to derive EUL in years based on the linear tube. For ER linear lighting measures: the study assumes an average RUL of 6.6 years (~1/3rd ballast EUL) for claimable savings based on evaluated AMLs provided by Eversource.
Interactive Effects	Apply fossil fuel heating penalties as per 2019 TRM
NEIs	2019 TRM
NTG	Assume declining NTG factor (see Table B-10)
Program eligibility	Assume measures offered in all three study years

Table B-10 lists the NTG factors for non-residential lighting measures used in this study. These values were provided and developed by the PAs based on results of the C&I Lighting Inventory and Market Model Updates report.

Table B-10. Non-Residential Lighting NTG Factors

Segment	2022	2023	2024
Bulbs / Lamps	0.00	0.00	0.00
Linear Lighting (ROF)	0.25	0.25	0.25
Linear Lighting (ER)	0.75	0.75	0.75
High Bays	0.40	0.38	0.35
Exterior Lighting	0.35	0.31	0.28

The markets for non-residential lighting measures are characterized using lighting socket saturation data from the 2016 C&I market characterization study and inefficient lighting penetration assumptions based on the 2019 C&I Lighting Inventory and Market Model Updates final report and agreed to by all PAs through their coordination efforts.[25,26] Table B-11 lists the inefficient lighting penetration assumptions used in the study. This is based on the inefficient lighting penetration listed in the study, then adding 10% inefficient lamps to each segment to account for expected slowdowns in efficient lighting installations in 2020 and 2021 due to COVID.

[25]MA C&I Market Characterization On-site Assessments and Market Share and Sales Trend Study: Volume I – Main Report. November 2016. Accessible at: http://ma-eeac.org/wordpress/wp-content/uploads/MA-CI-Market-Characterization-Study.pdf

[26] 2019 C&I Lighting Inventory and Market Model Updates final report (MA19C14)

Table B-11. Non-Residential 2022 Inefficient Lighting Penetration Assumptions

Segment	Inefficient Lighting Penetration
Bulbs / Lamps	10%
Linear Lighting	23%
High/low Bays	27%
Exterior Lighting	34%
Other / Exit Signs[27]	41%

Lighting Controls

Occupancy and daylighting controls are characterized according to the MA TRM, which calculates savings as a function of the controlled fixture's wattage, hours of use prior to control installation, and a deemed savings factor.[28] Networked luminaire level controls are characterized according to the WI TRM (an analogous entry in the MA TRM is not available), which also calculates savings as a function of the controlled fixture's wattage, hours of use prior to control installation, and a deemed savings factor.[29] Table B-12 lists the savings factor assumptions used in this study, which are taken from the previously referenced TRM sources.

Table B-12. Lighting Controls Savings Factors

Measure	Savings Factor
Occupancy	24%
Daylighting	28%
Networked	47%

The study accounts for measure interactions resulting from the combined installation of efficient LED lighting and lighting control measures through the DEEP model's chaining algorithm as described in Section B.4.4.

Home Energy Report Characterization

In October 2019, Eversource discontinued its Home Energy Report (HER) program. Eversource is currently designing and implementing a revised program called "Delivered Energy Insights". Delivered Energy Insights is intended to be a blended targeted marketing and behavioral program to increase participation in the utility's other efficiency programs as well as drive savings through customer behavioral changes.

[27] Inefficient lighting penetrations for exit signs / other lighting was not included in the C&I Lighting Inventory and Market Model Update. Instead, this study uses recent baseline data from a neighboring jurisdiction to estimate exit signs / other inefficient lighting penetration.

[28] 2019 Energy Efficiency Plan-Year Report, Appendix 3, Technical Reference Manual. Page 593.

[29] Wisconsin Focus on Energy 2020 Technical Reference Manual. Page 448.

Delivered Energy Insights will differ from the previous HER program in several ways, including:

- It will be distributed by e-mail only to customers with an e-mail on file with the utility on an opt-out basis,
- It will compare current energy usage to the customer's past energy usage. It will no longer benchmark customer energy usage to neighboring customers, and
- It will include seasonal and customer-relevant advice on reducing energy consumption.

Delivered Energy Insights savings have not been evaluated, so it is unclear what type of savings it will produce. However, a qualitative assessment of the program revisions suggests Delivered Energy Insights will result in lower behavioral savings per customer than the previous HER program as the Delivered Energy Insights program will no longer compare customer consumption to their neighbors. These comparisons have been shown to drive behavioral savings in other programs. The removal of this comparison will likely reduce the per customer savings from the Delivered Energy Insights program.

Without quantitative data to estimate Delivered Energy Insights behavioral savings, this study makes a broad assumption that the average per customer behavioral savings of the Delivered Energy Insights programs will be 50% of the per-customer savings experienced under the previous HER program to account for the above-described factors.[30]

The market for this measure is defined based on data provided by the utility specifying the number of e-mailable customers expected to participate in the program during the study period (i.e., are not on a do-not-contact list). This amount is further reduced by 50% to account for the expected evaluation control group during the study period, which will not initially receive a Delivered Energy Insights report.

Top-Down Measure Characterizations

Due to lack of sufficient baseline data, this study characterizes Custom Agriculture (Cannabis Production) and Custom IT (Datacenters) savings using top-down characterization approaches.

Custom Agriculture (Cannabis Production)

To estimate savings for Custom Agriculture (Cannabis Production), we create energy use archetypes of typical indoor and outdoor facilities by end-use, and then apply measure savings to estimate the technical savings potential from a single facility. These facility-level savings are then scaled to the MA market based on market growth projections.

[30] This study does not explicitly attribute savings related to increasing program participation to the HER measure to avoided double-counting savings estimated in other programs. This aligns with the MA TRM and evaluations of MA's behavior programs, which account for and "remove savings co-generated by behavioral and standard programs to order to avoid double counting savings." See "*Massachusetts Cross-Cutting Behavioral Program Evaluation Opower Results*". Navigant Consulting, Inc. and Illume Advising, LLC. March 2015.

The MA Cannabis Control Commission has implemented stringent energy efficiency requirements which come into effect in 2021.[31] These effectively eliminate the potential for lighting savings, but opportunities within HVAC remain and this is the focus of our analysis.

To estimate potential energy savings from a typical cannabis facility, we construct archetypal facilities by heating fuel and type (indoor / greenhouse), based on total energy use by square footage and end-use breakdown of energy use from a recent MA study.[32] These archetypes are aligned with the market segmentation data available from the MA Cannabis Control Commission[33], including average square footage by indoor and outdoor facilities.

Potential energy savings measures are characterized by end-use for a typical facility and exclude those included elsewhere in this study such as VFDs and standard high-efficiency heating systems to avoid the double-counting of savings.[34] We conclude that a typical facility can reduce HVAC energy consumption by an average of 20% by optimizing design including envelope improvements, pumps/fans, integrated environmental controls, and dehumidification.

Since cannabis cultivation is a relatively nascent industry in Massachusetts, we assume the applicable market for this study to be new cannabis cultivation facilities during the study period. Existing facilities are excluded from the analysis under the assumption that these facilities will not be willing to retrofit additional efficiency measures, as most equipment will still have significant remaining useful life.

We estimate the current market using the approved cultivation licenses from the Massachusetts Cannabis Control Commission.[35] The number of new facilities in 2022 is calculated by applying an annual industry growth estimate of 18.1%, which we apply during each year of the study period.[36] The portion of these facilities within Eversource's electric territory is scaled based on the proportion of Eversource's total electric consumption within the state.

Custom IT (Data Centers) Characterization

Custom IT (Data Centers) savings are estimated based on improvements to baseline power usage effectiveness (PUE) ratios.[37] Energy-efficiency measures for data centers span the categories of IT equipment, air management, cooling and electrical systems, and heat recovery. An advantage of using

[31] Massachusetts Cannabis Cultivation ISP, Jun 2020

[32] Energy Efficiency for Massachusetts Marijuana Cultivators, Resource Innovation Institute, Oct 2020

[33] MA Cannabis Control Commission Licenses Awarded by Type (cultivator only), retrieved Dec 2020

[34] Greenhouse Energy Profile Study, Posterity Group (for IESO), Sept 2019 ; Energy Efficiency for Massachusetts Marijuana Cultivators, Resource Innovation Institute, Oct 2020

[35] MA Cannabis Control Commission Licenses Awarded by Type (cultivator only), retrieved Dec 2020

[36] Massachusetts Cannabis Sales on Track for Record Q1 2020, BDS Analytics, April 7 2020

[37] Power usage effectiveness (PUE) is a metric used to assess the energy efficiency of data centers. It is the ratio of total power consumed to operate a data center facility to the total power drawn by all IT equipment within the facility. A PUE of 2.0 implies that half of the facility's energy consumption is used to operate IT equipment with the remaining half used to manage the facility. (Best Practices Guide for Energy-Efficient Data Center Design, March 2011).

the PUE ratio is that it includes any secondary energy savings from non-IT measures caused by measures applied to the IT equipment.

This analysis assumes that data centers in Massachusetts follow global trends and operate at an average PUE of 1.8.[38] Although it is theoretically possible to achieve a PUE of 1.0, most new data centers with the most recent technology and practices achieve a PUE between 1.2 and 1.4.[39] This analysis assumes an upgraded efficiency PUE of 1.4 considering that efficiency measures will apply to new and existing data centers and that not all existing data centers will be able to safely or economically upgrade to a lower PUE. This estimate is equivalent to reducing a data center's baseline energy consumption by approximately 22%.

The analysis assumes that savings opportunities arise when IT equipment is replaced upon failure with an equipment average effective useful life of 4 years.[40] Incremental costs are assumed to be $0.13 per first-year annual kWh saved.[41]

The market for custom IT savings is defined as the annual electricity consumption of data centers within the Eversource electric service territory. Approximately 1.66% of electricity consumed in the United States is consumed by data centers.[42] Eversource's forecasted electricity consumption in 2022 is 21.8 TWh. By applying the same electricity consumption proportion, we estimate data centers in Eversource's electric territory consume approximately 362 GWh annually. With the increasing importance of data center services, data center power consumption is expected to grow significantly in the near-term. The analysis assumes an annual growth rate of 6.4% in data center power consumption.[43]

B.3.2 Market Characterization

Market characterization is the process of defining the size of the **market** available for each characterized measure. Primary and secondary data are compiled to establish a **market multiplier**, which is an

[38] Uptime Institute. *2020 Data Center Industry Survey Results*. July 2020. Accessible at: https://uptimeinstitute.com/2020-data-center-industry-survey-results

[39] Uptime Institute. *2020 Data Center Industry Survey Results*. July 2020. Accessible at: https://uptimeinstitute.com/2020-data-center-industry-survey-results

[40] NREL. *Data Center IT Efficiency Measures.* December 2014. Accessible at: https://www.energy.gov/sites/prod/files/2015/01/f19/UMPChapter20-data-center-IT.pdf

[41] Incremental cost is based on an MA case study. The case study reported a total upgrading cost of $405,305, of which Mass Save provided an incentive of 75% of incremental costs valued at $183,358. The incremental cost was calculated as follows: $183,358 ÷ 75% = $244,477. The upgrades allowed the data center to save 1.83 MWh of energy annually, leading to an incremental cost of $0.13 per kWh saved. Case study accessible at: Energy Efficiency Case Study presented by National Grid, The Markley Group Data Center

[42] According to the IEA, data centers in North America consumed, roughly, 79 TWh of energy in 2020. The energy consumed by data centers in USA alone was calculated by pro-rating 79 TWh by the proportion of total electricity consumed by USA in North America (82% of total energy consumption of North America). As per the calculation, 64.7 TWh of energy was consumed by data centers in USA, which is 1.66% of the total energy consumed by USA.

(Data Centers and Data Transmission Networks, International Energy Agency, June 2020; Electricity Explained, U.S. Energy Information Administration, Aug 2020)

[43] MarketsandMarkets. *Data Center Power Market by Solution, Service, End-User Type, Vertical And Region - Global Forecast to 2025.* September 2020.

assessment of the market baseline that details the current penetration (e.g., the number of homes with basements) of energy-using equipment and saturation of energy efficiency equipment (e.g., the percentage homes without basement insulation) in each market sector and segment. The market multiplier is applied to each market segment's **population** (based upon customer account data as described in Appendix A) to establish each measure's market. The market multiplier can be understood as the average number of opportunities per customer within the market segment in terms of the measure's market unit.

This study characterized markets by leveraging aggregated Eversource customer data to establish segment populations and baseline data from relevant sources to establish market multipliers. Where possible, baseline data is Eversource- or Massachusetts-specific. When Eversource and Massachusetts specific data was not available (or was based on a lower number of observations), baseline data from neighboring jurisdictions in the Northeast United States were leveraged and adjusted for Eversource specific attributes where possible.

For most early replacement and replace on burnout measures, markets are characterized based on the total number of existing units in the market to account for equipment turnover rates. However, for LED measures, the study characterizes markets with the assumption that once a socket has been converted to an efficient LED, it stays converted and is no longer an efficiency opportunity due to the rapidly transforming nature of this market.

B.3.3 Program Characterization

Program characterization is the process of estimating the average administrative program costs in terms of fixed and variable costs, and incentive levels, of existing programs. Inputs generated through the program characterization process include:

- **Fixed costs** are the portion of non-incentive administrative costs that are independent of the amount of savings attributable to the program.
- **Variable costs** are the portion of non-incentive administrative costs that change in magnitude with the amount of savings attributable to the program.
- **Incentives** are the portion of the measure's incremental costs that are covered by the program. Incentive levels vary by program scenario.

This study characterized programs by reviewing the utility's evaluated 2019 program investments and savings, as well as planned savings and investments in the 2019-2021 EE Plan. These were then compared to Dunsky's internal database of program incentive levels and costs from other potential studies and program design work, and the program costs and incentive levels were set for each program scenario (i.e., BAU, BAU+, and Max). Only programs with reported savings are included within the model (i.e., hard-to-measure initiatives are excluded).

Average BAU incentive levels are estimated based on actual incentives paid in 2019 weighted by savings achieved in 2019. BAU+ incentives are determined by increasing BAU incentives by 50% to a maximum of 90% of incremental costs - except for weatherization measures where incentive levels are set to 90%. Incentive levels that exceed 90% under BAU remain unchanged. Max scenario incentives are set at 100% of incremental costs for all measures. Incentives are generally applied at the program level. In cases where average incentive levels for measures at the end-use level differ significantly within a program, sub-program incentive levels are used.

Fixed and variable costs are estimated based on non-incentive costs (i.e., program planning and administration; marketing and advertising; sales, technical assistance & training; evaluation and market research; and performance incentives) reported for modeled programs in 2019.

Table B-13, Table B-14, and Table B-15 show the average BAU incentive level across all end-uses for each modeled program for Eversource Electric, Eversource Gas and EGMA. Detailed measure-level incentives are available within the detailed data tables.

Table B-13. Energy Efficiency Program Characterization Parameters – Eversource Electric

Program (Eversource Electric)	Fixed Costs	Variable Costs[44]	Average Incentive Level[45]		
			BAU	BAU+	Max
A1a - Residential New Homes & Renovations	$828,619	$12.97	44%	90%	100%
A2a - Residential Coordinated Delivery	$4,137,558	$57.45	80%	90%	100%
A2c - Residential Retail	$4,323,771	$7.06	63%	80%	100%
A2d - Residential Behavior	$49,329	$1.12	100%	100%	100%
B1a - Income Eligible Coordinated Delivery	$5,057,441	$202.87	100%	100%	100%
C1a - C&I New Buildings & Major Renovations	$1,675,010	$15.32	62%	90%	100%
C2a - C&I Existing Building Retrofit	$8,105,053	$7.62	61%	80%	100%
C2b - C&I New & Replacement Equipment	$3,728,966	$5.06	47%	68%	100%

[44] Variable costs are expressed in terms of dollars ($) per annual GJ saved.

[45] Incentive levels are expressed in terms of percentage of incremental cost. The values presented here are simple averages for each program across end uses; in cases where incentives are broken down by end use for modelling, the specific incentive levels used are available in the detailed data tables.

Table B-14. Energy Efficiency Gas Program Characterization Parameters - Eversource Gas

Program (Eversource Gas)	Fixed Costs	Variable Costs[46]	Average Incentive Level[47]		
			BAU	BAU+	Max
A1a - Residential New Homes & Renovations	$214,121	$4.54	83%	90%	100%
A2a - Residential Coordinated Delivery	$1,462,948	$48.79	65%	90%	100%
A2c - Residential Retail	$437,358	$3.24	41%	61%	100%
A2d - Residential Behavior	$8,570	$0.21	100%	100%	100%
B1a - Income Eligible Coordinated Delivery	$1,538,967	$125.59	100%	100%	100%
C1a - C&I New Buildings & Major Renovations	$246,506	$1.87	62%	90%	100%
C2a - C&I Existing Building Retrofit	$905,666	$3.03	63%	83%	100%
C2b - C&I New & Replacement Equipment	$1,039,609	$7.41	48%	68%	100%

Table B-15. Energy Efficiency Gas Program Characterization Parameters – EGMA

Program (EGMA)	Fixed Costs	Variable Costs[48]	Average Incentive Level[49]		
			BAU	BAU+	Max
A1a - Residential New Homes & Renovations	$211,729	$6.87	100%	100%	100%
A2a - Residential Coordinated Delivery	$1,630,757	$33.12	70%	86%	100%
A2c - Residential Retail	$333,601	$2.60	43%	65%	100%
A2d - Residential Behavior	$8,570	$0.21	100%	100%	100%

[46] Variable costs are expressed in terms of dollars ($) per annual GJ saved.

[47] Incentive levels are expressed in terms of percentage of incremental cost. The values presented here are simple averages for each program across end uses; in cases where we have broken down programs by end use for modelling, the specific incentive levels used are available in the detailed files.

[48] Variable costs are expressed in terms of dollars ($) per annual GJ saved.

[49] Incentive levels are expressed in terms of percentage of incremental cost. The values presented here are simple averages for each program across end uses; in cases where we have broken down programs by end use for modelling, the specific incentive levels used are available in the detailed files.

Program (EGMA)	Fixed Costs	Variable Costs[48]	Average Incentive Level[49]		
			BAU	BAU+	Max
B1a - Income Eligible Coordinated Delivery	$1,325,091	$120.34	100%	100%	100%
C1a - C&I New Buildings & Major Renovations	$274,006	$9.87	37%	56%	100%
C2a - C&I Existing Building Retrofit	$1,441,772	$5.66	54%	71%	100%
C2b - C&I New & Replacement Equipment	$678,550	$9.78	50%	74%	100%

B.3.4 Economic Parameters

DEEP harnesses key economic parameters such as avoided costs, retail energy and demand rates, and discount rates to assess measure cost-effectiveness and customer adoption. Appendix A outlines the development of these inputs, which were used across all modules of this study.

B.3.5 Adoption Parameters

DEEP requires several key inputs to determine achievable measure adoption including market barrier levels and measure ramp-up levels.

- **Market barrier levels** define maximum adoption rates and are assigned for each measure-market combination based on market research, professional experience, and evidence of participation in existing programs. Different end-uses and segments exhibit different barriers. Barrier levels may change over time if market transformation effects are anticipated.

- **Measure ramp-up levels** modify the initial uptake of measures not offered by existing programs and/or offered at lower levels than expected given the market context to account for ramping up new programs and measure marketing. In this study, measures that represent significant savings and are not currently offered by existing programs have ramp rates of 33%, 66%, and 100% applied in the first three years of the study, respectively. For measures that are currently offered but at levels lower than expected, ramp rates of 50%, 75%, 100% were applied in the first three years, respectively.

B.4 Assess Potential

Using the comprehensive set of model inputs, DEEP assesses three levels of energy savings potential: technical, economic, and achievable. In each case, these levels are defined based on the governing regulations and practice in the modeled jurisdiction, such as applying the appropriate cost-effectiveness tests and applying the relevant benefit streams and net-to-gross (NTG) ratios to ensure consistency with evaluated past program performance. Table B-16 provides a summary of how DEEP treats each potential type.

Table B-16. DEEP Treatment of Technical, Economic, and Achievable Potential

APPLIED CALCULATION	TECHNICAL POTENTIAL	ECONOMIC POTENTIAL	ACHIEVABLE POTENTIAL
1. COST-EFFECTIVENESS	No screen	TRC	PCT
2. MARKET BARRIERS	No barriers (100% Inclusion)	No barriers (100% Inclusion)	Market barriers (Adoption Curves)
3. COMPETING MEASURES	Winner takes all	Winner takes all	Competition groups applied
4. MEASURES INTERACTIONS	Chaining adjustment	Chaining adjustment	Chaining adjustment
5. NET SAVINGS	Not considered	Program Net-to-Gross Ratios (NTGR)	Program Net-to-Gross Ratios (NTGR)

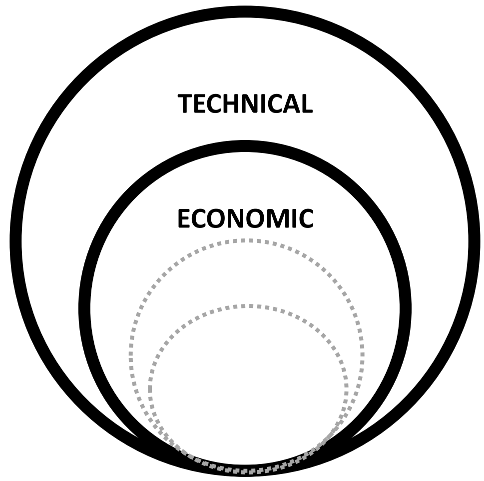
For each level of potential, DEEP calculates annual and cumulative potential:

- **Annual potential** is the incremental savings attributable to program activities in the study year. It includes re-participation in programs (e.g., when a customer may receive an incentive for a new heat pump to replace a heat pump previously received through the program).[50] DEEP expresses annual potential both in terms of incremental lifetime savings and incremental annual savings. This is the most appropriate measure for annual program planning and budgeting.
- **Cumulative potential** is the total savings attributable to program activities from the beginning of the study period to the relevant study year. It accounts for mid-life baseline adjustments to measures implemented in previous years, as well as the retirement of savings for measures reaching their end of life. As such it does not include new savings for re-participation in programs, thereby providing an assessment of the cumulative impact of the measure/program (e.g., the reduction in energy sales). This is the most appropriate measure for resource planning.

[50] For a study that covers only three program years, program re-participation has a negligible impact on savings.

B.4.1 Technical and Economic Potential

Technical potential is all theoretically possible energy savings stemming from the applied measures. Technical potential is assessed by combining measure and market characterizations to determine the maximum amount of savings possible for each measure-market combination without any constraints such as cost-effectiveness screening, market barriers, or customer economics. This excludes early replacement and retirement opportunities, which are to be addressed in the subsequent achievable potential analysis. Technical potential is calculated for each year in the study period.



DEEP's calculation of technical potential accounts for markets where multiple measures compete. In these instances, the measure procuring the greatest energy savings is selected while all other measures are excluded to avoid double counting energy savings while maximizing overall technical energy savings (see description of measure competition below for additional detail).

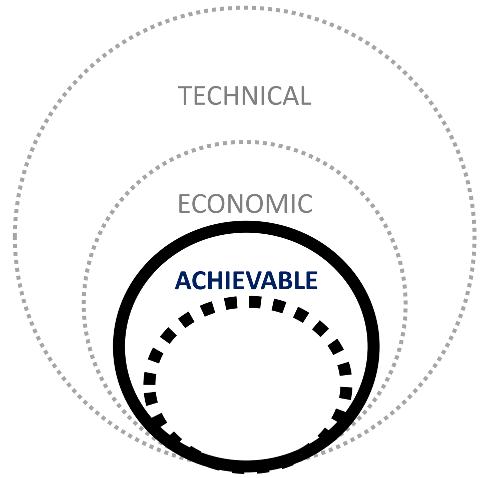
Additionally, the calculation of technical potential also accounts for measures that interact and impact the savings potential of other measures (see description of measure interactions below for additional detail).

Economic potential is a subset of technical potential that only includes measures that pass cost-effectiveness screening. Economic screening is performed at the measure level and only includes costs related to the measure. All benefits and costs applied in the cost-effectiveness screening are multiplied by their corresponding cumulative discounted avoided costs to derive a present value ($) of lifetime benefits. All benefits and costs are adjusted to real dollars expressed in the first year of the study. Economic screening does not include general program costs. Like technical potential, the calculation of economic potential also accounts for measure competition and interaction.

This study screens measures based on the TRC. Measures that had a benefit-cost ratio below 1.0 are excluded from economic potential.

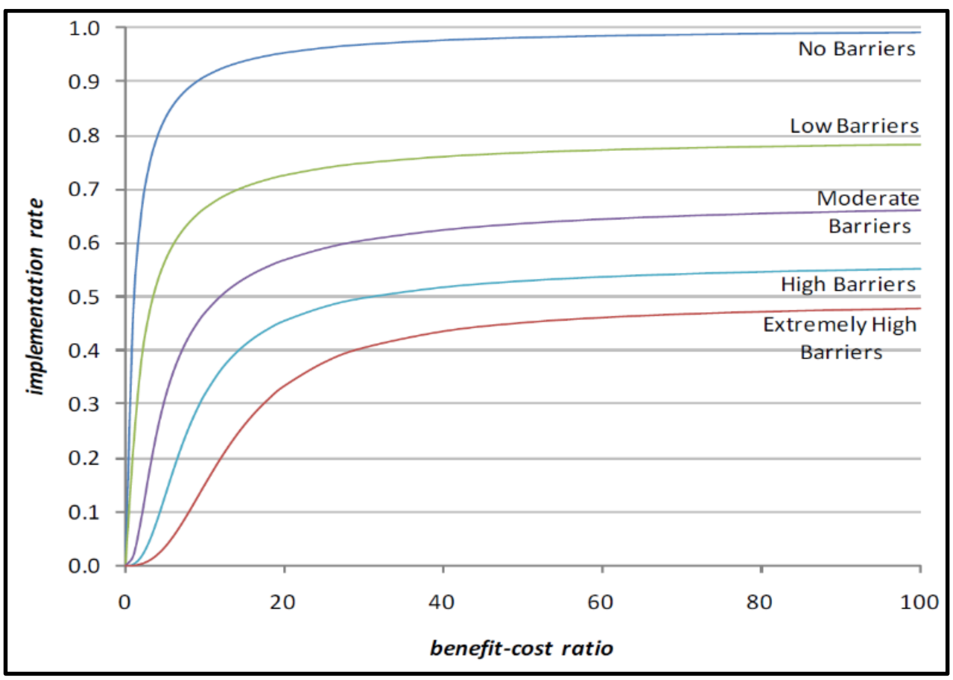
B.4.2 Achievable Potential and Scenario Modeling

Achievable potential is the energy savings stemming from the customer adoption of energy-savings measures. Rooted in the United States' Department of Energy (U.S. DOE) adoption curves,[51] DEEP defines annual adoption rates based on a combination of customer cost-effectiveness and market barrier levels. Customer cost-effectiveness is calculated within the model based on inputs from measure and program characterization as well as economic and adoption parameters. Figure B-1 presents a representative example of the resulting adoption curves.



While this methodology is rooted in the U.S. DOE's extensive work on adoption curves, it applies two important refinements as described below:

Figure B-1. Representative Example of Adoption Curves



Refinement #1: Choice of the cost-benefit criteria. The DOE model assumes that participants make their decisions based on a benefit-cost ratio calculated using discounted values. While this may be true for a select number of large, more sophisticated customers, experience shows that most consumers use simpler estimates, including simple payback periods. This has implications for the choice and adoption of measures, since payback period ignores the time value of money as well as savings after the break-even point. The model converts DOE's discount rate-driven curves to equivalent curves for payback periods

51 The USDOE uses this model in several regulatory impact analyses. An example can be found in http://www.regulations.gov/contentStreamer?objectId=090000648106c003&disposition=attachment&contentType=pdf, section 17-A.4.

and applies simple and discounted payback periods based on sector. Generally, DEEP assumes residential customers assess cost-effectiveness by considering a measure's simple payback period, while commercial customers assess cost-effectiveness by considering a discounted payback period.

Refinement #2: Ramp-up. Two key factors – measure awareness and program delivery structure – can limit program participation, especially during the first few years after a program's launch or redesign and result in lower participation than DOE's achievable rates would suggest. For example, a new home retrofit program that requires the enrollment and training of skilled auditors and contractors by program vendors could take some time to achieve the uptake assumed using DOE's curves. As described under adoption parameter development, this study adjusts adoption rates on a case-by-base basis where appropriate.

Scenario Modeling

Multiple levels of achievable potential are modeled within DEEP by applying varying incentive and market barrier levels, which impact the degree of customer adoption. Additional details on parameters for each scenario can be found in Appendix F.

Varying levels of achievable adoption will also impact program spending by modulating incentive payments and variable program costs. As part of program characterization, variable program costs may be adjusted between scenarios to account for increased program expenses for providing additional enabling activities above current program levels.

It is important to note that program cost estimates are based on historical costs and DEEP does not consider dynamic impacts on program budgets resulting from internal (to the program) and external factors impacting program and incremental costs. For example, the variable cost of delivering programs may decline over time as program learnings are applied to future administrative and delivery practices within a program, or incentive costs may decline if incremental costs decline over time. Likewise, program costs may increase if factors lead to increasing measure costs, for example, the lack of enough contractors to deploy high adoption measures leading to an increase in overall labor costs.

