Guidehouse

Massachusetts Energy Efficiency, Electrification, and Demand Response Potential Study for 2022-2024

Prepared for:

nationalgrid

National Grid

Submitted by:

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Common Acronyms

AC	Air Conditioning
ACEEE	American Council for an Energy Efficient Economy
AESC	Avoided Energy Supply Component Study
BAU	Business-as-Usual Scenario
BAU+	Business-as-Usual Enhanced Scenario
BCR	Benefit-Cost Ratio
BEV	Battery Electric Vehicle
BTM	Behind-the-Meter
BYOD	Bring Your Own Device
BYOT	Bring Your Own Thermostat
C&I	Commercial and Industrial
CBSA	Commercial Building Stock Assessment
COVID	Extended Economic Recovery from COVID-19 Scenario
CSP	Curtailment Service Provider
DLC	Direct Load Control
DNV	DNV Consulting Firm, formerly known as DNV-GL
DOE	United States Department of Energy
DR	Demand Response
DRIPE	Demand Reduction Induced Price Effects
DSM	Demand Side Management
EE	Energy Efficiency
EEAC	Energy Efficiency Advisory Council
EERE	Energy Efficiency & Renewable Energy
EMS	Energy Management System
EO	Energy Optimization
ES	Energy Storage
EV	Electric Vehicle
FTE	Full-Time Equivalent
HVAC	Heating, Ventilation, and Air Conditioning
IT	Information Technology
LLLC	Luminaire Level Lighting Control
MAX	Maximum Achievable Scenario
MECO	Massachusetts Electric Company

Common Acronyms, continued

NAICS	North American Industry Classification System
NEI	Non-Energy Impact
NEW	New Construction
NPV	Net Present Value
NTG	Net-to-Gross
O&M	Operation(al) and Maintenance
PA	Program Administrators
PHEV	Plug-in Hybrid Electric Vehicle
PNNL	Pacific Northwest National Laboratory
PV	Present Value
QC	Quality Control or Quality Control Check
RET	Retrofit
ROB	Replace-on-Burnout
SEER	Seasonal Energy Efficiency Ratio
TRC	Total Resource Cost
TRM	Technical Reference Manual
TSD	Technical Support Document

Executive Summary

National Grid engaged Guidehouse, Inc. (Guidehouse) to prepare energy efficiency (EE), energy optimization (EO), and demand response (DR) potential studies for electricity, natural gas, propane, and fuel oil for its service area in the Commonwealth of Massachusetts over a 3-year forecast horizon, from 2022 to 2024.

The study's objective is to assess the potential in the residential, low-income, and commercial and industrial (C&I) sectors by analyzing EE, EO, and DR measures and improvements to end user behaviors to reduce energy consumption. Measure and market characterization data is input to Guidehouse's Demand Side Management Simulator (DSMSim™) and Demand Response Simulator (DRSim™) models, which calculate technical, economic, and achievable potential across National Grid's service areas in Massachusetts. These results will be used to inform energy efficiency goal setting and associated program design for National Grid in Massachusetts.

Four scenarios were modeled:

- **Business-as-Usual (BAU):** Estimates of achievable potential calibrated to 2019 program actuals and assuming similar budgets and program activity, combined with the measures and technologies contained in the technical and economic potential estimates.
- **Business-as-Usual Enhanced (BAU+):** For weatherization, incentives set to 90% of incremental cost; for other measures, raising incentive levels to 50% higher relative to existing incentive levels (to a maximum of 90% of incremental cost).
- **Maximum Achievable Potential (MAX):** Estimates of achievable potential calibrated to 2019 program actuals, with 100% incremental cost-based incentives across the board.
- **Extended Economic Recovery (COVID):** This enhanced program design option assumes the economic recovery from the COVID-19 pandemic extends into the 2022-2024-timeframe. A common set of revised economic assumptions for this scenario are layered onto both the BAU and BAU+ scenarios.

Estimation of Energy Efficiency Potential

Guidehouse employed its proprietary DSMSim™ Demand-Side Management Simulator potential model (DSMSim) to estimate the technical, economic, and achievable potential for electric and natural gas energy efficiency and summer peak passive demand savings across Massachusetts. DSMSim is a bottom-up technology diffusion and stock tracking model implemented using a System Dynamics[1] framework. The model explicitly accounts for different types of efficient measures, such as retrofit (RET), replace-on-burnout (ROB), and new construction (NEW), and the impacts these measures have on savings potential. The model then reports the technical, economic, and achievable potential savings in aggregate by sector, customer segment, end-use category, and highest impact measures.

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[1] See Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill, 2000, for detail on System Dynamics modelling. Also see http://en.wikipedia.org/wiki/System_dynamics for a high-level overview.

Guidehouse developed potential and cost estimates using a bottom-up analysis. The analysis involved five steps:

1. Characterize the market
2. Develop baseline projections
3. Define and characterize EE options
4. Develop key assumptions for potential and costs
5. Estimate potential and costs

This study defines **technical potential** as the energy savings that can be achieved assuming that all installed measures can immediately be replaced with the efficient measure, wherever technically feasible, regardless of the cost, market acceptance, or whether a measure has failed (or burned out) and is in need of being replaced.

Economic potential is a subset of technical potential, using the same assumptions regarding immediate replacement as in technical potential but limiting the calculation only to those measures that have passed the benefit-cost test chosen for measure screening—in this case, the Total Resource Cost (TRC) test as used by National Grid in Massachusetts.

Achievable potential further considers the likely rate of demand side management (DSM) resource acquisition given factors like the rate of equipment turnover (a function of a measure's lifetime), simulated incentive levels, consumer willingness to adopt efficient technologies, and the likely rate at which marketing activities can facilitate technology adoption. The adoption of DSM measures can be broken down into the calculation of the equilibrium market share and the calculation of the dynamic approach to equilibrium market share, as discussed in more detail in Section 6.1.

Achievable potential savings reported in this study are net rather than gross, meaning these include the impacts of free ridership, spillover, and market effects attributable to DSM programs. Providing net potential is appropriate for National Grid's primary intended purposes for conducting this study—setting 2022-2024 goals and targets—because net savings is the definition used in Massachusetts.

Estimation of Energy Optimization Potential

For the purposes of this study, EO is defined as optimizing a customer's heating energy consumption through the use of more efficient technologies. Most often, this involves converting from oil- and propane-fired heat to electric heat pumps, though other permutations are considered. The EO potential analysis involved the same steps described above for EE. Guidehouse used primary data based on the recent energy optimization analyses we developed on behalf of the Massachusetts Program Administrators (PAs) for the residential and non-residential sectors and relevant secondary sources for this analysis, as documented in this report.

As with EE potentials, the foundation for the EO potential assessment is the development of disaggregated bottom-up energy efficiency projections by customer class, segment, and end use. Additionally, the EO achievable potential estimates are calibrated to historical adoption EO measures, which also reflects actual customer choices between EE and EO. Through this process, customers in the model essentially choose between EE and EO measures—one cannot have both for any individual end use—reducing the impact of potential double counting within the respective achievable potential estimates. For example, low and standard efficiency residential fuel oil and propane heating systems can become high efficiency versions using the same fuels (EE), or these can be converted to high efficiency heat pumps (EO) in the models. The combined market shares of eligible customers who may choose these options should not exceed 100% as a that would be, by definition, double counting. However, due to the distinct nature of the EE and EO studies, as incentive levels change from the BAU scenario, the likelihood of double counting between the two studies increases. Guidehouse believes that the impact of double-counting is small due to the inherent customer adoption choice through historical program calibration, relatively small magnitude of achievable EO potential through the study period.

Demand Response Potential Estimation Approach

Guidehouse developed DR potential and cost estimates using a bottom-up analysis following the five-step process outlined for EE and EO. Guidehouse used both primary data from National Grid and relevant secondary sources for this analysis, as documented in this report. The DR market and measure characterization efforts provide input data to Guidehouse's DRSim^{TM} Demand-Response Simulator model (DRSim), which estimates potential and costs and assesses the cost-effectiveness of DR options.

The foundation for the DR potential assessment is the development of disaggregated bottom-up peak demand projections by customer class, segment, and end use. The projections for each scenario account for the impacts of achievable energy efficiency and energy optimization potential for the corresponding EE and EO scenario. The steps to determine the baseline peak projections were:

1. Define the peak period
2. Calculate coincident peak demand factors
3. Obtain end-use shares
4. Determine energy sales after subtracting Guidehouse's energy efficiency potential analysis results
5. Apply coincident peak demand factors and end-use shares to calculate bottom-up peak demand projections

The same three scenarios from the energy efficiency potential analysis were considered in the baseline summer peak projections: (1) BAU, (2) BAU+, and (3) MAX, which correspond to the DR scenarios modeled. These scenarios incorporate a DR baseline adjustment with EE results corresponding to the three scenarios, plus DR-enabling technology saturation values from EE results and variations in participation assumptions corresponding to variations in DR program participation incentives. Guidehouse considered a wide spectrum of DR-enabling technologies for realizing load reduction across different end uses and customer segments; these technologies represent those that National Grid currently offers or could offer in the future. The DR options characterization involved specifying unit impacts, participation assumptions, and itemized costs for realizing load reductions across the different end-use and DR-enabling technology combinations (referred to as DR sub-options) for residential and C&I customers. The scenarios accounted for differences in participation assumptions, driven by variations in customer incentive levels.

Guidehouse fed these inputs into the DRSim tool and assessed the cost-effectiveness of DR options and developed achievable potential and annual cost estimates, as well as levelized costs and supply curves for the different DR options. The potential and cost findings are summarized in the Findings section.

Findings

EE Potential Results

Figure ES-1 provides the net technical and economic electricity potential at the meter for National Grid in Massachusetts. Technical and economic potential remain relatively flat over the 3-year study horizon, respectively. Economic potential is only slightly below technical, indicating the prevalence of established measures (i.e., ones that have already passed cost-effectiveness screening and are included in the Massachusetts Technical Reference Manual, or TRM) and that most measures pass the economic TRC threshold of 1.0.[2] Exceeding the cost-effectiveness threshold is helped, in part, by the number of benefit categories recognized in Massachusetts' cost-effectiveness screening.

Figure ES-2 shows the net incremental annual electricity potential results for the three achievable potential scenarios presented: (1) MAX, (2) BAU+, and (3) BAU (base case). Each case shows declining savings over the 3-year study horizon, which is largely due to the saturation of commercial lighting and custom measures.

Figure ES-3 shows the net lifetime incremental annual electricity potential results for the three achievable potential scenarios. Lifetime savings trend are similar the first-year annual indicating that the measure mix and weighted average lifetime of portfolio measures does not change dramatically throughout the study period.

Figure ES-4 presents the net technical and economic summer peak passive demand savings at meter. Like electricity potential, they remain steady through the study period.

Figure ES-5 presents incremental annual achievable net summer peak passive demand savings at meter potential for the three achievable potential scenarios. Like electricity potential, the savings remain steady through the study period.

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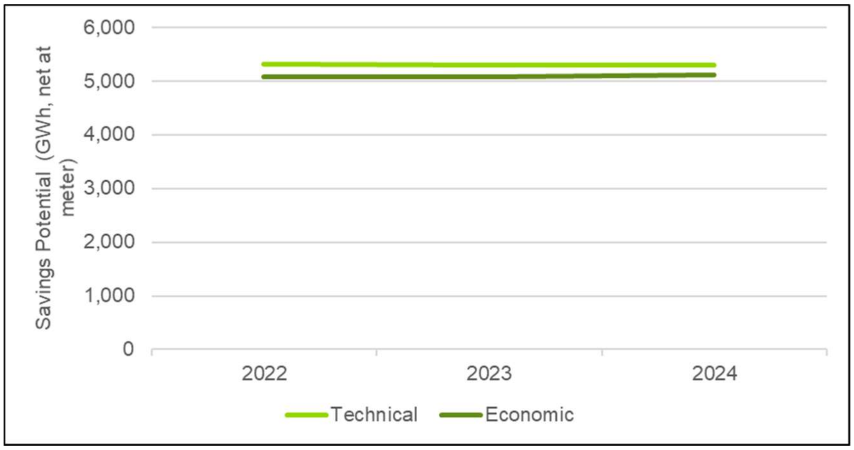
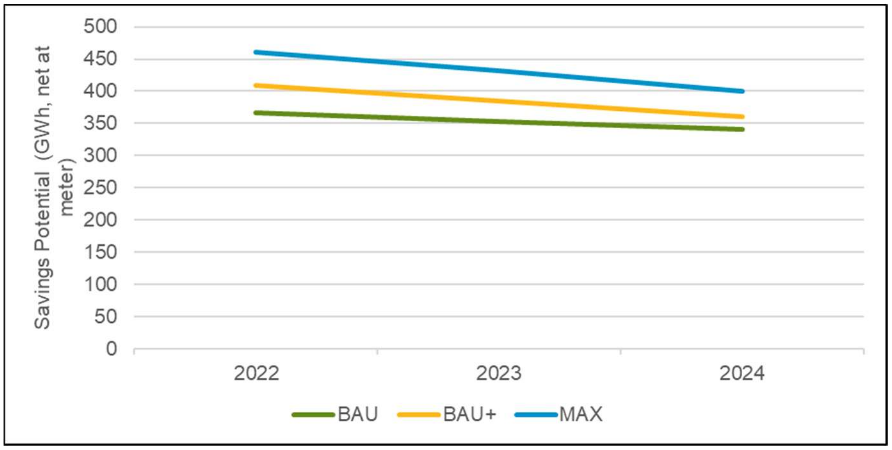
[2] Achievable potential was screened using a TRC threshold of 0.8, as explained in Section 8.

Figure ES-1. EE Technical and Economic Potential Electricity Savings (GWh, Net at Meter)



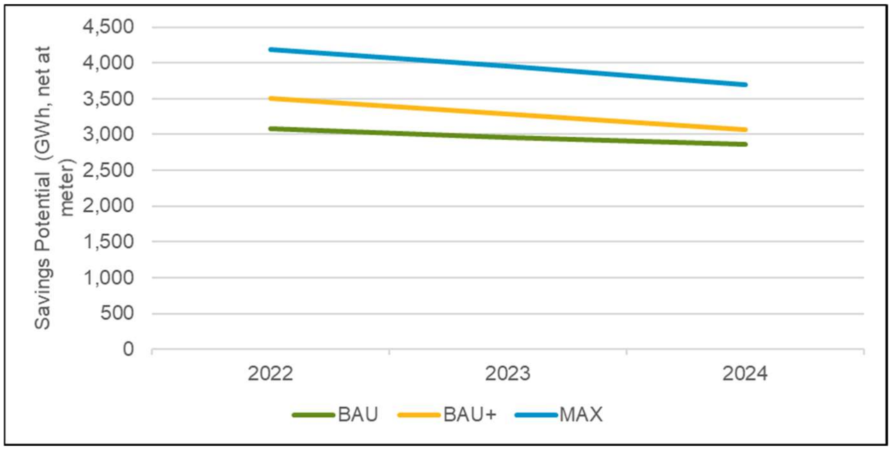
Source: Guidehouse analysis

Figure ES-2. EE Achievable Potential Electricity Incremental Annual Savings (GWh, Net at Meter)



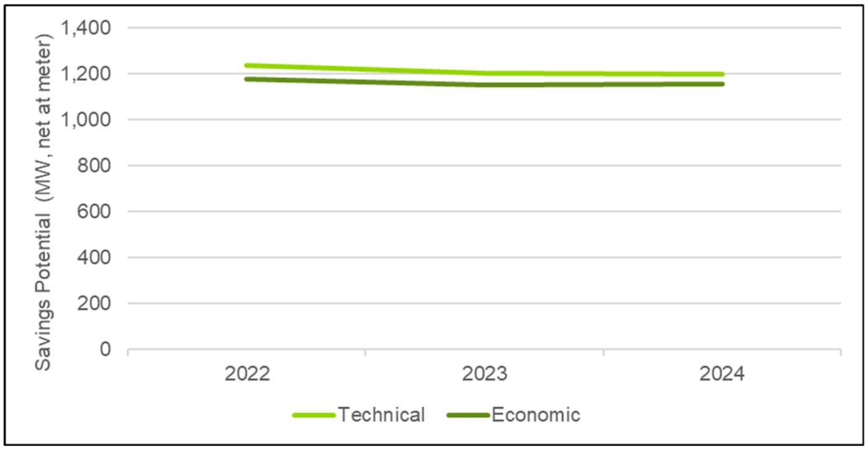
Source: Guidehouse analysis

Figure ES-3. EE Lifetime Achievable Potential Electricity Incremental Annual Savings (GWh, Net at Meter)



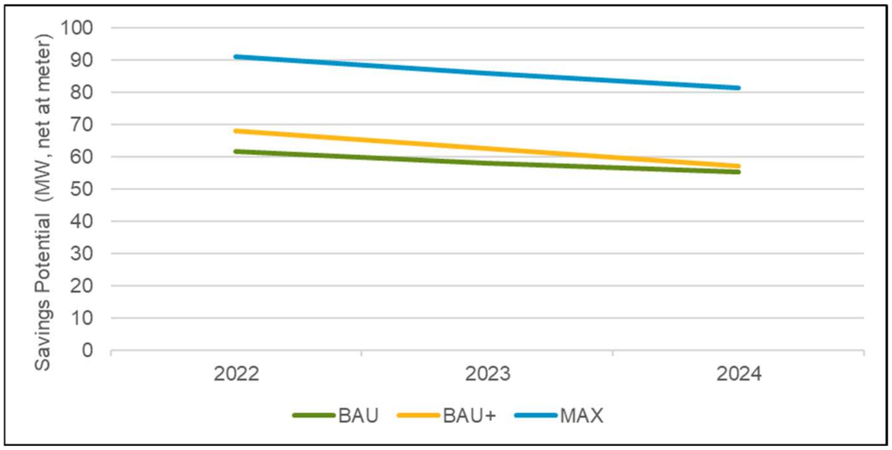
Source: Guidehouse analysis

Figure ES-4. Technical and Economic Potential Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

Figure ES-5. EE Achievable Potential Summer Peak Passive Demand Incremental Annual Savings (MW, Net at Meter)



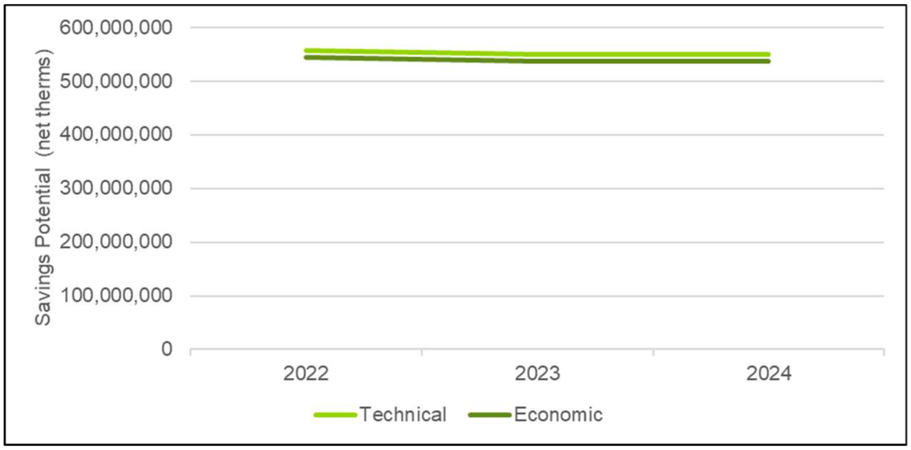
Source: Guidehouse analysis

The total net technical and economic natural gas savings potential are shown in Figure ES-6. Similar to the electricity results, technical and economic savings remain relatively flat over the study horizon and are close together.

Figure ES-7 presents net incremental achievable natural gas results for three achievable potential scenarios: (1) MAX, (2) BAU+, and (3) BAU case over the 3-year period. Achievable gas potential is rising for each scenario throughout the study period.

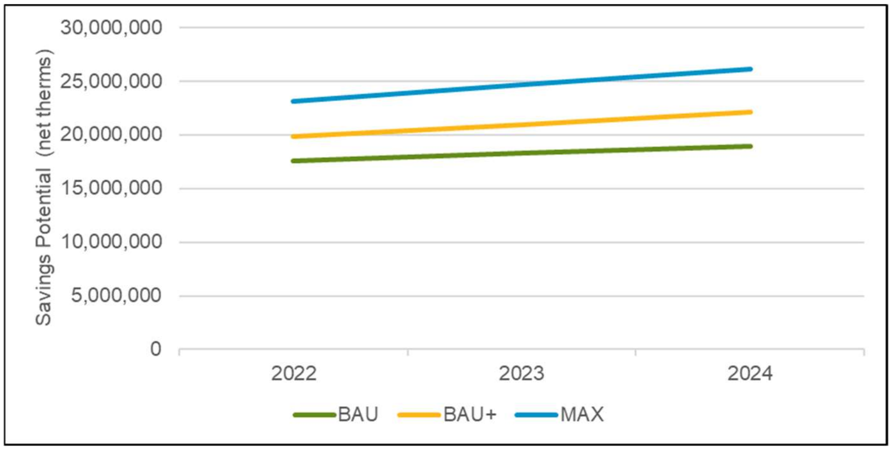
Growth in natural gas potential is largely driven by steady increases in residential and commercial hot water end uses potential. This outweighs the saturation of commercial and industrial custom potential that shows a steady decline throughout the study period. Figure ES-8 shows the net lifetime incremental annual natural gas potential results for the three achievable potential scenarios. Lifetime savings trend are similar the first-year annual indicating that the measure mix and weighted average lifetime of portfolio measures does not change dramatically throughout the study period.

Figure ES-6. EE Technical and Economic Potential Natural Gas Savings (Net therms)



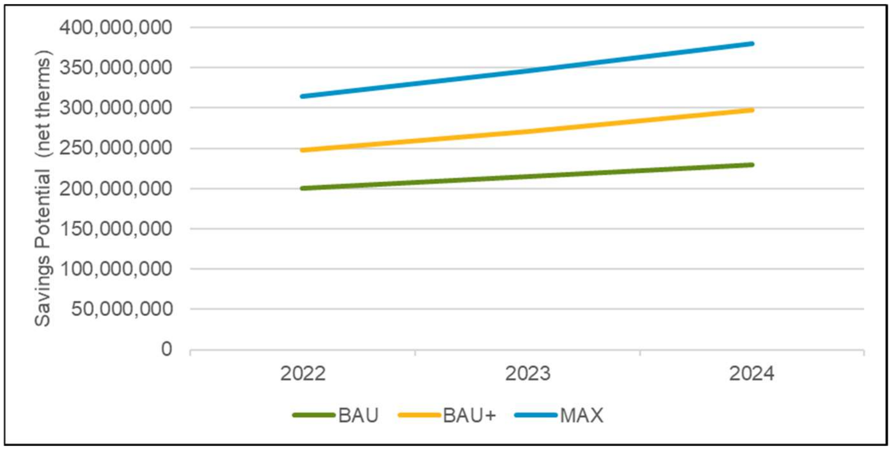
Source: Guidehouse analysis

Figure ES-7. EE Achievable Potential Natural Gas Incremental Annual Savings (Net therms)



Source: Guidehouse analysis

Figure ES-8. EE Lifetime Achievable Potential Natural Gas Incremental Savings (Net therms)



Source: Guidehouse analysis

Table ES- 1. Summary Energy Efficiency BAU Achievable Potential, 2022-2024Table ES- 1, Table ES- 2, and Table ES- 3 below summarize the EE potential for each of the three scenarios, for each year of the analysis and in total over the 3-year period, by sector and fuel.

Table ES- 1. Summary Energy Efficiency BAU Achievable Potential, 2022-2024

Incremental	Electricity	Summer Peak Electric Demand	Natural Gas	Propane	Fuel Oil
Annual Net BAU Scenario	MWh	MW	Therms	MMBtu	MMBtu
Residential Sector					
2022	125,601	20.73	11,793,655	260,779	19,318
2023	132,705	21.78	12,726,842	301,036	23,410
2024	139,718	22.93	13,695,535	335,592	27,611
Total	398,024	65.44	38,216,032	897,408	70,339
Commercial & Industrial Sector					
2022	241,758	40.84	5,784,105	433	627
2023	219,670	36.18	5,556,680	484	771
2024	200,553	32.22	5,261,190	508	927
Total	661,981	109.25	16,601,976	1,425	2,324
Portfolio Total					
2022	367,359	61.57	17,577,760	261,213	19,944
2023	352,375	57.96	18,283,523	301,520	24,181
2024	340,271	55.15	18,956,725	336,100	28,538
Total	1,060,005	174.68	54,818,008	898,833	72,663

Source: Guidehouse analysis

Table ES- 2. Summary Energy Efficiency BAU+ Achievable Potential, 2022-2024

Incremental	Electricity	Summer Peak Electric Demand	Natural Gas	Propane	Fuel Oil
Annual Net BAU+ Scenario	MWh	MW	Therms	MMBtu	MMBtu
Residential Sector					
2022	128,001	21.08	14,015,726	336,542	23,180
2023	135,719	22.17	15,459,412	385,697	27,976
2024	143,265	23.39	16,964,952	429,555	32,970
Total	406,985	66.64	46,440,090	1,151,795	84,126
Commercial & Industrial Sector					
2022	280,921	47.04	5,777,674	433	738
2023	249,112	40.35	5,453,555	484	912
2024	216,640	33.79	5,150,155	508	1,110
Total	746,673	121.18	16,381,384	1,425	2,761
Portfolio Total					
2022	408,922	68.12	19,793,400	336,976	23,919
2023	384,831	62.53	20,912,967	386,181	28,888
2024	359,905	57.17	22,115,107	430,063	34,080
Total	1,153,658	187.82	62,821,474	1,153,220	86,887

Source: Guidehouse analysis

Table ES- 3. Summary Energy Efficiency MAX Achievable Potential, 2022-2024

Incremental Annual Net MAX Scenario	Electricity MWh	Summer Peak Electric Demand MW	Natural Gas Therms	Propane MMBtu	Fuel Oil MMBtu
Residential Sector					
2022	142,683	38.01	15,802,102	410,947	30,558
2023	152,771	41.25	17,668,900	468,784	36,199
2024	162,998	45.40	19,570,669	520,850	41,827
Total	458,452	124.66	53,041,671	1,400,581	108,585
Commercial & Industrial Sector					
2022	317,434	53.00	7,303,816	433	800
2023	278,743	44.56	6,968,292	484	987
2024	237,149	36.02	6,588,691	508	1,208
Total	833,326	133.58	20,860,799	1,425	2,995
Portfolio Total					
2022	460,117	91.01	23,105,918	411,381	31,358
2023	431,514	85.81	24,637,193	469,267	37,186
2024	400,147	81.42	26,159,359	521,357	43,035
Total	1,291,778	258.24	73,902,470	1,402,006	111,579

Source: Guidehouse analysis

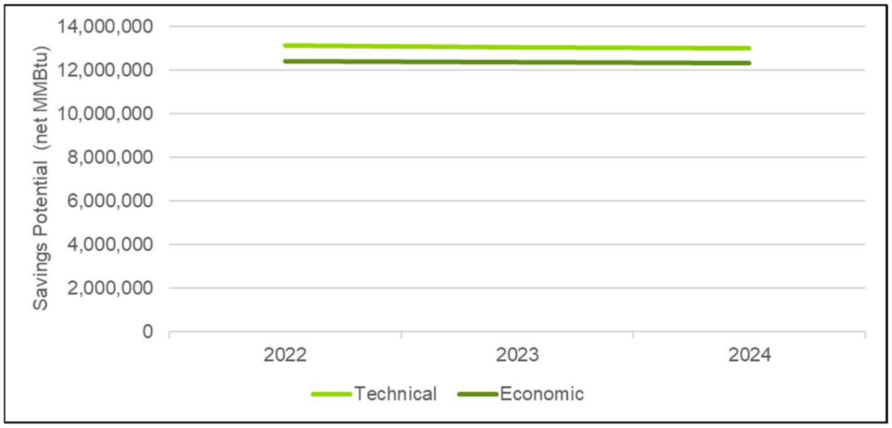
EO Potential Results

Figure ES-9 provides the net technical and economic energy optimization (EO) potential for propane for National Grid in Massachusetts. These technical potential savings are due to the inclusion of fuel-switching measures, allowing a large portion of HVAC load to be technically removed. Propane energy optimization measures are largely cost-effective from a TRC perspective. Adoption of these energy optimization measures will decrease fossil fuel consumption but result in an increase in electricity consumption in National Grid's service territory.

Figure ES-10 shows the net annual incremental achievable potential results for propane for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. Achievable potential is increasing for each scenario throughout the study period.

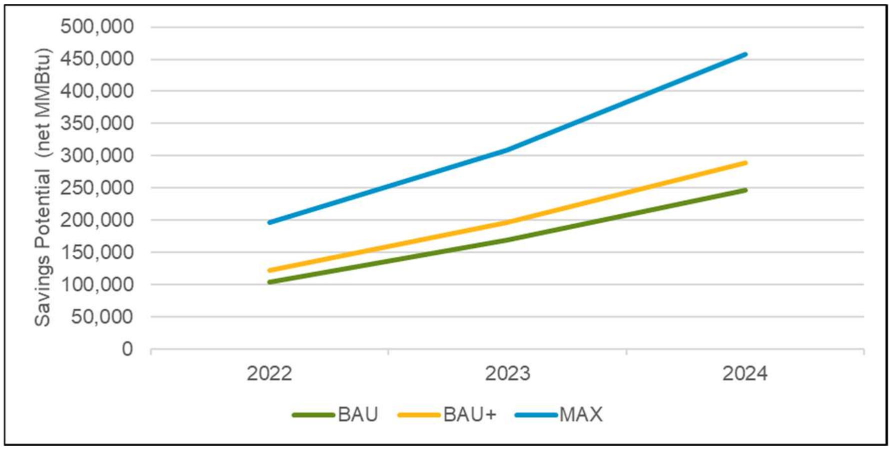
Figure ES-11 shows the net lifetime incremental achievable potential results for propane for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. It mirrors the trajectory of annual EO propane potential.

Figure ES-9. EO Technical and Economic Potential Propane Savings (Net MMBtu)



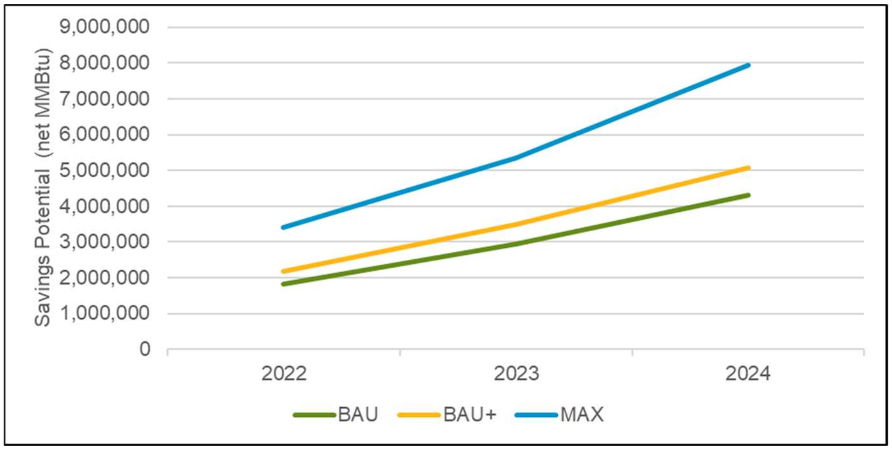
Source: Guidehouse analysis

Figure ES-10. EO Achievable Potential Propane Incremental Annual Savings (Net MMBtu)



Source: Guidehouse analysis

Figure ES-11. EO Lifetime Achievable Potential Propane Incremental Savings (Net MMBtu)

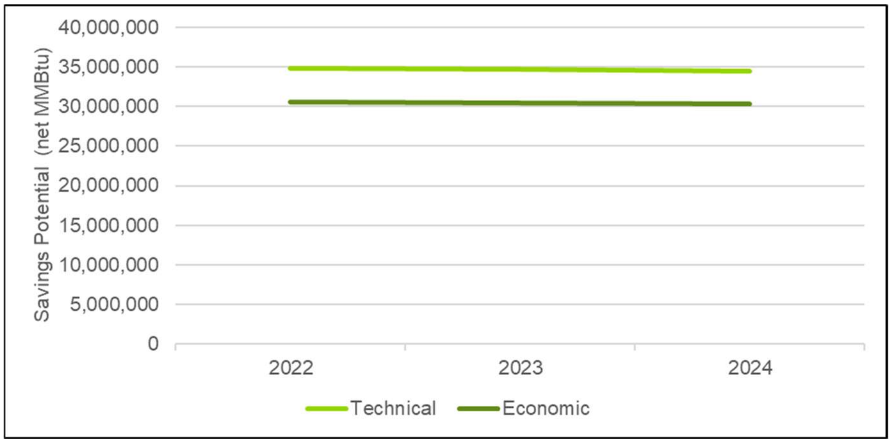


Source: Guidehouse analysis

Figure ES-12 provides the net technical and economic energy optimization (EO) potential for fuel oil for National Grid in Massachusetts. These technical potential savings are due to the inclusion of fuel-switching measures, allowing a large portion of HVAC load to be technically removed. Fuel oil energy optimization measures are largely cost-effective from a TRC perspective. Adoption of these energy optimization measures will decrease fossil fuel consumption but result in an increase in electricity consumption in National Grid's service territory.

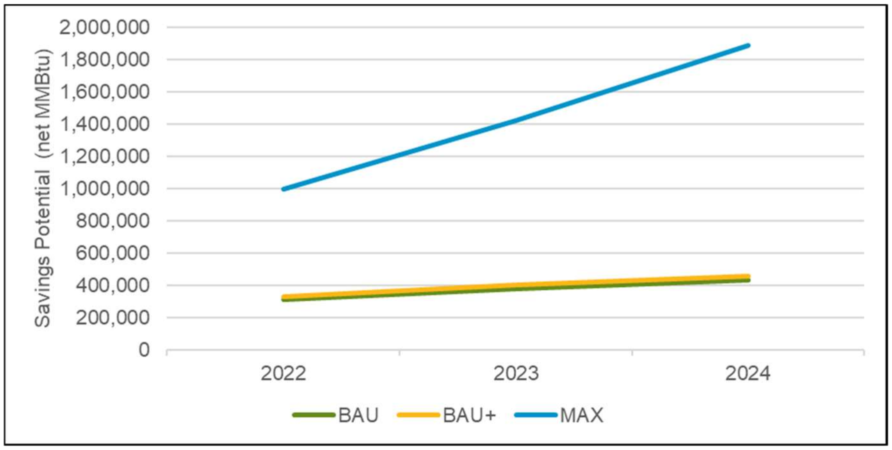
Figure ES-13 shows the net annual incremental achievable potential results for fuel oil for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. Achievable potential is increasing for each scenario throughout the study period. The BAU and BAU+ case show similar potentials. This indicates that customers are not sensitive to changes in incentive levels between these two cases. However, the increase in incentives to 100% of incremental costs in the MAX potential shows a significant impact on achievable savings potential. Figure ES-14 shows the net lifetime incremental achievable potential results for fuel oil for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. It mirrors the trajectory of annual EO fuel oil potential.

Figure ES-12. EO Technical and Economic Potential Fuel Oil Savings (Net MMBtu)



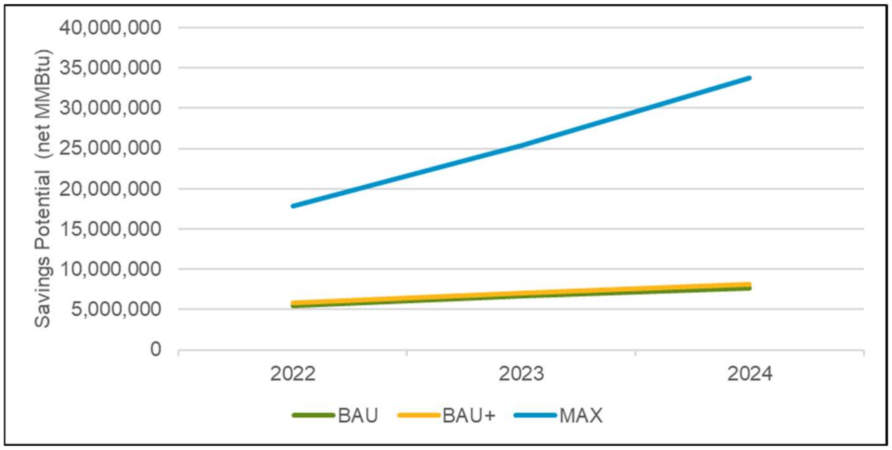
Source: Guidehouse analysis

Figure ES-13. EO Achievable Potential Fuel Oil Incremental Annual Savings (Net MMBtu)



Source: Guidehouse analysis

Figure ES-14. EO Lifetime Achievable Potential Fuel Oil Incremental Savings (Net MMBtu)



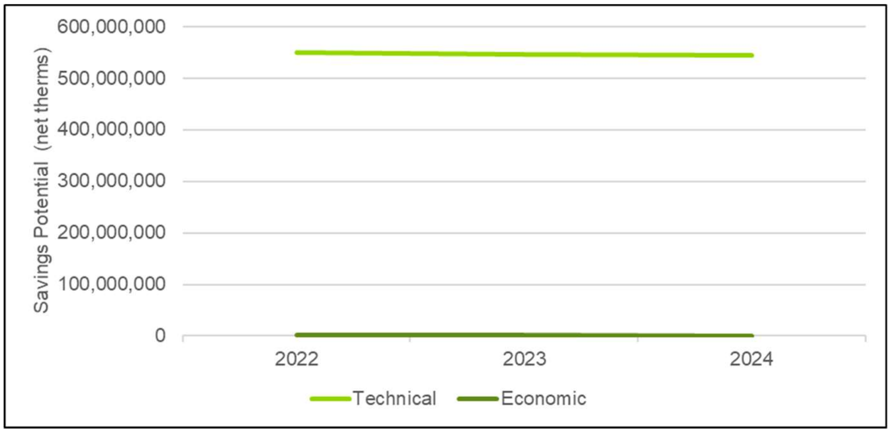
Source: Guidehouse analysis

Figure ES-15 provides the net technical and economic energy optimization (EO) potential for natural gas for National Grid in Massachusetts. These technical potential savings are due to the inclusion of fuel-switching measures, allowing a large portion of HVAC load to be technically removed. Economic potential is far lower than technical potential for natural gas energy optimization measures, indicating that they are largely not cost-effective from a TRC perspective. Adoption of these energy optimization measures will decrease fossil fuel consumption but result in an increase in electricity consumption in National Grid's service territory.

Figure ES-16 shows the net annual incremental achievable potential results for natural gas for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. Each scenario shows the same potential. This is indicative of low customer sensitivity to incentives. The poor customer economics of reducing gas bills and increasing electric bills leads to these results.

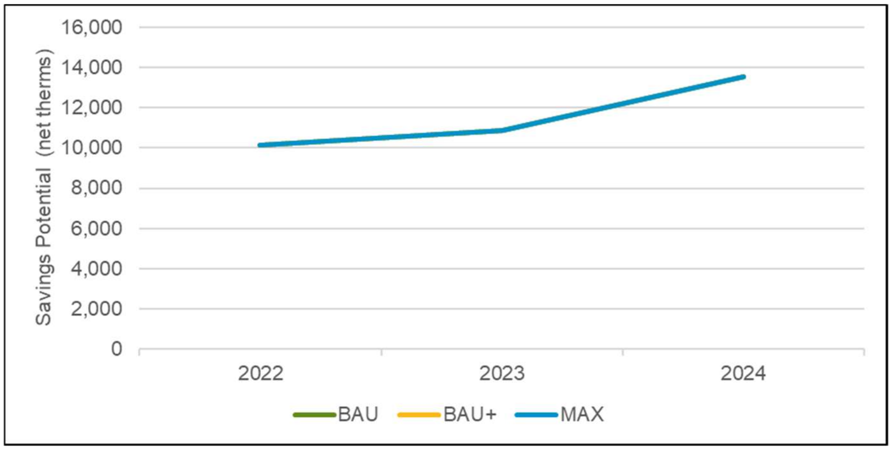
Figure ES-17 shows the net lifetime incremental achievable potential results for natural gas for the three achievable potential scenarios presented: (1) MAX, (2) BAU+ case, and (3) BAU case. It mirrors the trajectory of annual EO fuel oil potential.

Figure ES-15. EO Technical and Economic Potential Natural Gas Savings (Net MMBtu)



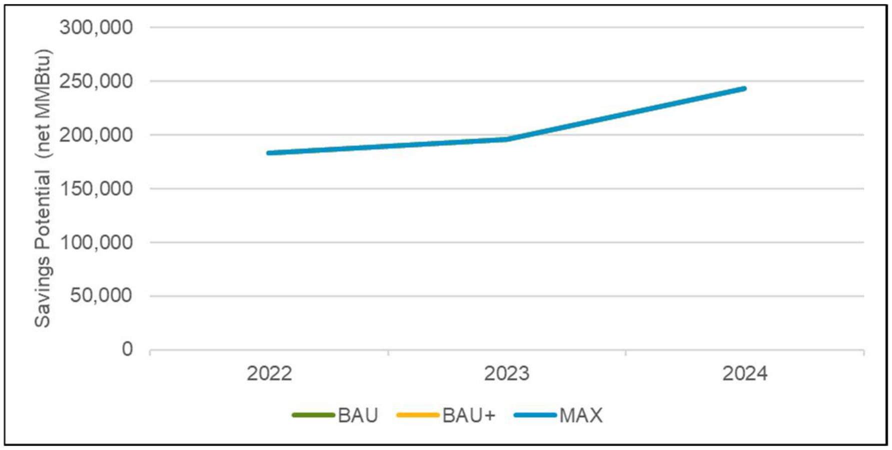
Source: Guidehouse analysis

Figure ES-16. EO Achievable Potential Natural Gas Incremental Annual Savings (Net MMBtu)



Source: Guidehouse analysis

Figure ES-17. EO Lifetime Achievable Potential Natural Gas Incremental Savings (Net MMBtu)



Source: Guidehouse analysis

Table ES- 4, Table ES- 5, and Table ES- 6 below summarize the EO potential for each of the three scenarios, for each year of the analysis and in total over the 3-year period, by sector and fuel.

Table ES- 4. Summary Energy Optimization BAU Achievable Potential, 2022-2024

Incremental	Electricity	Summer Peak Electric Demand	Natural Gas	Propane	Fuel Oil
Annual Net BAU Scenario	**MWh**	**MW**	**Therms**	**MMBtu**	**MMBtu**
Residential Sector					
2022	-26,327	1.05	20,303	281,015	83,773
2023	-35,246	1.29	21,759	344,496	146,878
2024	-44,135	0.60	27,055	395,896	223,205
Total	-105,708	2.94	69,117	1,021,406	453,856
Commercial & Industrial Sector					
2022	-3	0.00	0	32,442	20,658
2023	-3	0.00	0	34,171	22,204
2024	-3	0.00	0	35,173	22,902
Total	-8	0.00	0	101,785	65,764
Portfolio Total					
2022	-26,329	1.05	20,303	313,457	104,431
2023	-35,249	1.29	21,759	378,667	169,082
2024	-44,138	0.60	27,055	431,068	246,108
Total	-105,716	2.94	69,117	1,123,192	519,620

Source: Guidehouse analysis

Table ES- 5. Summary Energy Optimization BAU+ Achievable Potential, 2022-2024

Incremental	Electricity	Summer Peak Electric Demand	Natural Gas	Propane	Fuel Oil
Annual Net BAU+ Scenario	MWh	MW	Therms	MMBtu	MMBtu
Residential Sector					
2022	-28,725	1.10	20,303	297,936	100,433
2023	-38,800	1.51	21,759	368,326	174,005
2024	-49,013	0.98	27,055	423,565	265,362
Total	-116,539	3.59	69,117	1,089,827	539,800
Commercial & Industrial Sector					
2022	-3	0.00	0	32,442	21,843
2023	-3	0.00	0	34,171	23,255
2024	-3	0.00	0	35,173	23,914
Total	-8	0.00	0	101,786	69,012
Portfolio Total					
2022	-28,728	1.10	20,303	330,379	122,276
2023	-38,803	1.51	21,759	402,497	197,260
2024	-49,016	0.98	27,055	458,738	289,277
Total	-116,547	3.59	69,117	1,191,614	608,813

Source: Guidehouse analysis

Table ES- 6. Summary Energy Optimization MAX Achievable Potential, 2022-2024

Incremental	Electricity	Summer Peak Electric Demand	Natural Gas	Propane	Fuel Oil
Annual Net MAX Scenario	**MWh**	**MW**	**Therms**	**MMBtu**	**MMBtu**
Residential Sector					
2022	-81,812	12.40	20,303	958,729	166,879
2023	-120,563	19.32	21,759	1,384,043	277,228
2024	-164,612	26.35	27,055	1,848,268	424,649
Total	-366,987	58.07	69,117	4,191,040	868,756
Commercial & Industrial Sector					
2022	-3	0.00	0	37,528	30,555
2023	-3	0.00	0	39,591	32,110
2024	-3	0.00	0	40,798	32,913
Total	-9	0.00	0	117,917	95,578
Portfolio Total					
2022	-81,815	12.40	20,303	996,258	197,433
2023	-120,566	19.32	21,759	1,423,634	309,338
2024	-164,615	26.35	27,055	1,889,066	457,562
Total	-366,996	58.07	69,117	4,308,957	964,334

Source: Guidehouse analysis

DR Potential and Cost Results

The DR options included in the analysis are representative of commonly deployed and emerging DR programs in the industry and are listed in Table ES- 7.

Table ES- 7. Summary of DR Options Considered in Study

DR Option	Brief Description	Eligible Customer Classes	End Use
Direct Load Control (DLC)	Control of electric loads by a thermostat and/or load control switch.	Residential Small C&I Medium C&I	Central Air Conditioning (AC)[3]
			Room AC[4]
			Heating, Ventilation, and Air Conditioning (HVAC)[5]
			Water Heating
			Pool Pump
			Washer
			Dryer
			Dehumidifier
Commercial and Industrial (C&I) Curtailment	Firm capacity reduction commitment. $/kW payment based on delivered capacity, administered through third party aggregators.	Large C&I	HVAC
			Lighting
			Water Heating
			Refrigeration
			Total Facility
Bring Your Own Device (BYOD)-Battery	Use of batteries for load shifting and dispatching to the grid.	Residential Small C&I Medium C&I Large C&I	Batteries
Electric Vehicle (EV) Managed Charging	Charging modulation to reduce EV demand during peak periods.	EV	EV

Source: Guidehouse

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[3] Central AC and Room AC apply to residential. For small commercial and industrial, Guidehouse refers to the end use load type as HVAC.

[4] *Ibid.*

[5] *Ibid.*

Table ES- 8 shows the Net Present Value (NPV) of TRC benefits, costs, and TRC benefit-cost ratios calculated for each DR option over 6-year program life (2022-2027). This calculation includes costs and benefits for only cost-effective sub-options considered in the study.

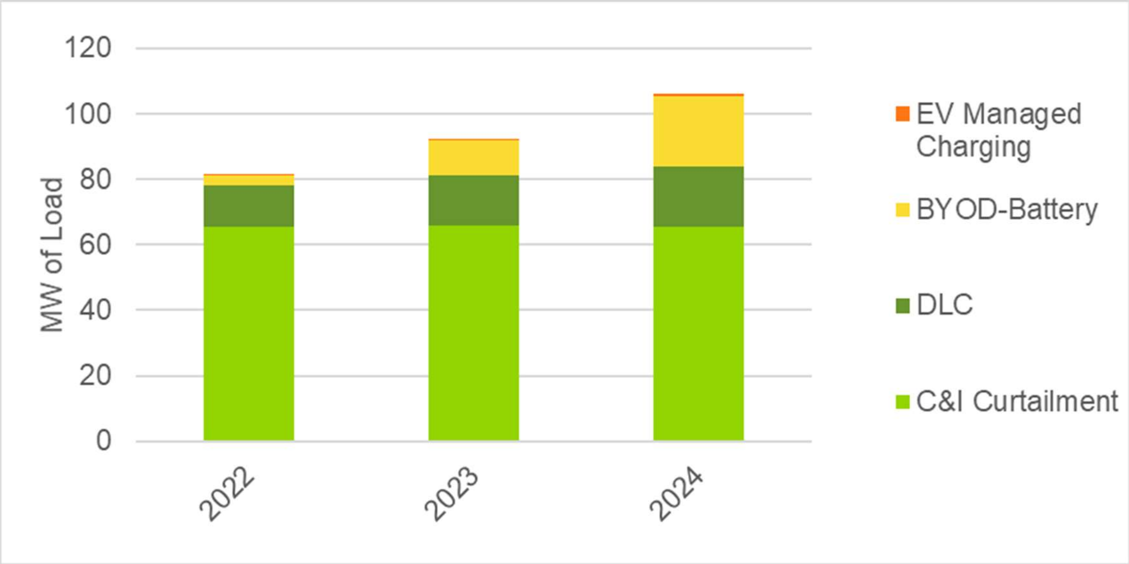
Table ES- 8. DR Achievable BAU Case, Benefit-Cost Assessment by Option

DR Option	NPV TRC Benefits (2022-2027)	NPV TRC Costs (2022-2027)	TRC Benefit-Cost Ratio
DLC	$21.6M	$9.3M	2.3
BYOD-Battery	$36.5M	$29.4M	1.2
EV Managed Charging	$2.1M	$1.7M	1.2
C&I Curtailment	$56.1M	$16.8M	3.3

Source: Guidehouse analysis

Figure ES-18 shows the MW breakdown of the DR achievable potential by cost-effective DR option and sector for the BAU scenario. Residential BAU DR potential is estimated to grow from 14 MW in 2022 to 34 MW in 2024. DLC initially dominates residential potential, however, batteries are expected to comprise a significant share of the residential potential in the later years. Potential for C&I is primarily driven by C&I Curtailment. C&I potential is expected to grow slightly, primarily due to the increase in DLC and battery potential. The C&I Curtailment program is an established program, so enrollment and potential are expected to remain steady over the study period.

Figure ES-18. DR Achievable Potential for Cost-Effective Options, BAU Scenario

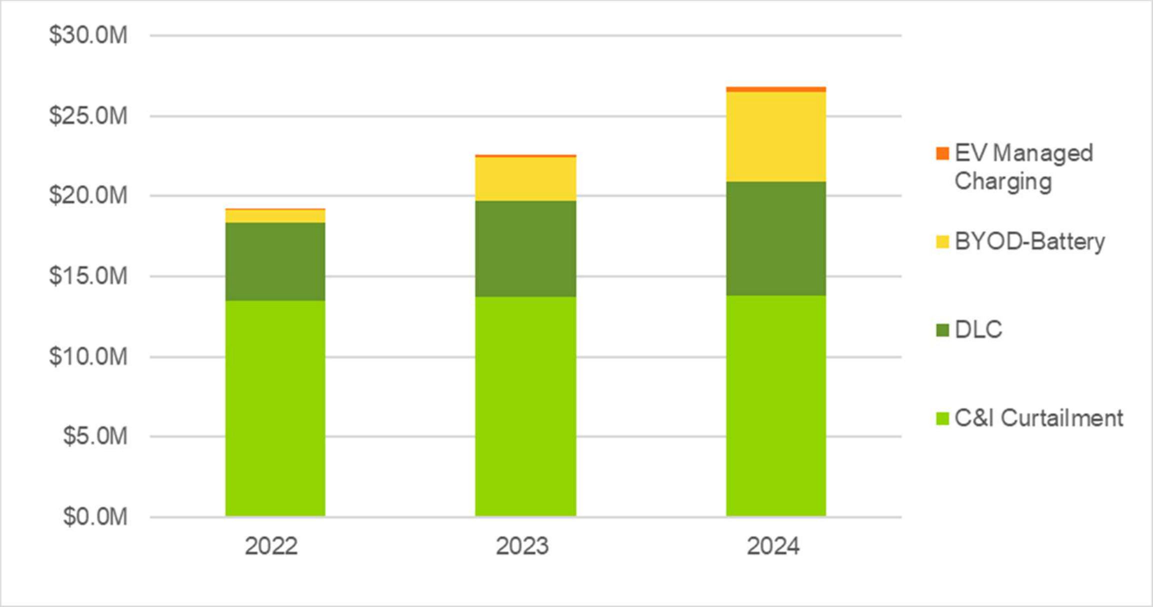


Source: Guidehouse analysis

DR Annual Program Costs

Figure ES-19 summarizes the annual program costs for cost-effective DR options in the BAU case. Most of the program costs are attributable to incentives, which scale by participants or demand reduction, so the total program costs scale with potential.

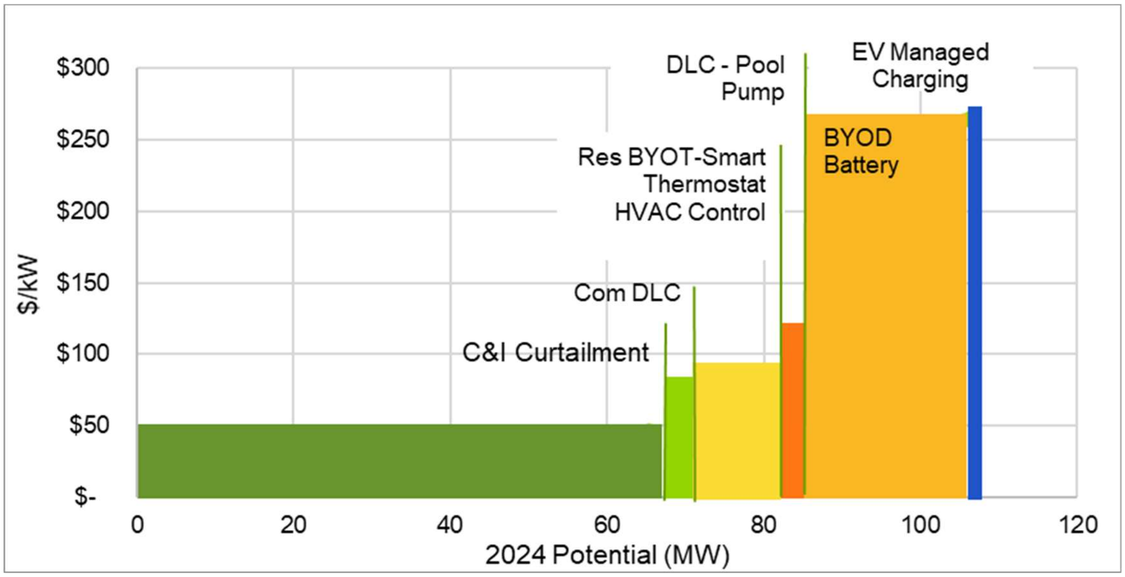
Figure ES-19. DR Annual Program Costs by Option for Cost-Effective DR Options, BAU Scenario



Source: Guidehouse analysis

Figure ES-20 shows the supply curve for cost-effective DR sub-options only. The x-axis represents achievable potential in 2024 and the y-axis represents the levelized cost ($/kW-yr.) associated with realizing each potential increment. The C&I Curtailment sub-option from large C&I customers has highest potential at least cost. Other significant contributors are BYOD-Battery and Residential BYOT options at higher costs.

Figure ES-20. Supply Curve for Cost-Effective DR Sub-Options



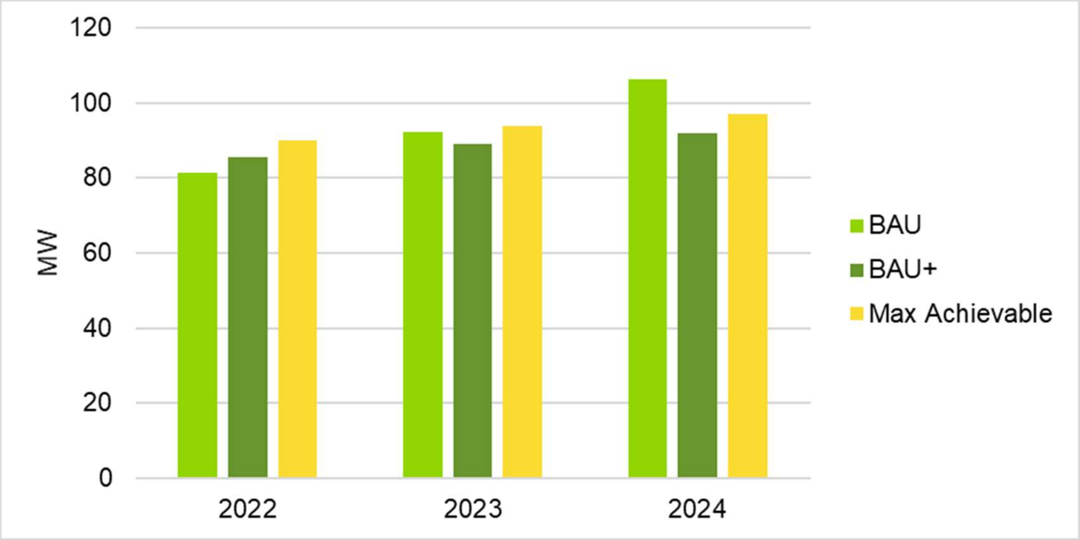
Source: Guidehouse analysis

Demand Response Scenario Analysis

For the BAU+ and MAX cases, Guidehouse adjusted assumed participation levels, incentive amounts, baseline peak, and equipment saturation to determine the impacts on the DR achievable potential. The peak demand forecasts varied by case, as these were tied to the different demand reduction scenario impacts from the energy efficiency potential analysis. The same three scenarios from the EE analysis were considered in the baseline summer peak projections: (1) BAU, (2) BAU+, and (3) MAX.

Figure ES-21 shows achievable MW potential for cost-effective DR options only. The residential BAU+ and MAX scenarios show lower potential compared to the BAU scenario because EV managed charging and battery control are not cost-effective in these two scenarios, which means these are not included in the achievable potential estimates.

Figure ES-21. DR All Scenarios, Cost-Effective Achievable Potential



Source: Guidehouse analysis

Table ES- 9 shows the DR portfolio costs over the study period and across scenarios. Both C&I and residential costs follow the trend for the demand reduction potential. For C&I, costs are higher in for the BAU+ and MAX scenarios due to higher incentives paid to customers and higher enrollment. Residential costs follow the same trend as DR potential forecasts, with the BAU case having the highest costs.

Table ES- 9. DR Portfolio Costs

DR Portfolio Cost	BAU	BAU+	MAX
2022	$5.2M	$6.4M	$8.5M
2023	$7.5M	$6.8M	$9.1M
2024	$10.7M	$7.2M	$9.7M

Source: Guidehouse analysis

Conclusions

This study has resulted in updated, expanded, and improved information on the Massachusetts customer base and the potential for energy and demand reductions possible through energy efficiency, electrification, and demand response programs and initiatives. While much energy efficiency (and demand response) potential remains, there are unique challenges in Massachusetts in realizing this potential over the next 3 years. The potential study incorporates these real factors into the analysis by utilizing MA baseline study and historic program data to accurately reflect efficient measure saturations, as well as incorporating emerging technologies into the measure mix. Based on the assumptions made, the analyses conducted and results presented, these are appropriate estimates of potential.

Energy Efficiency

- **Near-Term Electricity Savings:** The majority of near-term annual savings are from the Residential Behavior and C&I Custom Large C&I and Lighting end uses. Residential Home Energy Report ranks as the highest electricity-saving annual achievable potential measure for the Residential sector, while custom energy efficiency leads C&I.

- **Near-Term Summer Peak Passive Demand Savings:** The majority of near-term summer peak passive demand savings measures come from the Residential Behavior and Residential HVAC, and C&I Lighting end uses. Residential Home Energy Report ranks as the highest demand-saving achievable potential measure for the Residential sector. Custom energy efficiency leads the C&I sector.

- **Key Drivers:** Major differences of energy efficiency potential compared to *Energy Efficiency Potential Study for 2019-2021 National Grid Massachusetts, Final Report*,[6] (the "2018 Potential Study") potential estimates were also influenced by Residential and C&I lighting saturation and rising measure costs, as well as lower avoided costs, particularly for natural gas and electric capacity.

- **Achieving Potential:** While this report shows that much EE potential remains, there are unique challenges in Massachusetts in realizing this potential over the next 3 years. Assumptions adopted in this study represent these factors and National Grid should be aware of the factors as it develops its plans.

    - **Prior Energy Efficiency Success:** National Grid has effectively implemented energy efficiency programs in Massachusetts for decades, often exceeding goals in terms of the amount of savings achieved. As greater levels of energy efficiency are implemented in Massachusetts and market saturation increases, it may become more challenging to harvest additional savings represented in the energy efficiency potential.

    - **Significant Energy Efficiency Measure Saturation and Low Net-to-Gross Ratios:** These reduce the available savings potential, particularly for efficient lighting.

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[6] Energy Efficiency Potential Study for 2019-2021 National Grid Massachusetts, Final Report, September 6, 2018

  - **Codes and Standards:** The challenge of continuing to capture savings from energy efficiency programs within an increasingly saturated market is exacerbated by tightening codes and standards, particularly as a result of federal lighting standards and Massachusetts state and local building energy codes adopted prior to February 2021.[7]

  - **Changing Energy Efficiency Measure Costs:** Changes to the portfolio measure mix that occur due to market saturation and codes and standards changes drive incremental costs upward for many measures. More complex measures, such as advanced lighting design, luminaire level lighting controls (LLLCs) and networked/connected lighting controls, may require a more sophisticated workforce, additional training, as well as increased installation and configuration time, compared to static non-controllable lighting measures. This could result in increased incremental costs for these types of measures.

  - **Investment Level:** National Grid should carefully consider whether the significantly higher levels of investment in electricity and natural gas programs projected for the maximum achievable case are attainable, particularly whether mobilizing a significant increase in direct and indirect services to meet the increased level of demand for efficiency upgrades can be reasonably met.

Electrification

- **Residential HVAC Energy Optimization:** EO savings potential is dominated by HVAC technologies. High technical and economic potential are attributed to HVAC energy optimization measures that completely or partially remove the fossil-fueled end-use load from a home. Although still a significant portion of potential, achievable results indicate that efficient electrification technologies, such as air source and mini-split heat pumps, are the primary drivers of future HVAC EO savings potential but are a fraction of technical and economic potential. Therefore, although energy optimization measures present a great technical opportunity for MMBtu savings, there are significant market barriers to customer adoption.

- **Natural Gas Electrification:** Electrification potential of natural gas-fueled heating is influenced by the current low prices of natural gas. In many cases, this yields unfavorable customer economics and low adoption rates for this form of electrification.

Demand Response

- **Growth in DR Potential:** Total DR Potential in National Grid's Massachusetts service territory is estimated to grow by 30% over 2022-2024. This increase in savings is primarily driven by steady growth in battery adoption and utilization for DR dispatch, primarily from residential customers, over the 3-year timeframe.

- **Large C&I Contribution in Total Potential:** Large C&I customers have the highest share in the total potential. The C&I Curtailment option represents the DR potential from these customers and has the highest share in total potential and is the least cost option. This share declines over time with greater contribution from residential DR, primarily

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[7] Massachusetts appliance standards changes enacted in March 2021 will be addressed in a forthcoming addendum to this study.

from batteries. The C&I Curtailment potential remains more or less steady over 2022-2024 timeframe.

- **Battery Potential Growth:** Due to the high incentives for battery participation in DR, potential from battery dispatch is estimated to grow significantly from 3.2 MW in 2022 to 21.4 MW in 2024 primarily in residential. Batteries are forecasted to contribute over half of the demand reduction potential in the residential sector in 2024 and a 20% contribution in total DR potential in 2024.

- **Residential Thermostat Program Growth and Contribution:** The potential from residential HVAC control via smart thermostats (BYOT program) is estimated to grow by 14% over 2022-2024 as the program progressively scales up over time. It maintains a 10%-12% share in total potential estimates.

- **Cost-Effectiveness across Scenarios:** The C&I Curtailment option, which is the largest contributor at the lowest cost in the BAU scenario, remains cost-effective across in the other two scenarios (BAU+ and MAX). Similarly, the residential smart thermostat option remains cost-effective across all scenarios. However, the battery dispatch option and the EV Managed Charging option are not cost-effective in the other two scenarios, leading to a decline in total potential in BAU+ and MAX scenarios in relation to the BAU scenario.

- **Comparison with Prior Study:** DR potential estimates increased over 2018 estimates within the BAU scenario because of the inclusion of new DR measures, namely behind-the-meter battery control and managed EV charging. However, these measures are borderline cost-effective (these are not in the BAU+ or maximum achievable scenarios), and it will be important for National Grid to continue to monitor actual demonstration project performance.

General

- A small amount of potential identified in this study is due to new or emerging measures and is contingent on the assumptions made in modeling that potential. These assumptions cannot be tied to historical achievements and may be less well researched or documented than those for more established measures, which predominate the estimates of potential in this study. Should new or emerging measures modeled in this study be adopted as part of program goals in 2022-2024, Guidehouse encourages National Grid to pay special attention to program design for programs incorporating these new measures so that modeled savings can be realized.

1. Introduction

This section provides an overview of the potential study, including background and study goals, a discussion of the report's organization and key caveats and limitations of the potential study. Guidehouse's best-in-class modeling tools ensure the rigor, validity and sensibility required of the DSM Potential Study results. Our potential study models have been validated in numerous US states, and our DSM potential studies and models have been quoted by ACEEE as being "robust and transparent… [and] their methodology for forecasting participation is industry standard best-practice."[8]

As is typical in the development of such studies, Guidehouse worked collaboratively with National Grid and its stakeholders to ensure the study, to the fullest extent, best reflects current Massachusetts market conditions. Guidehouse received considerable guidance and feedback from National Grid staff, particularly in the development of global input assumptions, measure characterizations, and historical portfolio performance calibration. We also carefully considered, and as appropriate, were responsive to stakeholders' input, incorporating their feedback into the analysis approach.

1.1 Context and Study Goals

Guidehouse was retained by National Grid to develop an estimate of the potential for electric energy efficiency (EE), energy optimization (EO), and demand response (DR) in Massachusetts during the 3-year timeframe covering the period 2022 to 2024. Guidehouse worked with National Grid to develop information on current levels and patterns of energy use in Massachusetts, characterize potential measures which could be implemented to increase energy efficiency, electrification, and demand response through DSM programs in the state, and develop estimates of EE, EO, and DR potential. The study data and analysis will be used to inform energy efficiency and demand response program design for National Grid in Massachusetts. Table 1-1 summarizes the various elements of the project scope.

Table 1-1. Summary of Project Scope

Element	Dimensions
Forms of Energy	Electricity, Natural Gas, Propane, and Fuel Oil
Type of Potential	Energy Efficiency, Energy Optimization, and Demand Response Technical, Economic, Achievable
Sectors	Residential, and Commercial and Industrial (C&I)
Climate	Single Weather Zone
Time Horizon	2022-2024 (3 years)

1.2 Interactive Review Process

This study began in May 2020 and encompassed four phases; each involved interactive engagement and review, which is described as follows.

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[8] ACEEE study titled "Cracking the TEAPOT: Technical, Economic, and Achievable Energy Efficiency Potential Studies," August 2014.