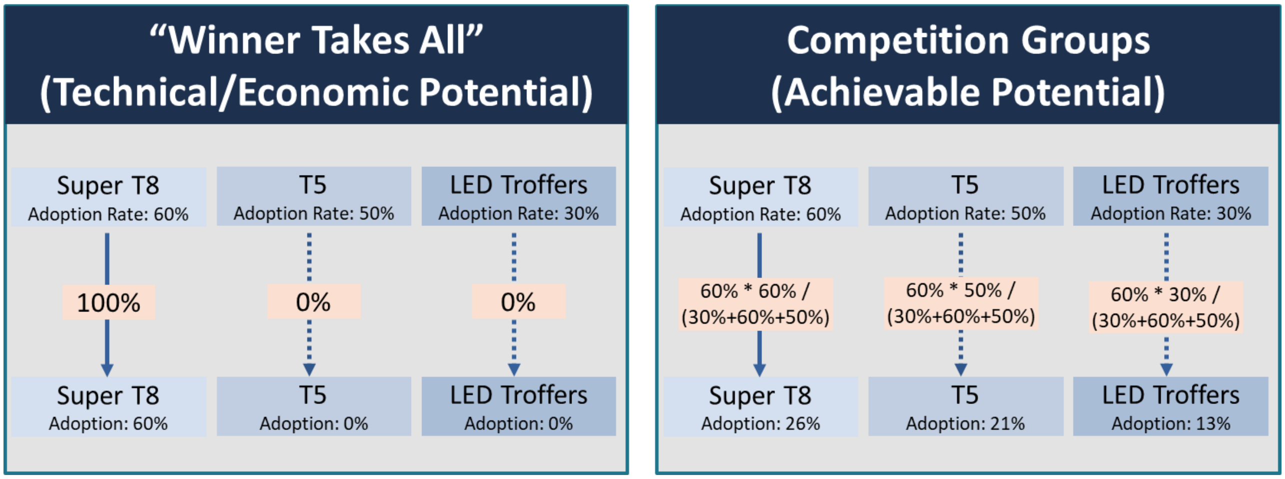
B.4.3 Measure Competition

Measure competition occurs when measures share the same market opportunity but are mutually exclusive. For example, LED troffers, T5 lamps and Super T8 lamps can all serve the same market opportunity but will not be simultaneously adopted. In these cases, DEEP assesses the market potential for each measure as follows:

- **Technical Potential**: 100% of the market is applied to the measure with the highest savings.
- **Economic Potential:** 100% of the market is applied to the measure with the highest savings that passes cost-effectiveness screening.
- **Achievable Potential**: The market is split between all cost-effective measures by pro-rating the achievable adoption rate based on the maximum adoption rate and each of the measures' respective adoption rates.

Figure presents an example where three measures compete: LED troffers, Super T8 and T5 lamps. First, the adoption rate is calculated for each measure independent of any competing measures, as outlined in the figure below. Based on this assessment, the maximum adoption rate is 60%, corresponding to the measure with the highest potential adoption. Next, the adoption of each measure is pro-rated based on their relative adoption rates to arrive at each measure's share of the 60% total adoption rate. As a result, the total adoption rate is still 60%, but it is shared by three different measures.

Figure B-2. Example of DEEP Measure Competition

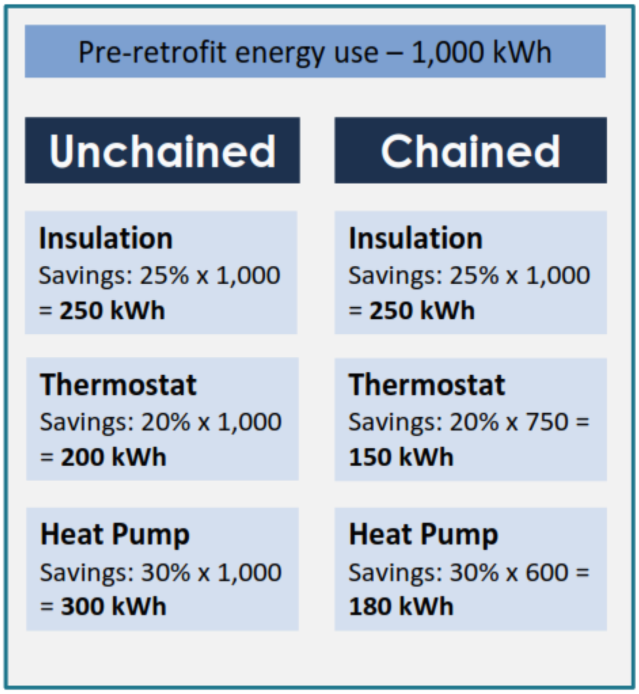


B.4.4 Measure Chaining

Measure interactions occur when the installation of one measure will impact the savings of another measure. For example, the installation of more efficient insulation will reduce the savings potential of subsequently installing a smart thermostat. In DEEP, measures that interact are "chained" together and their savings are adjusted when other chained measures are adopted in the same segment. Chaining is applied at all potential levels and these interactive effects are automatically calculated according to measure screening and uptake at each potential level.

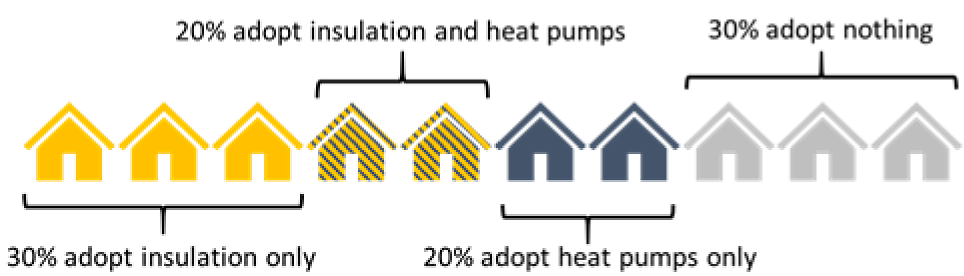
DEEP applies a hierarchy of measures in the chain reducing the savings from each measure that is lower down the chain. The model adjusts the chained measures' savings for each individual measure, with the final adjustment calculated based on the likelihood that measures will be chained together (determined by their respective adoption rates) and the collective interactive effects of all measures higher in the chain. Figure B-3 provides an example of the calculations used to determine the interactive savings effects for a customer where insulation is added in addition to a smart thermostat and a heat pump.

Figure B-3. Example of Savings Calculation for DEEP Chained Measures



The model estimates the number of customers adopting chained measures based on the relative adoption rates of each measure. In an example where insulation has a 50% adoption rate and heat pumps have a 40% adoption rate in isolation when chaining is considered, the model might assume 40% of customers adopting insulation will also install a heat pump, which means 50% of customers adopting a heat pump will also improve their installation levels. This segments the market into customers adopting only one of the measures, customers adopting both measures, and customers adopting none of the measures as shown in Figure B-4.

Figure B-4. Representative Example of Adoption for DEEP Chained Measures



Note: The above figure is representative of the DEEP model's treatment of chained measures only and not representative of any actual program or measure inputs. In many cases, efficiency programs require weatherization prior to the incentivization of a heat pump.

C. Heating Electrification Methodology

C.1 Overview

The heating electrification potential analysis estimates the market opportunity for electrifying existing and yet-to-be-built natural gas, oil, and propane primary space and water heating systems for Eversource's residential and commercial electric customers. The potential is estimated using Dunsky's Heating Electrification Adoption (HEAT™) model, a highly granular bottom-up model.

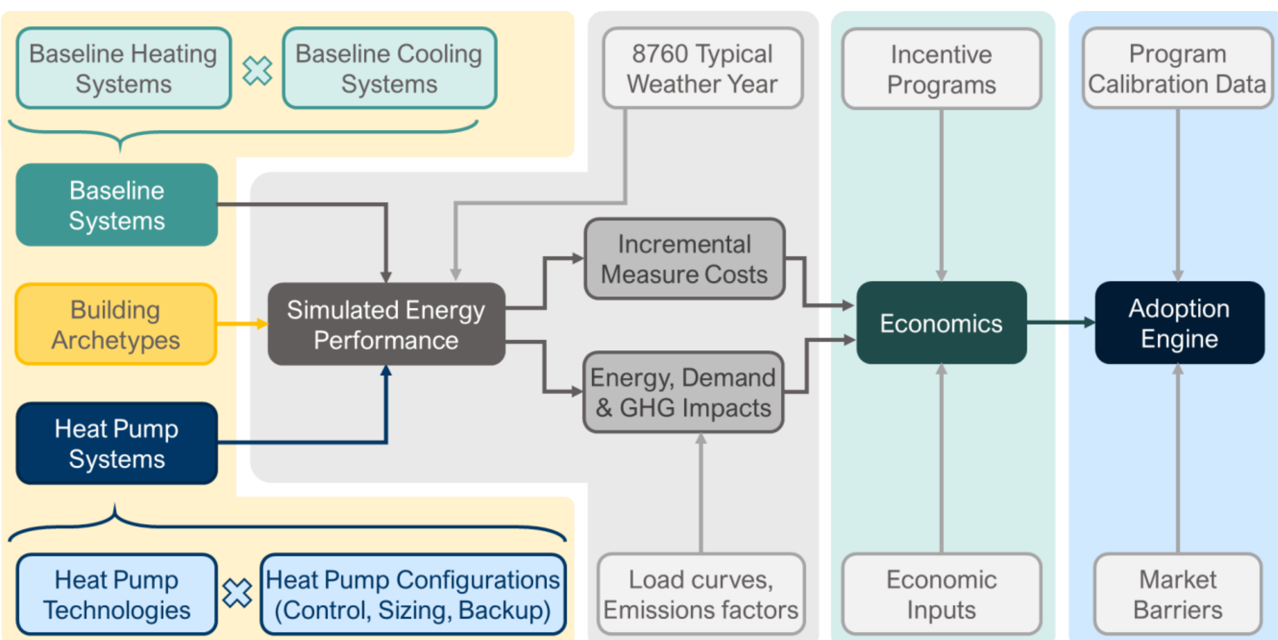
Sections C.2 and C.3 describe the HEAT™ model. Section C.4 focuses on the model inputs and sources used for this study.

C.2 Dunsky's Heating Electrification Adoption Model

The costs and benefits of heating electrification are highly dependent not only on the baseline systems and their potential electrified replacements but also on the remaining useful lives of both heating and cooling systems, partial vs. full replacements, heat pump sizing, and control strategies. Moreover, the heat pump's performance (capacity as well as efficiency) varies according to the outdoor air (or ground) temperature.

To account for this, HEAT was designed to model multiple permutations of replacement cases, sizing strategies and control strategies for each combination of baseline heating system, baseline cooling system and heat pump technology. HEAT simulates the baseline and heat pump cases to calculate their energy performance and full cost, which allows HEAT to yield the incremental costs and savings for thousands of modeled cases.

Figure C-1. HEAT Model Flow



C.3 HEAT Modeling Steps

As outlined in Figure C-1 the general approach for estimating heating electrification potential consists of defining valid heat pump systems for each baseline heating and cooling system configuration; modeling the heat pump's performance given prevailing climatic conditions; calculating incremental costs and energy/demand impacts; using those results to calculate measure cost-effectiveness and customer economics; and assessing customer adoption under various achievable scenarios.

The present section outlines these modeling steps in more detail, while detailed model inputs and sources used for this study are detailed in Section C.4.

C.3.1 Building Archetypes

Building Archetypes

The first step is to define a building archetype that represents each market segment, including its heating, cooling and domestic hot water loads. Each archetype is then equipped with many possible configurations of baseline heating and baseline cooling systems, as described in section C.3.2.

Market Segments

Table C-1 lists the market segments, for which a building archetype is defined.

Table C-1. Building Segments

Residential Segments
Single Family (furnace)
Single Family (boiler)
Multi-family
Low Income

C&I Segments
Office
Retail
Food Service
Healthcare/ Hospitals
Campus/ Education
Warehouse
Lodging
Other Commercial
Food Sales
Manufacturing/ Industrial

Building Vintage

Each building segment is modeled both as an average existing building archetype and as a new construction / major renovation building archetype.

Heating & Cooling Loads

Instead of modeling the energy consumption of each equipment independently, space heating and cooling loads are derived for each archetype in terms of annual loads and distributed hourly based on the outdoor air temperature, similarly to a temperature-bin model. Each heating and cooling system therefore must meet these building loads. Section C.4.3 details the specific loads and inputs used in this potential study.

C.3.2 Baseline Systems

Baseline Systems

For each Building Archetype, several heating and cooling systems exist which could be replaced, partially or fully, with a heat pump system, both in existing buildings and new construction. These heating and cooling systems are labeled as Baseline Systems.

Baseline Heating System

As shown in Table C-2 below, each building archetype can have multiple combinations of heating fuel and baseline heating equipment. The modeled baseline heating equipment types are furnaces, boilers, and packaged rooftop units (RTU). Each of these heating equipment types can be fired by three fuels included in the scope of the potential study and modeled through HEAT: natural gas, fuel oil and propane.

Note that replacing electric resistance heat with heat pumps is considered an energy efficiency measure instead of an electrification opportunity and is therefore included in the efficiency results leveraging the DEEP model (refer to section B of this methodology appendix). Additionally, the electrification of wood-fired heating systems is not included in this analysis.

Baseline Cooling System

Buildings using each of these baseline heating equipment types and heating fuels can be combined with various cooling systems. For the residential sector, HEAT models central air conditioners and room air conditioners. For C&I buildings, chillers and central package air conditioners are also included.

For the Room Air Conditioner space cooling baseline, this study uses window AC units for residential buildings[52] and a blend of window and ductless mini-split AC units for commercial buildings.

Table C-2 lists the baseline heating fuel, heating equipment, and cooling system baselines considered in this study.

Table C-2. Baseline Systems

Sector	Baseline Fuel	Baseline Space Heating Equipment	Baseline Space Cooling System
Residential	Natural gas Fuel oil Propane	Boiler Furnace	Central Air Conditioner Room Air Conditioner No Air Conditioning
C&I	Natural gas Fuel oil Propane	Boiler Furnace Packaged Rooftop Unit (RTU)	Chiller Central Package Air Conditioner Central Split Air Conditioner Room Air Conditioner Blend No Air Conditioning

52 Assumption from RES21 Energy Optimization Study

Customers without air conditioning

The study includes buildings without any air conditioning (AC). For this space cooling baseline, the study assumes that a portion of these customers would have adopted AC in the absence of adopting a heat pump, and a portion who would not have adopted AC. For residential customers, this study uses a 50/50 split of customers without AC who would / would not have adopted AC, while for C&I it is assumed that customers without AC would not have adopted AC.

For customers without AC who would not have adopted AC, since the counterfactual is no space cooling at all, the incremental cost of space heating electrification does not include any adjustments for avoiding the cost of space cooling equipment, and electric energy and demand used for space cooling are treated as negative savings (i.e., increased consumption vs. baseline). This ultimately makes these customers less likely to adopt heating electrification.

For the remainder of customers - without AC, but who would have adopted AC - the incremental cost of space heating electrification will be reduced, and measure adoption will result in energy and demand savings from space cooling as the heat pump will provide more efficient space cooling than the counterfactual baseline AC equipment. The counterfactual cooling equipment is assumed to be central AC where customers have a furnace, and a room AC where they have a boiler.

Baseline Water Heating System

While many hot water systems can be electrified through a custom project, this study's scope only includes heat pump water heaters and therefore includes only baseline water heaters which can be replaced on a one-for-one basis. This is summarized in Table C-3.

Table C-3. Baseline Water Heaters

Market	Baseline Water Heater	Included in study
Residential	Storage Water Heater	✓
	Tankless Water Heater	✓
	Combination Boiler	✓
C&I	Storage Water Heater	✓
	Tankless Water Heater	×
	Indirect/Volume Water Heater[53]	×
	Volume Water Heater	×

[53] Refers to dedicated storage tanks which are combined with an external boiler to produce hot water.

C.3.3 Heat Pump Systems

Each combination of baseline heating system and baseline colling systems can be replaced partially (resulting in a dual-fuel or hybrid system) of fully (resulting in an all-electric system) using various heat pump technologies.

Heat Pump Technologies

Table C-4 summarizes the heating electrification technologies considered in this study.

Table C-4. Heating electrification technologies included in this study

Sector	End-use	Heat Pump Technology
Residential	Space heating	Cold climate ductless mini-split heat pump (ccDMSHP) [54]
		Cold climate central ducted air source heat pump (ccASHP) [54]
		Water-to-air ground-source heat pump (GSHP)
		Water-to-water ground source heat pump (GSHP)
	Water heating	Heat pump storage water heaters (HPWH)
C&I	Space heating	Cold climate ductless mini-split heat pump (ccDMSHP) [54]
		Cold climate central ducted air source heat pump (ccASHP) [54]
		Packaged rooftop cold climate air source heat pump (RTU ccHP)
		Variable refrigerant flow heat pump (VRF)
		Air-to-water heat pump (ATWHP)
		Water-to-air ground source heat pump (GSHP)
		Water-to-water ground source heat pump (GSHP)
	Water heating	Heat pump storage water heaters (HPWH)

Each of the heat pump technologies can be sized and controlled in different ways, and can have different back up systems. The backup, control, and sizing options included in the model are described below.

Heat Pump Backup

HEAT models both a full replacement case, where the baseline heating system and cooling system are removed and replaced by a heat pump with an electric resistance backup system, resulting in an all-electric system, and a partial replacement case, where the cooling system is removed, but the baseline heating system remains in place to act as the heat pump backup, resulting in a dual-fuel or hybrid system.

A heat pump's backup system serves both as supplementary heat source when using the heat pump is not optimal (e.g., when the heat pump's output capacity doesn't meet demand, or when the cost of

[54] It is assumed that all heat pumps that go through Mass Save's Fuel Optimization program are cold climate models, as the models in the Heat Pump Qualified Product List (HPQPL) are at or above the NEEP definitions for cold-climate, and while the HPQPL does not include NEEP's COP requirement at 5°F, it does require a level of cold climate performance through a minimum capacity degradation requirement at 17°F.

heating with the heat pump exceeds the cost of heating with the backup), and as a source of emergency heat in the case of heat pump failure. The backup can either be the existing fuel-fired heating system, or a dedicated system, such as an electric resistance coil built into the air handling unit.

Heat Pump Sizing

As heat pumps lose some capacity as outdoor temperatures drop, sizing strategies aim to determine the right balance to leverage the heat pump's high efficiency while limiting costly oversizing. The optimal sizing strategies can differ between partial (dual fuel) and full (all electric) replacements, where the backup heating equipment have various installation and energy cost considerations.

Where needed, HEAT can simulate multiple competing sizing strategies for each heat pump. Section C.4.2 summarizes the sizing strategies used in this potential study.

Heat Pump Controls

Similarly to heat pump sizing, multiple control strategies can offer various levels of system performance for the same installed equipment. These control strategies can be split into two categories:

- Switchover temperature: The heat pump runs only above a pre-defined outdoor air temperature, and the backup system - whether electric of fuel-based – supplies the full heating load under that switchover temperature. Optimal switchover temperatures can vary based on the difference in rates and equipment efficiency (electric heat pump vs fuel-based heating equipment).

- Run together: the heat pump supplies the heat it is able to supply at specific outdoor air temperatures, and the backup system - whether electric of fuel-based - supplies the remaining heat in order to match the building's heating load.

HEAT can simulate multiple competing control strategies for each heat pump measure. Section C.4.2 summarizes the control strategies used in this potential study.

Matching Heat Pump Technologies to Baseline Systems

Not all heat pump technologies are applicable to all baseline systems. In general, the type of existing distribution system (hydronic pipes, ventilation ducts, refrigerant piping) defines the valid heat pump technology for a specific baseline system. Baseline cooling systems are also an important consideration since heat pumps may replace the existing AC equipment and will also provide space cooling services. In HEAT, valid baseline configurations are constrained to include only commercially viable and non-deep-retrofit options. For example, the study does not consider replacing a hydronic only system (e.g. gas-fired boiler) with a forced-air heat pump system (e.g. central ducted ASHP) due to the high cost of these types of deep retrofits. Table C-5 summarizes the valid applications of the different heat pump technology mapping used in the study.

Table C-5. Valid Heat Pump Applications

Sector	Heat Pump Measure	Baseline Configurations
Residential	ccASHP	Furnaces; Boilers with central ducted AC units
	ccDMSHP	Boilers only
	Water-to-air GSHP	Furnaces; Boilers with central ducted AC units
	Water-to-water GSHP	Boilers only
C&I	ccDMSHP	Boilers with room AC or no AC
	ccASHP	Furnaces; Boilers with central ducted AC units
	RTU ccHP	Packaged rooftop units; Boilers with central packaged units
	VRF	New construction & Major renovations only
	Air-to-water HP (ATWHP)	All boiler-based systems
	Water-to-air GSHP	All duct-based systems (furnaces, RTUs)
	Water-to-water GSHP	All boiler-based systems

C.3.4 Simulated Energy Performance

Simulated Energy Performance

A heat pump's performance (capacity as well as efficiency) varies according to the outdoor air (or ground) temperature. For each combination of baseline heating system, baseline cooling system and heat pump technology, HEAT is designed to model multiple permutations of replacement case (partial vs full), sizing strategy and control strategy, and simulates both the baseline and heat pump cases to calculate their energy performance. The model combines hourly temperature data, building heating and cooling loads, floor areas and sizing strategies to compute the required heat pump size, hourly heat pump efficiency, and hourly heat pump output capacity.

Hourly Simulation

The heating and cooling loads for each building archetype are simulated in HEAT using an approach similar to a temperature-bin model, but where every hour of the year (8760) is simulated. That enables heat pumps to be assessed precisely, based on their outdoor air temperature-based capacity and efficiency curves, and also captures the impact on a customer's electricity bill more precisely for rates which include a demand charge ($ per kW).

For each heating electrification measure, HEAT computes the required system size and energy performance of both the baseline system and the heat pump + backup system based on hourly temperature data, building heating/cooling load, floor area, sizing strategy, and control strategy. Where the heat pump is sized based on heating demand, HEAT sizes the heat pump based on its capacity at the design outdoor air temperature, rather than by using its nominal capacity.

Energy, Demand and GHG Impacts

To determine the energy and demand impacts of a partial or full retrofit, both the baseline case and the heat pump case are simulated as described above. The difference between the baseline and heat pump simulations yields the hourly energy savings, and therefore the demand savings.

For the summer and winter utility peak impacts, the hottest and coldest hour within the peak window is identified prior to the model run, so that the peak impact at those two specific hours can be assessed from the hourly simulations.

For building-level peak impacts, the hourly heating and cooling demand is added to the building's 8760 load profile for other end uses. The monthly maximum demand is calculated and compared between the baseline and the retrofitted case. This approach allows HEAT to account for shifts in the timing of the peak due to electrification of the heating system.

GHG impacts are determined by multiplying average annual emissions factors to the fuel-specific energy savings (or increase).

C.3.5 Economics

Economics

The model combines the incremental measure costs with energy and maintenance savings to produce customer, utility, and societal financial metrics.

Cost streams

The incremental measure costs are defined by identifying the expected full cost streams of the baseline case (replacing each equipment at the end of its useful life) and the altered cost streams after installing heat pumps, accounting for the avoided cost of the replaced heating and/or cooling system where applicable. The impact on customer bills and total resource costs uses retail and avoided fuel costs (per MMBtu) and electricity costs (per kWh and per kW), respectively, as defined in Appendix A. A discount rate is applied to these future cost streams to get the present value of both the baseline and the retrofit cases, which are compared to yield the incremental measure cost. The impact on customer bills and societal avoided costs uses fuel costs (per MMBtu) and electricity costs (per kWh and per kW) as defined in Appendix A.

Assessment of equipment installed costs

Measure capital and maintenance costs are computed with a bottom-up approach based on equipment capacity within the HEAT model. For each heat pump and baseline technology, we determine a fixed and variable cost for the assumed efficiency of equipment so that the equipment costs are closer to reality, where a 2-ton unit is less than twice the cost of a single-ton unit – in other words, using a single dollar per ton cost would underestimate the cost of a small unit and/or overestimate the cost of larger units.

This approach allows for the computation of tens of thousands of combinations of baseline heating and cooling systems, heat pump technologies, heat pump sizing strategies, control strategies and backup equipment.

Early replacement opportunities

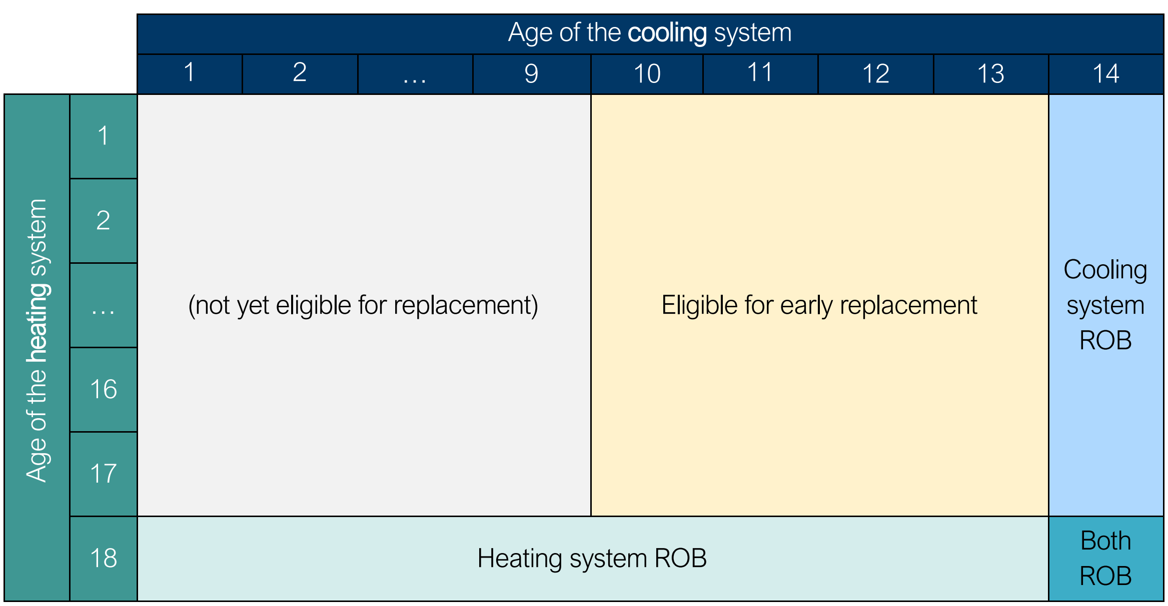
HEAT includes both the heating system burnout and cooling system burnout as replacement opportunities, as well as some early replacement opportunities.

Since most baseline heating and cooling equipment will likely not reach their end of life at the same time, at least one of them might be replaced early with the installation of heat pumps. Moreover, the economics for the early replacement of both heating and cooling equipment with a heat pumps can be compelling in some cases.

Therefore, HEAT includes some early replacement opportunities every year. Figure shows a representation of replacement opportunities for a hypothetical case where the baseline cooling system has an EUL of 14 years and the heating system has an EUL of 18 years.

Based on input from the program administrators (PA), the cooling system threshold for early replacement is set at two-thirds of useful life (i.e., if the cooling system is above that age threshold, the customer is considered as an opportunity for heating electrification). The PA's are not targeting heating system early replacement, so only heating systems that are at their end of life are considered a trigger for a heating electrification opportunity. As the economics might not be favorable for a certain early replacement case, those who do not adopt a heating electrification measure are simply considered again the next year, when the economics are likely more favorable than the previous year as the equipment ages. This continues until either the cooling or heating equipment reaches its end of life, which is then considered a replace on burnout (ROB) case.

Figure C-2. Early replacement and replace on burnout (ROB) opportunities



Cost-Effectiveness

HEAT computes financial metrics that highlight the measure's cost-effectiveness from a customer's perspective: simple payback (years), Internal Rate of Return (IRR), and Net Present Value (NPV). The model also computes various cost-effectiveness test ratios (PCT, PACT, TRC, SCT) from their applicable costs and benefits. These cost-effectiveness metrics are leveraged for economic screening, economics-driven adoption, or reporting purposes. Screening takes place at the most granular level (ex: a single-family home in East Massachusetts with an oil boiler and a room AC at the end of its useful life, partially replaced with a ccDMSHP sized for cooling with a switchover temperature of 30°F, in 2022).

C.3.6 Adoption Engine

Adoption Engine

The final step in the modeling is the adoption engine, which involves the calibration of diffusion curves to historical program uptake and the forecast of heat pump adoption based on customer economics, technology diffusion and competition between measures.

Assess Potential

Table B-16 (page 35) details the treatment of the Technical, Economic, and Achievable potential.

In addition to the technical and economic potential, multiple achievable scenarios can be forecasted based on incentive levels, energy rates, the rate of cost decline, barrier levels, and heat pump availability. The three achievable scenarios for the heating electrification module of this study are listed in Table C-18.

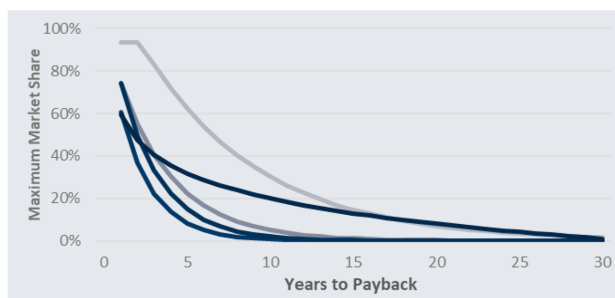
Technology Diffusion

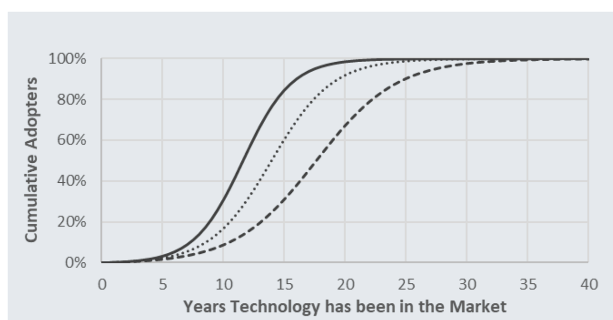
As heating electrification is considered to be an emerging trend in energy efficiency programs, HEAT's adoption engine is built on two factors:

Customer Economic Potential: The expected uptake driven by customer economics and willingness-to-pay for heat pumps. Decision-making is assumed to be based on Simple payback (years) for residential customers and on Internal Rate of Return (IRR) for commercial customers. Sample willingness-to-pay curves are shown in Figure

Technology adoption: The rate of adoption of heat pumps over time considering local barriers and market characteristics is captured through Bass Diffusion curves, where new adopters are classified as either innovators or imitators. Key model parameters are calibrated using historical uptake trends from programs.

Figure C-3. Customer economics curves (above) and technology adoption curves (below)





Measure competition

The model accounts for competing measures available to potential adopters to estimate the proportion of customers that will opt for a given measure given the economics and barriers they face. As a specific building archetype with specific heating and cooling equipment can be electrified through a number of combinations of heat pump technologies, heat pump sizing strategies, backup equipment and control strategies, these combinations are all modeled and put in competition by the HEAT model.

- Technical Potential: 100% of the market is applied to the measure with the highest savings.
- Economic Potential: 100% of the market is applied to the measure with the highest savings that passes cost-effectiveness screening.
- Achievable Potential: The market is split between all cost-effective measures by pro-rating the adoption rate based on the maximum adoption rate and each of the measures' adoption rates.

C.4 HEAT Model Inputs

HEAT requires an extensive set of model inputs related to heating and cooling technologies, markets, economic factors, and adoption parameters to accurately assess heating electrification potential.