- **Measure list development.** The measure list used was developed in concert with the two other potential studies being done in parallel for the other electric and gas Program Administrators (PA) in Massachusetts. Guidehouse recommended a list of measures and made modifications to it in response to comments by National Grid. The National Grid measure list was shared with the other Program Administrators to develop a common PA measure list. Ultimately, this list was shared with the consultants to the Massachusetts Energy Efficiency Advisory Council (EEAC Consultants) and a final measure list was accepted.
- **Measure characterization.** Following this process, the individual Potential Studies began measure characterization. Consistency across the studies was established by conducting a comparison of measure input assumptions for several (approximately 25) measures[9] anticipated to contribute a large portion of savings. This resulted in the adjustment of input assumptions for some measures.
- **National Grid review of results.** Potential model results were reviewed with National Grid at several stages. Key reviews occurred after measure characterization and model calibration, with cross-Program Administrator comparison of high-level results, and when updated avoided costs from the 2021 Avoided Energy Supply Component Study were available.
- **External party review of results.** The stakeholder engagement process and level of participation in Massachusetts was typical of what Guidehouse has seen in other jurisdictions. Guidehouse appreciates the thorough review and comments provided by stakeholders, and thanks them for their feedback and participation in the process. National Grid shared draft results with the EEAC Consultants on March 22, 2021. Modifications related to feedback from the consultant review was incorporated into this final report.

1.3 Caveats and Limitations

Several caveats and limitations are associated with the results of this study, as detailed below.

1.3.1 Program Design

The results of this study provide the savings potential for National Grid in Massachusetts and provides insights into how this potential can be translated into program design in key areas. However, this potential study is not intended to provide, nor does it have information on, detailed program designs. Different program designs and delivery mechanisms would inevitably result in different levels of adoption of efficient technologies, which means the output of this study is an estimate what can be achieved under the specific set of assumptions outlined in this study. Program design is typically a separate activity and is outside the scope of this study.

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[9] The measures were in the following sectors and fuels

Residential Electric: Electric Resistance heat to DMSHP, DMSHP, Air Sealing, Heat Pump Water Heaters, Insulation

Residential Gas: Smart Thermostat (gas), Gas Furnace, Gas Boiler

C&I Electric: Air-source heat pump, Heat Pump Water Heaters

C&I Gas: Gas boiler, Boiler reset control

Demand Response: Smart thermostats, C&I curtailment, Battery storage, Pool pumps

Energy Optimization: Oil boilers to DMSHP, Oil Furnace to central HP

1.3.2 Measure Characterization

The scope of this study employed both primary data collection techniques and a variety of secondary data sources for estimates of measure savings, costs and market presence (e.g., saturations and densities). Primary data specific to Massachusetts was used wherever possible. Where Massachusetts-specific data was not available, the best available data was used. This situation and approach did not limit our ability to achieve the study objectives and is consistent with the previous EE and DR potential studies for National Grid in Massachusetts, as well as Guidehouse's experience in other jurisdictions.

Furthermore, the team considers the measure list used in this study to appropriately focus on those technologies likely to have the highest impact on savings potential over the study horizon. However, there is the possibility that unidentified emerging technologies may arise that could increase savings opportunities over the forecast horizon and broader societal changes may affect levels of energy use in ways not anticipated in the study. For some measures, the study assumes the consumption and cost baseline will change in the future due to new codes and standards that have been promulgated but have not yet come into compliance.[10] Assumptions regarding future code and standards changes are documented in the measure characterization sheets for relevant measures. However, this study does not make assumptions about future code and standard changes that have not yet been codified.

Potential studies must make assumptions about the adoption of technologies and options that inevitably come with a degree of uncertainty. While techniques such as use of payback acceptance curves and technology diffusion models are considered to provide reasonable aggregate estimates of savings potential, such techniques (which must be applied to dozens or in some cases hundreds of measures) are limited in their ability to accurately predict adoption for specific measures or in specific customer segments.

For EE and EO,, model calibration steps (e.g., comparing forecast results with past achieved results) seek to ground the forecasts in the real world, but inaccuracies are bound to exist the further one drills into a technology or segment—even if the aggregate results are considered to be reasonable. One reason that aggregate results can in many cases be more reliable than individual technology or segment results is that forecasting inaccuracies at the measure-level will exhibit a pooling effect when aggregated up to the portfolio (whereby positive or negative differences at a finer level of aggregation can help to offset each other in an aggregate result). While more in-depth technology adoption techniques do exist (e.g., discrete choice analysis) to improve the forecast accuracy for any given technology, application of these techniques to the quantity of measures analyzed in studies such as this are not typically warranted, considering the dramatic increase in costs one would have to incur to calibrate a different adoption model for every single measure.

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[10] For example, the U.S. DOE has established a minimum energy consumption standard for residential central air conditioners and heat pumps with a compliance date of January 1, 2023. Source: https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0102 (10 CFR 430.32 (c)(1&5))
The model accounts for this future change to product standards by adjusting the energy efficiency baseline to match the new federal standard and making appropriate adjustments in incremental cost assumptions.

Other measures with modeled known future codes or standards are:

- Res LED Bulb, where standards eliminate savings.
- Res Gas Boiler and Combination Boiler, per 10 CFR 430.32 (e)(2)
- Res Oil Boiler per 10 CFR 430.32 (e)(2)
- C&I Insulation

1.4 Interpreting Results

This report includes a high-level account of savings potential results for National Grid in Massachusetts and focuses largely on aggregated forms of savings potential. EE and EO potentials are estimated at the finest level of granularity, which is at the measure-level within each customer segment. The measure-level data is mapped to the various customer segments and end-use categories to permit a reviewer to easily create custom aggregations. Measure level results are available in the study appendices as noted below. Demand response potentials are estimated using a bottom-up analysis, with primary data from National Grid and relevant secondary sources of information, as documented in the study appendices (noted below).

1.5 Report Organization

The report is organized as follows:

- Section 2 provides an overview of **Global Data** developed and used in the study.
- Section 3 discusses the **Energy Efficiency Measure Characterization**, including key parameters.
- Section 4 presents the **Energy Efficiency Technical Potential Forecast** for energy efficiency measures, including a summary of results by sector and end use**.** This is presented for electricity and natural gas measures.
- Section 5 provides the **Energy Efficiency Economic Potential Results** for energy efficiency measures, including a summary of results by sector and end use**.** This is presented for electricity and natural gas measures.
- Section 6 presents the **Energy Efficiency Market Potential Approaches**, including discussion of equilibrium market share, behavioral measures, investment and incentive strategy, re-participation, and model calibration.
- Section 7 discusses the **Scenario Configuration Approach** for the BAU+ and MAX scenarios.
- Section 8 presents the **Energy Efficiency Achievable Potential Results by Scenario** for energy efficiency measures, including a summary of results by sector, end use, customer segment, and measure, as well as cost-effectiveness tests and investment insights. This is presented for electricity and natural gas measures. Additionally, associated delivered fuel savings are presented by program.
- Section 9 provides the **Energy Optimization Measure Characterization**.
- Section 10 presents the **Energy Optimization Technical Potential Forecast** for energy optimization measures, including a summary of results by sector and end use**.**
- Section 11 provides the **Energy Optimization Economic Potential Results** for energy optimization measures, including a summary of results by sector and end use**.**
- Section 12 presents the **Energy Optimization Market Potential Approaches**, including discussion of measure competition, investment and incentive strategy, re-participation, and model calibration.
- Section 13 presents the **Energy Optimization Achievable Potential Results by Scenario** for energy optimization measures, including a summary of results by sector,

end use, customer segment, and measure, as well as cost-effectiveness tests and investment insights.

- Section 14 presents the **Demand Response Potential Assessment Methodology,** including market characterization, baseline projections, characterization of options, and key assumptions.
- Section 15 provides the **Demand Response Potential and Cost-Effectiveness Results** for the technical and achievable potentials, investment levels, scenario analysis, and discusses snapback effects. Achievable potential results are presented for DR options, sub-options, customer class, and building type for cost-effective DR options.
- Section 16 presents the **Extended Economy Recovery (COVID) Scenario Analysis** and Results
- Section 17 presents the **Conclusions** of the study.

The report also includes the following four appendices:

- Appendix A. National Grid Massachusetts 2022-2024 Potential Study Modeling Methodology
- Appendix B. Energy Efficiency Results File
- Appendix C. Energy Optimization Results File
- Appendix D. Demand Response Results File

2. Global Data

Guidehouse aggregated multiple data sources to simulate many elements of the market conditions in Massachusetts that help to define the potential for energy saving technologies modeled in this study. These inputs include electricity, electric demand, and natural gas sales forecasts, residential household counts, business and industrial building stock, and end-use energy allocations. Together, these inputs are referred to as the global data and help to define the context of the modeled savings potential, and the scope of potential adoption. Guidehouse developed global data for National Grid's electric and natural gas service territories separately. To develop these inputs, Guidehouse prioritized primary data, or data specific to National Grid including:

- National Grid historical and forecasted consumption and demand data
- National Grid residential and C&I accounts tracking data
- National Grid benefit-cost ratio (BCR) calculation model inputs
- Residential (2019) and C&I (2019) end-use (Baseline Study) surveys, and site visits
- National Grid end-use intensity-based forecasts (Load Forecast Models)
- Previous Massachusetts DSM potential studies

Where Massachusetts-specific information was not available, Guidehouse utilized secondary data, including internal Guidehouse data sources. Guidehouse's review of these resources was generally used to support the data sources provided by National Grid and to ensure consistency among National Grid data, Guidehouse's estimates, and publicly available resources.

2.1 Segmentation of Customer Sectors

Guidehouse developed consumption, demand, floorspace, customer counts, fuel splits, and end-use allocations by territory, sector, and customer segment where possible. Where data was not available to estimate these splits, Guidehouse aggregated to the sector level. Guidehouse worked with National Grid to determine an appropriate level of segmentation for each sector.

The segmentation also reflects Guidehouse's modeling approach for representing efficiency measures within the DSMSim™ model. DSMSim models energy efficiency measures at the segment level, and tracks building and equipment stocks for each segment within National Grid's service territory. Differences in fuel choices (i.e., space and water heating market shares), types of equipment used (i.e., use of a furnace or boiler for space heating), and equipment and system efficiency levels are all represented within the model for each segment, as required and as permitted by data availability.

Table 2-1 shows the segmentation used for the Residential and C&I sectors, with additional detail provided for each sector in the following sections.

Table 2-1. Customer Segments by Sector

Residential	Commercial & Industrial	
Single-Family Market Rate	Colleges & Universities	Retail
Single-Family Low-Income	Food Sales	Schools
Multifamily Market Rate	Food Service	Warehouse
Multifamily Low-Income	Healthcare	Fabrication
	Hospital	Food Manufacturing
	Lodging	Heavy Industry
	Office	High Tech Facilities
	Com - Other	Ind - Other
	Public Assembly	Process
		Com - Multifamily[11]

Source: Guidehouse

2.1.1 Residential Sector

Guidehouse divided residential customers into four segments based on the type of residential building occupied, as shown in Table 2-2.

Table 2-2. Description of Residential Segments

Segment	Description
Single-Family Market Rate	Single-family homes with 1 unit
Single-Family Income Eligible	Single-family homes with 1 unit, Income Eligible occupants
Multifamily Market Rate	Apartments, attached housing, 2-3 units
Multifamily Income Eligible	Apartments, attached housing, 2-3 units, Income Eligible occupants

Source: Guidehouse

Guidehouse developed the breakdown of the Residential sector into dwelling types based on National Grid customer data. Table 2-3 shows the stock estimates (in units of households) by housing type. Multifamily buildings with four or more units are included in the C&I building stock in the Com - Multifamily segment.

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[11] Multifamily buildings with more than 4 units.

Table 2-3. Base Year Housing Stocks (Residential Units)

Housing Type	Electric Dwellings	Natural Gas
Single-Family Market Rate	561,674	106,866
Single-Family Income Eligible	588,197	21,810
Multifamily Market Rate	77,638	703,767
Multifamily Income Eligible	88,653	57,001
Total	**1,316,162**	**889,444**

Source: Guidehouse analysis based on National Grid data

2.1.2 C&I Sector

Guidehouse divided the C&I sector into 18 segments. Floorspace and sales forecasts for these segments were aggregated and provided by National Grid based on NAICS code mapping from customer tracking databases.

Guidehouse selected the C&I segments with the goal that the building types within those segments be reasonably similar in terms of electricity use, operating and mechanical systems, and annual operating hours. This approach allowed for consistency in building characteristics within each segment as required by the measure characterization and modeling processes. These segments were mapped to usage and demand data by rate classes and building type descriptions provided by National Grid, allowing for the customer segment level disaggregation in this study. C&I segment floorspace stocks were estimated directly from account forecast data provided by National Grid. Table 2-4 summarizes the resulting floor space estimates developed for each C&I segment for the study's base year, 2019.

Table 2-4. Base Year C&I Area

Customer Segment	Electric Floorspace (1,000 sq. ft.)	Natural Gas Floorspace (1,000 sq. ft.)
Colleges & Universities	25,034	30,667
Food Sales	32,250	20,928
Food Service	47,490	47,023
Healthcare	57,214	44,641
Hospital	3,626	4,002
Lodging	173,128	57,119
Office	255,102	207,641
Com - Other	111,397	83,481
Public Assembly	36,589	33,765
Retail	168,291	121,347
Schools	42,867	45,675
Warehouse	82,638	53,104
Fabrication	47,200	34,061
Food Manufacturing	6,484	4,475

Customer Segment	Electric Floorspace (1,000 sq. ft.)	Natural Gas Floorspace (1,000 sq. ft.)
Heavy Industry	2,119	1,528
High Tech Facilities	2,708	918
Ind - Other	18,338	14,807
Process	13,447	7,592
Com - Multifamily	377,444	322,874
Total	**1,503,367**	**1,135,647**

Source: Guidehouse analysis

2.2 End-Use Definitions

This potential study defines end uses as a specific activity or customer need that requires energy, such as space heating or domestic water heating, without specifying the particular type of equipment used to satisfy that need.

Table 2-5 presents the list of end uses by sector used in the potential study. These end-use categories are used primarily for the binning of potential estimates, and for quality control steps to check the range of savings forecasts against the estimated end-use consumption.

Table 2-5. End Uses by Sector

Residential	C&I
Behavior	Behavior
Custom	Compressed Air
ENERGY STAR Homes	Custom
Envelope	Envelope
Hot Water	Food Service
HVAC	Hot Water
Lighting	HVAC
Motors/Drives	Lighting
Plug Load	Motors/Drives
Process	Process
Refrigeration	Refrigeration

Source: Guidehouse

2.3 Fuel Shares

Due to the separation of building stock by primary fuel type (electricity and natural gas), fuel shares were not needed for this study. Propane and fuel oil equipment shares are characterized in the measure density values and applied to the electric territory stock forecast.

2.4 End-Use Allocations

End-use allocations were developed for each customer segment and impact type. These represent the percentage of whole building consumption that is attributable to each end use. End use allocations were sourced from 2018 National Grid potential study inputs, originally derived from a previous study completed by DNV. End-use allocations are used in this study as guidelines for result quality control, not directly for potential scaling.

2.5 Sales Forecast

National Grid internal forecasts were leveraged for each fuel type. For electric energy, the National Grid forecast adjusted for photovoltaic (PV) production and electric vehicles (EV) consumption was used. Energy efficiency (EE) accomplishments to-date (through 2018) were locked[12] and additional forecasted EE was removed from the forecast to avoid double counting. The electric demand forecast was developed in a similar manner to energy. PV and energy storage (ES) are removed from the pre-DER forecast, while EV is added to show load growth due to charging. EE and demand response (DR) accomplishments are locked at 2018 values. Similarly to electric sales forecasts, gas forecasts are net of EE through 2018 accomplishments. Table 2-6 shows the estimated total electricity, demand, and natural gas consumption by sector.

Table 2-6. National Grid Electricity, Demand, and Natural Gas Consumption in 2019 (at Meter)

Segment	GWh Electricity Consumption	MW Electric Demand	MM Therm Natural Gas Consumption
Residential	7,664	2,462	664
C&I	12,242	2,016	656
Total	19,906	4,477	1,320

Source: Guidehouse analysis

2.6 Avoided Costs

Avoided costs for electric energy and capacity, gas, propane, fuel oil, water and non-energy impacts were developed using the National Grid 2019 BCR model and later updated to March 2021 Avoided Energy Supply Component Study (AESC 2021) values. Benefit streams from the BCR model were combined at the impact type level before import into DSMSim. Therefore, each avoided cost stream may contain multiple BCR model benefits. Electric energy (per kWh) includes energy, DRIPE, environmental compliance, and cross DRIPE benefits. Electric capacity (per kW) includes capacity, reliability, transmission, and distribution benefits. Capacity DRIPE is imported as a unique benefit stream as its valuation methodology differs from the other capacity scaling benefit streams. Gas (per MMBtu) includes natural gas, DRIPE, cross DRIPE, and environmental compliance benefits. Propane (per MMBtu) includes propane and environmental compliance benefits. Fuel Oil (per MMBtu) includes oil, DRIPE, and environmental compliance benefits. Water (per gallon) includes only the price of water and

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[12] The model was calibrated to 2019 results. Results through 2018 are accepted and locked.

sewage. Non-energy impacts are mapped to measures and include per unit and per impact, one-time and per year benefits.

Comparison measures from the BCR model were imported into DSMSim to QC the TRC results. Through this process, Guidehouse confirmed that the avoided cost inputs and TRC model logic are within rounding error between the two models.

2.7 Retail Rates

Retail rates for electric energy and capacity, gas, propane, fuel oil, and water were developed using a variety of resources. Propane, fuel oil, and water rates are equal to the commodity price portion of the avoided costs from the National Grid BCR model. Electric and gas rates are based on tariff documents available on National Grid's website and forecasted over the study period with internal National Grid estimates. For natural gas, the total per therm rate by rate class is weighted based on 2019 rate class usage provide by National Grid. For residential electric energy, delivery and commodity charges per kWh are summed and weighted (by R-1 and R-2 rate classes) based on customer counts. There are no demand charges for residential electricity.

For C&I electric energy and demand, delivery and commodity charges are weighted based on energy consumption between rate classes (G-1 through G-3 rate classes). Weighting for customer segments by rate class were provided by National Grid. Guidehouse performed a sensitivity analysis to determine how simple payback is impacted by the weighting of rate classes G-1 through G-3 compared to breaking out rate classes individually. The simple payback of the composite retail rates is within +/-10% of each individual rate class results. Therefore, Guidehouse used the composite rates in lieu of developing rate class logic into the model as this approach will closely estimate potential and decrease false precision due to lack of measure-level rate class differentiation.

2.8 Other Economic Inputs

Other economic inputs such as line losses, inflation rate, and discount rates were sourced from the National Grid 2019 BCR model. Note that discount rates are real (0.46%) in order to match BCR model TRC logic.

3. Energy Efficiency Measure Characterization

Guidehouse and National Grid fully characterized 110 energy efficiency measures across National Grid's Residential and C&I sectors. The selected measures were determined from a common measure list adopted by the Massachusetts Program Administrators and reflected those anticipated to have high impact and most likely to be cost-effective as criteria for inclusion into DSMSim. Other measures with lower anticipated impacts were included as well; the characterization of these measures was adopted from the 2018 Market Potential Study.

3.1 Energy Efficiency Measure List

Guidehouse and National Grid developed a comprehensive measure list of energy efficiency measures likely to contribute to economic potential. Guidehouse reviewed current program offerings, National Grid's 2019-2021 DSM Plan, the 2018 Potential Study, and potential model measure lists from other jurisdictions to identify energy efficiency measures with the highest expected economic impact: Guidehouse focused on EE and electrification measures which, in aggregate, are projected to achieve 90% or more of the incremental achievable savings. Guidehouse worked with National Grid to finalize the measure list and ensure it contained technologies viable for future DSM program planning activities. Guidehouse did not include a generic future emerging technologies measure that would attempt to capture potential savings from technologies not currently ready for the market. All measures included are currently available in the market and economically viable. This list was compared with similar lists from the other Program Administrators and suggestions from the Energy Efficiency Advisory Council consultant team and a final common measure list was selected by the Program Administrators.

For measures not included in common list, Guidehouse used the 2018 Potential Study's measure characterizations, removed measures that are no longer relevant, and modeled and aggregate results by end use. In this way, the results provide a comprehensive assessment of potential.

Measures included in this study that were not included in the 2018 Potential Study[13] include the following:

- Residential Home Energy Reports
- Commercial Strategic Energy Management
- Commercial Fryer
- Commercial Oven
- Commercial Steamer
- Commercial Food Holding Cabinet
- Commercial High Temperature Commercial Dishwasher

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[13] Commercial Lighting was realigned into new categories, but measures were not added

3.2 Energy Efficiency Measure Characterization Key Parameters

The measure characterization effort consisted of defining more than fifty individual parameters for each measure included in this study. Table 3-1 defines 14 key parameters and how these items impact technical and economic potential savings estimates.

Table 3-1. Key Measure Characterization Parameters

Parameter Name	Definition	Example
Baseline Measure	Existing inefficient equipment or process to be replaced.	T5/T8 Fluorescent Lighting
Energy Efficiency Measure	Efficient equipment, process, or project to replace the baseline.	Indoor LED Linear Lamp
Measure Lifetime	The lifetime in years for the base and energy efficient technologies. The base and energy efficient lifetimes only differ in instances where the two cases represent inherently different technologies, such as solar water heaters compared to a baseline of regular storage water heaters	T5/T8 Fluorescent Lighting: 10 years Indoor LED Linear Lamp: 12 years
Measure Costs	The incremental cost between the assumed baseline and efficient technology using the following variables: • Base Costs: The cost of the base equipment, including both material and labor costs. • Energy Efficient Costs: The cost of the energy efficient equipment, including both material and labor costs. Retrofit measure costs will include the full material cost of the efficiency measure and associated labor rates for removal of existing equipment and installation of the efficient technology. Dual baseline measures take into account both the initial retrofit measure cost and savings, and that of the portion of measure life once a new code or standard is projected to become effective.	Baseline cost: $690 Efficient cost: $500
Replacement Type	Identifies when in the technology or building's life an efficiency measure is introduced. Replacement type affects when in the potential study period the savings are achieved as well as the duration of savings and is discussed in greater detail in *National Grid Massachusetts 2022-2024 Potential Study Modeling Methodology* (see Appendix A).	Retrofit (RET), replace-on-burnout (ROB) and new construction (NEW)
Annual Energy Consumption	The annual energy consumption for electricity in kWh and demand in kW, for gas in therms, for propane and fuel oil in MMBTU and for each baseline and energy efficiency measure.	Baseline: 196 kWh/year Efficient: 163 kWh/year
Unit Basis	The normalizing unit for energy, demand, cost, and density estimates.	Per bulb, per hp, per kWh consumption, per therm consumption.
Scaling Basis	The unit used to scale the energy, demand, cost and density estimate for each measure according to the reference forecast.	Per home, per 1,000 SF of commercial area, etc.

Parameter Name	Definition	Example
Sector and End-use Mapping	The team mapped each measure to the appropriate end uses, customer segments and sectors. Where Massachusetts-specific information was not available, Guidehouse utilized secondary data, including internal Guidehouse data sources. Guidehouse's review of these resources was generally used to support the data sources provided by National Grid and to ensure consistency among National Grid data, Guidehouse's estimates, and publicly-available resources. In order to develop the final estimates of energy consumption, Guidehouse compared and calibrated estimates with actual sales data obtained from National Grid's End Use Intensity Models. Section 2.1 describes the breakdown of customer segments with each sector.	Commercial HVAC Tune-up is mapped to the Non-Res HVAC end use in the commercial sector.
Fuel Type Multiplier	Assigns the percentage of electric/gas fuel type to measures with electric/gas fuel type such as water heaters and space heating equipment	The Electric Space heating multiplier only assigns electric space heating measures to customers that have electric heating.
Measure Density	Used to characterize the occurrence or count of a baseline or energy efficiency measure, or stock, within a residential household or within 1,000 square feet of a commercial building. This parameter was not defined for industrial measures as they scaled by consumption.	35 bulbs per household.
Energy Efficiency Saturation	The fraction of the residential housing stock or commercial building space that has the efficiency measure installed each year. For the industrial sector, saturations are based on energy consumption.	40% of all residential bulbs are LEDs so saturation of LEDs is 40%.
Technical Suitability	The percentage of the base technology that can be reasonably and practically replaced with the specified efficient technology.	Occupancy sensors have a technical applicability of less than 1.0 because they are only practical for interior lighting fixtures that do not need to be on at all times.
Competition Group	Identifies measures competing to replace the same baseline density in order to avoid double counting of savings. Appendix A provides further explanation on competition groups.	Efficient storage tank water heater or a tankless water heater can replace an inefficient storage water heater, but not both.

3.3 Energy Efficiency Measure Characterization Approaches and Sources

This section provides approaches and sources for the main measure characterization variables. Table 3-2 lists sources of data accessed for measure characterization.

Table 3-2. Sources for Measure Characterization Inputs

Measure Input	Data Sources
Measure Costs, Measure Life, Energy Savings	• MA TRM, Plan Version 2019-2021 and 2019 Plan Year Report Version • National Grid program data • LED Lighting Price Research Study, November 2020 • 2018 National Grid Market Potential Study • US DOE Appliance Standards and Rulemakings supporting documents • Engineering analyses • Other non-MA TRMs • Guidehouse measure database and previous potential studies
Fuel Type Applicability Splits, Density, Baseline Initial Saturation, Technical Suitability, End-Use Consumption Breakdown	• Massachusetts Residential Baseline Study (published in 2020)[14] • C&I baseline data[15] • 2018 National Grid Market Potential Study • Commercial Building Stock Assessment (CBSA) • Guidehouse's other potential studies
Codes and Standards	• US DOE engineering analyses • Local building code

3.3.1 Energy and Demand Savings

Guidehouse took four general bottom-up approaches to analyzing residential and C&I measure energy and demand savings:

1. **Technical Reference Manual (TRM) Standard Algorithms:** Guidehouse used the MA TRM (Plan Version 2019-2021 and 2019 Plan Year Report Version) as the primary source of savings for this study. From the TRM, Guidehouse sourced deemed savings and standard algorithms for unit energy savings and demand savings calculations.
2. **Program Evaluation Data:** Guidehouse used measure-specific program evaluation data from National Grid to inform energy and demand savings if these were more recent than the TRM values.
3. **National Grid Program Data**: For Custom measures, Guidehouse used the National Grid Custom program data to estimate consumption and savings for all custom measures included in this study. The savings assumptions for Custom measures were

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[14] Navigant (2019) and Guidehouse (2020), "Massachusetts Residential baseline Study." Available at https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Comprehensive-Report-2019-04-30.pdf and https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf. Both 2019 and 2020 versions of the baseline study were accessed for this study.

[15] C&I baseline data from a DNV study in progress at the time of this Potential Study.

derived from National Grid's Custom program data over the last 3 years. We also leveraged the characterization from the 2018 potential study which used the same methodology of using actual program data. Guidehouse collaborated with National Grid and DNV to get the site level energy savings as well as the segment/building level consumption data to calculate the percent savings for each measure within each segment. Depending on the granularity of the available data, we characterized the Custom measure for each segment if segment level savings and consumption were available. In the absence of segment level information, we took an overall average across Custom measures to get an average segment level savings percentage. We used the breakdown of the end uses in the overall Custom data to assign technical suitability values by end use but the measure itself was not divided into different end uses.

4. **Engineering Analysis:** Guidehouse used appropriate engineering algorithms to calculate energy savings for any measures not included in National Grid programs or available TRMs. As an example, this approach was taken for all Commercial Food Service measures that did not have any program specific data or data in the TRM.

3.3.2 Incremental Costs

Guidehouse relied primarily on National Grid-provided program data and recent evaluation studies for incremental cost data. Prime references for residential HVAC measures include the cost studies that the Massachusetts Residential Program Administrators conducted in 2018 using contractors surveys, customer invoice data, and web scraping of retail price data to inform incremental cost analyses of space and water heating equipment[16] and heat pump and air conditioning equipment.[17] Costs cited to 2018 publications were updated to current dollars using the Bureau of Labor Statistics' consumer price index. For measures related to residential refrigeration and other plug loads, Guidehouse referenced incremental cost information published by the US DOE as part of efficiency standards rulemaking proceedings covering these products. Guidehouse also conducted secondary research and used a variety of other publicly available cost data sources indicated in the accompanying measure input detail. For commercial lighting measures, Guidehouse leveraged the cost values in the LED Lighting Price Research Study, November 2020. Incremental costs for Custom measures were calculated based on National Grid's actual program data. Similar to the calculation of site-level savings, $/kWh and $/therm values were calculated based on site-level data.

3.3.3 Incentives, Administrative Costs, and NTG

Incentives and NTG were included from National Grid's BCR model for all electric, gas, propane, and fuel oil measures. For measures without a historical program basis for characterization, incentives were set at 50% of incremental cost and TRM NTG assumptions were used. Costs for administering and marketing programs were also taken from National Grid historical program data.

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[16] Navigant (2018). "Water Heating, Boiler, and Furnace Cost Study (RES 19)." Available at: https://ma-eeac.org/wp-content/uploads/RES19_Assembled_Report_2018-09-27.pdf

[17] Navigant (2018). "Ductless Mini-Split Heat Pump Cost Study (RES 28)." Available at: https://ma-eeac.org/wp-content/uploads/RES28_Assembled_Report_2018-10-05.pdf
Navigant (2018). "Cost Study of Heat Pump Installations for Dual Fuel Operation (RES 23)." Available at: https://ma-eeac.org/wp-content/uploads/RES23_Task2_AC-HP_Cost_Study_Results_Memo_v3_clean.pdf

3.3.4 Building Stock and Densities

Guidehouse relied heavily on the Massachusetts Residential Baseline Study[18] for information on equipment densities and saturations for residential measures. Density and saturation inputs for between 70-80% of savings (depending on impact and potential type) were sourced from this study. For lower impact measures, measures not well suited for baseline research, and measures characterized directly through program offerings (e.g., custom, strategic energy management, and behavioral), Guidehouse used National Grid historical program results and other secondary sources.

For the commercial sector, Guidehouse relied on the C&I baseline data[19] for informing equipment densities and saturation. Guidehouse also leveraged the program data as well as the 2018 Potential Study to derive year-over-year saturation for measures that were not included in the DNV study. The Massachusetts Statewide Commercial Building Stock Assessment (CBSA) and previous potential studies in other jurisdictions were reviewed for any other overall updates to the saturation values. For the custom measure, Guidehouse used the year-over-year National Grid program data for the past three years to understand the penetration of custom measures in the program.

3.3.5 Identifying and Characterizing Emerging Technologies

For those measures on the measure list which have not been previously characterized, Guidehouse conducted a review of relevant literature as well as discussions with both internal and external industry experts. For each technology, the team documented the following metrics:

- Vintage and locale of the supporting data (when and where it was developed)
- Transparency and updatability of supporting data
- What analysis approach was used and whether any descriptive statistics are provided
- Cost-effectiveness of the emerging technology, as evaluated using methods described above
- Likelihood of the adoption of the emerging technology

3.4 Codes and Standards Adjustments

Estimates of future adjustments in savings related to codes and standards are included as part of the measure characterization process.[20]

The US DOE publishes federal energy efficiency regulations for many types of residential appliances and commercial equipment. The US DOE Technical Support Documents (TSD)[21] contain information on energy and cost impacts of each appliance standard. In the TSD, Section

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[18] Navigant (2019) and Guidehouse (2020), "Massachusetts Residential baseline Study." Available at https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Comprehensive-Report-2019-04-30.pdf and https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf. Both 2019 and 2020 versions of the baseline study were accessed for this study.

[19] C&I baseline data from a DNV study in progress at the time of this Potential Study.

[88] See the accompanying EE measure input workbook (Appendix E) for codes and standards adjustments.

[21] Appliance standards rulemaking notices and TSD can be found at: https://www.energy.gov/eere/buildings/appliance-and-equipment-standards-program

5 includes engineering analysis, Section 7 includes energy use analysis, and Section 8 includes cost impact. As these codes and standards take effect, the energy savings from existing measures impacted by these codes and standards decline and the reduction is transferred to the codes and standards savings potential.

Guidehouse accounts for the effect of codes and standards through baseline energy and cost multipliers (sourced from the DOE's analysis), which reduce the baseline equipment consumption starting from the year a code or standard takes effect. The baseline cost of an efficient measure affected by codes and standards will often increase upon the code's implementation. Guidehouse incorporated the 2023 residential central ACs standard in this study, which results in the baseline for residential air conditioners changing from 14 Seasonal Energy Efficiency Ratio (SEER) to 14.3 SEER in 2023. Accordingly, the model accounts for a reduction in energy consumption and an increase in cost in 2023 for the baseline technology through the codes and standards multipliers. As such, computed measure-level potential is net of these adjustments from codes and standards implemented after the study's first year.[22]

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[22] It is important to note that the second tier of Energy Independence and Security Act of (EISA) 2007 regulations went into effect beginning January 2020, and general service lamps must now comply with a higher standard. The EUL of some lamps extend beyond this date, but DOER decided to end all upstream residential lighting program activity by 2022, claiming there is no PA attributed savings through retailers. For residential LED bulb measures, the model reduces savings to zero in 2021 for direct install programs and reduces savings to zero in 2022 for upstream measures.

4. Energy Efficiency Technical Potential Forecast

This section briefly describes Guidehouse's approach to calculating technical potential and presents the results for National Grid in Massachusetts pertaining to total technical savings potential at different levels of aggregation. Results are shown by sector and end-use category. For more details and levels of aggregation of technical potential, please see Appendix B.

4.1 Approach to Estimating Energy Efficiency Technical Potential

This study defines **technical potential** as the total energy savings available assuming that all applicable installed baseline measures can *immediately* be replaced with the efficient measure/technology—wherever technically feasible—regardless of the cost, market acceptance, or whether a measure has failed and must be replaced. Therefore, technical potential in neither cumulative nor incremental, but instead shows the total potential if all savings were to be achieved in a single year.

National Grid Massachusetts 2022-2024 Potential Study Modeling Methodology (see Appendix A) discusses the approach to estimating technical potential in more detail. Guidehouse used its DSMSim model to estimate the technical potential for demand side resources considered for this study. DSMSim is a bottom-up, technology-diffusion and stock-tracking model implemented using a System Dynamics framework.[23]

4.2 Energy Efficiency Technical Potential Results by Sector

Figure 4-1 shows the total electricity technical savings potential, gross at generator, for each sector. Both the C&I sector and Residential sector technical electricity savings are relatively flat. C&I technical potential savings are over twice as big as Residential technical potential.

Figure 4-2 shows the summer peak demand technical savings potential, net at meter, for each sector. Both C&I and Residential sector summer peak savings show a slight decrease over time, potentially due to a decrease in suitable building stock.

Figure 4-3 shows the net natural gas technical savings potential for each sector. C&I Savings are relatively flat, while residential savings potential decreases, potentially due to a decrease in suitable building stock.

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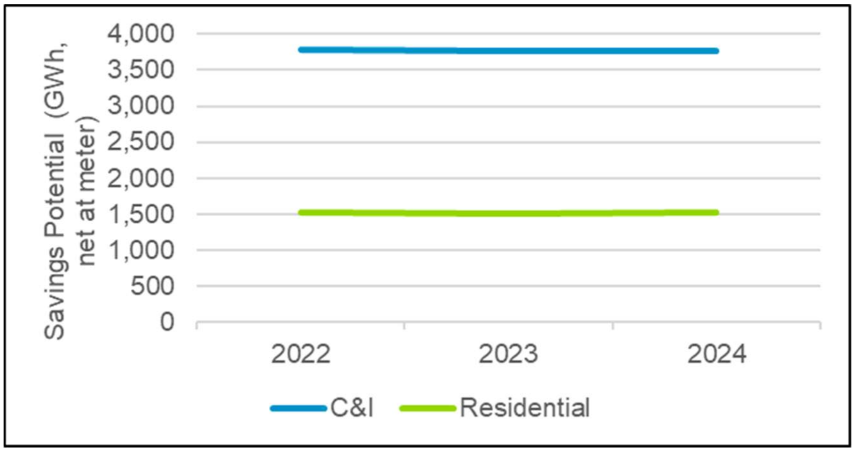
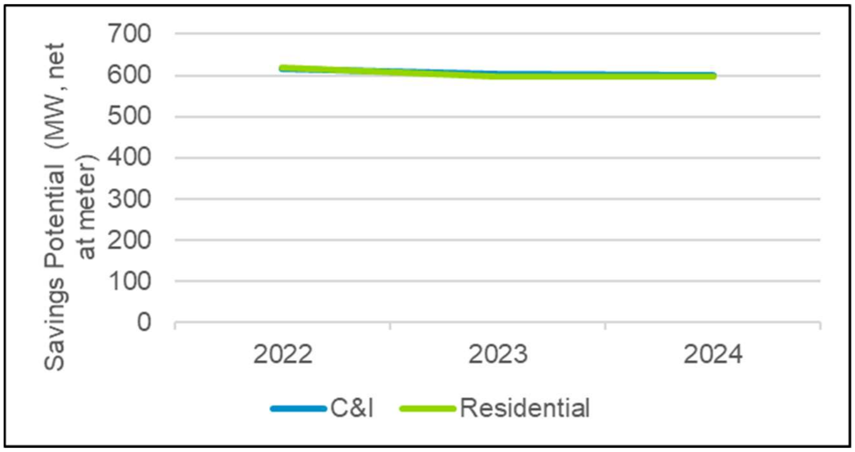
[23] See Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill. 2000 for detail on System Dynamics modelling. Also see http://en.wikipedia.org/wiki/System_dynamics for a high-level overview.

Figure 4-1. EE Technical Potential, Electricity Savings by Sector (GWh, Net at Meter)



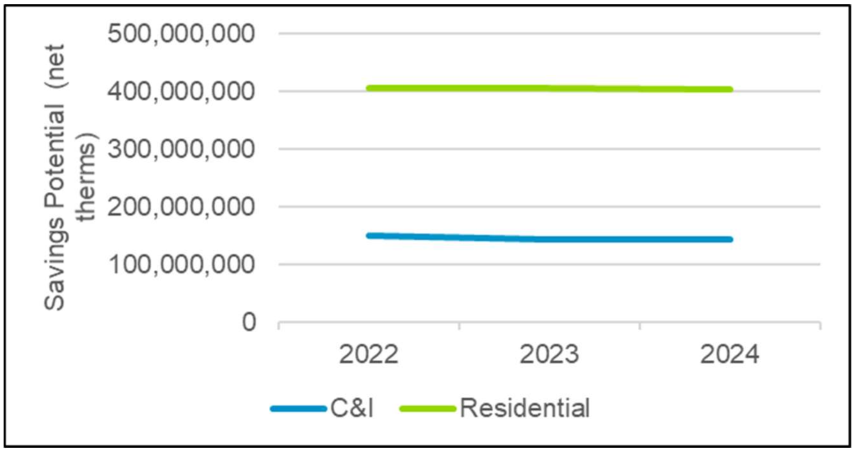
Source: Guidehouse analysis

Figure 4-2. EE Technical Potential, Summer Peak Passive Demand Savings by Sector (MW, Net at Meter)



Source: Guidehouse analysis

Figure 4-3. EE Technical Potential, Natural Gas Savings by Sector (Net therms)



Source: Guidehouse analysis

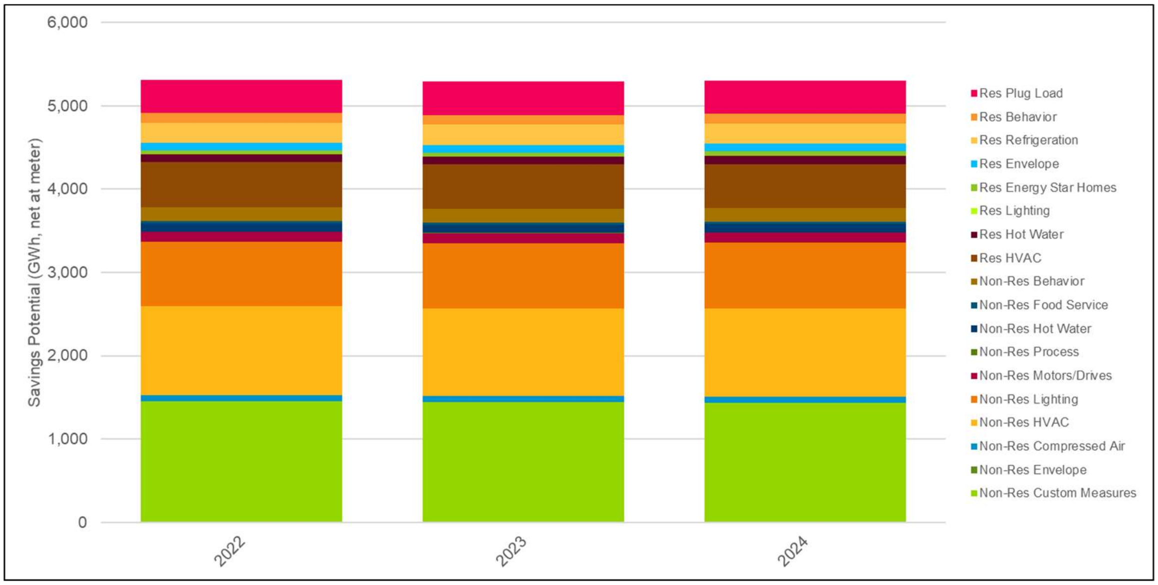
4.3 Energy Efficiency Technical Potential Results by End Use

Figure 4-4 shows the electricity technical savings potential, net at meter, across all end uses and sectors. The three largest end uses are Custom, HVAC, and Lighting for the C&I Sector.

Figure 4-5 shows the summer peak passive demand technical savings potential, net at the meter, across all end uses and sectors. The dominant end use is Residential HVAC, which is very peaky.

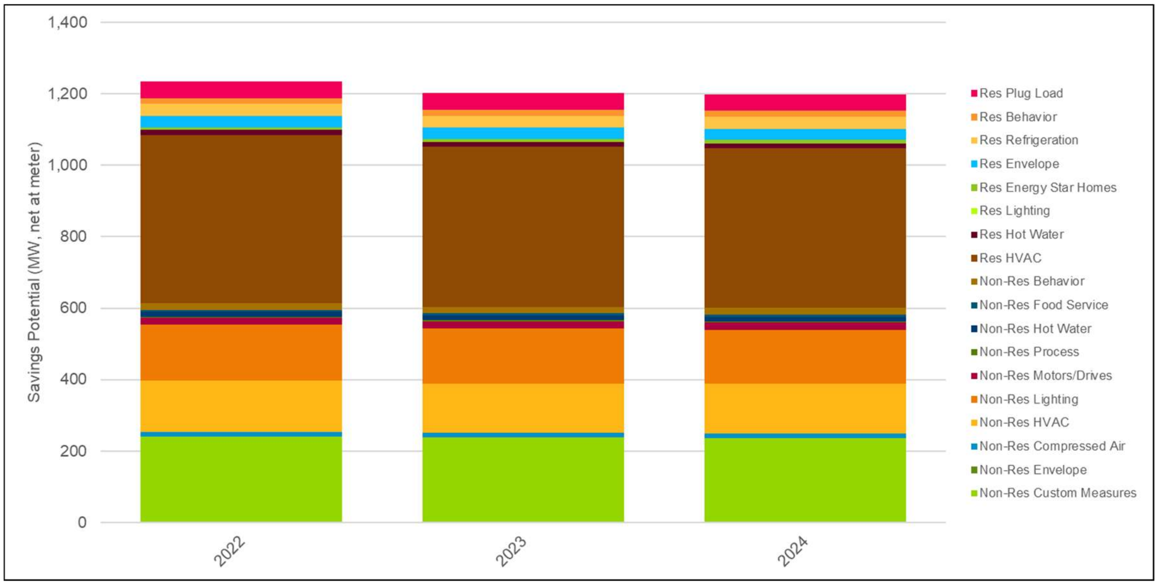
Figure 4-6 shows the natural gas technical savings potential, across all end uses and sectors. The dominant end uses are Residential envelope and HVAC, demonstrating the large role that weather-dependent savings opportunities play.

Figure 4-4. EE Technical Potential, Electricity Savings by End Use (GWh, Net at Meter)



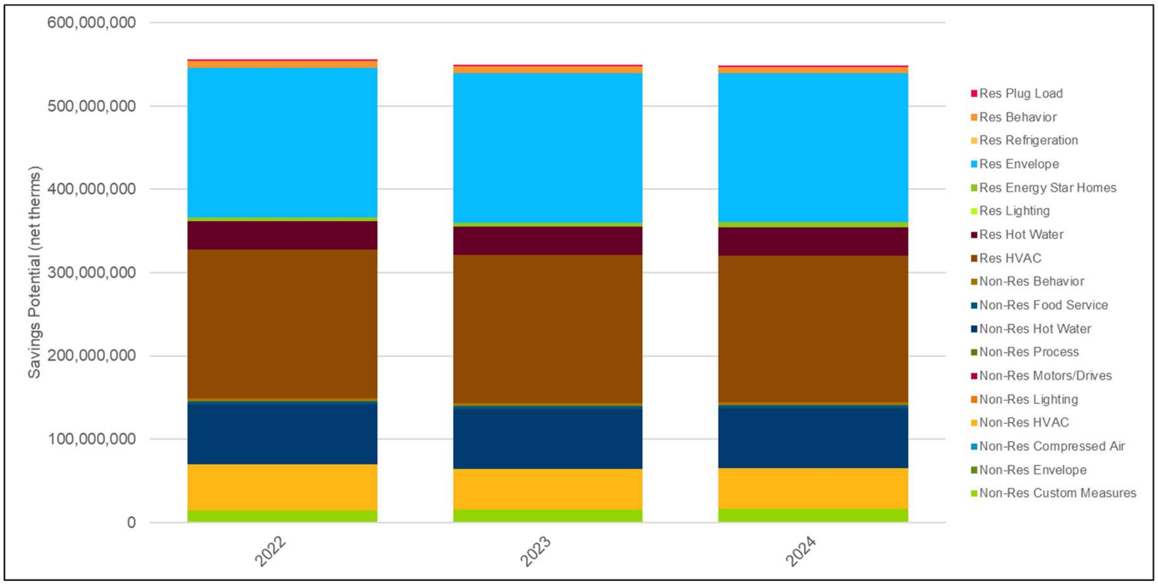
Source: Guidehouse analysis

Figure 4-5. EE Technical Potential, Summer Peak Passive Demand Savings by End Use (MW, Net at Meter)



Source: Guidehouse analysis

Figure 4-6. EE Technical Potential, Natural Gas Savings by End Use (Net therms)



Source: Guidehouse analysis

5. Energy Efficiency Economic Potential Results

This section describes the economic savings potential, which is potential that meets a prescribed level of cost-effectiveness, available for National Grid in Massachusetts. The section begins by explaining Guidehouse's approach to calculating economic potential. It then presents the results for economic savings potential at different levels of aggregation. Results are shown by sector and end-use category. Guidehouse developed economic potential using a TRC of 1.0 as the measure screen. For more details and levels of aggregation of economic potential, please see Appendix B.

5.1 Approach to Estimating Economic Potential

Economic potential is a subset of technical potential, using the same assumptions regarding immediate replacement as technical potential but including only those measures that have passed the benefit-cost test chosen for measure screening—in this case, the TRC test, per National Grid's guidance. The TRC ratio for each measure is calculated each year and compared against the measure-level TRC ratio screening threshold of 1.0. A measure with a TRC ratio greater than or equal to 1.0 is a measure that provides monetary benefits greater than or equal to its costs. If a measure's TRC meets or exceeds the threshold, it is included in the economic potential. Measures with TRC ratios less than 1.0 were non-cost-effective and do not appear in the economic potential.

The TRC test is a benefit-cost metric that measures the net benefits of energy efficiency measures from combined stakeholder viewpoint of the program administrator and its customers. The TRC benefit-cost ratio is calculated in the model using Equation 5-1.

Equation 5-1. Benefit-Cost Ratio for Total Resource Cost Test

$$TRC = \frac{PV(Avoided\ Costs + O\&M\ and\ NEI\ Savings)}{PV(Technology\ Cost + Admin\ Costs)}$$

Where:

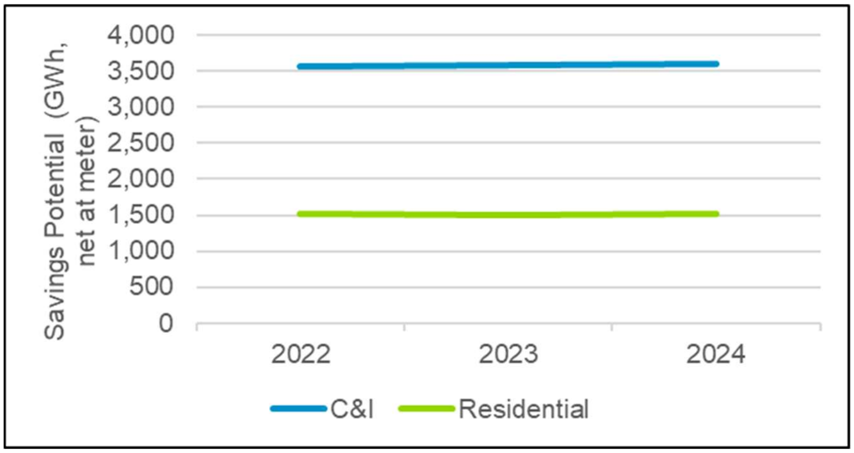
- *PV( )* is the present value calculation that discounts cost streams over time; using the selected nominal discount rate (2.33%)
- *Avoided Costs* are the monetary benefits resulting from electricity and capacity savings (e.g., avoided costs of infrastructure investments, due to electricity conserved by efficient measures)
- *O&M and NEI Savings* are the non-energy impacts such as operation and maintenance cost savings, comfort benefits and reduced bill arrearages
- *Technology Cost* is the incremental equipment cost to the customer before utility incentives
- *Admin Costs* are the administrative costs incurred by the program administrator

Guidehouse calculated TRC ratios for each measure based on the present value of benefits and costs (as defined above) over each measure's life. Similar to technical potential, only one economic measure (meaning that its TRC ratio meets the threshold) from each competition group is included in the summation of economic potential across measures (e.g., at the end-use category, customer segment, sector, service territory or total level). If a competition group is composed of more than one measure that passes the TRC test, then the economic measure that provides the greatest savings potential for its primary fuel type is included in the summation of economic potential. This approach ensures that double counting is not present in the reported economic potential.

5.2 Energy Efficiency Economic Potential Results by Sector

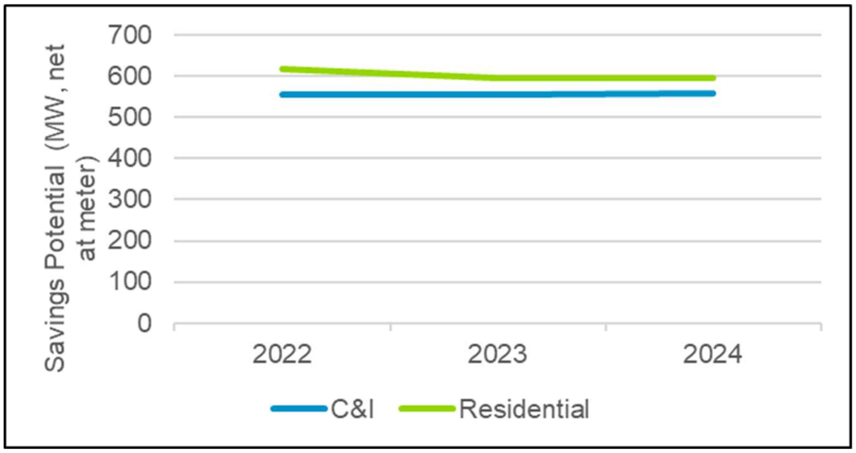
Figure 5-1 shows economic electricity savings potential, net at meter, across all sectors. Figure 5-2 shows the economic summer peak passive demand potential, net at meter, in each of the sectors. Figure 5-3 shows the economic net natural gas potential. The Residential and C&I economic savings trajectories and magnitude are similar to the technical potential – indicating that the majority of measures that comprise the technical potential and win their competition group are also cost-effective, creating a similar trajectory.

Figure 5-1. EE Economic Potential, Electricity Savings by Sector (GWh, Net at Meter)



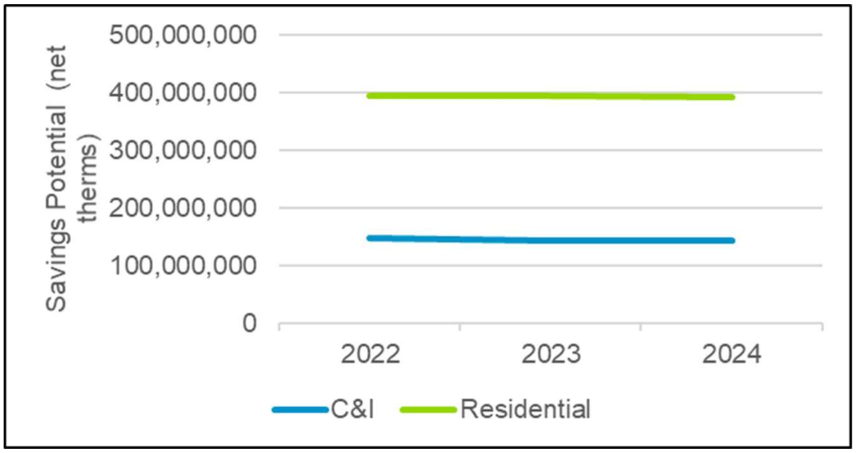
Source: Guidehouse analysis

Figure 5-2. EE Economic Potential, Summer Peak Passive Demand Savings by Sector (MW, Net at Meter)



Source: Guidehouse analysis

Figure 5-3. EE Economic Potential, Natural Gas Savings (Net therms)

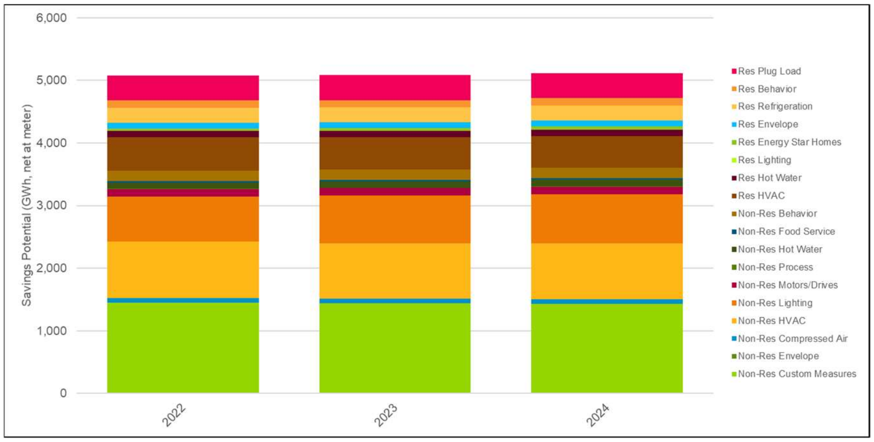


Source: Guidehouse analysis

5.3 Energy Efficiency Economic Potential Results by End Use

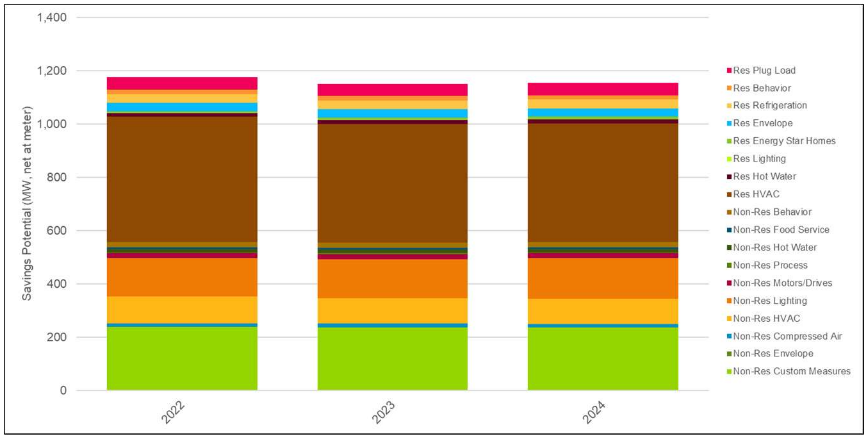
Figure 5-4 shows the economic electricity potential, net at meter, by end use for both C&I and Residential sectors. Figure 5-5 shows the economic summer peak passive demand potential, net at meter, by end use, for both C&I and Residential sectors. Figure 5-6 shows the economic natural gas potential by end use for both C&I and Residential sectors. The breakdown of economic potential by end use is very similar to the technical potential.

Figure 5-4. EE Economic Potential, Electricity Savings by End Use (GWh, Net at Meter)



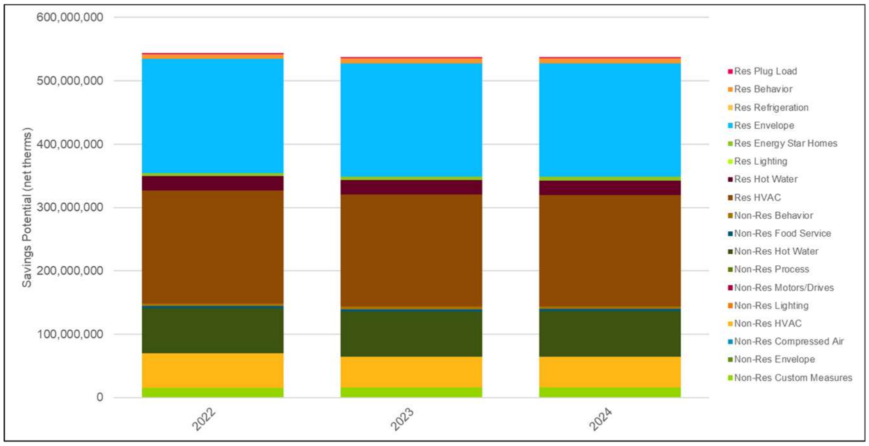
Source: Guidehouse analysis

Figure 5-5. EE Economic Potential, Summer Peak Passive Demand Savings by End Use (MW, Net at Meter)



Source: Guidehouse analysis

Figure 5-6. EE Economic Potential, Natural Gas by End Use (Net therms, Net at Meter)



Source: Guidehouse analysis

6. Energy Efficiency Achievable Market Potential Approaches

Achievable market potential further considers the likely rate of demand side management (DSM) resource acquisition, given factors like the rate of equipment turnover (a function of a measure's lifetime), simulated incentive levels, consumer willingness to adopt efficient technologies, word-of-mouth effects that increase awareness in customers, and the likely rate at which marketing activities can facilitate technology adoption. The adoption of DSM measures can be broken down into calculation of the equilibrium market share and calculation of the dynamic approach to equilibrium market share, as discussed in more detail below.

Achievable potential differs from program potential in that achievable potential does not specifically consider the various delivery mechanisms that can be used by program managers to tailor their approach depending on the specific measure or market. Rather, achievable potential represents a high-level assessment of savings that could be achieved over time, factoring in broader assumptions about customer acceptance and adoption rates that are not dependent on a specified program design. Additional effort is typically undertaken by program designers, using the directional guidance from a market potential study, to develop detailed plans for delivering energy efficiency programs. Achievable potential in this report relies on a TRC measure screen for cost-effectiveness, with the threshold set at a TRC of 0.80 for the majority of measures, intended to reflect Massachusetts' regulatory practice of screening at the program level. Some measures achieve a TRC ratio between the 0.8 and 1.0 achievable and economic thresholds and are therefore included in achievable potential but not economic potential. The total potential attributed to these measures is minimal.

Table 6-1 summarizes the key methodology considerations and decision points informing the analysis in this report, with more detail provided in the report sections noted in the right-hand column of the figure. Guidehouse decided upon this methodology through discussions with National Grid about which approach best serves the objective of the study to understand achievable potential.

Table 6-1. EE Achievable Potential Methodology Overview

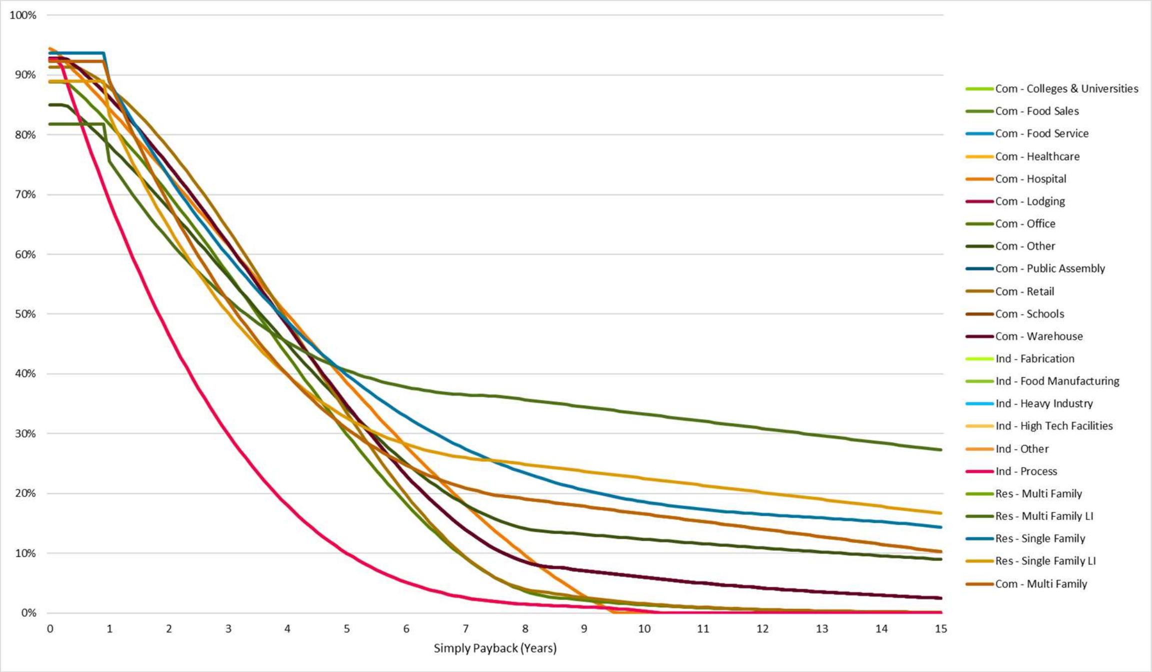
Methodology Parameters	Approach
Benefit-cost test screen	Use the TRC as the primary screen for economic and achievable potential.
Diffusion parameters	Adjust diffusion parameters referencing ranges recommended by industry standard data sources to produce savings that are reasonably aligned with National Grid's DSM sector-level historical achievements.
Budget constraints	Do not apply budget constraints.
Incentive strategy	Set incentive levels equal to historical program levels where applicable and 50% of incremental costs
Treatment of administrative costs	Include program level incentive to administrative cost ratios, benchmarked to historical performance, that scale administrative costs with calculated incentive budget.
Net-to-Gross (NTG)	Achievable potential estimates are developed using net savings based on historical program NTG inputs and TRM values.
Re-participation	Assume 100% of measures re-participate as an efficient measure at the end of their measure life.
Codes and standards	Use the same assumptions about codes and standards as in technical and economic potential.

6.1 Calculation of Equilibrium Market Share

The equilibrium market share can be thought of as the percentage of individuals choosing to purchase a technology provided those individuals are fully aware of the technology and its relative merits (e.g., the energy- and cost-saving features of the technology). For DSM measures, a key differentiating factor between the base technology and the efficient technology is the energy and cost savings associated with the efficient technology. Of course, that additional efficiency often comes at a premium in initial cost. This study calculates an equilibrium market share as a function of the payback time of the efficient technology relative to the baseline technology. In effect, measures with more favorable customer payback periods after the incorporation of incentives will have higher equilibrium market share, which reflects consumers' economically rational decision-making. While such approaches certainly have limitations, they are nonetheless directionally reasonable and simple enough to permit estimation of market share for the hundreds of technologies appearing in most potential studies.

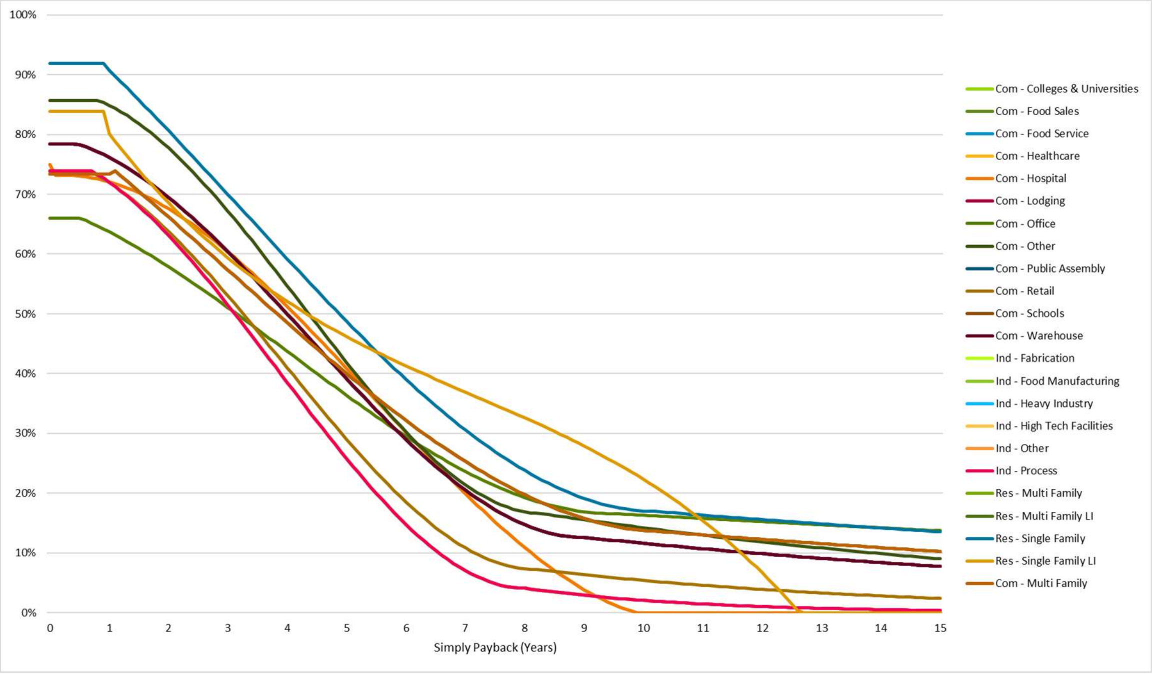
To inform this study, the team used equilibrium payback acceptance curves that Guidehouse developed using primary research from the 2018 Potential Study. To develop these curves, Guidehouse relied on surveys of 1000 residential and 200 C&I customers. These surveys presented decision makers with numerous choices between technologies with low up-front costs, but high annual energy costs, and measures with higher up-front costs but lower annual energy costs. Guidehouse fitted generalized logit models to customer willingness to pay survey results by technology cost bin and segment to develop the set of curves, which Guidehouse used in this study. The resulting willingness to pay curves, shown in Figure 6-1 and Figure 6-2, are used as starting points for achievable potential calibration described in Appendix A – National Grid Massachusetts 2022-2014 Potential Modeling Methodology.

Figure 6-1. Low Cost Willingness to Pay Curves by Customer Segment



Source: Guidehouse analysis

Figure 6-2. High Cost Willingness to Pay Curves by Customer Segment



Source: Guidehouse analysis

Because the payback period of a technology can change over time (as technology or energy costs change over time), the equilibrium market share can also change over time. The equilibrium market share is therefore recalculated for every year of the forecast to ensure the dynamics of technology adoption take this effect into consideration. As such, equilibrium market share is a bit of an oversimplification and a misnomer, as it can itself change over time and is therefore never truly in equilibrium, but it is used nonetheless to facilitate understanding of the approach.

6.2 Calculation of the Approach to Equilibrium Market Share

Two approaches are used for calculating the approach to equilibrium market share, one for technologies being modeled as retrofit (RET) measures, and one for technologies simulated as replace-on-burnout (ROB) or new construction (NEW) measures.[24] *National Grid Massachusetts 2022-2024 Potential Study Modeling Methodology* (see Appendix A) discusses the approach to equilibrium market share in more detail.

6.3 Behavioral Measures

Behavior measures typically impose little to no direct costs to the participant[25] and their rate of adoption is highly dependent on the marketing and incentive efforts taken by program administrators. Given these unique characteristics of behavior measures, the payback acceptance curves and technology diffusion models have limited applicability to these types of measures. As such, this study models the adoption of behavior measures in terms of an equilibrium saturation level relative to economic potential, and a given amount of time to reach that equilibrium state. Equilibrium saturation levels were derived from Guidehouse's review of National Grid's historical and planned DSM program activity for the applicable measures.

6.4 Energy Efficiency Investment Strategy

National Grid elected to view achievable potential without imposing any explicit budget constraints on the simulated results. The implication of this decision is that achievable potential is only constrained by stock turnover, customer willingness to adopt efficient measures, and calibration to historical participation levels. Without future budget constraints, the program administrator spending falls out naturally from the input assumptions for per-unit incentives and program administrative cost, without tying spending to a given budget level. In this study, the per-unit incentive and administrative spending levels are fixed at the same levels (in real dollars, compared with nominal dollars) over the study horizon. Therefore, changes in spending (in real dollars) only reflect a changing mix and magnitude of savings among measures.

6.5 Energy Efficiency Incentive Strategy

Per National Grid's guidance, this study sets measure incentives based on National Grid's current program levels where available and 50% of incremental cost for new measures to the portfolio for the BAU scenario. Incentive levels are varied for the alternative scenarios as described in Section 7.1.

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[24] Each of these approaches can be better understood by visiting Guidehouse's technology diffusion simulator, available at: http://forio.com/simulate/navigantsimulations/technology-diffusion-simulation.

[25] Participants may incur indirect costs through implementation of adjustments to typical operations in response to energy information feedback (e.g., through upgrading a water heater). However, estimating these indirect costs requires additional data on the actions taken by the participant beyond participating in the behavioral program and is beyond the scope of this analysis.

6.6 Re-Participation

The model assumes that 100% of program participants re-adopt energy efficient measures after the end of the efficient measure's expected useful lifetimes. This implies that efficient measures generally do not revert to a minimum code or lower efficiency level. As such, the model's cost accounting incurs an incentive cost upon the initial conversion of a minimum code or lower efficiency measure to an efficient measure, but it does not incur incentive costs when replacing incumbent equipment that was already updated to efficient equipment during the study horizon. Thus, incremental savings are counted only for new program participants, and these savings are summed up year-over-year to represent cumulative potential.

Behavior measures, such as Home Energy Reports, are an exception to this approach. When a behavior measure is re-adopted at the end of its expected useful lifetime, the incentives provided for those measures are added to total program administrator spending. The rationale is that similar savings opportunities provided by behavior measures are only available with ongoing support and/or administration from the program administrator. Since ongoing program administrator support is required to achieve behavior measure savings, the incentives provided to repeat adopters are incurred multiple times throughout the study horizon.

6.7 Energy Efficiency Model Calibration

Any model simulating future product adoption faces challenges with calibration, as there is no future world against which one can compare simulated results to actual results. Engineering models, on the other hand, can often be calibrated to a higher degree of accuracy since simulated performance can be compared directly with performance of actual hardware. Since DSM potential models do not have this luxury, Guidehouse therefore had to rely on other techniques to provide both the developer and the recipient of the model results with a level of comfort that simulated results are reasonable. For this study, Guidehouse took several steps to ensure that forecast model results were reasonable, including:

- Identifying the subset of potential measures that were included in historical National Grid program offerings in order to have a basis for comparison with historical program achievements.
- Ensuring similar trends and magnitudes between National Grid's historical sector- and end use-level savings and simulated sector- and end use-level savings from the measure subset in the model's base year. 2019 historical achievements were used in the calibration process as they represent the most recent available data.
- Comparing high-level budget estimates to 2019 historical spending to determine reasonability of investments.
- Studying results with program administrators to identify trends, high impact measure mixes, and savings trajectories for review at a more granular level than the sector and end-use calibration.

Before making comparisons of model results to historical achievements, it was first necessary to identify the potential measures that were included in National Grid's historical program offerings. The simulated savings from this subset of potential measures became the basis for comparing modeled savings to historical savings during the calibration process. It is important to note that although the team calibrated to historical results for this subset of measures, the model's results for total achievable potential may differ from National Grid's historically achieved program savings. This is due to the iterative process for achievable potential review and addition of new measures and competition groups to the portfolio. The subset measure calibration step is an important starting point for calibration that is built upon to account for the differences in measure mix between the potential study and historical DSM programs.

To achieve alignment with National Grid’s historical savings, Guidehouse adjusted technology diffusion coefficients and payback acceptance curves. Calibration required an iterative process of modifying the aforementioned parameters until all goals of calibration were reasonably satisfied. For example, the marketing effectiveness parameters are the key lever for calibrating the magnitude of historical savings for each sector and end-use combination, the word-of-mouth parameter strongly influences the rate of adoption and savings growth over time, and the measure-level payback acceptance curves allow for detailed calibration of high impact measures with significant historical data to support granular review. Guidehouse varied these diffusion parameters within commonly observed ranges until simulated savings were trending reasonably compared with historic, sector-level savings.

To summarize, the calibration process ensures that forecast potential is grounded against real-world data considering the many factors that determine likely adoption of DSM measures, including both economic and non-economic factors.

7. Energy Efficiency Scenario Configuration Approach

The reference scenario (business as usual, or BAU) was developed through the calibration process detailed in Section 6.7. Two alternative scenarios, BAU+ and MAX, were developed through adjustments to incentive levels. No other calibration or investment levers were adjusted for these two scenarios. The two alternative COVID scenario configurations are described in Section 16.

7.1 Scenario Configuration

Guidehouse developed two alternative achievable scenarios and two sensitivity cases relative to the BAU Scenario.

The two scenarios are:

- **Business-as-Usual (BAU+) Scenario**
    - For weatherization measures: Incentive set to 90% of incremental cost
    - For other measures: Raise incentive levels to 50% higher relative to BAU scenario (maximum of 90% of incremental cost)
        - Note: where existing incentives for low income customers exceed these values, the higher of the two values would be used (i.e., if the PAs are already paying 100% of the incremental cost for a measure directed at a low income customer, the 100% of incremental cost value would be used for the BAU+ scenario).
- **Maximum Achievable (MAX) Scenario**
    - Incentive set to 100% of incremental costs

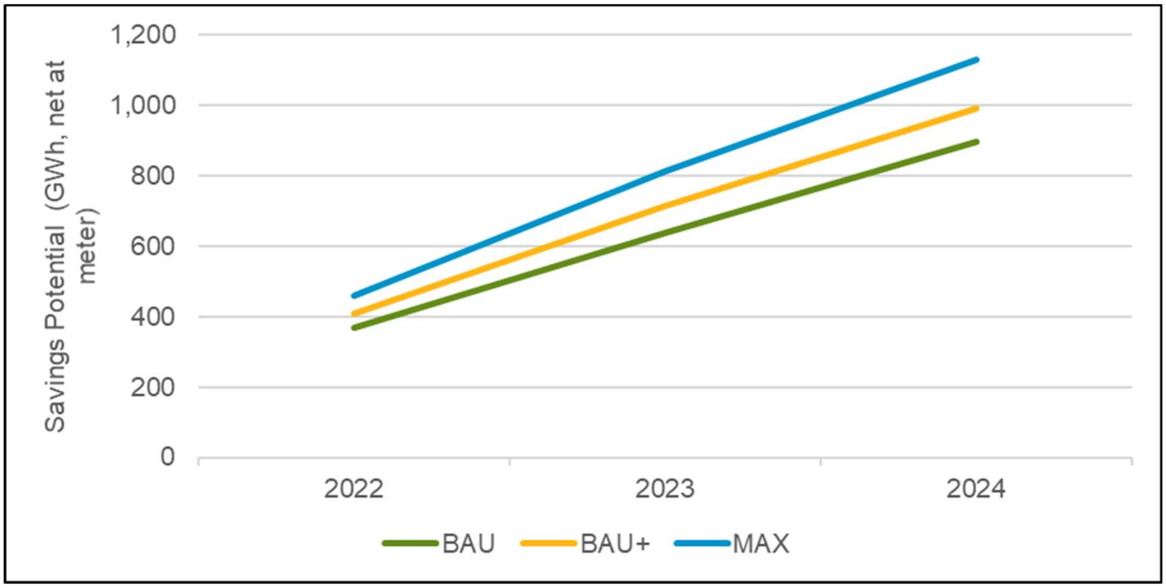
8. Energy Efficiency Achievable Potential Results by Scenario

This section provides the achievable potential results calculated by the model at varying levels of aggregation, using the TRC benefit-cost test as a screen set to 0.80. At-the-meter, net savings results are shown by sector, end-use category, and by highest impact measures. For more details and levels of aggregation of achievable potential, including summaries for the BAU+ and MAX scenarios, please see Appendix B.

8.1 Comparison of Energy Efficiency Savings by Potential Type

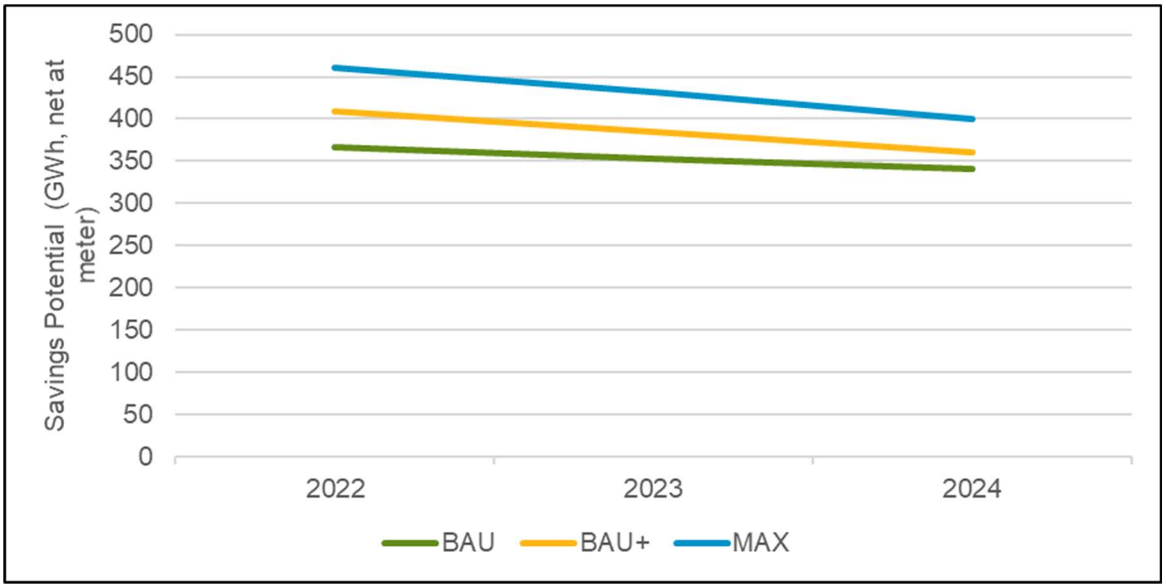
As Figure 8-1 shows, the cumulative electric energy achievable potential, net at meter, for each scenario, which accounts for the rate of DSM acquisition, increases steadily throughout the study period. Incremental annual electric energy efficiency in GWh, net at the meter, decreases over time in each scenario, as Figure 8-2 shows.

Figure 8-1. EE Achievable Potential, Cumulative Annual Electricity Savings, by Scenario (GWh, Net at Meter)



Source: Guidehouse analysis

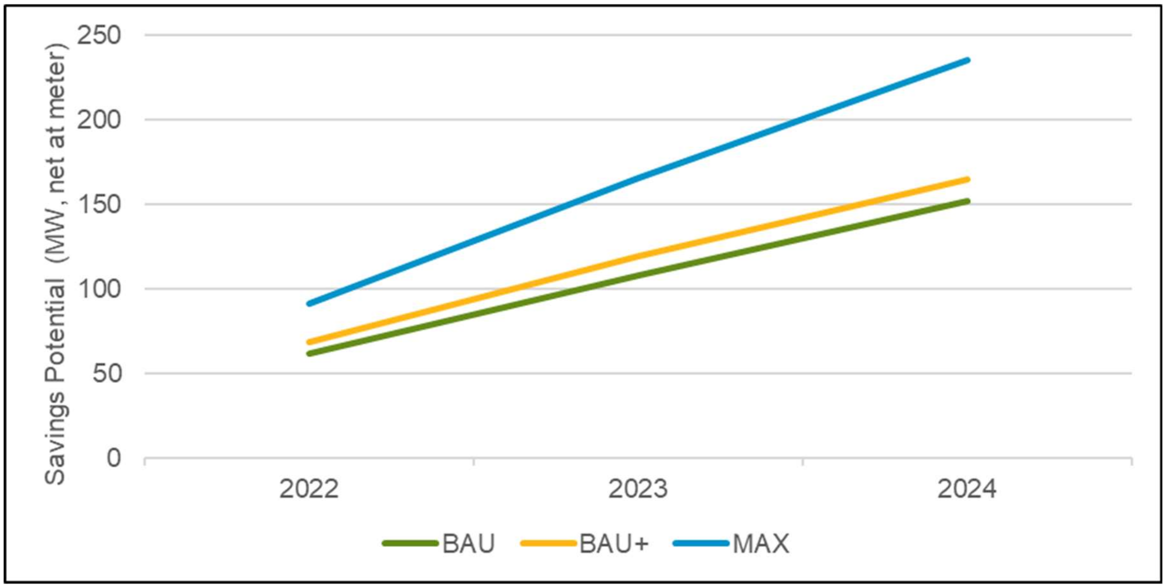
Figure 8-2. EE Achievable Potential, Incremental Annual Electricity Savings, by Scenario (GWh, Net at Meter)



Source: Guidehouse analysis

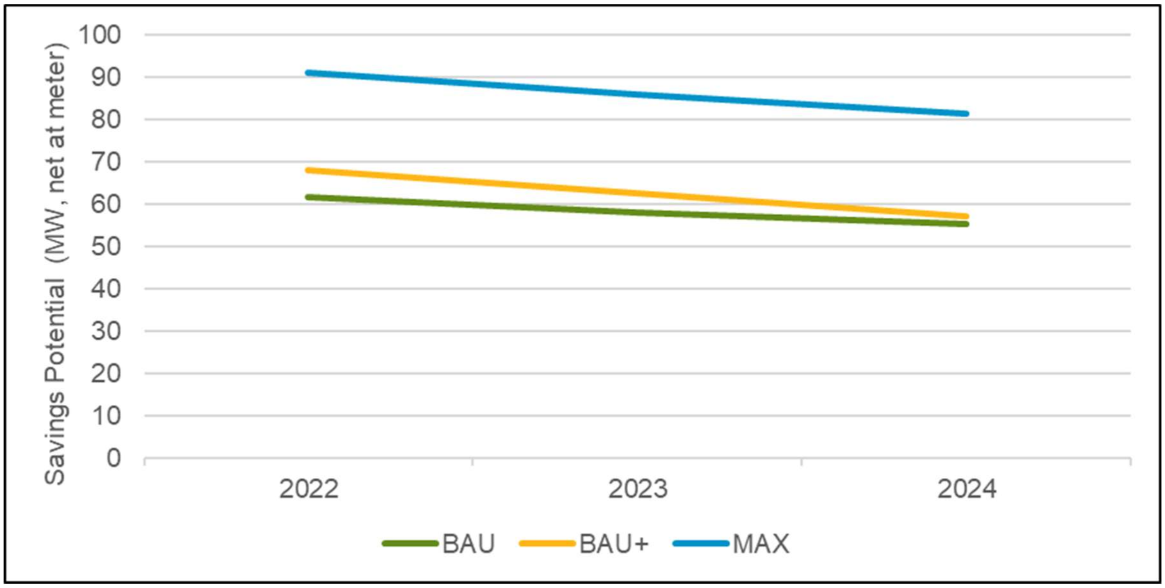
Figure 8-3 shows the cumulative annual summer peak demand potential, net at meter, by scenario. These demand savings are auxiliary impacts from the installation of energy efficiency measures, whereas the demand savings from demand-focused measures are estimated in a separate analysis on demand response potential in Section 15. The cumulative achievable potential increases steadily throughout the study period. Figure 8-4 shows the incremental summer peak passive demand achievable potential decreasing in each year of the analysis.

Figure 8-3. EE Achievable Potential, Cumulative Annual Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

Figure 8-4. EE Achievable Potential, Incremental Annual Summer Peak Passive Demand Savings, by Scenario (MW, Net at Meter)

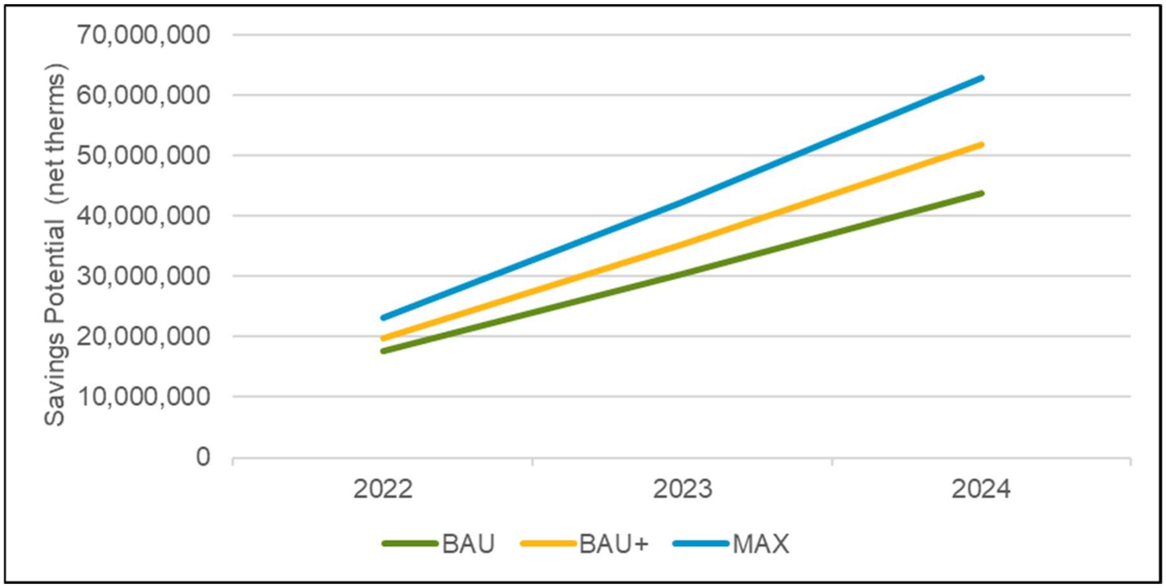


Source: Guidehouse analysis

Figure 8-5 shows cumulative natural gas savings achievable potential, in net therms, by scenario. The cumulative potential increases over the study period.

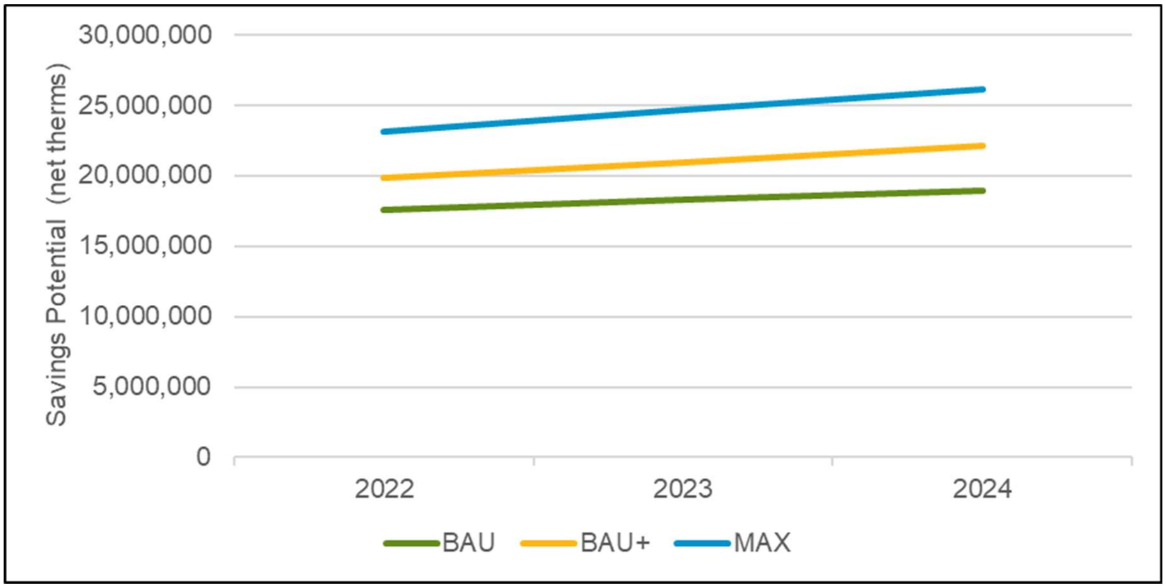
Figure 8-6 shows incremental natural gas savings achievable potential, in net therms, by scenario. The annual incremental potential increases gradually over the study period.

Figure 8-5. EE Achievable Potential, Cumulative Annual Natural Gas Savings, by Scenario (Net therms)



Source: Guidehouse analysis

Figure 8-6. EE Achievable Potential, Incremental Annual Natural Gas Savings, by Scenario (Net therms)

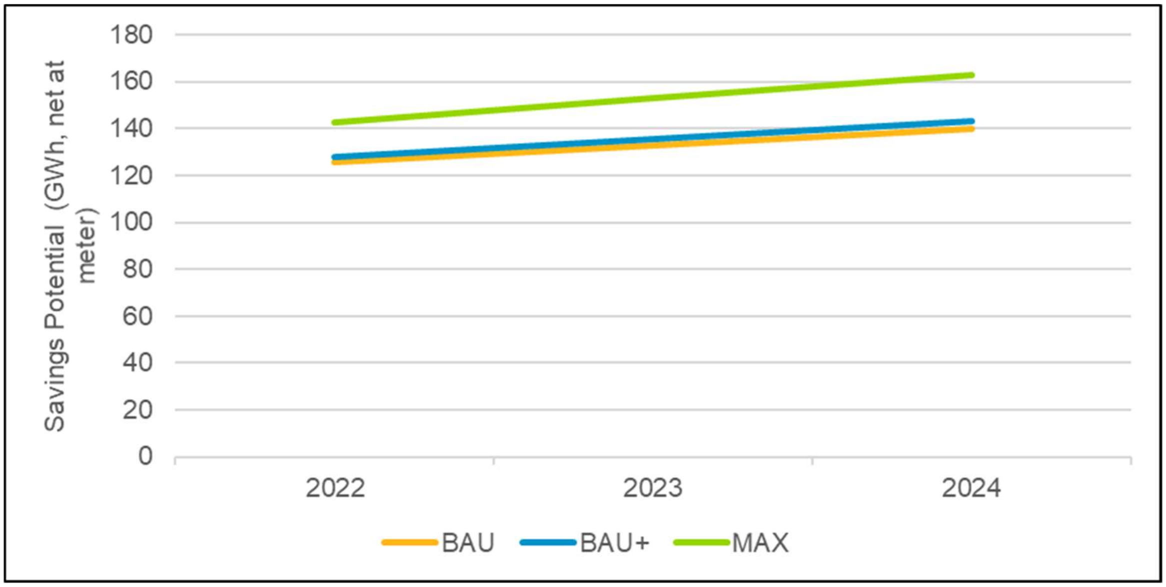


Source: Guidehouse analysis

8.2 Energy Efficiency Potential Results by Sector

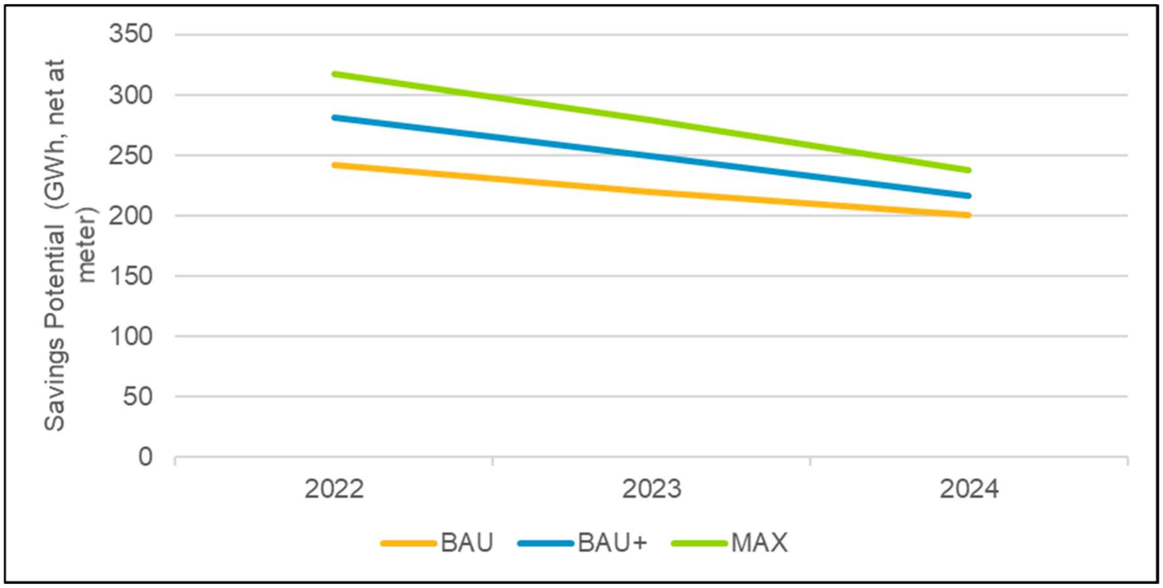
Figure 8-7 shows the incremental annual electricity achievable savings potential, net at meter, by scenario for the Residential sector. Figure 8-8 shows the incremental annual electricity achievable savings potential, net at generator, by scenario for the C&I sector. Residential electric energy savings potential increases in all three scenarios while C&I savings potential decreases.

Figure 8-7. EE Residential Achievable Potential, Incremental Annual Electricity Savings (GWh, Net at Meter)



Source: Guidehouse analysis

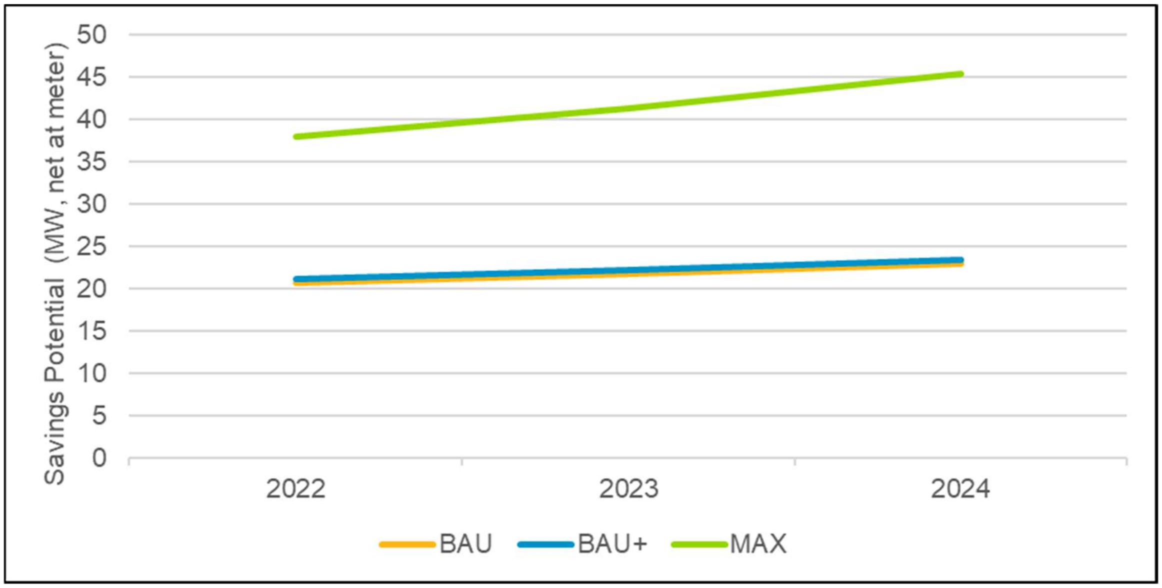
Figure 8-8. EE C&I Achievable Potential, Incremental Annual Electricity Savings (GWh, Net at Meter)



Source: Guidehouse analysis

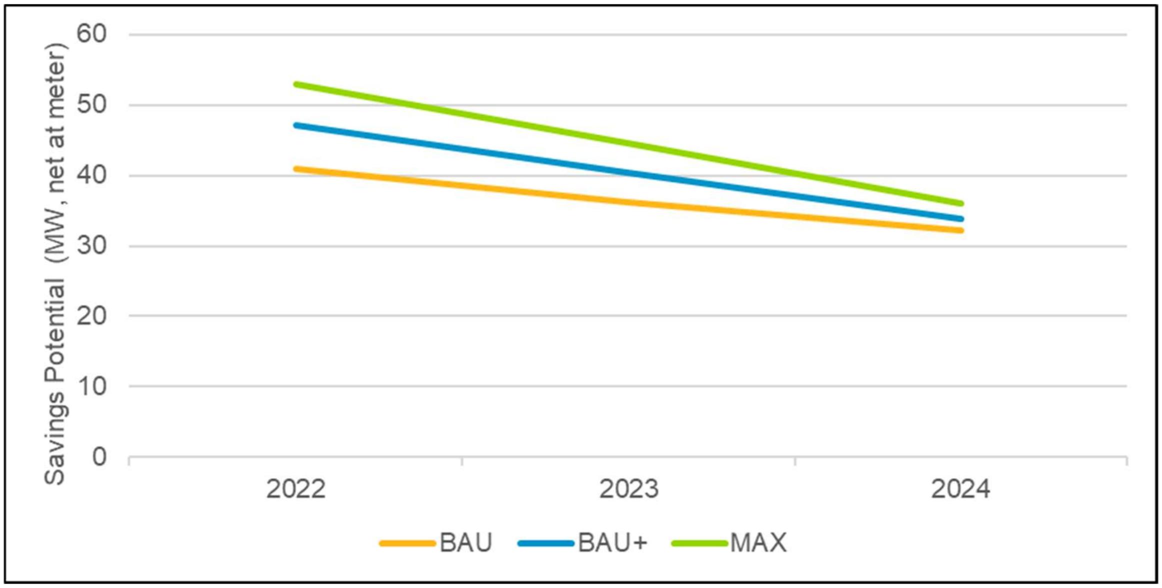
Figure 8-9 shows the incremental annual summer peak passive demand achievable potential, net at meter, by scenario for the Residential sector. Figure 8-10 shows the incremental annual summer peak passive demand achievable potential, net at meter, by scenario for the C&I sector. Residential electric demand savings potential increases in all three scenarios while C&I savings potential decreases.

Figure 8-9. EE Residential Achievable Potential, Incremental Annual Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

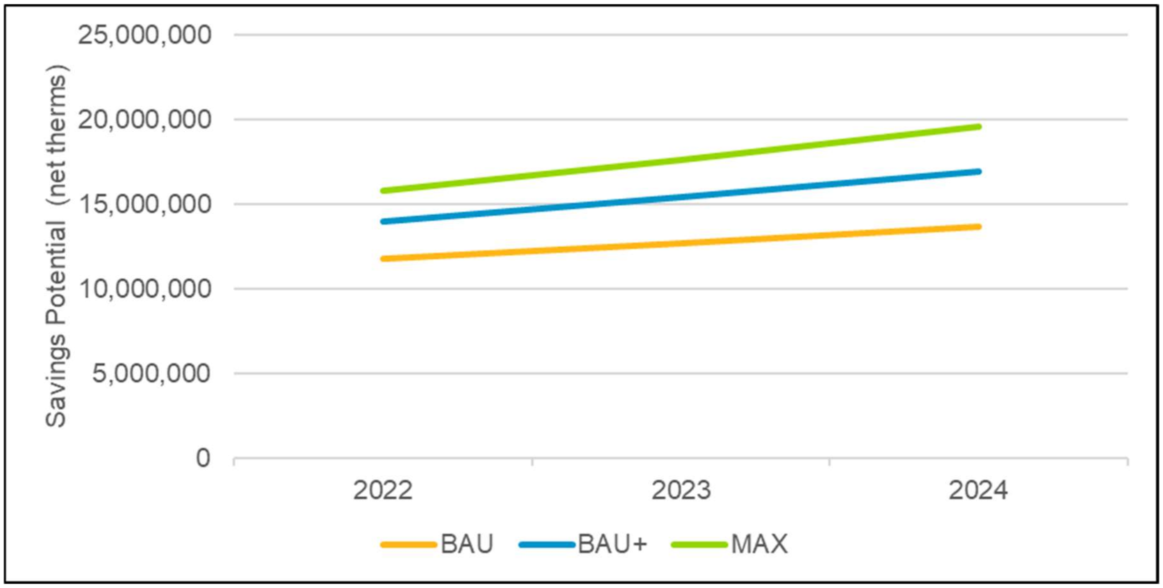
Figure 8-10. EE C&I Achievable Potential, Incremental Annual Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

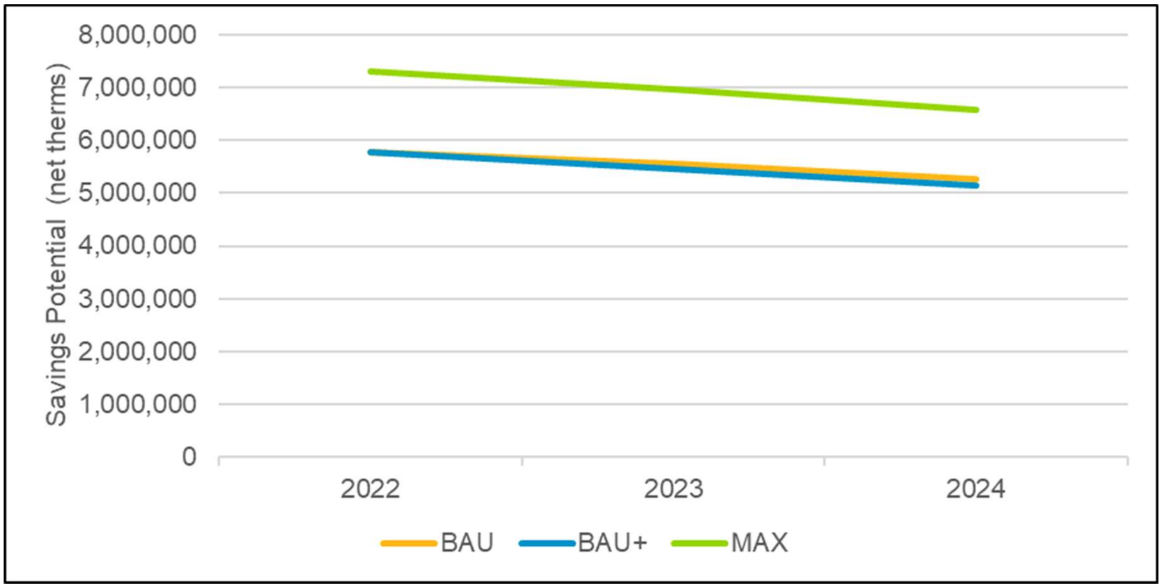
Figure 8-11 shows the incremental annual natural gas savings potential, net at meter, by scenario for the Residential sector. Figure 8-12 shows the incremental annual natural gas savings potential, net at meter, by scenario for the C&I sector. Residential gas energy savings potential increases in all three scenarios while C&I savings potential decreases.

Figure 8-11. EE Residential Achievable Potential, Incremental Annual Natural Gas Savings (Net therms)



Source: Guidehouse analysis

Figure 8-12. EE C&I Achievable Potential, Incremental Annual Natural Gas Demand Savings (Net therms)

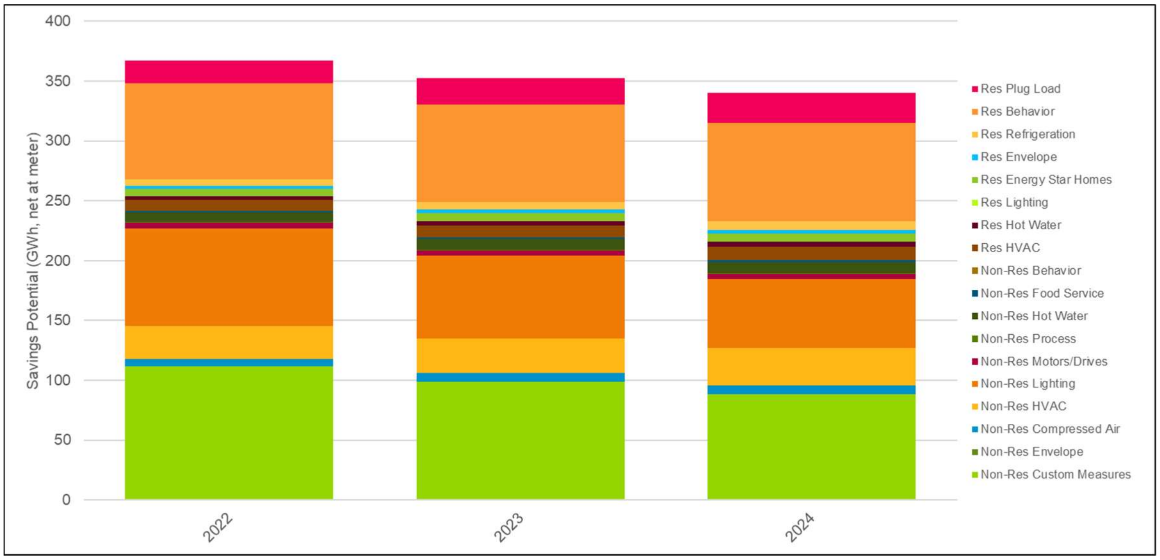


Source: Guidehouse analysis

8.3 Energy Efficiency Potential Results by End Use

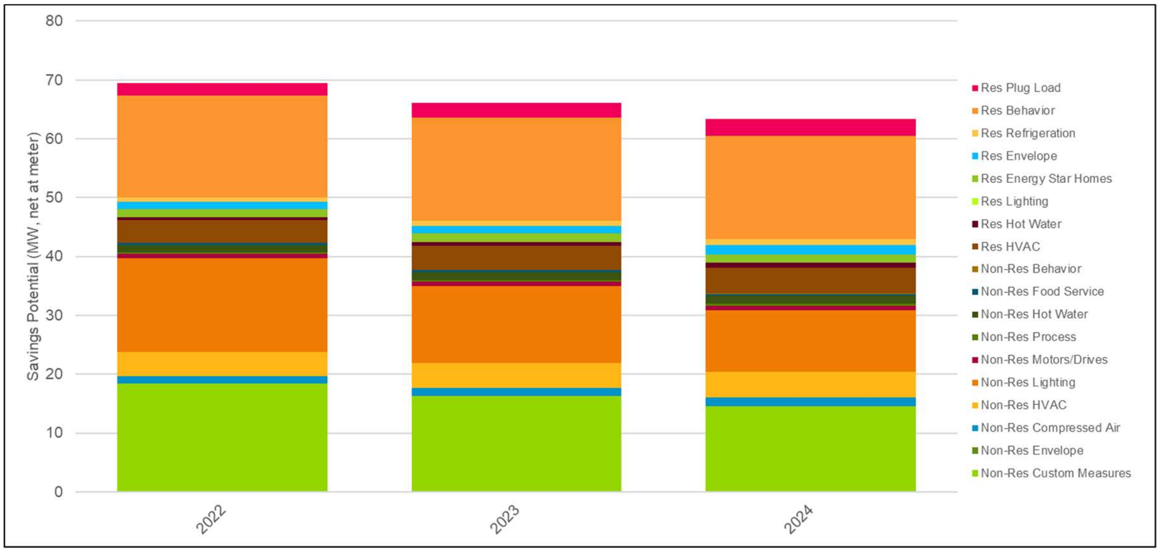
Figure 8-13 shows the incremental annual electricity achievable potential, net at meter, across end uses. Figure 8-14 shows the incremental annual summer peak demand achievable potential, net at meter, across end uses. In both figures, the dominant end uses are Residential Behavior, C&I Custom, and C&I Lighting measures.

Figure 8-13. EE BAU Scenario Achievable Potential, Incremental Annual Electricity Savings by End Use (GWh, Net at Meter)



Source: Guidehouse analysis

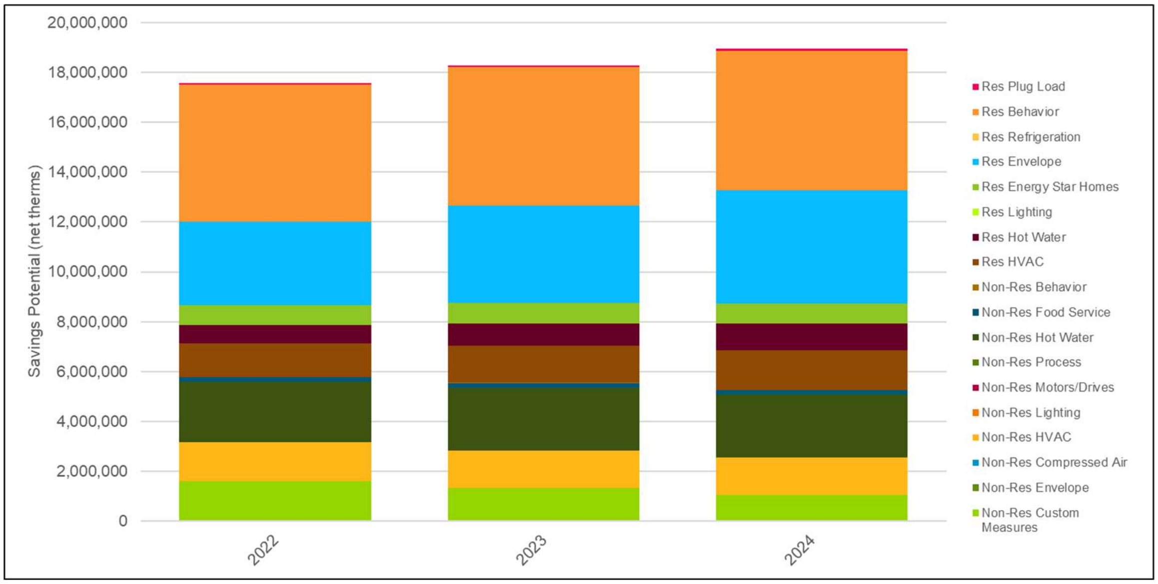
Figure 8-14. EE BAU Scenario Achievable Potential, Incremental Annual Summer Peak Demand Savings by End Use (MW, Net at Meter)



Source: Guidehouse analysis

Figure 8-15 shows the incremental natural gas net achievable potential, across end uses. The dominant end uses are Residential Behavior and Residential Envelope measures.

Figure 8-15. EE BAU Scenario Achievable Potential, Incremental Annual Natural Gas Savings by End Use (Net therms)



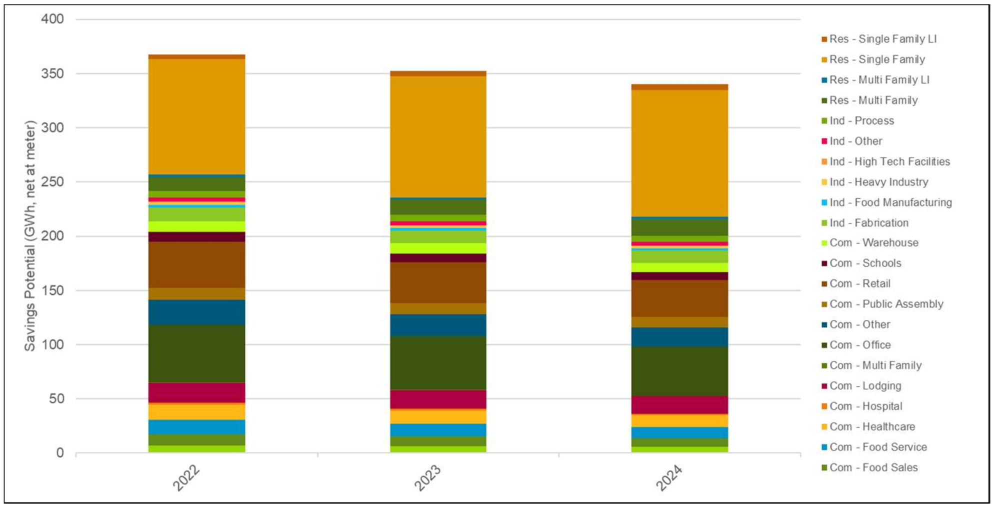
Source: Guidehouse analysis

8.4 Energy Efficiency Potential Results by Customer Segment

Figure 8-16 shows the incremental annual electricity achievable potential, net at meter, across customer segments. The dominant segment is Residential Single Family. Other segments show fewer savings due to segmentation and associated measures. Potential savings in some segments, such as Commercial Retail and Multifamily decrease over the study period, while others remain fairly steady. Additional details and tabular data for customer segment level results are provided in Appendix B.

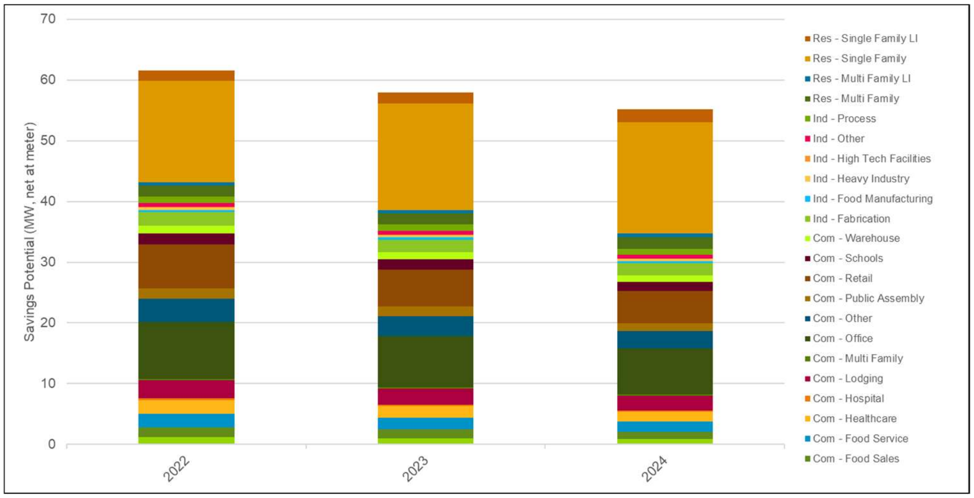
Figure 8-17 shows the incremental annual summer peak passive demand achievable savings potential, net at meter, across customer segments. Similar to electricity, the dominant segment is Residential Single Family. The segment-level patterns are generally the same as for electric energy savings. Additional details and tabular data for customer segment level results are provided in Appendix B.

Figure 8-16. EE BAU Scenario Achievable Potential, Incremental Annual Electricity Savings by Customer Segment (GWh, Net at Meter)



Source: Guidehouse analysis

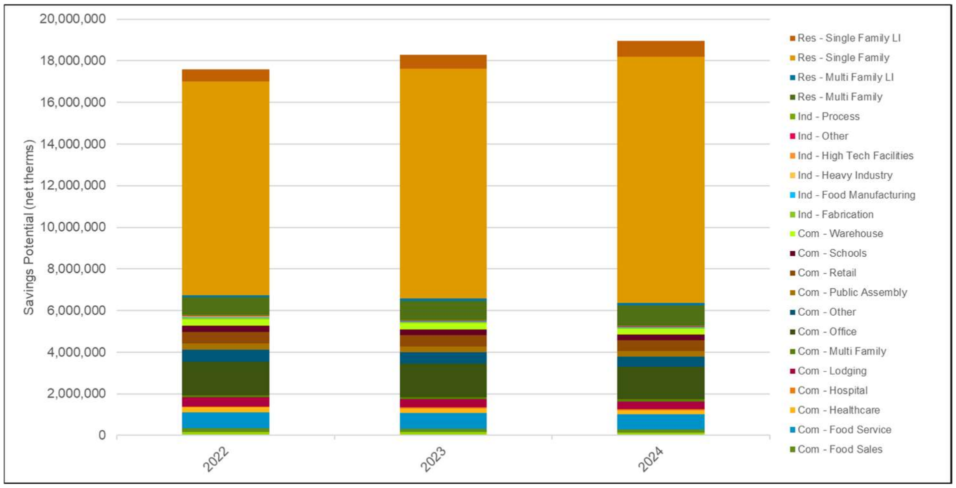
Figure 8-17. EE BAU Scenario Achievable Potential, Incremental Annual Summer Peak Passive Demand Savings by Customer Segment (MW, Net at Meter)



Source: Guidehouse analysis

Figure 8-18 shows the incremental annual net natural gas achievable potential, across customer segments. The dominant segments is, once again, Residential Single Family, which also shows an increase over the study period. Additional details and tabular data for customer segment level results are provided in Appendix B.

Figure 8-18. EE BAU Scenario Achievable Potential, Incremental Annual Natural Gas Savings by Customer Segment (Net therms)

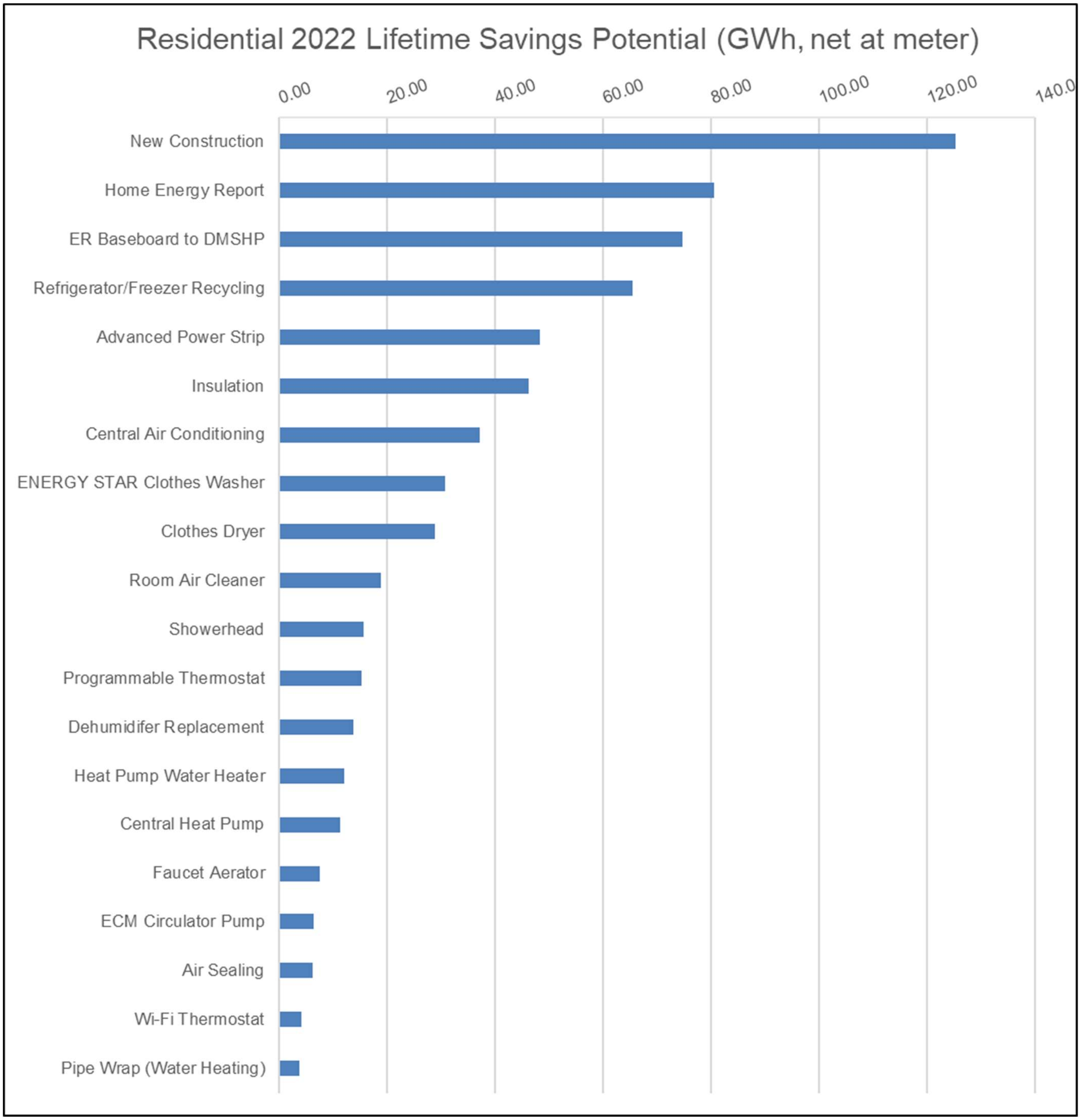


Source: Guidehouse analysis

8.5 Energy Efficiency Potential Results by Measure

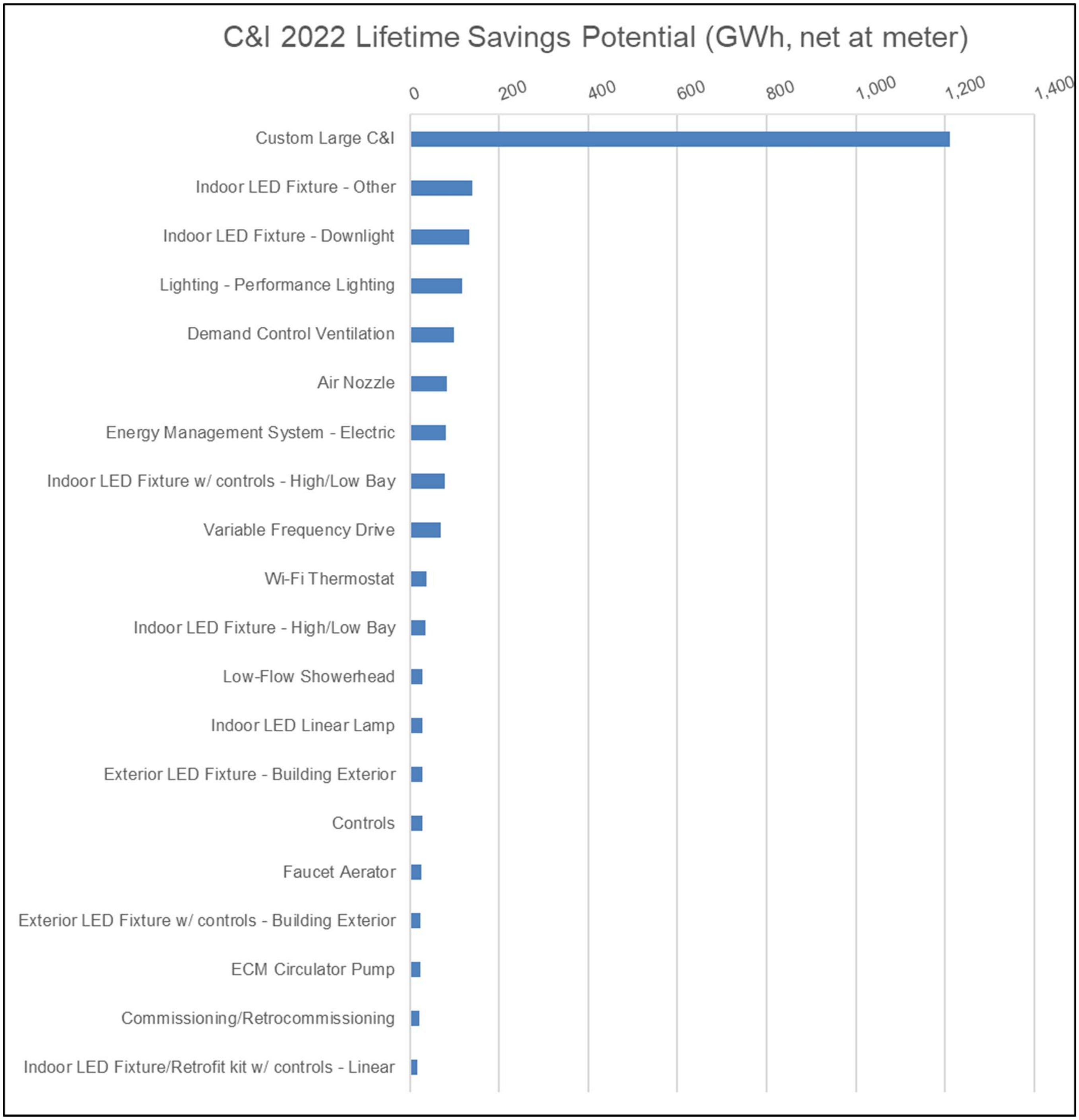
Figure 8-19 and Figure 8-20 show the top lifetime electricity saving measures, net at meter, in 2022 for the Residential and C&I sectors, respectively. Annual savings are dominated by Home Energy Reports in the Residential sector and by Custom measures in the C&I sector, however, in the Residential sector, new construction is the highest lifetime savings measure. This is due to the one-year measure life of home energy reports. Similar results for the BAU+ and MAX scenarios are included in Appendix B. Appendix B also contains first-year annual and lifetime savings by measure.

Figure 8-19. EE BAU Scenario Lifetime Achievable Potential, 2022 Top Residential Measures for Electricity Savings (GWh, Net at Meter)



Source: Guidehouse analysis

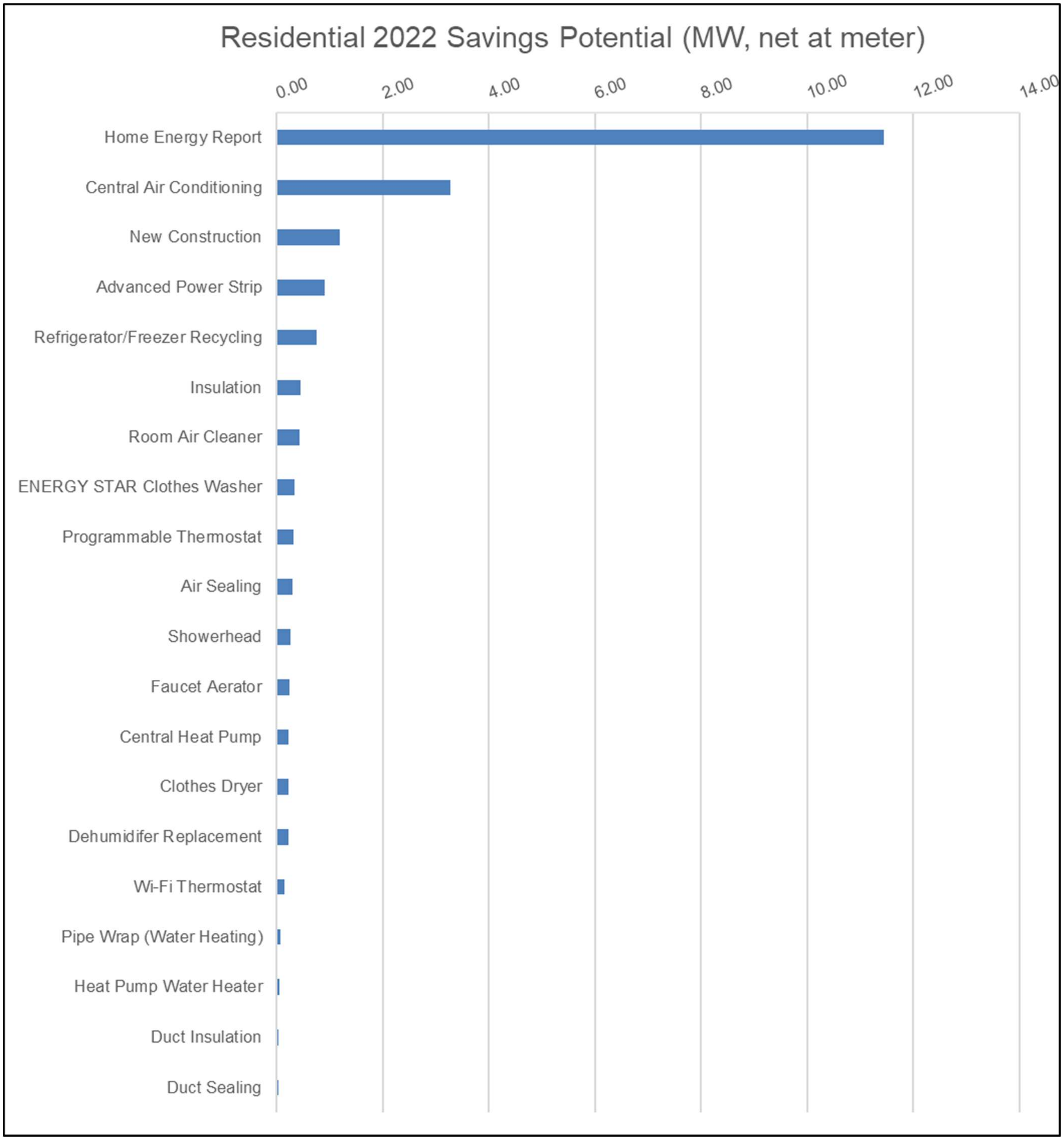
Figure 8-20. EE BAU Scenario Lifetime Achievable Potential, 2022 Top C&I Measures for Electricity Savings (GWh, Net at Meter)



Source: Guidehouse analysis

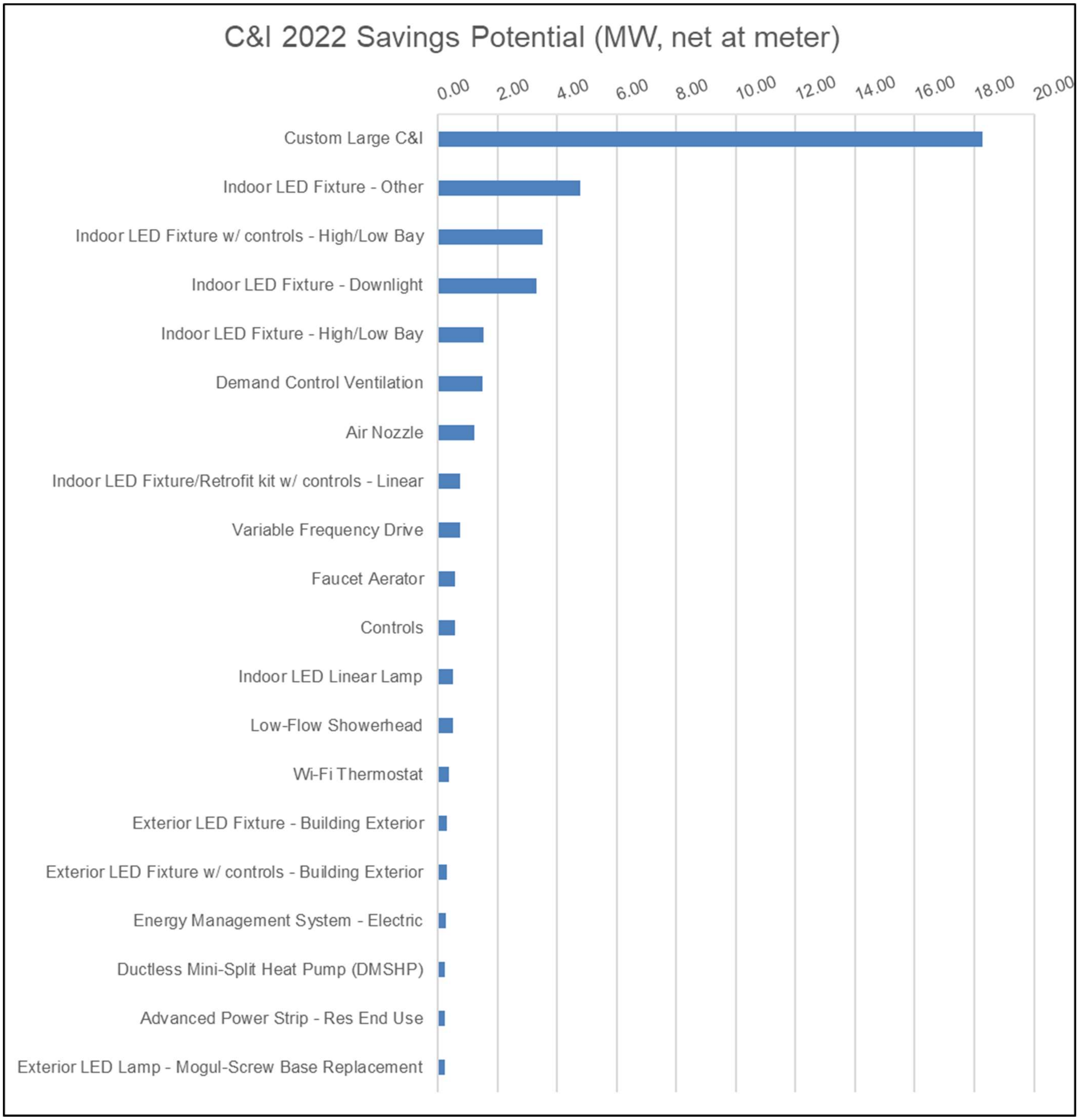
Figure 8-21 and Figure 8-22 show that the top summer peak passive demand savings measures, net at meter, in 2022, are dominated by Home Energy Reports and Central AC in the Residential Sector and Custom measures in the C&I sector. The distribution of potential savings by measure is somewhat more evenly distributed in the C&I sector than the Residential sector.