More details on the inputs used in this potential study are provided in the present chapter, starting with measure inputs (equipment costs and efficiencies), followed by market inputs (populations and market shares), and concluding with jurisdictional inputs (economic inputs and weather data).

Table C-4 lists the sources and references used, following the same format as the equivalent table from the efficiency module in section B.3.

Table C-6. HEAT Measure Input Sources

Key	Source
MA-2	Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2019-2021 - Plan Version.
MA-3	MA RES21, Energy Optimization Study
MA-4	MA RES19 Water Heating, Boiler, and Furnace Cost Study
MA-5	MA RES23 Cost Study of Heat Pump Installations for Dual Fuel Operation
MA-6	MA RES28 Ductless Mini-Split Heat Pump Cost Study
ASHRAE	ASHRAE Journal Article, Long-Term Commercial GSHP Performance, Part 4: Installation Costs, 2012
NY-1	Energy + Environmental Economics New York Heat Pump Potential Model Overview, 2019
RI-4	Brattle Group Heating Sector Transformation, and Heating Sector Transformation in Rhode Island: Technical Support Document
PSEG-LI	PSEG Long Island - Technical Reference Manual - 2019
EIA	EIA, Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, 2018

C.4.1 Measure Inputs

This section provides detail on the measure inputs used in the heat model, in particular the capital costs, maintenance costs, and expected useful life (EUL) of various heating and cooling technologies and heat pumps.

Note that the costs are calculated in HEAT based on a combination of fixed and variable costs depending on equipment size. For reporting purposes, existing Single-Family Homes are used as reference size for residential equipment, and for commercial, existing Office Buildings are used as reference size.

Measure-level inputs and results can be obtained in the detailed results workbooks, found in Appendix F and provided in Excel Workbook format.

Baseline Space Heating Equipment

Residential

Table C-7. Residential Baseline Space Heating Equipment Specifications (existing Single-Family Home)

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	AFUE	EUL
Gas Boiler	110	$6,000	$90	79%	20
Oil Boiler	110	$4,600	$140	75%	20
Propane Boiler	110	$6,600	$90	75%	20
Gas Furnace	80	$4,900	$40	85%	17
Oil Furnace	80	$6,600	$70	79%	18
Propane Furnace	80	$4,900	$40	79%	18

Commercial

Table C-8. Commercial Baseline Space Heating Equipment Specifications (existing Office Building)

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	AFUE	EUL
Gas Boiler	300	$11,500	$340	79%	20
Oil Boiler	300	$12,500	$340	75%	20
Propane Boiler	300	$12,500	$340	75%	20
Gas Furnace	300	$8,900	$420	85%	18
Oil Furnace	300	$9,500	$420	79%	17
Gas RTU	300	$0 *	$0 *	85%	17

** Costs accounted for on the cooling baseline side (Central Package Air Conditioner)*

Baseline Space Cooling Equipment

Residential

Table C-9. Residential Baseline Space Cooling Equipment Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	SEER	EUL
Central Split AC	2.5	$3,400	$70	10	14
Room AC (window AC)	2.5	$750	$40	8	8

Commercial

Table C-10. Commercial Baseline Space Cooling Equipment Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	SEER	EUL
Chiller	15	$58,100	$800	16	23
Central Package Air Conditioner	15	$28,300	$660	12	17
Central Split Air Conditioner	15	$11,900	$360	10	14
Room AC Blend *	15	$10,700	$180	8	8

* 50/50 split of window air-conditioners and ductless mini-split air-conditioners.

Heat Pump Equipment

Heat Pump installed costs include costs for controls, integration, and electrician costs. The costs used here are based primarily on Massachusetts-specific studies and are higher than costs typically seen in other studies. The prefix "cc" refers to cold climate heat pumps (refer to footnote 54). Measure applicability is summarized in Table C-5.

Residential

Table C-11. Residential Heat Pump Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	EUL	COP *	SEER
ccDMSHP (multihead)	2.5	$11,600	$90	18	-	20
ccASHP (central ducted)	2.5	$13,000	$90	17	-	18
GSHP (Water-to-Air)	2.5	$22,800	$90	25	-	17
GSHP (Water-to-Water)	2.5	$26,700	$90	25	-	-

* Refer to Figure C-4 for heat pump COP relative to outdoor air temperature.

Commercial

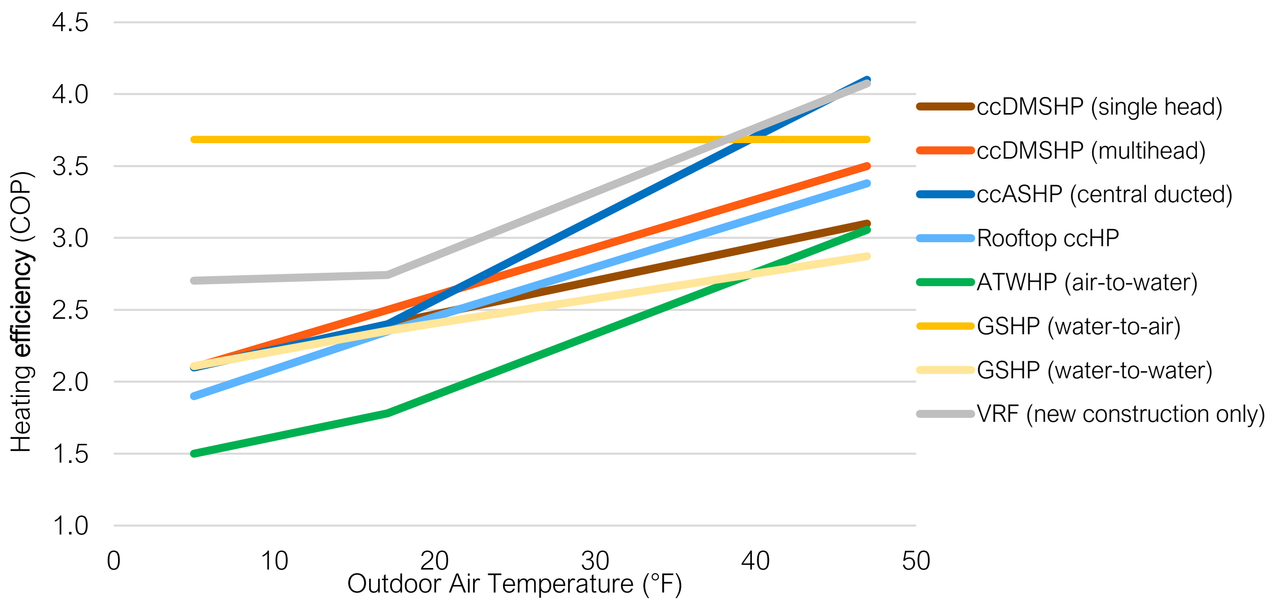
Table C-12. Commercial Heat Pump Specifications

Equipment	Capacity (tons)	Installed Cost	Maintenance Cost (annual)	EUL	COP *	SEER
ccDMSHP (multihead)	15	$67,600	$450	18	-	20
ccASHP (central ducted)	15	$74,600	$450	17	-	18
RTU ccHP	15	$55,100	$620	17	-	18
GSHP (Water-to-Air)	15	$97,400	$560	25	-	17
GSHP (Water-to-Water)	15	$97,400	$520	25	-	N/A
ccATWHP (Air to Water)	15	$76,100	$690	17	-	N/A
VRF	15	$66,100	$620	17	-	18

* Refer to Figure C-4 for heat pump COP relative to outdoor air temperature.

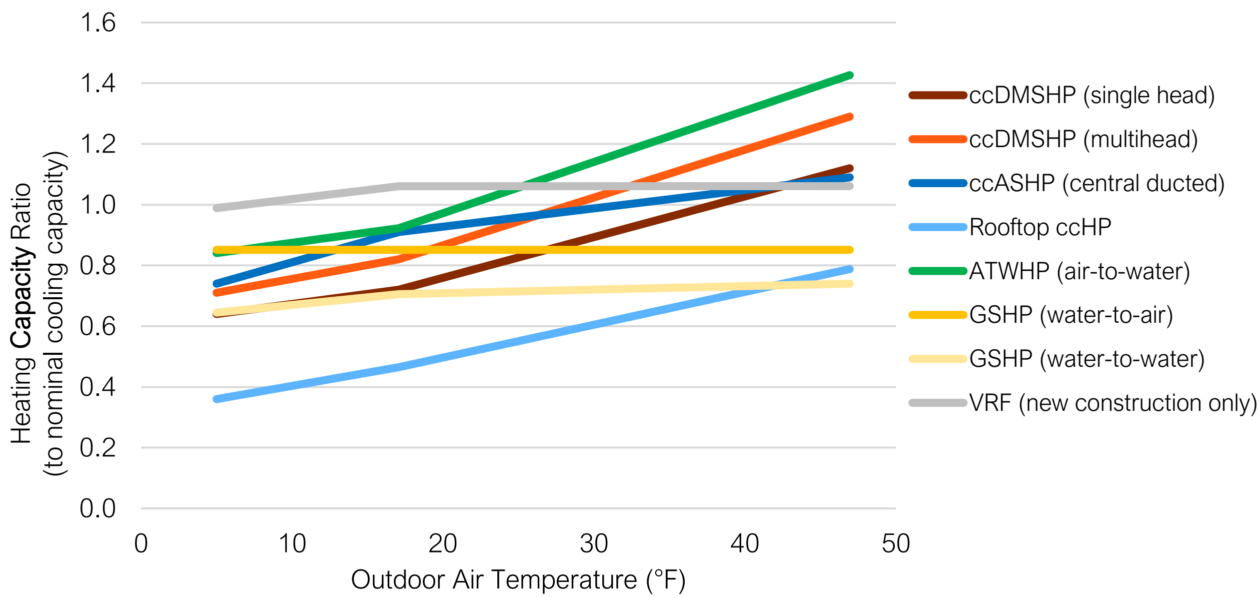
Performance

Figure C-4. Heat Pump efficiency vs Outdoor Air Temperature



Note – Water-loop heat pump (GSHP water-to-water and ATWHP) efficiency varies indirectly to outdoor air temperatures through the heating loop's outdoor reset control

Figure C-5. Heat Pump Heating Capacity vs Outdoor Air Temperature



Backup Heating Equipment

Residential

Table C-13. Residential Backup Heating Equipment Specifications

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	EUL
Electric Baseboards	40	$3,200	$0 *	18
Electric Resistance Coil	40	$1,100	$0 *	17
Buffer Tank Electric Boiler	40	$3,500	$80	20

* *No additional maintenance costs over heat pump/primary heating systems*

Commercial

Table C-14. Commercial Backup Heating Equipment Specifications

Equipment	Capacity (MBH)	Installed Cost	Maintenance Cost (annual)	EUL
Electric Baseboards	200	$12,400	$0 *	25
Electric Resistance Coil	200	$10,900	$0 *	18
Buffer Tank Electric Boiler	200	$8,400	$30	25

* *No additional maintenance costs over heat pump/primary heating systems*

Baseline Domestic Hot Water Equipment

The capital cost and maintenance cost for the baseline domestic hot water equipment is assumed to be the same for residential and commercial.

Table C-15. Baseline Domestic Hot Water Equipment Specifications

Equipment	Installed Cost	Maintenance Cost (annual)	EUL
Gas Storage Water Heater	$1,600	$0 *	15
Oil Storage Water Heater	$2,200	$180	13
Propane Storage Water Heater	$1,700	$0 *	13

** Maintenance costs considered negligible*

Efficient Domestic Hot Water Equipment

The capital cost and maintenance cost for a Heat Pump water heater is assumed to be the same for residential and commercial.

Table C-16. Efficient Domestic Hot Water Equipment Specifications

Equipment	Installed Cost	Maintenance Cost (annual)	EUL
Heat Pump Water Heater	$2,100	$20	13

C.4.2 Heat Pump Sizing and Controls

This section summarizes the sizing and control strategies used in this potential study.

Heat Pump Sizing

Heat pump strategies try to find the optimal balance between an additional size increase, with the incremental savings provided by that size increase.

In general, for partial replacements the heat pumps are sized for cooling, and for full replacements they are sized to meet the full building heating demand taking into account the heat pump technology's capacity at that design outdoor air temperature. It should be noted that a less aggressive heat pump sizing strategy for full replacements would likely result in a better customer and societal cost-effectiveness by reaching closer to the optimal sizing balance referenced above.

The table below provides an example of how heat pump sizing can vary depending on its level of replacement (partial/full) for single-family homes. The most common archetype single-family home was used for reference.

Segment	Equipment	Partial replacement (tons)	Full replacement (tons)
Single Family **(Boiler)**	**ccDMSHP** (ductless)	1.0 or 2.5	3.7 *
	GSHP (Water-to-Water)	N/A	4.0
Single Family **(Furnace)**	**ccASHP** (central ducted)	2.5	3.4
	GSHP (Water-to-Air)	N/A	3.1

* While full replacement measures with ductless heat pumps assume that the indoor heads will only cover 90% of floor area in heating (based on the assumption that some very small rooms such as bathrooms will have electric baseboards instead), the main difference in size between heat pumps types is related to their relative capacity performance curves, as shown in Figure . Note that the Single Family (Boiler) segment is assumed to have a larger heating load than the Furnace equivalent, so larger heat pumps are required for full replacement in these homes.

Additional examples and details can be obtained in the detailed results workbooks, found in Appendix F and provided in Excel Workbook format.

Heat Pump Controls

As with heat pump sizing, different control strategies result in different system performance for the same installed equipment. These control strategies can be split into two categories, as described in section C.3.4: Run together, or Switchover temperature. The control strategy assumptions detailed below were provided by the PA's.

For partial replacements, it is assumed that the control strategy is a fixed switchover temperature, determined based on the customer's energy rates and the equipment efficiencies. The heat pump would switch to the backup technology at a certain outdoor air temperature (OAT) as follows:

- Propane systems: 15°F (source: MA-2)
- Oil systems: 30°F (source: MA-2)
- Gas systems: 50°F (source: MA-3)

For full replacements, it is assumed that the electric resistance backup runs in parallel with the heat pump when the heat pump's output capacity is insufficient to meet the building's heating demand. However, as explained above, since the heat pump is sized to match the building's design heating demand, the electric resistance backup is hardly used.

C.4.3 Market Inputs

Building Archetypes

Floor Area

The floor area for the various segments within residential and business archetypes were determined from penetration and saturation baseline study market data. It was assumed that new and existing buildings have the same average floor area. Table C-17 lists these average floor areas.

Heating & Cooling Loads

For existing buildings, residential annual heating loads come from reference MA-2, and commercial annual heating loads are derived from equipment sizing from DOE archetypes and EFLH from MA-2.

Table C-17 provides a reference summary of the heating and cooling loads for existing buildings in the residential and commercial segments in Boston.

Table C-17. Building Archetype Summary

Sector	Segment	Floor Area (sq ft)	Annual Heating Load (MMBtu)	Annual Cooling Load (MMBtu)
Residential	Single Family (furnace)	1,830	68	14
	Single Family (boiler)	1,830	76	14
	Multi-family	1,180	44	8
	Low Income	1,430	54	10
C&I	Office	6,280	164	172
	Retail	3,250	86	48
	Food Service	2,360	104	102
	Healthcare/ Hospitals	11,120	388	346
	Campus/ Education	29,030	760	528
	Warehouse	9,020	158	110
	Lodging	3,880	136	120
	Other Commercial	5,900	206	72
	Food Sales	13,010	340	568
	Manufacturing/ Industrial	17,440	304	316

For new buildings, a simple scaling factor derived from the New Buildings Institute report (*Moving Energy Codes Forward: A Guide for Cities and States*) is used in order to account for the improvement in envelope and HVAC distribution and efficiency compared to the average existing building.

For the Western Massachusetts region (Chicopee Falls climate zone), the annual heating and cooling loads are scaled based on the ratio of heating and cooling degree days in the two zones.

Water Heating Load

For consistency between the various parts of this potential study, the water heating load uses the same approach as the efficiency measure's characterization.

Market Size

Population

Applicable markets are estimated using Eversource customer population counts and baseline data on existing space and water heating equipment, cooling, equipment, and primary heating fuel. This population data is broken down to the segment level for commercial and residential segments.

The population data for Eversource is broken out to find the estimated population for Eastern and Western Massachusetts, respectively represented by Boston and Chicopee Falls. This split is proportionate for consumption, rather than customer counts, to adjust for any differences in the average consumption between regions.

Equipment and Fuel Shares

Equipment and fuel shares are determined from baseline study market data, which provides breakdowns for commercial and residential segments' existing space and water heating equipment, cooling, equipment, and primary heating fuel. The equipment shares are fuel and segment specific – for example, the proportion of single-family homes with propane furnaces.

For new residential buildings, baseline configurations for new construction are based on the 2019 Residential New Construction Baseline/Compliance Study. For commercial new construction, it is assumed no oil heating would be used. The portion that would be allocated to oil heating was reallocated to propane and gas heating, following existing building proportions.

Market Applicability Factors

Several Market Applicability Factors are applied by segment to account for the:

- limiting factors of **hydronic distribution system compatibility** (0.7 to 0.8 depending on segment, mainly related to the terminal equipment's required loop temperatures or the project complexity related to the location of the building's heating plant)
- availability of land to drill **geothermal boreholes** (0.8 to 0.9 depending on segment)
- applicability of **HPWHs** in homes (0.36), based on a RI study[55]
- availability of modulating cold climate heat pump versions of **packaged rooftop AC** units (0.9)
- applicability of **existing ducts** for use in heating in homes with central AC but no furnaces (0.12)[56]

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[55] National Grid Rhode Island Residential Appliance Saturation Survey (Study RI2311) Report, Section 3.3.3.

[56] Based on analysis of NYSERDA on-site residential baseline data.

C.4.4 Jurisdictional Inputs

Incentive Program Scenarios

The model reads in three different incentive levels: BAU, BAU+ and Max. These incentive levels are described below.

Table C-18. Achievable Program Scenarios

BAU	Applies incentives **in line with Eversource's 2019-2021 Energy Efficiency Plan** to simulate business as usual: $1,250 a ton for air-source, $3,000 a ton for ground-source HPs. Incentive levels are capped at 90% of full heat pump installation cost. HPWHs are incentivized at $400 per unit (propane) and $600 per unit (oil and gas). Measures not currently offered within programs are also included (gas, units > 5.4 tons).
BAU+	Increases incentives **above and beyond** levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives are 50% higher than BAU: $1,875 a ton for air-source, $4,500 a ton for ground-source HPs. Incentive levels are capped at 90% of full heat pump installation cost.
Max	Increases incentives **above and beyond** levels within Eversource's 2019-2021 Energy Efficiency Plan. Incentives are twice the BAU levels: $2,500 a ton for air-source, $6,000 a ton for ground-source HPs. Incentive levels are capped at 90% of full heat pump installation cost.

Typical Meteorological Data

The HEAT model imports climate data for the typical meteorological year (TMY) from NREL's National Solar Radiation database. TMY datasets contain one year of hourly data that best represents the median weather conditions of a typical year from a multiyear period.

The table below shows some key weather metrics for the two climate zones. There is little difference between the design outdoor air temperature in the two zones, meaning that installed capacities are very similar. The difference in heating degree days is more significant, so heating loads and hence energy savings are larger in the Chicopee Falls Climate zone.

Table C-19. Climate Zone Summary

Climate Zone	Weather file (TMY3)	Heating degree-days (60°F)	Cooling degree-days (65°F)	Heating Design OAT (°F)
Eastern MA	Boston Logan Airport	4,613	803	8.1
Western MA	Chicopee Falls	5,126	733	6.8

Economic Inputs

HEAT harnesses key economic parameters such as avoided costs, retail energy rates, and discount rates to assess measure cost-effectiveness and customer adoption. Appendix A outlines the development of these inputs, which are used across all modules of this study.

Net-to-Gross

Net-to-Gross ratios are taken from MA-2. The ratios used are 0.9 for residential measures, and 1.0 for Income Eligible measures. Where the measure was not detailed in the TRM, the most similar measure is chosen, except for GSHPs where a value of 0.77 is used to account for increased free-ridership. [57]

For commercial segments, the NTG is assumed to be 1.0 for all measures.

Market Barriers

As explained in section C.3.6, HEAT's adoption engine involves the calibration of market barriers to historical program uptake. Eversource's 2019 and 2020 results (up to October 2020) were leveraged for this calibration exercise.

[57] Source: Connecticut Ground Source Heat Pump Impact Evaluation & Market Assessment https://www.energizect.com/sites/default/files/CT%20GSHP%20Impact%20Eval%20and%20Market%20Assessment%20%28R7%29%20-%20final%20report.pdf

D. Demand Response Methodology

D.1 Overview

The following sections outline Dunsky's Demand Response Optimized Potential (DROP) Model methodology, used to assess the technical, economic and achievable peak-hour demand savings from electric demand response programs. This appendix begins with a general discussion of Dunsky's modeling and then provides details on the specific assumptions and inputs made in this study.

The strength of Dunsky's approach to analyzing demand response (DR) potential, is that it takes into account two specific considerations that differentiate it from energy efficiency potential assessments.

DR Potential is Time-Sensitive

- DR measures are often subject to constraints based on when the affected demand can be reduced and for how long.
- DR measure "bounce-back" effects (caused by shifting loads to another time) can be significant, creating new peaks that limit the achievable potential.
- DR measures impact one another by modifying the System Load Shape – thus the entire pool of measures (at all sites) must be assessed together to capture these interactive effects and provide a true estimate of the achievable potential impact on the system peak.

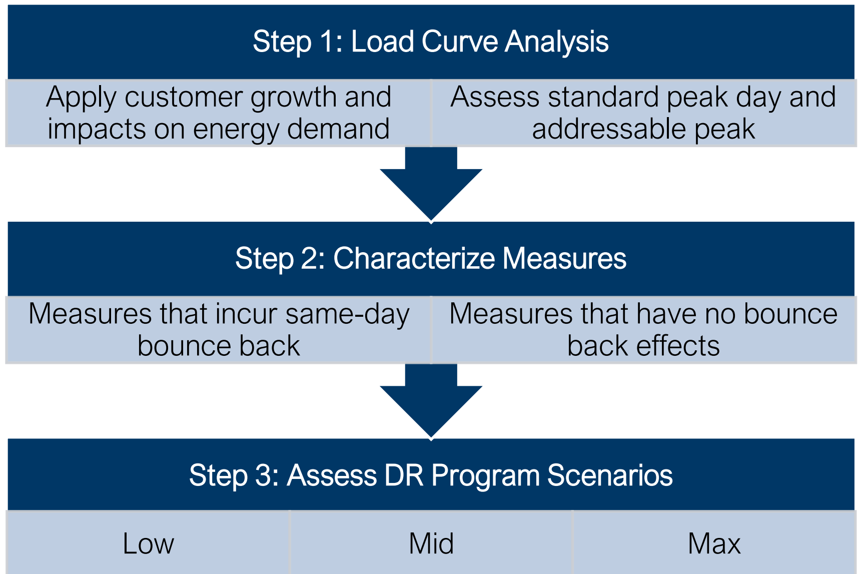
Many DR Measures Offer Little to no Direct Economic Benefits to Customers

- Participants must receive an incentive over and above simply covering the incremental cost associated with installing the DR equipment.[58]
- Incentives can be based on an annual payment basis, a rebate/reduced rate based on a participant agreement to curtail load, or through time-dependent rates that send a price signal encouraging load reduction during anticipated system peak hours.
- Savings are expected to persist only as long as programs remain active.

Figure D-1 presents an overview of the analysis steps applied to assess the DR potential in this study. For each step, system-specific inputs are identified and incorporated into the model. Each step is described below.

[58] This study did not account for reductions in customer peak demand charges that may arise from DR program participation. Since DR events are typically called for a small number of days each month, the impact on commercial monthly peak demand charges is assumed to be minimal.

Figure D-1. Demand Response Potential Assessment Steps



D.2 Load Curve Analysis

The first modeling step of Dunsky's approach is to define the baseline load forecast and determine the key parameters of the utility load curve that influence the DR potential. The process begins by conducting a statistical analysis of historical utility data to determine the 24-hour load curve for the "Standard Peak Day" against which DR measure impacts are assessed. The utility peak demand forecast period is then applied to adjust the amplitude of the standard peak day curve over the study period. Finally, relative market sector growth factors and efficiency and heating electrification program savings (as well as solar PV and EV adoption, where relevant)[59] are applied to further adjust the peak day load curve (growth factors used in the study can be referenced in Appendix A).

[59] BAU+ scenario results for EE and HE savings were applied to adjust the load curve.

Figure D-2. Load Curve Analysis Tasks

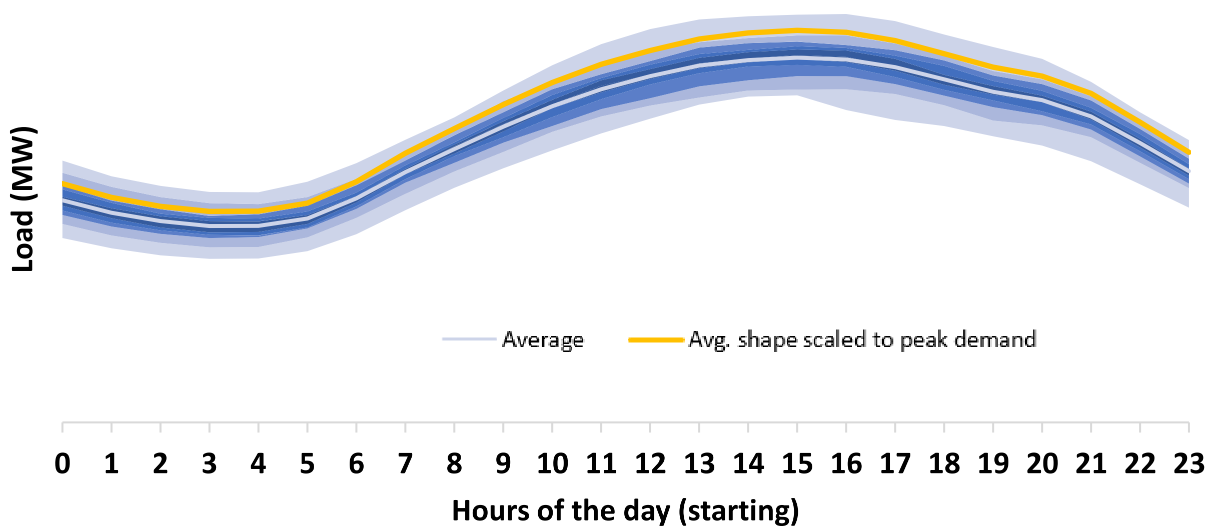
Once complete, the load curve analysis provides a tool that can assess the individual measure, and combined program impacts against a valid utility peak baseline curve that evolves to reflect market changes over the study period.

D.2.1 Identify Standard Peak Day

The **Standard Peak Day** is assessed through an analysis of historical hourly annual load curves[60]. For each year, a sample of the peak days is identified (e.g. top 10 peak demand days in each year where historical data is available) and a pool of peak days is established. From this, the average peak day shape is established from the pool of peak day hourly shapes. The standard peak day load curve is then defined by raising the average peak day load curve such that the peak moment matches the projected annual peak demand (keeping the shape consistent with the average curve), as shown in Figure below.

[60] For detail on the data used to establish the standard peak day for this study, please see the description of study inputs for the DROP model in section D.5.

Figure D-3. Example of a Standard Peak Day Curve



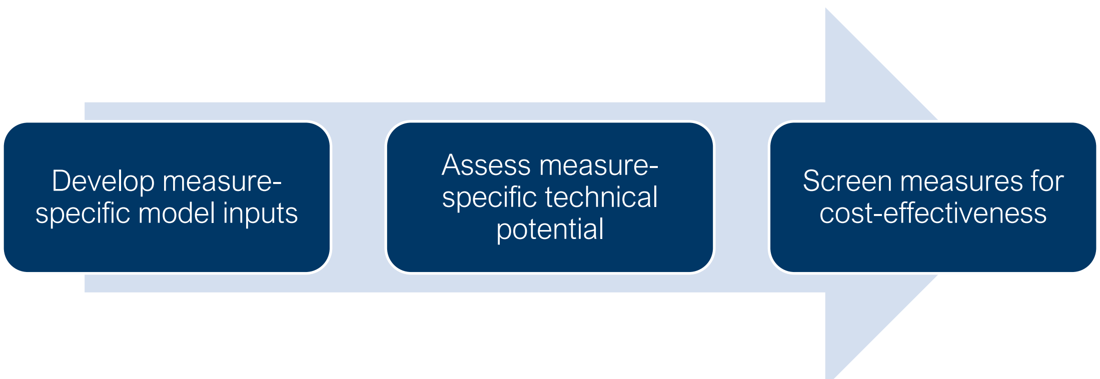
Note: Each blue shading area represents a 10-percentile gradient.

From the standard peak day curve, a DR window is identified which represent the time period that capture the highest demand hours. These are assessed against the historical annual curves to ensure that 90% of DR peak events within a given year fall within the defined DR windows. These are used to characterize certain DR measures, providing guidance on which hours to target customer driven curtailment periods, and to create pre-charge/reduction/re-charge curves for equipment control measures, as described in the next step.

D.3 DR Measures Characterization

DR potential is assessed drawing on Dunsky's database of specific demand reducing measures developed from a review of commonly applied approaches in DR programs across North America, as well as other emerging opportunities such as battery storage.[61] Measures are characterized with respect to the local customer load profiles[62], and the technical and economic DR potentials are assessed for each individual measure.

Figure D-4. DR Measure Characterization Tasks



Once complete, the measure-specific economic potential is loaded into the model to assess the achievable potential scenarios when all interactive load curve effects are considered.

D.3.1 Measure Specific Model Inputs

Measures are developed covering all customer segments and end-uses, and can be broadly categorized into two groups:

- Type 1 DR Measures (typically constrained by demand bounce-back and/or pre-charging):
    - These measures exhibit notable pre-charging or bounce-back demand profiles within the same day as the DR event is called. This can create new peaks outside of the DR window and may lead to significant interaction effects among measures when their combined impact on the utility peak day curve is assessed.
    - Typically, Type 1 measures can only be engaged for a limited number of hours before causing participant discomfort or inconvenience. This is reflected in the DR measure load curves developed for each measure-segment combination. (example: direct load control of a residential water heater)

[61] A detailed list of measures applied in this study is provided in Appendix E.

[62] When local profiles are not available, profiles from similar jurisdiction are used.

- **Type 2 DR Measures (unconstrained by load curve):**
  - These measures do not exhibit a demand bounce-back and are therefore not constrained by the addressable peak.
  - Some of them can be engaged at any time, for an extended duration. (example: back-up generator at a commercial facility)

Dunsky's existing library of applicable DR measure characterizations was applied and adjusted to reflect hourly end-use energy profiles for each applicable segment. Key metrics of the characterization are:

1. **Load Shape:** Each measure characterization relies on defined 24-hour load shape both before and after the demand response event. The load shapes are based on the population of measures within each market segment and are defined as the average aggregate load in each hour across the segment.
2. **Effective Useful Life (EUL):** Effective useful life of the installed equipment/control device. For behavioural measures with no equipment, a one-year EUL is applied.
3. **Costs:** At measure level, the costs include the initial cost of the installed equipment (i.e. controls devices and telemetry) and the annual operational cost (program administration, customer incentives etc.).
4. **Constraints:** Some measures are subject to specific constraints such as the number of hours per day or year, maximum number of events per year and event durations.

Once the measures are adapted to the utility customer load profiles and markets, the technical and economic potentials are assessed for each measure independently as outlined below. Because these are assessed independently (i.e. not considering interactions among measures), the technical and economic potentials are not considered to be additive, but instead provide important measure characterization inputs to assess the collective achievable potential when measures are analyzed together in step 3.

D.3.2 Technical Potential (Measure Specific)

The technical potential represents a theoretical assessment of the total universe of controllable loads that could be applicable to a DR program. It is defined as the technically feasible load (kW) impact for each DR measure considering the impact on the controlled equipment power draw coincident with the utility annual peak.

More specifically, the technical potential is calculated from the maximum hourly load impact during a DR event multiplied by the applicable market of the given measure[63]. It is important to note that the

[63] For thermostats, and heat pumps, the applicable markets were defined using outputs from the BAU+ scenarios in the relevant study component (i.e., energy efficiency, heating electrification)

technical potential assessment does not consider the utility load curve constraints, such as the impact that shifting load to another hour may have on the overall annual peak.

D.3.3 Economic Potential (Measure Specific)

The assessment of each measure's economic potential is conducted in three key steps: adjustment of the technical potential, screening for cost-effectiveness, and adjusting for market adoption limitations.

1. **Technical Potential Adjustment:** The measure's hourly load curve impact is applied to the utility standard peak day load curve, to assess the impact. For each individual measure an optimization algorithm that assesses various control schemes and market portions is applied to arrive at the maximum number of participants and impact for the given measure, either during the standard peak day, or over the sample annual hourly load profile.

2. **Cost-Effectiveness Screening:** Once each measure's impact on the peak is assessed, measures are screened using the applicable cost-effectiveness test, considering installation costs and baseline incentive costs.[64] It is important to note the customer incentives are not treated as a pass through cost for DR programs because they typically do not cover a portion of the customers' own equipment incremental costs (i.e. customers typically have no direct equipment costs, unlike in efficiency programs where the incentives provided cover a portion of the participant's incremental costs for the efficiency upgrade).

   For measures that pass the cost-effectiveness screening, program incentives can then be set either as a fixed portion of the avoided costs net of measure costs (i.e. 50%) or at the level that maximizes the cost-effectiveness test value for the measure in question.

Table D-1. DR Benefits and Costs Included in Determination of the TRC

Benefits	Costs
Avoided Capacity Costs Other ancillary benefits (as applicable)	Controls equipment installation Controls equipment Operations and Maintenance (O&M) (if required) Annual incentives ($/ participant) Peak reduction incentives ($/kW contracted)

3. **Market Adoption Adjustment**: The market for a given DR program or measure may be constrained either by the impact on the load curve, or by the expected participation (or adoption) among utility customers.

   In the first case, the economic potential assessment (described above) determines the number

[64] Any measure that cannot achieve a cost-effectiveness test greater than 1.0 is not retained for further consideration in the model.

of devices needed to achieve the measure's maximum impact on the utility peak load. Adding any further participation will come at a cost to the utility, but with little or no DR impact benefits.

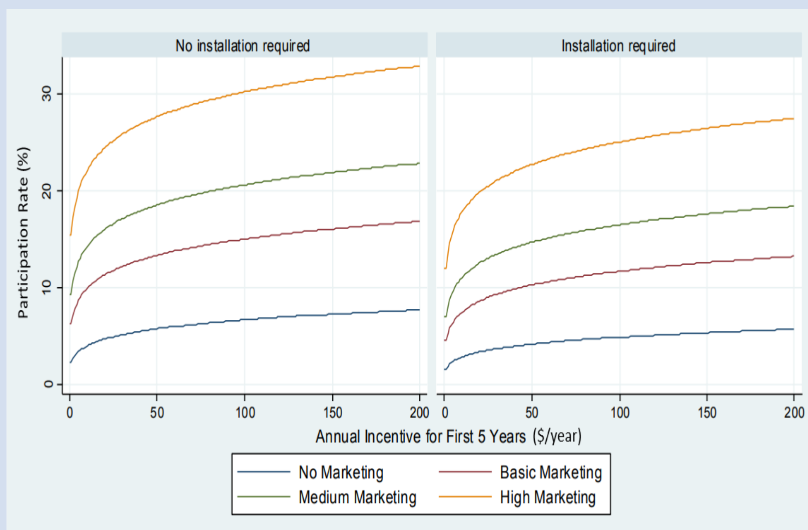
In the second case, the model determines the expected maximum program participation based on the incentive offered, the need to install controls equipment, the level of marketing, and the total number of eligible customers, by applying DR program propensity curves (described in the call out box below) developed by the Lawrence Berkeley National Laboratory.[65]

The DR model assesses both the utility curve economic potential market and the maximum adoption at the resulting incentive levels, then constrains the market (maximum number of participants) to the lower of the two. This is then applied as a measure input for the achievable potential assessment described in the next step.

Demand Response Propensity Curves

For each measure the propensity curve methodology, as developed by the Lawrence Berkeley National Laboratory to assess market adoption under various program conditions, is applied. The curves represent achievable enrollment rates as a function of incentive levels, marketing strategy, number of DR calls per year, and the need for controls equipment. Their development is based on empirical studies, calibrated to actual enrollment from utility customer data. Specific curves are available for each sector.

Figure D-5. Residential Adoption Curves used in the study



[65] Lawrence Berkeley National Laboratory, March 2017. 2025 California Demand Study Potential Study, Phase 2 Appendix F. Retrieved at: http://www.cpuc.ca.gov/General.aspx?id=10622

D.4 Assessment of Achievable Potential Scenarios

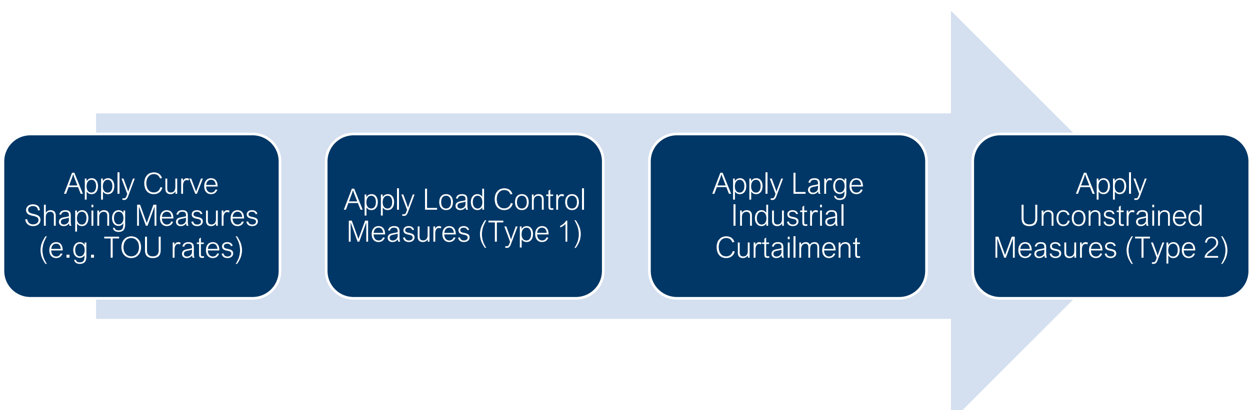
The achievable potential is determined through an optimization process that considers market adoption constraints, individual measure constraints, and the combined inter-measure impacts on the utility load curve.

Scenarios are developed to assess the combined impact of selected programs and measures. For example, one scenario may assess the achievable potential of the impact of applying residential BYOD smart thermostat control and industrial curtailment, while another may assess the combined potential from direct install DLC equipment and industrial curtailment. This approach recognizes that there can be various strategies to access the DR potentials from the same pool of equipment (i.e. offering two measures for residential water heating DLC exert a reduction in residential water heating peak demand, thereby reducing or eliminating the potential from one or both water heater measures). The scenarios are assembled from logical combinations of programs and measures designed to test various strategies to maximize the achievable peak load reduction.

D.4.1 Assessing Achievable Potential

For each scenario, measures are applied in groups and in order starting with the least flexible/most constrained measures and progressing to the measures/groups that are less and less constrained, as per the order illustrated below.

Figure D-6. Achievable Potential Assessment Tasks



- **Curve Shaping:** Rates Based Measures (such as time of use rates) are typically applied first as these are designed to alter customer behaviour with time, and are considered the least flexible (i.e. with the exception of critical peak pricing, they cannot be engaged by the utility to respond to a specific DR event, but must be set in place and exert a prolonged effect on the utility load curve shape). Curve shaping can also include passive demand reduction via increased adoption of efficiency measures.

- **Type 1 - Load Control Measures:** Direct control of connected loads such as water heaters and thermostats, and customer controlled shut-off or ramp down of commercial HVAC loads are applied next. These are typically constrained to specific times of day based on the utility peak load shape, and the controlled equipment load shape (i.e. turning of residential water heaters at midday may be feasible but deliver next to no savings as there is minimal hot water demand at that hour). These are assessed against the load curve altered by any shaping measures, and measures that may double count savings are eliminated. A new aggregate utility load curve is then created, applying the achievable load control peak reductions, and bounce-back effect.

- **Industrial / Commercial Curtailment:** Next customer curtailment is applied, which typically carries constraints related to the number of curtailment hours per day (consecutive and total), the number of events per year, and in some cases the time of day that curtailment can be applied (but does not carry same-day bounce-back effects). These are applied to the adjusted load curve to assess the potential impact of large industrial and commercial curtailment measures on the magnitude and timing of the overall annual peak.

- **Type 2 - Unconstrained Measures:** Finally, the remaining Type 2 measures that have no constraints on the duration, frequency or timing of their application are applied. These may include measures such as dual-fuel heating and back-up generators which can be engaged as needed and whose potential is not impacted by the shape of the utility load curve.

Achievable results present the anticipated performance, including realisation rate based on MA TRM[66]. The potential study is independently derived and does not start with policy targets.[67] It should be noted that is a simulated environment. Multiple factors (day of the week, weather, etc.) can impact the actual curtailment of a given event.

D.4.2 DR Programs and Scenarios

Dunsky has developed a set of best-in-class program archetypes based on a review of programs in other jurisdictions. For each program, development, marketing and operating costs are estimated and applicable measures are mapped to the corresponding program, applying key features from the program archetypes, and taking into account current programs offered by the utility.

The model first determines the achievable DR potential of the combined measures within all programs, and then assesses the program level cost-effectiveness, summing all program and measure costs, as well as applicable measure benefits. A specific program lifetime is assumed for each program, except where the program is based on control devices with a longer EUL, in which case the program is assumed to cover the entire device life. In cases where DR device EULs are shorter than the program lifetime, preparticipation / re-installation costs are applied. This approach allows the model to fairly assess the programs costs and benefits for an on-going program.

New measure and program ramp-up: Where applicable, new programs and measures can be ramped up accounting for the time needed to enroll customers and install controls equipment to reach the full

[66] Realisation rates: 78% for C&I interruptible load, 104% for C&I storage daily dispatch, 101% for C&I storage targeted dispatch, all other measures are at 100%.

[67] The potential for battery storage was derived independently from the MA energy storage target of 1,000MWh by the end of 2025.Only customer-owned Battery storage (BTM) was accounted for in this study, and this applied both an assessment of the ability for DR incentives to increase customer adoption of battery storage and the propensity of customers with batteries to participate in the DR programs.

achievable potential. Ramp up trajectories applied to the achievable potential markets after all interactive effects (i.e. new peaks created or program interactions that affect the net impact of any other program) have been assessed. Typically, it is assumed that it takes three years for a new or expanded program or measure to reach full participation and roll out (i.e. a ramp rate of 33% per year was applied for adding new programs).

Based on these steps the Achievable DR potential for each measure, program and scenario are developed, along with an appropriate assessment of the measure, program and scenario level cost-effectiveness.

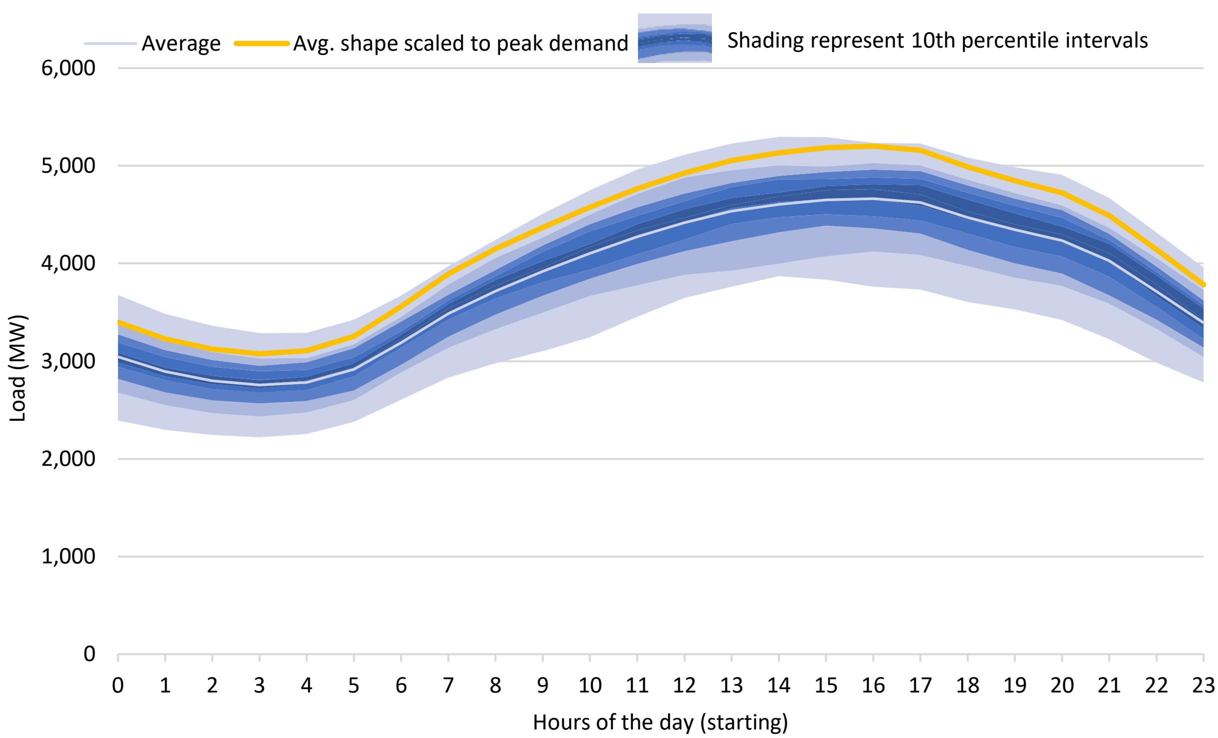
D.5 Demand Response Input

In addition to data described in this appendix, a number of other inputs were used in the demand response potential assessment.

D.5.1 Standard Peak Day

Eversource provided Dunsky with hourly historical load data. The data covered January 1st, 2015 to December 31st, 2019 (43,819 data points). This historical data was used to create standard peak days for the system.

Figure D-7. Standard Summer Peak Day – Eversource, Massachusetts



D.5.2 End-Use Breakdowns

Dunsky developed end-use load curves for each market sector and end-use and where relevant, for individual segments. **Note that these breakdowns are for the electric consumption only, not the whole building (all fuel) energy use.** The load shapes were used to:

1. Assess standard peak day adjustments for DR addressable peak.
2. Characterize measures when local load curves were not available.
3. Benchmark savings when calibrating the model.

The end-use load curves were developed from the following sources:

- US Department of Energy (US DOE) published load curves, taken from buildings in the Massachusetts climate zones, and adjusted to account for heating energy source.
- Engineered load profiles and Dunsky's in-house developed sample consumption profiles.

In this study, the industrial sector was grouped into one segment "Manufacturing / Industrial". The segment was modeled using one industrial end-use ("Industrial). Industrials were evaluated using Dunsky's internal datasets.

Using this breakdown, an annual (hourly – 8670 hours) building energy consumption simulation from the US DOE (*Commercial Reference Buildings & Building America House Simulation Protocols*) allowed for the recreation of the end-use breakdown for a standard peak day. The figure below presents the end-use and sector breakdown of the electric system.

Figure D-8. Summer Standard Peak Day – Sector Breakdown

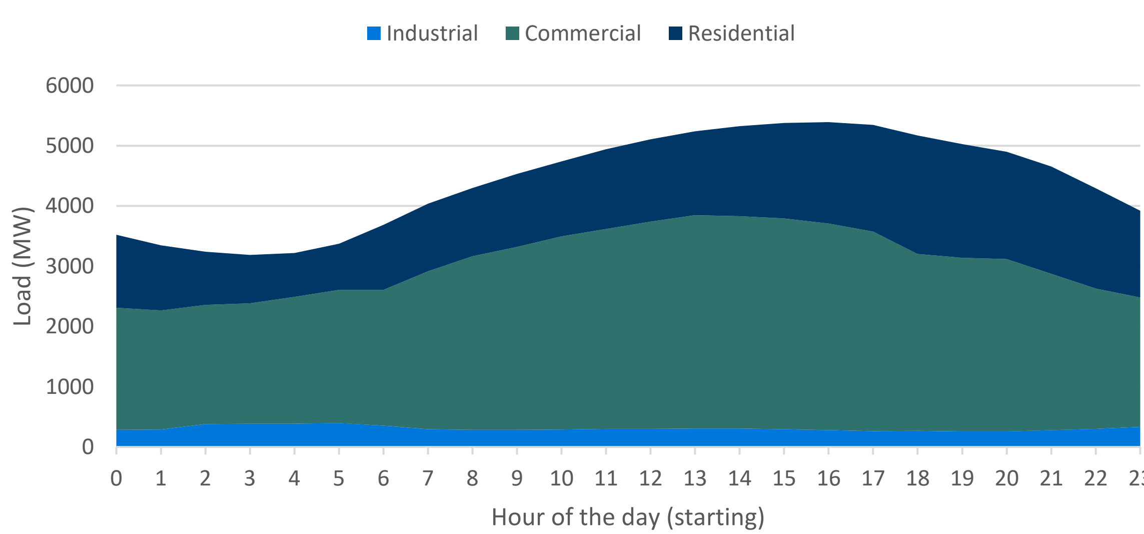
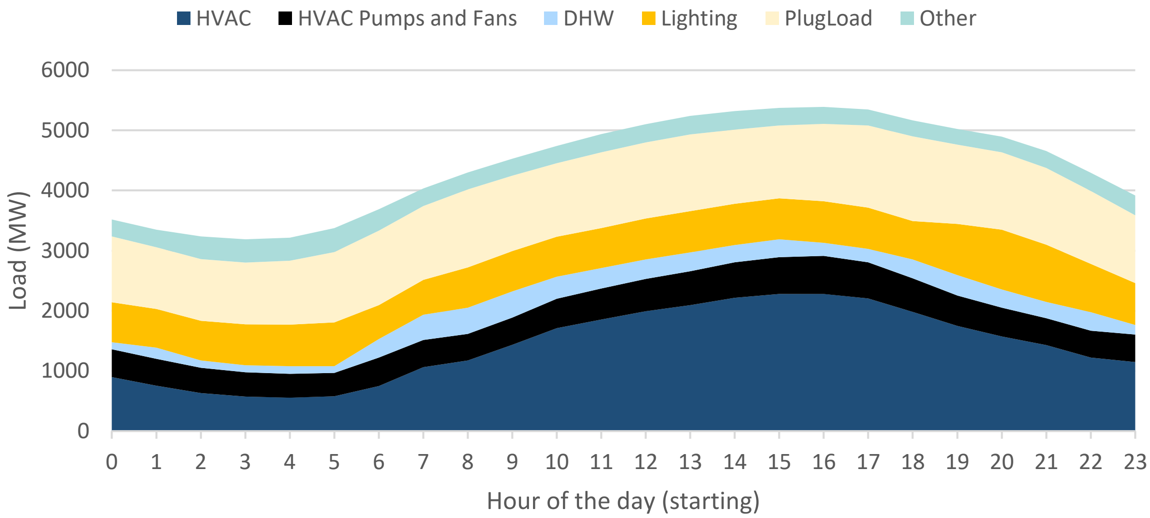


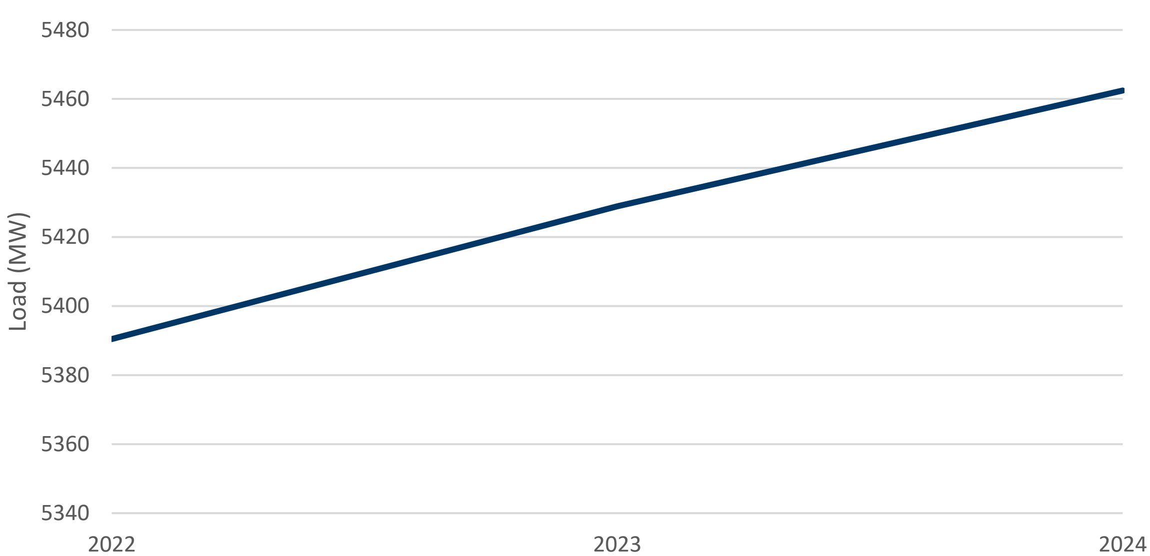
Figure D-9. Summer Standard Peak Day – End-use Breakdown



D.5.3 Future impacts

The standard peak day was forecasted using the same peak demand forecast as the rest of the potential study. It is presented in the figure below.

Figure D-10. Eversource load forecasting (before EE/HE/EV impacts)



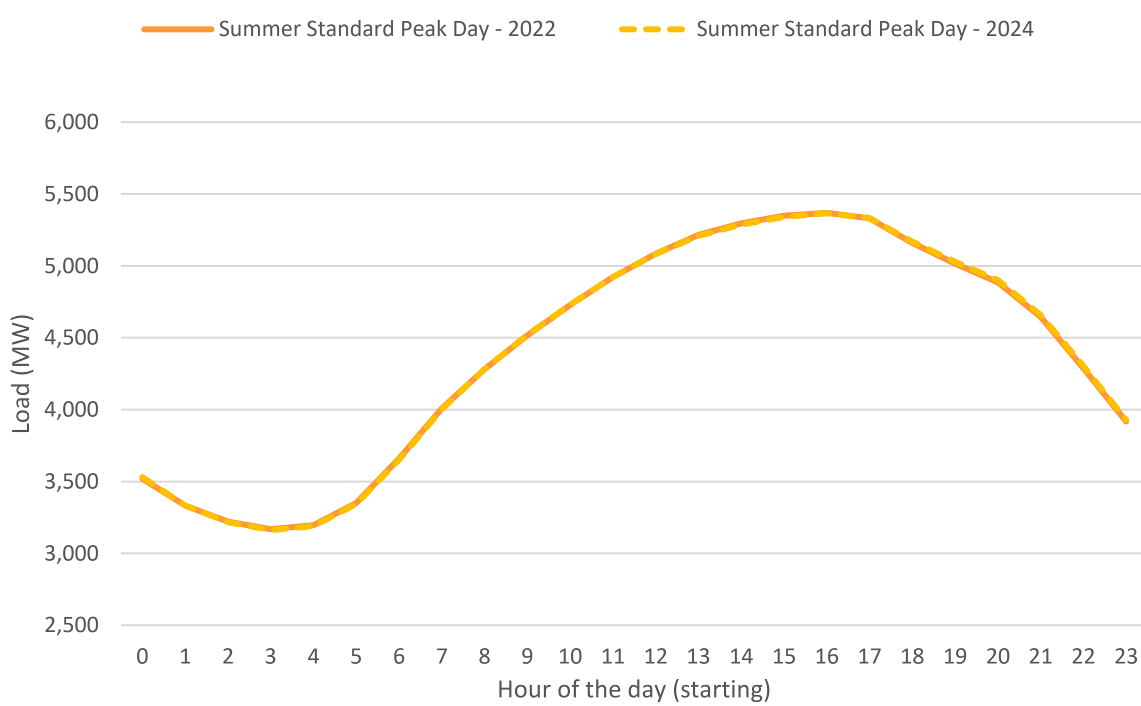
Furthermore, results (baseline scenarios) for energy efficiency and heating electrification forecast were combined with the load forecast in order to have a better grasp at the future load shape.

Table D-2. Impact of energy efficiency, heating electrification and EV on Key Demand Response Factors (2024)[68]

Season	Average hourly reduction	Peak reduction	Peak-to-average difference
Summer	74 MW	97 MW	- 22 MW

When considering load growth with forecasted impacts of energy efficiency and heating electrification as shown in the table above, the combined effects are nearly imperceptible in summer, as shown in Figure D-11. Since the period covered in the study is three years, the impact of such measures on the peak shape is somewhat limited.

Figure D-11. Evolution of the Standard Peak Day



D.5.4 Measures

To assess the DR potential in the jurisdiction, Dunsky characterized over 25 demand reducing measures, based on commonly applied approaches in DR programs across North America, and emerging opportunities such as battery storage. Measures were selected to ensure meaningful potential when targeting Eversource's peak (e.g., no winter-only measures, cost-effective other jurisdictions, etc.). As defined in this appendix, the measures are covering all customer segments and

[68] Negative savings represent an increase in peak demand.

can be categorized into two groups: Type 1 (constrained by the addressable peak) and type 2 (unconstrained by the addressable peak). Measures of all types have the following key metrics:

- Load shape of the measure
- Constraints
- Measure Effective Useful Life (EUL)
- Costs

Dunsky applied our existing library of applicable DR measure characterizations and adjusted them to reflect end-use energy use profiles in Massachusetts' climate. Each measure was evaluated independently for each segment of the study. The following tables provide an overview of each measure characterization and approach.

Table D-3. Residential Demand Response Measures

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test[69]	ADOPTION LIMIT[70]
Appliances						
Clothes Dryer - DLC	Appliance shut off during event	Smart Plug	Number of non-smart clothes dryers in the jurisdiction	Smart Plug	Fail	Not cost-effective
Clothes Dryer - BYOD	Appliance shut off during event	Smart Appliance	Number of smart clothes dryers in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives[71]
Dehumidifier - BYOD	Appliance shut off during event	Smart Appliance	Number of smart dehumidifiers in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives
Pool Pumps – Timer or Smart Switch – DLC	Postponing filtering and cleaning work of the pump	Simple Timer Switch or Smart Switch	Number of non-smart pool pumps in the jurisdiction	Timer or Smart Switch	Pass	Market size & Incentives
Pool Pumps – BYOD	Postponing filtering and cleaning work of the pump	Smart Appliance	Number of smart pool pumps in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives
Hot Water						
Resistance Storage Water Heater - DLC	Appliance shut off during event	Smart Switch	Non-smart electric water heater (excl. heat pump water heater)	Smart Switch	Fail	Not cost-effective
Resistance Storage Water	Appliance shut off during event	Smart Water Heater	Smart electric water heater (excl. heat pump	Incentive upon program inscription	Pass	Market size & Incentives

[69] Main results from cost-effectiveness (CE) test: Some specific segments in a given measure may present different results.

[70] Main limiting factor: Some specific segments could have different adoption limits.

[71] The number of participants is a function of both market size and incentives. Increasing any of them could enhance adoption, as long as the new potential is not in competition with another measure.