Figure 8-21. EE BAU Scenario First-Year Achievable Potential, 2022 Top 20 Residential Measures for Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

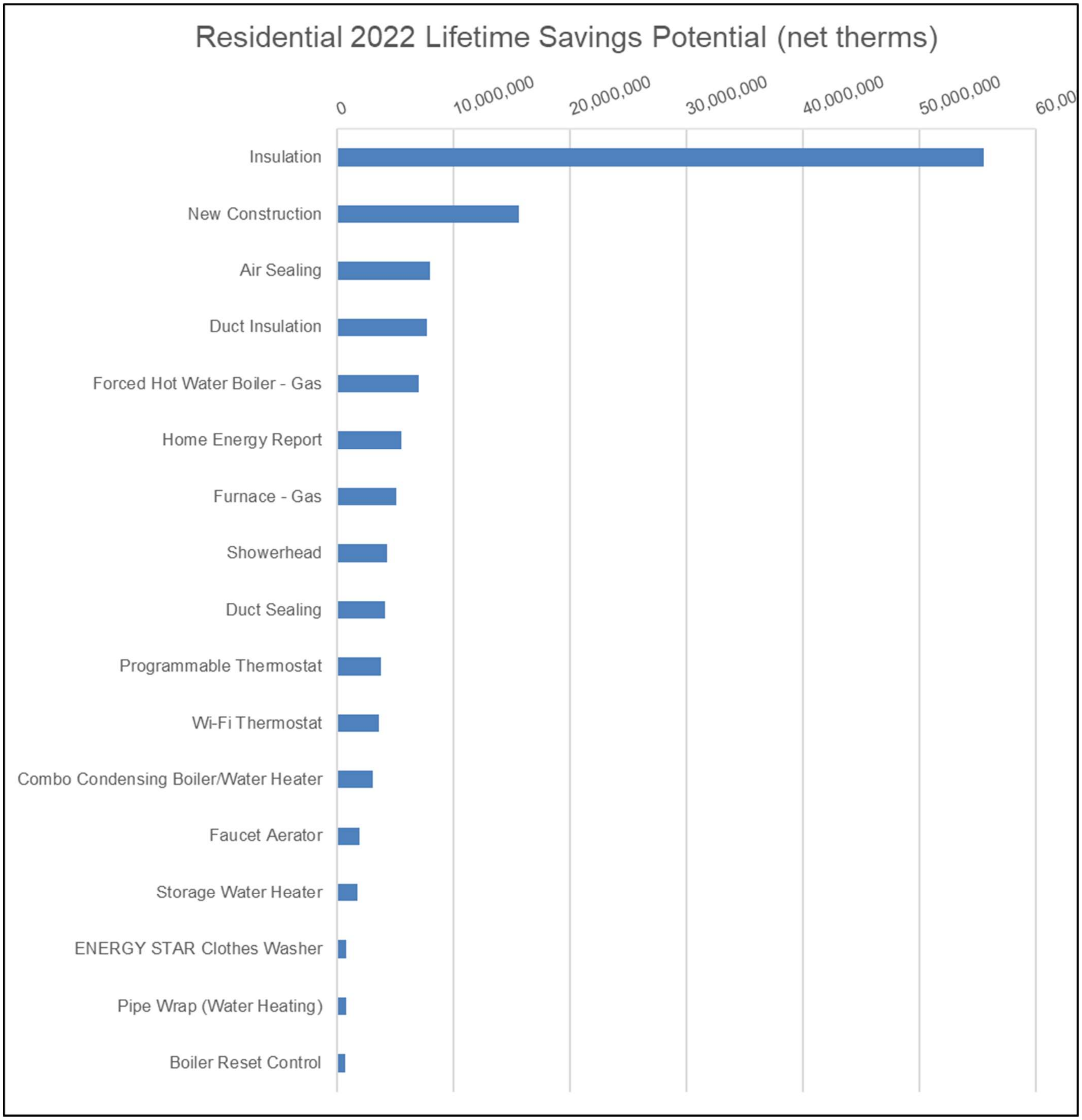
Figure 8-22. EE BAU Scenario First-Year Achievable Potential, 2022 Top 20 C&I Measures for Summer Peak Passive Demand Savings (MW, Net at Meter)



Source: Guidehouse analysis

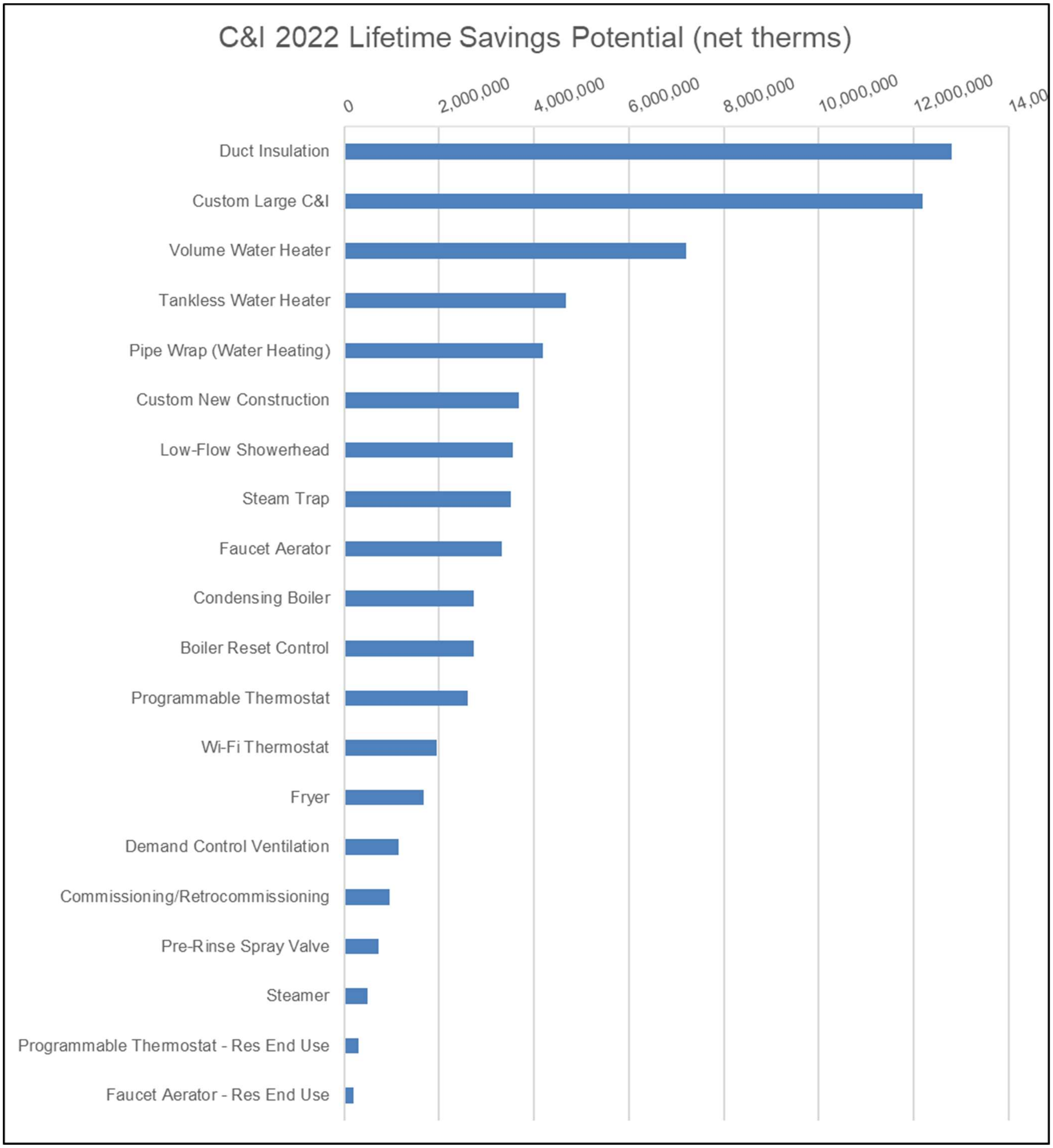
Figure 8-23 and Figure 8-24 show that the top lifetime natural gas savings measures in 2022, for the Residential and C&I sectors respectively. Home Energy Reports dominate the first-year annual savings for the Residential sector while insulation and other longer EUL measures provide greater lifetime savings. Custom measures lead the C&I sector savings. Appendix B contains first-year annual and lifetime savings by measure.

Figure 8-23. EE BAU Scenario Lifetime Achievable Potential, 2022 Top Residential Measures for Natural Gas Savings (net therms)



Source: Guidehouse analysis

Figure 8-24. EE BAU Scenario Lifetime Achievable Potential, 2022 Top 20 C&I Measures for Natural Gas Savings (net therms)



Source: Guidehouse analysis

8.6 Results by Program

This section presents results for savings, and benefits and costs, for the BAU scenario for the Residential sector, separately for electric and then natural gas programs. C&I sector results then follow. Based on National Grid's 2019 BCR Model, measures were mapped to different programs.

8.6.1 Residential Sector

Table 8-1 presents the incremental annual net savings for Residential electric programs for the 3-year study horizon for the BAU scenario.

Table 8-1. Residential Sector, Electric Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

Residential Sector Electric Programs Net Savings BAU Scenario	Electricity		Oil	Propane
	GWh	Summer Peak Demand (MW)	MMBtu	MMBtu
A1a – Residential New Homes & Renovations – Electric				
2022	6,261	1.19	0	6,180
2023	6,539	1.24	0	7,595
2024	6,574	1.24	0	8,951
A2a – Residential Coordinated Delivery – Electric				
2022	19,193	2.94	171,232	5,229
2023	22,871	3.48	198,118	6,569
2024	26,664	4.04	220,974	8,093
A2c – Residential Retail – Electric				
2022	14,043	3.03	61,015	3,637
2023	15,532	3.14	70,592	4,067
2024	17,059	3.30	78,714	4,358
A2d – Residential Behavior – Electric				
2022	80,454	11.45	0	0
2023	81,232	11.56	0	0
2024	81,973	11.67	0	0
B1a – Income Eligible Coordinated Delivery – Electric				
2022	5,650	2.13	28,533	4,272
2023	6,531	2.36	32,326	5,179
2024	7,449	2.68	35,904	6,209
Residential Total – Electric Programs				
2022	125,601	20.73	260,779	19,318
2023	132,705	21.78	301,036	23,410
2024	139,718	22.93	335,592	27,611

Source: Guidehouse analysis

Table 8-2 presents the benefits and costs by Residential electric programs for the 3-year study horizon for the BAU scenario.

Table 8-2. Residential Sector, Electric Programs, Benefits and Costs, BAU Scenario, 2022-2024

Residential Sector Incremental Annual Net BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[26] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
A1a – Residential New Homes & Renovations – Electric					
2022	4.1	$23.06	$5.66	$0.99	$3.52
2023	4.0	$25.02	$6.27	$1.06	$3.77
2024	3.9	$26.27	$6.72	$1.10	$3.91
A2a – Residential Coordinated Delivery – Electric					
2022	3.6	$158.90	$43.92	$7.91	$24.67
2023	3.7	$186.60	$51.02	$9.22	$28.76
2024	3.7	$212.04	$57.38	$10.41	$32.49
A2c – Residential Retail – Electric					
2022	3.4	$63.02	$18.75	$2.89	$10.25
2023	3.5	$70.84	$20.50	$3.22	$11.41
2024	3.5	$77.85	$22.19	$3.52	$12.47
A2d – Residential Behavior – Electric					
2022	1.8	$11.68	$6.57	$6.57	$0.00
2023	1.8	$11.64	$6.57	$6.57	$0.00
2024	1.8	$11.72	$6.57	$6.57	$0.00
B1a – Income Eligible Coordinated Delivery – Electric					
2022	3.1	$50.84	$16.23	$4.42	$17.68
2023	3.1	$58.63	$18.82	$5.16	$20.64
2024	3.1	$66.43	$21.39	$5.91	$23.63
Residential Sector Total – Electric Programs					
2022	3.4	$307.50	$91.12	$22.78	$56.12
2023	3.4	$352.73	$103.18	$25.23	$64.58
2024	3.5	$394.31	$114.25	$27.51	$72.50

Source: Guidehouse analysis

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[26] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

Table 8-3 presents the incremental annual net savings for Residential natural gas programs for the 3-year study horizon for the BAU scenario.

Table 8-3. Residential Sector, Natural Gas Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

Residential Sector Natural Gas Programs Net Savings BAU Scenario	Natural Gas Therms
A1a – Residential New Homes & Renovations – Natural Gas	
2022	781,420
2023	810,251
2024	807,126
A2a – Residential Coordinated Delivery – Natural Gas	
2022	3,551,913
2023	4,162,625
2024	4,856,245
A2c – Residential Retail– Natural Gas	
2022	1,356,493
2023	1,492,808
2024	1,612,148
A2d – Residential Behavior – Natural Gas	
2022	5,500,622
2023	5,556,909
2024	5,610,465
B1a – Income Eligible Coordinated Delivery – Natural Gas	
2022	603,206
2023	704,249
2024	809,552
Residential Sector Total – Natural Gas Programs	
2022	11,793,655
2023	12,726,842
2024	13,695,535

Source: Guidehouse analysis

Table 8-4 presents the benefits and costs by Residential natural gas programs for the 3-year study horizon for the BAU scenario.

Table 8-4. Residential Sector, Natural Gas Programs, Benefits and Costs, BAU Scenario, 2022-2024

Residential Sector Incremental Annual Net BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[27] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
A1a – Residential New Homes & Renovations –Natural Gas					
2022	2.4	$29.37	$12.43	$2.95	$9.88
2023	2.4	$30.37	$12.89	$3.06	$10.24
2024	2.4	$30.18	$12.83	$3.05	$10.20
A2a – Residential Coordinated Delivery – Natural Gas					
2022	2.4	$129.19	$54.80	$9.24	$29.63
2023	2.4	$151.55	$63.78	$10.76	$34.53
2024	2.4	$176.75	$74.20	$12.53	$40.19
A2c – Residential Retail – Natural Gas					
2022	1.9	$43.80	$23.54	$5.28	$17.68
2023	1.9	$47.31	$25.17	$5.66	$18.93
2024	1.9	$50.18	$26.50	$5.96	$19.96
A2d – Residential Behavior – Natural Gas					
2022	4.6	$11.98	$2.62	$2.62	$0.00
2023	4.6	$12.00	$2.62	$2.62	$0.00
2024	4.6	$12.06	$2.62	$2.62	$0.00
B1a – Income Eligible Coordinated Delivery – Natural Gas					
2022	2.9	$36.77	$12.56	$3.02	$12.10
2023	2.9	$42.81	$14.51	$3.49	$13.95
2024	3.0	$49.08	$16.56	$3.97	$15.88
Residential Sector Total – Natural Gas Programs					
2022	2.4	$251.11	$105.95	$23.11	$69.29
2023	2.4	$284.03	$118.98	$25.58	$77.64
2024	2.4	$318.26	$132.71	$28.12	$86.22

Source: Guidehouse analysis

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[27] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

8.6.2 C&I Sector

Table 8-5 presents the incremental annual net savings for C&I electric programs for the 3-year study horizon for the BAU scenario.

Table 8-5. C&I Sector, Electric Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

C&I Sector Electric Programs Net Savings BAU Scenario	Electricity		Oil	Propane
	GWh	Summer Peak Demand (MW)	MMBtu	MMBtu
C1a – C&I New Buildings & Major Renovations – Electric				
2022	1,341	0.18	0	0
2023	1,122	0.15	0	0
2024	1,137	0.15	0	0
C2a – C&I Existing Building Retrofit – Electric				
2022	190,779	34.21	410	512
2023	171,962	30.37	458	649
2024	154,620	26.75	482	803
C2b – C&I New & Replacement Equipment – Electric				
2022	49,638	6.46	23	115
2023	46,585	5.67	25	122
2024	44,796	5.32	26	124
C&I Total – Electric Programs				
2022	241,758	40.84	433	627
2023	219,670	36.18	484	771
2024	200,553	32.22	508	927

Source: Guidehouse analysis

Table 8-6 presents the benefits and costs by C&I electric programs for the 3-year study horizon for the BAU scenario.

Table 8-6. C&I Sector, Electric Programs, Benefits and Costs, BAU Scenario, 2022-2024

C&I Sector Incremental Annual Net BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[28] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
C1a – C&I New Buildings & Major Renovations – Electric					
2022	2.0	$1.91	$0.96	$0.14	$0.43
2023	2.0	$1.59	$0.80	$0.11	$0.36
2024	2.0	$1.60	$0.81	$0.12	$0.37
C2a – C&I Existing Building Retrofit – Electric					
2022	4.0	$274.51	$69.41	$18.98	$60.09
2023	4.1	$252.75	$61.37	$17.01	$53.87
2024	4.2	$232.75	$54.84	$15.30	$48.45
C2b – C&I New & Replacement Equipment – Electric					
2022	2.3	$83.93	$36.60	$8.34	$26.40
2023	2.3	$79.63	$34.36	$8.04	$25.47
2024	2.3	$76.63	$33.19	$7.83	$24.80
C&I Sector Total – Electric Programs					
2022	3.4	$360.35	$106.97	$27.45	$86.92
2023	3.5	$333.97	$96.53	$25.17	$79.70
2024	3.5	$310.98	$88.84	$23.25	$73.61

Source: Guidehouse analysis

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[28] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants. s

Table 8-7 presents the incremental annual net savings for C&I natural gas programs for the 3-year study horizon for the BAU scenario.

Table 8-7. C&I Sector, Natural Gas Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

C&I Sector Natural Gas Programs Net Savings BAU Scenario	Natural Gas 100k Decatherms
C1a – C&I New Building & Major Renovations – Natural Gas	
2022	368,838
2023	454,921
2024	441,475
C2a – C&I Existing Building Retrofit – Natural Gas	
2022	4,122,070
2023	3,886,513
2024	3,624,060
C2b – C&I New & Replacement Equipment – Natural Gas	
2022	1,293,198
2023	1,215,246
2024	1,195,654
C&I Sector Total – Natural Gas Programs	
2022	5,784,105
2023	5,556,680
2024	5,261,190

Source: Guidehouse analysis

Table 8-8 presents the benefits and costs by C&I gas programs for the 3-year study horizon for the BAU scenario.

Table 8-8. C&I Sector, Natural Gas Programs, Benefits and Costs, BAU Scenario, 2022-2024

C&I Sector Incremental Annual Net BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[29] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
C1a – C&I New Buildings & Major Renovations – Natural Gas					
2022	1.5	$4.37	$2.97	$1.00	$1.17
2023	1.5	$5.34	$3.66	$1.23	$1.45
2024	1.4	$5.14	$3.55	$1.20	$1.41
C2a – C&I Existing Building Retrofit – Natural Gas					
2022	11.9	$111.39	$9.37	$5.22	$6.12
2023	12.6	$108.74	$8.63	$4.74	$5.57
2024	12.7	$101.37	$8.00	$4.33	$5.08
C2b – C&I New & Replacement Equipment – Natural Gas					
2022	3.6	$23.69	$6.51	$2.36	$2.77
2023	3.7	$24.70	$6.72	$2.44	$2.87
2024	3.7	$24.72	$6.73	$2.45	$2.87
C&I Sector Total – Natural Gas Programs					
2022	7.4	$139.45	$18.85	$8.58	$10.07
2023	7.3	$138.77	$19.02	$8.42	$9.89
2024	7.2	$131.23	$18.28	$7.97	$9.35

Source: Guidehouse analysis

8.6.3 Electric Program MMBtu Savings

Table 8-9 and Table 8-10 present the first year and lifetime incremental annual net MMBtu savings for residential and C&I electric programs for the 3-year study horizon for the BAU scenario, respectively. Program MMBtu savings are a summation of electricity[30], propane, and fuel oil measure potential normalized to MMBtus.

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[29] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

[30] Electric savings were converted to MMBtu using MWh/MMBtu conversion factors specific to each measure that account for the lifetime and load shape of individual measures and the source fuel efficiency of the electric generation mix in New England.

Table 8-9. Residential Sector, Electric Programs, Incremental Annual and Lifetime Net MMBtu Savings, BAU Scenario, 2022-2024

	First Year MMBtu (all fuels)	Lifetime MMBtu (all fuels)
BAU Scenario	**MMBtu**	**MMBtu**
A1a – Residential New Homes & Renovations – Electric		
2022	51,255	932,014
2023	53,992	989,531
2024	53,270	1,014,845
A2a – Residential Coordinated Delivery – Electric		
2022	314,108	5,126,636
2023	366,101	5,945,775
2024	407,877	6,685,465
A2c – Residential Retail – Electric		
2022	165,378	2,186,796
2023	184,261	2,453,920
2024	197,439	2,702,104
A2d – Residential Behavior – Electric		
2022	579,171	579,171
2023	576,285	576,285
2024	552,570	552,570
B1a – Income Eligible Coordinated Delivery – Electric		
2022	73,435	1,172,670
2023	83,751	1,343,659
2024	92,229	1,511,658
Residential Total – Electric Programs		
2022	1,183,346	9,997,287
2023	1,264,391	11,309,170
2024	1,303,385	12,466,642

Source: Guidehouse analysis

Table 8-10. C&I Sector, Electric Programs, Incremental Annual and Lifetime Net MMBtu Savings, BAU Scenario, 2022-2024

	First Year MMBtu (all fuels)	Lifetime MMBtu (all fuels)
BAU Scenario	**MMBtu**	**MMBtu**
C1a – C&I New Buildings & Major Renovations – Electric		
2022	9,676	98,302
2023	7,995	81,274
2024	7,698	81,435
C2a – C&I Existing Building Retrofit – Electric		
2022	1,376,201	12,249,994
2023	1,224,420	11,059,973
2024	1,046,429	9,972,078
C2b – C&I New & Replacement Equipment – Electric		
2022	357,828	3,894,615
2023	331,331	3,674,152
2024	302,747	3,512,202
C&I Total – Electric Programs		
2022	1,743,705	16,242,911
2023	1,563,746	14,815,398
2024	1,356,874	13,565,715

Source: Guidehouse analysis

9. Energy Optimization Measure Characterization

9.1 Energy Optimization Measure List

Energy optimization measures involve a fuel-neutral approach to energy efficiency, and measures typically involve the replacement of fuel-fired heating equipment with more efficient electric heating systems. Guidehouse and National Grid developed a comprehensive measure list of energy optimization measures likely to contribute to economic potential. The energy optimization measure list includes measures that fully replace oil-, propane-, and gas-fired space and water heating systems with electric heat pump system. The list also includes measures that use dual-fuel heating systems to displace of portion of customers' fuel-fired heating with electric heat pumps.

9.2 Energy Optimization Measure Characterization

Guidehouse characterized energy optimization measures using the same parameters and input template as described for EE measures in Section 3.2. For energy and demand savings and incremental cost data, Guidehouse referenced the Massachusetts Energy Optimization Model that was initially developed for the Massachusetts Residential Program Administrators in 2018 and subsequently updated in 2020 to cover small commercial buildings.[31] The Massachusetts Energy Optimization Model combines climate data for Massachusetts with electric heat pump performance curves to estimate the energy savings and costs for a wide variety of energy optimization measures.

As with conventional EE measures, Guidehouse sourced residential equipment densities and saturations from the Massachusetts Residential Baseline Study[32] and sourced commercial equipment densities from C&I baseline data.[33]

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[31] Navigant (2020). "Energy Optimization Model Updates (MA19R16-B-EO)." Available at: https://ma-eeac.org/wp-content/uploads/MA19R16-B-EO_Energy-Optimization-Measures-and-Assumptions-Update-Memo_Final_2020-03-02-1.pdf

[32] Navigant (2019) and Guidehouse (2020), "Massachusetts Residential baseline Study." Available at https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Comprehensive-Report-2019-04-30.pdf and https://ma-eeac.org/wp-content/uploads/RES-1-Residential-Baseline-Study-Ph4-Comprehensive-Report-2020-04-02.pdf. Both 2019 and 2020 versions of the baseline study were accessed for this study.

[33] C&I baseline data from a DNV study in progress at the time of this Potential Study.

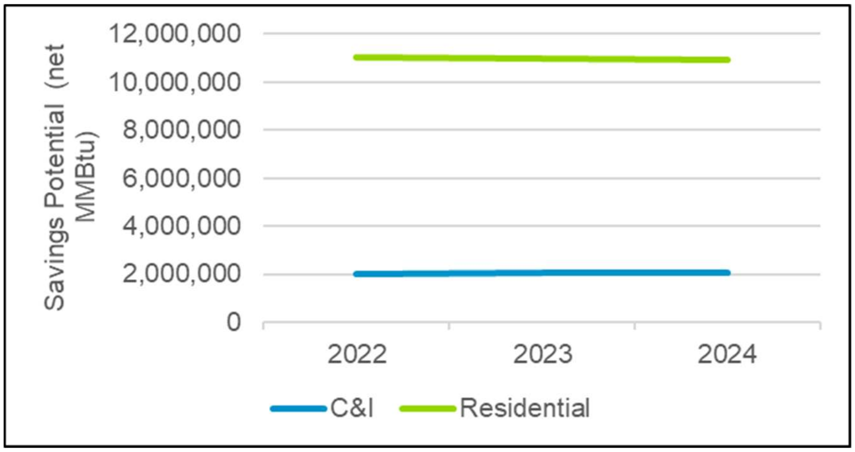
10. Energy Optimization Technical Potential Forecast

This section briefly describes Guidehouse's approach to calculating technical potential and presents the results for National Grid in Massachusetts pertaining to total technical savings potential at different levels of aggregation. Results are shown by sector, end-use category, and highest impact measures. Technical potential calculations and modeling follow the same methodology as the energy efficiency study.

10.1 Energy Optimization Technical Potential Results by Sector

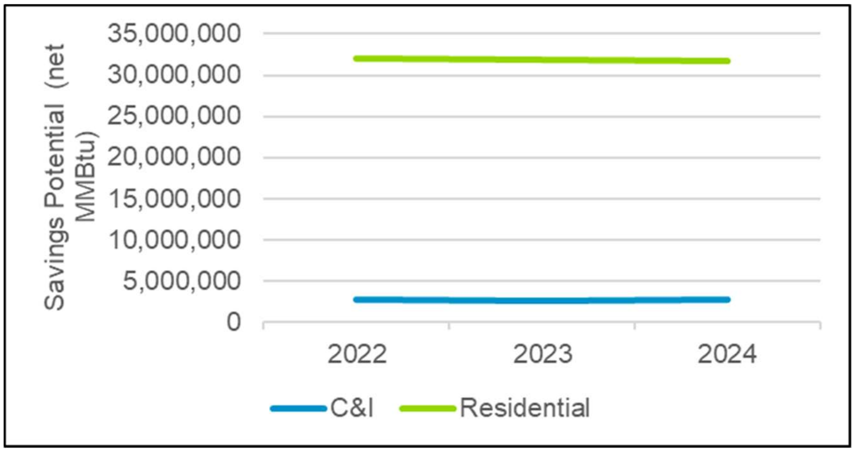
Figure 10-1 shows the total propane technical savings potential, in net MMBtus, for C&I sector and Residential sectors. Figure 10-2 shows the fuel oil technical savings potential, in net MMBtu, for each sector. Figure 10-3 shows the net natural gas technical savings potential, in net therms, for each sector. C&I technical potential savings are small for propane and fuel oil, and very small relative to Residential potential for natural gas.

Figure 10-1. EO Technical Potential, Propane Savings by Sector (Net MMBtus)



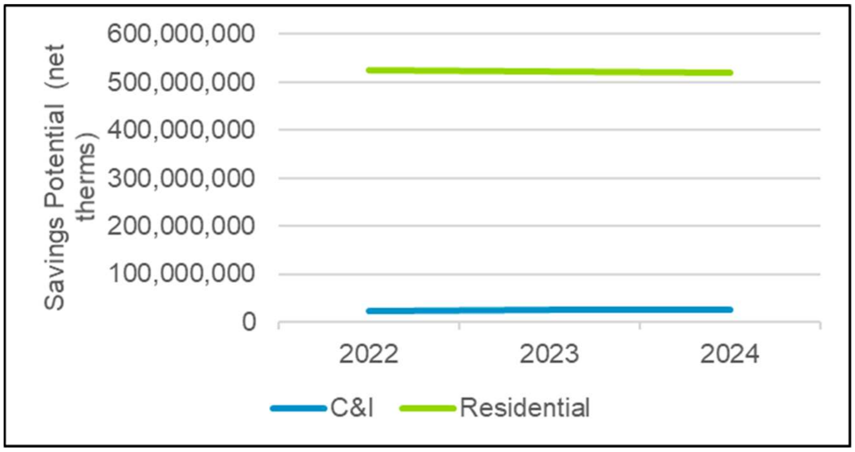
Source: Guidehouse analysis

Figure 10-2. EO Technical Potential, Fuel Oil Savings by Sector (Net MMBtus)



Source: Guidehouse analysis

Figure 10-3. EO Technical Potential, Natural Gas Savings by Sector (Net therms)

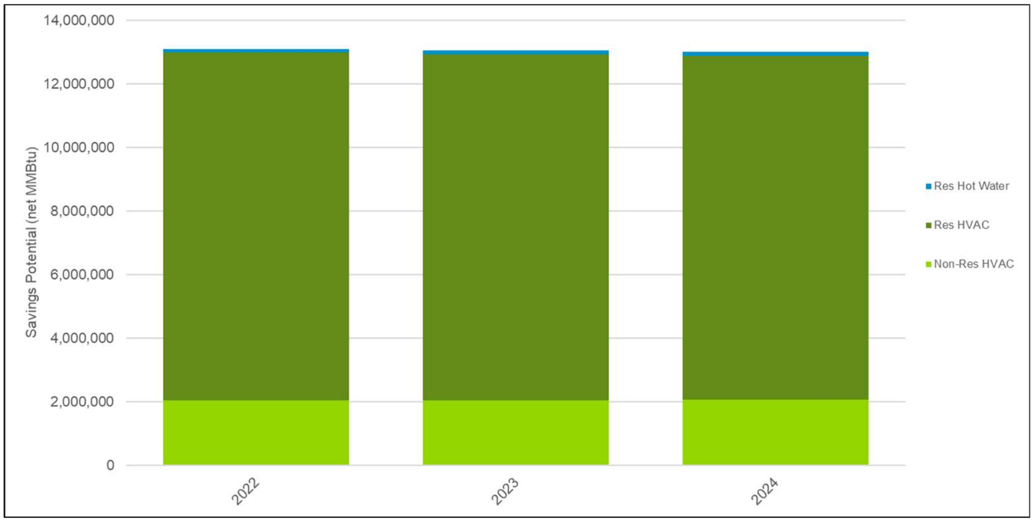


Source: Guidehouse analysis

10.2 Energy Optimization Technical Potential Results by End Use

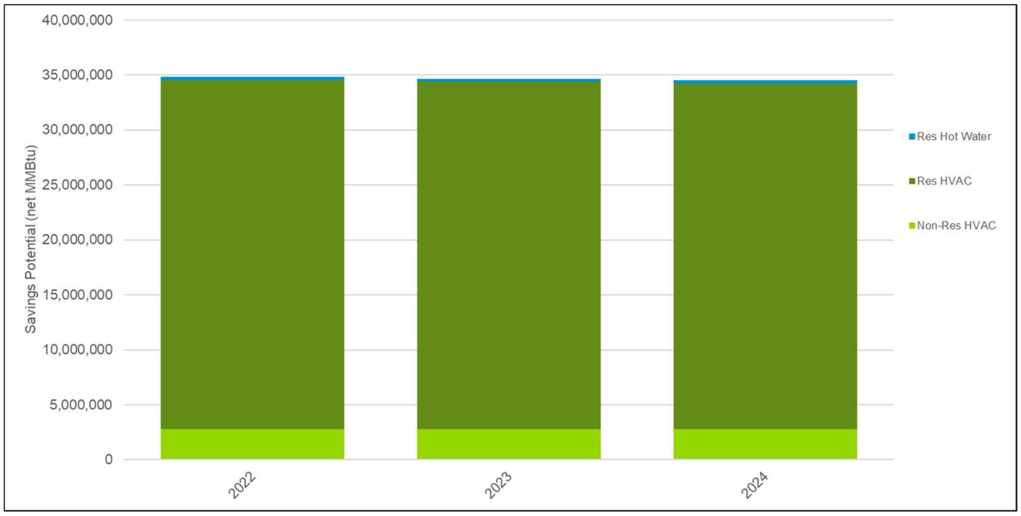
Figure 10-4 shows the fuel oil technical savings potential, in net MMBtu, across all end uses and sectors. Figure 10-5 shows the propane technical savings potential, in net MMBtu, across all end uses and sectors. Figure 10-6 shows the natural gas technical savings potential, in net therms, across all end uses and sectors. The Residential HVAC end use captures almost all of the potential technical savings for all three end uses.

Figure 10-4. EO Technical Potential, Propane Savings by End Use (Net MMBtus)



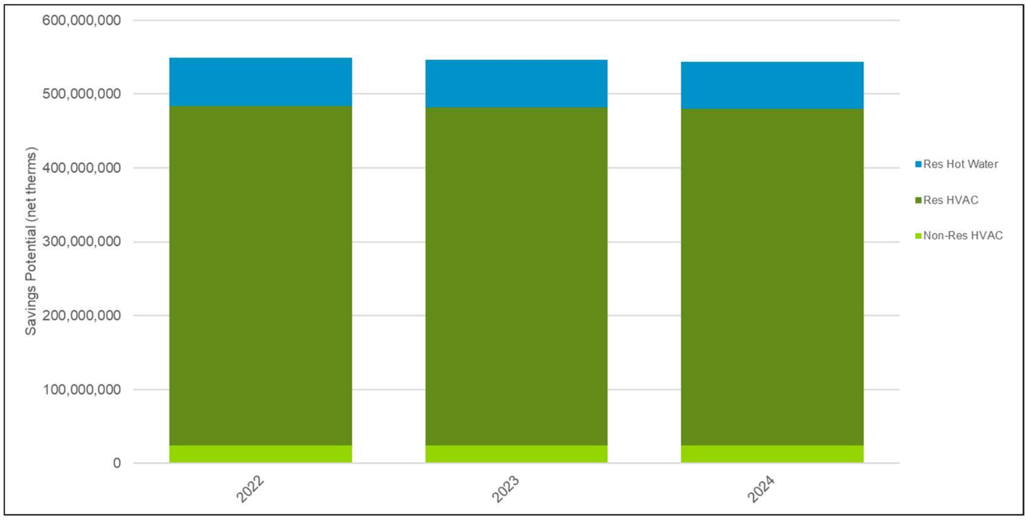
Source: Guidehouse analysis

Figure 10-5. EO Technical Potential, Fuel Oil Savings by End Use (Net MMBtus)



Source: Guidehouse analysis

Figure 10-6. EO Technical Potential, Natural Gas Savings by End Use (Net therms)



Source: Guidehouse analysis

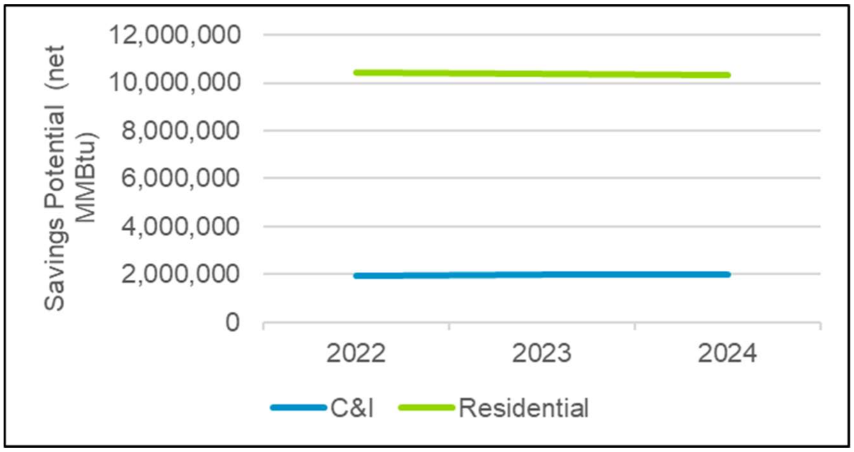
11. Energy Optimization Economic Potential Results

This section describes the economic savings potential, which is potential that meets a prescribed level of cost-effectiveness, available for National Grid in Massachusetts. As with technical potential, Guidehouse's modeling of economic potential mirrors the energy efficiency study. This section also presents the results for economic savings potential at different forms of aggregation. Results are shown by sector, end-use category, and highest impact measures. Guidehouse developed economic potential using a TRC of 1.0 as the measure screen.

11.1 Energy Optimization Economic Potential Results by Sector

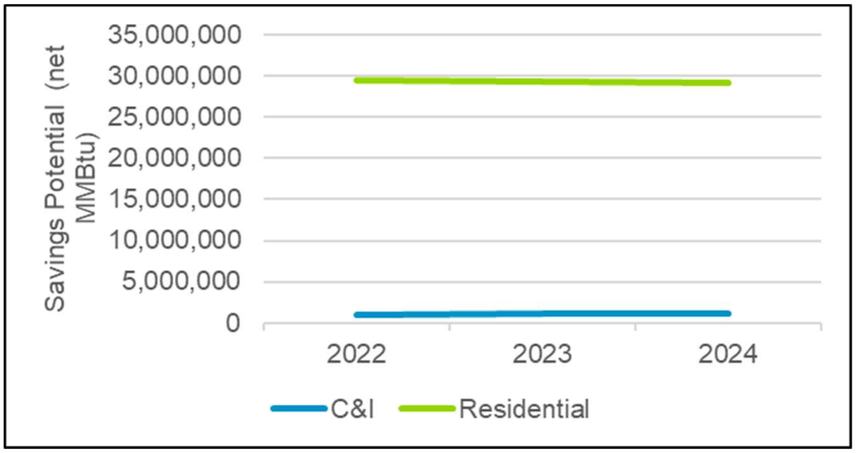
Figure 11-1 shows economic propane savings potential, in net MMBtu, across all sectors. Figure 11-2 shows the economic fuel oil potential, in net MMBtu, in each of the sectors. Figure 11-3 shows the economic net natural gas potential, in net therms, in each of the sectors. The relative magnitude and trajectory of the annual economic potential estimates for fuel oil and propane are similar to those of the technical potential. However, the economic EO potential for natural gas in both sectors is greatly decreased relative to technical potential and the potential for the C&I sector becomes negligible.

Figure 11-1. EO Economic Potential, Propane Savings by Sector (Net MMBtus)



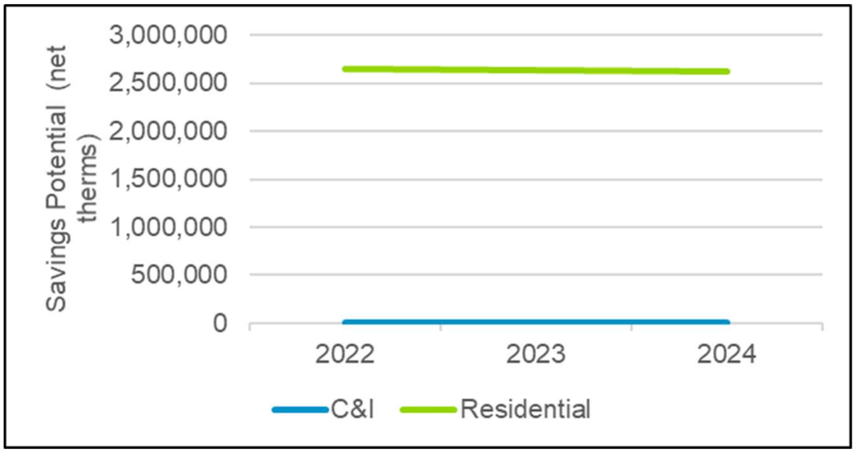
Source: Guidehouse analysis

Figure 11-2. EO Economic Potential, Fuel Oil Savings by Sector (Net MMBtus)



Source: Guidehouse analysis

Figure 11-3. EO Economic Potential, Natural Gas Savings (Net therms)

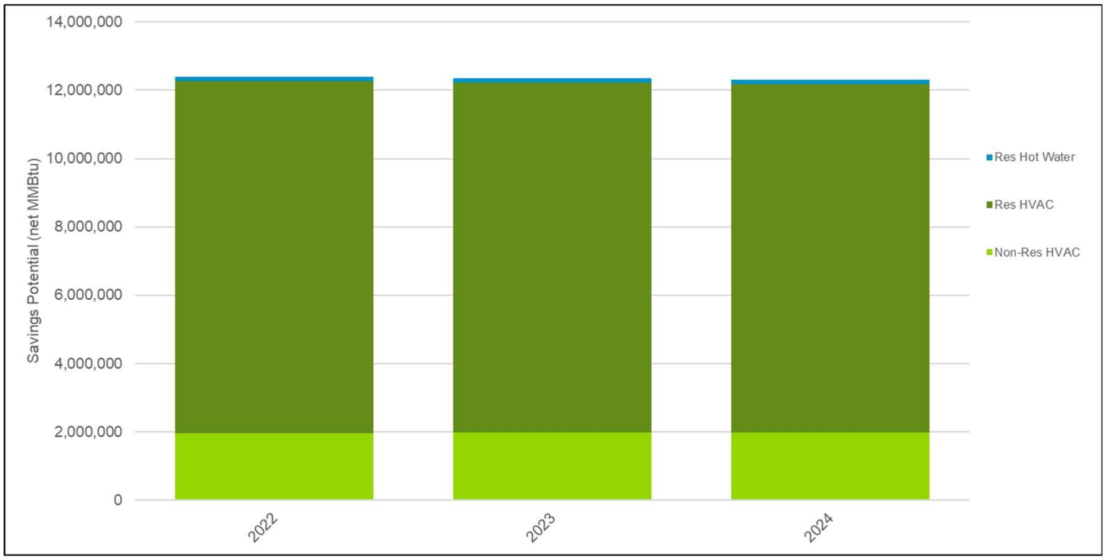


Source: Guidehouse analysis

11.2 Energy Optimization Economic Potential Results by End Use

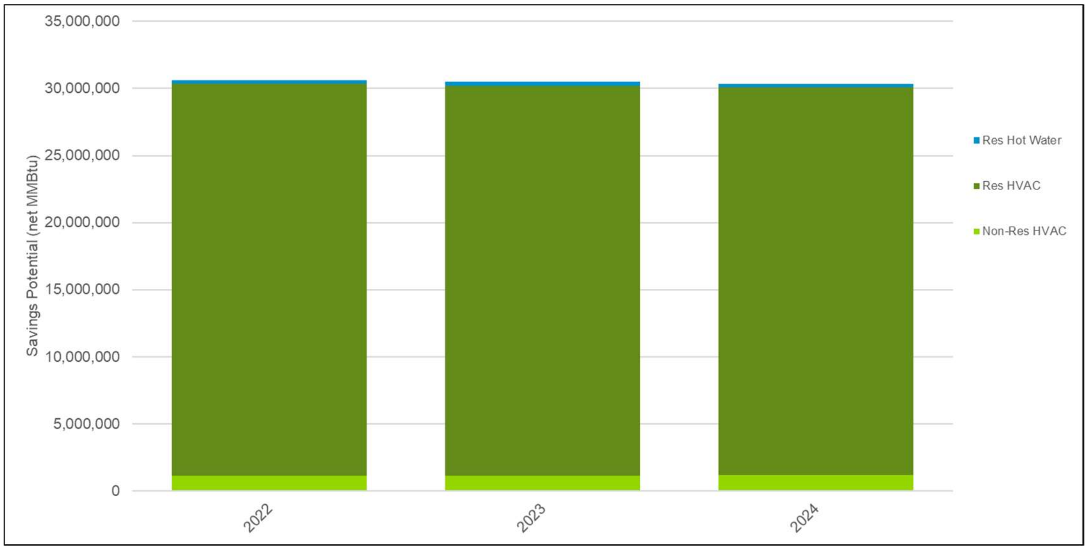
Figure 11-4 shows the economic propane potential, in net MMBtu, by end use for both C&I and Residential sectors. Figure 11-5 shows the economic fuel oil potential, in net MMBtu, by end use, for both C&I and Residential sectors. Figure 11-6 shows the economic natural gas potential, in net MMBtu, by end use for both C&I and Residential sectors. The economic potential by end use is almost exclusively in the Residential Heating end use for all three fuels.

Figure 11-4. EO Economic Potential, Propane Savings by End Use (Net MMBtus)



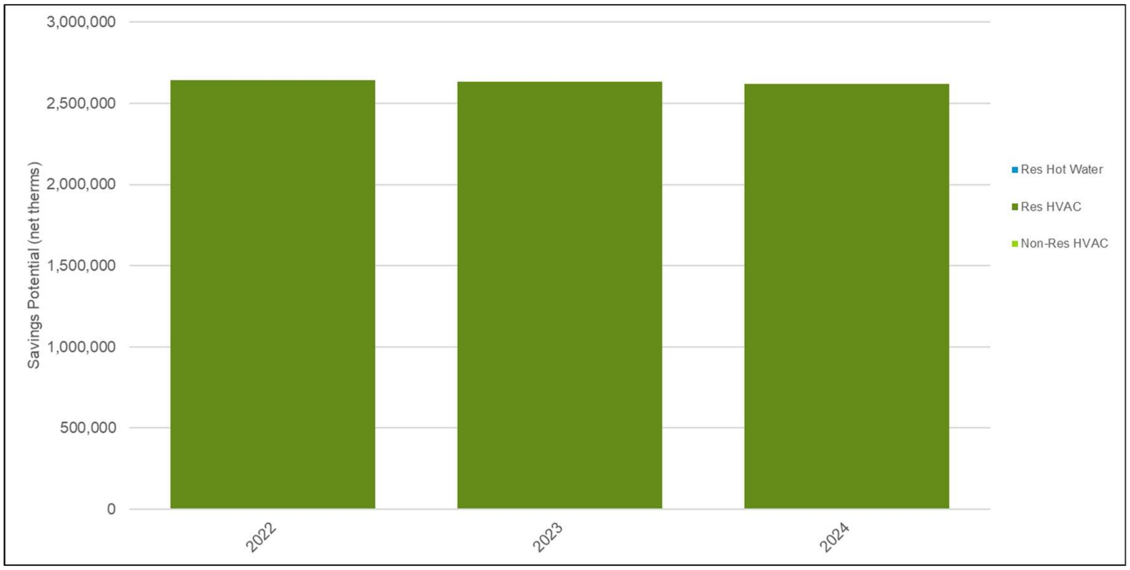
Source: Guidehouse analysis

Figure 11-5. EO Economic Potential, Fuel Oil Savings by End Use (Net MMBtus)



Source: Guidehouse analysis

Figure 11-6. EO Economic Potential, Natural Gas Savings by End Use (Net therms)



Source: Guidehouse analysis

12. Energy Optimization Market Potential Approaches

Achievable potential calculations for energy optimization are performed in the same way as for the energy efficiency study. See Appendix A for a detailed review of DSMSim model achievable potential methodologies.

12.1 Energy Optimization Model Calibration

Any model simulating future product adoption faces challenges with calibration, as there is no future world against which one can compare simulated results to actual results. Engineering models, on the other hand, can often be calibrated to a higher degree of accuracy since simulated performance can be compared directly with performance of actual hardware. Since DSM potential models do not have this luxury, Guidehouse therefore had to rely on other techniques to provide both the developer and the recipient of model results with sufficient confidence in the simulated results. For the energy optimization portion of this study, Guidehouse did not have a robust historical set of program participation data and therefore took a slightly modified approach to calibrating results, including:

- Identifying the subset of modelled measures that were included in historical National Grid program offerings in order to have a basis for comparison with historical program achievements. This included residential propane and fuel oil to electric measures and excluded commercial or natural gas energy optimization measures.
- Ensuring similar trends and magnitudes between National Grid's historical sector- and end use-level savings and simulated sector- and end use-level savings from the measure subset in the model's base year. 2019 historical achievements were used in the calibration process as they represent the most recent available data.
- Conducting discussions with program administrators to determine reasonable growth trends and understand non-economic barriers to energy optimization.

Due to the limited availability of historical program performance, especially for natural gas and commercial energy optimization measures, Guidehouse used a combination of trend estimation and program growth feasibility to develop future year trajectories. Additionally, in cases where only one fuel type could be calibrated to historical data, the resulting calibration factors were applied to measures or fuel types with no historical data. This approach assumes that customers will act similarly when approaching an energy optimization decision between a variety of fuel options. Due to the limited historical data available for calibration, energy optimization achievable potential results should be considered a rough estimation.

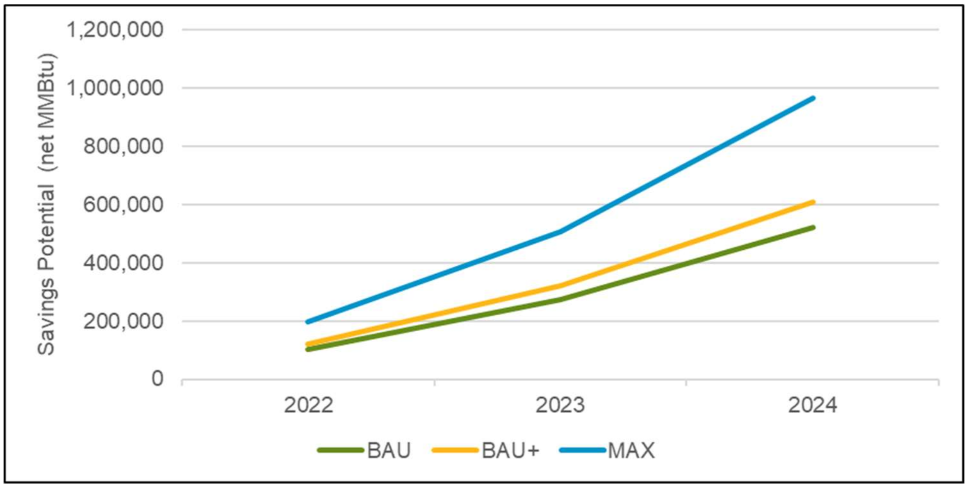
13. Energy Optimization Achievable Potential Results by Scenario

This section provides the achievable potential results calculated by the model at varying levels of aggregation, using the TRC benefit-cost test as a screen set to 0.80. At-the-meter, net savings results are shown by sector, end-use category, and by highest impact measures.

13.1 Comparison of Energy Optimization Savings by Potential Type

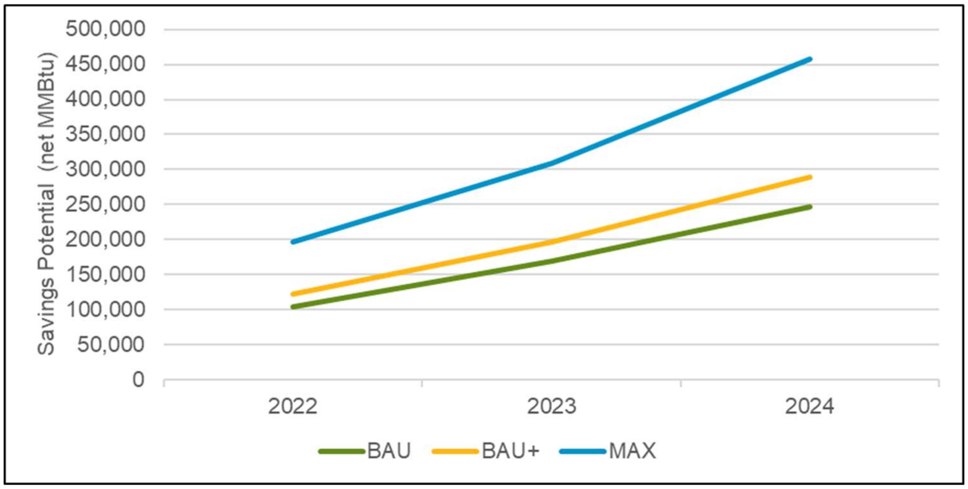
As Figure 13-1 shows, the cumulative propane achievable potential, in net MMBtu, for each scenario, which accounts for the rate of acquisition, increases steadily throughout the study period. Incremental annual achievable propane savings, in net MMBtu, increases significantly over time in each scenario, as Figure 13-2 shows.

Figure 13-1. EO Achievable Potential, Cumulative Annual Propane Savings, by Scenario (Net MMBtus)



Source: Guidehouse analysis

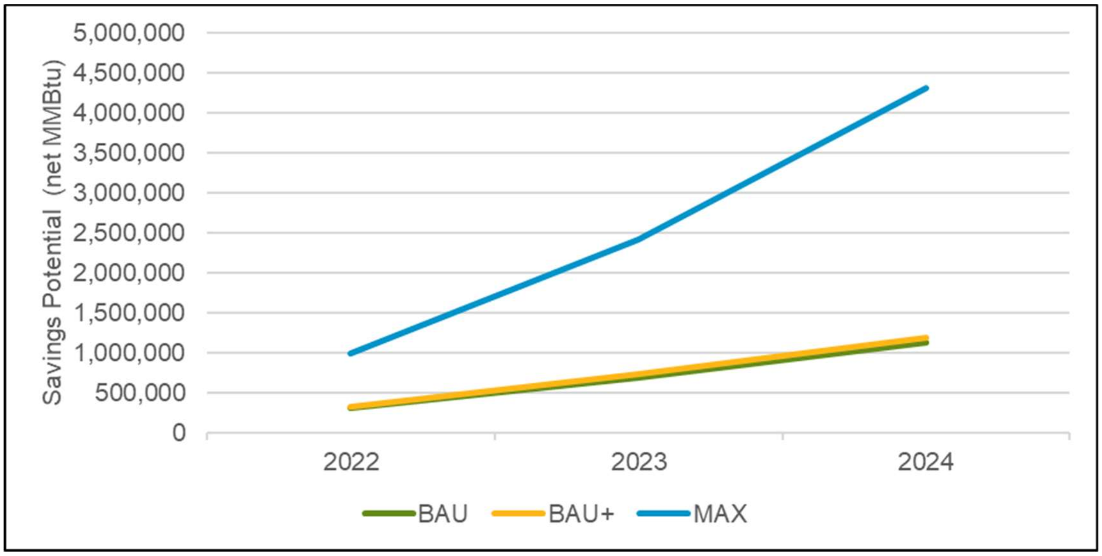
Figure 13-2. EO Achievable Potential, Incremental Annual Propane Savings, by Scenario (Net MMBtus)



Source: Guidehouse analysis

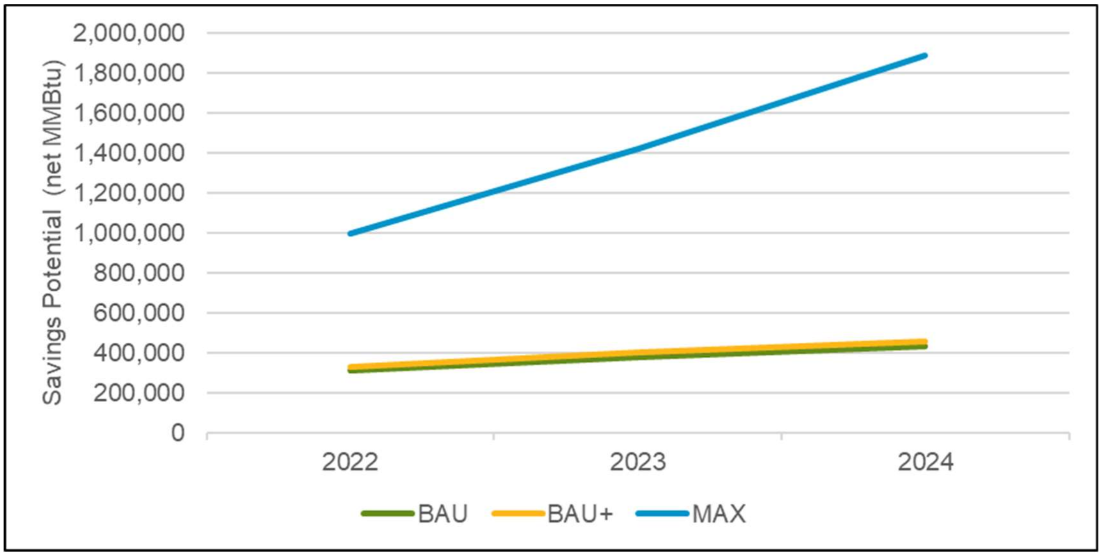
Figure 13-3 shows the cumulative annual fuel oil achievable potential savings, in net MMBtu, by scenario. Figure 13-4 shows the incremental annual fuel oil achievable potential increasing in each year of the analysis. The difference between the MAX scenario and the other two scenarios indicates the sensitivity of the results to the incentive and market input assumptions for that scenario.

Figure 13-3. EO Achievable Potential, Cumulative Annual Fuel Oil Savings (Net MMBtus)



Source: Guidehouse analysis

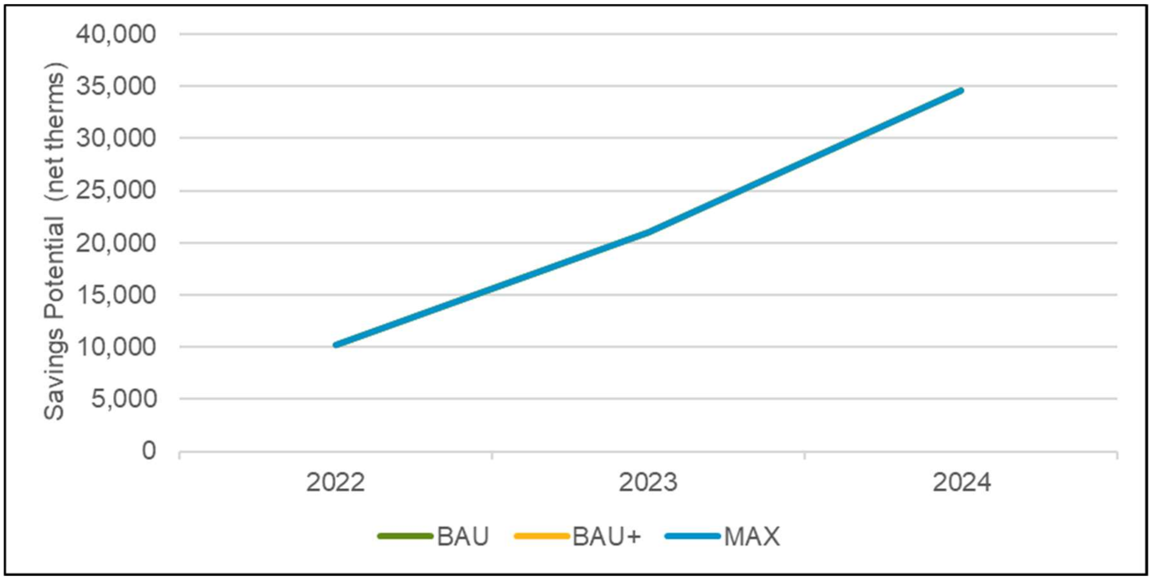
Figure 13-4. EO Achievable Potential, Incremental Annual Fuel Oil Savings, by Scenario (Net MMBtus)



Source: Guidehouse analysis

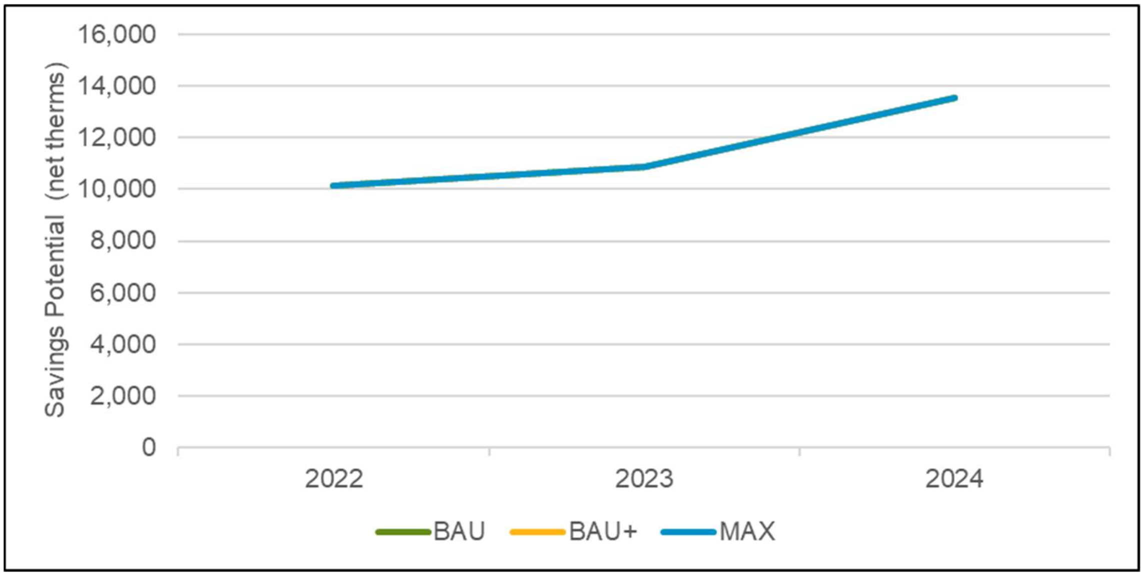
Figure 13-5 shows cumulative natural gas savings achievable potential, in net therms, by scenario. The cumulative potential increases over the study period. Figure 13-6 shows incremental natural gas savings achievable potential, in net therms, by scenario. The incremental potential increases over the study period as well. For natural gas, there is no difference between the three scenarios. This indicates that the gas benefits to customers are too small to overcome electric bill increases and therefore simply changing incentives to 100% incremental costs are not enough to change customer decision making. Customer sensitivity to rebate levels up to 100% incremental cost is low.

Figure 13-5. EO Achievable Potential, Cumulative Annual Natural Gas Savings, by Scenario (Net therms)



Source: Guidehouse analysis

Figure 13-6. EO Achievable Potential, Incremental Annual Natural Gas Savings, by Scenario (Net therms)

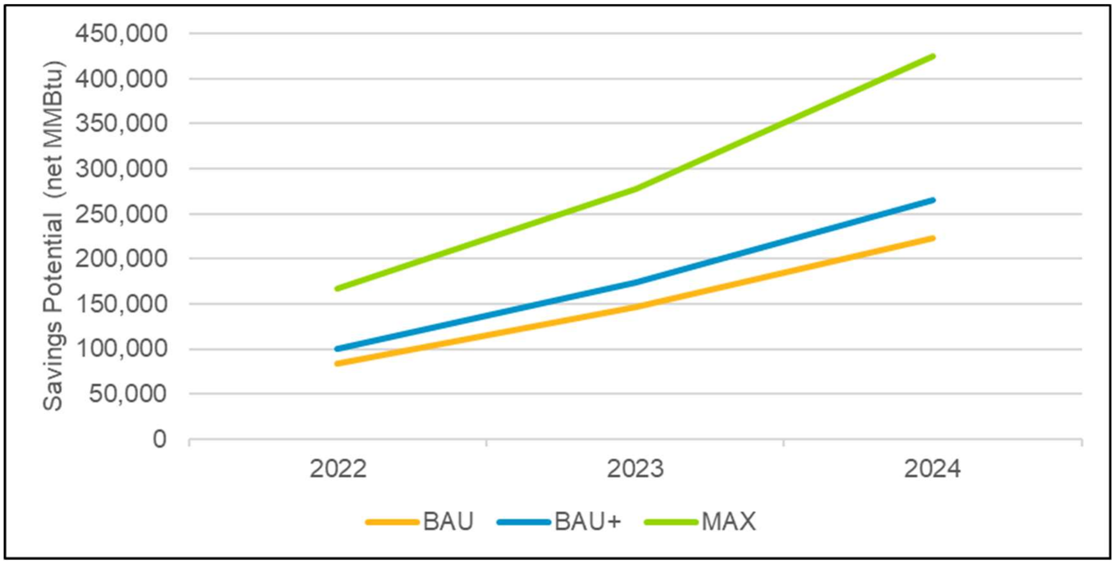


Source: Guidehouse analysis

13.2 Energy Optimization Potential Results by Sector

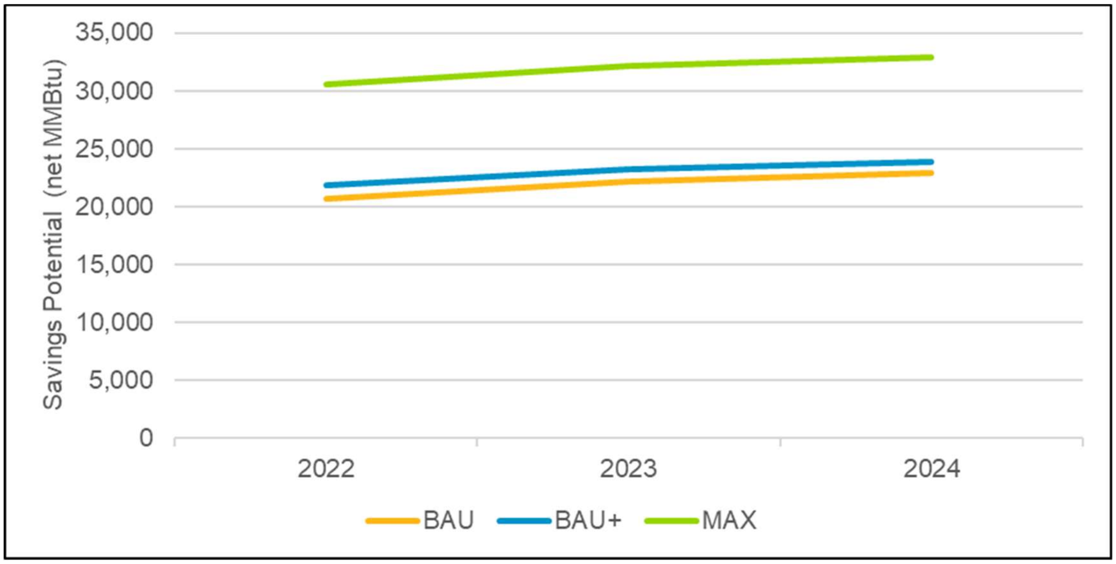
Figure 13-7 shows the incremental annual propane achievable savings potential, in net MMBtu, by scenario for the Residential sector. Figure 13-8 shows the incremental annual propane achievable savings potential, in net MMBtu, by scenario for the C&I sector. Achievable savings is relatively low compared to economic savings.

Figure 13-7. EO Residential Achievable Potential, Incremental Annual Propane Savings (Net MMBtus)



Source: Guidehouse analysis

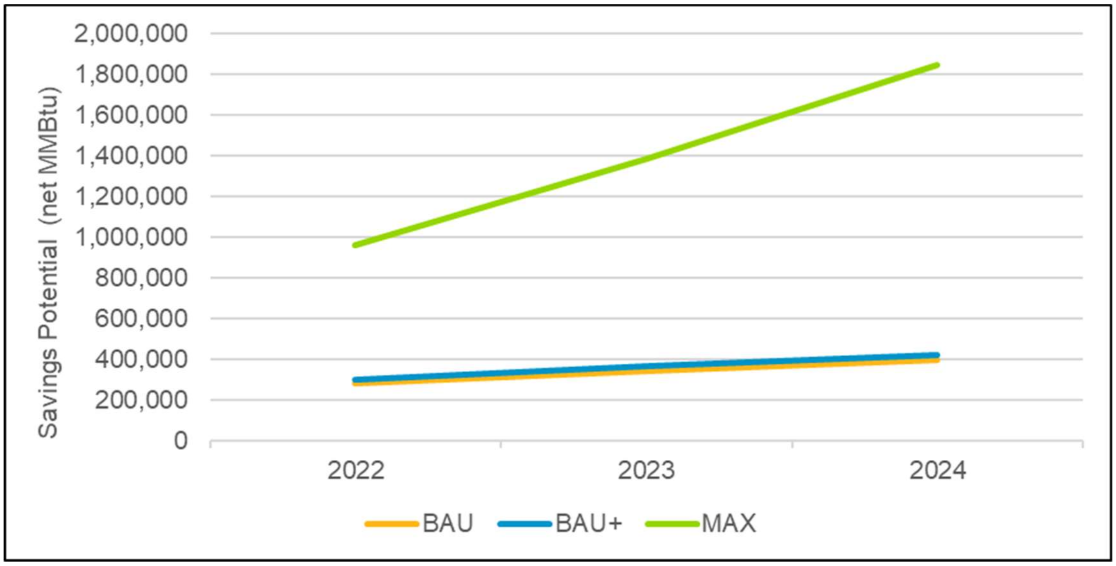
Figure 13-8. EO C&I Achievable Potential, Incremental Annual Propane Savings (Net MMBtus)



Source: Guidehouse analysis

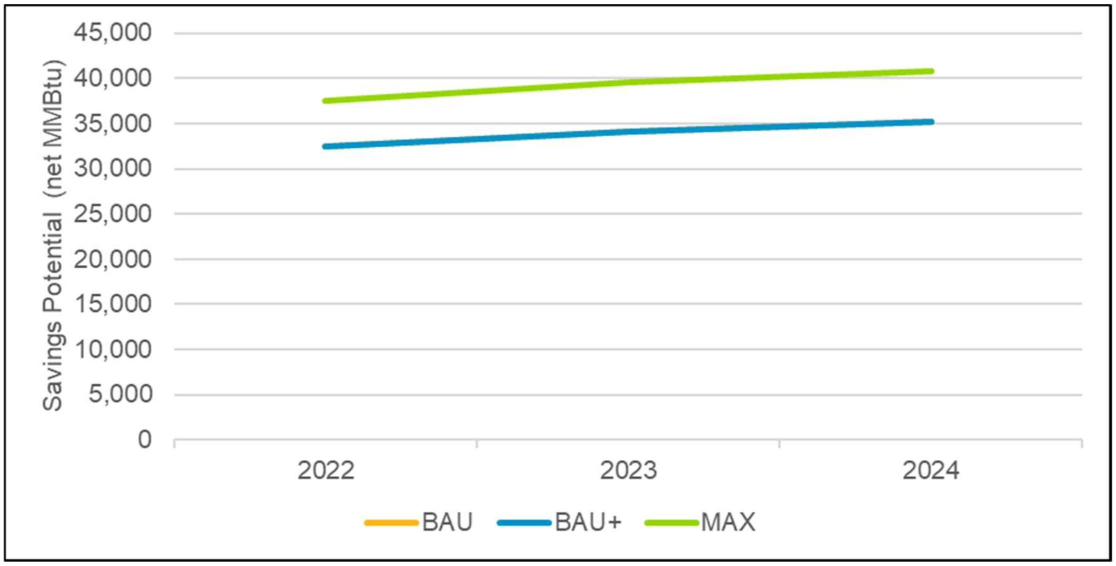
Figure 13-9 shows the incremental annual fuel oil achievable savings potential, in net MMBtu, by scenario for the Residential sector. Figure 13-10 shows the incremental annual fuel oil achievable potential, net at meter, by scenario for the C&I sector. The relative scales of the two figures show how much more achievable potential there is in the Residential sector.

Figure 13-9. EO Residential Achievable Potential, Incremental Annual Fuel Oil Savings (Net MMBtus)



Source: Guidehouse analysis

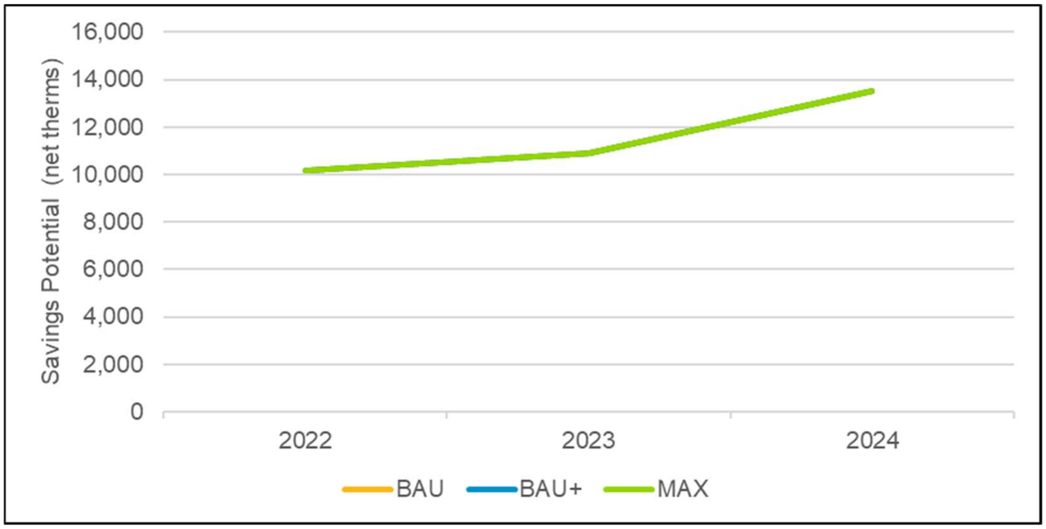
Figure 13-10. EO C&I Achievable Potential, Incremental Annual Fuel Oil Savings (Net MMBtus)



Source: Guidehouse analysis

Figure 13-11 shows the incremental annual natural gas achievable savings potential, in net MMBtu, by scenario for the Residential sector. There is no achievable potential for C&I gas EO for any scenario.

Figure 13-11. EO Residential Achievable Potential, Incremental Annual Natural Gas Savings (Net therms)

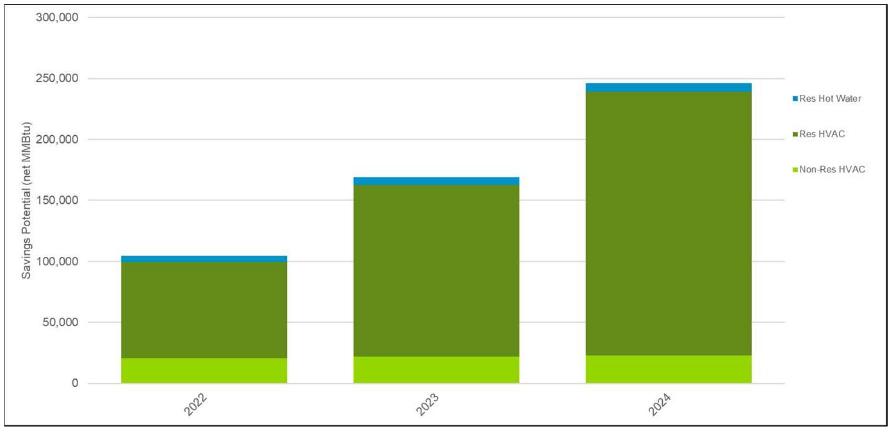


Source: Guidehouse analysis

13.3 Energy Optimization Potential Results by End Use

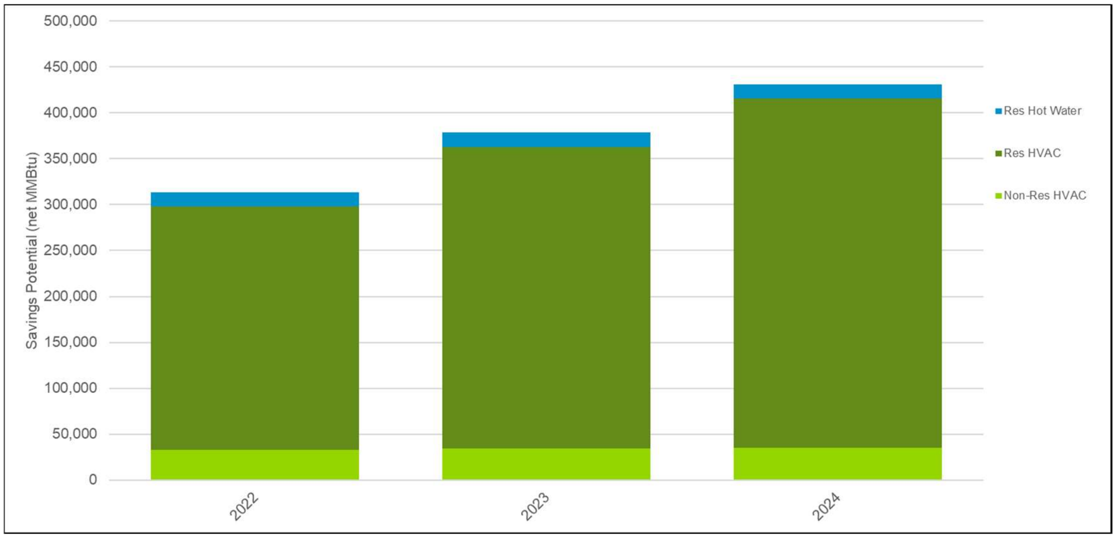
Figure 13-12 shows the incremental annual propane achievable savings potential, in net MMBtu, across end uses. Figure 13-13 shows the incremental annual fuel oil achievable savings potential, in net MMBtu, across end uses. Figure 13-14 shows the incremental natural gas net achievable savings potential, in net MMBtu. The dominant end use for all three fuels is Residential HVAC.

Figure 13-12. EO BAU Scenario Achievable Potential, Incremental Annual Propane Savings by End Use (Net MMBtus)



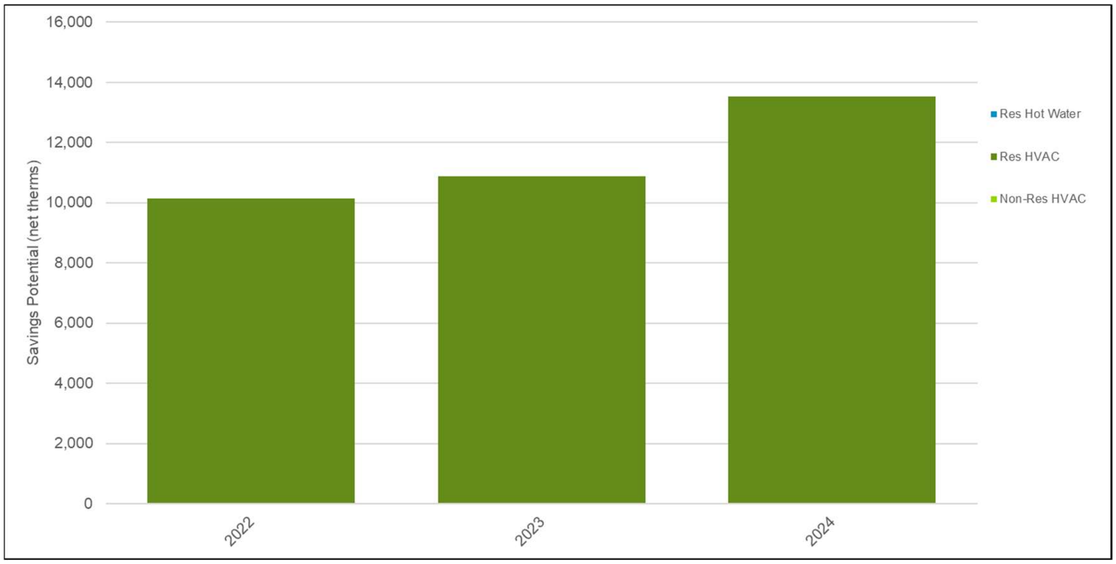
Source: Guidehouse analysis

Figure 13-13. EO BAU Scenario Achievable Potential, Incremental Annual Fuel Oil Savings by End Use (Net MMBtus)



Source: Guidehouse analysis

Figure 13-14. EO BAU Scenario Achievable Potential, Incremental Annual Natural Gas Savings by End Use (Net therms)

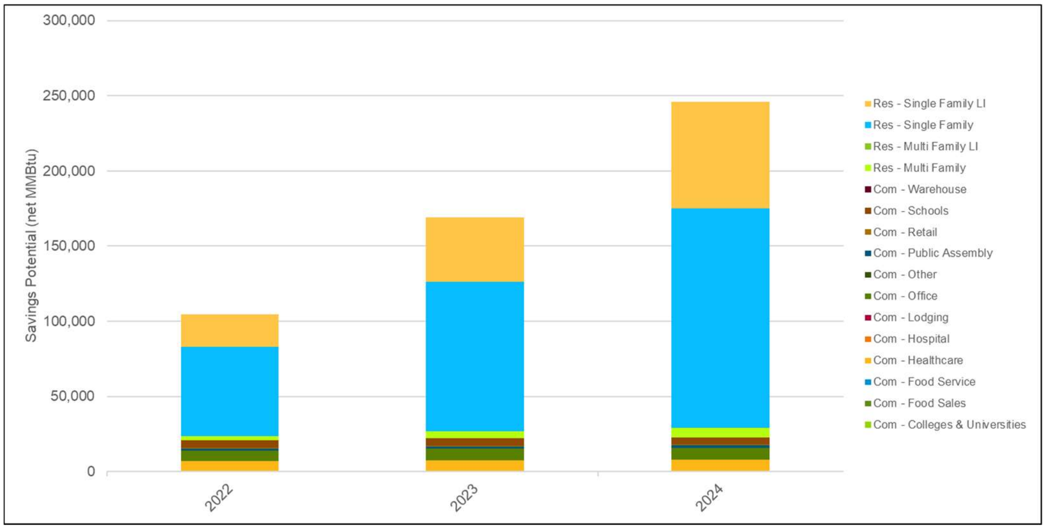


Source: Guidehouse analysis

13.4 Energy Optimization Potential Results by Customer Segment

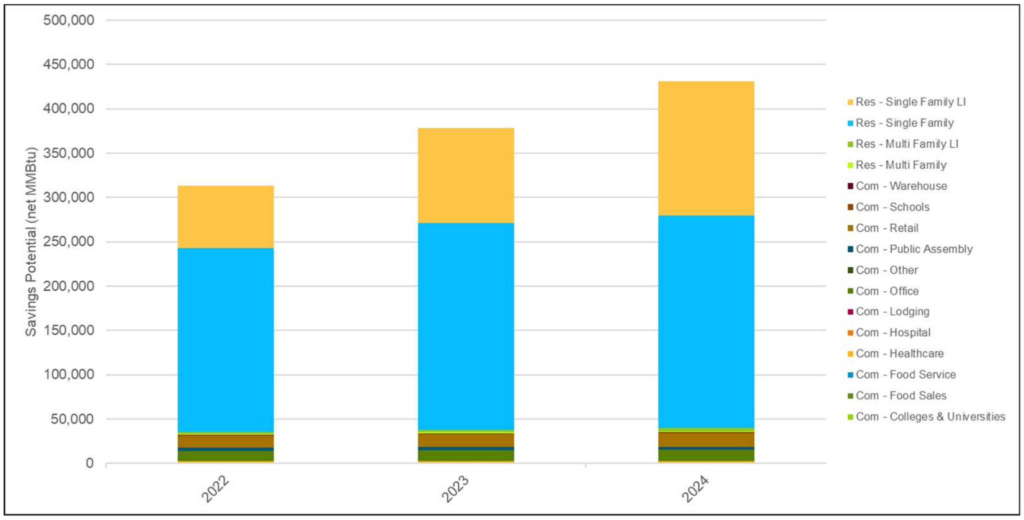
Figure 13-15 shows the incremental annual propane achievable savings potential, in net MMBtu across customer segments. Figure 13-16 shows the incremental annual fuel oil achievable potential, in net MMBtu, across customer segments. Figure 13-17 shows the incremental annual net natural gas achievable potential, across customer segments. The dominant segment for propane and fuel oil is Single Family (for non-low income and low income customers) and the dominant segment for natural gas is Residential Multifamily, which is the only segment with achievable natural gas EO potential. There is no achievable potential in any C&I segment. Additional details and tabular data for customer segment level results are provided in Appendix B.

Figure 13-15. EO BAU Scenario Achievable Potential, Incremental Annual Propane Savings by Customer Segment (Net MMBtus)



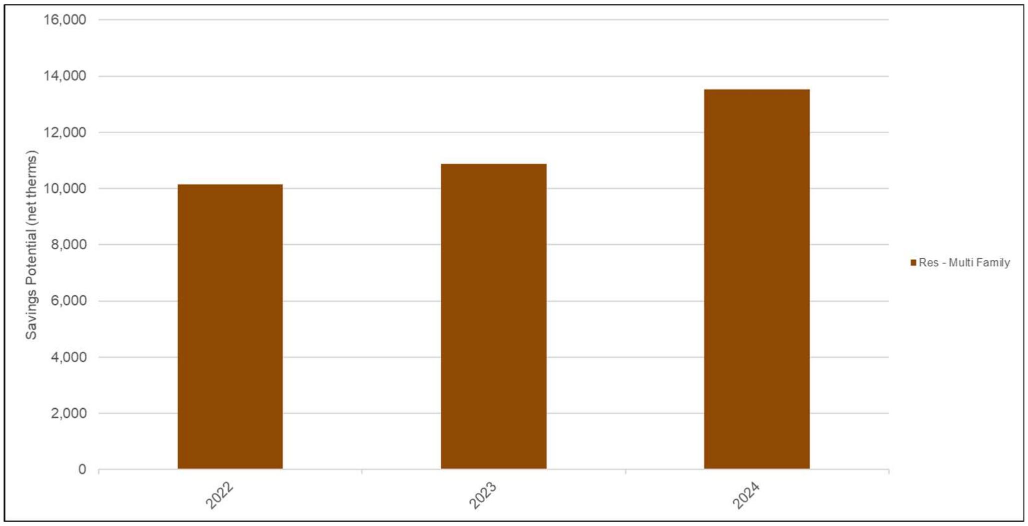
Source: Guidehouse analysis

Figure 13-16. EO BAU Scenario Achievable Potential, Incremental Annual Fuel Oil Savings by Customer Segment (Net MMBtus)



Source: Guidehouse analysis

Figure 13-17. EO BAU Scenario Achievable Potential, Incremental Annual Natural Gas Savings by Customer Segment (Net therms)

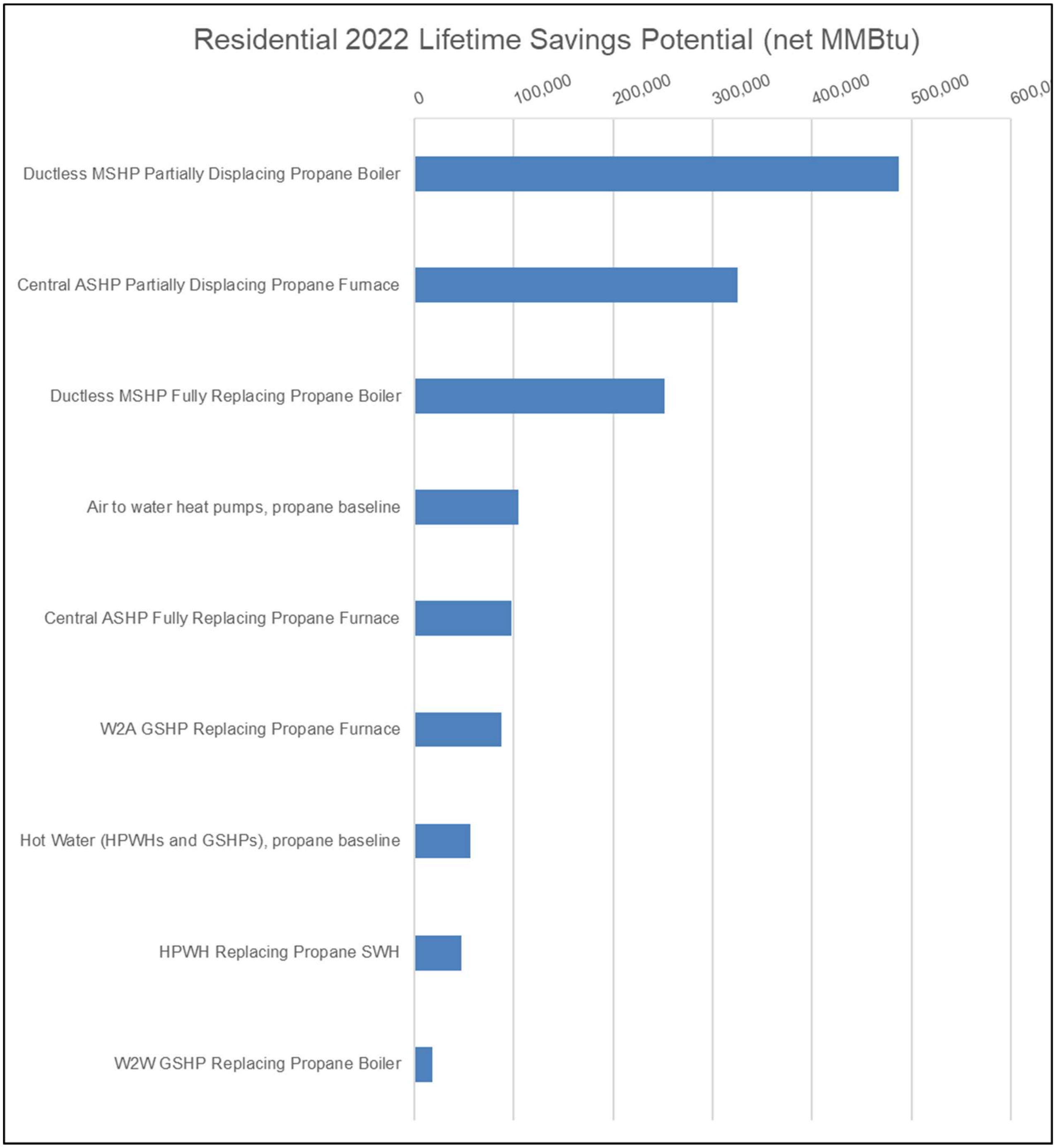


Source: Guidehouse analysis

13.5 Energy Optimization Potential Results by Measure

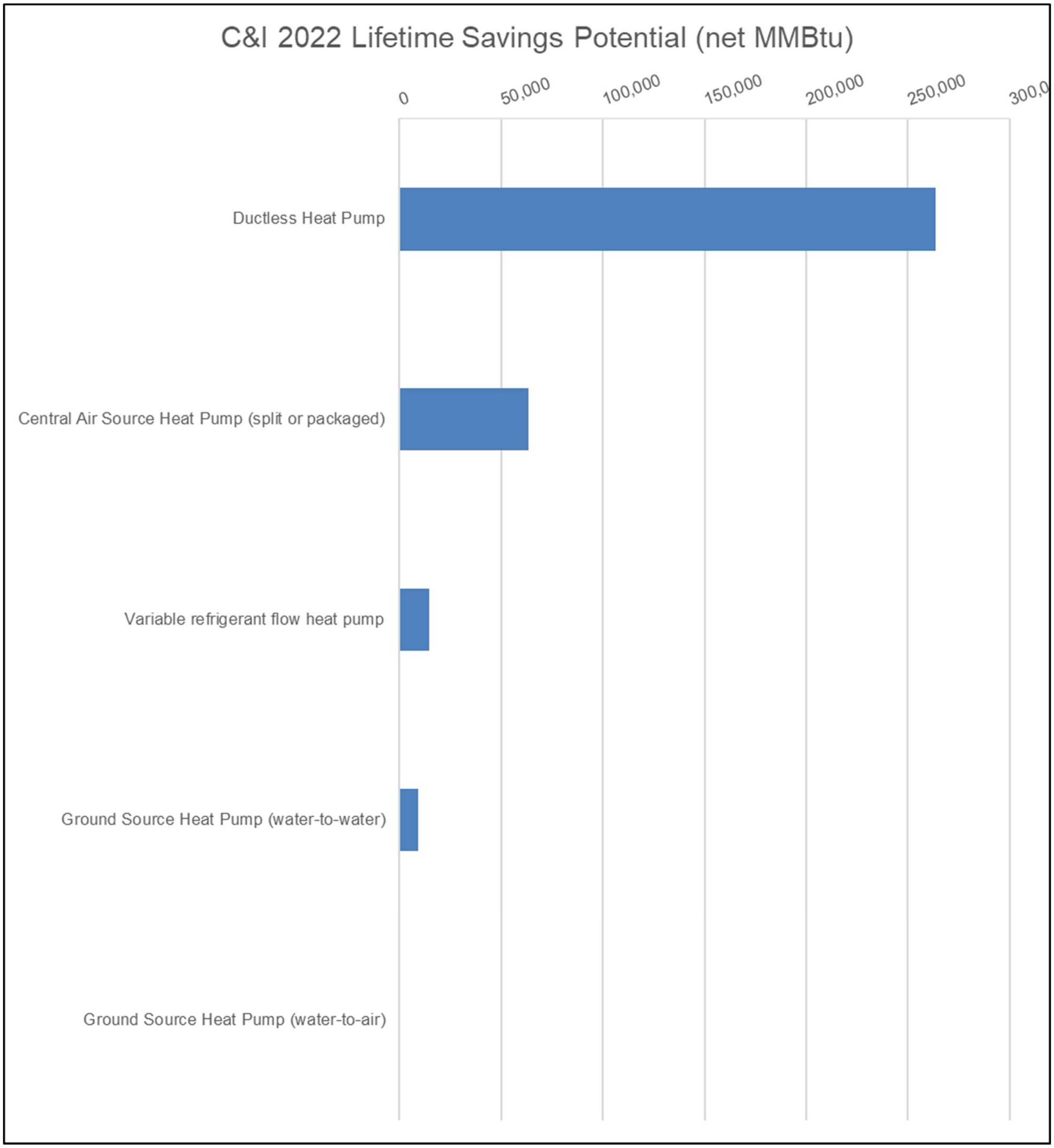
Figure 13-18 and Figure 13-19 show the top Residential and C&I propane lifetime savings measures, in net MMBtu, in 2022, respectively. Only 9 Residential measures and 5 C&I measures show achievable potential. Ductless heat pumps are the dominant measure in both sectors.

Figure 13-18. EO BAU Scenario Lifetime Achievable Potential, 2022 Residential Measures for Propane Savings (Net MMBtus)



Source: Guidehouse analysis

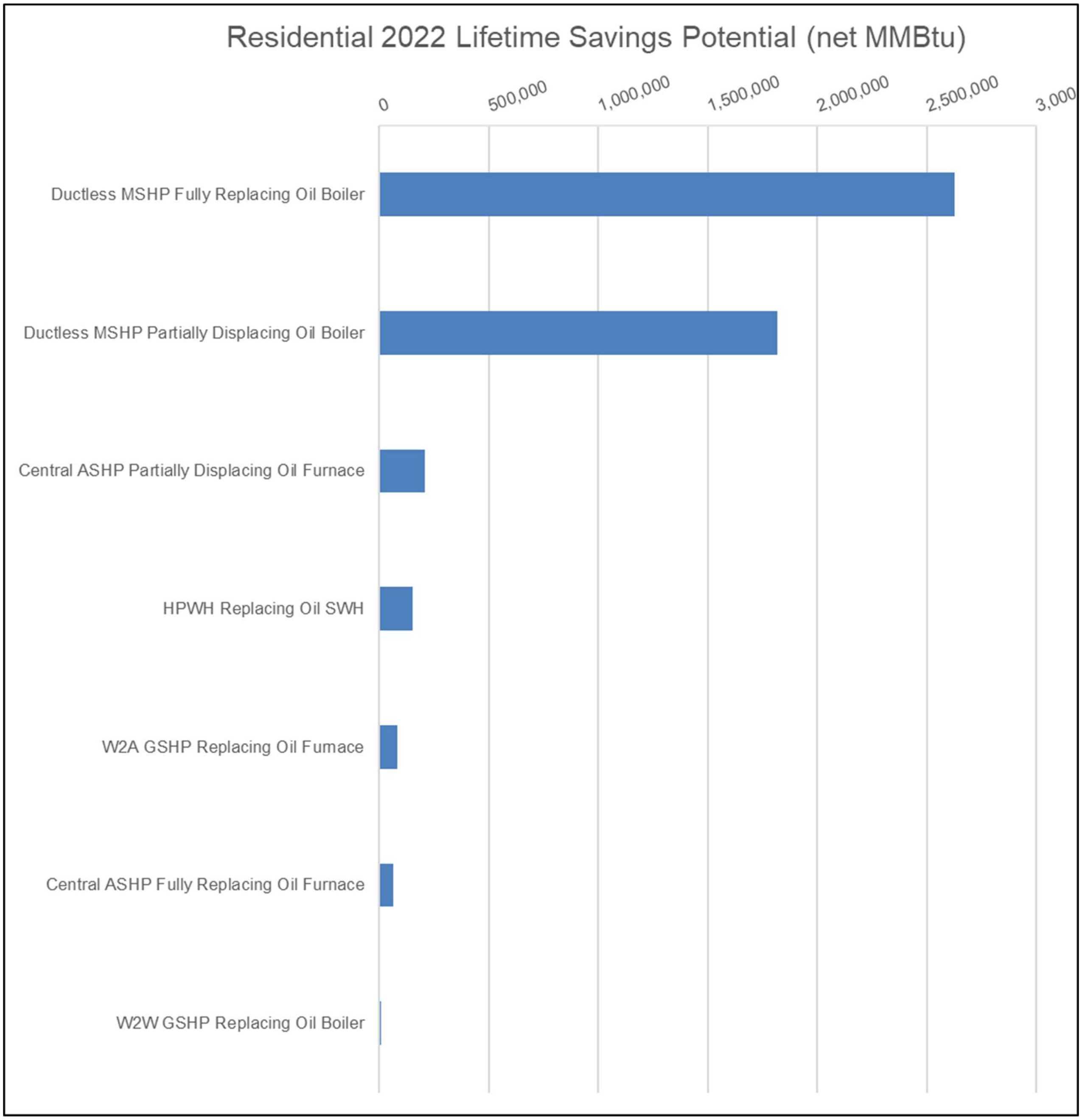
Figure 13-19. EO BAU Scenario Lifetime Achievable Potential, 2022 C&I Measures for Propane Savings (Net MMBtus)



Source: Guidehouse analysis

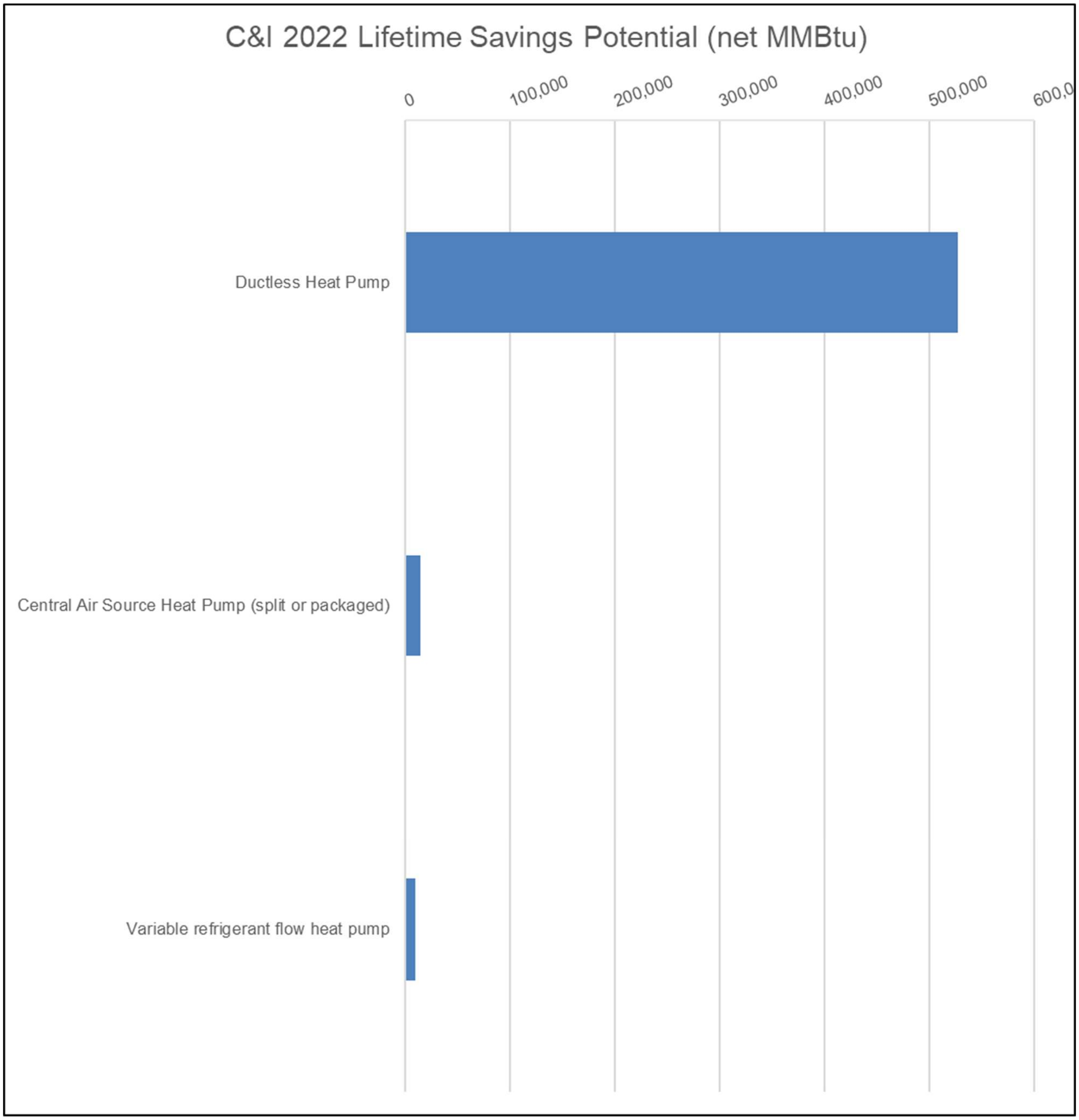
Figure 13-20 and Figure 13-21 show the top Residential and C&I fuel oil lifetime savings measures, in achievable net MMBtu, in 2022, respectively. Only 7 Residential measures and 3 C&I measures show achievable potential. Ductless heat pumps are the dominant measure in both sectors.

Figure 13-20. EO BAU Scenario Lifetime Achievable Potential, 2021 Residential Measures for Fuel Oil Savings (Net MMBtus)



Source: Guidehouse analysis

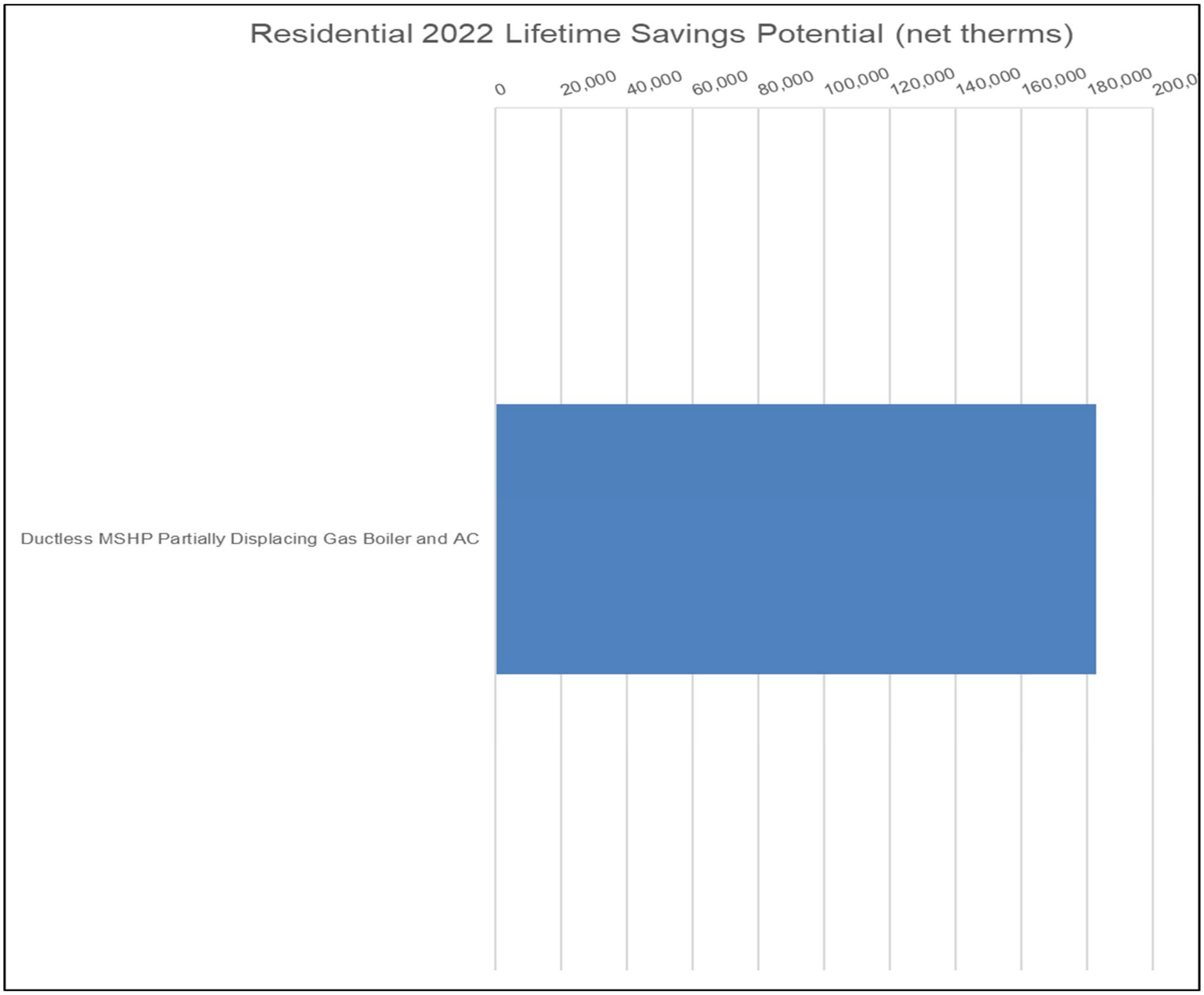
Figure 13-21. EO BAU Scenario Lifetime Achievable Potential, 2021 C&I Measures for Fuel Oil Savings (Net MMBtus)



Source: Guidehouse analysis

Figure 13-22 shows achievable potential natural gas EO lifetime savings, in net MMBtu, for 2022. The figure shows that all achievable potential natural gas EO savings are from one measure; there are no commercial measures for gas EO with achievable savings.

Figure 13-22. EO BAU Scenario Lifetime Achievable Potential, 2021 Residential Measures for Natural Gas Savings (net therms)



Source: Guidehouse analysis

13.6 Energy Optimization Results by Program

This section presents results for savings, and benefits and costs, for the EO BAU scenario for the Residential sector, separately for electric and then natural gas service territory energy optimization measure programs. C&I sector results then follow. Based on National Grid's 2019 BCR Model, EO measures were mapped to different programs.

13.6.1 Residential Sector

Table 13-1 presents the incremental annual net savings for Residential energy optimization programs for the 3-year study horizon for the BAU scenario. Units in the table are aggregated across all technologies and may vary by measure; they account for the possibility that a customer may install more than one unit, i.e., one unit does not equal one customer.

Table 13-1. Residential Sector, Energy Optimization Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

BAU Scenario	Electricity		Oil	Propane	Technology Quantity
	GWh	Summer Peak Demand (MW)	MMBtu	MMBtu	Units
A2a – Residential Coordinated Delivery – Electric					
2022	-5,616	1.10	49,989	28,844	1,545
2023	-8,169	1.49	59,291	56,721	2,127
2024	-10,622	1.84	65,584	86,350	2,665
A2c – Residential Retail – Electric					
2022	-14,290	-1.22	159,011	33,485	3,401
2023	-16,667	-1.65	175,659	47,499	3,908
2024	-18,208	-3.12	175,878	65,752	4,092
B1a – Income Eligible Coordinated Delivery – Electric					
2022	-6,421	1.16	72,015	21,442	1,622
2023	-10,410	1.46	109,546	42,657	2,577
2024	-15,305	1.88	154,433	71,101	3,757
Residential Total – Electric Programs					
2022	-26,327	1.05	281,015	83,771	6,568
2023	-35,246	1.29	344,496	146,876	8,612
2024	-44,135	0.60	395,896	223,203	10,514

Source: Guidehouse analysis

Table 13-2 presents the benefits and costs by Residential energy optimization programs for the 3-year study horizon for the BAU scenario.

Table 13-2. Residential Sector, Energy Optimization Programs, Benefits and Costs, BAU Scenario, 2022-2024

BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[34] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
A2a – Residential Coordinated Delivery – Electric					
2022	6.0	$63.38	$10.56	$1.75	$6.19
2023	6.5	$86.35	$13.36	$2.40	$8.49
2024	6.9	$116.29	$16.96	$2.99	$10.61
A2c – Residential Retail – Electric					
2022	6.3	$86.81	$13.77	$3.91	$13.86
2023	6.2	$93.04	$15.00	$4.50	$15.95
2024	6.1	$96.52	$15.82	$4.89	$17.34
B1a – Income Eligible Coordinated Delivery – Electric					
2022	3.1	$75.74	$24.35	$4.37	$17.50
2023	3.2	$114.50	$35.56	$6.92	$27.68
2024	3.3	$156.27	$46.69	$10.08	$40.33
Residential Sector Total – Electric					
2022	4.6	$225.93	$48.69	$10.03	$37.55
2023	4.6	$293.90	$63.92	$13.82	$52.13
2024	4.6	$369.08	$79.47	$17.97	$68.28

Source: Guidehouse analysis

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[34] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

Table 13-3 presents the incremental annual net savings for Residential natural gas energy optimization programs for the 3-year study horizon for the BAU scenario.

Table 13-3. Residential Sector, Natural Gas Energy Optimization Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

BAU Scenario	Natural Gas Therms
A2a – Residential Coordinated Delivery – Natural Gas	
2022	10,152
2023	10,879
2024	13,527
Residential Sector Total – Natural Gas	
2022	10,152
2023	10,879
2024	13,527

Source: Guidehouse analysis

Table 13-4 presents the benefits and costs by Residential natural gas energy optimization programs for the 3-year study horizon for the BAU scenario.

Table 13-4. Residential Sector, Natural Energy Optimization Gas Programs, Benefits and Costs, BAU Scenario, 2022-2024

BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[35] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
A2a – Residential Coordinated Delivery – Natural Gas					
2022	0.5	$0.01	$0.02	$0.02	$0.06
2023	0.5	$0.01	$0.02	$0.02	$0.07
2024	0.5	$0.01	$0.02	$0.02	$0.08
Residential Sector Total – Natural Gas					
2022	0.5	$0.01	$0.02	$0.02	$0.06
2023	0.5	$0.01	$0.02	$0.02	$0.07
2024	0.5	$0.01	$0.02	$0.02	$0.08

Source: Guidehouse analysis

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[35] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

13.6.2 C&I Sector

Table 13-5 presents the incremental annual net savings for C&I energy optimization programs for the 3-year study horizon for the BAU scenario. No C&I gas measures passed economic or achievable cost-effectiveness screening thresholds. Therefore, there is no C&I natural gas energy optimization program savings or spending.

Table 13-5. C&I Sector, Energy Optimization Programs, Incremental Annual Net Savings, BAU Scenario, 2022-2024

BAU Scenario	Electricity		Oil	Propane
	GWh	Summer Peak Demand (MW)	MMBtu	MMBtu
C2b – C&I New & Replacement Equipment – Electric				
2022	-3	0.00	32,442	20,658
2023	-3	0.00	34,171	22,204
2024	-3	0.00	35,173	22,902
C&I Total – Electric Programs				
2022	-3	0.00	32,442	20,658
2023	-3	0.00	34,171	22,204
2024	-3	0.00	35,173	22,902

Source: Guidehouse analysis

Table 13-6 presents the benefits and costs by C&I energy optimization programs for the 3-year study horizon for the BAU scenario.

Table 13-6. C&I Sector, Energy Optimization Programs, Benefits and Costs, BAU Scenario, 2022-2024

BAU Scenario	Net TRC Test Ratio = (a) / (b)	Net TRC Benefits NPV 2019 $ Million (a)	Net TRC Costs NPV 2019 $ Million (a)	Program Administrative Costs[36] NPV 2019 $ Million	Program Incentive Costs NPV 2019 $ Million
C2b – C&I New & Replacement Equipment – Electric					
2022	2.8	$13.80	$4.91	$1.77	$5.61
2023	2.8	$14.47	$5.10	$1.77	$6.03
2024	2.8	$14.92	$5.31	$1.91	$6.22
C&I Sector Total – Electric					
2022	2.8	$13.80	$4.91	$1.77	$5.61
2023	2.8	$14.47	$5.10	$1.77	$6.03
2024	2.8	$14.92	$5.31	$1.91	$6.22

Source: Guidehouse analysis

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[36] Program Administrative Costs include:(1) Program Planning and Administration; (2) Marketing and Advertising; (3) Sales, Technical Assistance and Training; and (4) Evaluation and Market Research; these costs do not include incentives paid to program participants.

14. Demand Response Potential Assessment Methodology

This section describes the approach for developing potential and cost estimates for Demand Response (DR), referred to as active demand reduction or active demand management. Using the 2018 Demand Response Potential Study as a starting point, Guidehouse worked with National Grid to represent relevant DR program types that National Grid currently offers or could potentially offer to realize summer peak demand reductions. Guidehouse developed demand response potential and cost estimates using a bottom-up analysis. The analysis utilizes a combination of primary data (e.g., market and DR program data from National Grid) and relevant secondary sources to develop data inputs required for assessing DR potential and cost-effectiveness. These data inputs feed into Guidehouse's DRSim^{TM} model, customized for the study, which produces DR potential, annual program costs, and cost-effectiveness of DR options at various levels of disaggregation.

The following subsections describe the approach for DR potential estimation and cost-effectiveness assessment (summarized in Figure 14-1), which consists of the following steps:

1. Undertake market characterization for DR potential assessment
2. Develop baseline projections (customer count and coincident peak demand) over the study period (2022 – 2027)
3. Define and characterize DR options and map applicable options to relevant customer classes and/or building types
4. Develop programmatic assumptions, which include participation, unit load reductions, and cost assumptions
5. Estimate potential, annual costs, levelized costs and cost-effectiveness by DR option, customer class and building type
6. Conduct scenario analysis and present DR potentials, annual costs, and cost-effectiveness results by scenario

Figure 14-1. DR Potential Assessment Steps

Step 1: Market Characterization	•Characterize market for DR potential estimation: Number of customers and coincident peak load estimates by customer class and building type for base year
Step 2: Develop Baseline Projections	•Define peak and develop baseline peak demand projections over the study period.
Step 3: Define DR Options	•Define and characterize DR options (i.e., technologies) and map applicable options to relevant customer classes.
Step 4: Define Key Assumptions for Potential and Costs	•Develop assumptions for participation, unit load reduction, and itemized costs for each DR option.
Step 5: Estimate Potential, Costs, and Cost-effectiveness	•Present potential estimates, annual costs, levelized costs, and assess cost-effectiveness of DR options.
Step 6: Undertake Scenario Analysis	•Present potential results by scenario, which consider baseline adjustments, and participation scenarios with varying incentives.

Source: Guidehouse

14.1 DR Market Characterization

Market characterization is the first step in DR potential assessment. The market characterization process aimed to segment the market appropriately for the analysis. Guidehouse based the segmentation on the examination of National Grid's rate schedules and the customer segments established in the energy efficiency potential assessment. Specifically, Guidehouse collected data on key pieces of information, such as customer count and peak demand, by customer segment and end-use to serve as inputs into the model.

Table 14-1 presents the different levels of market segmentation for DR potential assessment. Guidehouse used data provided by DNV that indicated the breakdown of C&I customers and sales by rate class and business type to disaggregate customer count and peak demand estimates by the different levels.

Table 14-1. Market Segmentation for DR Potential Assessment

Level	Description
Level 1: By Sector	• Residential • C&I • Electric Vehicles[37]
Level 2: By Customer Class	• Residential • C&I – Small C&I – Medium C&I – Large C&I • Electric Vehicles
Level 3: By Building Type	• Residential – Residential • C&I – Com – Colleges & Universities – Com – Food Sales – Com – Food Service – Com – Healthcare – Com – Hospital – Com – Lodging – Com – Office – Com – Other – Com – Public Assembly – Com – Retail – Com – Schools – Com – Warehouse – Ind– Fabrication – Ind – Food Manufacturing – Ind – Heavy Industry – Ind – Other – Ind – Process – Ind – Tech Facilities • Electric Vehicles – LDV

Source: Guidehouse

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[37] EVs were considered separately and represent only Light Duty Vehicles (LDVs).

Level 1: Sector

Guidehouse segmented customers into Residential and C&I sectors. Additionally, Electric vehicles (EVs) are considered in aggregate and are not called out separately, since the EV forecast did not specify the distribution of EVs between Residential and C&I.

Level 2: Customer Class

Guidehouse further segmented C&I customers into small, medium, and large C&I (referred to as customer class) by mapping rate schedules to these categories, shown in Table 14-2.

Table 14-2. Mapping Between National Grid Rate Class and DR Study Customer Class

Rate (from DNV data)	Mapped Rate[1]	DR Study Customer Class
G-1	G-1	Small C&I
G-2	G-2	Medium C&I
G-3	G-3	Large C&I
R-1	R-1	Residential
G-51	G-1	Small C&I
G-52	G-1	Small C&I
G-53	G-1	Small C&I
G-54	G-2	Medium C&I
G-56	G-2	Medium C&I
R-5	R-1	Residential
R-6	R-2	Residential
T-11	R-4	Residential
R-2	R-2	Residential

[1] DNV provided the mapping from the rates in their data extract to rates currently used by National Grid.

Source: DNV, Guidehouse

Level 3: Building types

Guidehouse further segmented C&I customers into building types using the data provided by DNV. The segmentation by building type aligns with the segmentation in the energy efficiency potential assessment.

14.2 Baseline Projections

The next step after market segmentation was to develop baseline projections for the number of accounts and associated summer peak demand by customer class and building type over the study period. The baseline projections define and forecast customer data for the study period, similar to the market characterization in the EE assessment. The baseline projections for the number of accounts and peak demand were developed at the following levels:

- Number of accounts
    - By customer class and building type

- Summer peak demand projections
    - By customer class, building type and end use

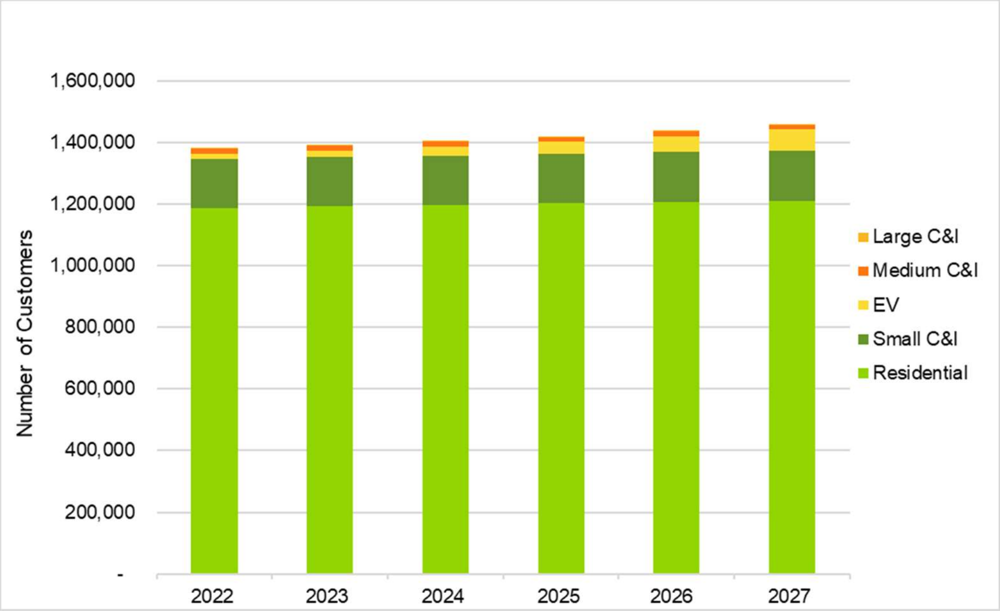
14.2.1 Customer Count Projections

The steps to generate customer count projections include:

- Determine proportion of customers in each building type and rate class within each sector from dataset provided DNV. Missing or unknown building types or rate classes were assumed to be evenly distributed across the rest of the building types and rate classes.
- Apply building type and rate class proportions to National Grid sector-level customer forecast

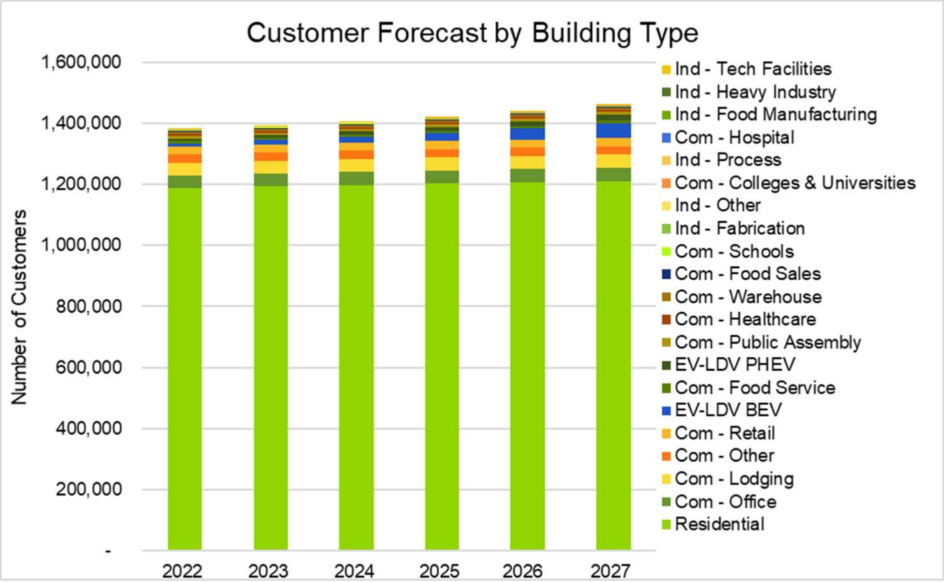
Figure 14-2 and Figure 14-3 summarize the account count projections by customer class.

Figure 14-2. Customer Count Forecast by Customer Class



Source: Guidehouse analysis

Figure 14-3. Customer Count Forecast by Building Type



Source: Guidehouse analysis

14.2.2 Peak Period Definition and Peak Demand Projections

A key element of market characterization for the DR potential study is to develop disaggregated bottom-up peak demand projections by customer class, building type, and end use, which serves as the foundation for the DR potential estimates. Figure 14-4 outlines the approach followed to develop baseline peak demand projections.

Figure 14-4. Baseline Peak Projection Steps

Define Peak Period	• The peak period was defined as the top 15 ISO-NE coincident peak hours for C&I customer segments and the top 45 hours for all other segments.
Calculate Coincident Peak Demand Factors	• Use the peak period and normalized, rate-class 8,760 load shapes from National Grid to from a prior National Grid study conducted by Guidehouse to obtain peak load factors
Obtain End Use Shares	• End use shares sourced from OpenEI[1] and used in the previous study were retained.
Determine Energy Sales after DSM	• Subtract Guidehouse's EE and EO potential study results from National Grid sales forecast before DSM.
Calculate Bottom-Up Peak Demand	• Apply coincident peak demand factors and end use shares to forecasted retail energy sales to obtain demand projections for the peak period
Develop Separate Projections for Electric Vehicles	• Use EV adoption forecast and load profiles provided by National Grid to develop peak demand projections. Additional discussion on EVs can be found in Section 15.2.4

[1] Commercial and Residential Hourly Load Profiles; Office of Energy Efficiency & Renewable Energy (EERE). https://openei.org/doe-opendata/dataset/commercial-and-residential-hourly-load-profiles-for-all-tmy3-locations-in-the-united-states

Source: Guidehouse

The first step in this approach was to define the peak period. The peak period was defined the top 15 ISO-NE coincident peak hours for all C&I customer segments and the top 45 hours for all other segments. The number of hours corresponds with typical event hours for the thermostat and C&I ConnectedSolutions programs, which serve as a proxy for Residential and C&I peak hours respectively.[38] Guidehouse used this definition to develop coincident peak demand estimate by customer class, building type and end use. The primary data sources for developing these estimates were 8,760 system data, forecasted sector-level sales data, building-level sales data, and energy efficiency potential results. Guidehouse used the data from these sources to develop coincident peak demand estimates by customer class and building type for the base year, and then projected these estimates for future years by scaling these values with the retail sales forecast. Discussion on coincident summer peak demand estimates for EVs can be found in Section 14.2.4.

Three different scenarios from the Energy Efficiency Potential Study were considered in the baseline summer peak projections: (1) BAU, (2) BAU+, and (3) MAX. The corresponding scenarios in the DR scenario have the same names. These scenarios are described later in the section.

Figure 14-5 shows the baseline peak projections across the various scenarios. The projections for each scenario account for the impacts of achievable energy efficiency and energy optimization potential for the corresponding EE and EO scenario[39]. During the study period (2022-2024), the baseline peak is comparable across all of the scenarios, however in future years, the BAU+ scenario has a slightly lower peak due to increased EE achievements, and the MAX scenario has a higher peak due to more aggressive program assumptions around EO.

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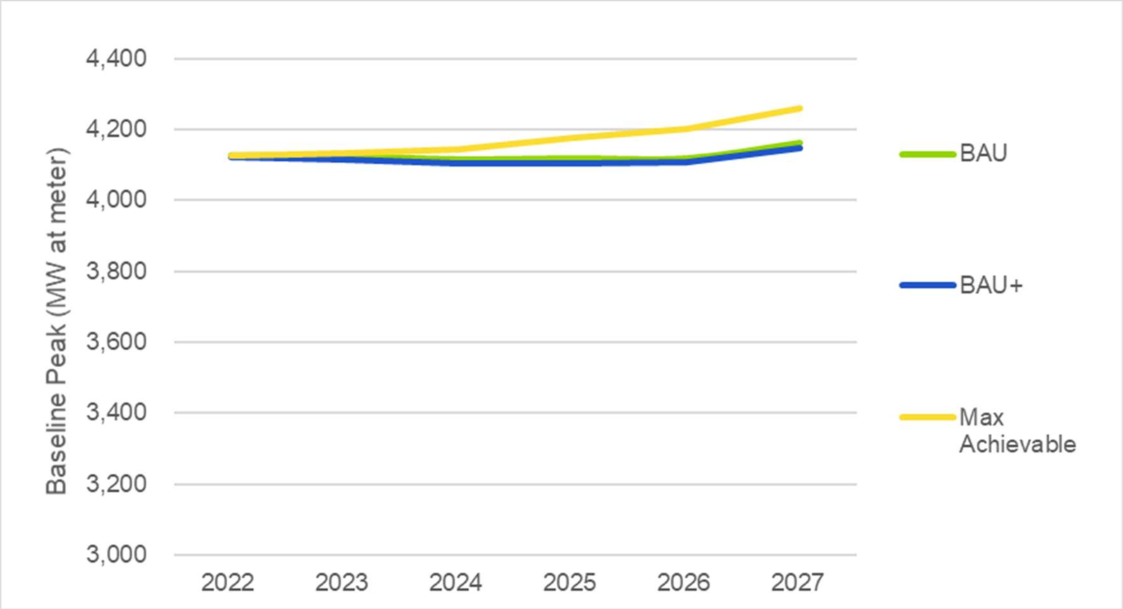
[38] Based on correspondence with National Grid, the thermostat program typically has 15 3-hour events, and the C&I ConnectedSolutions program has between 2 to 8 3-hour events.

[39] This exercise implicitly assumes that the EE and EO measures are additive and do not overlap. Guidehouse believes the potential for double counting is minimal for multiple reasons including the fact we have calibrated to existing programs where measures are already in competition, the relatively minimal amount of full replacement EO measures being adopted, and uncertainty on the degree to which EE and EO measures with similar market opportunities would truly overlap.

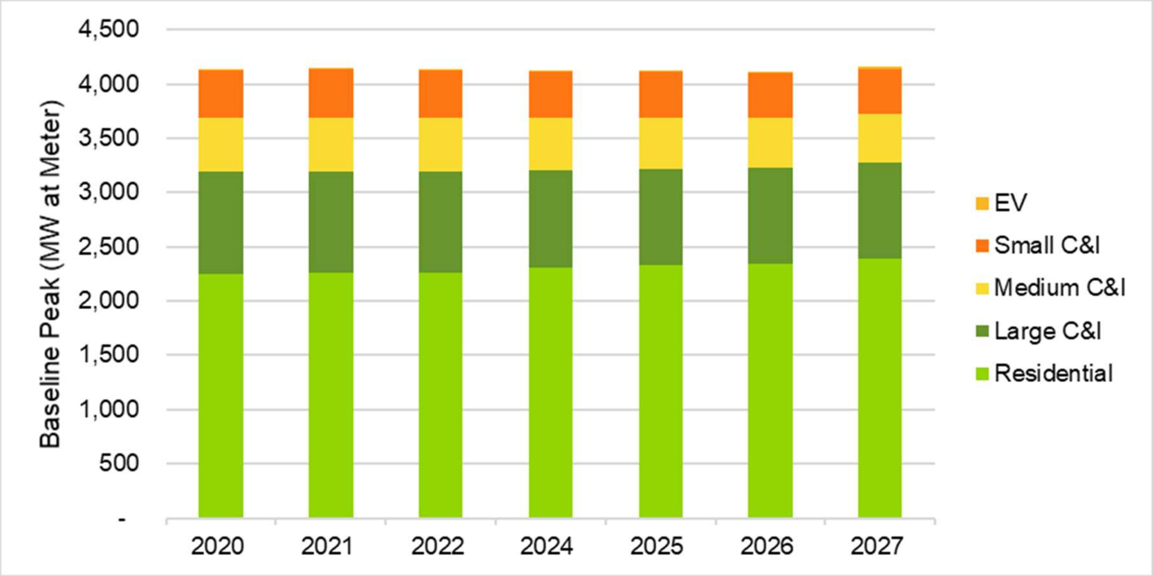
Figure 14-5. Summer Baseline Peak Forecast by DR Scenario (MW at Meter)



Source: Guidehouse analysis

The following baseline peak figures are for the BAU scenario, and the same distribution holds for the other scenarios. Figure 14-6 shows the estimated peak demand over the forecast period, broken out by customer class. Residential makes up the largest segment, followed by Large C&I and Small and Medium C&I. EV demand was projected separately using vehicle count and charging profile data.

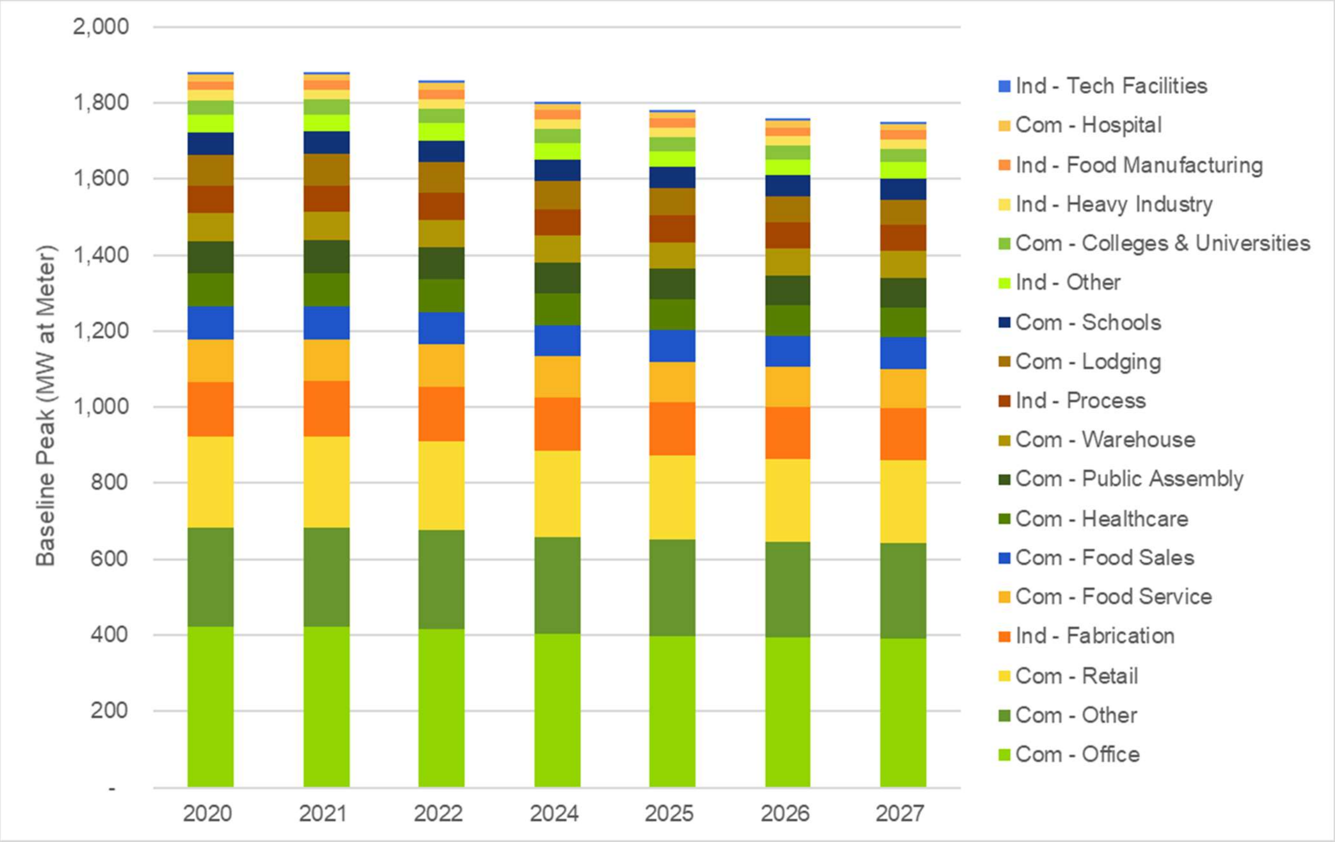
Figure 14-6. Baseline Peak Forecast by Customer Class under BAU (MW at Meter)



Source: Guidehouse analysis

Figure 14-7 shows the baseline peak forecast broken out by building type for only the C&I sector.