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test[69]	ADOPTION LIMIT[70]
Heater - BYOD			water heater)			
Heat Pump Storage Water Heater – BYOD	Appliance shut off during event	Smart Heat Pump Water Heater	Smart heat pump water heater	Incentive upon program inscription	Pass	Market size & Incentives
HVAC						
Central Air-Conditioner (AC) – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with central AC and with manual or programmable thermostat	Installation of a WiFi thermostat	Pass	Market size & Incentives
Central Air-Conditioner – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with central AC and with Wi-Fi Thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Ductless HP/AC – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with a Ductless HP/AC	Installation of a WiFi thermostat	Pass	Market size & Incentives
Ductless HP/AC – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Households with a Ductless HP/AC a smart thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Room AC – BYOD	Temperature setback (including pre-cooling strategies)	Smart Appliance	Smart room AC in the jurisdiction	Incentive upon program inscription	Pass	Market size & Incentives
Other						
Electrical Vehicle (EV) - DLC	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug (such as	Number of EVs in the jurisdiction x % charged at home using new smart charger	Smart EVSE or Smart Plug	Pass	Market size & Incentives

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test[69]	ADOPTION LIMIT[70]
		FloCarma Plug)				
Electrical Vehicle (EV) - BOYD	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug (such as FloCarma Plug)	Number of EVs in the jurisdiction x % charged at home using existing smart charger	Smart EVSE or Smart Plug	Fail	Not cost-effective
Battery Energy Storage – With Solar - BYOD	Battery discharges during event and extra power is send back into the grid	Battery	Households with solar panels and battery	None	Pass	Market size & Incentives
Battery Energy Storage – Without Solar - BYOD	Battery discharges during event to cover the house loads only	Battery	All households with a battery, excluding households with solar panels	None	Pass	Market size & Incentives

Table D-4. Non-Residential Demand Response Measures

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test [72]	ADOPTION LIMIT[73]
Appliances						
Commercial Refrigeration	Refrigeration loads shed	Auto-DR	Refrigeration load per building with low-temperature cases x number of buildings (Grocery only)	Automated demand response	Pass	Market size & Incentives
Hot Water						
Resistance Storage Water Heater - DLC	Appliance shut off during event	Smart Switch	Non-smart electric water heaters (excl. heat pump water heater)	Smart Switch	Fail	Not cost-effective
Resistance Storage Water Heater - BYOD	Appliance shut off during event	Smart Water Heater	Smart electric water heaters (excl. heat pump water heater)	Incentive upon program inscription	Fail	Not cost-effective
HVAC						
WiFi Thermostat – DLC	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Small C&I buildings with central AC and with manual or programmable thermostat	Wi-Fi Thermostat	Pass	Market size & Incentives
WiFi Thermostat – BYOD	Temperature setback (including pre-cooling strategies)	Wi-Fi Thermostat	Small C&I buildings with central AC and with Wi-Fi thermostat	Incentive upon program inscription	Pass	Market size & Incentives
Other - Curtailment						
Medium Commercial &	Turning off some of the fixtures, HVAC demand	Manual or existing BAS system not	All medium-sized C&I buildings	None	Pass	Market size & Incentives

[72] Main results from cost-effectiveness (CE) test: Some specific segments in a given measure may present different results.

[73] Main limiting factor: Some specific segments could have different adoption limits

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test [72]	ADOPTION LIMIT[73]
Institutional	(fresh airflow reduction, temperature adjustment, interruption of dehumidification, etc.), devices, appliances or processes	optimized				
Large Commercial & Institutional	Turning off some of the fixtures, HVAC demand (fresh airflow reduction, temperature adjustment, interruption of dehumidification, etc.), devices, appliances or processes	Manual or existing BAS system not optimized	All large-sized C&I buildings	None	Pass	Market size & Incentives
Medium (Auto-DR) Commercial & Institutional	Reduce level by 30% during peak events	Upgrade to a DR-optimized BMS system or installation of new equipment.	All medium-sized C&I buildings	Auto-DR system	Pass	Market size & Incentives
Large (Auto-DR) Commercial & Institutional	Reduce level by 30% during peak events	Upgrade to a DR-optimized BMS system or installation of new equipment.	All large-sized C&I buildings	Auto-DR system	Pass	Market size & Incentives
Large Industrial Curtailment	Load shifting with no intraday rebound, via expansion of existing programs or interruptible rates	Manual, BAS or Auto-DR	All large-sized Industrial buildings	None	Pass	Market size & Incentives
Medium	Load shifting with no	Manual, BAS or Auto-	All medium-sized	None	Pass	Market size &

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test [72]	ADOPTION LIMIT[73]
Industrial Curtailment	intraday rebound, via expansion of existing programs or interruptible rates	DR	Industrial buildings			Incentives
Other						
Electrical Vehicle (EV)	Shut off during event	Smart Electric Vehicle Supply Equipment (EVSE) or Smart Plug	Number of EVs in the jurisdiction x % charged at the office	Smart EVSE or Smart Plug	Fail	Not cost-effective
Emergency Generator (Gas)	Use of emergency generator during event	Manual, BAS or Auto-DR	Number of gas emergency generator in the jurisdiction	Costs of EPA stationary nonemergency compliance	Pass	Market size & Incentives
Combined Heat and Power	Use of CHP system during event	Manual, BAS or Auto-DR	Number of CHPs in the jurisdiction (non already involved with C&I program)	None	Pass	Market size & Incentives
Battery Energy Storage – With Solar (Small C&I)	Battery discharges during event and extra power is send back into the grid	Battery	Small C&I buildings with solar panels and battery	None	Pass	Market size & Incentives
Battery Energy Storage – Without Solar (Small C&I)	Battery discharges during event to cover the building loads only	Battery	Small C&I buildings with a battery, excluding households with solar panels	None	Pass	Market size & Incentives
Medium Battery Energy Storage - Daily	Battery Energy Storage discharges during event	Battery	Medium C&I buildings with a battery	None	Pass	Market size & Incentives
Large Battery Energy Storage	Battery Energy Storage discharges during event	Battery	Large C&I buildings with a battery	None	Pass	Market size & Incentives

MEASURE BY END USE	DEMAND RESPONSE STRATEGY	ENABLING DEVICE	MARKET SIZE	INITIAL MEASURE COST	CE Test [72]	ADOPTION LIMIT[73]
- Daily						
Medium Battery Energy Storage - Targeted	Battery Energy Storage discharges during event	Battery	Medium C&I buildings with a battery	None	Pass	Market size & Incentives
Large Battery Energy Storage - Targeted	Battery Energy Storage discharges during event	Battery	Large C&I buildings with a battery	None	Pass	Market size & Incentives
Medium Thermal Energy Storage - Daily	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Medium C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives
Large Thermal Energy Storage - Daily	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Large C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives
Medium Thermal Energy Storage - Targeted	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Medium C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives
Large Thermal Energy Storage - Targeted	Thermal Energy Storage discharges during event	Thermal Storage (Ice - Summer only)	Large C&I buildings with a thermal energy storage system	None	Pass	Market size & Incentives

D.5.5 Programs

The table below presents the program costs for each major program type applied in the DR potential model, which were developed based on historical program information provided by Eversource. Program costs account for program development (set up), annual management costs, and customer engagement costs. These are added over and above any equipment installation and customer incentive costs to assess the overall program cost-effectiveness. To assess cost-effectiveness, programs costs are evaluated over nine years to recoup development and initial costs. In some cases, a program's constituent measures may be cost-effective, but the program may not pass cost-effectiveness testing due to the additional program costs. Under those scenarios, the measures in the underperforming program are eliminated from the achievable potential measure mix, and the DR potential steps are recalculated to reassess the potential and cost-effectiveness of each measure and program.

Table D-5. DR Program Administration Costs Applied in Study[74] (excluding DR equipment costs)

Program Name	Development Costs (High Scenario)	Program Fixed Annual Costs	Other Costs ($/customers) for marketing, IT, admin
Connected Solutions - Smart Homes (e.g. Smart Thermostat, EV Chargers, etc.)	$150,000	$150,000	$40
Connected Solutions - Home Batteries	$150,000	$75,000	$40
Connected Solutions - C&I Curtailment	$150,000	$150,000	$30
Connected Solutions - C&I Energy Storage	$150,000	$75,000	$30

[74] Costs were estimated through a jurisdictional scan of programs costs from existing DR programs.

E. Detailed Results Tables

Appendix E contains additional detailed inputs and results tables for each component of the study and is provided in an Excel workbook format.

AEG Applied Energy Group

cadeo

LIBERTY UTILITIES MARKET POTENTIAL STUDY

April 2021

Report prepared for:
LIBERTY UTILITIES

Energy Solutions. Delivered.

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EXECUTIVE SUMMARY

In 2020, Berkshire Gas Company, Liberty Utilities (Liberty), and Unitil (Fitchburg Gas and Electric) contracted with Applied Energy Group (AEG) and our partner Cadeo to perform a comprehensive demand-side management (DSM) market potential study (MPS). This study is an integral part of the utilities' program planning process; ultimately the MPS provides guidance for the development of the utilities' program plans. This report covers the market characterization, baseline, and potential for Liberty[1].

Definitions of Potential

In this study, the savings estimates are developed for five types of potential: technical potential, economic potential, and three levels of achievable potential: Business as Usual (BAU), Business as Usual Enhanced (BAU Plus), and Maximum Achievable. These are developed at the measure level, and results are provided as annual savings impacts over the three-year planning period. The various levels are described below.

- Technical Potential is the theoretical upper limit of efficiency potential, assuming that customers adopt all feasible measures regardless of their cost or customer preference. At the time of existing equipment failure, customers replace their equipment with the most efficient option available. In new construction, customers and developers also choose the most efficient equipment option.
    - Technical potential also assumes the adoption of every other available measure, where applicable. For example, it includes installation of high-efficiency windows in all new construction opportunities and smart thermostats installed on all applicable space heating systems. These retrofit measures are phased in over a number of years to align with the stock turnover of related equipment units, rather than modeled as immediately available all at once.
- Economic Potential represents the adoption of all cost-effective energy efficiency measures. In this analysis, the cost-effectiveness is measured by the total resource cost (TRC) test, which compares lifetime energy and documented non-energy benefits to the incremental costs of the measure, including additional operations and/or maintenance if applicable. If the lifetime benefits outweigh the costs (that is, if the TRC ratio is greater than 1.0), a given measure is considered in the economic potential. Customers are then assumed to purchase the cost-effective option at any decision juncture.
- Achievable Potential refines economic potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and recent Liberty program history. This study assesses three levels of achievable potential developed in coordination with the other PAs and vendors conducting studies in Massachusetts. These are described in more detail in Chapter 2:
    - Business as Usual (BAU) Potential is calibrated to current program activity and assumes incentives (and as a result, program participation) remain as they are today.
    - BAU Plus and Maximum Achievable both reflect likely participation increases due to incentive increases described in Chapter 2.

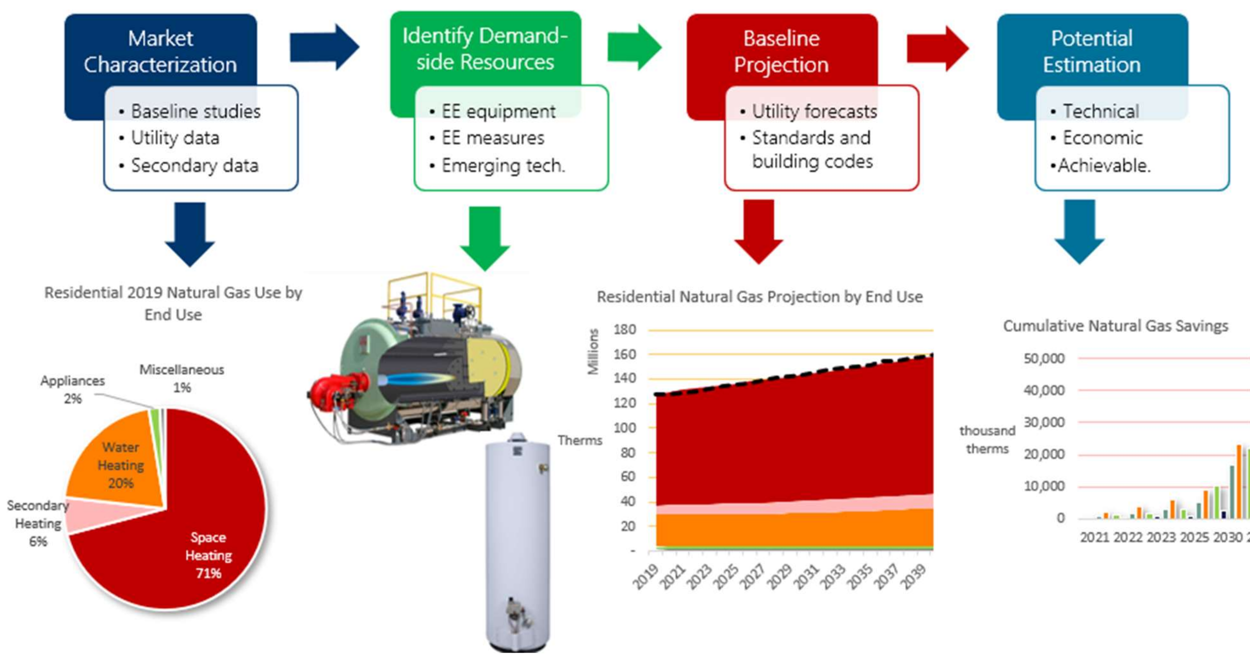
Study Approach

To perform the potential analysis, AEG used a bottom-up approach following the major steps listed and illustrated in Figure ES- 1. The analysis steps are described in more detail in Section 2.

[1] Liberty's customer counts, baseline consumption and potential were developed inclusive of Blackstone Gas customers

1. Characterize the market in the base year (2019) using customer surveys, information and data from Liberty, and secondary data sources, to describe how customers currently use energy by sector, segment, end use and technology.
2. Develop a baseline projection of how customers are likely to use natural gas in absence of future energy efficiency programs. This defines the metric against which future program savings are measured. This projection uses up-to-date technology data, modeling assumptions, and energy baselines that reflect both current and anticipated federal, state, and local energy efficiency legislation and standards that will impact potential.
3. Estimate technical, economic, and achievable potential at the measure level for 2022 through 2024 to inform Liberty's program design.

Figure ES- 1 Analysis Approach



Key Findings

First-year potential savings for 2022 through 2024 and lifetime savings are presented in Table ES- 1. The achievable BAU potential is in the range of 315,549 therms to 316,532 therms per year, or 0.45% of the baseline projection. The residential sector accounts for the largest share of savings, approximately 52% of achievable BAU potential savings in each year.

Table ES- 1 Liberty First-Year Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Reference Baseline	**69,989,044**	**70,371,791**	**70,943,822**
First-year Savings			
Achievable BAU Potential	316,029	316,532	315,549
Achievable BAU Plus Potential	358,227	358,321	357,382
Achievable Max Potential	455,116	454,573	452,537
Economic Potential	1,002,037	987,899	973,874
Technical Potential	1,202,085	1,186,266	1,171,092
Savings as % of Baseline			
Achievable BAU Potential	0.45%	0.45%	0.44%
Achievable BAU Plus Potential	0.51%	0.51%	0.50%
Achievable Max Potential	0.65%	0.65%	0.64%
Economic Potential	1.43%	1.40%	1.37%
Technical Potential	1.72%	1.69%	1.65%

Figure ES- 2 Liberty BAU Achievable Savings by Sector (Therms)

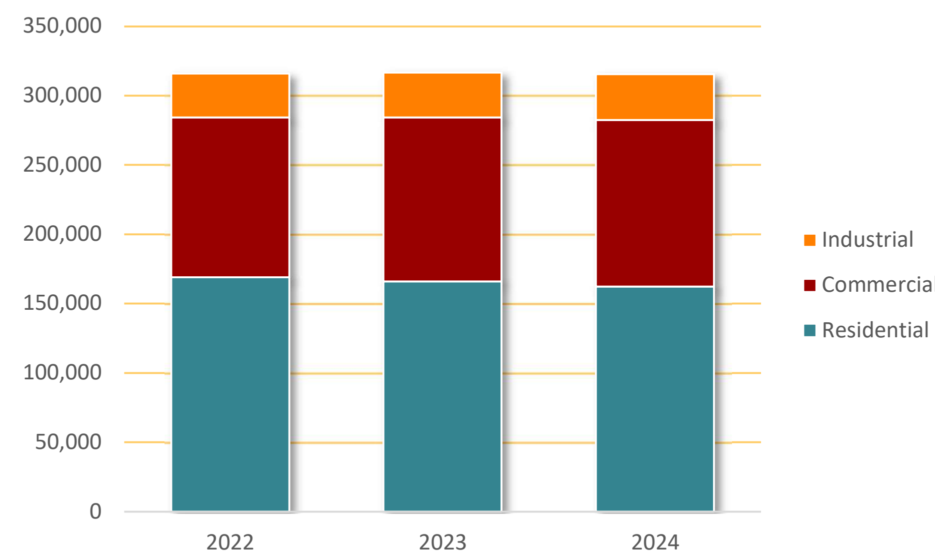


Table ES- 2 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Liberty's actual costs will naturally vary.

Table ES- 2 Liberty Natural Gas Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$5,850,896	$5,749,277	$5,783,219
BAU Plus	$7,520,215	$7,385,295	$7,429,111
Max	$10,949,822	$10,712,645	$10,762,388

Conclusion

Liberty's portfolio of energy efficiency programs is performing solidly, however there is room for some modest increase in annual potential acquisition if incentives are increased and programs can address market barriers. However, both of these prospects will increase the cost of acquiring potential.

This study provides important information for planning the next program cycles. This study:

- Describes and characterizes the customer base by energy source, sector, customer segment and end use. At a glance, it is possible to see where the opportunities for program savings are likely to come from.
- Defines a baseline projection of energy use by end use against which savings can be measured. This baseline takes into account existing and planned appliance standards and building codes, as well as naturally occurring efficiency.
- Evaluates a diverse set of energy efficiency measures in all three customer sectors.
- Estimates the total amount of savings possible from cost-effective measures; these are savings above and beyond those already included in the baseline projection.
- Describes a set of achievable potential savings scenarios – BAU, BAU Plus, and Max – based on increased incentives driving increased savings achievement that can be useful for program development in the upcoming planning years 2022 through 2024

The results presented in this report are estimates based on the best available information available at the time of the analysis and we expect variation in outcomes in the real world. This fact gives staff the opportunity to deviate from specific annual values developed in the study as they design programs and commit to annual program targets as well as gather more territory-specific information about baselines, saturation and demand for program offerings.

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INTRODUCTION

In 2020, the Berkshire Gas Company, Liberty Utilities (Liberty), and Unitil (Fitchburg Gas and Electric) contracted with Applied Energy Group (AEG) and our partner Cadeo to perform this comprehensive demand-side management (DSM) Market Potential Study (MPS) for their natural gas service territory. The key objectives of the study were to:

- Estimate demand-side savings associated with traditional and emerging energy efficiency measures.
- Engage with the statewide coordinators during the study to coordinate assumptions, measure lists, and preliminary analysis results across vendors and utilities.

This study begins with market characterization to help Liberty understand how their customers use natural gas today, then proceeds with baseline projection estimates incorporating the latest information on federal, state, and local codes and standards for improving energy efficiency. Finally, the study assesses various tiers of energy efficiency potential including technical, economic, and three levels of achievable potential.

Liberty will use the results of this study as guidance for their upcoming DSM planning process to optimally implement energy efficiency programs over the 2022-2024 term.

Potential Study Tasks

To produce a reliable and transparent estimate of efficiency potential, AEG performed the following tasks to meet Liberty's key objectives:

- Characterize the market in the base year (2019) using Massachusetts statewide baseline study data, customer data from Liberty, and secondary data sources to describe how customers currently use energy by sector, segment, end use and technology.
- Develop a baseline projection of how customers are likely to use natural gas in absence of future energy efficiency programs. This counterfactual projection defines the metric against which future program savings are measured. This projection used up-to-date technology data, modeling assumptions, and energy baselines that reflect both current and anticipated federal, state, and local energy efficiency legislation and standards that will impact potential.
- Estimate the technical, economic, and achievable potential at the measure level for energy efficiency over the 2022 to 2024 planning horizon to inform Liberty's program design.

This report documents the results of the study as well as the steps followed in its completion. Throughout this study, AEG worked with Liberty to understand the baseline characteristics of their service territory, including a detailed understanding of energy consumption, the assumptions and methodologies used in Liberty's official load forecast, and recent DSM program accomplishments.

Abbreviations and Acronyms

Throughout the report we use a number of abbreviations and acronyms. Table 1-1 shows the abbreviation or acronym, along with an explanation.

Table 1-1 Explanation of Abbreviations and Acronyms

Acronym	Explanation
AEO	Annual Energy Outlook forecast developed by EIA
AESC	Avoided Energy Supply Components
BCR	Benefit Cost Ratio
BEST	AEG's Building Energy Simulation Tool
C&I	Commercial and Industrial
DRIPE	Demand Reduction Induced Price Effect
DSM	Demand Side Management
EE	Energy Efficiency
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EUL	Effective Useful Life
EUI	Energy Utilization Index
HH	Households
HVAC	Heating Ventilation and Air Conditioning
LoadMAP™	AEG's Load Management Analysis and Planning tool
mTherms	Thousand therms
MMtherms	Million therms
NEI	Non-Energy Impacts
O&M	Operations and Maintenance
PA	Program Administrator
Sq.Ft.	Square feet
TRC	Total Resource Cost
TRM	Technical Reference Manual
UEC	Unit Energy Consumption

2

ANALYSIS APPROACH AND DATA SOURCES

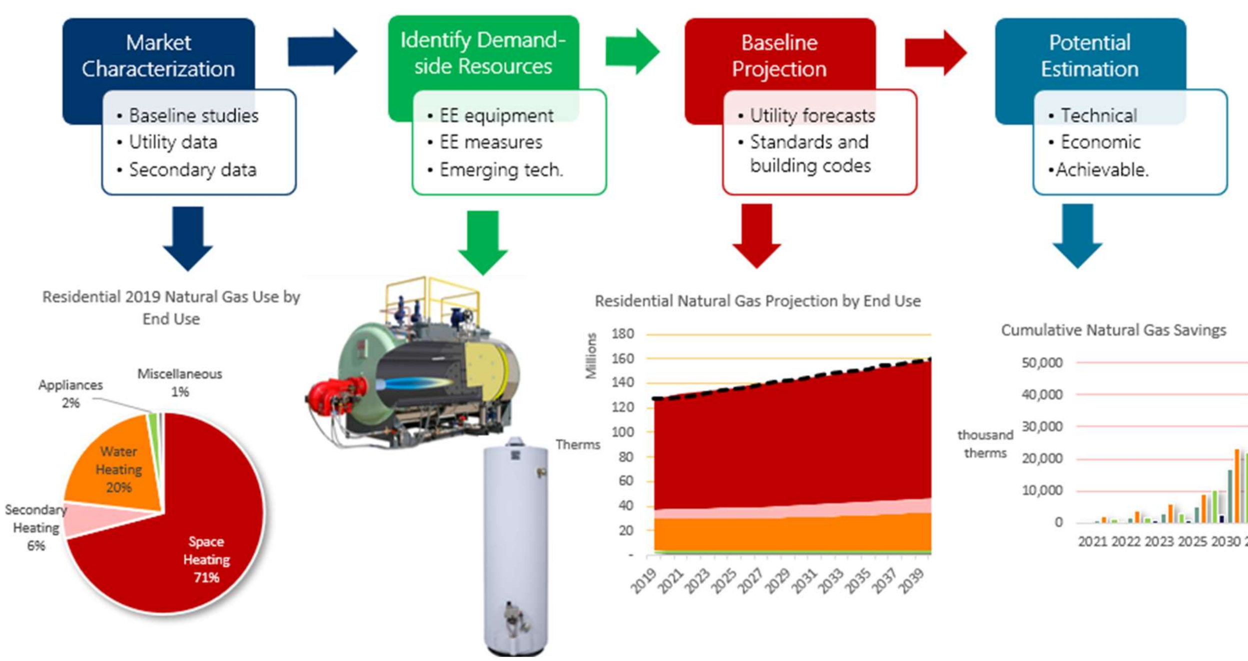
This section describes the analysis approach taken for the study and summarizes the data sources used to develop the potential estimates.

Overview Analysis Approach

To perform the potential analysis, AEG used a bottom-up approach following the major steps listed below and illustrated in Figure 2-1. We describe these analysis steps in more detail in the remainder of this section.

1. Performed a market characterization to describe natural gas use at an end-use level for the residential and commercial sectors for the base year, 2019. The Massachusetts Baseline Studies for the Residential and Commercial sectors are the primary data source for this characterization. They were supplemented as needed by a variety of secondary data sources.
2. Defined and characterized energy efficiency measures to be applied to all sectors, segments, and end uses. AEG developed the measure list using Liberty's current programs, the Massachusetts state TRM, measure lists developed in coordination with the other Massachusetts Potential Study teams, measure lists from other studies, and new/emerging technologies.
3. Developed a baseline end-use projection of energy consumption by sector, segment, end use, and technology for 2020 through 2024.
4. Estimated technical, economic and three levels of achievable potential at the measure level for 2022 through 2024.

Figure 2-1 Analysis Approach



Definitions of Potential

In this study, the savings estimates are developed for five types of potential: technical potential, economic potential, and three levels of achievable potential: Business as Usual (BAU), Business as Usual Enhanced (BAU Plus), and Maximum Achievable. These are developed at the measure level, and results are provided as annual savings impacts over the three-year planning period. The various levels are described below.

- **Technical Potential** is the theoretical upper limit of efficiency potential, assuming that customers adopt all feasible measures regardless of their cost or customer preference. At the time of existing equipment failure, customers replace their equipment with the most efficient option available. In new construction, customers and developers also choose the most efficient equipment option.

  Technical potential also assumes the adoption of every other available measure, where applicable. For example, it includes installation of high-efficiency windows in all new construction opportunities and smart thermostats installed on all applicable space heating systems. These retrofit measures are phased in over a number of years to align with the stock turnover of related equipment units, rather than modeled as immediately available all at once.

- **Economic Potential** represents the adoption of all cost-effective energy efficiency measures. In this analysis, the cost-effectiveness is measured by the total resource cost (TRC) test, which compares lifetime energy and documented non-energy benefits to the incremental cost of the measure, including additional operations, maintenance, and/or program administrative costs if applicable. If the benefits outweigh the costs (that is, if the TRC ratio is greater than 1.0), a given measure is considered in the economic potential. Customers are then assumed to purchase the cost-effective option at any decision juncture.

- **Achievable Potential** refines economic potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and recent Liberty program history. This study assesses three levels of achievable potential developed in coordination with the other PAs and vendors conducting studies in Massachusetts.

  - Business as Usual (BAU) Potential is calibrated to current program activity and assumes incentives (and as a result, program participation) remain as they are today.
  - BAU Plus and Maximum Achievable both reflect likely participation increases due to incentive increases described later in this chapter.

LoadMAP Model

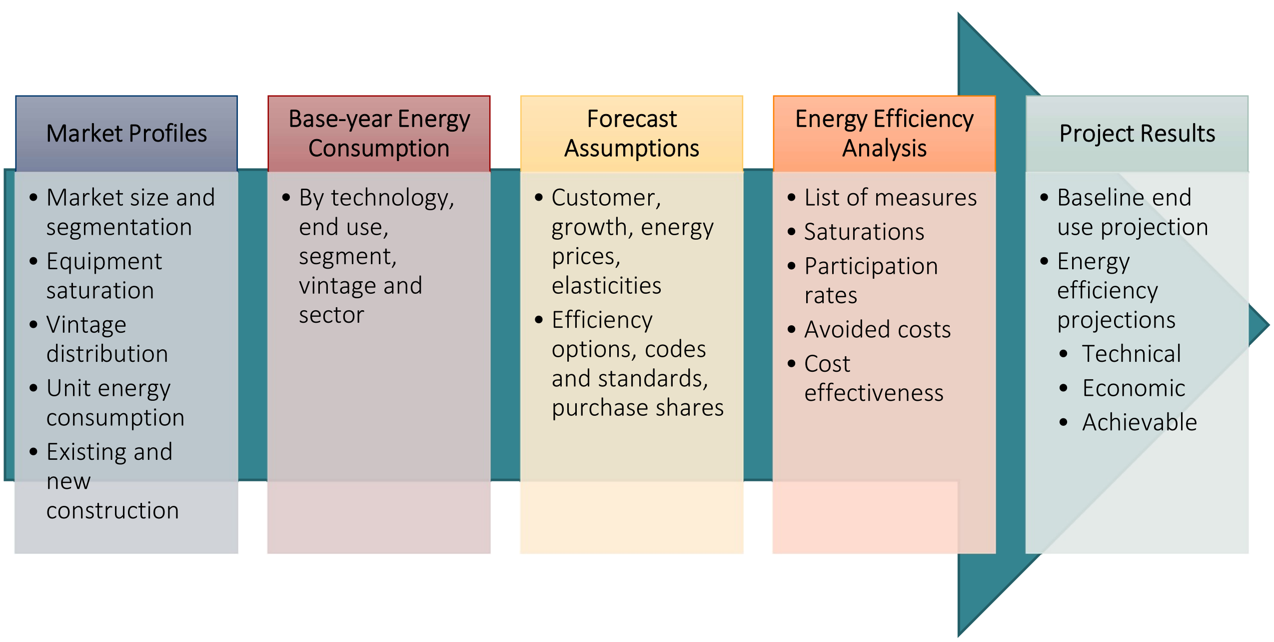
For this analysis, AEG used its Load Management Analysis and Planning tool (LoadMAP™) version 5.0 to develop both the baseline end use projection and the estimates of potential. AEG developed LoadMAP in 2007 and has enhanced it over time. Built in Excel, the LoadMAP framework (see Figure 2-2) is both accessible and transparent and has the following key features.

- Embodies the basic principles of rigorous end use models (such as EPRI's REEPS and COMMEND) but in a more simplified, accessible form.
- Includes stock-accounting algorithms that treat older, less efficient appliance/equipment stock separately from newer, more efficient equipment. Equipment is replaced according to the measure life and appliance vintage distributions defined by the user.
- Balances the competing needs of simplicity and robustness by incorporating important modeling details related to equipment saturations, efficiencies, vintage, and the like, where market data are

available, and treats end uses separately to account for varying importance and availability of data resources.

- Isolates new construction from existing equipment and buildings and treats purchase decisions for new construction and existing buildings separately.
- Uses a simple logic for appliance and equipment decisions. Other models available for this purpose embody complex decision choice algorithms or diffusion assumptions, and the model parameters tend to be difficult to estimate or observe and sometimes produce anomalous results that require calibration or even overriding. The LoadMAP approach allows the user to drive the appliance and equipment choices year by year directly in the model. This flexible approach allows users to import the results from diffusion models or to input individual assumptions. The framework also facilitates sensitivity analysis.
- Can accommodate various levels of segmentation. Analysis can be performed at the sector level (e.g., total residential) or for customized segments within sectors (e.g., housing type or income level).
- Natively outputs model results in a detailed line-by-line summary file, allowing for review of input assumptions, cost-effectiveness results, and potential estimates at a granular level.
- Consistent with the segmentation scheme and the market profiles we describe below, the LoadMAP model provides projections of baseline energy use by sector, segment, end use, and technology for existing and new buildings. It also provides forecasts of total energy use and energy efficiency savings associated with the various types of potential.[2]

Figure 2-2 LoadMAP Analysis Framework



[2] The model computes energy projection for each type of potential for each end use as an intermediate calculation. Annual-energy savings are calculated as the difference between the value in the baseline projection and the value in the potential projection (e.g., the technical potential projections).

MPS Analysis Tasks

Market Characterization

To estimate the savings potential from energy-efficient measures, it is necessary to understand how much energy is used today and what equipment is currently in service. This characterization begins with a segmentation of Liberty's energy footprint to quantify energy use by sector, segment, end use application, and the current set of technologies used. For this we rely primarily on information from the Massachusetts baseline studies.

Segmentation for Modeling Purposes

The segmentation scheme for this study is presented in Table 2-1.

Table 2-1 Overview of Liberty Segmentation Scheme

Dimension	Segmentation Variable	Description
1	Company	Liberty Utilities
2	Sector	Residential, Commercial, Industrial
3	Segment	Residential: by housing type (single family and multi family), income level (low-income/ not low-income) Commercial: office, retail, restaurant, grocery, college, school, health care, lodging, warehouse, miscellaneous Industrial: By industry type as appropriate to the utility customer base
4	Vintage	Existing and new construction
5	End uses	Space heating, water heating, etc. (as appropriate by sector and energy type)
6	Appliances/end uses and technologies	Technologies such as furnaces, boilers, etc. for space heating, etc.
7	Equipment efficiency levels for new purchases	Baseline and higher-efficiency options as appropriate for each technology

With the segmentation scheme defined, we then performed a high-level allocation of energy sales in the base year, 2019. We used secondary sources to allocate energy use and customers to the various sectors and segments such that the total customer count and energy consumption matched the Liberty system totals from 2019. This information provided control totals at a sector level for calibrating the LoadMAP model to known data for the base-year.

Market Profiles

The next step was to develop market profiles for each sector, customer segment, end use, and technology. A market profile includes the following elements:

- Market size is a representation of the number of customers in the segment. For the residential sector, the unit is number of households. In the commercial sector, it is floor space measured in square feet.
- Saturations define the fraction of homes or square feet with the various technologies. (e.g., percent of homes with gas water heating).
- UEC (unit energy consumption) or EUI (energy-utilization index) describes the amount of energy consumed in the base year by a specific technology in homes or buildings that have the

technology. UECs are expressed in therms/household for the residential sector, and EUIs are expressed in therms/square foot for the commercial sector.

- **Annual energy intensity** for the residential sector represents the average energy use for the technology across all homes in 2019. It is computed as the product of the saturation and the UEC and is defined in therms/household terms. For the commercial sector, intensity, computed as the product of the saturation and the EUI, represents the average use for the technology across all floor space in the base year.
- **Annual usage** is the annual energy used by each end use technology in the segment. It is the product of the market size and intensity and is quantified in mTherms.

Baseline End Use Projection

The next step was to develop a baseline projection of annual natural gas use for 2020 through 2024 by customer segment and end use to quantify the likely consumption in the future in absence of any energy efficiency programs. The end-use projection includes the relatively certain impacts of codes and standards that will unfold over the study timeframe. All such mandates that were defined as of January 2021 are included in the baseline[3]. The baseline projection also includes projected naturally occurring energy efficiency during the potential forecast period. The baseline projection is the foundation for the analysis of savings from future efficiency cases and scenarios as well as the metric against which potential savings are measured.

Inputs to the baseline projection include:

- Current market growth forecasts (i.e., customer growth, income growth) provided by Liberty
- Trends in fuel shares and equipment saturations from the US Department of Energy
- Existing and approved changes to building codes and equipment standards
- Naturally occurring efficiency improvements, which include purchases of high-efficiency equipment options outside of EE programs.

Energy Efficiency Measure Development

This section describes the framework used to assess the savings, costs, and other attributes of energy efficiency measures. These characteristics form the basis for measure-level cost-effectiveness analyses as well as for determining measure-level savings. For all measures, AEG assembled information to reflect equipment performance, incremental costs, non-energy impacts, and equipment lifetimes. We used this information along with avoided cost data from the 2021 final AESC in the economic screen to determine economically feasible measures.

Figure 2-3 outlines the approach for measure analysis. The framework for assessing savings, costs, and other attributes of measures involves identifying the list of measures to include in the analysis, determining their applicability to each market sector and segment, fully characterizing each measure, and performing cost-effectiveness screening. AEG participated in coordinating calls arranged by Apex Analytics[4] so that high profile measure inputs could be discussed among the various potential study vendors.

We compiled a robust list of measures for each customer sector, drawing upon Liberty's program experience, measures identified in coordination with the other Massachusetts Potential Study teams, the

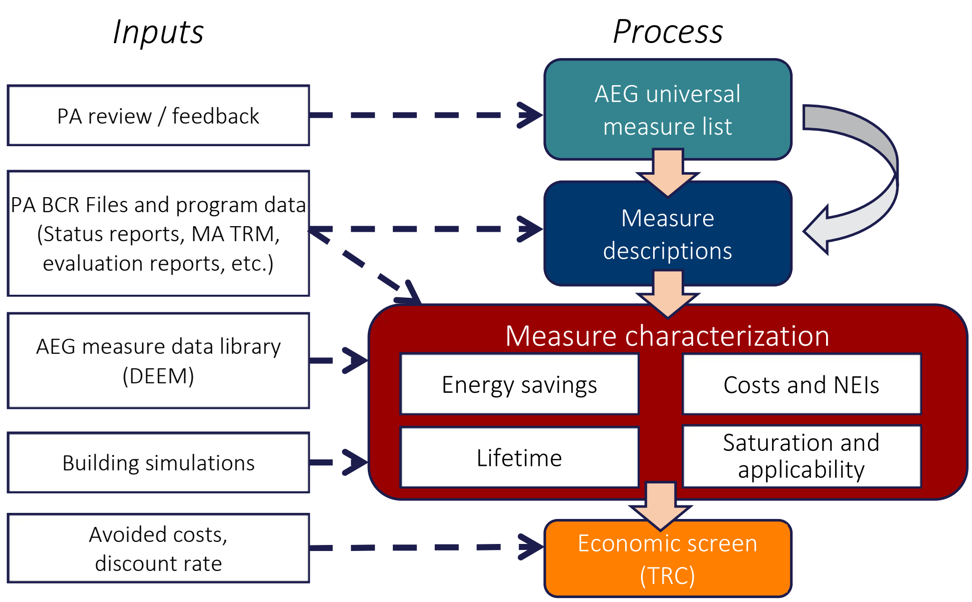
[3] The findings of the recently passed MA Clean Energy Climate Plan were not available in time to be incorporated into this analysis

[4] Apex Analytics served as a facilitator to assist PAs and vendors in coordinating their assumptions.

Massachusetts Technical Reference Manual (TRM), AEG's measure databases and building simulation models, and secondary sources. New and emerging technologies were identified for inclusion in the list through a detailed screening process that assessed the feasibility of measures. AEG engineers, through the AEG DEEM database, constantly monitor for new and emerging measures by following trends in energy-efficient technologies that are available on the market, as well as those expected to be on market in the coming years.

This universal list of measures covers all major types of end use equipment, as well as devices and actions to reduce energy consumption. If considered today, some of these measures would not pass the economic screens initially but may pass in future years as a result of lower projected equipment costs or higher avoided cost benefits.

Figure 2-3 Approach for Measure Assessment



The selected measures are categorized into two types according to the LoadMAP modeling taxonomy: equipment measures and non-equipment measures.

Equipment measures are efficient energy consuming pieces of equipment that save energy by providing the same service with a lower energy requirement than a standard unit. An example is an ENERGY STAR® residential water heater that replaces a standard-efficiency water heater. For equipment measures, many efficiency levels may be available for a given technology, ranging from the baseline unit (often determined by code or standard) up to the most efficient product commercially available. These measures are applied on a stock-turnover basis, and in general, are referred to as lost opportunity measures since once a purchase decision is made, there will not be another opportunity to improve the efficiency of that equipment item until the lifetime expires again.

- Equipment Life. Energy using equipment is modeled with both a minimum and maximum lifetime rather than a single average value. This provides a more real-world smooth curve of decaying and replaced equipment as opposed to a single mass failure in which a whole population of equipment would be replaced. Instead, the model assumes some equipment will be replaced earlier than the average lifetime, and some replacements may be delayed past the average useful life.

- Purchase Shares. In the base case, market data from surveys or the Department of Energy's Annual Energy Outlook (AEO) provide the foundational assumptions of how replacement or new construction equipment will be distributed across the available options. These purchase shares will then be altered in the potential scenarios according to their definitions above. For example, in the technical potential case, 100% of replacement and new construction purchases will be the most efficient option and for economic potential, 100% of purchases will be in the most efficient cost-effective option (if any). For the achievable cases, only a subset of the purchases is diverted to the economic efficiency option, defined by the participation rates.

Non-equipment measures save energy by reducing the need for delivered energy, but typically do not involve replacement or purchase of major end use equipment (such as a furnace or water heater). Since measure installation is not tied to a piece of equipment reaching the end of its useful life, these are generally categorized as "retrofit" measures. Non-equipment measures can apply to more than one end use. An example would be insulation that modifies a household's space heating consumption, but does not change the efficiency of the furnace. The existing insulation can be achievably upgraded without waiting any existing equipment to malfunction, and saves energy used by the furnace. Non-equipment measures typically fall into one of the following categories:

- Building shell (windows, insulation, roofing material)
- Equipment controls (smart thermostats, water heater setback)
- Whole-building design (advanced new construction)
- Displacement measures (destratification fans to reduce use of space heating equipment)
- Retro-commissioning
- Energy management programs
- Behavioral

Once we assembled the list of measures, AEG assessed their energy-saving parameters and characterized incremental cost, effective useful life (EUL), and other performance factors. Following the measure characterization, we performed an economic screening of each measure, which serves as the basis for developing the economic and achievable potentials.

Representative Measure Data Inputs

Table 2-2 and Table 2-3 present examples of the detailed data inputs behind both equipment and non-equipment measures, respectively, for the case of residential furnaces. Table 2-2 displays the various efficiency levels available as equipment measures, as well as the corresponding useful life, energy usage, and equipment cost estimates. The columns labeled On Market and Off Market reflect equipment availability due to codes and standards or the entry of new products to the market.

Table 2-2 Example Equipment Levels for Residential Furnaces (Single Family Homes)

Efficiency Level	Min. Life (years)	Max Life (years)	Full Equipment Cost	Energy Usage (therms/year)	On Market	Off Market
AFUE 85% (Baseline)	10	20	$3,148	480	2019	2023
AFUE 90% (Baseline 2023+)	10	20	$3,661	453	2019	n/a
ENERGY STAR (4.1) - AFUE 95%	10	20	$3,864	429	2019	n/a
AFUE 97%	10	20	$4,222	421	2019	n/a

Table 2-3 lists some of the non-equipment measures applicable to residential furnaces. All measures are evaluated for cost-effectiveness based on the lifetime benefits relative to the cost of the measure. The total savings, costs, and monetized non-energy benefits are calculated for each year of the study and depend on the base year saturation of the measure, the applicability[5] of the measure, and the savings as a percentage of the relevant energy end uses.

Table 2-3 Example Non-Equipment Measures (Single Family Homes)

End Use	Measure	Base-Year Saturation[6]	Applicability	Lifetime (yrs)	Installed Cost per Unit	Energy Savings (therms/unit)	Analysis Unit
Space Heating	Insulation - Ceiling Installation	0%	5%	25	$1.22	0.03	Sq.ft (roof)
Space Heating	Insulation – Wall Cavity Installation	0%	5%	25	$1.72	0.04	Sq.ft (wall)
Space Heating	ENERGY STAR Connected Thermostat	35%	100%	15	$303	31.1	unit
Water Heating	Water Heater – Faucet Aerators	35%	100%	7	$3.00	2.1	faucet

Calculation of Energy Efficiency Potential

The approach used to calculate the energy efficiency potential adheres to the approaches and conventions outlined in the *National Action Plan for Energy-Efficiency (NAPEE) Guide for Conducting Potential Studies*.[7] This document represents credible and comprehensive industry best practices for specifying energy efficiency potential. Three types of potential developed as part of this effort: are described below.

Technical Potential

The calculation of technical potential is a straightforward algorithm which, as described in the Definitions of Potential section, assumes that customers adopt all feasible measures regardless of their cost.

[5] Applicability factors take into account whether the measure is applicable to a particular building type and whether it is feasible to install the measure. For instance, duct repair and sealing is not applicable to homes with zonal heating systems since there is no ductwork present to repair.

[6] Note that saturation levels reflected for the base year change over time as more measures are adopted.

[7] National Action Plan for Energy Efficiency (2007). *National Action Plan for Energy Efficiency Vision for 2025: Developing a Framework for Change*. www.epa.gov/eeactionplan.

Economic Potential – Screening Measures for Cost-Effectiveness

With technical potential established, the next step is to apply an economic screen and arrive at the subset of measures that are cost-effective and ultimately included in achievable potential. Like Technical Potential, this is a hypothetical that is generally equal to technical where measures are cost effective[8], and zero where they are not.

LoadMAP performs an economic screen for each individual measure in each year of the planning horizon. This study uses the TRC test as the cost-effectiveness metric, which compares the lifetime energy benefits and monetized non-energy impacts of each applicable measure with its costs. The lifetime benefits are calculated by multiplying the annual energy savings for each measure by the avoided costs and discounting the dollar savings to the present value equivalent. Lifetime costs include not only incremental measure cost, but also any non-energy impacts as quantified in the Massachusetts TRM – which may include one-time or annual values, also discounted to present value. The analysis uses the measure savings, costs, and lifetimes that were developed as part of the measure characterization process described in the Energy Efficiency Measure Development section.

The LoadMAP model performs the economic screening dynamically, taking into account changing savings and cost data over time. Thus, some measures might pass the TRC test for some — but not all — of the years in the forecast.

It is important to note the following about the economic screen:

- The economic evaluation of every measure in the screen is conducted relative to a baseline condition. For instance, in order to determine the energy savings potential of a measure, consumption with the measure applied must be compared to the consumption of a baseline condition.
- Economic screening is conducted only for measures that are applicable to each building type and vintage; thus, if a measure is deemed to be irrelevant to a building type and vintage, it is excluded from the respective economic screen.

The economic potential includes every program-ready opportunity for energy efficiency savings.

Achievable Potential - Estimating Customer Adoption

Once the economic potential is established, estimates for achievable customer adoption rates for each measure are applied specifying the percentage of customers assumed to select the highest–efficiency, cost-effective option. This phases the potential for capturing energy efficiency in over a more realistic time frame that considers barriers such as imperfect information, supplier constraints, technology availability, and individual customer preferences.

For this potential study, AEG leveraged existing database of customer participation from across the country for territories similar to the PAs, then calibrated these adoption rates to match existing program performance, establishing the business-as-usual (BAU) case.

The BAU Plus and maximum achievable cases were then derived from the BAU case using lift factors that AEG developed through analysis of utility programs throughout the country and the scenario definitions agreed upon in coordination with the PA's potential study vendors.

[8] Some interactions between measures that operate on the same end use are altered when other measures drop out, so economic potential can change slightly compared to technical, however such changes are usually miniscule

- **Business as usual (BAU):** Pre-COVID incentive levels. Expected that 2022-2024 participation will look like the past and does not introduce new measures unless substantially similar to current program offerings.
- **Business as Usual Enhanced (BAU Plus):** Increases weatherization incentives to 90% of incremental cost, and other incentives by up to 50%, to a maximum of 90% (unless current incentives are already higher than this). In this scenario we also introduce adoption of cost-effective measures not currently part of existing programs, based on the average participation of existing program measures.
- **Maximum Achievable:** Takes all incentives to 100% and assumes best practices regarding program delivery and outreach.

Data Development

This section details the data sources used in this study, followed by a discussion of how these sources were applied. In general, data were adapted to local conditions, for example, by using local sources for measure data and local weather for building simulations.

Data Sources

The data sources are organized into the following categories:

- Liberty-specific data
- Massachusetts Statewide Residential and Commercial surveys
- Cadeo's analysis and research
- AEG's databases and analysis tools
- Other secondary data and reports

Liberty Data

Our highest priority data sources for this study were those that were specific to Liberty.

- **Liberty customer account database.** The data request included billing data for 2019, the most recent year for which complete billing data was available. Liberty provided 2019 natural gas sales and customers by sector.
- **Additional Customer Data.** Liberty also provided customer totals and consumption for Blackstone Gas customers to be included in this analysis
- **Load forecast data.** Liberty provided the following forecast data: customer growth forecasts, and sales forecasts.
- **Energy efficiency program data (BCR Models).** Liberty provided historical energy efficiency program accomplishments for 2016-2019.

Massachusetts State Data

- **Massachusetts Baseline studies** for the residential and commercial sectors
- **Economic Information.** Avoided costs and discount rate from the 2021 Avoided Energy Supply Components study (AESC), final draft
- **Massachusetts Statewide Technical Reference Manual (TRM)** : AEG used the 2019 Report edition of the Massachusetts TRM

Cadeo Analysis and Research

Cadeo contributed research and analysis to improve the clarity of data used to inform the potential study, utilizing existing data source noted in this section as well as their past experience with energy efficiency programs in the region, including:

- Analysis of the current and past Massachusetts Commercial baseline studies in combination with the EIA data noted below to improve the quality of the commercial natural gas market characterization
- Reviewed program history in the PA territories to provide insight and analysis on the remaining market available for residential measures

AEG Data

AEG maintains several databases and modeling tools that we use for forecasting and potential studies. Relevant data from these tools has been incorporated into the analysis and deliverables for this study.

- AEG Energy Market Profiles. For more than 15 years, AEG staff has maintained profiles of end use consumption for the residential, commercial, and industrial sectors. These profiles include market size, fuel shares, unit consumption estimates, and annual energy use by fuel, customer segment and end use for 10 regions in the U.S. The Energy Information Administration surveys (RECS, CBECS and MECS) as well as state-level statistics and local customer research provide the foundation for these regional profiles.
- Building Energy Simulation Tool (BEST). AEG's BEST is a derivative of the DOE 2.2 building simulation model, used to estimate base-year UECs and EUIs, as well as measure savings for the HVAC-related measures.
- AEG's Database of Energy Efficiency Measures (DEEM). AEG maintains an extensive database of measure data for our studies. Our database draws upon reliable sources including the California Database for Energy Efficient Resources (DEER), the EIA Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case, RS Means cost data, and Grainger Catalog cost data.
- Recent studies. AEG has conducted more than sixty studies of EE potential in the last five years. We checked our input assumptions and analysis results against the results from these other studies, within the region and numerous studies from across the U.S.

Other Secondary Data and Reports

Finally, a variety of secondary data sources and reports were used for this study. The main sources are identified below.

- Annual Energy Outlook. The Annual Energy Outlook (AEO), conducted each year by the U.S. Energy Information Administration (EIA), presents yearly projections and analysis of energy topics. For this study, we used data from the 2019 AEO.
- Energy Information Administration Surveys. The Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) provided supplemental and benchmarking data for market characterization.
- Local Weather Data. Weather data (heating degree days both actual and normal) was provided by the PAs

- **Other relevant resources:** These include reports from the Consortium for Energy Efficiency, the Environmental Protection Agency, and the American Council for an Energy-Efficient Economy.

Application of Data to the Analysis

We now discuss how the data sources described above were used for each step of the study.

Data Application for Market Characterization

To construct the high-level market characterization of energy consumption and market size units (households for residential, floor space for commercial), we used Liberty-provided billing data, Massachusetts baseline studies, and secondary data from AEG's Energy Market Profiles databases.

Data Application for Market Profiles

The specific data elements for the market profiles, together with the key data sources, are shown in Table 2-4. To develop the market profiles for each segment, we used the following approach:

1. Developed control totals for each segment, which are the authoritative total market size, segment-level annual natural gas, and annual intensity (use per customer or market unit) to which the models will be calibrated. This analysis relied primarily on detailed customer data provided by the PAs which included designations of customer type (such as single family residence or commercial office), as well as data on building/home size and associated energy consumption.
2. Compared and cross-checked with other recent AEG studies.
3. Worked with Liberty staff to vet the data against their knowledge and experience.

Table 2-4 Data Applied to the Market Profiles

Model Inputs	Description	Key Sources
Annual energy consumption	Base-year energy consumption by sector as well as detailed market segment	Liberty account database Liberty customer surveys Liberty Load Forecasts
Market size	Base-year residential dwellings, commercial floor space	Liberty customer forecasts Liberty account database Liberty customer surveys Previous Liberty MPS
Annual intensity	Residential: Annual use per household Commercial and Industrial: Annual use per square foot	Liberty customer surveys AEG's Energy Market Profiles Other recent studies
Appliance/equipment saturations	Fraction of dwellings with an appliance/technology Percentage of C&I floor space with equipment/technology	Massachusetts Baseline Studies American Community Survey (ACS) Previous Liberty MPS AEG's Energy Market Profiles
UEC/EUI for each end use technology	UEC: Annual natural gas use in homes and buildings that have the technology EUI: Annual natural gas use per square foot for a technology in floor space that has the technology	Massachusetts TRM HVAC uses: BEST simulations using prototypes developed for Liberty AEG's DEEM Recent AEG studies
Appliance/equipment age distribution	Age distribution for each technology	Massachusetts Baseline Studies Previous Liberty MPS Recent AEG Studies

Data Application for Baseline Projection

Table 2-5 summarizes the LoadMAP model inputs required for the market profiles. These inputs are required for each segment in each sector, as well as for new construction and existing dwellings/buildings.

Table 2-5 Data Applied for the Baseline Projection in LoadMAP

Model Inputs	Description	Key Sources
Customer growth forecasts	Forecasts of new construction and turnover of existing buildings in residential and C&I sectors	Liberty customer forecasts
Equipment purchase shares for baseline projection	For each equipment/technology, purchase shares for each efficiency level; specified separately for existing equipment replacement and new construction	Shipment data from AEO and ENERGY STAR AEO regional forecast assumptions[9] Appliance/efficiency standards analysis

In addition, assumptions were incorporated for known future equipment standards as of January 2021, as shown in Table 2-6 and Table 2-7. The assumptions tables here extend through 2025, after which all standards are assumed to hold steady.

Table 2-6 Residential Natural Gas Equipment Standards

End Use	Technology	2020	2021	2022	2023	2024	2025
Space Heating	Furnace – Direct Fuel	AFUE 85%				AFUE 92%*	
	Boiler – Direct Fuel	AFUE 84%					
Secondary Heating	Fireplace	N/A					
Water Heating	Water Heater <= 55 gal.	UEF 0.60					
	Water Heater > 55 gal.	UEF 0.603					
Appliances	Clothes Dryer	CEF 3.30					
	Stove/Oven	N/A					
Miscellaneous	Pool Heater	TE 0.82					
	Miscellaneous	N/A					

[9] We developed baseline purchase decisions using the Energy Information Agency's *Annual Energy Outlook* report (2019), which utilizes the National Energy Modeling System (NEMS) to produce a self-consistent supply and demand economic model. We calibrated equipment purchase options to match distributions/allocations of efficiency levels to manufacturer shipment data for recent years and then held values constant for the study period.

Table 2-7 Commercial and Industrial Natural Gas Equipment Standards

End Use	Technology	2020	2021	2022	2023	2024	2025
Space Heating	Furnace	AFUE 85% / TE 0.85					
	Boiler	Industry Standard Practice Baseline (AFUE 85%)					
	Unit Heater	Standard (intermittent ignition and power venting or automatic flue damper)					
Water Heater	Water Heating	TE 0.80					

Efficiency Measure Data Application

Table 2-8 details the energy-efficiency data inputs to the LoadMAP model. It describes each input and identifies the key sources used in the Liberty analysis.

Table 2-8 Data Needs for the Measure Characteristics in LoadMAP

Model Inputs	Description	Key Sources
Energy Impacts	The annual reduction in consumption attributable to each specific measure. Savings were developed as a percentage of the energy end use that the measure affects.	1. MA TRM Algorithms or deemed savings 2. AEO 2019 3. Building Energy Simulations 4. AEG DEEM library 5. Other secondary sources
Costs	Equipment Measures: Includes the full cost of purchasing and installing the equipment on a per-household, per-square-foot, or per employee basis for the residential and commercial sectors, respectively. Non-Equipment Measures: Existing buildings – full installed cost. New Construction - the costs may be either the full cost of the measure, or as appropriate, it may be the incremental cost of upgrading from a standard level to a higher efficiency level.	1. PA BCR files (EM&V) 2. AEO 2019 3. AEG DEEM 4. Other secondary sources
Measure Lifetimes	Estimates derived from the technical data and secondary data sources that support the measure demand and energy savings analysis.	1. MA TRM 2. AEO 2019 3. AEG DEEM 4. Other secondary sources
Applicability	Estimate of the percentage of dwellings in the residential sector, or square feet in the commercial sector, where the measure is applicable and where it is technically feasible to implement.	1. MA TRM 2. MA Baseline Studies and PA specific inputs 3. AEG DEEM 4. Other secondary sources
On Market and Off Market Availability	Expressed as years for equipment measures to reflect when the equipment technology is available or no longer available in the market.	AEG appliance standards and building codes analysis

Data Application for Cost-Effectiveness Screening

To the extent feasible, costs for measures in the potential study were derived from the BCR files provided by the PAs. In cases where costs needed to be normalized and adjusted for different customer segments (e.g., properly sizing furnaces for different home sizes or commercial buildings), values from well vetted sources such as the US Energy Information Administration were used to supplement the BCR data.

To perform the cost-effectiveness screening, a number of economic assumptions were needed. All cost and benefit values were analyzed as real 2020 dollars, using information from the AESC study including:

- Avoided costs of energy
- DRIPE values and other benefits
- Discount rate (real)[10]

Estimates of Customer Adoption Rates

Adoption rates for equipment and non-equipment measures are described separately below.

Customer adoption rates, also referred to as take rates or ramp rates, are applied to measures on a year-by-year basis. These rates represent customer adoption of measures when delivered through a portfolio of well-operated efficiency programs under a reasonable policy or regulatory framework. The approach for estimating Liberty adoption rates had two parts:

1. Initial adoption rate assumptions from AEG past research. AEG has performed numerous market research studies in various jurisdictions across the country and initially developed potential estimates using adoption rates based on this past research in territories broadly analogous to Liberty's as a first stepping stone towards BAU potential.
2. Calibrating adoption rates to current programs. AEG next compared Liberty's historic program participation and accomplishments to the model's initial estimate to determine necessary adjustments.

To recap, BAU adoption rates were estimated as follows:

- Group measures in the potential study into categories that align with existing Liberty programs
- Assess achievable potential using AEG's past research and estimates of participation
- Calibrate the final BAU participation by comparing participation in current programs to potential under AEG's original assumptions and adjusting the participation rates accordingly

- These adoption rates are applied to economic potential in 2022-2024 to compute achievable potential.
- Adoption rates are held fixed for the three-year planning period. Assuming the same incentive and delivery structure across these three years (for BAU), participation is assumed to hold constant. This is consistent with the BCR Models and TRM, which also hold assumptions constant for the planning period.
- The BAU Plus and Maximum Achievable cases were produced by applying a "lift" factor to the BAU adoption rates. AEG's previous market research into customer behavior and program interest provided guidance on the amount of increased adoption that could be expected under each of the defined scenarios.
- Adoption rates for each potential case are provided in the appendix worksheet accompanying this report.

[10] Discount rate was 0.81%, taken from the AESC 2021 final workbooks.

Technical diffusion curves for non-equipment measures. While equipment measures are driven by the stock turnover model and have a natural limit to how many units come available in a given year, non-equipment measures do not have this natural periodicity. A home's insulation or thermostat, for example, can be upgraded or replaced at any time, and there is rarely a "failure" condition that would force this decision. To reflect this, rather than installing all available non-equipment measures in the first year of the projection (instantaneous potential), AEG generally assumes these measures phase in over a 20-year period, providing a steady rollout of available market for each year.

Following this technical diffusion step, the process from technical to economic and achievable adoption and potential follows the same sequence as above.

3

ANALYSIS AND RESULTS

This section details the study results and potential estimates for Liberty as a whole and by sector.

Overall Energy Efficiency Potential

This section presents the natural gas energy efficiency potential for the planning period 2022-2024.

Incremental Potential for Planning Cycle Years

First-year potential savings for 2022 through 2024 are presented in Table 3-1. The achievable BAU potential is in the range of 315,549 therms to 316,532 therms per year, or 0.45% of the baseline projected in absence of future DSM (see chapter 2 for further details on the baseline case assumptions).. BAU Plus potential is approximately 13% higher with a range of 357,382 therms to 358,321 therms per year, or 0.51% of the baseline. Maximum achievable potential is approximately 44% higher than BAU, with a range of 452,537 therms to 455,116 therms per year, or 0.65% of the baseline.

Notably, the majority of technical potential is economic, which is unusual in most potential studies, but due in this case to very high avoided costs in Massachusetts and significant non-energy impacts associated with a number of measures. However, cost-effectiveness by itself does not necessarily produce achievable potential, as discussed in Chapters 2, 3, and the Conclusion.

Table 3-1 Liberty Utilities First-Year Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Reference Baseline	**69,989,044**	**70,371,791**	**70,943,822**
First-year Savings			
Achievable BAU	316,029	316,532	315,549
Achievable BAU Plus	358,227	358,321	357,382
Achievable Max	455,116	454,573	452,537
Economic	1,002,037	987,899	973,874
Technical	1,202,085	1,186,266	1,171,092
Savings as % of Baseline			
Achievable BAU	0.45%	0.45%	0.44%
Achievable BAU Plus	0.51%	0.51%	0.50%
Achievable Max	0.65%	0.65%	0.64%
Economic	1.43%	1.40%	1.37%
Technical	1.72%	1.69%	1.65%

Table 3-2 presents the breakout of each level of potential by sector. The residential sector accounts for the largest share of Achievable BAU potential, approximately 52% of achievable BAU potential savings in each year as illustrated in Figure 3-1.