Figure 14-7. Baseline Peak Forecast by Building Type for C&I under BAU (MW at Meter)



Source: Guidehouse analysis

14.2.3 Behind the Meter Battery Adoption Projections

For estimating DR potential associated with BTM batteries, Guidehouse needed battery adoption projections by customer class. However, this data was not available from National Grid and therefore Guidehouse had to independently project battery adoption by customer class for National Grid's service area. These projections considered battery size and operating characteristics and estimated customer adoption based on payback period. The payback period calculations incorporated electric bill savings to the customer from offsetting grid power use (assumes batteries are charged using solar), demand charge reduction (only applicable to customers with demand charges), and incentives from DR program participation. Guidehouse used the battery size and per kW upfront capital costs and ongoing O&M costs from Guidehouse Insights reports[40] and PNNL[41] to estimate total costs incurred by the customer. The customer benefits and costs were used to calculate payback period and used in conjunction

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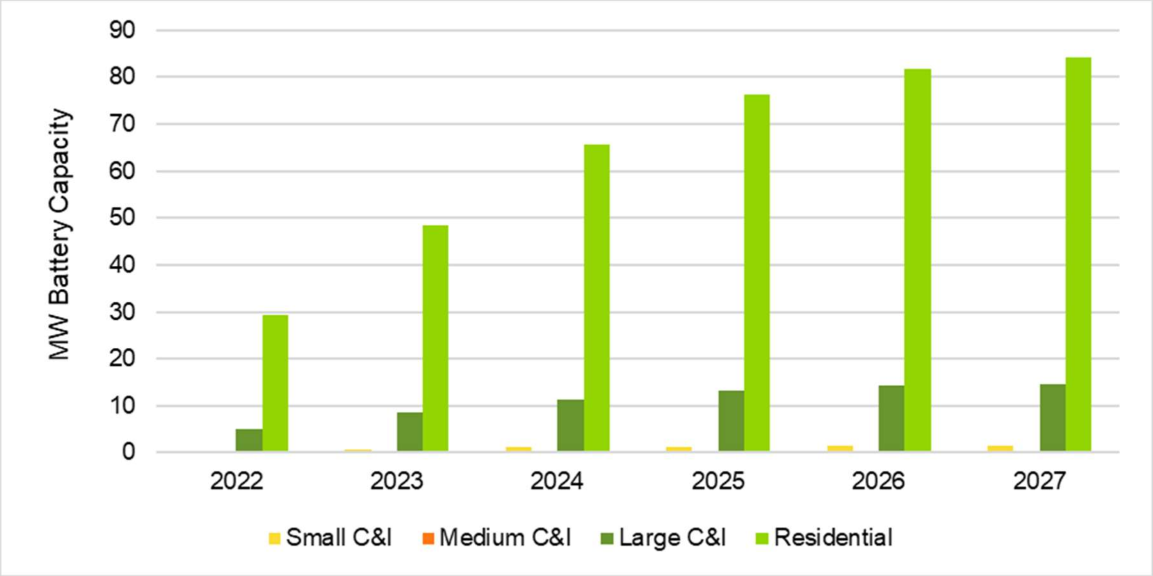
[40] https://guidehouseinsights.com/reports#contentType=Report&filters=distributed-solar-plus-storage

[41] Energy Storage Technology and Cost Characterization Report, PNNL, July 2019. https://www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

with payback acceptance curves to estimate long-run economic adoption of batteries. The economic adoption of batteries by residential customers was scaled up to represent non-economic drivers for battery adoption, primarily for resiliency reasons. The scale up due to non-economic factors was considered only for residential customers. The scale up factor was based on information in the *2019 Residential Energy Storage Demand Response Demonstration Evaluation* report and discussions with National Grid.[42] The adoption was then simulated to follow a Bass-diffusion curve ramping up to the long-run market adoption at the end of the study period. Figure 14-8 presents battery adoption projections by customer class.

Figure 14-8. Battery Capacity Projections (MW at Meter)



Source: Guidehouse analysis

14.2.4 Electric Vehicle Projections

Guidehouse used EV adoption projections from the "Base Case MECO Light-duty Vehicles in Operation Forecast" provided by National Grid and shown in Figure 14-9, which includes battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

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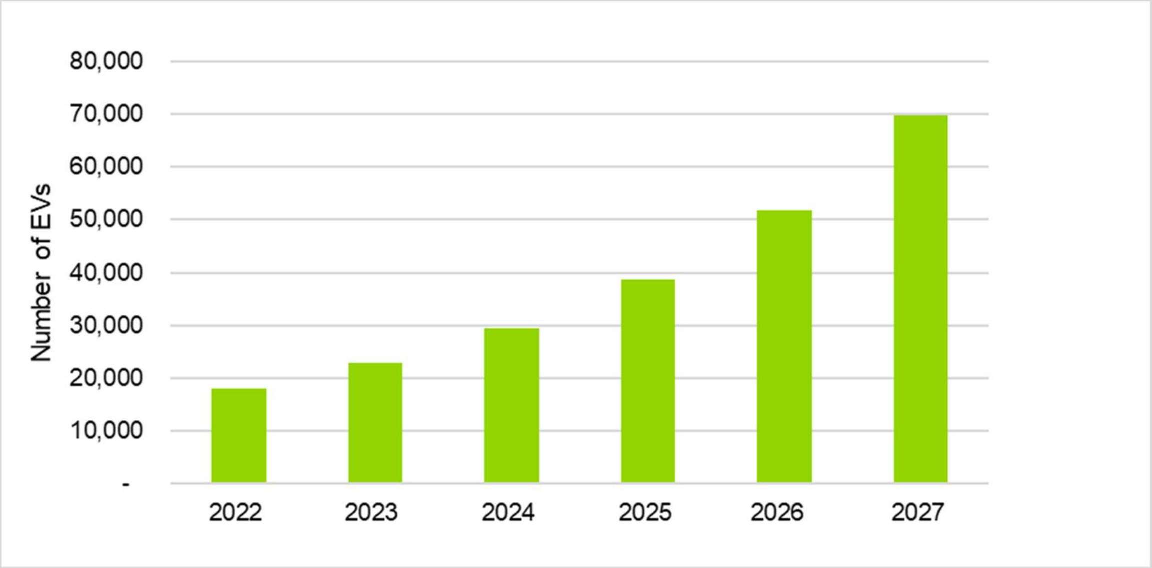
[42] Guidehouse doubled the expected economic adoption of batteries to account for resiliency drivers.

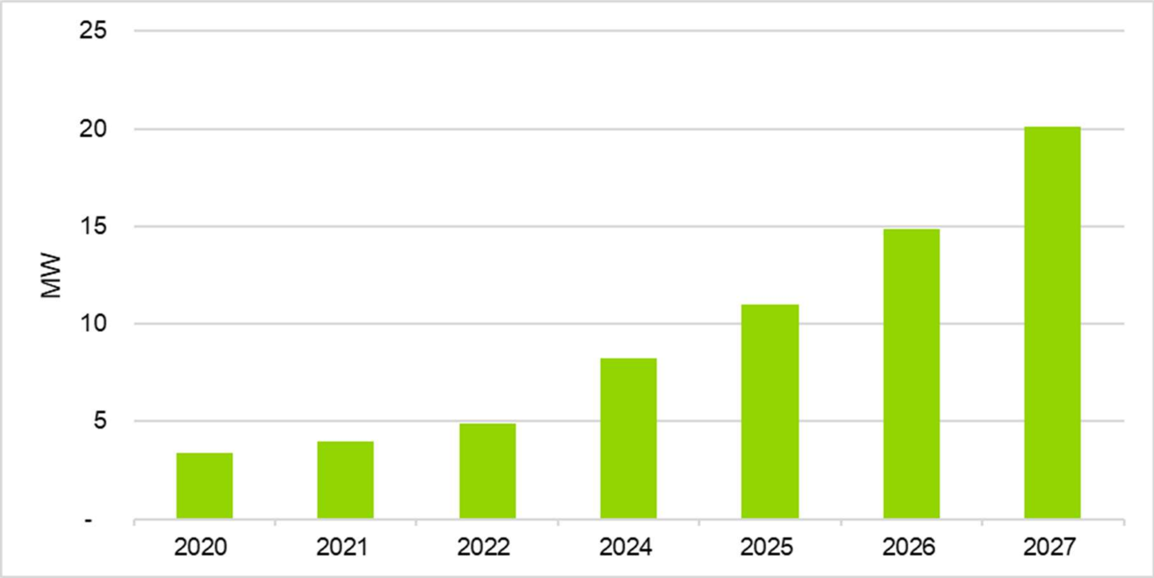
Figure 14-9. Base Case MECO Light Duty Vehicles in Operation Forecast



Source: Guidehouse analysis

Baseline peak demand projections from EVs are estimated using EV load profiles from the Smart Charge Rhode Island report[43], which National Grid provided to Guidehouse. The peak load for each vehicle type was calculated for the hours corresponding with ISO-NE's peak period of 1 p.m. – 5 p.m. and then applied to the vehicle forecast. Figure 14-10 presents the peak demand projections from EVs.

Figure 14-10. Peak Demand Projections from EVs



Source: Guidehouse analysis, SCRI Load Profiles

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[43] The report covers Sep 2019 – Mar 2020.

14.3 Characterization of DR Options

Once the baseline peak demand projections were developed, the next key step in the DR potential assessment was to characterize the different types of DR options that could be utilized to curtail summer peak demand. Table 14-3 summarizes the DR options included in the analysis. Table 14-4 lists the sub-options that represent specific end uses and control technologies under the broad program types, referred to as DR options. The DR options are representative of what National Grid currently offers and other commonly deployed programs and emerging DR-enabling technologies in the industry.

The Direct load control (DLC) option applies to residential and small and medium C&I customers. The end-uses and DR enabling technologies under DLC include National Grid's Bring Your Own Thermostat (BYOT) option under Connected Solutions and other end-uses and DR enabling technology combinations to directly control electric water heating, pool pumps, and smart appliances during peak demand periods. For small and medium C&I customers, DR sub-options included HVAC thermostat control and electric water heating control.

The C&I Curtailment option represents demand reductions through control of a variety of end uses at customer facilities using a combination of manual and automated control mechanisms, including load shifting to backup generators.[44] This option applies to large C&I customers. National Grid currently has preferred Curtailment Service Providers (CSPs) to scope and plan demand reduction strategies from these customers.[45] The projected demand reductions under C&I Curtailment represent what is currently available through existing customer recruitment along with the additional capacity that could be potentially available over the 2022-2024 timeframe considered in this study.

Dispatch of BTM batteries for peak demand reduction was considered for all customer classes, representing National Grid's current program. Additionally, the study estimated peak demand reduction potential from managed charging of EVs, which National Grid plans to offer.

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[44] Backup generators participate in DR programs as long as these meet emissions standards. National Grid provided ConnectedSolutions program participation data which helped inform the potential assessment. Guidehouse maintained current enrollment levels did not forecast any additional backup generator potential.

[45] National Grid provides a list of preferred CSPs to the customer to help identify DR opportunities and create the plan required to participate in the incentive offering.

Table 14-3. Summary of DR Options Considered in Study

DR Option	Brief Description	Eligible Customer Classes	End Use
Direct Load Control	Direct control of electric loads by a thermostat and/or load control switch or via smart appliances	Residential Small C&I Medium C&I	Central AC[46]
			Room AC[47]
			HVAC[48]
			Water Heating
			Pool Pump
			Washer
			Dryer
			Dehumidifier
C&I Curtailment	Firm capacity reduction commitment. $/kW payment based on delivered capacity, administered through third party aggregators.	Large C&I	HVAC
			Lighting
			Water Heating
			Refrigeration
			Total Facility
BYOD-Battery	Dispatch of BTM Batteries for peak demand reduction	Residential Small C&I Medium C&I Large C&I	Batteries
EV Managed Charging	Charging modulation to reduce EV demand during peak periods	EV	EV

Source: Guidehouse

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[46] Central AC and Room AC apply to residential. For small commercial and industrial, Guidehouse refers to the end use load type as HVAC.

[47] *Ibid.*

[48] *Ibid.*

Table 14-4. Summary of DR Sub-Options

DR Option	DR Sub-Option	End Use
DLC	BYOT-Smart Thermostat HVAC Control	Central AC
	BYOD- Room AC	Room AC
	Switch-water heating control-electric resistance	Water Heating
	BYOD-water heaters-electric resistance	
	Switch-water heating control-HPHW	
	BYOD-water heaters-HPHW	
	Switch-Pool Pump	Pool Pump
	BYOD-Pool Pump	
	BYOD-Clothes Washer	Washer
	BYOD-Clothes Dryer	Dryer
	BYOD-Dehumidifier	Dehumidifier
	Com DLC-Thermostat-HVAC Control	HVAC
	Com DLC-water heating control	Water Heating
C&I Curtailment	C&I Curtailment-Manual HVAC	HVAC
	C&I Curtailment- Auto-DR HVAC[49]	
	C&I Curtailment- Standard Lighting Control	Lighting
	C&I Curtailment- Advanced Lighting Control	
	C&I Curtailment- Water Heating	Water Heating
	C&I Curtailment- Industrial	Total Facility
	TES-Ice Storage	HVAC
	TES-Phase Change Materials	
	Back-up Generators	All
BYOD-Battery	Res BYOD-Battery	
	Com BYOD-Battery	
EV Managed Charging	EV Managed Charging-LDV	EV

Source: Guidehouse

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[49] Automated Demand Response (Auto-DR) is a platform to automatically activate a pre-programmed load reduction strategy in response to a signal from a Demand Response Automation Server (DRAS). Load is curtailed by the customer's building management or Supervisory Control and Data Acquisition (SCADA) system after being triggered by a signal that is sent from NSP's control room to the vendor's operations center, and on to the customer's facility. Customer always retains the ability to override the curtailment sequence in the event a site cannot participate in a specific demand response dispatch. Auto-DR ensures higher reliability of response without manual intervention.

14.4 Key Assumptions for DR Potential and Cost-Effectiveness Assessment

The final step in Guidehouse's assumptions development process was to estimate programmatic inputs such as participation rates, unit load reductions and costs for the DR options. These assumptions were based on current DR program data (enrollment, impacts, and costs) from National Grid's Massachusetts service territory[50] and the Guidehouse team's experience with similar DR potential studies and program performance data/information from DR programs in other jurisdictions.

Table 14-5 summarizes the key DR potential and cost estimation variables considered in this study. The detailed documentation of the basis of the assumptions and their values are provided in the DR Potential model input workbook associated with the report.

Table 14-5. Key Variables for DR Potential and Cost Estimates

Key Variables	Description
Participation Rates	• Percentage of eligible customers enrolled in DR programs by DR Options, DR sub-options, customer class and building types • Participation ramp (rate at which the program ramps up to steady state participation over a specified period)
Unit Impacts	• kW reduction per device for DLC (residential and small and medium C&I customers) • Percentage of enrolled load by end use/total facility/battery for DLC
Costs	• One-time fixed costs related to program development • One-time variable costs for customer recruitment and program marketing, equipment installation and enablement • Recurring fixed and variable costs such as annual program admin. costs, customer incentives, O&M, etc.
Global Parameters	• Program Lifetime, Discount Rate, Inflation Rate, Line Losses, Avoided Costs

Source: Guidehouse

Guidehouse calculated achievable potential for DR according to Equation 14-1:

Equation 14-1. DR Achievable Potential

$$\begin{aligned}
&\mathit{Achievable\ Potential} \\
&\quad = \mathit{Eligible\ Load}_{\mathit{DR\ Sub\ Option,Segment,End\ Use,Year}} \\
&\quad * \mathit{Unit\ Impact}_{\mathit{DR\ Sub\ Option,Segment,Year}} \\
&\quad * \mathit{Achievable\ Participation\ Rate}_{\mathit{DR\ Sub\ Option,Segment,Year}} \\
&\quad * (1 - \mathit{Event\ Opt\ Out\ Rate})_{\mathit{DR\ Sub\ Option,Year}}
\end{aligned}$$

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[50] National Grid provided information about its ongoing and planned DR activities. Guidehouse incorporated that information in building the potential estimates and inform assumptions around potential estimation. Detailed documentation of the basis for assumptions is presented in the appendices to this report.

In addition to the potential estimates, Guidehouse developed annual and levelized costs by DR options and sub-options and conducted cost-effectiveness assessment of these options and sub-options. Development of DR program annual and levelized costs involve itemization of the various cost components, such as one-time program development costs, DR-enablement costs, equipment costs, participant marketing and recruitment costs, annual program administration costs, O&M costs, and customer incentives.

14.4.1 Key Assumptions for DR Potential and Cost-Effectiveness Assessment

The development of potential and cost assumptions is based on program data provided by National Grid, Guidehouse's industry expertise in the area and relevant secondary sources of information such as DR potential studies and evaluation reports from other jurisdictions, and DR program databases. The key assumptions are briefly described below.

14.4.1.1 Participation

The participation assumptions for DR options are developed by customer class and segment and represent the most likely or achievable participation estimates in these options. The participation assumptions are developed by customer class and DR option and represent steady-state participation levels after the program is fully ramped up. For the Res BYOT-Smart Thermostat HVAC Control, C&I Curtailment, BYOD-Battery DR sub-options, which represent current DR activities by National Grid, participation assumptions are calibrated to current program enrollment data. In addition to the steady state participation, Guidehouse assumed program ramp up rates to reach the steady state participation levels based on benchmarking with similar programs, standard industry assumptions, and Guidehouse's industry expertise. Unit Impact Assumptions

The unit impacts specify the amount of load that could be reduced during a DR event once customers are enrolled in a DR program. Unit impacts can be specified either directly as kW reduction per participant or as % of enrolled load.

For the DLC option, unit impacts are based on kW reduction for each sub-option representing control technology and end-use combination. For each sub-option under C&I Curtailment, unit impacts are specified as % if enrolled load. For BYOD-Battery, unit impacts are specified as % of battery capacity.

The model includes the unit impact assumptions used for potential estimation and includes detailed documentation for the basis of these assumptions. Key sources for unit impacts for Residential end uses include *the 2019 Residential Energy Storage Demand Response Demonstration Evaluation*[51], *2019 National Grid Cost-Effectiveness of Electric Demand Response for Residential End-Uses* report[52], and the *2019 Wi-Fi Thermostat Evaluation Report*[53]. For C&I Curtailment, unit impacts are developed by DR sub-option as the unit impact values are tied to the end uses and the type of control. For example, the load reductions

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[51] https://ma-eeac.org/wp-content/uploads/MA19DR02-E-Storage_Res-Storage-Winter-Eval_wInfographic_2020-09-23.pdf

[52] http://ma-eeac.org/wordpress/wp-content/uploads/Cost-Effectiveness-of-DR-for-Residential-End-Uses-Final-Report-2019-04-18.pdf

[53] http://ma-eeac.org/wordpress/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

associated with Manual HVAC control and Auto-DR HVAC control are different and are specified accordingly.

14.4.1.2 Program Costs and Related Assumptions for Cost-Effectiveness

Guidehouse developed detailed itemized cost assumptions for each DR option to assess annual program costs and calculate levelized costs for each option. These cost calculations feed into the cost-effectiveness assessment of DR options using the TRC test. The DR analysis input assumptions file presents detailed itemized cost assumptions used in this study and documents the basis for these assumptions.

The cost assumptions fall into the following broad categories:

- **One Time Fixed Costs,** specified in terms of $/DR option, which include the program start-up costs, including for example, the software and IT-infrastructure related costs, and associated labor time/costs (in terms of FTEs) incurred to set up the program.
- **One Time Variable Costs,** which include marketing and recruitment costs for new participants, and enabling technology costs associated with control and communications technologies to enable DR. The enabling technology cost is specified either in terms of $/new participant on a per site basis, or as $/kW of enabled load reduction on a participating load basis.[54]
- **Annual Fixed Costs,** specified in terms of $/year, which primarily includes FTE costs for annual program administration and ongoing IT related costs not included in the one-time fixed category above.
- **Annual Variable Costs,** which primarily includes customer incentives, specified either as a fixed annual incentive amount per participant ($/participant/yr.), or in terms of load reduction ($/kW reduction), depending on the program type. It also includes additional O&M costs that may be associated with servicing technology installed at customer premises.

Other than the itemized program costs, the key variables for cost-effectiveness calculations in the model are:

- Discount rate of 2.33%,[55] used for Net Present Value (NPV) calculations.
- Inflation rate of 1.86%.[56]
- Line loss of 8.00%.[57]

Guidehouse sourced DR-related avoided costs from Appendix J from the *Avoided Energy Supply Components in New England: 2021 Report (Fifth Draft).* The avoided costs included in this analysis are listed in Table 14-6.

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[54] The enabling technology costs represents the incremental costs associated with controls and communications for making the device DR-enabled. These costs are not expected to decline meaningfully over time, and are modelled as being static.

[55] Exhibit-5-2019-2021-ADR-BCR-Model-2-19-19-National-Grid-Electric.xlsx file sent by National Grid (Lookups-Assumptions tab)

[56] Ibid.

[57] Ibid.

Table 14-6. Summary of Benefit-Cost Streams for TRC

Benefits	Costs
Avoided Retail Uncleared Capacity Costs	Program Development Cost
Avoided Transmission Capacity Costs	Program Administrative Cost
Avoided Distribution Capacity Costs	Program Delivery Cost
Avoided Capacity DRIPE	Marketing & Recruitment Cost
Avoided Reliability Costs	Technology Enablement Cost
	O&M Cost
	Incentives

Source: 2019 ADR BCR Model

In accordance with the *2019 ADR BCR Screening Model for DR* and correspondence with National Grid, Guidehouse applied limited demand response scaling factors to derate the avoided capacity and capacity DRIPE benefits. This scaling factor is shown in Table 14-7 derates the benefits from DR to account for program design constraints, such as limitations on how often events can be called, annual maximum hours for which events can be called, window of hours during the day during which events can be called, and sometimes even on the number of days in a row that events may be called. The derating factor helps lower the benefits from DR so that a MW from DR is not considered at par as a MW from a generator, which does not have similar availability constraints and could potentially be available round the clock.

Table 14-7. Limited DR Scaling Factor

DR Option	Limited DR Scaling Factor
DLC	43%
C&I Curtailment	18%
BYOD-Battery	100%
EV Managed Charging	95%

Source: 2019 ADR BCR Model, National Grid correspondence

The cost-effectiveness assessment is calculated over a 6-year program life (2022-2027). Only DR options that had TRC benefit-to-cost ratios of 1.0 or greater were deemed cost-effective and included in the achievable potential estimates. Section 15 presents cost-effectiveness results.

14.4.2 Descriptions of Scenarios and Related Assumptions

Guidehouse developed achievable potential estimates under three scenarios – BAU, BAU+, and Max Achievable. These scenarios represent variations in the following input assumptions:

- **Baseline peak demand projections**: The baseline peak demand projections for DR for the BAU, BAU+, and MAX scenarios are adjusted with the corresponding outputs from the energy efficiency potential study. The baseline peak demand projections are highest for the BAU scenario since the corresponding energy efficiency scenario has the lowest relative savings compared to the other scenarios. Similarly, the baseline peak demand projections for DR potential estimates are lowest under the MAX case. The BAU+

baseline peak demand projections reside in between the BAU and MAX peak demand projections.

- **Saturation values for C&I Energy Management System (EMS) and Advanced Lighting Controls:** For estimating the potential associated with Auto-DR for HVAC load and C&I Advanced Lighting controls, Guidehouse used the market adoption estimates for Energy Management System (EMS) and advanced lighting controls from the energy efficiency potential analysis to serve as enabling technology saturation values for estimating DR potential. The market adoption of these DR-enabling technologies varied by scenario.
- **Programmatic assumptions:** In addition to these two input variations, the scenarios represent variations in the following programmatic assumptions, summarized in Table 14-8. The MAX and BAU+ scenarios have higher incentives and associated higher program participation compared to the BAU scenario. The percentage changes represented here are based on Guidehouse's industry insights from similar analysis in other jurisdictions.[58] These percentages reflect that residential and small and medium C&I customer participation in DR programs is more sensitive to variations in incentives than that for larger C&I customers.

Table 14-8. Summary of Changes in Programmatic Assumptions Across Scenarios

Scenario	Relative Scenario	% Change in Incentives Compared to Relative Scenario	% Change in Participation Compared to Relative Scenario
BAU+	BAU	+50%	Large C&I: +10% Small and Medium C&I: 15-20% Residential: +20%
MAX	BAU	+100%	Large C&I: +15% Small and Medium C&I: +30-40% Residential: +30%

Source: Guidehouse analysis

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[58] A primary source was the 2025 California DR Potential Study, conducted by Lawrence Berkeley National Lab. Accessed at https://buildings.lbl.gov/publications/2025-california-demand-response

15. Demand Response Potential and Cost-Effectiveness Results

This section presents DR potential and costs results based on the approach described in Section 15. Results are presented for the three scenarios discussed in the previous section in the following order:[59]

- Achievable Potential Results by the following levels:
  - DR option for BAU case for residential and C&I
  - DR sub-option for BAU case for residential and C&I
  - Scenarios for Residential and C&I
  - Current results comparison to 2018 DR Potential Study results
- Cost-Effectiveness Assessment Results with Benefit-to-Costs Ratios by the following levels:
  - Cost-effectiveness results for all DR options and sub-options under the BAU scenario
  - Comparison of cost-effectiveness results across scenarios
- DR Program Cost Results by the following levels:
  - Annual program costs across scenarios
  - Levelized costs and supply curves for BAU

15.1 DR Achievable Potential Results

This section presents achievable potential results by sector for cost-effective DR options for the BAU scenario. We discuss cost-effectiveness later in the chapter. Figure 15-1 shows the potential for all sectors combined, estimated at 81.5 MW in 2022, 92.3 MW in 2023 and 106.3 MW in 2024.

Most of the potential comes from C&I Curtailment, followed by DLC (only includes cost-effective sub-options) and batteries. C&I Curtailment share in total potential declines from 80% in 2022 to 62% in 2024 with contribution from BYOD-Battery going up substantially from 4% of the total potential in 2022 to 20% of the total potential in 2024. DLC share in total potential remains almost steady at 16%-17% over the 3-year period. Under residential DLC, only smart thermostat HVAC control (BYOT) and pool pump control (BYOD) are cost-effective. Water heating and smart appliances control are not cost-effective for residential. Under C&I DLC, which applies to small and medium C&I customers, only HVAC control via thermostats and water heating control for medium C&I are cost-effective. Managed Charging of EVs contribute less than 1% of the total potential since this is relatively new (National Grid plans to launch this summer) and would take time to scale up.

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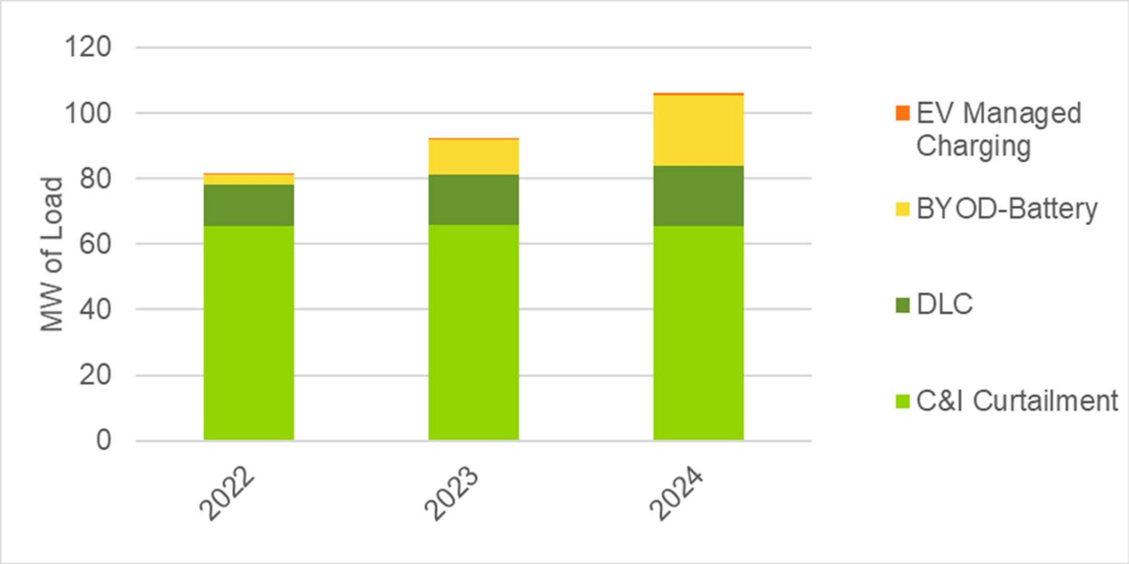
[59] Detailed potential and cost results are included in the excel-based results dashboards (Appendix D) accompanying this report.

Figure 15-1. DR Achievable Potential (MW) by DR Options (All Sectors)

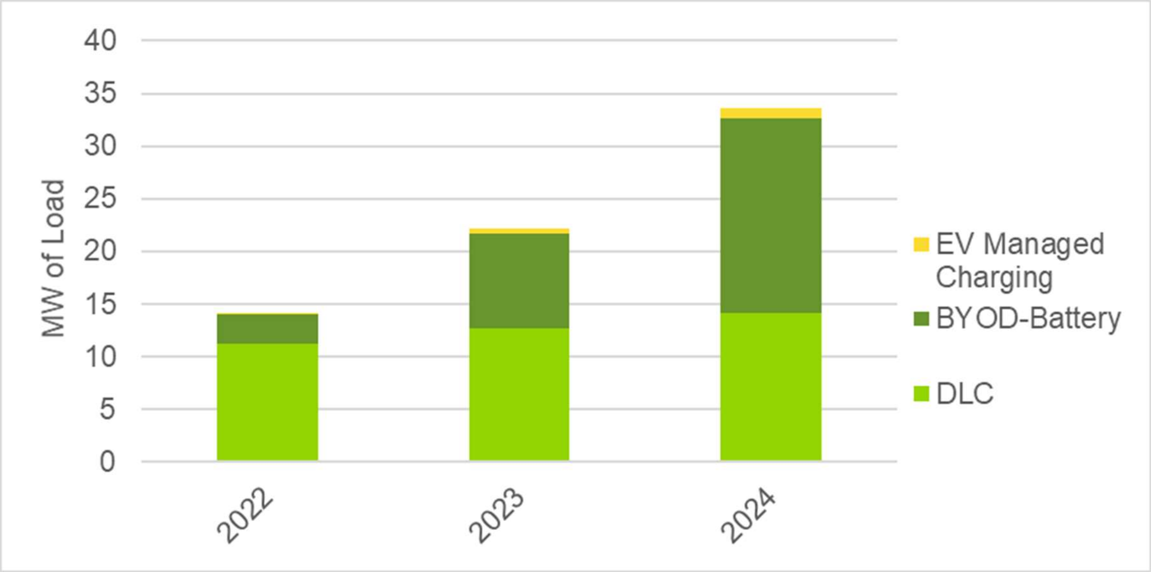


Source: Guidehouse analysis

15.1.1 Achievable Potential Results by DR Option

Figure 15-2 and Figure 15-3 show the MW breakdown of the DR achievable potential by DR option. Residential BAU DR potential is estimated to grow from 14 MW in 2022 to 34 MW in 2024. Batteries are expected to become a key DR resource under the BAU scenario, contributing over half of the residential potential in 2024.

Figure 15-2. DR Achievable Potential (MW) by DR Options (Residential)

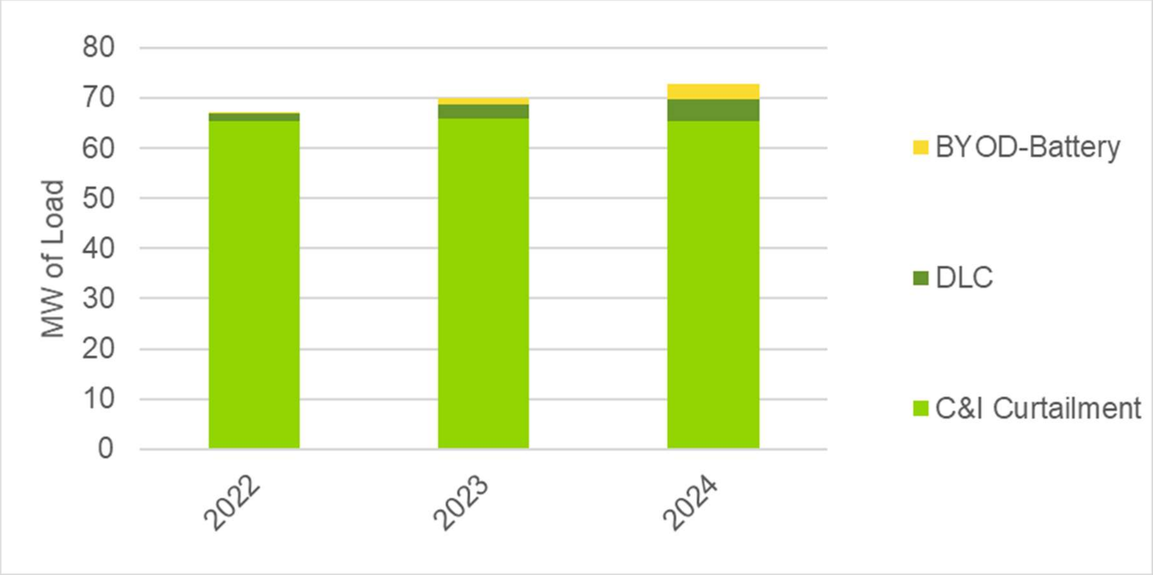


Source: Guidehouse analysis

C&I potential is expected to grow slightly, primarily due to the increase in DLC and BYOD-Battery potential. For the C&I Curtailment program, which is an established program, the estimated potential remains near steady over the 2022-2024 timeframe. The increase in C&I

Curtailment program participation over that period is countered by a decline in baseline peak demand for these customers (represented in the previous chapter under baseline peak demand projections discussions), which effectively leads to the C&I Curtailment potential remaining steady over the 2022-2024 period.[60]

Figure 15-3. DR Achievable Potential (MW) by DR Options (C&I)



Source: Guidehouse analysis

15.1.2 Achievable Potential Results by DR Sub-Option

This section presents a breakdown of the potential by the different DR sub-options included in the analysis. The DR sub-options differentiate control technologies by end-use within specific DR options such as Direct Load Control and C&I Curtailment (discussed in the previous chapter).

Figure 15-4 shows achievable results for Residential sub-options. Smart thermostat-based HVAC control (which represents the BYOT program offered by National Grid) has the highest contribution in the BAU potential in 2022, contributing 64% of the potential. Batteries grow to have the highest contribution in 2024 as battery adoption and enrollment in DR experiences a steady increase over the 3-year period, constituting 55% of the 2024 potential. Other contributors in 2024 are pool pumps with in-built smart controls at a total of 2.9 MW and EV managed charging at 0.9 MW.

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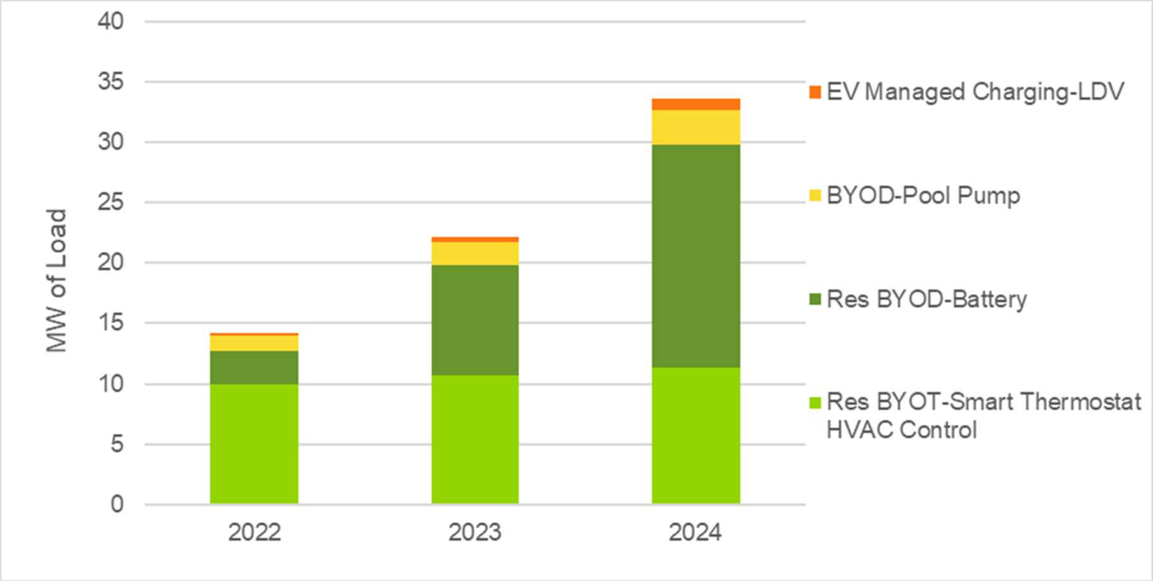
[60] Guidehouse reviewed C&I Connected Solutions program data from National Grid and calibrated to 2020 program performance and made reasonable assumptions for ramping up participation over the 2022-2024 period.

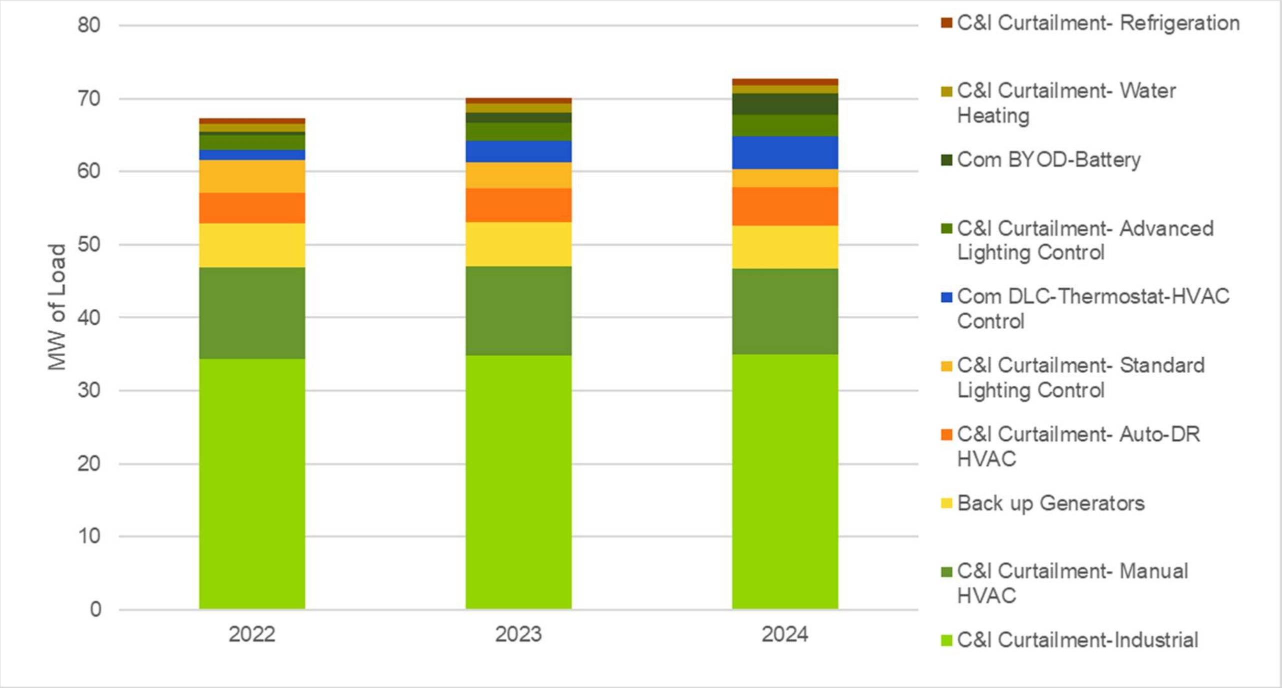
Figure 15-4. DR Achievable Potential (MW) by DR Sub-Options for 2022-2024 (Residential)



Source: Guidehouse analysis

Figure 15-5 shows achievable results for C&I sub-options. For C&I customers, curtailment of industrial end uses has the highest contribution, making up 48% of the potential in 2024. Manual HVAC curtailment (16%), backup generators (9%), and automatic HVAC curtailment (7%) also have significant contributions.

Figure 15-5. DR Achievable Potential (MW) by DR Sub-Options for 2022-2024 (C&I)



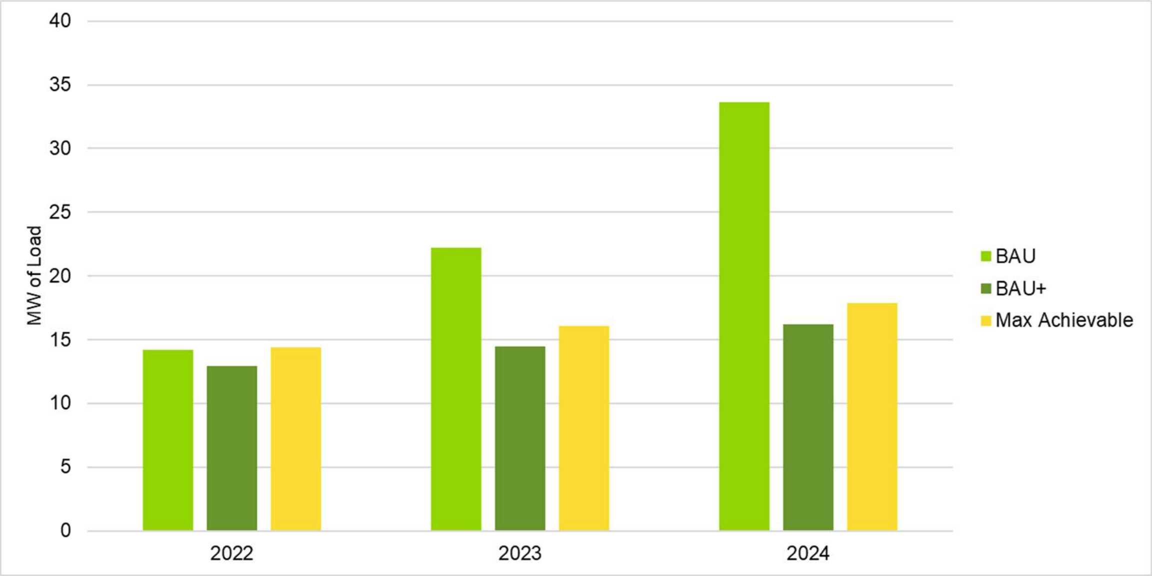
Source: Guidehouse analysis

15.1.3 Achievable Potential Results by Scenario

Figure 15-6 and Figure 15-7 present sector-level DR potential for residential and C&I respectively across the scenarios modeled. Additional discussion on parameters for each scenario run can be found in Section 14.4.1.2.

The Residential BAU+ and Max Achievable (referred to as “MAX”) scenarios show lower potential compared to the BAU case because the higher incentive assumptions for these scenarios (which in turn drive higher participation) result in EV managed charging and the battery dispatch options being not cost-effective, which means these are not included in the residential sector potential estimates for BAU+ and MAX Achievable scenarios. Additional discussion and results related to cost-effectiveness are presented in Section 15.2.

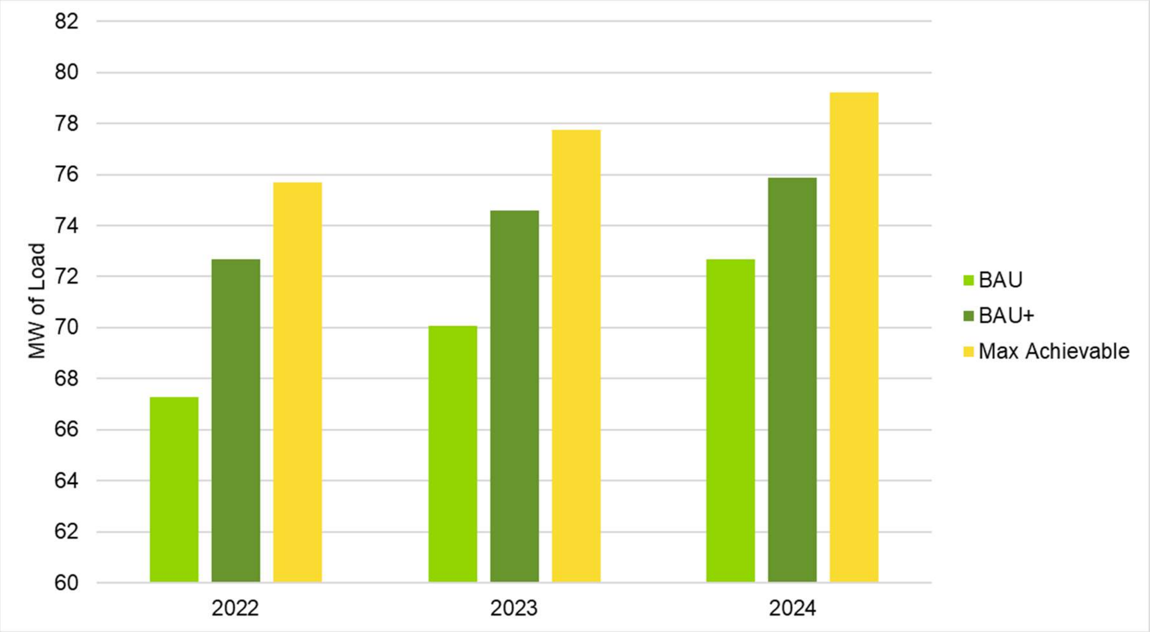
Figure 15-6. DR Achievable Potential by Scenario (Residential)



Source: Guidehouse analysis

On the other hand, C&I Potential is higher in BAU+ and MAX scenarios than under BAU (see Figure 15-7). Among the C&I DR options, C&I Curtailment has the highest contribution in potential and remains cost-effective in both BAU+ and MAX Achievable scenarios. Battery dispatch for DR is not cost-effective in either BAU+ and MAX scenarios and DLC is not cost-effective in the MAX scenario. However, both BYOD-Battery and DLC have relatively small share in the total C&I sector DR potential and therefore the decline in potential from these two options not being cost-effective does not show in the scenario results figure.

Figure 15-7. DR Achievable Potential by Scenario (C&I)

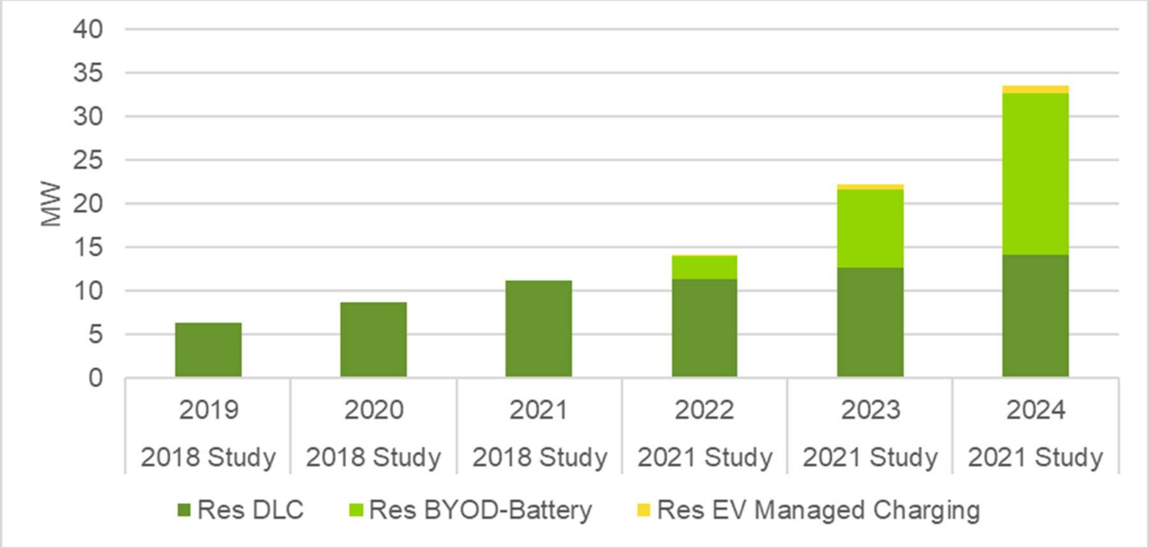


Source: Guidehouse analysis

15.1.4 Achievable Potential Comparison to 2018 Study

The potential results from this study are generally consistent with the trend presented in the previous study. Figure 15-8 presents achievable, cost-effective Residential potential from both studies, with the BAU results from the previous study displayed for 2019-2021 and BAU results from this study displayed for 2022-2024. Additional DR Options are included in this study, namely batteries and EVs, that were not present in the previous study. Both cost-effective DLC sub-options (i.e., Res BYOT-Smart Thermostat HVAC Control and BYOD-Pool Pump) were cost-effective in the previous study; however, due to changes in the avoided costs, the Switch-Pool Pump, which was cost-effective in the previous study, is no longer cost-effective in this study.

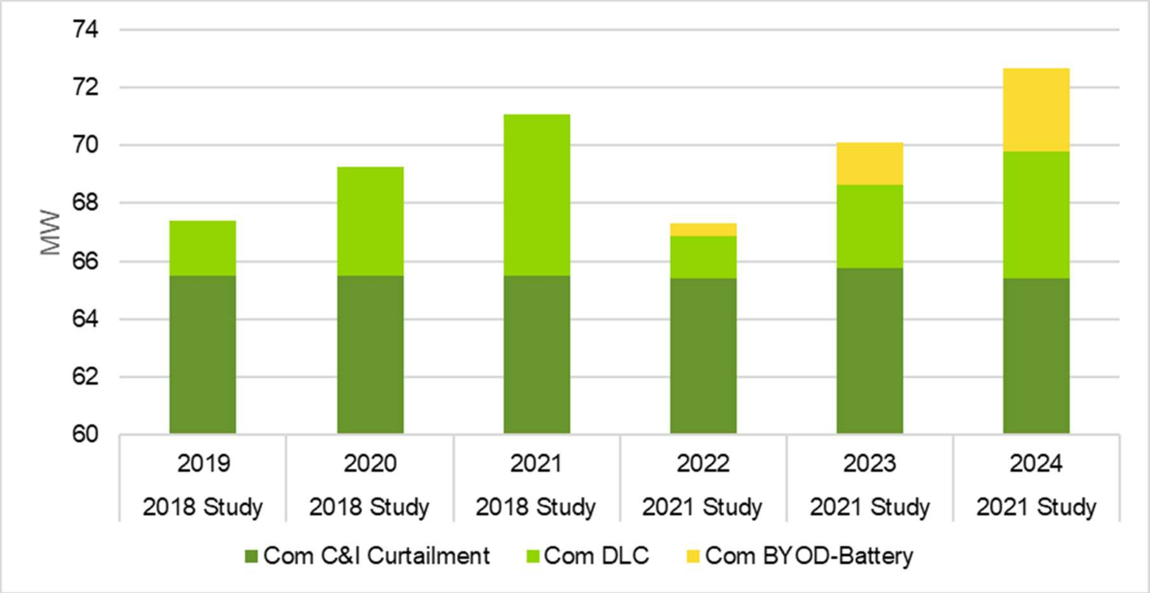
Figure 15-8. Achievable, Cost-Effective Potential Comparison with 2018 Study (Residential)



Source: Guidehouse analysis

Figure 15-9 presents C&I potential results in comparison to the 2018 trend. C&I Curtailment results are consistent with the previous study given that it is an established program and enrollment is approaching a steady-state saturation. Both the current study and the 2018 study assumed a DLC program offer to small and medium customers, though none currently exists. The 2018 study assumed a steeper ramp up of the small and medium business DLC potential than the current study and consequently the potential estimates for this option were higher in the 2018 study than the DLC potential estimates from small and medium businesses in the current study. . The 2018 study did not include battery dispatch option, so that potential does not appear in the 2018 results.

Figure 15-9. Achievable, Cost-Effective Potential Comparison with 2018 Study (C&I)



Source: Guidehouse analysis

15.2 DR Cost-Effectiveness Assessment Results

The DR potential and cost analysis first assessed cost-effectiveness of DR options and sub-options for the BAU scenario. It then assessed cost-effectiveness under the BAU+ and MAX cases (which consider higher incentive costs and participation than BAU) only for DR options and sub-options that were cost-effective under BAU. The study assessed cost-effectiveness of the DR options over 2022 to 2027, which considers a 6-year program life.[61]

The cost-effectiveness assessment results are first presented for the BAU scenario. The BAU results are then compared with BAU+ and MAX scenario cost-effectiveness results for the DR options and sub-options that were cost-effective under BAU.

15.2.1 Business-as-Usual Scenario Cost-Effectiveness Results

Table 15-1 shows the TRC BC ratios for the Business-as-Usual (BAU) scenario by the customer class and DR Sub-Option type. Green cells indicate that the sub-option is cost-effective (i.e. BC ratio above 1.0), and red cells mean that the sub-option is not cost-effective. For the residential sector, cost-effective DR sub-options are HVAC control via smart thermostats (which represents National Grid’s current BYOT program), control of smart pool pumps, and battery dispatch for DR (which represents National Grid’s current battery dispatch program) are cost-effective. Other than smart pool pumps, none of the other appliance control measures are cost-effective. Additionally, managed charging of EVs is cost-effective. For small & medium C&I customers, the Direct Load Control of HVAC and water heating equipment is cost-effective as are batteries. For Large C&I customers, all C&I curtailment sub-options are cost-effective in addition to backup generators and batteries. However, load shifting using either Phase Change Materials or Ice Storage is not cost-effective for large C&I customers.

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[61] Most programmatic costs, including customer incentives, program admin. and O&M costs are incurred annually. However, certain costs such as customer marketing and recruitment costs are incurred only one-time when the customer enrolls in the program. The analysis assumed program continuity over the 2022-2027 timeframe and therefore assumed continuing customer participation over a 6-yr. timeframe.

Table 15-1. BAU Scenario (2022-2027) Benefit-Cost Ratios by DR Options and Sub-Options

Customer Class	DR Option	DR Sub-Option	BAU TRC Benefit-Cost Ratio
Residential	DLC	BYOT-Smart Thermostat HVAC Control	2.3
		BYOD-Pool Pump	1.9
		Switch-Pool Pump	0.9
		BYOD-water heaters-electric resistance	0.4
		BYOD-Dehumidifier	0.4
		BYOD-water heaters-HPWH	0.4
		BYOD-Room AC	0.3
		Switch-water heating control-electric resistance	0.2
		Switch-water heating control-HPWH	0.2
		BYOD-Clothes Dryer	0.1
		BYOD-Clothes Washer	0.03
	BYOD-Battery	BYOD-Battery	1.2
Small C&I	DLC	DLC-Thermostat-HVAC Control	2.9
		DLC-water heating control	0.5
	BYOD-Battery	BYOD-Battery	1.2
Medium C&I	DLC	DLC-Thermostat-HVAC Control	2.7
		DLC-water heating control	1.3
	BYOD-Battery	BYOD-Battery	1.3
Large C&I	C&I Curtailment	C&I Curtailment-Advanced Lighting Control	3.3
		C&I Curtailment-Auto-DR HVAC	3.3
		C&I Curtailment-Refrigeration	3.3
		C&I Curtailment-Industrial	3.3
		C&I Curtailment-Water Heating	3.3
		Back-up Generators	3.3
		C&I Curtailment-Manual HVAC	3.3
		C&I Curtailment-Standard Lighting Control	3.3
		TES-Phase Change Materials	0.6
		TES-Ice Storage	0.3
	BYOD-Battery	BYOD-Battery	1.4
EV	EV Managed Charging	EV Managed Charging-LDV	1.2

Source: Guidehouse analysis

Table 15-2 aggregates the cost, benefits, and BC ratios for the cost-effective sub-options listed in the previous table up to the DR Option level. The BC ratios for the BYOD-Battery and EV Managed Charging DR options hover around the 1.0 threshold and are more sensitive to changes in program parameters and avoided costs.

Table 15-2. BAU Scenario (2022-2027) Benefit-Cost Ratios for Cost-Effective Sub-Options by DR Options

DR Option	NPV Benefit	NPV Cost	BC Ratio
DLC	$21.6M	$9.3M	2.3
BYOD-Battery	$36.5M	$29.4M	1.2
EV Managed Charging	$2.1M	$1.7M	1.2
C&I Curtailment	$56.1M	$16.8M	3.3

Source: Guidehouse analysis

15.2.2 Comparison of Cost-Effectiveness Results by Scenarios

In addition to the BAU scenario, Guidehouse modeled potential results under BAU+ and MAX scenarios in which assumed participation levels and incentive amounts were increased to determine the impacts on the DR Achievable potential.

Table 15-3 shows cost-effective results across the three scenarios for the DR Sub-Options that pass the BAU cost-effectiveness screening. Due to differences in program assumptions (increase in participation driven by higher incentives in BAU+ and MAX vis-à-vis BAU) across the scenarios, some measures that were borderline cost-effective under BAU become non-cost-effective under the BAU+ and MAX scenarios. Battery dispatch and EV managed charging are not cost-effective in the BAU+ and MAX scenarios, while medium C&I water heating control is not cost-effective under MAX scenario only. Other DR options and sub-options that were cost-effective under BAU remain cost-effective in the other two scenarios.

Table 15-3. DR Benefit-Cost Ratios by Scenario

Customer Class	DR Option	DR Sub-Option	BAU TRC BC Ratio	BAU+ TRC BC Ratio	MAX TRC BC Ratio
Residential	DLC	BYOT-Smart Thermostat HVAC Control	2.3	1.9	1.6
		BYOD-Pool Pump	1.9	1.5	1.3
	BYOD-Battery	BYOD-Battery	1.2	0.8	0.6
Small C&I	DLC	DLC-Thermostat-HVAC Control	2.9	2.3	1.9
	BYOD-Battery	BYOD-Battery	1.2	0.8	0.6
Medium C&I	DLC	DLC-Thermostat-HVAC Control	2.7	2.2	1.8
		DLC-water heating control	1.3	1.1	0.9
	BYOD-Battery	BYOD-Battery	1.3	0.9	0.7
Large C&I	C&I Curtailment	C&I Curtailment-Advanced Lighting Control	3.3	2.4	1.8
		C&I Curtailment-Auto-DR HVAC	3.3	2.4	1.8
		C&I Curtailment-Refrigeration	3.3	2.4	1.8
		C&I Curtailment-Industrial	3.3	2.4	1.8
		C&I Curtailment-Water Heating	3.3	2.4	1.8
		Back-up Generators	3.3	2.4	1.8
		C&I Curtailment-Manual HVAC	3.3	2.4	1.8
		C&I Curtailment-Standard Lighting Control	3.3	2.4	1.8
	BYOD-Battery	BYOD-Battery	1.4	0.96	0.7
EV	EV Managed Charging	EV Managed Charging-LDV	1.2	0.96	0.8

Source: Guidehouse analysis

15.3 Annual Program Costs

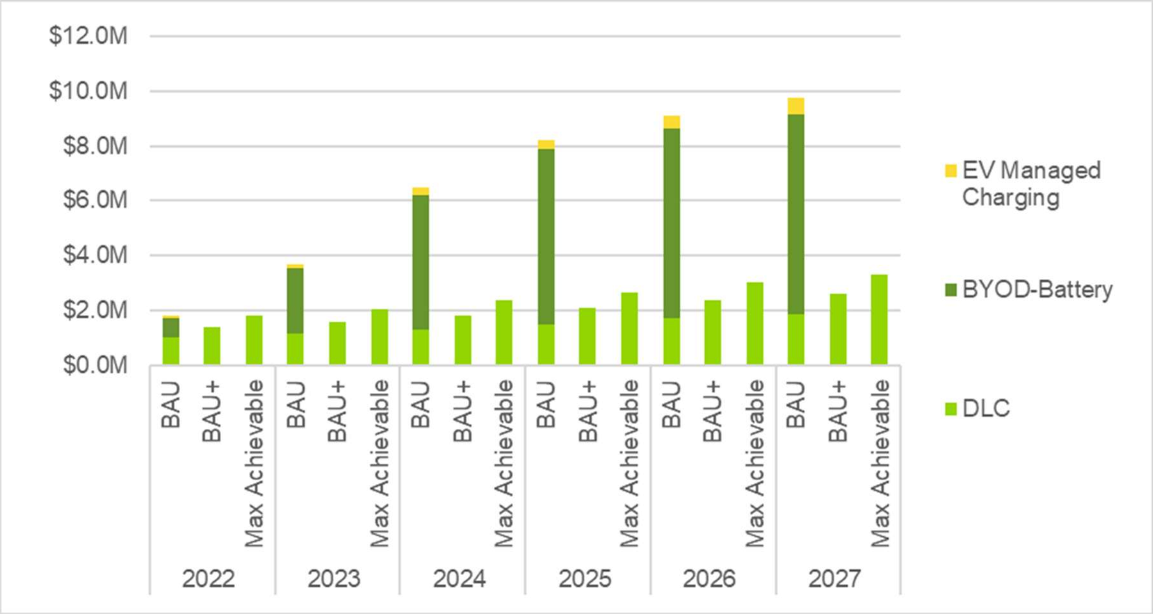
This section first presents the annual cost estimates of the DR Portfolio by sector, DR option, and scenario type and then for cost categories by sector and by scenario type.

The figures and tables below show the annual costs at the portfolio level by scenario. These costs represent the total annual costs National Grid is estimated to incur to realize the potential values discussed above. The costs represent a sum of different types of fixed and variable costs, either incurred one-time or on a recurring basis, for implementing the DR programs (refer to Section 14.4.1.2 for a description of the different types of costs).

For measures that are cost-effective under all three scenarios, costs are higher in for the BAU+ and MAX scenarios due to higher incentives paid to customers and higher enrollment. Like potential, costs for non-cost-effective measures are excluded.

Figure 15-10 present the program costs for cost-effective Residential DR Options. Due to the high incentives and growth in battery DR potential, battery program costs constitute most of the residential program costs. BYOD-Battery and EV Managed Charging costs do not appear for BAU+ and MAX scenarios since they are not cost-effective.

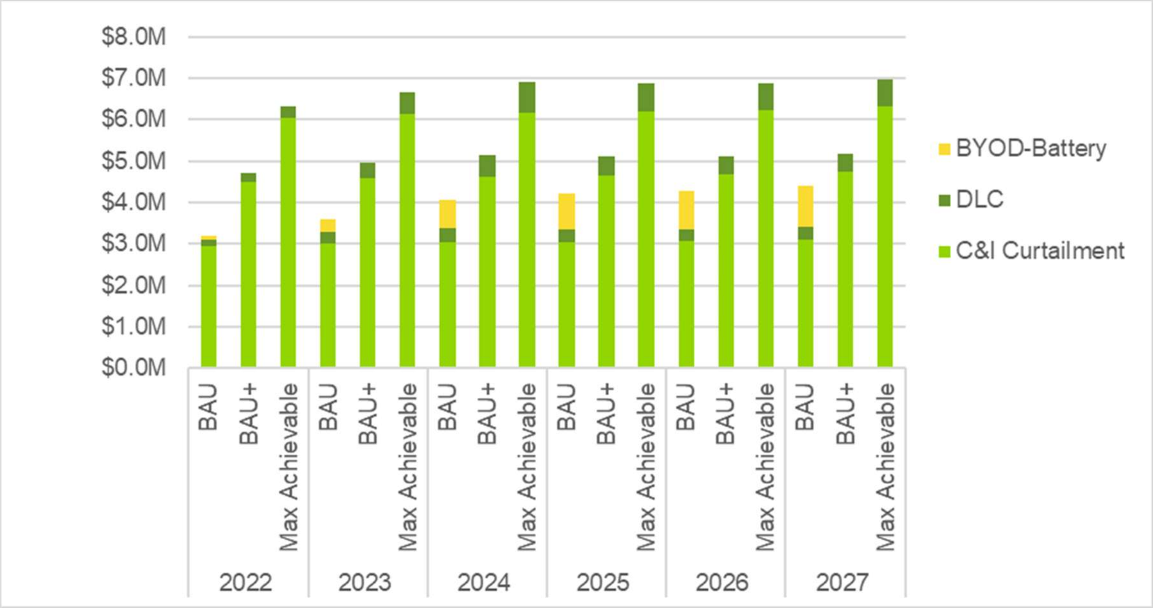
Figure 15-10. Program Costs by DR Option and Scenario (Residential)



Source: Guidehouse analysis

Figure 15-11 shows program costs for DR Options associated with Small C&I, Medium C&I, and Large C&I. Most of the costs are driven by C&I Curtailment because that DR Option also contributes the most savings.

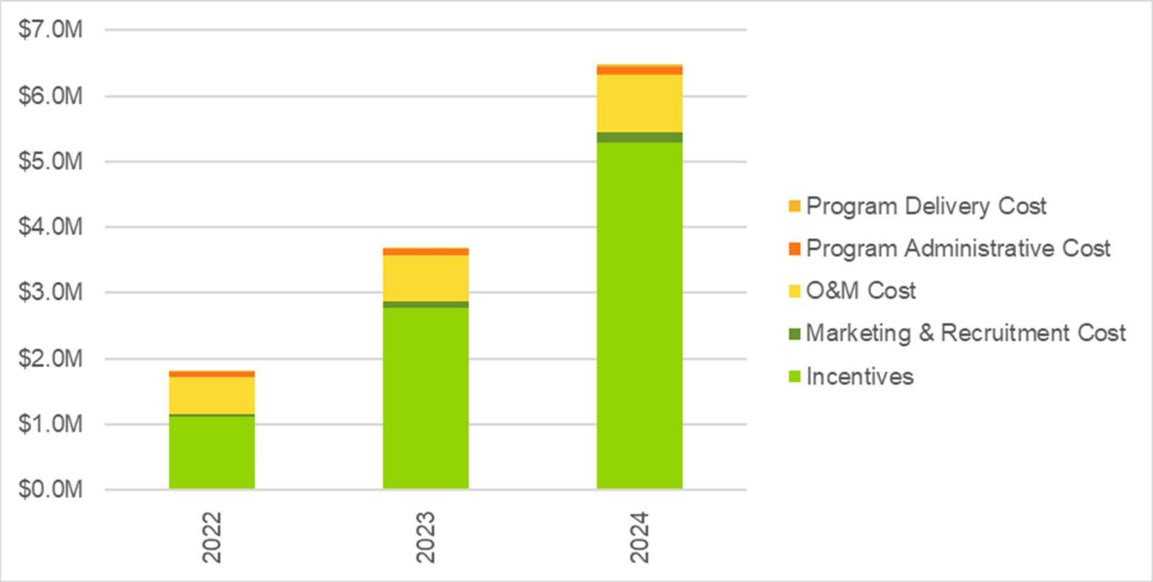
Figure 15-11. Program Costs by DR Option and Scenario (C&I)



Source: Guidehouse analysis

Figure 15-2 shows BAU program costs by cost category for cost-effective, residential DR sub-options. Most of the costs are from incentives, followed by O&M costs.