Table 3-2 Liberty First-Year Achievable Savings Potential by Sector (Therms)

Achievable Potential by Sector	2022	2023	2024
Achievable BAU Potential			
Residential	169,076	166,059	162,292
Commercial	115,296	118,287	120,162
Industrial	31,656	32,186	33,095
Achievable BAU Plus Potential			
Residential	196,420	192,685	188,728
Commercial	126,970	130,225	132,254
Industrial	34,837	35,411	36,401
Achievable Max Potential			
Residential	248,124	242,648	236,735
Commercial	162,391	166,584	169,190
Industrial	44,601	45,342	46,612
Economic Potential			
Residential	599,858	576,302	554,624
Commercial	340,524	349,436	355,644
Industrial	61,655	62,161	63,605
Technical Potential			
Residential	701,009	675,741	652,912
Commercial	439,324	448,269	454,478
Industrial	61,751	62,256	63,702

Figure 3-1 Liberty BAU Achievable Savings by Sector (Therms)

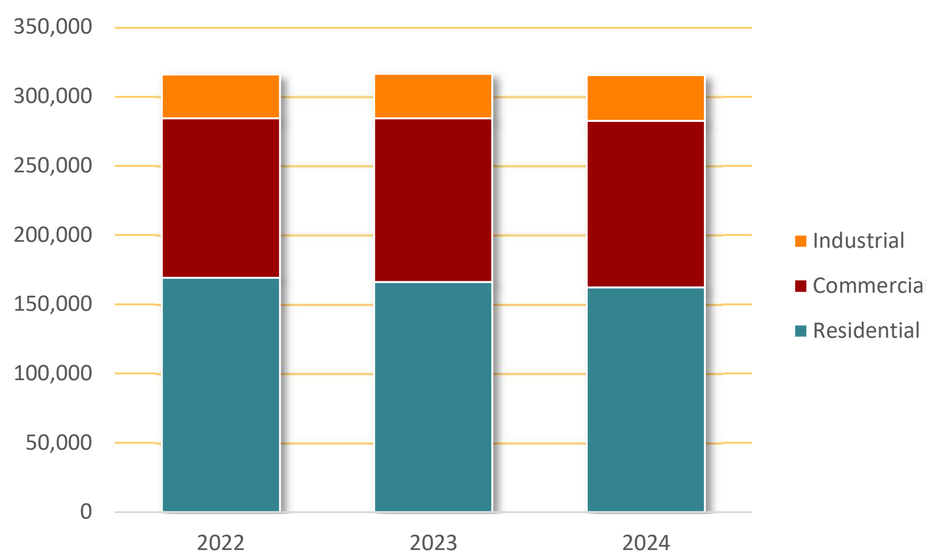


Table 3-3 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Liberty's actual costs will naturally vary.

Table 3-3 Liberty Natural Gas Total Portfolio Cost to Achieve by Potential Level

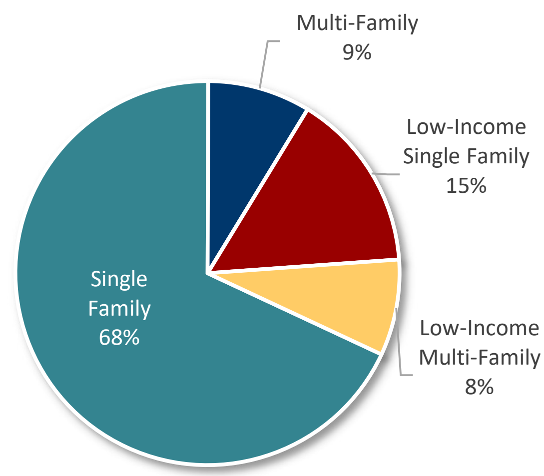
Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$5,850,896	$5,749,277	$5,783,219
BAU Plus	$7,520,215	$7,385,295	$7,429,111
Max	$10,949,822	$10,712,645	$10,762,388

Residential Sector

In 2019, there were approximately 79,118 households in Liberty's residential sector that used a total of 4,613,805 Dth. These numbers are inclusive of Blackstone Gas customers and estimated multifamily apartment dwellings billed on commercial rate classes[11].

AEG relied on customer segmentation information already contained in the billing data for classification of residential customers into single and multifamily homes, and into low income and non-low-income households. Household counts for some mass-metered multifamily buildings were estimated using RECS[12] average consumption per home and the total consumption of the building.

Figure 3-2 Liberty Residential Use by Segment, 2019



As shown in Table 3-4, Average use per household was 583 therms, but there is a large difference between single family homes, which range from 686-692 therms depending on income level, and multifamily homes, which have much lower consumption per home. This average use per home also includes both gas heating customers and non-heating customers. Non-low-income single family customers account for 68% of total usage, and multifamily customers account for 9% (Figure 3-2). Low-income single family and multifamily customers together make up the remaining 23%. Single family dwellings include buildings with 2-4 units.

[11] Though they are on a commercial rate class and often targeted through commercial programs, the energy use characteristics for multifamily apartments, and the resulting potential, are best modeled through the residential sector in our process. C&I metered multifamily accounts for ~40% of multifamily consumption, or ~6% of the overall residential consumption shown here.

[12] DOE Residential Energy Consumption Survey, data for New England households with natural gas

Table 3-4 Liberty Residential Control Totals, 2019

Segment	Households	Annual Use (Dth)	Intensity (therms / HH)
Single Family	45,785	3,142,231	686
Multi-Family	12,099	400,747	331
Low-Income Single Family	10,098	698,853	692
Low-Income Multi-Family	11,136	371,973	334
Total	**79,118**	**4,613,805**	**583**

Figure 3-3 shows the average annual natural gas consumption by end use for all residential customers. Space heating accounts for the largest amount of total usage at 72%, followed by water heating at 22%.

Figure 3-4 presents the energy intensity by end use and housing type. The single family and low-income single family segments have almost 700 therms per household, whereas the multi-family and low-income multi-family segments have around 330 therms per household.

Figure 3-3 Liberty Residential Gas Consumption by End Use, 2019

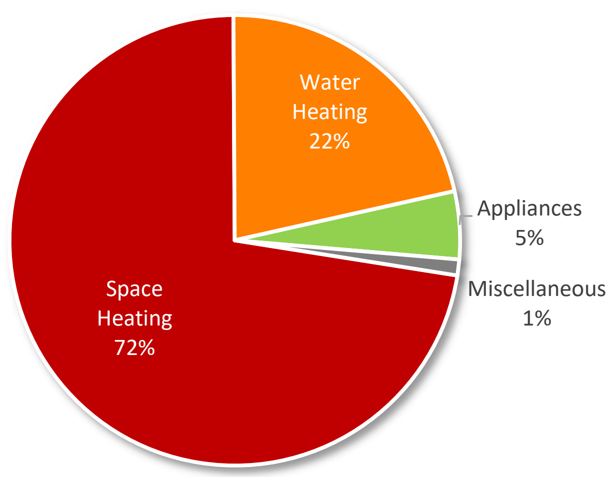
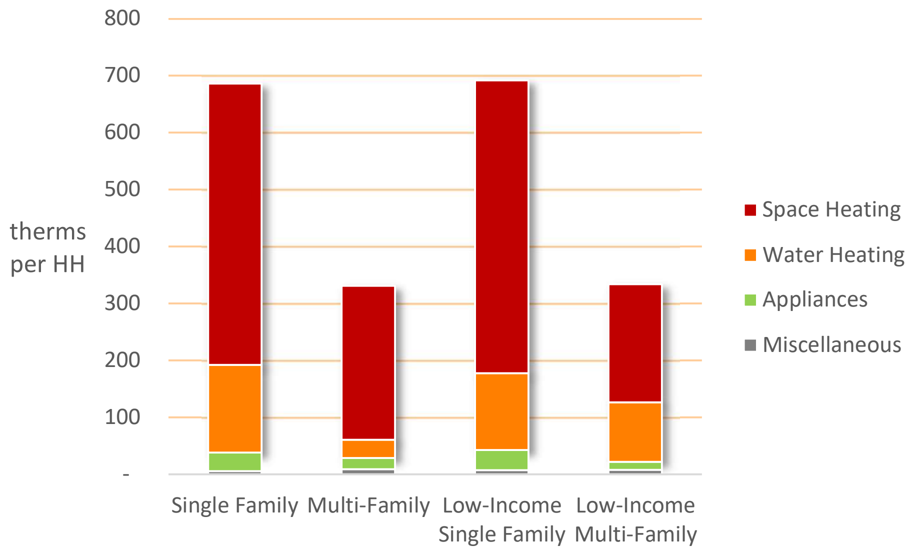


Figure 3-4 Liberty Residential Natural Gas Intensity by End Use and Segment, 2019



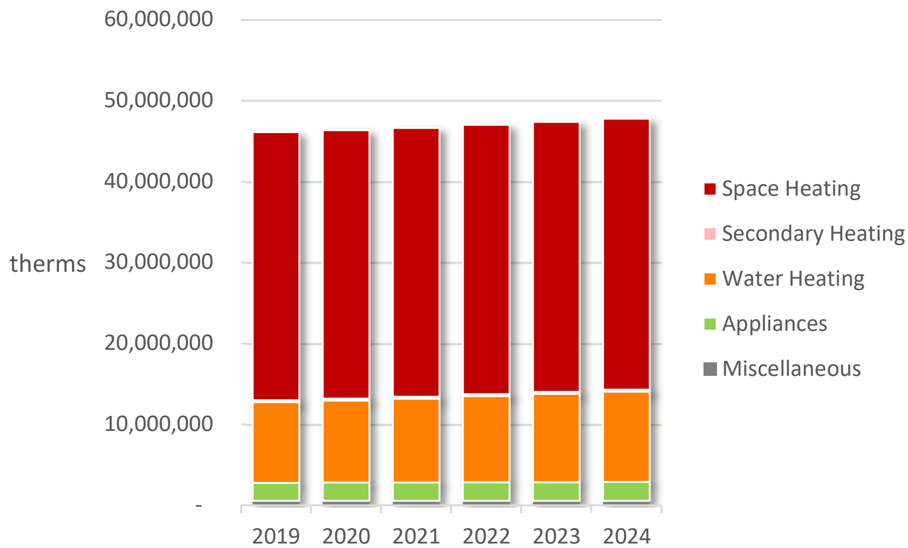
Residential Baseline Projection

Table 3-5 and Figure 3-5 present AEG's natural gas baseline projection at the end use level for the residential sector. The projection includes effects of standards, codes, and naturally occurring conservation, but not future DSM program activity (see Chapter 2 for more details on the development of the baseline). The projection shows very slight growth in consumption from 2019-2024 due to the net effect of market growth opposed by turnover of vintage equipment into code or higher models.

Table 3-5 Liberty Residential Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	33,171,708	33,165,325	33,191,792	33,320,066	33,408,657	33,516,108
Secondary Heating	234,732	236,459	238,432	241,250	243,573	246,152
Water Heating	9,955,893	10,165,939	10,389,750	10,658,092	10,902,294	11,160,832
Appliances	2,244,867	2,256,063	2,269,639	2,291,572	2,308,438	2,327,760
Miscellaneous	530,846	535,005	539,523	545,617	550,501	555,721
Total	**46,138,047**	**46,358,791**	**46,629,136**	**47,056,597**	**47,413,463**	**47,806,573**

Figure 3-5 Liberty Residential Baseline Projection by End Use



Residential Potential

Table 3-6 presents the residential sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 169,076 therms, or 0.36% of the counterfactual baseline projection.

Table 3-6 Liberty Summary of Residential Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**47,056,597**	**47,413,463**	**47,806,573**
Potential Savings			
Achievable BAU	169,076	166,059	162,292
Achievable BAU Plus	196,420	192,685	188,728
Achievable Max	248,124	242,648	236,735
Economic	599,858	576,302	554,624
Technical	701,009	675,741	652,912
Potential Savings as % of Baseline			
Achievable BAU	0.36%	0.35%	0.34%
Achievable BAU Plus	0.42%	0.41%	0.39%
Achievable Max	0.53%	0.51%	0.50%
Economic	1.27%	1.22%	1.16%
Technical	1.49%	1.43%	1.37%

The market rate single family segment accounts for almost two-thirds of the residential savings (61%). The low-income single family segment represents 25% of the savings with the multifamily segments representing 14% of the savings combined. Single family dwellings include buildings with 2-4 units (Figure 3-6).

Figure 3-6 Liberty Residential Natural Gas Potential by Segment

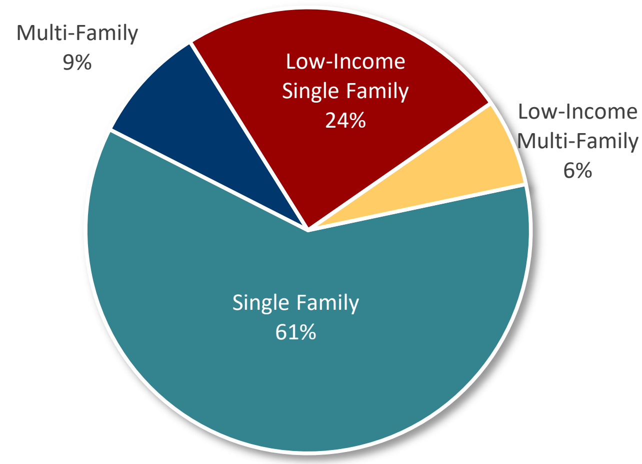


Table 3-7 shows residential potential by segment for all cases and for each year of the planning cycle.

Table 3-7 Residential Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Single Family	102,900	100,877	98,686
	Multi-Family	14,834	14,450	13,973
	Low-Income Single Family	40,335	39,962	39,354
	Low-Income Multi-Family	11,007	10,770	10,279
BAU Plus	Single Family	119,969	117,475	115,196
	Multi-Family	18,103	17,644	17,143
	Low-Income Single Family	45,364	44,876	44,230
	Low-Income Multi-Family	12,983	12,691	12,158
BAU Max	Single Family	151,876	148,204	144,783
	Multi-Family	24,451	23,804	23,079
	Low-Income Single Family	54,079	53,343	52,352
	Low-Income Multi-Family	17,718	17,297	16,521
Economic	Single Family	395,985	379,482	366,652
	Multi-Family	48,872	47,044	44,922
	Low-Income Single Family	105,459	102,048	98,176
	Low-Income Multi-Family	49,541	47,728	44,874
Technical	Single Family	465,606	448,037	434,535
	Multi-Family	59,011	56,886	54,529
	Low-Income Single Family	120,759	117,135	113,127
	Low-Income Multi-Family	55,633	53,682	50,721

Figure 3-7 breaks down potential according to the end use and measure category (equipment or non-equipment). The "weatherization & controls" category, affecting the space heating end use, accounts for the largest share of the residential BAU achievable potential, followed by space heating and water heating equipment.

Figure 3-7 Liberty Residential Natural Gas Achievable BAU Potential by End Use

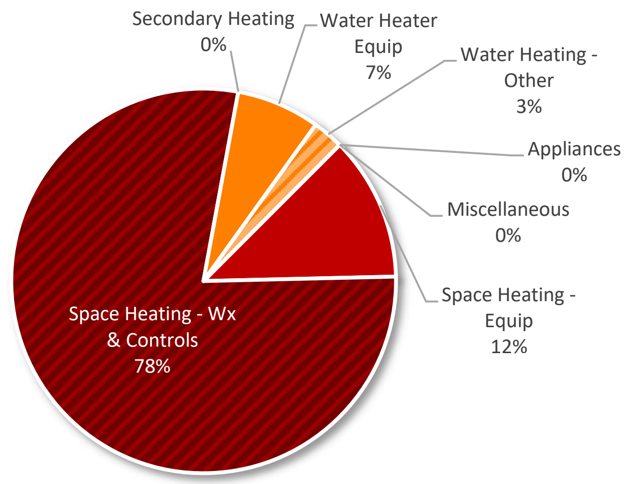


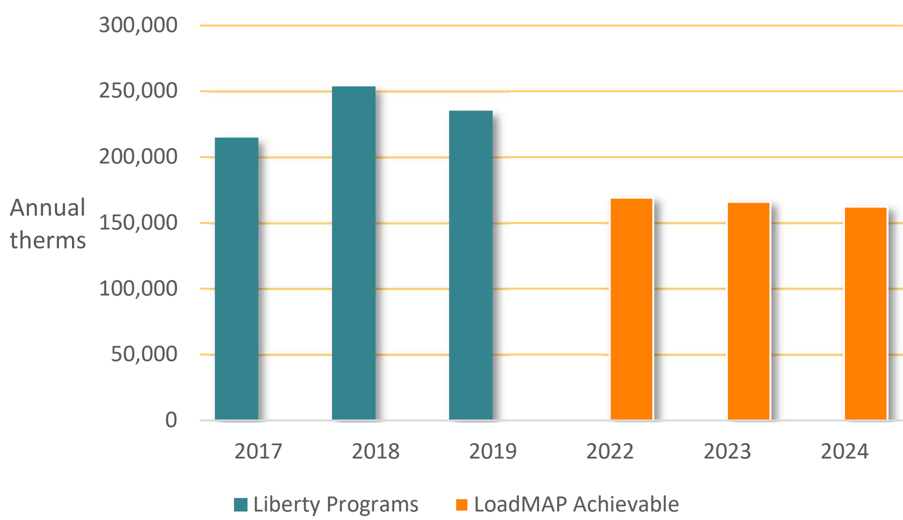
Table 3-8 shows potential broken out by vintage – new construction vs existing – and case.

Table 3-8 Residential Natural Gas Potential (therms) by Case and Vintage

Case	Segment	2022	2023	2024
BAU	Existing	156,220	154,653	152,285
	New	12,856	11,406	10,007
BAU Plus	Existing	179,379	177,760	175,227
	New	17,040	14,925	13,500
BAU Max	Existing	224,338	221,960	218,272
	New	23,786	20,687	18,463
Economic	Existing	507,748	497,918	483,905
	New	92,109	78,384	70,719
Technical	Existing	606,703	595,370	579,985
	New	94,307	80,371	72,927

Finally, Figure 3-8 compares the residential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. While measure participation is similar to Liberty's past achievements, savings per unit against the market average for some equipment types – notably boilers, furnaces, and water heaters – are smaller due to the effects of naturally occurring efficient purchases in the reference baseline as taken from AEO's future purchase assumptions[13].

Figure 3-8 Liberty Natural Gas Residential Savings Historical Comparison – BAU vs Historic



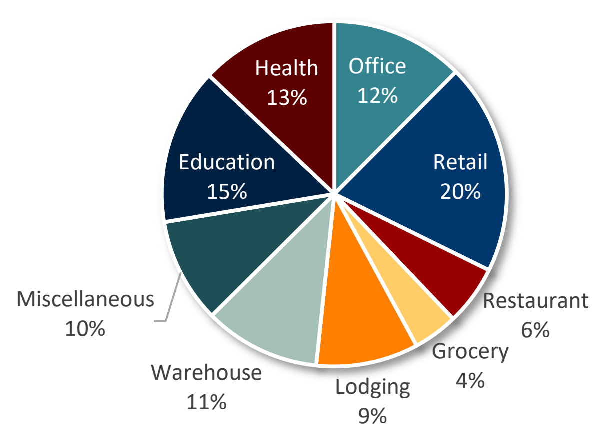
Commercial Sector

In 2019, Liberty commercial customers used a total of 1,621,299 Dth[14]. We allocated this usage to nine commercial segments, shown in Table 3-9, using identifiers provided in Liberty's customer 2019 customer data, which was enhanced with tax assessor data and industry codes provided by DNV. As shown in Figure 3-9, the retail segment accounted for approximately 20% of the total commercial natural gas consumed in 2019, followed by education (15%), healthcare (13%), office (12%), warehouse (11%), miscellaneous (10%), lodging (9%), restaurant (6%), and grocery (4%). Please note that industrial customers are segmented separately later in this section.

Table 3-9 Liberty Commercial Control Totals, 2019

Segment	Annual Use (Dth)	Intensity (therm/sqft)	Floor Space (Million Sq. Ft.)
Office	200,405	0.42	4.77
Retail	318,735	0.32	10.06
Restaurant	90,111	1.37	0.66
Grocery	67,415	0.71	0.96
Education	235,874	0.45	5.27
Healthcare	207,961	0.91	2.29
Lodging	154,359	0.55	2.82
Warehouse	174,709	0.43	4.11
Misc.	158,090	0.66	2.41
Total	**1,607,660**	**0.48**	**33.33**

Figure 3-9 Liberty Commercial Use by Segment, 2019

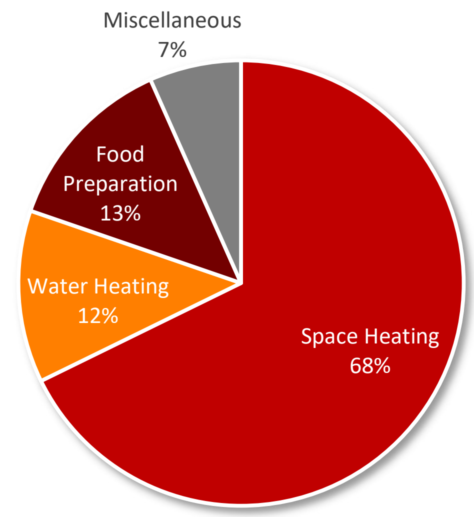


[13] See chapter 2 for a description of the counterfactual baseline and how AEO data informs the reference baseline

[14] Total includes Blackstone customers

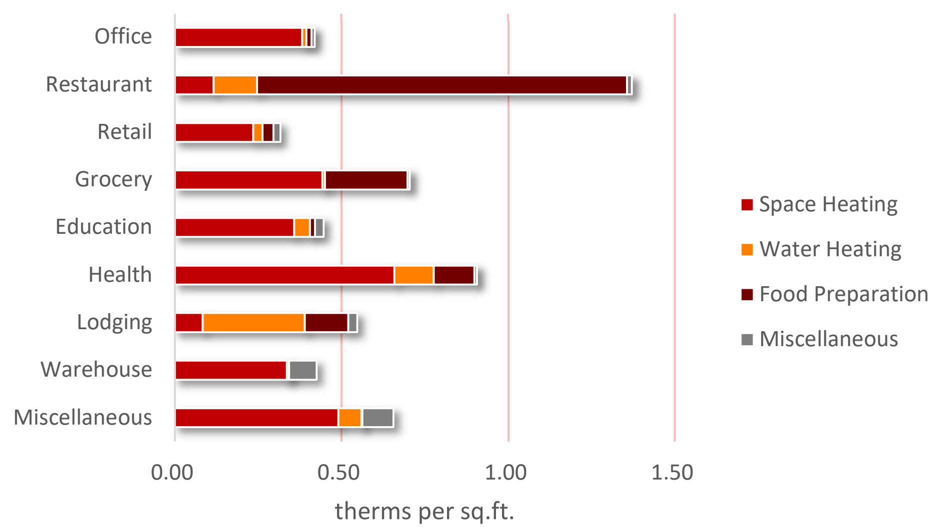
Figure 3-10 shows the distribution of annual natural gas consumption by end use across all commercial buildings. Space heating accounts for roughly two-thirds of commercial natural gas consumption.

Figure 3-10 Liberty Commercial Consumption by End Use, 2019



As shown in Figure 3-11, natural gas intensity by end use varies significantly across segments. For example, due to cooking equipment consumption, the restaurant segment is the most energy intensive, with significantly higher usage per square foot than any other segment.

Figure 3-11 Liberty Commercial Intensity by End Use and Segment, 2019



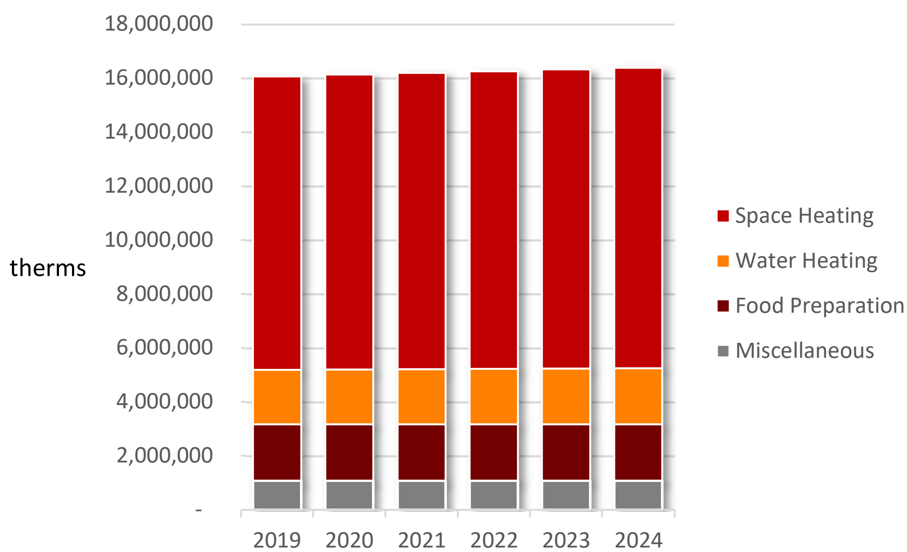
Commercial Baseline Projection

Table 3-10 and Figure 3-12 present AEG's natural gas baseline projection[15] at the end use level for the commercial sector. As in residential, the net effect of market growth and equipment turnover produces a slight increase in total consumption over time.

Table 3-10 Liberty Commercial Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	10,893,088	10,940,762	10,989,703	11,039,208	11,088,670	10,893,088
Water Heating	2,011,118	2,024,841	2,038,866	2,052,873	2,066,588	2,011,118
Food Preparation	2,098,949	2,098,949	2,098,949	2,098,949	2,098,949	2,098,949
Miscellaneous	1,073,442	1,073,442	1,073,442	1,073,442	1,073,442	1,073,442
Total	**16,076,597**	**16,137,994**	**16,200,960**	**16,264,472**	**16,327,649**	**16,389,737**

Figure 3-12 Liberty Commercial Baseline Projection by End Use



Commercial Potential

Table 3-11 presents the commercial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 115,296 therms, or 0.71% of the baseline projection. Because commercial measures have fewer targeted NEIs and tend to be more expensive, economic potential for the commercial sector is not as close to technical potential as in the residential sector.

[15] As noted elsewhere above, this is the counterfactual, no-DSM projection based on market growth assumptions provided by Liberty

Table 3-11 Liberty Summary of Commercial Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**16,264,472**	**16,327,649**	**16,389,737**
Potential Savings			
Achievable BAU	115,296	118,287	120,162
Achievable BAU Plus	126,970	130,225	132,254
Achievable Max	162,391	166,584	169,190
Economic	340,524	349,436	355,644
Technical	439,324	448,269	454,478
Potential Savings as % of Baseline			
Achievable BAU	0.71%	0.72%	0.73%
Achievable BAU Plus	0.78%	0.80%	0.81%
Achievable Max	1.00%	1.02%	1.03%
Economic	2.09%	2.14%	2.17%
Technical	2.70%	2.75%	2.77%

Figure 3-13 shows the distribution of BAU potential across market segments. Retail, Lodging, and Restaurants make up more than half the achievable potential, primarily due to highly cost effective water heating savings, both equipment and non-equipment, and (in the case of the latter two) food service equipment.

Figure 3-13 Liberty Commercial Natural Gas Achievable BAU Potential by Segment

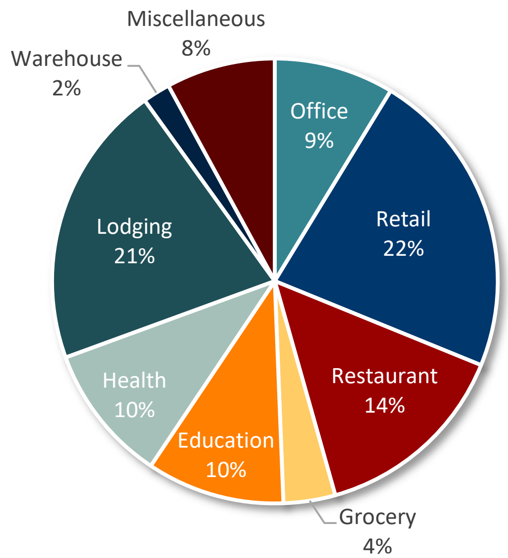


Table 3-12 and Table 3-13 show commercial potential by segment and by vintage – new construction or existing.

Table 3-12 Commercial Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Office	10,900	10,951	10,937
	Retail	30,275	30,473	30,489
	Restaurant	14,652	15,372	15,875
	Grocery	3,728	3,933	4,086
	Education	12,181	12,387	12,501
	Health	10,346	10,789	11,099
	Lodging	20,917	21,904	22,605
	Warehouse	2,417	2,457	2,480
	Miscellaneous	9,879	10,020	10,090
BAU Plus	Office	12,254	12,305	12,284
	Retail	32,989	33,192	33,196
	Restaurant	16,152	16,942	17,494
	Grocery	4,194	4,418	4,583
	Education	13,515	13,736	13,856
	Health	11,458	11,942	12,280
	Lodging	23,094	24,178	24,947
	Warehouse	2,623	2,667	2,692
	Miscellaneous	10,692	10,845	10,922
BAU Max	Office	16,026	16,087	16,053
	Retail	41,016	41,247	41,229
	Restaurant	21,134	22,164	22,883
	Grocery	5,344	5,636	5,854
	Education	17,193	17,474	17,624
	Health	14,879	15,511	15,951
	Lodging	30,046	31,464	32,470
	Warehouse	3,326	3,382	3,414
	Miscellaneous	13,427	13,618	13,713
Economic	Office	40,858	41,141	41,235
	Retail	81,692	82,691	83,230
	Restaurant	37,892	39,774	41,155
	Grocery	13,999	14,753	15,345
	Education	41,541	42,250	42,714
	Health	34,593	35,886	36,843
	Lodging	50,567	52,871	54,587
	Warehouse	12,484	12,747	12,942

Case	Segment	2022	2023	2024
	Miscellaneous	26,898	27,323	27,593
Technical	Office	60,316	60,305	60,106
	Retail	95,093	96,516	97,464
	Restaurant	37,892	39,774	41,155
	Grocery	16,281	17,018	17,591
	Education	79,119	79,323	79,280
	Health	48,630	49,906	50,843
	Lodging	51,047	53,390	55,144
	Warehouse	18,443	18,871	19,227
	Miscellaneous	32,502	33,166	33,667

Table 3-13 shows potential by case and vintage – new construction or existing buildings – and case.

Table 3-13 Commercial Natural Gas Potential (therms) by Case and Vintage

Case	Segment	2022	2023	2024
BAU	Existing	100,285	102,991	104,654
	New	15,011	15,295	15,508
BAU Plus	Existing	110,533	113,500	115,317
	New	16,437	16,725	16,937
BAU Max	Existing	141,107	144,998	147,400
	New	21,285	21,586	21,790
Economic	Existing	283,874	292,584	298,729
	New	56,650	56,853	56,915
Technical	Existing	374,958	381,353	385,206
	New	64,366	66,916	69,271

Industrial Sector

In 2019, Liberty industrial customers used a total of 668,400 Dth (Table 3-14). We allocated this usage to 10 industrial segments based on a combination of direct assignment for large customer accounts and distribution of the remaining consumption according to MECS[16] averages. As shown in Figure 3-14, the food manufacturing segment accounted for approximately 28% of the total natural gas consumed in 2019, followed by chemicals (18%), textiles (15%), other industrial (14%), petroleum and coal products (10%), primary metals (9%), and paper and printing (4%). Plastics and rubber manufacturing, machinery and wood products each make up less than 1% of natural gas consumed.