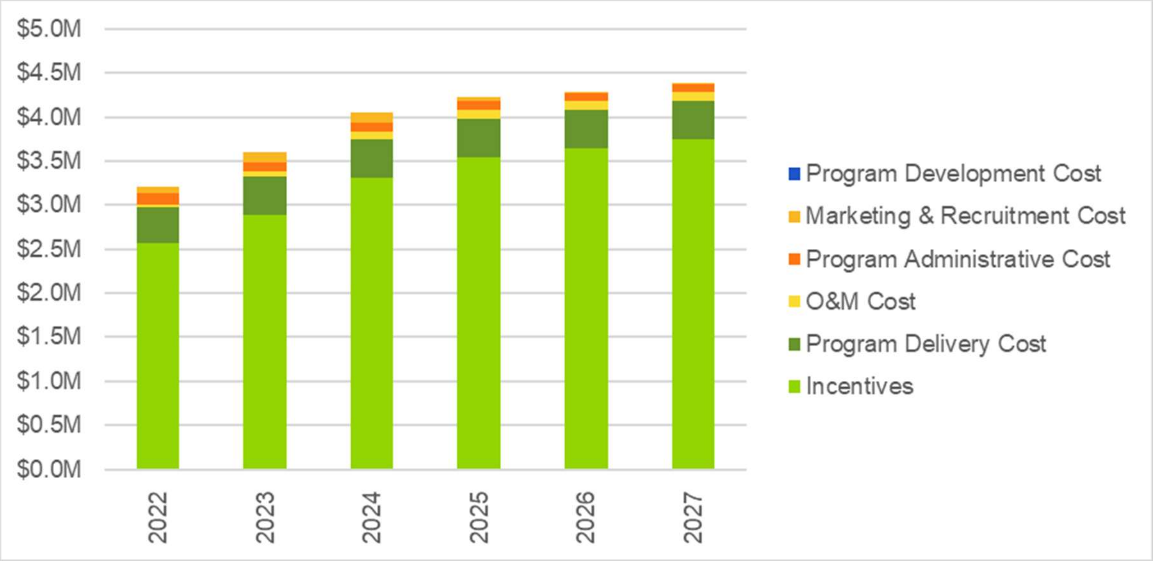
Figure 15-12. Program Costs by Category for BAU (Residential)



Source: Guidehouse analysis

Figure 15-13 shows BAU program costs by cost category for cost-effective, C&I DR sub-options. Like residential, incentives make up most of the costs. Program delivery cost is the next largest contributor to costs.

Figure 15-13. Program Costs by Category for BAU (C&I)



Source: Guidehouse analysis

15.4 Levelized Costs and Supply Curve

This section presents the levelized cost estimates for the DR options. Levelized costs are calculated over the study period and shown for all DR options and sub-options in the BAU case.

Table 15-4 shows the levelized costs for all cost-effective DR sub-options under BAU. C&I Curtailment is expected to provide the most demand reduction for the lowest levelized cost. Residential smart thermostats and batteries yield significant potential, costing around $88/kW-year and $268/kW-year respectively.

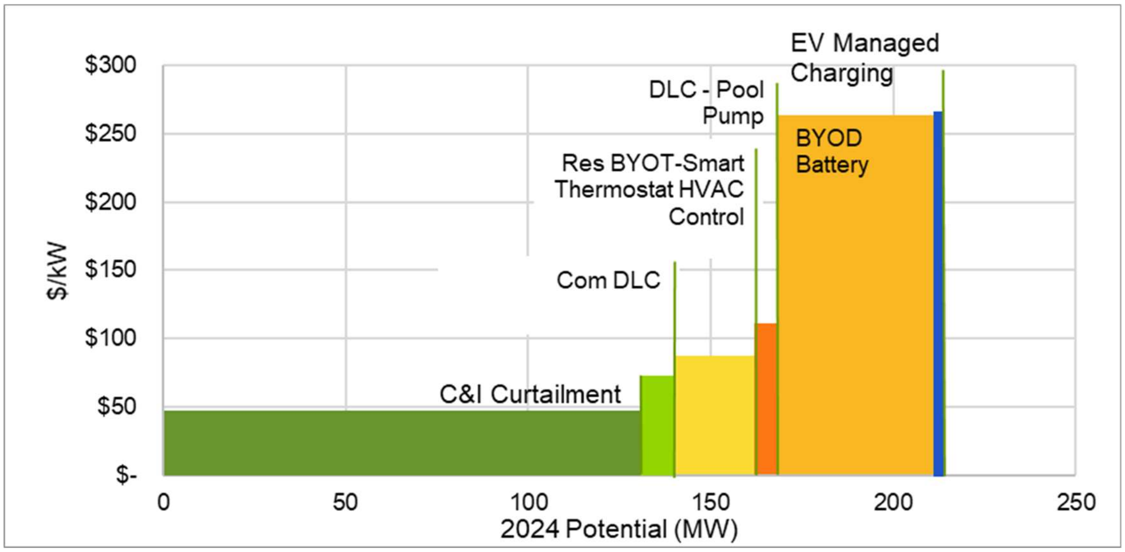
Table 15-4. DR Levelized Cost ($/kW-yr.) by Cost-Effective DR Sub-Options (BAU)

DR Sub-Option	Customer Classes	Levelized Cost ($/kW-yr.)
C&I Curtailment	Large C&I	$46.7
Com DLC-Thermostat-HVAC Control	Small C&I	$71.0
Com DLC-Thermostat-HVAC Control	Medium C&I	$78.1
Res BYOT-Smart Thermostat HVAC Control	Residential	$88.6
BYOD-Pool Pump	Residential	$111.5
Com DLC-Water Heating Control	Medium C&I	$155.3
Com BYOD-Battery	Large C&I	$228.2
Com BYOD-Battery	Medium C&I	$241.1
Com BYOD-Battery	Small C&I	$269.7
EV Managed Charging-LDV	EV	$265.2
Res BYOD-Battery	Residential	$268.0

Source: Guidehouse analysis

Figure 15-14 shows the supply curve for only cost-effective DR sub-options. The x-axis represents achievable potential in 2024 and the y-axis represents the levelized cost associated with realizing each potential increment.

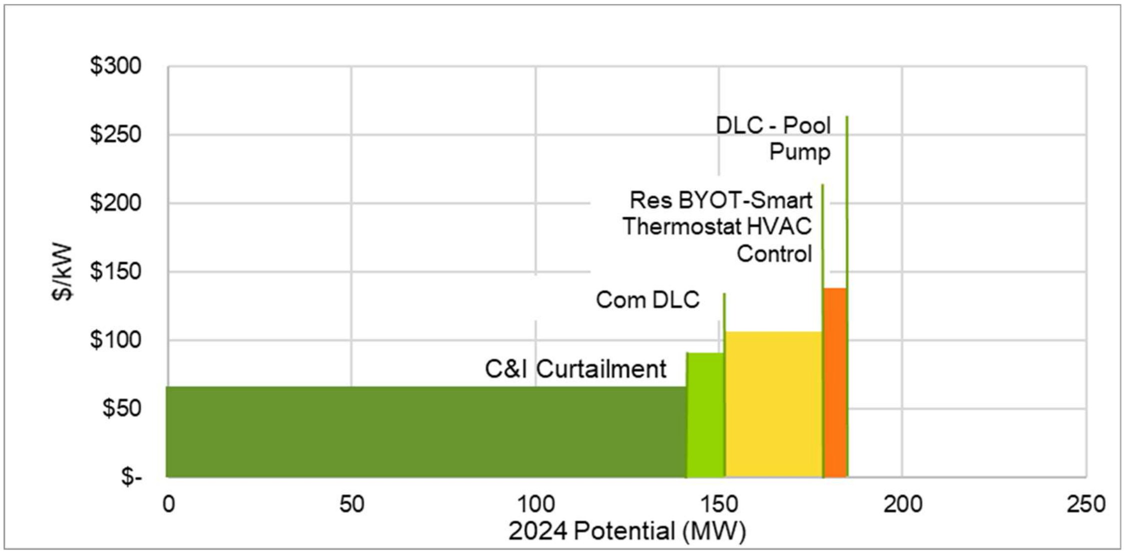
Figure 15-14. Supply Curve for Cost-Effective DR Sub-Options (BAU)



Source: Guidehouse analysis

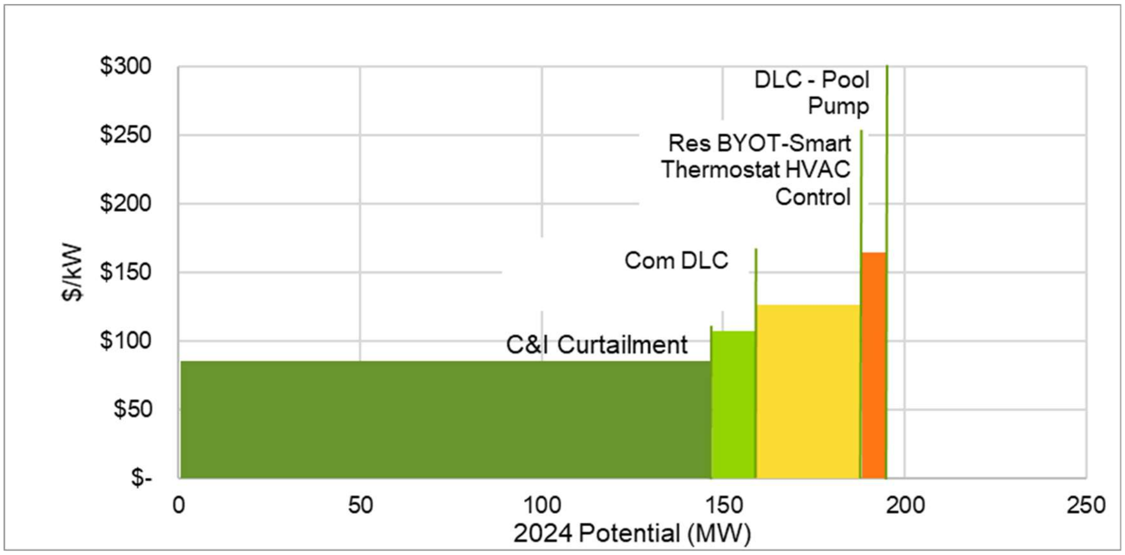
Figure 15-15 and Figure 15-16 present the supply curves for the two other scenarios. Cost-effective options are included.

Figure 15-15. Supply Curve for Cost-Effective DR Sub-Options (BAU+)



Source: Guidehouse analysis

Figure 15-16. Supply Curve for Cost-Effective DR Sub-Options (Max Achievable)



Source: Guidehouse analysis

16. Extended Economy Recovery (COVID) Scenario Analysis Results

16.1 Extended COVID-19 Recovery Scenario Formulation and Assumptions

The Extended Economic Recovery (COVID) scenario assumes the economic recovery from the COVID-19 pandemic extends into the 2022-2024-timeframe. A common set of revised economic assumptions for this scenario is layered on both the BAU and BAU+ scenarios. The same market size and barrier adjustment assumptions were applied to both Energy Efficiency and Energy Optimization analyses.

Guidehouse performed an achievable scenario to estimate the impact of extended COVID-19 recovery timelines. Assumptions for this scenario were developed in conjunction with other PAs using industry research on building stock (market size) and customer market barrier effects due to COVID-19, as well as estimated economic rebound to base case conditions. Based on this review, customer segments were split into three categories:

1. **Low COVID-19 Impact**: No anticipated closures, small market barrier increase
    a. *Market Size*: No Change
    b. *Market Barrier*: 1-year added to customer simple payback through 2023
2. **Medium COVID-19 Impact**: Anticipated short-term closures, moderate market barrier increase
    a. *Market Size*: 25% reduction in stock through 2022
    b. *Market Barrier*: 3-year added to customer payback phasing out through 2023
3. **High COVID-19 Impact**: Anticipated long-term closures, large market barrier increase
    a. *Market Size*: 25% reduction in stock for full study period
    b. *Market Barrier*: 5-year added to customer payback phasing out through 2023

Table 16-1 shows the mapping of customer segments to COVID-19 impact categories.

Table 16-1. COVID-19 Impact Category by Customer Segment

Sector	Customer Segment	COVID-19 Impact Category
C&I	Colleges & Universities	Medium
C&I	Food Sales	Low
C&I	Food Service	High
C&I	Healthcare	Medium
C&I	Hospital	Medium
C&I	Lodging	High
C&I	Office	High
C&I	Commercial Other	Medium

Sector	Customer Segment	COVID-19 Impact Category
C&I	Public Assembly	Medium
C&I	Retail	Low
C&I	Schools	Medium
C&I	Warehouse	Low
C&I	Fabrication	Medium
C&I	Food Manufacturing	Medium
C&I	Heavy Industry	Medium
C&I	High Tech Facilities	Medium
C&I	Industrial Other	Medium
C&I	Process	Medium
C&I	Commercial Multi Family	Low
Residential	Multi Family	Low
Residential	Multi Family Low-Income	Low
Residential	Single Family	Low
Residential	Single Family Low-Income	Low

Source: PA Assumptions

Based on Moody’s Analytics forecasts for Massachusetts considering COVID-19 recovery, the extended recovery scenario assumes a return to normal economic activity and full employment by 2023. Therefore, market barrier impacts are phased out between 2021 and 2023 to calibrated standard case assumption.

16.2 COVID-19 Scenario Energy Efficiency Results

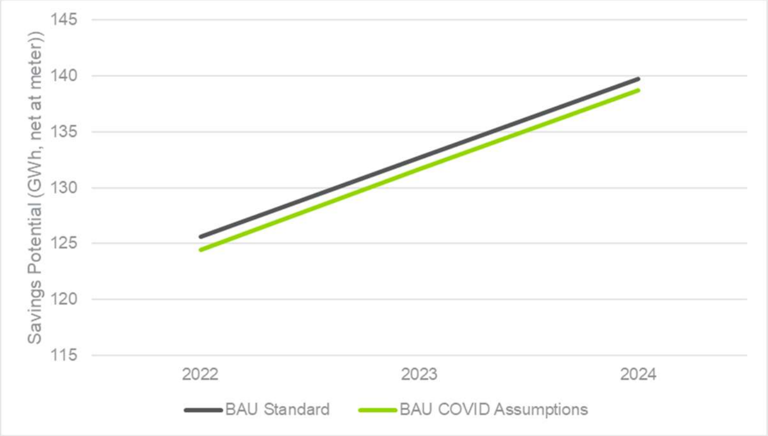
Figure 16-1 through Figure 16-6 show the impact of the COVID-19 scenario assumptions for incremental achievable potential for the BAU scenario by sector and impact type. The residential sector is minimally impacted by the extended COVID-19 recovery assumptions as all customer segments are mapped to the low impact category. A slight decrease in potential is observed, following the same trend as the standard BAU case presented in Section 8.

The C&I sector shows an overlap in potential in 2023 between the two cases. C&I potential is lower in 2022 under COVID-19 assumptions due to decreased stock forecasts and increased market barriers for most segments. However, in 2023, customer segments mapped to the medium impact category regain stock and all market barriers are returned to calibrated standard case values. At this point, extended COVID-19 recovery assumptions increase potential for 2023 and 2024 relative to the standard case. C&I lighting and custom measures begin to saturate the market and rapidly decline in potential early in the study period for the standard BAU case. The COVID-19 recovery assumptions push this saturation out in time, allowing for greater potential to be captured in these two end uses after 2022. Natural gas follows a similar trend for each sector.

For natural gas, C&I custom largely accounts for the overlapping nature of these cases for C&I natural gas potential. Scenario potentials do not fully converge in all cases in the future years as

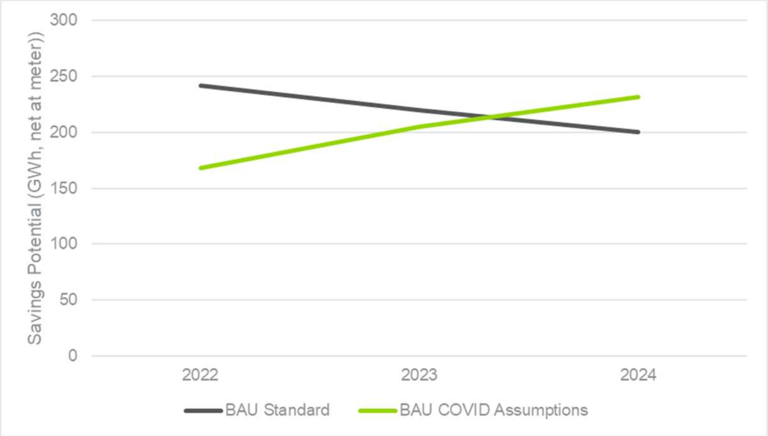
COVID-19 assumptions are removed due to decreased market penetration of efficient technologies in the early study horizon.

Figure 16-1. Comparison of EE BAU Standard and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Electricity Potential (GWh, Net at Meter)



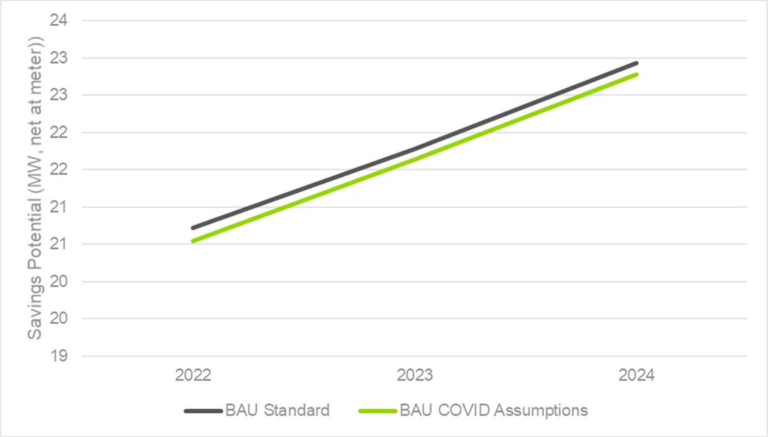
Source: Guidehouse analysis

Figure 16-2. Comparison of EE BAU Standard and Extended COVID-19 Recovery Scenarios, C&I Incremental Achievable Electricity Potential (GWh, Net at Meter)



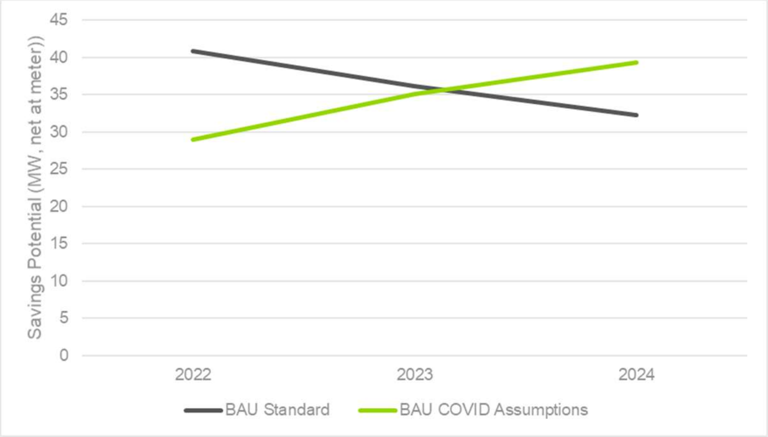
Source: Guidehouse analysis

Figure 16-3. Comparison of EE BAU Std. and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Electric Demand Potential (MW, Net at Meter)



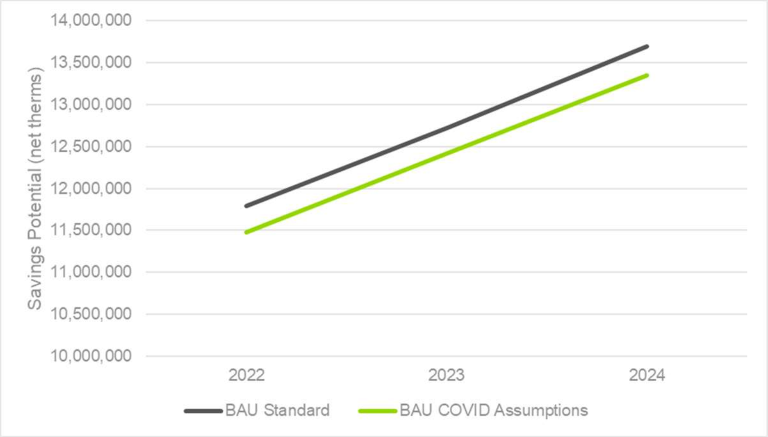
Source: Guidehouse analysis

Figure 16-4. Comparison of EE BAU Standard and Extended COVID-19 Recovery Assumptions, C&I Incremental Achievable Electric Demand Potential (MW, Net at Meter)



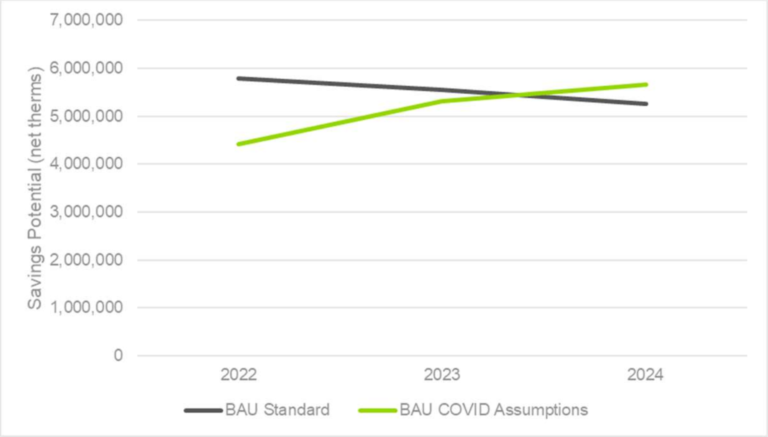
Source: Guidehouse analysis

Figure 16-5. Comparison of EE BAU Standard and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Natural Gas Potential (Net therms)



Source: Guidehouse analysis

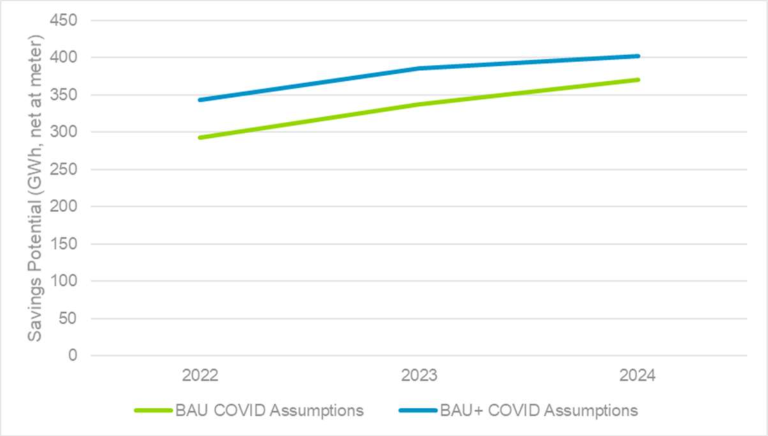
Figure 16-6. Comparison of EE BAU Standard and Extended COVID-19 Recovery Scenarios, C&I Incremental Achievable Natural Gas Potential (Net therms)



Source: Guidehouse analysis

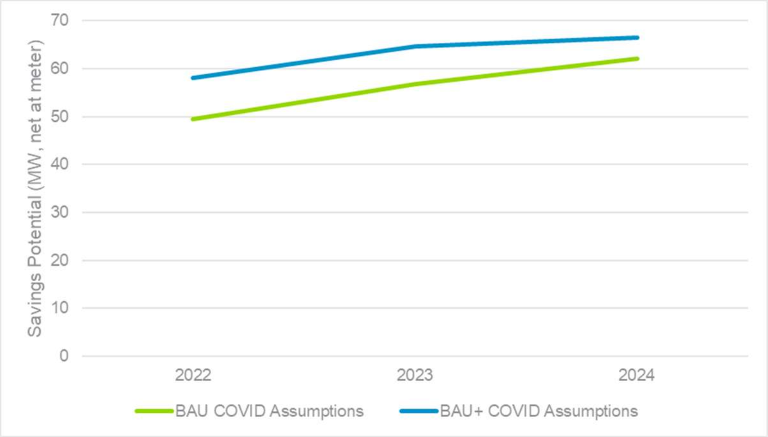
Figure 16-7 through Figure 16-9 compare incremental achievable potential for EE BAU and BAU+ Extended COVID-19 Recovery Assumption Scenarios. The BAU+ scenario shows increased savings for all fuel types in each simulation year.

Figure 16-7. Comparison of EE BAU and BAU+ Extended COVID-19 Recovery Scenarios, Incremental Achievable Electricity Potential (GWh, Net at Meter)



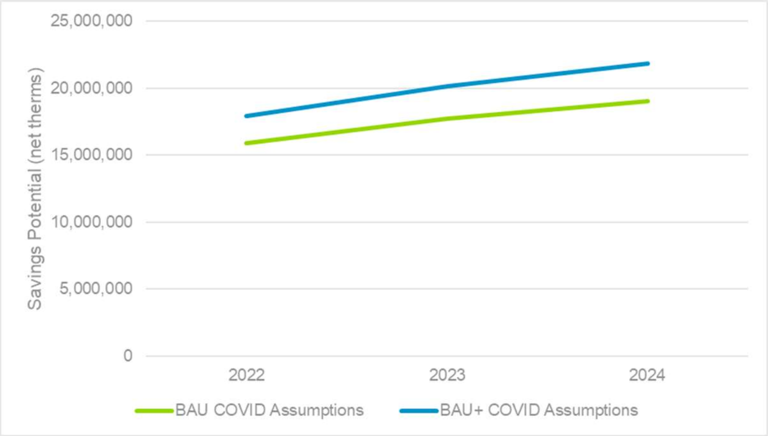
Source: Guidehouse analysis

Figure 16-8. Comparison of EE BAU and BAU+ Extended COVID-19 Recovery Scenarios, Incremental Achievable Electric Demand Potential (MW, Net at Meter)



Source: Guidehouse analysis

Figure 16-9. Comparison of EE BAU and BAU+ Extended COVID-19 Recovery Assumption Scenarios, Incremental Achievable Natural Gas Potential (Net therms)

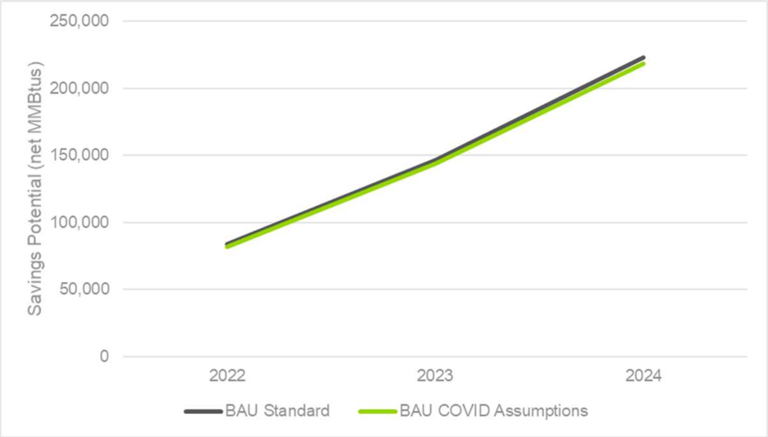


Source: Guidehouse analysis

16.3 COVID-19 Scenario Energy Optimization Results

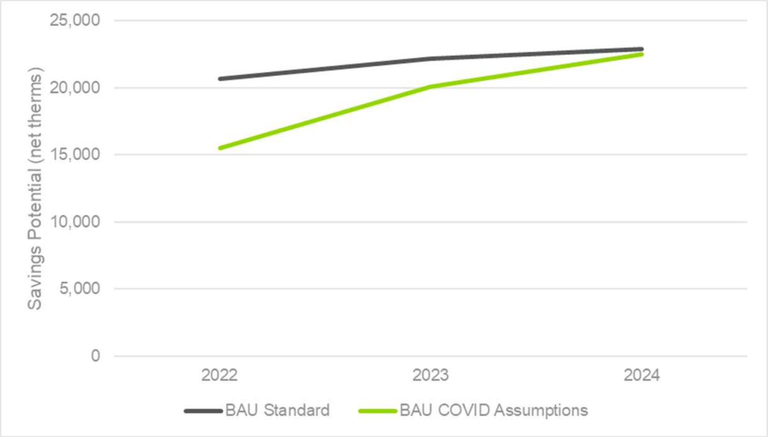
Figure 16-10 through Figure 16-14 show the impact of the COVID-19 scenario assumptions for incremental achievable potential for the BAU scenario by sector and impact type. The residential sector is minimally impacted by the extended COVID-19 recovery assumptions as all customer segments are mapped to the low impact category. A slight decrease in potential is observed, following the same trend as the BAU standard case for propane and fuel oil. Natural gas is not forecasted to be impacted by extended COVID-19 recovery assumptions. Only a single measure passes the achievable screen and is not sensitive to small changes in market barriers. The C&I sector shows approaching overlap in potential in 2024 between the two cases. C&I potential is lower in 2022 and 2023 under COVID-19 assumptions due to decreased stock forecasts and increased market barriers for most segments. As with the EE forecast, C&I propane and fuel oil potential with COVID assumptions increased above the standard case in 2024. Please note the limitations of interpreting the C&I EO results outlined in Section 12.1. No C&I natural gas measures pass the achievable TRC screen of 0.8. Scenario potentials do not converge in the future years as COVID-19 assumptions are removed due to decreased market penetration of efficient technologies in the early study horizon. The residential sector is minimally impacted by the extended COVID-19 recovery assumptions as all customer segments are mapped to the low impact category. A slight decrease in potential is observed, following the same trend as the BAU standard case. The C&I sector shows and overlap in potential in 2023 between the two cases.

Figure 16-10. Comparison of EO BAU Standard and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Propane Potential (Net MMBtus)



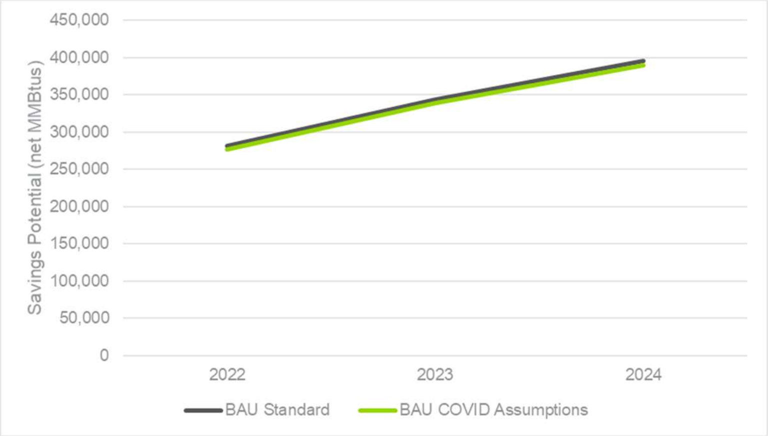
Source: Guidehouse analysis

Figure 16-11. Comparison of EO BAU Standard and COVID-19 Recovery Scenarios, C&I Incremental Achievable Propane Potential (Net MMBtus)



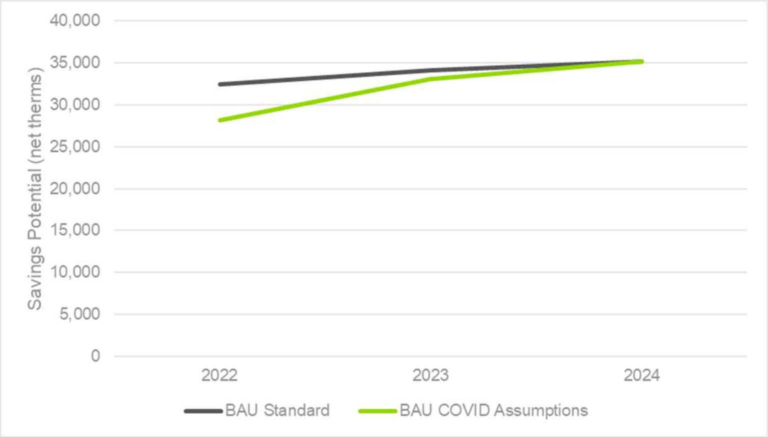
Source: Guidehouse analysis

Figure 16-12. Comparison of EO BAU Standard and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Fuel Oil Potential (Net MMBtus)



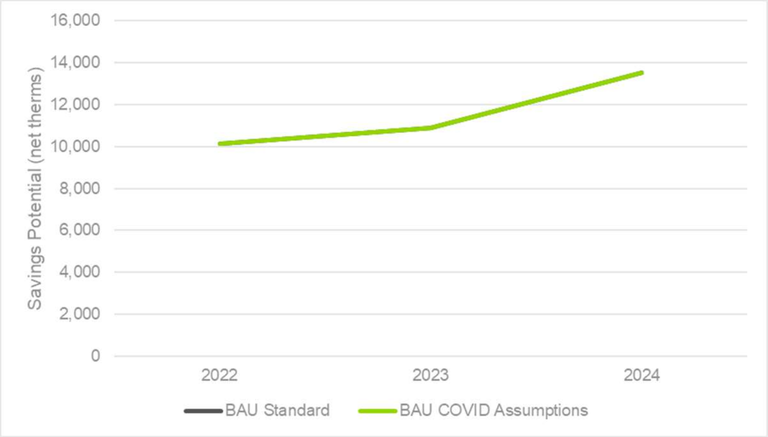
Source: Guidehouse analysis

Figure 16-13. Comparison of EO BAU Standard and Extended COVID-19 Recovery Scenarios, C&I Incremental Achievable Fuel Oil Potential (Net MMBtus)



Source: Guidehouse analysis

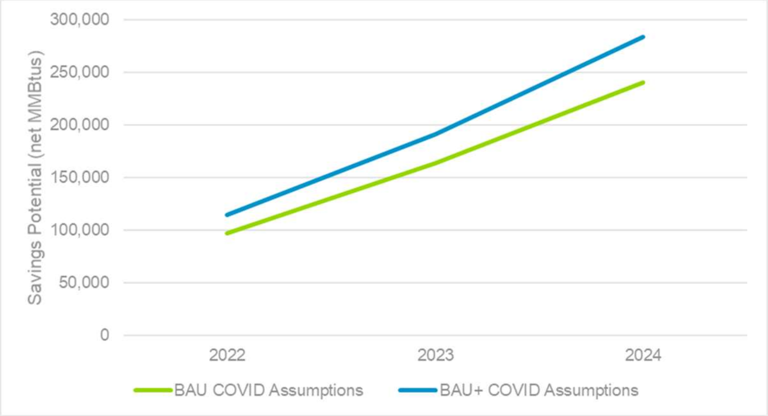
Figure 16-14. Comparison of EO BAU Standard and Extended COVID-19 Recovery Scenarios, Residential Incremental Achievable Natural Gas Potential (Net therms)



Source: Guidehouse analysis

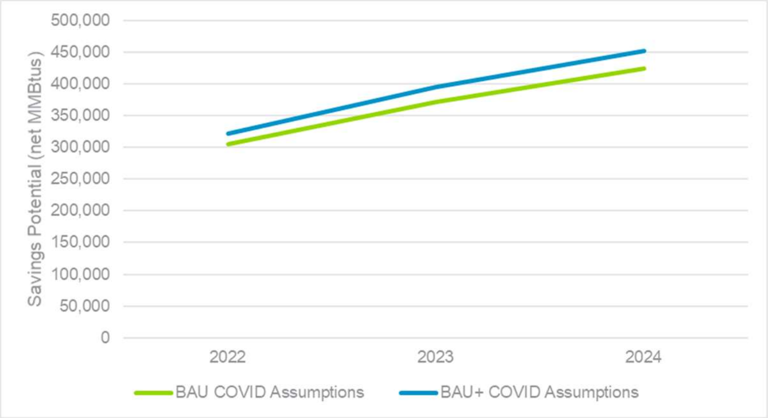
Figure 16-15 and Figure 16-16 compare incremental achievable potential for EO BAU and BAU+ Extended COVID-19 Recovery Assumption Scenarios. The BAU+ scenario shows increased savings for all fuel types in each simulation year. As described in the standard case section, Natural gas EO potential is not sensitive to changes in incentive within the scenario range.

Figure 16-15. Comparison of EE BAU and BAU+ Extended COVID-19 Recovery Assumption Scenarios, Incremental Achievable Propane Potential (Net MMBtus)



Source: Guidehouse analysis

Figure 16-16. Comparison of EE BAU and BAU+ Extended COVID-19 Recovery Assumption Scenarios, Incremental Achievable Fuel Oil Potential (Net MMBtus)



Source: Guidehouse analysis

17. Conclusions

This study has resulted in updated, expanded, and improved information on the Massachusetts customer base and the potential for energy and demand reductions possible through energy efficiency, electrification, and demand response programs and initiatives. While much energy efficiency (and demand response) potential remains, there are unique challenges in Massachusetts in realizing this potential over the next 3 years. The potential study incorporates these real factors into the analysis by utilizing MA baseline study and historic program data to accurately reflect efficient measure saturations, as well as incorporating emerging technologies into the measure mix. Based on the assumptions made, the analyses conducted and results presented, these are appropriate estimates of potential.

17.1 Energy Efficiency

- **Near-Term Electricity Savings:** The majority of near-term annual savings are from the Residential Behavior and C&I Custom Large C&I and Lighting end uses. Residential Home Energy Report ranks as the highest electricity-saving annual achievable potential measure for the Residential sector, while custom energy efficiency leads C&I.

- **Near-Term Summer Peak Passive Demand Savings:** The majority of near-term summer peak passive demand savings measures come from the Residential Behavior and Residential HVAC, and C&I Lighting end uses. Residential Home Energy Report ranks as the highest demand-saving achievable potential measure for the Residential sector. Custom energy efficiency leads the C&I sector.

- **Key Drivers:** Major differences of energy efficiency potential compared to the 2018 National Grid Massachusetts potential study potential estimates were also influenced by lighting saturation and rising measure costs, as well as lower avoided costs, particularly for natural gas and electric capacity.

- **Achieving Potential:** While this report shows that much EE potential remains, there are unique challenges in Massachusetts in realizing this potential over the next 3 years. Assumptions adopted in this study represent these factors and National Grid should be aware of the factors as it develops its plans.

    - **Prior Energy Efficiency Success:** National Grid has effectively implemented energy efficiency programs in Massachusetts for decades, often exceeding goals in terms of the amount of savings achieved. As greater levels of energy efficiency are implemented in Massachusetts and market saturation increases, it may become more challenging to harvest additional savings represented in the energy efficiency potential.

    - **Significant Energy Efficiency Measure Saturation and Low Net-to-Gross Ratios:** These reduce the available savings potential, particularly for efficient lighting.

    - **Codes and Standards:** The challenge of continuing to capture savings from energy efficiency programs within an increasingly saturated market is exacerbated by tightening codes and standards, particularly as a result of federal lighting standards and Massachusetts state and local building energy codes adopted prior to February 2021.[62]

- **Changing Energy Efficiency Measure Costs:** Changes to the portfolio measure mix that occur due to market saturation and codes and standards changes drive incremental costs upward for many measures. More complex measures, such as advanced lighting design, luminaire level lighting controls (LLLCs) and networked/connected lighting controls, may require a more sophisticated workforce, additional training, as well as increased installation and configuration time, compared to static non-controllable lighting measures. This could result in increased incremental costs for these types of measures.

- **Investment Level:** National Grid should carefully consider whether the significantly higher levels of investment in electricity and natural gas programs projected for the maximum achievable case are attainable, particularly whether mobilizing a significant increase in direct and indirect services to meet the increased level of demand for efficiency upgrades can be reasonably met.

17.2 Electrification

- **Residential HVAC Energy Optimization:** EO savings potential is dominated by HVAC technologies. High technical and economic potential are attributed to HVAC energy optimization measures that completely or partially remove the fossil-fueled end-use load from a home. Although still a significant portion of potential, achievable results indicate that efficient electrification technologies, such as air source and mini-split heat pumps, are the primary drivers of future HVAC EO savings potential but are a fraction of technical and economic potential. Therefore, although energy optimization measures present a great technical opportunity for MMBtu savings, there are significant market barriers to customer adoption.

- **Natural Gas Electrification:** Electrification potential of natural gas-fueled heating is influenced by the current low prices of natural gas. In many cases, this yields unfavorable customer economics and low adoption rates for this form of electrification.

17.3 Demand Response

- **Growth in DR Potential:** Total DR Potential in National Grid's Massachusetts service territory is estimated to grow by 30% over 2022-2024. This increase in savings is primarily driven by steady growth in battery adoption and utilization for DR dispatch, primarily from residential customers, over the 3-year timeframe.

- **Large C&I Contribution in Total Potential:** Large C&I customers have the highest share in the total potential. The C&I Curtailment option represents the DR potential from these customers and has the highest share in total potential and is the least cost option. This share declines over time with greater contribution from residential DR, primarily

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[62] Massachusetts appliance standards changes enacted in March 2021 will be addressed in a forthcoming addendum to this study.

from batteries. The C&I Curtailment potential remains more or less steady over 2022-2024 timeframe.

- **Battery Potential Growth:** Due to the high incentives for battery participation in DR, potential from battery dispatch is estimated to grow significantly from 3.2 MW in 2022 to 21.4 MW in 2024 primarily in residential. Batteries are forecasted to contribute over half of the demand reduction potential in the residential sector in 2024 and a 20% contribution in total DR potential in 2024.

- **Residential Thermostat Program Growth and Contribution:** The potential from residential HVAC control via smart thermostats (BYOT program) is estimated to grow by 14% over 2022-2024 as the program progressively scales up over time. It maintains a 10%-12% share in total potential estimates.

- **Cost-Effectiveness across Scenarios:** The C&I Curtailment option, which is the largest contributor at the lowest cost in the BAU scenario, remains cost-effective across in the other two scenarios (BAU+ and MAX). Similarly, the residential smart thermostat option remains cost-effective across all scenarios. However, the battery dispatch option and the EV Managed Charging option are not cost-effective in the other two scenarios, leading to a decline in total potential in BAU+ and MAX scenarios in relation to the BAU scenario.

- **Comparison with Prior Study:** DR potential estimates increased over 2018 estimates within the BAU scenario because of the inclusion of new DR measures, namely behind-the-meter battery control and managed EV charging. However, these measures are borderline cost-effective (these are not in the BAU+ or maximum achievable scenarios), and it will be important for National Grid to continue to monitor actual demonstration project performance.

17.4 General

- A small amount of potential identified in this study is due to new or emerging measures and is contingent on the assumptions made in modeling that potential. These assumptions cannot be tied to historical achievements and may be less well researched or documented than those for more established measures, which predominate the estimates of potential in this study. Should new or emerging measures modeled in this study be adopted as part of program goals in 2022-2024, Guidehouse encourages National Grid to pay special attention to program design for programs incorporating these new measures so that modeled savings can be realized.

Guidehouse

Appendix A: Massachusetts 2022-2024 Potential Study Modeling Methodology

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April 19, 2021

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Energy Efficiency and Energy Optimization

Guidehouse will use a custom-designed version of its DSM Potential tool – DSMSim™ – to estimate technical, economic, and achievable EE and EO potential using best practice methods that have been vetted with many other clients**Error! Reference source not found.**. DSMSim™ is a bottom-up technology diffusion and stock/flow tracking model implemented in a powerful, flexible, modeling platform that can readily deal with high degrees of dimensionality and the evolving needs of potential studies**Error! Reference source not found.**.

The DSMSim™ model has been widely used to forecast energy and demand potential across the United States and Canada **Error! Reference source not found.**and adheres to all the current best practices in the evaluation industry. Key features include:

- Ability to accommodate standard or customized cost test protocols, such as those outlined in national standard practice manuals[1], as well as the National Grid Massachusetts benefit-cost tests defined in National Grid's BCR models
- Ability to seamlessly assess sensitivities on avoided costs, retail rates, and load shape profiles, including the effects of seasonality and time of day
- Handles any number of measures, programs, sectors, program periods and savings types (electric energy/demand, gas, water, emissions, etc.)
- Accounting for three measure replacement types (i.e., retrofit, ROB, and new construction measures) and the effects of similar technologies competing for market share
- Results based on planned input assumptions (incentives, administrative costs, non-energy benefits, participation, etc.) can be compared against those derived from actual values after program implementation is finalized
- Can easily switch between net and gross savings and cost-effectiveness results
- Provides cost-effectiveness metrics at the measure, program, sector, portfolio, end-use or building type level, including combinations of these levels of granularity
- Powerful sensitivity and scenario analysis capability to identify key assumptions and largest leverage points
- Input data is imported from an Excel spreadsheet for portability, version control, and scenario analysis
- All summary results and intermediate calculations are immediately available in tabular or graphical form, in specified units, and can be exported to Excel

Guidehouse will develop EE potential estimates starting with technical potential, followed by economic, and then finally achievable potential scenarios. 0 illustrates the key inputs and the layers of the potential modeling approach.

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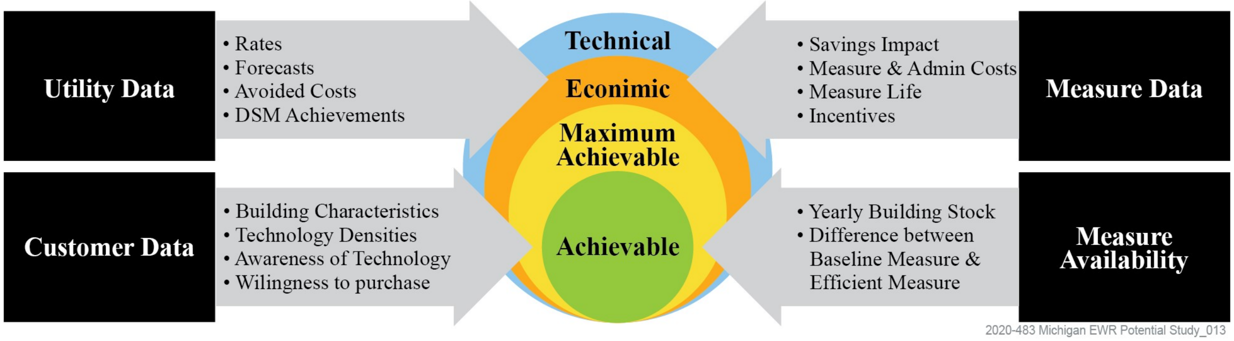
[1] E.g., the 2001 California Standard Practice Manual (CASPM); subsequent 2007 revision to the CASPM; 2017 National Standard Practice Manual by the National Efficiency Screening Project; etc.

Figure 1. *Approach to Achievable Potential Analysis*



Source: Guidehouse 2020

Developing Technical Potential

Technical potential is defined as the energy savings that can be achieved assuming that all installed measures can immediately be replaced with the efficient measure/technology, wherever technically feasible, regardless of the cost, market acceptance, or whether a measure has failed and must be replaced.

Guidehouse's modeling approach considers an energy-efficient measure to be any change made to a building, piece of equipment, process, or behaviour that could save energy. The savings can be defined in numerous ways, depending on which method is most appropriate for a given measure.

The calculation of technical potential in this study will differ depending on the assumed measure replacement type, since technical potential is calculated on a per-measure basis and includes estimates of savings per unit, measure density (e.g., quantity of measures per home), and total building stock.

The potential forecast will estimate the incremental annual and cumulative technical potential of energy and peak demand savings capable through energy efficiency, without consideration of any non-engineering constraints, and include all possible efficient measures, disregarding economic feasibility and market acceptance. Technical potential will also consider how any anticipated future codes and standards will affect the baseline.

The DSMSim™ model accounts for three replacement types, where technical potential from **retrofit** and **replace-on-burnout** measures are calculated differently from technical potential for **new construction** measures. The formulae used to calculate technical potential by replacement type are discussed in the two subsections below.

Retrofit (RET) and Replace-On-Burnout (ROB) Measures

Retrofit (RET) measures, commonly referred to as advancement or early-retirement measures, are replacements of existing equipment before the equipment fails. RET measures can also be efficient processes that are not currently in place and that are not required for operational purposes. RET measures incur the full cost of implementation rather than incremental costs to some other baseline technology or process because the customer could choose not to replace the measure and would, therefore, incur no costs. In contrast, replace-on-burnout measures (ROB), sometimes referred to as lost-opportunity measures, are replacements of existing equipment that have failed and must be replaced, or existing processes that must be renewed. Because the failure of the existing measure requires a capital investment by the customer, the cost of implementing ROB measures is always incremental to the cost of a baseline (and less efficient) measure.

RET and ROB measures have a different meaning for technical potential compared with NEW measures. In any given year, the entire building stock is used for the calculation of technical potential. This method does not limit the calculated technical potential to any pre-assumed rate of adoption of retrofit measures. Existing building stock is reduced each year by the quantity of demolished building stock in that year and does not include new building stock that is added throughout the simulation.

For RET and ROB measures, annual potential is equal to total potential, thus offering an instantaneous view of technical potential. The equation used to calculate technical potential for retrofit measures is provided below.

Annual/Total Savings Potential *= Existing Building Stock* $_{YEAR}$ *(e.g., buildings*[8]*) X Measure Density (e.g., widgets/building) X Savings* $_{YEAR}$ *(e.g., sq.ft.*[3]*/widget) X Technical Suitability (dimensionless)*

New Construction (NEW) Measures

Similar to replace-on-burnout measures, the cost of implementing new measures is incremental to the cost of a baseline (and less efficient) measure. However, new construction technical potential is driven by equipment installations in new building stock rather than by equipment in existing building stock. New building stock is added to keep up with forecasted growth in total building stock and to replace existing stock that is demolished each year. Demolished (sometimes called replacement) stock is calculated as a percentage of existing stock in each year and can be specified to market conditions. New building stock (the sum of growth in building stock and replacement of demolished stock) determines the incremental annual addition to technical potential, which is then added to totals from previous years to calculate the total potential in any given year.

The equations used to calculate technical potential for new construction measures are provided below.

Annual Incremental Technical Potential (AITP): $AITP_{YEAR}$ *= New Buildings*$_{YEAR}$ *(e.g., buildings/year*[10]*) X Measure Density (e.g., widgets/building) X Savings*$_{YEAR}$ *(e.g., sq.ft./widget) X Technical Suitability (dimensionless)*

Total Technical Potential (TTP): $TTP_Y = \sum_{Start\ Year\ End\ Year} AITPyear$

Competition Groups

The study defines competition as efficient measures competing for the same installation as opposed to competing for the same savings (e.g., window A/C vs. split-system A/C) or for the same budget (e.g., lighting vs. water heating). For instance, a consumer may install a condensing water heater or a tankless water heater; both of which belong to the same competition group, as only one of these would be installed. General characteristics of competing technologies used to define the competition groups proposed for this study include:

- Competing efficient technologies share the same baseline technology characteristics, including baseline technology densities, costs, and consumption

- The total (baseline plus efficient) maximum densities of competing efficient technologies are the same
- Installation of competing technologies is mutually exclusive (i.e., installing one precludes installation of the others for that application)
- Competing technologies share the same replacement type (RET, ROB, or NEW)

To address the overlapping nature of measures within a competition group, Guidehouse's analysis only selects one measure per competition group to include in the summation of technical potential across measures (i.e., at the end use, customer segment, sector, service territory, or total level). The measure with the largest savings potential in a given competition group is used for calculating total technical potential of the competition group. This approach ensures that double counting is not present in the reported technical potential, though the technical potential for each individual measure is still calculated.

Technical Potential

For technical potential, the overall modelling framework is shown in 0. The chart identifies the data inputs, the resource potential module, and the specific output types provided from the various modules. 0 also summarizes the various dimensions of outputs produced from the potential model, including type of potential (technical) reported at various levels (sector, end use, etc.) and in certain units (kWh, kW, Dth, etc.).

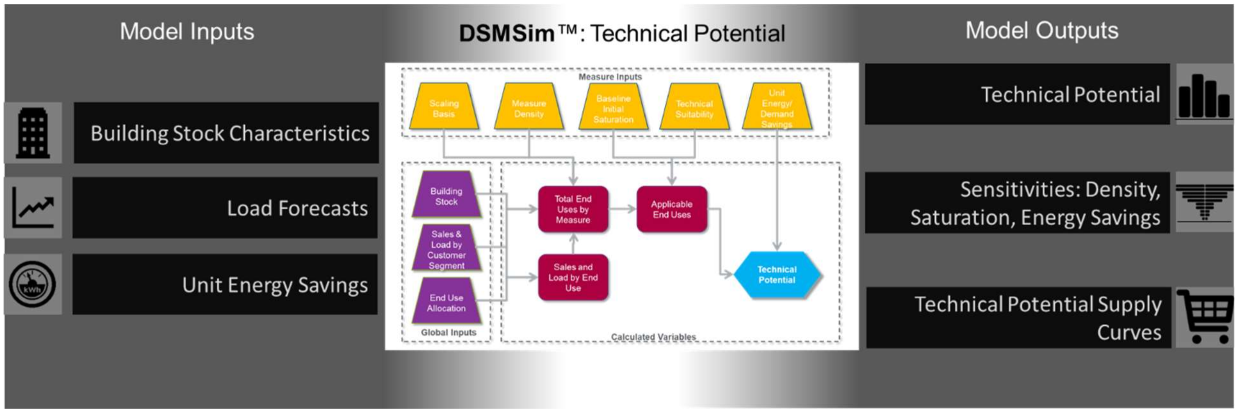


Figure 2. Guidehouse's Technical Potential Model Data Flow

Developing Economic Potential

Economic potential is a subset of technical potential and uses the same assumptions regarding immediate replacement as in technical potential. However, this only includes those measures that have passed the benefit-cost (B/C) tests chosen for measure screening. A measure with a B/C ratio greater than or equal to 1.0 is a measure that provides present value monetary benefits greater than or equal to its present value costs. If a measure's B/C meets or exceeds the threshold, it is included in the economic potential.

DSMSim™ can calculate the five standard tests,[2] and use any of these tests for economic screening. It can also allow the economic potential threshold value to be adjusted (set at 1.0, or

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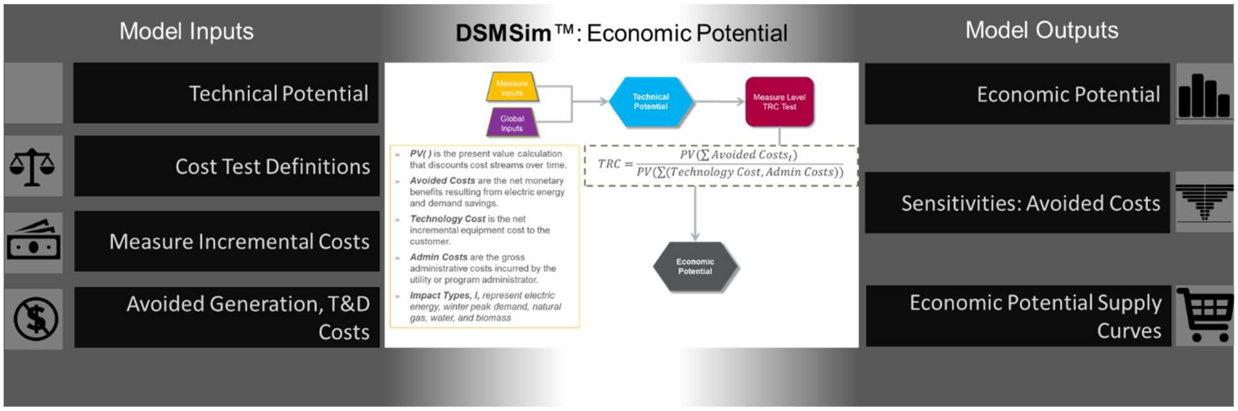
[2] *The California Standard Practice Manual (CASPM) defines five standard cost tests for cost-benefit analysis: Participant Cost Test, Program Administrator Cost Test, Ratepayer Impact Measure Test, Total Resource Cost Test, and Societal Cost Test.*

higher or lower). As with technical potential, Guidehouse recognizes codes and standards, replacement types, and competition groups in the development of economic potential.

Similar to technical potential, only one economic measure (meaning that its B/C ratio meets the threshold) from each competition group is included in the summation of economic potential across measures (e.g., at the end use, customer segment, sector, service territory or total level). If a competition group is composed of more than one measure that passes the TRC test, then the economic measure that provides the greatest savings potential is included in the summation of economic potential. This approach checks that double counting is not present in the reported economic potential, though economic potential for each individual measure is still calculated.

Within DSMSim™, we will use National Grid Massachusetts avoided cost forecasts, and other financial inputs to apply cost-benefit screens for all measures considered in the technical potential analysis. **0** illustrates the overall economic potential modelling framework, with the resulting economic potential outputs outlined on the right-hand side.



- ***PV( )*** is the present value calculation that discounts cost streams over time.
- ***Avoided Costs*** are the net monetary benefits resulting from electric energy and demand savings.
- ***Technology Cost*** is the net incremental equipment cost to the customer.
- ***Admin Costs*** are the gross administrative costs incurred by the utility or program administrator.
- ***Impact Types, I,*** *represent electric energy, winter peak demand, natural gas, water, and biomass*

$$TRC = \frac{PV(\sum Avoided\ Costs_I)}{PV(\sum(Technology\ Cost, Admin\ Costs))}$$

Figure 3. Guidehouse's Economic Potential Model Data Flow

Develop Achievable Potential

Achievable potential is a subset of economic potential, but further considers the likely rate of efficient measure acquisition, which is driven by a number of factors including the rate of equipment turnover (a function of measure's lifetime), simulated incentive levels, budget constraints, consumer willingness to adopt efficient technologies, and the likely rate at which marketing activities can facilitate technology adoption. This section provides a high-level summary of the approach to calculating achievable potential, which is fundamentally more complex than calculation of technical or economic potential.

The critical first step in the process of accurately estimating achievable potential is to simulate market adoption of efficient measures. Annual program participation is modeled through technology adoption and diffusion algorithms. The long-run equilibrium market share[3] (i.e., how quickly a technology reaches final market saturation) is calculated by comparing a measure's payback period to a customer payback acceptance curve. Each measure's payback period is

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[3] This term, although something of a misnomer due to the fact that the long run market share is dynamic, changing with building stocks, technology prices, and avoided costs for example, is used to describe the percentage of the market that would participate in a program if perfect information was available to the customer. As awareness of each measure increases, the market will move toward this point.

derived from subtracting the energy bill savings (retail rates multiplied by energy savings) and incentive from the measure's incremental participant cost. Guidehouse's model employs an enhanced Bass Diffusion model[4] to simulate the S-shaped growth toward equilibrium commonly seen for technology adoption. The Bass Diffusion model describes the process of the adoption of products as an interaction between users and potential users. In the model, achievable potential adopters "flow" to adopters by two primary mechanisms – adoption from external influences, such as marketing and advertising, and adoption from internal influences, such as word-of-mouth or peer-effects – with differences in stock turnover captured for replace-on-burnout measures relative to retrofit and new construction.

Guidehouse typically uses payback acceptance curves to estimate equilibrium market share. Payback acceptance curves have been developed in the past by presenting decision makers with numerous choices between technologies with low upfront costs but high annual energy costs, and measures with higher upfront costs but lower annual energy costs. **0** shows payback acceptance curves for the National Grid Massachusetts study a the customer segement. Each curve represents the percentage of willing to purchase a technology based on its payback time. Separate curves were developed for high upfront cost and low upfront cost measures.

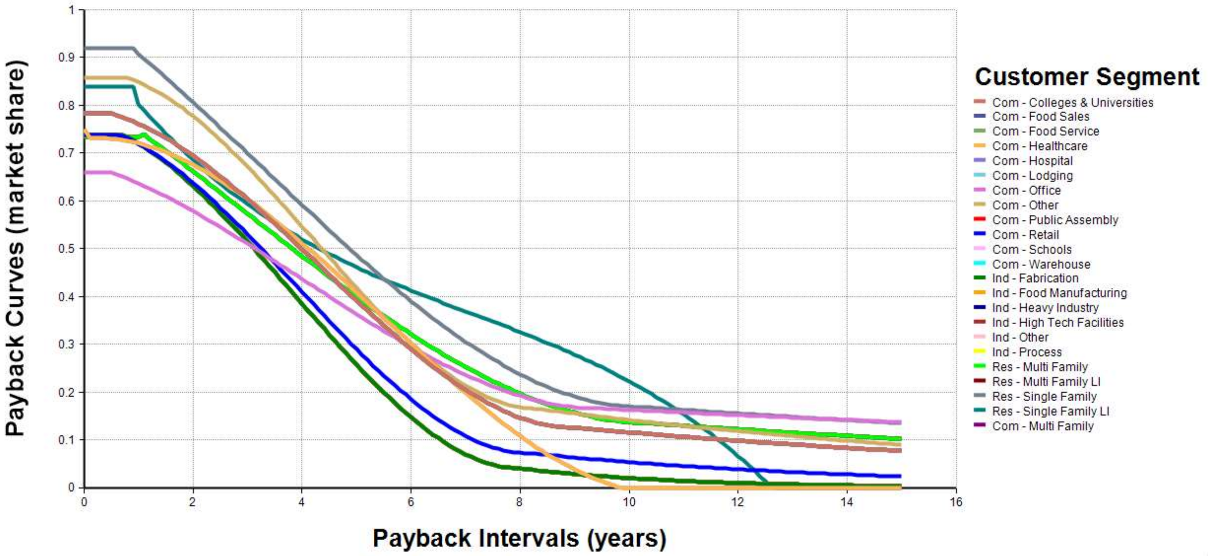

Figure 4. Payback Acceptance Curves

Since the payback time of a technology can change over time; as technology costs and/or energy costs change over time, the equilibrium market share can also change over time. The equilibrium market share is, therefore, recalculated for every time-step within the market simulation to make certain the dynamics of technology adoption considers this effect. As such, the term "equilibrium market share" is a bit of an oversimplification and a misnomer, as it can itself change over time and is, therefore, never truly in equilibrium; it is used nonetheless to facilitate understanding of the approach.

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[4] *Bass, Frank (1969). "A new product growth model for consumer durables". Management Science 15 (5): pgs. 215–227.*

Calculation of the Approach to Equilibrium Market Share

Two approaches are used for calculating the approach to equilibrium market share (i.e., how quickly a technology reaches final market saturation): one for new technologies or those being modeled as a retrofit (a.k.a. discretionary) measures, and one for technologies simulated as ROB (a.k.a. lost opportunity) measures[11].

The retrofit and new technologies adoption approach uses an enhanced version of the classic Bass diffusion model[12,13] to simulate the S-shaped approach to equilibrium that is commonly observed for technology adoption.

Figure 5 provides a stock/flow diagram illustrating the causal influences underlying the Bass model. In this model, achievable potential adopters flow to adopters by two primary mechanisms: adoption from external influences, such as program marketing/advertising, and adoption from internal influences, including word-of-mouth. The fraction of the population willing to adopt is estimated using the payback acceptance curves in.

The marketing effectiveness and external influence parameters for this diffusion model are typically estimated upon the results of case studies where these parameters were estimated for dozens of technologies.[14] Recognition of the positive, or self-reinforcing, feedback generated by the word-of-mouth mechanism is evidenced by increasing discussion of the concepts such as social marketing as well as the term viral, which has been popularized and strengthened most recently by social networking sites such as Facebook and YouTube. However, the underlying positive feedback associated with this mechanism has been ever present and a part of the Bass diffusion model of product adoption since its inception in 1969.

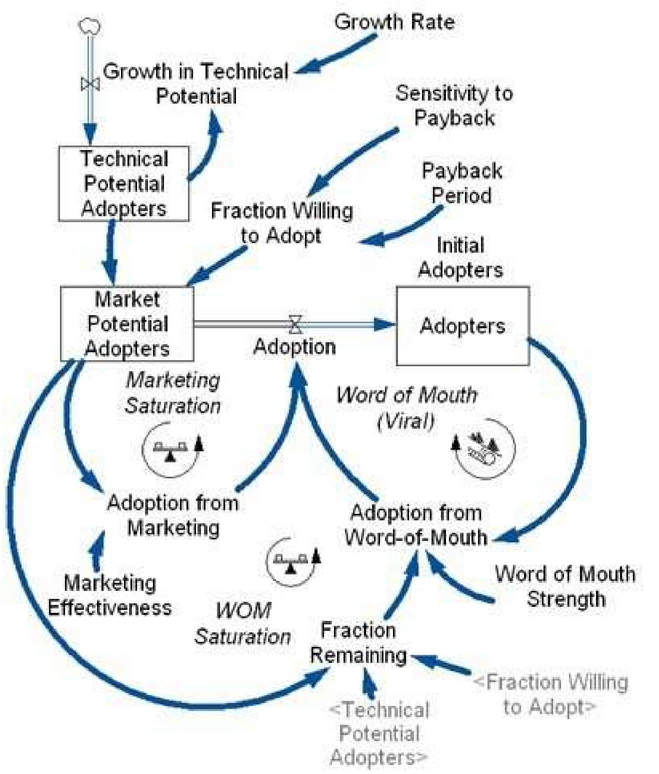

Figure 5. Stock/Flow Diagram of Diffusion Model for New Products and Retrofits

The dynamics of adoption for **ROB technologies adoption approach** is somewhat more complicated for new/retrofit technologies since it requires simulating the turnover of long-lived technology stocks. To account for this, the DSMSim™ model tracks the stock of all technologies and explicitly calculates technology retirements and additions consistent with the lifetime of the technologies. This approach considers the technology churn in the estimation of achievable potential, since only a fraction of the total stock of technologies are replaced each year, which affects how quickly technologies can be replaced. A model that endogenously generates growth in the familiarity of a technology, analogous to the Bass approach described above, is overlaid on the stock-tracking model to capture the dynamics associated with the diffusion of technology familiarity. A simplified version of the model employed in DSMSim™ is shown in Figure 6.

Model Calibration

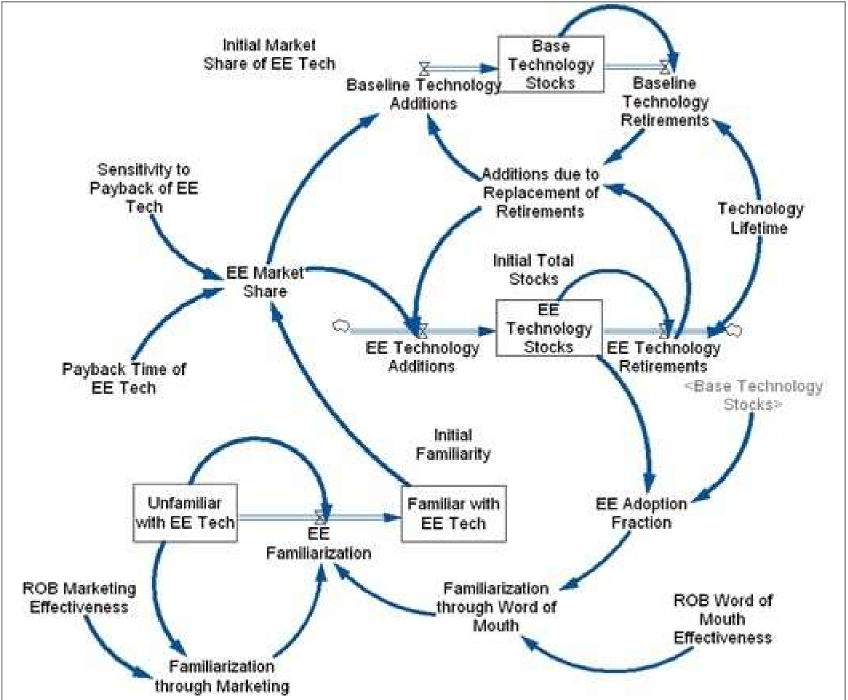

Figure 6. Stock/Flow Diagram of Diffusion Model for Replace-on-Burnout Measures

Another critical step in the process is the model calibration. We begin calibrating the model's marketing effectiveness and word-of-mouth parameters at the sector and end use level using National Grid historical program participation.