[16] DOE Manufacturing Energy Consumption Survey

Although some of these customer segments are not significant consumers of energy in Liberty's territory, the Industrial segment list was developed in coordination across Berkshire, Liberty, and Unitil and reflects segments that are significant for at least one of them.

Table 3-14 Liberty Industrial Control Totals, 2019

Segment	Annual Use (Dth)	Annual Use (% of therms)
Chemicals	121,268	18.1%
Food	186,277	27.9%
Paper & Printing	28,790	4.3%
Petroleum & Coal Products	64,871	9.7%
Primary Metals	61,701	9.2%
Textiles	96,975	14.5%
Plastics & Rubber Products	5,422	0.8%
Machinery	4,765	0.7%
Wood Products	2,991	0.4%
Other Industrial	95,340	14.3%
Total	**668,400**	**100.0%**

Figure 3-14 Liberty Industrial Use by Segment, 2019

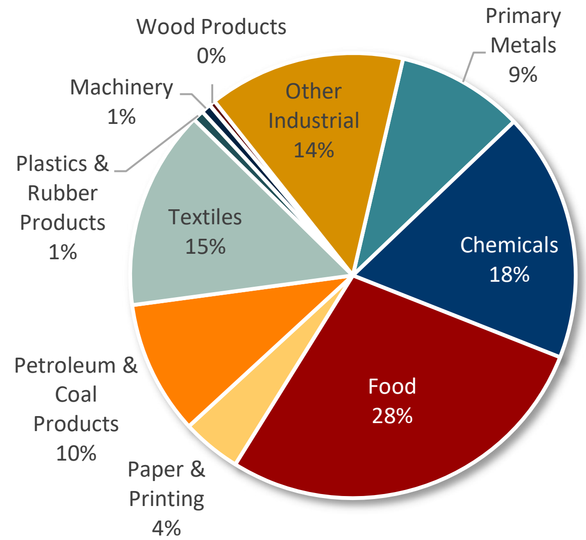
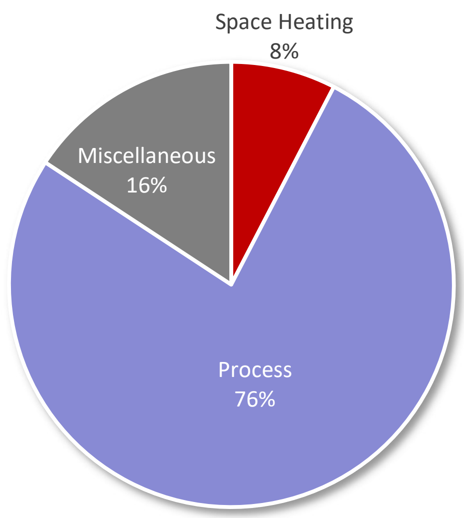


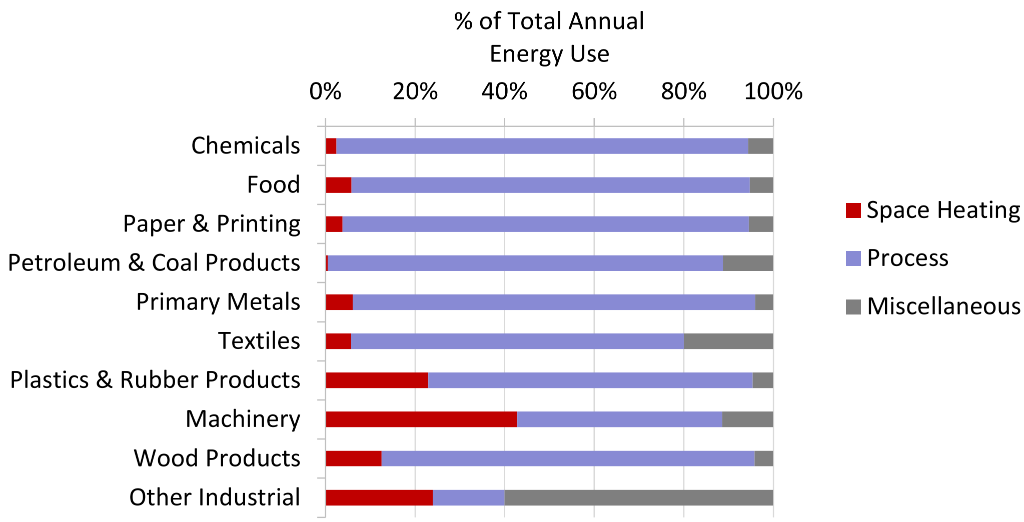
Figure 3-15 shows the distribution of annual natural gas consumption by end use across all industrial facilities. Industrial processes account for the majority of natural gas consumption in this sector.

Figure 3-15 Liberty Industrial Consumption by End Use, 2019



Natural gas intensity is driven largely by process for almost all segments other than Machinery and Other Industrial. Figure 3-16 shows how natural gas is apportioned across industrial end uses, taken from EIA's Manufacturing Energy Consumption Survey (MECS).

Figure 3-16 Liberty Industrial Intensity by End Use and Segment, 2019



Industrial Baseline Projection

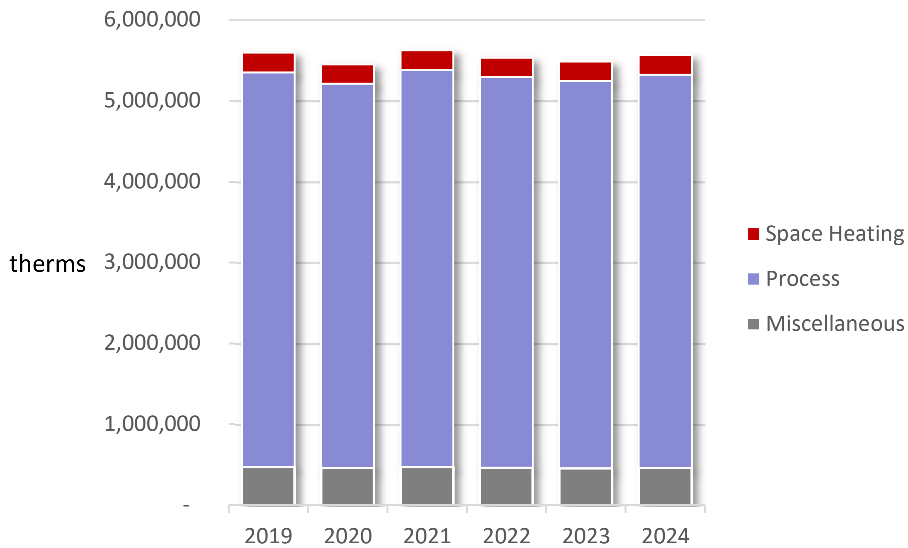
Table 3-15 and Figure 3-17 Liberty Industrial Baseline Projection by End Use present AEG's natural gas baseline projection[17] at the end use level for the commercial sector. Industrial is more volatile than residential or commercial, however the underlying mechanism of market growth driven by Liberty's forecast and some equipment turnover providing efficiency improvements at least up to code are still present.

Table 3-15 Liberty Industrial Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	243,794	237,354	244,856	240,757	238,505	243,794
Process	4,882,436	4,757,887	4,909,799	4,832,991	4,793,270	4,882,436
Miscellaneous	472,592	458,395	471,007	461,408	455,426	472,592
Total	**6,683,997**	**6,530,732**	**6,755,795**	**6,667,976**	**6,630,680**	**6,747,512**

[17] As noted elsewhere above, this is the counterfactual, no-DSM projection based on market growth assumptions provided by Liberty

Figure 3-17 Liberty Industrial Baseline Projection by End Use



Industrial Potential

Table 3-16 presents the industrial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 31,656 therms, or 0.47% of the baseline projection. The industrial sector has fewer prescriptive measures than commercial or residential, and nearly all of them are cost effective. As a result, economic potential is very close to technical.

Table 3-16 Liberty Summary of Industrial Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**6,667,976**	**6,630,680**	**6,747,512**
Potential Savings			
Achievable BAU	31,656	32,186	33,095
Achievable BAU Plus	34,837	35,411	36,401
Achievable Max	44,601	45,342	46,612
Economic	61,655	62,161	63,605
Technical	61,751	62,256	63,702
Potential Savings as % of Baseline			
Achievable BAU	0.47%	0.49%	0.49%
Achievable BAU Plus	0.52%	0.53%	0.54%
Achievable Max	0.67%	0.68%	0.69%
Economic	0.92%	0.94%	0.94%
Technical	0.93%	0.94%	0.94%

The food manufacturing segment accounts for over a quarter (28%) of the industrial achievable BAU potential from 2022 through 2024 and the other industrial segment represents a quarter (25%) of the savings (Figure 3-18).

Figure 3-18 Liberty Industrial Natural Gas Achievable BAU Potential by Segment

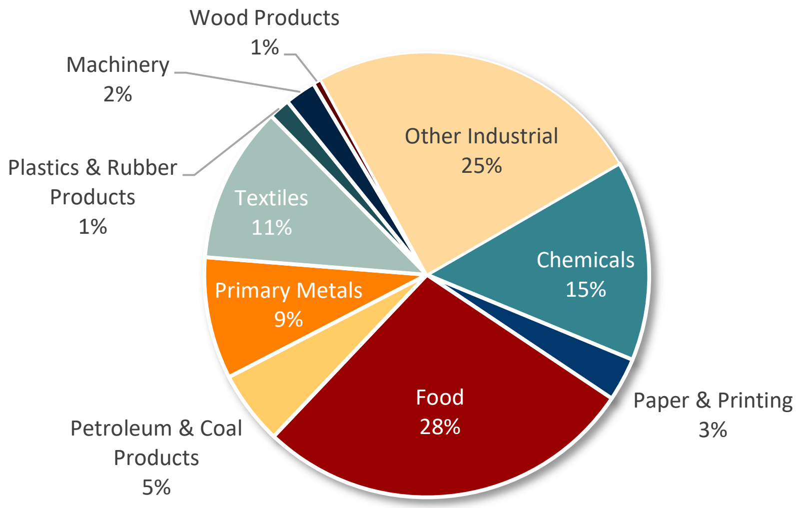


Table 3-17 and Table 3-18 show industrial potential by segment and by vintage.

Table 3-17 Industrial Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Chemicals	4,674	4,760	4,901
	Food	8,892	9,046	9,307
	Paper & Printing	1,015	1,031	1,059
	Petroleum & Coal Products	1,711	1,745	1,799
	Primary Metals	2,836	2,889	2,977
	Textiles	3,661	3,725	3,833
	Plastics & Rubber Products	508	516	529
	Machinery	726	736	755
	Wood Products	193	196	201
	Other Industrial	7,441	7,541	7,734
BAU Plus	Chemicals	5,047	5,079	5,171
	Food	10,542	10,668	10,919
	Paper & Printing	4,150	4,172	4,245
	Petroleum & Coal Products	1,553	1,562	1,590
	Primary Metals	1,910	1,926	1,968
	Textiles	3,052	3,360	3,691
	Plastics & Rubber Products	1,094	1,097	1,115
	Machinery	932	943	966
	Wood Products	782	788	804
	Other Industrial	5,774	5,815	5,934

Case	Segment	2022	2023	2024
BAU Max	Chemicals	6,586	6,706	6,903
	Food	12,528	12,744	13,109
	Paper & Printing	1,430	1,452	1,492
	Petroleum & Coal Products	2,411	2,459	2,534
	Primary Metals	3,995	4,071	4,193
	Textiles	5,158	5,248	5,398
	Plastics & Rubber Products	716	726	745
	Machinery	1,023	1,037	1,064
	Wood Products	271	276	284
	Other Industrial	10,483	10,622	10,891
Economic	Chemicals	10,372	10,452	10,698
	Food	19,069	19,209	19,652
	Paper & Printing	1,926	1,941	1,984
	Petroleum & Coal Products	2,990	3,029	3,110
	Primary Metals	4,799	4,861	4,990
	Textiles	6,641	6,708	6,872
	Plastics & Rubber Products	923	929	949
	Machinery	1,297	1,306	1,334
	Wood Products	337	341	349
	Other Industrial	13,301	13,384	13,667
Technical	Chemicals	10,373	10,453	10,699
	Food	19,073	19,214	19,657
	Paper & Printing	1,926	1,941	1,985
	Petroleum & Coal Products	2,990	3,029	3,110
	Primary Metals	4,800	4,863	4,992
	Textiles	6,644	6,710	6,874
	Plastics & Rubber Products	924	930	949
	Machinery	1,298	1,307	1,335
	Wood Products	338	341	349
	Other Industrial	13,386	13,468	13,752

Table 3-18 Industrial Natural Gas Potential (therms) by Case and Vintage

Case	Segment	2022	2023	2024
BAU	Existing	29,130	29,318	29,897
	New	2,527	2,868	3,198
BAU Plus	Existing	28,625	29,028	29,808
	New	6,212	6,382	6,593
BAU Max	Existing	41,041	41,301	42,108
	New	3,560	4,040	4,504
Economic	Existing	56,752	56,603	57,405
	New	4,903	5,557	6,200
Technical	Existing	56,844	56,694	57,496
	New	4,907	5,563	6,206

C&I Combined Potential by End Use

The following two graphs show the potential for the entire nonresidential sector by end use. Custom programs account for 80% of the achievable BAU potential savings (Figure 3-19), with industrial process accounting for a further 11%.

Figure 3-19 Liberty Nonresidential Natural Gas Achievable BAU Potential by End Use

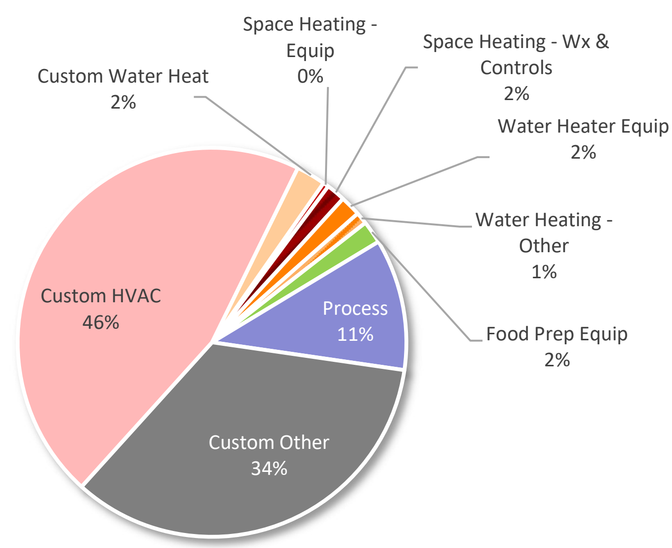
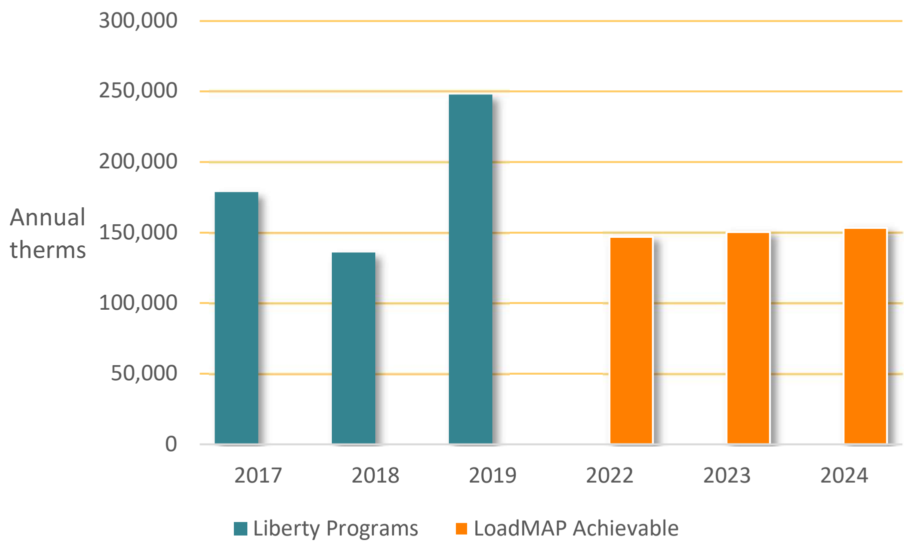


Figure 3-20 compares the nonresidential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. Overall forward savings are similar to past achievements.

Figure 3-20 Liberty Natural Gas Nonresidential Savings Historical Comparison – BAU vs Historic



4

INSIGHTS AND CONCLUSION

Liberty has been running energy efficiency programs in Massachusetts for several planning cycles, and the Business-as-Usual case presented in this report has been aligned with recent program activity. Comparing recent accomplishments with AEG's prior market research on general market acceptance and interest in energy programs shows that Liberty has areas of strong success and also that in several cases acquiring additional potential beyond current performance may be challenging.

High Performing Programs

- Residential Weatherization. Liberty's residential insulation and air sealing offerings show significantly more activity (as a % of economic potential) than AEG typically sees and may not have much more room to plausibly grow in annual acquisitions.
- Residential Smart Thermostats. Activity for this offering is modestly higher than AEG's typical take rates, indicating a mature, robust program.
- Commercial Weatherization. Retrofits of commercial buildings for weatherization are commonly difficult to obtain, however Liberty's programs have shown significant activity in this category over the past several years.
- Commercial Water Savings. This category includes measure such as faucet aerators, restaurant sprayer valves, and low flow showerheads. Liberty's program activity in these measures is much higher than AEG commonly sees in other territories.

Possible Opportunities for Growth

- Space heating and water heating equipment . Although these measures are already an active part of Liberty's programs for both the residential and nonresidential sectors, existing participation in these programs is not very high compared to expected turnover rates based on the generally accepted lifetimes for this equipment.

  This suggests there may be more units that require replacement each year but are not coming through the program, possibly because customers who lose heat or water heat suddenly are faced with an emergency decision, rather than a planned one that can consider the available rebates and benefits of a high efficiency model.
- Smart Thermostats in Nonresidential Buildings. Given Liberty's strong success with residential smart thermostats, the much lower activity for this measure in the nonresidential sector presents an opportunity for growth. Customer outreach may help small business owners become more fully aware of the benefits of web-enabled thermostats for their business space.

Challenges to increasing participation

Customer participation in energy efficiency measures reflects a combination of factors, including the economic conditions of potential program participants, urgency of timing, customers' general attitudes towards energy and efficiency, the perceived value of the efficiency measure to the customer, the value of the incentive itself, and obstacles that can arise when projects are assessed or begun.

Relating to that last point, internal analysis by the PAs[18] found that nearly 90% of residential homes that were assessed in preparation for weatherization installations encountered significant unanticipated barriers that either increased the cost of the project significantly or made it impractical to continue, such as pest control issues, asbestos, mold, or structural issues.

This combination of factors means that simply raising incentives, even to 100% of incremental costs, cannot guarantee a large increase in participation if underlying obstacles are not addressed. In 2020, a Residential Nonparticipant Customer Profile Study similarly found that the barriers to program participation run far beyond simply incentives or measure payback.[19]

Conclusion

Liberty's portfolio of energy efficiency programs is performing solidly, however there is room for some modest increase in annual potential acquisition if incentives are increased and programs can address market barriers. However, both of these prospects will increase the cost of acquiring potential.

This study provides important information for planning the next program cycles. This study:

- Describes and characterizes the customer base by energy source, sector, customer segment and end use. At a glance, it is possible to see where the opportunities for program savings are likely to come from.
- Defines a baseline projection of energy use by end use against which savings can be measured. This baseline takes into account existing and planned appliance standards and building codes, as well as naturally occurring efficiency.
- Evaluates a diverse set of energy efficiency measures in all three customer sectors.
- Estimates the total amount of savings possible from cost-effective measures; these are savings above and beyond those already included in the baseline projection.
- Describes a set of achievable potential savings scenarios – BAU, BAU Plus, and Max – based on increased incentives driving increased savings achievement that can be useful for program development in the upcoming planning years 2022 through 2024.

The results presented in this report are estimates based on the best available information available at the time of the analysis and we expect variation in outcomes in the real world. This fact gives staff the opportunity to deviate from specific annual values developed in the study as they design programs and commit to annual program targets as well as gather more territory-specific information about baselines, saturation and demand for program offerings.

[18] Pre-Weatherization Barrier analysis, data taken from RISE and provided by Liberty Gas

[19] https://ma-eeac.org/wp-content/uploads/MA19X06-B-RESNONPART_Report_FINAL_v20200228.pdf

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Appendix A: Adoption Rates
Liberty

Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	*2023*	*2024*	*2022*	*2023*	*2024*	*2022*	*2023*	*2024*
Residential	LostOpp_Heating	18%	18%	18%	20%	20%	20%	29%	29%	29%
Residential	LostOpp_DHW	11%	11%	11%	13%	13%	13%	18%	18%	18%
Residential	LostOpp_Cooking	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_OtherAppliance	22%	22%	22%	24%	24%	24%	35%	35%	35%
Residential	Retro_ResWx	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	Retro_Custom	6%	6%	6%	6%	6%	6%	9%	9%	9%
Residential	Retro_Duct_Seal/Ins	12%	12%	12%	13%	13%	13%	19%	19%	19%
Residential	Retro_Windows	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	Retro_HVAC_Maint	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	Retro_Smart_Tstat	57%	57%	57%	63%	63%	63%	91%	91%	91%
Residential	Retro_Pipe_Wrap	25%	25%	25%	27%	27%	27%	40%	40%	40%
Residential	Retro_DHW_Conservation	5%	5%	5%	5%	5%	5%	7%	7%	7%
Residential	LostOpp_Heating_LI	8%	8%	8%	8%	8%	8%	9%	9%	9%
Residential	LostOpp_DHW_LI	8%	8%	8%	9%	9%	9%	10%	10%	10%
Residential	LostOpp_Cooking_LI	0%	0%	0%	88%	88%	88%	97%	97%	97%
Residential	LostOpp_OtherAppliance_LI	22%	22%	22%	24%	24%	24%	26%	26%	26%
Residential	Retro_ResWx_LI	86%	86%	86%	95%	95%	95%	100%	100%	100%
Residential	Retro_Custom_LI	4%	4%	4%	5%	5%	5%	5%	5%	5%
Residential	Retro_Duct_Seal/Ins_LI	9%	9%	9%	10%	10%	10%	10%	10%	10%
Residential	Retro_Windows_LI	0%	0%	0%	94%	94%	94%	100%	100%	100%
Residential	Retro_HVAC_Maint_LI	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	Retro_Smart_Tstat_LI	32%	32%	32%	36%	36%	36%	39%	39%	39%
Residential	Retro_Pipe_Wrap_LI	18%	18%	18%	20%	20%	20%	22%	22%	22%
Residential	Retro_DHW_Conservation_LI	3%	3%	3%	3%	3%	3%	3%	3%	3%
Commercial	LostOpp_HVAC_Office	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	LostOpp_Water heating_Office	9%	9%	9%	10%	10%	10%	13%	13%	13%
Commercial	LostOpp_Food Prep_Office	19%	19%	19%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Other_Office	0%	0%	0%	26%	26%	26%	34%	34%	34%
Commercial	Retro_Weatherization_Office	42%	42%	42%	46%	46%	46%	60%	60%	60%
Commercial	Retro_Thermostats_Office	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Office	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Process_Office	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Office	63%	63%	63%	69%	69%	69%	90%	90%	90%
Commercial	Retro_Steam Trap_Office	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commercial	Retro_RCx_Office	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Office	14%	14%	14%	15%	15%	15%	20%	20%	20%
Commercial	LostOpp_HVAC_Retail	4%	4%	4%	4%	4%	4%	5%	5%	5%
Commercial	LostOpp_Water heating_Retail	27%	27%	27%	29%	29%	29%	38%	38%	38%
Commercial	LostOpp_Food Prep_Retail	3%	3%	3%	3%	3%	3%	4%	4%	4%
Commercial	LostOpp_Other_Retail	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Retail	52%	52%	52%	58%	58%	58%	75%	75%	75%
Commercial	Retro_Thermostats_Retail	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Retail	3%	3%	3%	4%	4%	4%	5%	5%	5%
Commercial	Retro_Process_Retail	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Retail	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Retail	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Retail	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Retail	21%	21%	21%	23%	23%	23%	30%	30%	30%
Commercial	LostOpp_HVAC_Restaurant	4%	4%	4%	5%	5%	5%	6%	6%	6%
Commercial	LostOpp_Water heating_Restaurant	6%	6%	6%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_Food Prep_Restaurant	20%	20%	20%	22%	22%	22%	29%	29%	29%

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Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	*2023*	*2024*	*2022*	*2023*	*2024*	*2022*	*2023*	*2024*
Commercial	LostOpp_Other_Restaurant	0%	0%	0%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Weatherization_Restaurant	50%	50%	50%	55%	55%	55%	72%	72%	72%
Commercial	Retro_Thermostats_Restaurant	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Restaurant	3%	3%	3%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Process_Restaurant	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Restaurant	42%	42%	42%	46%	46%	46%	61%	61%	61%
Commercial	Retro_Steam Trap_Restaurant	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commercial	Retro_RCx_Restaurant	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Restaurant	18%	18%	18%	19%	19%	19%	25%	25%	25%
Commercial	LostOpp_HVAC_Grocery	4%	4%	4%	4%	4%	4%	6%	6%	6%
Commercial	LostOpp_Water heating_Grocery	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Food Prep_Grocery	13%	13%	13%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_Other_Grocery	0%	0%	0%	5%	5%	5%	7%	7%	7%
Commercial	Retro_Weatherization_Grocery	39%	39%	39%	43%	43%	43%	57%	57%	57%
Commercial	Retro_Thermostats_Grocery	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Grocery	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Process_Grocery	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Grocery	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Grocery	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Grocery	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Grocery	13%	13%	13%	15%	15%	15%	19%	19%	19%
Commercial	LostOpp_HVAC_Education	4%	4%	4%	4%	4%	4%	6%	6%	6%
Commercial	LostOpp_Water heating_Education	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Food Prep_Education	13%	13%	13%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_Other_Education	0%	0%	0%	5%	5%	5%	7%	7%	7%
Commercial	Retro_Weatherization_Education	39%	39%	39%	43%	43%	43%	57%	57%	57%
Commercial	Retro_Thermostats_Education	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Education	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Process_Education	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Education	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Education	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Education	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Education	13%	13%	13%	15%	15%	15%	19%	19%	19%
Commercial	LostOpp_HVAC_Health	6%	6%	6%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_Water heating_Health	20%	20%	20%	23%	23%	23%	29%	29%	29%
Commercial	LostOpp_Food Prep_Health	19%	19%	19%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Other_Health	0%	0%	0%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Weatherization_Health	34%	34%	34%	38%	38%	38%	49%	49%	49%
Commercial	Retro_Thermostats_Health	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Health	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Process_Health	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Health	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Health	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Health	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Health	13%	13%	13%	15%	15%	15%	19%	19%	19%
Commercial	LostOpp_HVAC_Lodging	6%	6%	6%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_Water heating_Lodging	21%	21%	21%	24%	24%	24%	31%	31%	31%
Commercial	LostOpp_Food Prep_Lodging	29%	29%	29%	32%	32%	32%	42%	42%	42%
Commercial	LostOpp_Other_Lodging	0%	0%	0%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Weatherization_Lodging	69%	69%	69%	76%	76%	76%	90%	90%	90%
Commercial	Retro_Thermostats_Lodging	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Lodging	2%	2%	2%	2%	2%	2%	3%	3%	3%

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Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	***2023***	***2024***	***2022***	***2023***	***2024***	***2022***	***2023***	***2024***
Commercial	Retro_Process_Lodging	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Lodging	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Lodging	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Lodging	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Lodging	13%	13%	13%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_HVAC_Warehouse	3%	3%	3%	4%	4%	4%	5%	5%	5%
Commercial	LostOpp_Water heating_Warehouse	24%	24%	24%	26%	26%	26%	34%	34%	34%
Commercial	LostOpp_Food Prep_Warehouse	3%	3%	3%	3%	3%	3%	4%	4%	4%
Commercial	LostOpp_Other_Warehouse	0%	0%	0%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Weatherization_Warehouse	15%	15%	15%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Thermostats_Warehouse	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Warehouse	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_Process_Warehouse	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Warehouse	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Warehouse	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Warehouse	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Warehouse	5%	5%	5%	6%	6%	6%	8%	8%	8%
Commercial	LostOpp_HVAC_Miscellaneous	6%	6%	6%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_Water heating_Miscellaneous	24%	24%	24%	26%	26%	26%	34%	34%	34%
Commercial	LostOpp_Food Prep_Miscellaneous	23%	23%	23%	26%	26%	26%	34%	34%	34%
Commercial	LostOpp_Other_Miscellaneous	0%	0%	0%	15%	15%	15%	19%	19%	19%
Commercial	Retro_Weatherization_Miscellaneous	55%	55%	55%	60%	60%	60%	79%	79%	79%
Commercial	Retro_Thermostats_Miscellaneous	11%	11%	11%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Controls_Miscellaneous	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	Retro_Process_Miscellaneous	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Water Saving_Miscellaneous	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Miscellaneous	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	Retro_RCx_Miscellaneous	0%	0%	0%	19%	19%	19%	25%	25%	25%
Commercial	Retro_Custom_Miscellaneous	13%	13%	13%	14%	14%	14%	19%	19%	19%
Industrial	LostOpp_HVAC_Industrial	2%	2%	2%	3%	3%	3%	3%	3%	3%
Industrial	LostOpp_Water heating_Industrial	10%	10%	10%	11%	11%	11%	14%	14%	14%
Industrial	LostOpp_Food Prep_Industrial	4%	4%	4%	4%	4%	4%	5%	5%	5%
Industrial	LostOpp_Other_Industrial	0%	0%	0%	3%	3%	3%	4%	4%	4%
Industrial	Retro_Weatherization_Industrial	8%	8%	8%	8%	8%	8%	11%	11%	11%
Industrial	Retro_Thermostats_Industrial	11%	11%	11%	12%	12%	12%	15%	15%	15%
Industrial	Retro_Controls_Industrial	0%	0%	0%	1%	1%	1%	1%	1%	1%
Industrial	Retro_Process_Industrial	0%	0%	0%	19%	19%	19%	25%	25%	25%
Industrial	Retro_Water Saving_Industrial	66%	66%	66%	73%	73%	73%	90%	90%	90%
Industrial	Retro_Steam Trap_Industrial	0%	0%	0%	0%	0%	0%	0%	0%	0%
Industrial	Retro_RCx_Industrial	0%	0%	0%	19%	19%	19%	25%	25%	25%
Industrial	Retro_Custom_Industrial	3%	3%	3%	4%	4%	4%	5%	5%	5%