As noted, key inputs for the achievable potential assessment are payback acceptance curves that represent the percentage of customers from different sectors willing to purchase a technology based on the time it takes the technology to pay back the upfront cost through annual cost savings.

Calibration of a predictive model imposes unique challenges, as future data is not available to compare against model predictions. While engineering models, for example, can often be calibrated to a high degree of accuracy since simulated performance can be compared directly with performance of actual hardware, predictive models do not have this luxury. **Demand-side management models, therefore, must rely on other techniques to provide both the developer and the recipient of model results with a level of comfort that simulated results are reasonable.** We will take a number of steps to make sure that the initial, base year results used (2019) for the forecast model are reasonable and consider historic adoption, including:

- Comparing forecast values, by sector and end use, against historic achieved savings (e.g., from program savings for at least 2019). Although some studies indicate that demand-side management potential models are calibrated to check first-year simulated savings precisely equal to prior-year reported savings, we have found that forcing such precise agreement has the potential to introduce errors into the modeling process by effectively masking the explanation for differences—particularly when the measures included may vary significantly. Additionally, there may be sound reasons for first-year simulated savings to differ from prior-year reported savings (e.g., savings estimates have changed). Thus, while we will endeavor to achieve agreement to a degree that is reasonable between past results and forecast first-year results, our approach does not force the model to do so.
- Identifying and ensuring an explanation existed for significant discrepancies between forecast savings and prior-year savings, recognizing that some ramp-up is expected, especially for new measures or archetype programs.
- Calculating total program spending by sector and end use and comparing the resulting values to historical program spending.

The overall achievable potential modelling framework is shown in Figure 7. We will draw on the results of the economic potential analysis (and any sensitivity parameters identified) to develop the achievable potential outputs in the manner outlined on the right-hand bar of Figure 7.

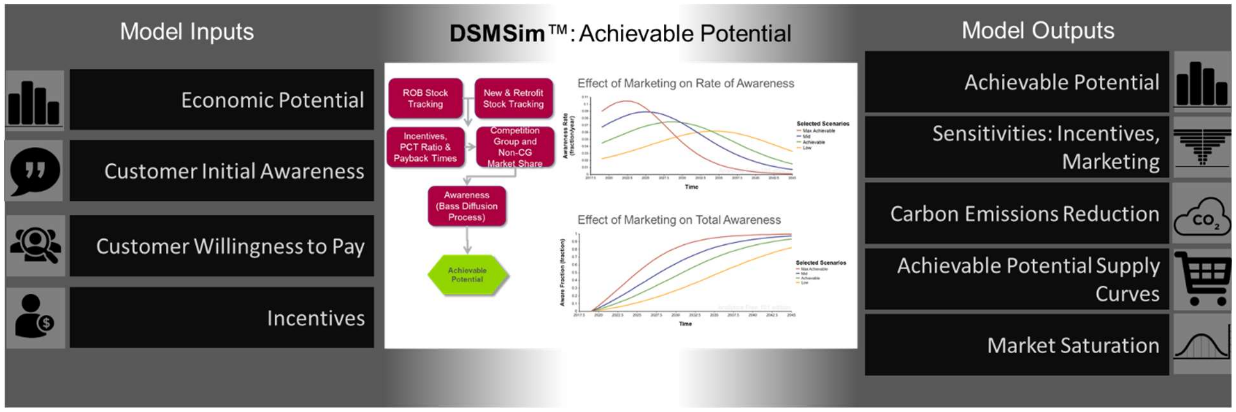

Figure 7. Guidehouse's Achievable Potential Model Data Flow

AEG
Applied Energy Group

cadeo

UNITIL MARKET POTENTIAL STUDY

April 2021

Report prepared for:
UNITIL SERVICE CORP.

Energy Solutions. Delivered.

This work was performed by:

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EXECUTIVE SUMMARY

In 2020, Berkshire Gas Company, Liberty Utilities, and Unitil (Fitchburg Gas and Electric, referred to in this report as Unitil) 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 Unitil's natural gas and electric territories, as well as potential for energy optimization (fuel switching) and demand response programs under Unitil's electric programs.

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 air conditioner maintenance in all existing buildings with central and room air conditioning. 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, capacity, and documented non-energy benefits to the incremental cost of the measure. 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 Unitil 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.

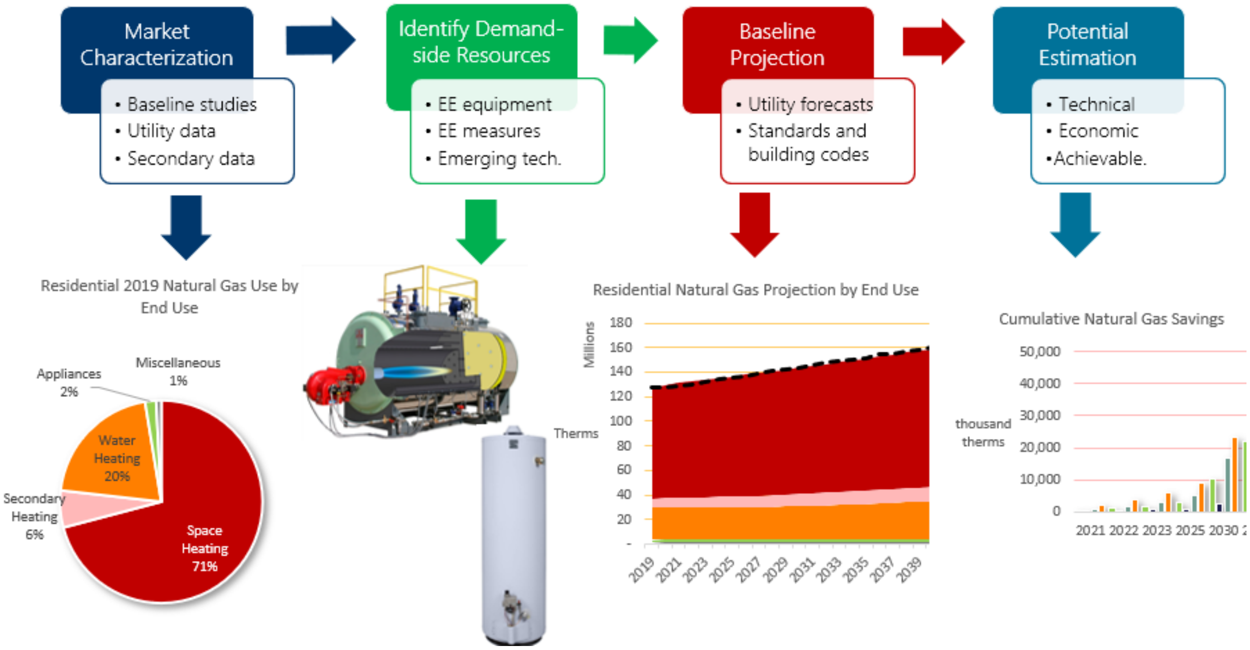
Study Approach

Energy Efficiency

To perform the energy efficiency potential analysis, AEG used a bottom-up approach following the major steps listed below and 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 Unitil 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 and electricity in absence of future energy efficiency programs. This counterfactual projection 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 potentials at the measure level for 2022 through 2024 to inform Unitil's program design.

Figure ES- 1 Analysis Approach



Energy Optimization

For Unitil's electric potential study, AEG also considered the opportunity for customers to convert non-electric end uses, such as fossil fuel fired water or space heating, to efficient electric equipment. As established at the study's beginning, this analysis is separated from the energy efficiency potential.

Similar to the energy efficiency analysis, the energy optimization analysis compares the high efficiency electric option with a base condition - in this case fossil fuel end use equipment – to determine how much fossil fuel savings (and what resulting electric load increase) is technically feasible, economically viable, and likely achievable under the Business-as-usual and other achievable scenarios described above.

Energy Optimization Measures

AEG estimated potential for energy optimization in both space heating and water heating for residential and commercial customers. The analysis considered switching from natural gas, fuel oil, or propane to electric heat pump technologies.

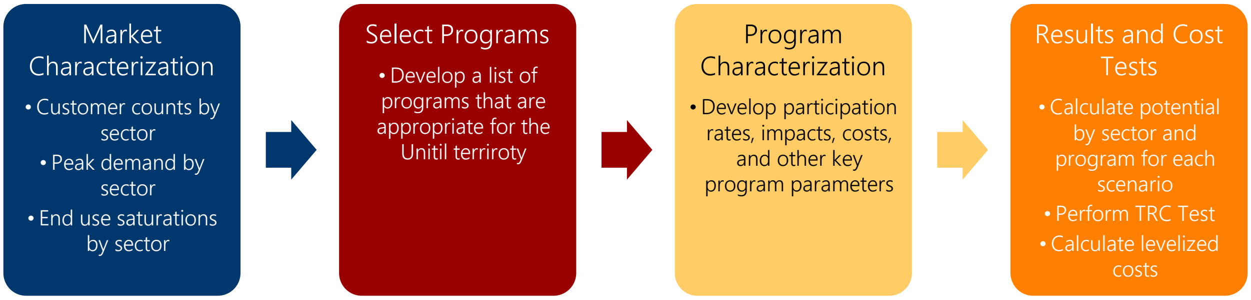
Demand Response

AEG was tasked with taking stock of the current demand response programs that Unitil offers, assessing the future potential of those programs, and providing an analysis of other program options that could be feasibly rolled out within the time frame analyzed. This section presents the methodology to determine the demand response potential for the years 2022 through 2024 across three different scenario options (BAU, BAU Plus, and Maximum Achievable). The analysis focuses on resources assumed achievable during the planning horizon, recognizing known market dynamics that may hinder resource acquisition.

This section describes our analysis approach and the data sources used to develop impact and cost estimates. The following three steps broadly outline our analysis approach:

1. Segment residential, commercial, and industrial customers for DR analysis and develop market characteristics (customer counts and coincident peak demand values) by segment for the base year and planning period.
2. Identify and select the relevant programs that are feasibly accessible within the analysis time frame.
3. Develop assumptions on key program parameters for potential and cost analysis.
4. Assess achievable potential by program for the 2022-2024 planning period across the different scenario options and estimate program cost effectiveness using the Total Resource Cost (TRC) test and levelized costs.

Figure ES- 2 Unitil Demand Response Methodology Process



Key Findings

Natural Gas Efficiency

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 146,082 therms to 148,006 therms per year, or 0.57% of the counterfactual no-DSM baseline projection. The commercial sector accounts for the largest share of savings, approximately 55% of achievable BAU potential savings in each year.

Table ES- 1 Unitil First-Year Natural Gas Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	25,540,741	25,729,457	25,843,377
Potential Savings			
Achievable BAU	146,555	148,006	146,082
Achievable BAU Plus	167,081	168,720	166,416
Achievable Max	210,116	212,163	208,658
Economic	410,847	415,615	406,669
Technical	529,876	533,780	526,053
Energy Savings as % of Baseline			
Achievable BAU	0.57%	0.58%	0.57%
Achievable BAU Plus	0.65%	0.66%	0.64%
Achievable Max	0.82%	0.82%	0.81%
Economic	1.61%	1.62%	1.57%
Technical	2.07%	2.07%	2.04%

Figure ES- 3 Unitil Natural Gas Achievable BAU Savings by Sector (Therms)

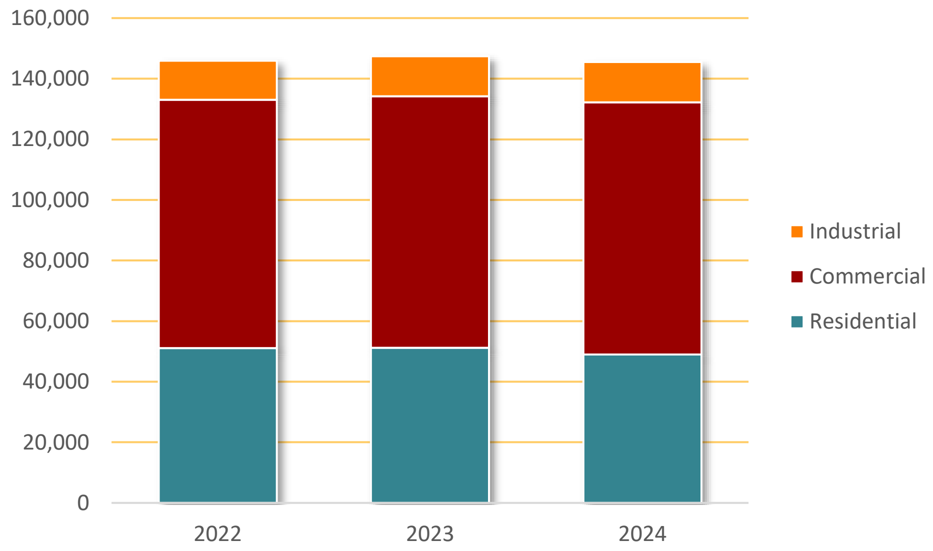


Table ES- 2 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Unitil's actual costs will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

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

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$ 1,867,701	$ 1,886,748	$ 1,843,943
BAU Plus	$ 2,434,862	$ 2,459,948	$ 2,402,612
Max	$ 3,762,384	$ 3,796,860	$ 3,694,872

Electric Efficiency

First-year potential savings for 2022 through 2024 and lifetime savings are presented in Table ES- 3. The achievable BAU potential is in the range of 3,595 MWh to 4,005 MWh per year, or approximately 1% of the counterfactual no-DSM baseline projection. As with natural gas, the commercial sector accounts for the larger share of savings, approximately 43% of achievable BAU potential savings in each year.

Table ES- 3 Unitil First-Year Electric Savings Potential for Planning Cycle (MWh)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**363,639**	**360,980**	**359,488**
Potential Savings			
Achievable BAU	4,005	3,728	3,595
Achievable BAU Plus	4,413	4,147	4,037
Achievable Max	5,037	4,719	4,574
Economic	9,093	8,532	8,307
Technical	10,241	9,658	9,407
Potential Savings as % of Baseline			
Achievable BAU	1.10%	1.03%	1.00%
Achievable BAU Plus	1.21%	1.15%	1.12%
Achievable Max	1.39%	1.31%	1.27%
Economic	2.50%	2.36%	2.31%
Technical	2.82%	2.68%	2.62%

Figure ES- 4 Unitil Electric Achievable BAU Savings by Sector

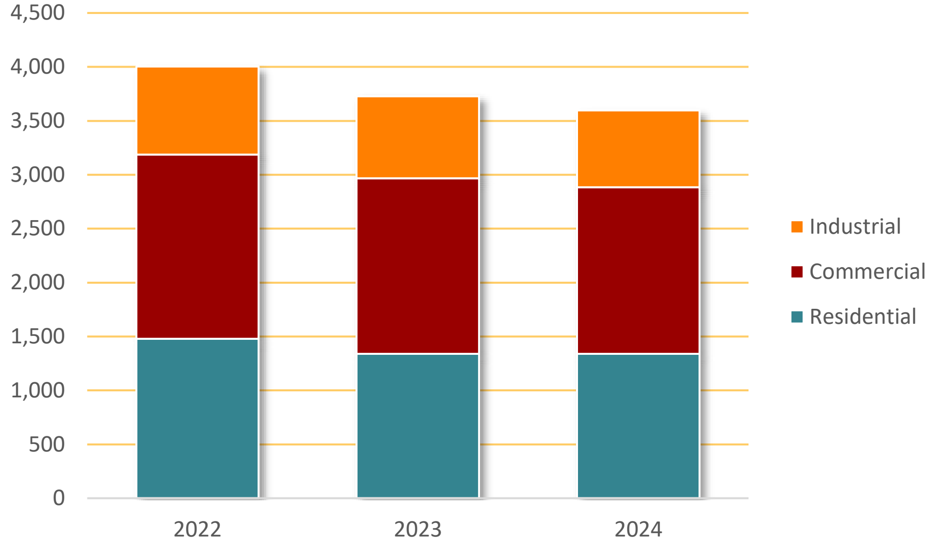


Table ES- 4 Unitil Electric Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$2,495,185	$2,521,216	$2,424,206
BAU Plus	$3,751,469	$3,799,617	$3,676,743
Maximum Potential	$5,240,192	$5,285,080	$5,091,788

Demand Response

Overall demand response summer potential savings for 2022 through 2024 are presented in Table ES- 5. Achievable BAU potential is made up solely of the current Unitil Residential WIFI and Industrial Curtailment programs held at their projected 2022 participation levels over the planning cycle. With 325 customers expected on the residential program in 2022 at an average impact of 0.5 kW, and three industrial customers with an average impact of 297 kW, the current programs are expected to reach 1.14 MW per year, or 1.2% of the baseline projection. The BAU Plus scenario expands the current programs to steady-state participation levels while Maximum Potential increases those by an additional 20%. The inclusion of all potential program options in the BAU Plus and Maximum Potential options represent a slight increase from BAU in 2022, but both grow to nearly double the MW of the BAU scenario by 2024.

Table ES- 5 Unitil Overall Demand Response Summer Potential for Planning Cycle

DSM Option	2022	2023	2024
Baseline Forecast (MW)	**94.3**	**94.5**	**94.6**
Annual Savings (MW)			
Achievable BAU Potential	1.14	1.14	1.14
Achievable BAU Plus Potential	1.29	1.56	2.01
Achievable Maximum Potential	1.32	1.66	2.47
Energy Savings (% of baseline)			
Achievable BAU Potential	1.2%	1.2%	1.2%
Achievable BAU Plus Potential	1.4%	1.7%	2.1%
Achievable Maximum Potential	1.4%	1.8%	2.6%

Demand Response overall winter potential savings for 2022 through 2024 are presented in Table ES- 6. The achievable BAU potential is 0.97 MW per year, or 1.2% of the baseline projection which represents the industrial curtailment program only as the current residential thermostat program drops off during the winter period. The BAU Plus and Maximum Achievable options represent a slight increase to the 2022 BAU savings and grow slowly through the planning period. Since the only difference between the summer and winter options is the inclusion or exclusion, respectively, of the Smart Thermostats - Cooling Program, the rest of the results reflect summer-only impacts to show all programs evaluated.

Table ES- 6 Unitil Overall Demand Response Winter Potential for Planning Cycle

DSM Option	2022	2023	2024
Baseline Forecast (MW)	**80.7**	**81.0**	**81.0**
Annual Savings (MW)			
Achievable BAU Potential	0.97	0.97	0.97
Achievable BAU Plus Potential	1.08	1.24	1.50
Achievable Maximum Potential	1.10	1.29	1.61
Energy Savings (% of baseline)			
Achievable BAU Potential	1.2%	1.2%	1.2%
Achievable BAU Plus Potential	1.3%	1.5%	1.9%
Achievable Maximum Potential	1.4%	1.6%	2.0%

Table ES- 7 shows the historical and projected potential for the two current Unitil DR programs under the BAU Plus scenario. The Residential WIFI program began in 2019 with 45 participants achieving 8kW of savings total. This program started ramping up further in 2020 growing to 151 participants with summer demand reductions of 110kW. Participants in this program are expected to increase to 325 (4.3% of eligible population) by 2022 which is reflected in the potential for that year. For the final two years of the planning cycle, participation grows steadily to 5.5% and 7% of the eligible population respectively.

Unitil's Industrial Curtailment program also began in 2019 with three large industrial customers participating. In 2019, the program reduced demand by 696kW on average and in 2020 this reduction grew to 890kW with the same participants. Program participants and demand reductions are expected to remain at 2020 levels for the remainder of the planning cycle.

Table ES- 7 Unitil Historical vs Projected DR savings- Summer BAU Plus Scenario

	2019	2020	2021	2022	2023	2024
Residential WIFI	0.008	0.110	N/A	0.177	0.234	0.304
Industrial Curtailment	0.696	0.890	N/A	0.890	0.890	0.890

Table ES- 4Table 5-3 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 Unitil's actual costs will naturally vary.

Energy Optimization

AEG considered opportunities to partially displace or fully convert fossil fuel space or water heating with electric heat pumps in both residential and commercial buildings. These opportunities were analyzed separately from energy efficiency to avoid overlap and confusion, and should not be confused with the ordinary lost opportunity heat pump upgrades or DMSHP displacing electric resistance heat which are part of the energy efficiency analysis. A summary of total potential is presented in Table ES- 8, and details are provided in Chapter 6.

Table ES- 8 Total Annual Energy Optimization Potential – All Fuels, 2022-2024 from Fuel Switching Only

Potential Case	Gas MMBTU	Oil MMBTU	Propane MMBTU	Electric MWh Impact[1]	Summer Peak	Winter Peak
BAU Potential	985	1,005	127	-891	-0.1	-0.1
BAU Plus Potential	6,490	1,126	141	-1,051	-0.1	-0.2
Max Achievable	17,737	1,573	192	-1,486	-0.2	-0.2
Economic Potential	156,716	7,846	1,898	-12,744	-1.9	-2.5
Technical Potential	292,247	8,248	2,070	-18,268	-5.9	-6.1

Conclusion

Energy Efficiency

The measure level savings potential estimated in this study support diverse future savings for electricity and natural gas in all three customer sectors. Existing offerings such as weatherization and smart thermostats continue to show strong potential over the planning period, however electric programs in particular may be challenged to find a replacement set of measure to compensate for the updated lighting baseline that removes lighting from future potential opportunities.

There is room for 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.

Demand Response

Unitil's current DR portfolio includes a residential Wi-Fi program as well as a C&I curtailment program. As the programs stand now, only the C&I program is cost-effective. However, if participation in the residential Wi-Fi program continues to grow as shown in the BAU Plus and Maximum Achievable scenarios, the impact from the additional participants outweighs the marketing and recruitment cost of getting them on the program. In addition, AEG found that DLC Smart Thermostats are cost-effective for small commercial

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[1] Negative electric impacts from fuel switching show the increased electric load due to the end use being added

customers so the program could be expanded beyond the residential sector as well. After extensive analysis, all other DR programs considered are not cost-effective in the Unitil territory.

Energy Optimization

There is still significant remaining potential to convert oil and propane heating systems to electric heat pumps, mainly on the residential side. However, uptake of these offerings has been limited, even in the face of large incentives, and most participation in this area remains in partial displacement, not complete elimination of fossil fuels on site. Full conversion is challenged by lower heat pump performance in very cold climates, which makes customers feel they still need the fossil fuel or gas-fired backup heat.

Natural gas, which has not historically been part of Unitil's fuel conversion portfolio, appears to have some limited cost-effective conversion potential for residential water heating and possibly some commercial segments, but none in residential space heating.

Use of this Potential Study

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, and Unitil Service Corp. (Unitil) 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 and electric service territories. The key objectives of the study were to:

- Estimate demand-side savings associated with traditional and emerging energy efficiency measures.
- For Unitil's electric territory, to estimate the potential for demand response and energy optimization (fuel switching) in addition to energy efficiency.
- 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 Unitil understand how their customers use natural gas and electricity 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.

Unitil will use the results of this study as guidance for their upcoming DSM planning process to optimally implement DSM 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 Unitil's key objectives:

- Characterize the market in the base year (2019) using Massachusetts statewide baseline study data, customer data from Unitil, 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 and electricity 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 Unitil'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 Unitil to understand the baseline characteristics of their service territory, including a detailed understanding of energy consumption, the assumptions and methodologies used in Unitil'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
DR	Demand Responses
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
EO	Energy Optimization
EUL	Effective Useful Life
EUI	Energy Utilization Index
GWh	Gigawatt-hours
HH	Households
HVAC	Heating Ventilation and Air Conditioning
kW	kilowatt
kWh	Kilowatt-hours
LoadMAP™	AEG's Load Management Analysis and Planning tool
mTherms	Thousand therms
MMtherms	Million therms
MW	Megawatt
MWh	Megawatt-hours
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 BY TOPIC

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

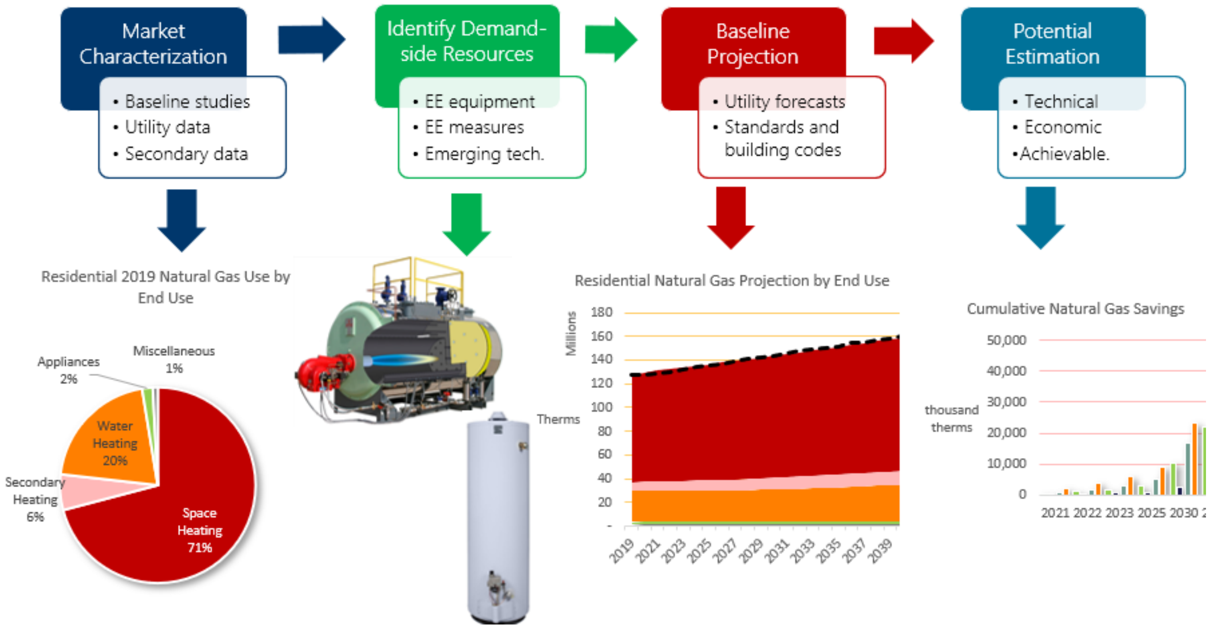
Energy Efficiency (Natural Gas and Electric) Analysis Approach

Analysis Approach

To perform the energy efficiency 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 and electric 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 Unitil'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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  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 air conditioner maintenance in all existing buildings with central and room air conditioning. 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 capacity benefits to the incremental cost of the measure. 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 Unitil 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.

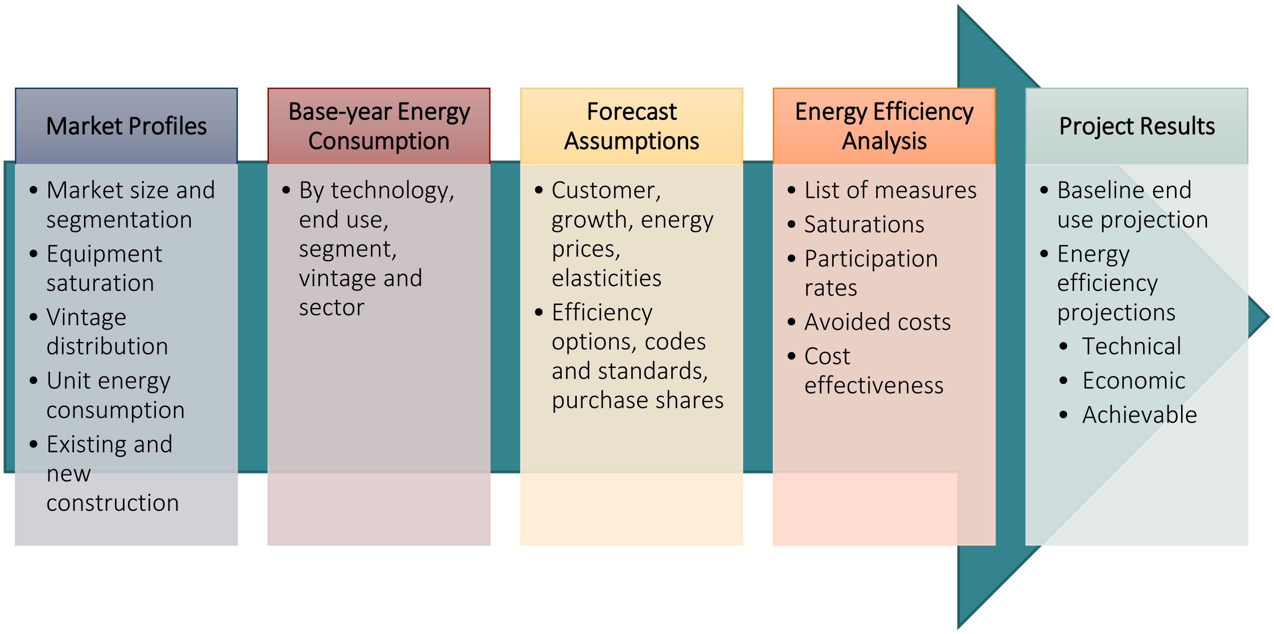
LoadMAP Model

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



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[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).

Energy Efficiency 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 Unitil'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 Unitil Analysis Segmentation Scheme

Dimension	Segmentation Variable	Description
1	Company	Unitil (Fitchburg Gas and Electric- gas and electric treated separately)
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	Cooling, space heating, water heating, lighting etc. (as appropriate by sector and fuel type)
6	Appliances/end uses and technologies	Technologies such as central or room air conditioners, furnaces, boilers, etc. for space heating, general service or linear lighting, 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 Unitil 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 mTherm.

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 Unitil
- 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 Unitil's program experience, measures identified in coordination with the other Massachusetts Potential Study teams, the

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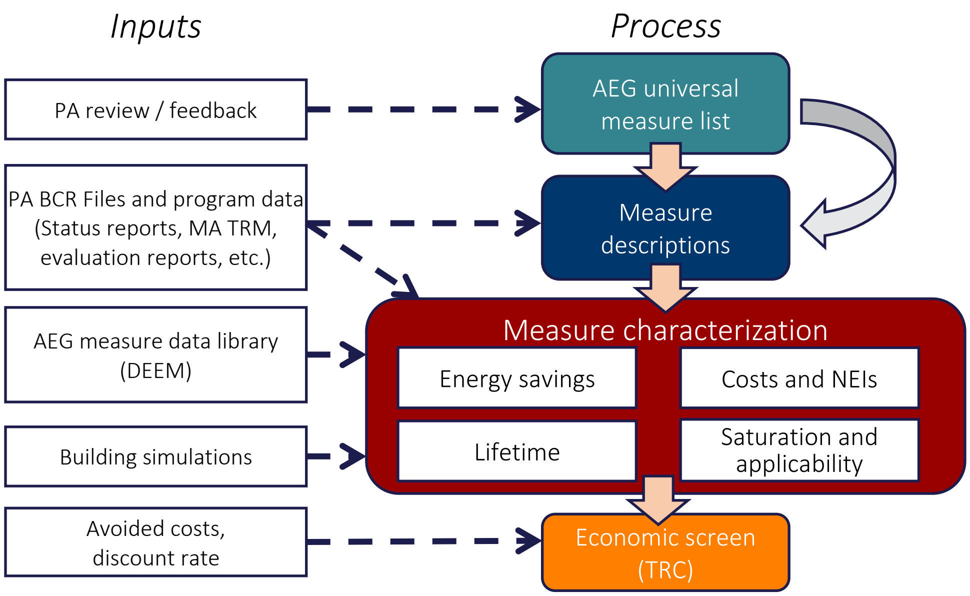
[3] The findings of the recently passed MA Clean Energy Climate Plan were not available in time to be incorporated into this analysis

[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 potential.

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

End Use	Measure	Base-Year Saturation[6][7]	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*.[8] This document represents credible and comprehensive industry best practices for specifying energy efficiency potential. Three types of potential developed 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 available as part of achievable potential. Like Technical Potential,

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[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 are 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] Measure where the base condition is nothing, as in insulation installation, have a base saturation of zero by default, while the applicability controls the portion of homes where the measure could apply

[8] 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.

this is a hypothetical that is generally equal to technical where measures are cost effective[9], 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 cost. 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[10]. 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, considering 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, 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.

- 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.

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[9] 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

[10] Discount rate and avoided costs taken from AESC 2021 final draft, as agreed in coordination with other MA potential studies

- 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.

Energy Optimization (Fuel Switching) Analysis Approach

For Unitil's electric potential study, but separate from the energy efficiency analysis, AEG also considered the opportunity for customers to convert non-electric end uses, such as fossil fuel fired water or space heating, to electric heat pumps. As established at the study's beginning, this analysis is separated from the energy efficiency potential to avoid overlap or double counting, as these conversions result in increased electric loads, which may appear to reduce or offset energy savings from efficiency.

The heat pumps assessed in the energy optimization analysis should also not be confused with the standard lost-opportunity heat pump upgrades (TRM measure 1.12) or DMSHP displacing or replacing electric resistance heat, both of which are covered under the standard energy efficiency analysis.

Energy Optimization Measures

AEG estimated potential for energy optimization in both space heating and water heating for residential and commercial customers. The analysis considered switching from natural gas, fuel oil, or propane to electric heat pump technologies.

Table 2-4 Dimensions of Energy Optimization Analysis

Dimension	Variations
Customer Sector & Segment	Residential: Single Family, Multifamily, Low-Income Single Family, Low-Income Multifamily Commercial: Office, Retail, Restaurant, Grocery, Education, Health, Lodging, Warehouse, Miscellaneous
End Use	Space Heating Water Heating
Existing Fuel in Use	Natural Gas Fuel Oil/Distillates Propane
Electric Technologies	Space Heating: Central Ducted Air-Source Heat Pump (SEER 21 / HSPF 9.1) or Ductless Mini-Split Heat Pump (SEER 19 / HSPF 9.0) Water Heating: Electric Heat Pump Water Heater (UEF 3.42)

Calculation of Energy Optimization Potential

Levels of potential for the energy optimization case are the same as those presented in the energy efficiency chapters above:

- Technical Potential considers the potential to switch every use of natural gas or fossil fuels for space heating or water heating to an electric heat pump, regardless of costs. This is a hypothetical upper limit to the potential for natural gas or fossil fuel displacement. Rather than model this hypothetical case as instantaneous, potential is phased in based on the equipment lifetimes, making it analogous to the technical potential schedule for the energy efficiency analysis.
- Economic Potential passes each measure through a cost effectiveness screen using the Total Resource Cost test (TRC), which compares the full lifecycle cost of the existing or replacement natural gas or fossil fuel unit with that of a high efficiency heat pump electric model. This analysis uses the same cost values for energy and peak impacts as the energy efficiency analysis, taken from the AESC 2021 final results.
- Achievable Potential is again presented in three levels:
    - Business as usual (BAU) potential assumes similar incentive levels to 2019-2020 program activity and does not bring on any programs that are not currently active (aside from allowing the current fossil fuel water heater replacement program to allow for natural gas water heater replacement if the economics make sense). Participation is expected to remain flat at current (2019-2020) levels. Participation in competing measures, such as full vs partial HVAC conversion and central vs ductless mini-split, is based on 2019-2020 program activity.
    - BAU Plus potential assumes incentives increase to 1.5x current levels and increases participation to reflect this, based on AEG's past research into the uplift possible from incentive increases. This level also brings commercial fuel switching measure participation more in line with its residential counterpart, thought it has not been a significant source of program activity for Unitil in the past.
    - Maximum Achievable potential increases incentives to 100% of incremental cost and increases participation in all measures by a proportion informed by AEG's past research into best-case program adoption with maximum incentives.

Potential estimates for the three achievable levels (BAU, BAU Plus, and Max Achievable) are presented in Chapter 7.

Demand Response Analysis Approach

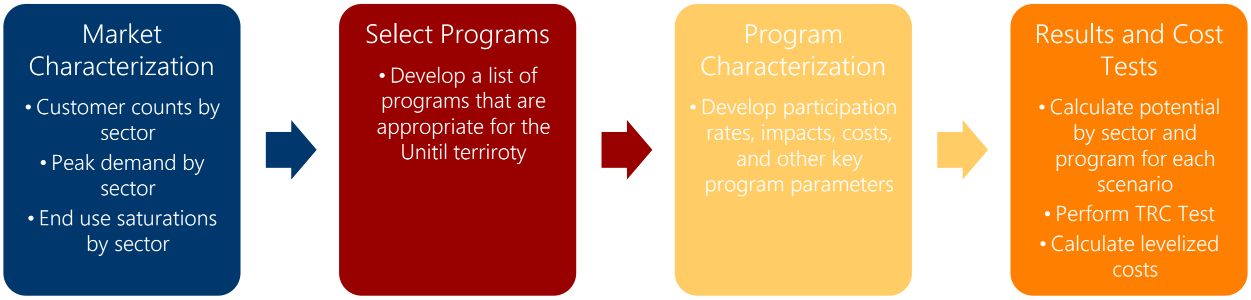
AEG was tasked with taking stock of the current demand response programs that Unitil offers, assessing the future potential of those programs, and providing an analysis of other program options that could be feasibly rolled out within the time frame analyzed. This section presents the demand response analysis approach for the planning period 2022 through 2024 across four different scenario options (BAU, BAU Plus, Maximum Potential, and Technical Potential). The analysis focuses on resources assumed achievable during the planning horizon, recognizing known market dynamics that may hinder resource acquisition.

This section describes our analysis approach and the data sources used to develop impact and cost estimates. The following three steps broadly outline our analysis approach:

- Segment residential, commercial, and industrial customers for DR analysis and develop market characteristics (customer counts and coincident peak demand values) by segment for the base year and planning period.

- Identify and select the relevant programs that are feasibly accessible within the analysis time frame.
- Develop assumptions on key program parameters for potential and cost analysis.
- Assess achievable potential by program for the 2022-2024 planning period across the different scenario options and estimate program cost effectiveness using the Total Resource Cost (TRC) test and levelized costs.

Figure 2-4 Unitil Demand Response Methodology Process



Demand Response Model

The demand response model calculates the potential results for each offering according to the following equation:

$$Offering\ Potential = Per\ Customer\ Impact * Customers * Saturation\ Rate * Participation\ Rate$$

To generate the final potential for each offering, the model determines an eligible population for each offering based on the end use saturations by sector of the enabling technology that would be necessary to participate in each offering. Each offering's eligible population is multiplied by the participation rate to arrive at the final number of offering participants. Once the number of participants is established by offering, they are multiplied by the per-customer impacts to generate the final potential results.

Scenario Options for Potential Results

AEG presents potential savings across four different scenario options: Business as usual (BAU), BAU Plus, Maximum Achievable, and Technical Potential. For demand response, Technical Potential is not shown due to the extreme nature of the scenario. The Technical Potential results can be found in a supplemental workbook provided to Unitil.

- Business as usual (BAU): Current programs remain constant at predicted 2022 participation levels. Expected that 2022-2024 DR participation will look like the past and does not introduce new measures.
- Business as Usual Enhanced (BAU Plus): In this scenario we also introduce adoption of all measures not currently part of existing Unitil programs and expand existing programs through increased marketing and recruitment.
- Maximum Achievable: Increases all program participation levels in the BAU Plus scenario by 20% over the planning period. Incentives are increased by 50% to achieve this increased participation.
- Technical Potential: 100% participation across all programs considered in the BAU Plus scenario over the planning period. All eligible customers with enabling DR technology to participate in this scenario.
- Economic Potential: Determined by the programs that pass the Total Resource Cost (TRC) test with a ratio greater than one for each of the above scenarios.

3

DATA DEVELOPMENT AND APPLICATION

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:

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

Unitil Data

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

- Unitil customer account database. The data request included billing data for 2019, the most recent year for which complete billing data was available. Unitil provided 2019 natural gas sales, electricity sales, and customers by sector.
- Load forecast data. Unitil provided the following forecast data: customer growth forecasts, and sales forecasts.
- Energy efficiency program data (BCR Files). Unitil 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 of energy and capacity, line losses, 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

- Conducted interviews with Unitil demand response program staff to improve understanding of market conditions and possible opportunities in new DR interventions and technologies

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 Northwest Power Conservation Council, Consortium for Energy Efficiency, the Environmental Protection Agency, and the American Council for an Energy-Efficient Economy.

Application of Data to the EE 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 Unitil-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 3-1. To develop the market profiles for each segment, we used the following approach:

1. Developed control totals for each segment. These include market size, segment-level annual natural gas and electricity use, and annual intensity. 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 Unitil staff to vet the data against their knowledge and experience.

Table 3-1 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	Unitil account database Unitil customer surveys Unitil Load Forecasts
Market size	Base-year residential dwellings, commercial floor space	Unitil customer forecasts Unitil account database Unitil customer surveys Previous Unitil MPS
Annual intensity	Residential: Annual use per household Commercial and Industrial: Annual use per square foot	Unitil 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 Unitil 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 Unitil AEG's DEEM Recent AEG studies
Appliance/equipment age distribution	Age distribution for each technology	Massachusetts Baseline Studies Previous Unitil MPS Recent AEG Studies

Unitil Electric Peak Totals

To allocate Unitil's provided system level peak loads to sectors, AEG used load research from other studies AEG has performed in the past. Using load factors – a relationship between annual energy and peak demand that varies by customer type – a preliminary distribution of peak values was calculated, then calibrated to Unitil's true peak hours. In this way, Unitil's electric energy savings and peak savings are both calibrated to their specific customers' energy use.

Both the Energy Efficiency and Demand analysis utilized these peak allocations.

Data Application for Baseline Projection

Table 3-2 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 3-2 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	Unitil 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[11] Appliance/efficiency standards analysis

In addition, assumptions were incorporated for known future equipment standards as of January 2021, as shown in Table 3-3 and Table 3-4. The assumptions tables here extend through 2025, after which all standards are assumed to hold steady.

Table 3-3 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					

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[11] 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 3-4 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 3-5 details the energy-efficiency data inputs to the LoadMAP model. It describes each input and identifies the key sources used in the Unitil analysis.

Table 3-5 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 2021 final draft including:

- Avoided costs of energy
- Avoided capacity costs (for Unitil's electric potential)
- DRIPE values and other benefits
- Discount rate (real)[12]

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.

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

- 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 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.

Application of Data to the Energy Optimization Analysis

The energy optimization analysis was anchored to Unitil's market characterization for their electric and natural gas territory and drew on additional data from:

- Massachusetts statewide surveys to estimate the presence of oil and propane using customers in Unitil's territory
- US Department of Energy's Commercial Building Energy Consumption Survey (CBECS) to supplement the Massachusetts statewide data
- Massachusetts Technical Reference Manual for oil and propane MMBTU savings per unit and non-energy impacts,
- Unitil BCR Model. for additional data on unit savings, costs, and current program activity to inform the BAU scenario
- AESC 2021 final avoided costs for oil and propane, including environmental compliance and other non-energy costs, in addition to the values for electricity, natural gas, and demand developed for the energy efficiency analysis
- AEG Research on program participation to inform the possible lift from BAU to the BAU Plus and Max Achievable scenarios based on the incentive adjustments described above.

Application of Data to the Demand Response Analysis

Demand Baseline

The peak demand for each year of the demand response potential baseline was taken from the Unitil-provided historic and forecast values using the same methodology as the energy efficiency analysis above.

DR Assumptions

The model for demand response uses several elements in conjunction to determine the final potential results for each program. Once the customer and demand forecasts are established, AEG identifies a list of program options that could provide feasible potential in the Unitil territory. Once the final program list is settled upon, each program is built up using typical per-customer impacts, participation rates, and costs found in similar programs using background research. These input assumptions are then fed into the DR model.

To generate the final potential for each program, the model determines an eligible population for each program based on the end use saturations by sector of the enabling technology that would be necessary to participate in each program. Each program's eligible population is multiplied by the participation rate to get the final number of participants. Once the number of assumed participants is established for each program, they are multiplied by the per-customer impacts to generate the final potential results.

Assumptions

As described above the demand response potential is based on the equipment saturation rate, the per customer impact and the expected participation rate. The values we assumed are shown for each sector in the tables below.

Table 3-6 below shows the equipment saturation rates used to determine the demand response potential. These values were adapted from the energy efficiency market characterization and were based on statewide MA assumptions from the residential and C&I studies of Central AC and WIFI thermostats.[13]

Table 3-6 Equipment Saturation Rates Used for DR Potential Estimates

	2022	2023	2024
Residential			
Water Heating	16.1%	16.1%	16.2%
Central Air Conditioning	26.2%	26.6%	27.1%
Electric Vehicles	0.3%	0.3%	0.3%
Solar PV Batteries	0.9%	0.9%	0.9%
Commercial			
Central Air Conditioning	21.4%	21.4%	21.4%
Water Heating	37.4%	37.4%	37.4%
Solar PV Batteries	0.2%	0.2%	0.2%
Industrial			
Solar PV Batteries	0.3%	0.4%	0.4%

Table 3-7 below shows the per customer impact assumption used to determine the demand response potential.

Table 3-7 Per Customer Impacts Used for DR Potential Estimates

Season		Program Option	Residential	Commercial	Industrial
DLC	Summer Only	Smart Thermostats – Cooling	0.5 kW	1.25 kW	NA
	Annual	Water Heating	0.5 kW	0.5 kW	NA
	Annual	Electric Vehicle Charging	0.5 kW	NA	NA
	Annual	Smart Appliances	0.5 kW	NA	NA
Other	Annual	Battery Energy Storage	1.3 kW	2.0 kW	15.0 kW
	Annual	Third Party Contracts	NA	10%	333 kW

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[13] Since this is based on statewide data, the saturations presented in Table 3-6 may overestimate the saturation of equipment in the Unitil territory which has a disproportionate number of multi-family housing units and an older housing stock.

4

NATURAL GAS ENERGY EFFICIENCY ANALYSIS AND RESULTS

This section details the study results and energy efficiency potential estimates for Unitil's natural gas territory as a whole and by sector.

Natural Gas 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 and lifetime savings are presented in Table 4-1. The achievable BAU potential is in the range of 146,082 therms to 148,006 therms per year, or 0.57% 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 14% higher with a range of 166,416 therms to 168,720 therms per year, or 0.65% of the baseline. Maximum achievable potential is approximately 43% higher than BAU, with a range of 208,658 therms to 212,163 therms per year, or 0.82% of the baseline.

Notably, the majority of technical potential is passing cost-effectiveness, 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 4-1 Unitil First-Year Natural Gas Savings Potential for Planning Cycle (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	25,540,741	25,729,457	25,843,377
Potential Savings			
Achievable BAU	146,555	148,006	146,082
Achievable BAU Plus	167,081	168,720	166,416
Achievable Max	210,116	212,163	208,658
Economic	410,847	415,615	406,669
Technical	529,876	533,780	526,053
Energy Savings as % of Baseline			
Achievable BAU	0.57%	0.57%	0.56%
Achievable BAU Plus	0.65%	0.66%	0.64%
Achievable Max	0.82%	0.82%	0.80%
Economic	1.60%	1.61%	1.57%
Technical	2.07%	2.07%	2.03%

Table 4-2 presents the breakout of each level of potential by sector. The commercial sector accounts for the largest share of achievable BAU potential, approximately 55% of achievable BAU potential savings in each year as illustrated in

Figure 4-1.

Table 4-2 Unitil First-Year Achievable Natural Gas Savings Potential by Sector (Therms)

Achievable Potential by Sector	2022	2023	2024
Achievable BAU Potential			
Residential	51,120	51,217	48,971
Commercial	81,964	82,962	83,240
Industrial	13,471	13,827	13,871
Achievable BAU Plus Potential			
Residential	58,692	58,909	56,328
Commercial	92,907	93,936	94,175
Industrial	15,483	15,875	15,913
Achievable Max Potential			
Residential	74,723	74,963	71,146
Commercial	116,025	117,341	117,612
Industrial	19,367	19,859	19,900
Economic Potential			
Residential	151,373	151,794	142,273
Commercial	232,503	236,845	237,576
Industrial	26,971	26,976	26,819
Technical Potential			
Residential	177,473	177,585	167,648
Commercial	325,400	329,186	331,553
Industrial	27,003	27,008	26,852

Figure 4-1 Unitil Natural Gas Achievable BAU Savings by Sector (Therms)

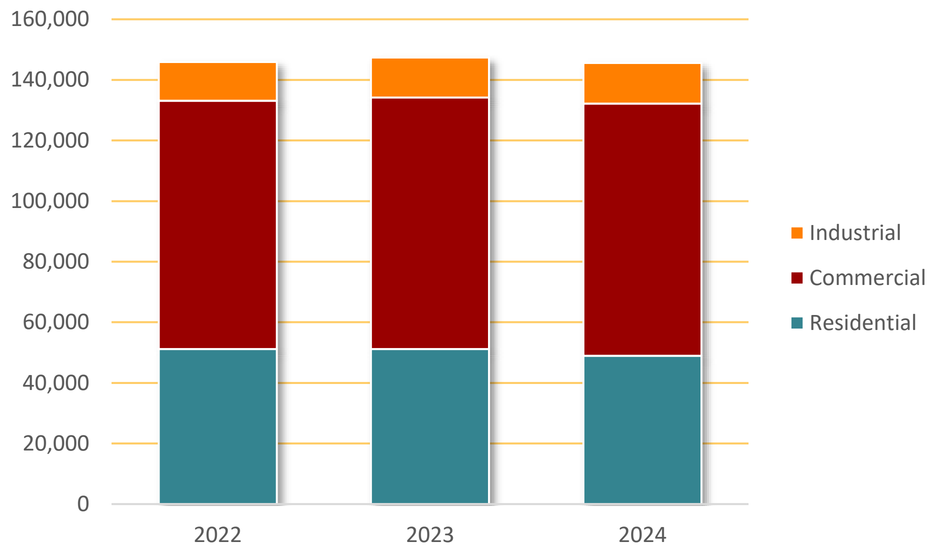

Table 4-3 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Unitil's actual costs will naturally vary.

Table 4-3 Unitil Natural Gas Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$1,867,701	$1,886,748	$1,843,943
BAU Plus	$2,434,862	$2,459,948	$2,402,612
Max	$3,762,384	$3,796,860	$3,694,872

Residential Sector

In 2019, there were approximately 18,223 households in Unitil's residential sector that used a total of 1,245,785 Dth. These numbers are inclusive of estimated multifamily apartment dwellings billed on commercial rate classes[14] .

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[15] average consumption per home and the total consumption of the building.

As shown in Table 4-4, average use per household was 594 therms across all homes, but there is a large difference between single family homes, which range from 702-752 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. Single family customers account for 67% of total usage, and low-income single family customers account for 14% (Figure 4-2). Multi-family and low-income multifamily customers account for the remainder of usage.

Figure 4-2 Unitil Gas Residential Use by Segment, 2019

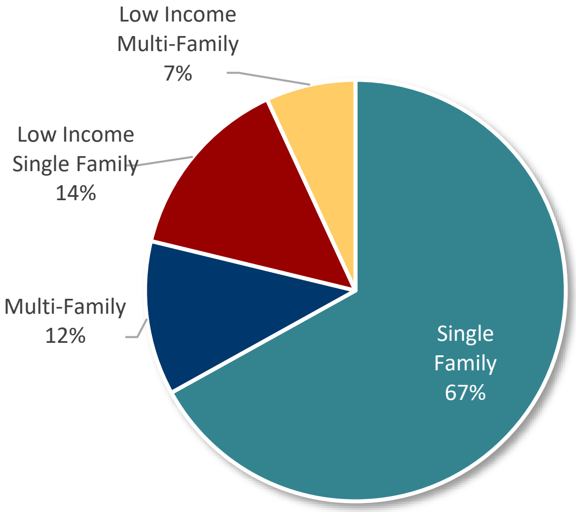

Table 4-4 Unitil Gas Residential Control Totals, 2019

Unitil Residential	Households	Annual Use (Dth)	Intensity (therms / HH)
Single Family	11,882	834,044	702
Multi-Family	2,595	147,369	339
Low-Income Single Family	2,371	178,385	752
Low-Income Multi-Family	1,385	85,986	363
Total	**18,233**	**1,245,785**	**594**

Figure 4-3 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.

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[14] 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 ~56% of multifamily consumption, or ~10% of the overall residential consumption shown here.

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

Figure 4-4 presents the energy intensity by end use and housing type. Low-income single family has the highest intensity at more than 700 therms per household.

Figure 4-3 Unitil Residential Gas Consumption by End Use, 2019

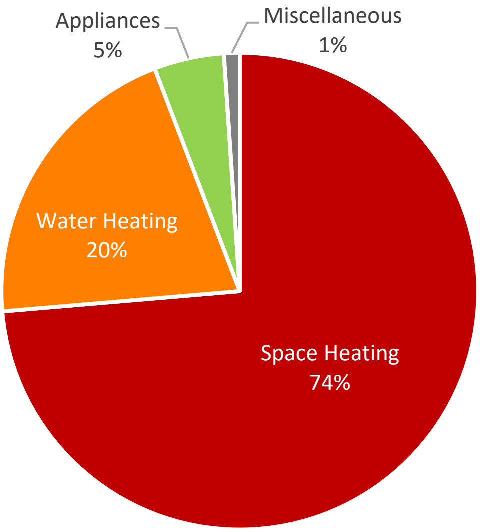


Figure 4-4 Unitil Residential Natural Gas Intensity by End Use and Segment, 2019

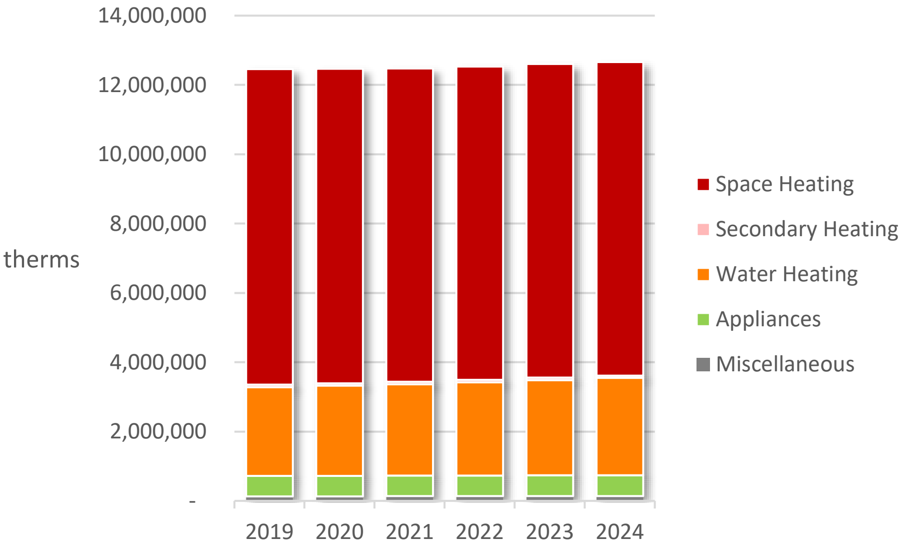
Residential Baseline Projection

Table 4-5 and Figure 4-5 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 4-5 Unitil Gas Residential Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	9,106,883	9,071,216	9,039,411	9,034,962	9,047,934	9,047,822
Secondary Heating	67,828	67,968	68,117	68,494	69,008	69,393
Water Heating	2,558,918	2,599,727	2,641,248	2,693,583	2,752,560	2,805,867
Appliances	590,785	591,339	592,009	594,811	598,869	601,800
Miscellaneous	133,432	133,927	134,416	135,294	136,384	137,205
Total	**12,457,847**	**12,464,177**	**12,475,201**	**12,527,144**	**12,604,755**	**12,662,087**

Figure 4-5 Unitil Gas Residential Baseline Projection by End Use



Residential Potential

Table 4-6 presents the residential sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 51,120 therms, or 0.41% of the counterfactual baseline projection.

Table 4-6 Unitil Summary of Residential Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Forecast	**12,527,144**	**12,604,755**	**12,662,087**
Potential Savings			
Achievable BAU	51,120	51,217	48,971
Achievable BAU Plus	58,692	58,909	56,328
Achievable Max	74,723	74,963	71,146
Economic	151,373	151,794	142,273

Technical	177,473	177,585	167,648
Potential Savings as % of Baseline			
Achievable BAU	0.41%	0.41%	0.39%
Achievable BAU Plus	0.47%	0.47%	0.44%
Achievable Max	0.60%	0.59%	0.56%
Economic	1.21%	1.20%	1.12%
Technical	1.42%	1.41%	1.32%

The market rate single family segment accounts for almost two-thirds of the residential savings (63%). The low-income single family segment represents 21% of the savings with the multi-family segments representing 16% of the savings combined. Single family dwellings include buildings with 2-4 units (Figure 4-6).

Figure 4-6 Unitil Residential Natural Gas Potential by Segment

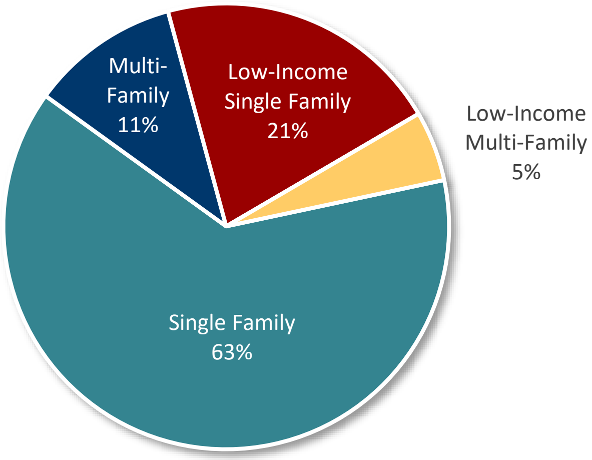


Table 4-7 shows residential potential by segment for all cases and for each year of the planning cycle.

Table 4-7 Residential Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Single Family	32,252	32,339	30,965
	Multi-Family	5,686	5,634	5,322
	Low-Income Single Family	10,392	10,451	10,100
	Low-Income Multi-Family	2,790	2,793	2,584
BAU Plus	Single Family	36,984	37,151	35,567
	Multi-Family	6,855	6,816	6,461
	Low-Income Single Family	11,613	11,693	11,289
	Low-Income Multi-Family	3,240	3,248	3,011
BAU Max	Single Family	47,038	47,228	44,869
	Multi-Family	9,257	9,200	8,690
	Low-Income Single Family	13,976	14,074	13,471
	Low-Income Multi-Family	4,453	4,462	4,116
Economic	Single Family	99,260	99,618	93,540
	Multi-Family	17,371	17,275	16,172
	Low-Income Single Family	24,173	24,343	22,850
	Low-Income Multi-Family	10,569	10,557	9,711
Technical	Single Family	117,181	117,360	111,026
	Multi-Family	20,795	20,620	19,421
	Low-Income Single Family	27,756	27,896	26,363
	Low-Income Multi-Family	11,740	11,708	10,839

Figure 4-7 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. Note that these latter categories do not include replacing natural gas equipment with electric heat pumps – that analysis was conducted separately and is presented in Chapter 7.

Figure 4-7 Unitil Residential Natural Gas Achievable BAU Potential by End Use

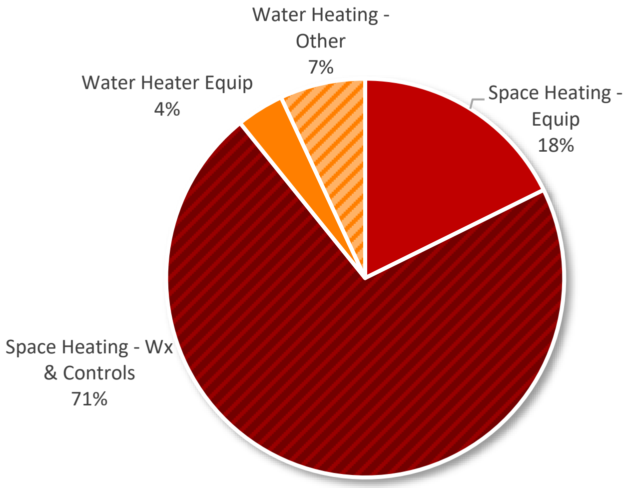


Table 4-8 shows potential broken out by vintage – new construction vs existing buildings.

Table 4-8 Residential Natural Gas Potential by Vintage and Case

Case	Vintage	2022	2023	2024
BAU	Existing	47,893	47,303	46,360
	New	3,226	3,914	2,611
BAU Plus	Existing	54,640	54,013	52,990
	New	4,052	4,895	3,338
BAU Max	Existing	68,884	67,932	66,413
	New	5,839	7,031	4,733
Economic	Existing	135,849	133,191	129,385
	New	15,524	18,603	12,888
Technical	Existing	161,574	158,521	154,352
	New	15,899	19,064	13,296

Finally, Figure 4-8 below 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 Unitil'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[16].

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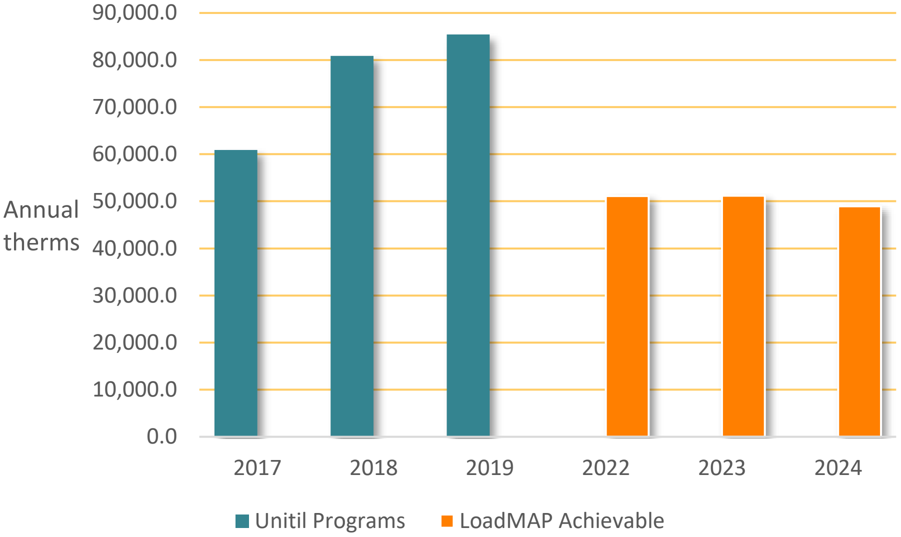
[16] See chapter 2 for a description of the counterfactual baseline and how AEO data informs the reference baseline

Figure 4-8 Unitil Natural Gas Residential Savings Historical Comparison – BAU vs Historic



Commercial Sector

In 2019, Unitil commercial customers used a total of 1,008,935 Dth. We allocated this usage to nine commercial segments, shown in Table 4-9 using identifiers provided in Unitil's 2019 customer data, which was enhanced with tax assessor data and industry codes provided by DNV. As shown in Figure 4-9, the lodging and miscellaneous segments each accounted for approximately 21% of the total commercial natural gas consumed in 2019, followed by retail (15%), education (12%), office (10%), healthcare (9%), restaurant (5%), warehouse (4%), and grocery (3%). Please note that industrial customers are segmented separately later in this section.

Table 4-9 Unitil Gas Commercial Control Totals, 2019

Segment	Annual Use (Dth)	Intensity (therm/sqft)	Floor Space (Million Sq. Ft.)
Office	90,879	0.42	2.16
Retail	150,852	0.32	4.76
Restaurant	45,881	1.37	0.33
Grocery	22,418	0.71	0.32
Education	257,455	0.45	5.75
Healthcare	80,529	0.91	0.89
Lodging	177,611	0.55	3.24
Warehouse	35,593	0.43	0.84
Misc.	147,718	0.66	2.25
Total	**1,008,935**	**0.49**	**20.54**

Figure 4-9 Unitil Gas Commercial Use by Segment, 2019

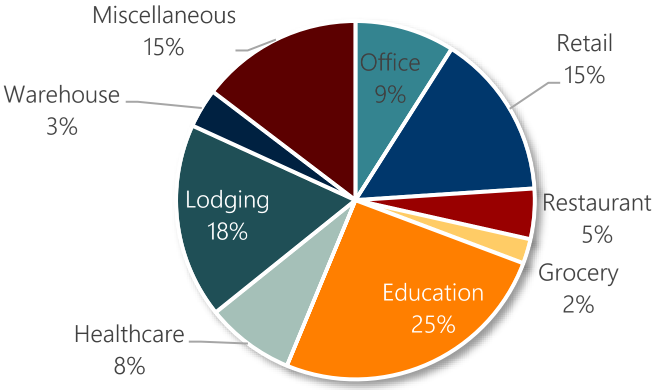
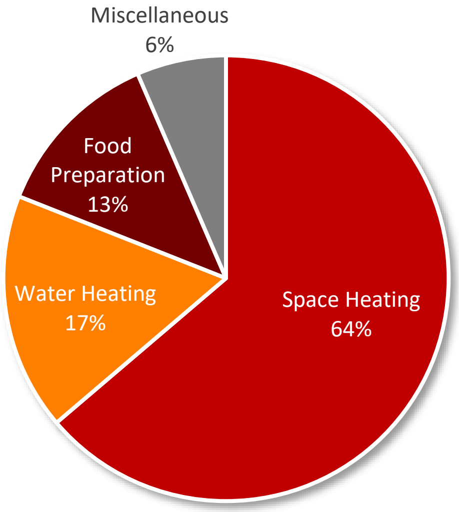


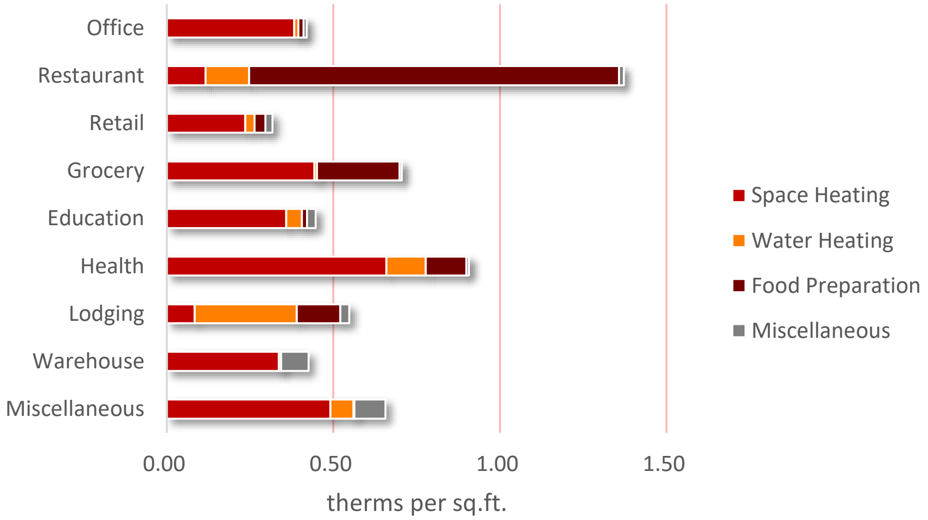
Figure 4-10 shows the distribution of annual natural gas consumption by end use across all commercial buildings. Space heating accounts for roughly two-thirds of commercial natural gas consumption.

Figure 4-10 Unitil Natural Gas Commercial Consumption by End Use, 2019



As shown in Figure 4-11, 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 4-11 Unitil Commercial Natural Gas Intensity by End Use and Segment, 2019



Commercial Baseline Projection

Table 4-10 and Figure 4-12 present AEG's independent natural gas baseline projection[17] 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.

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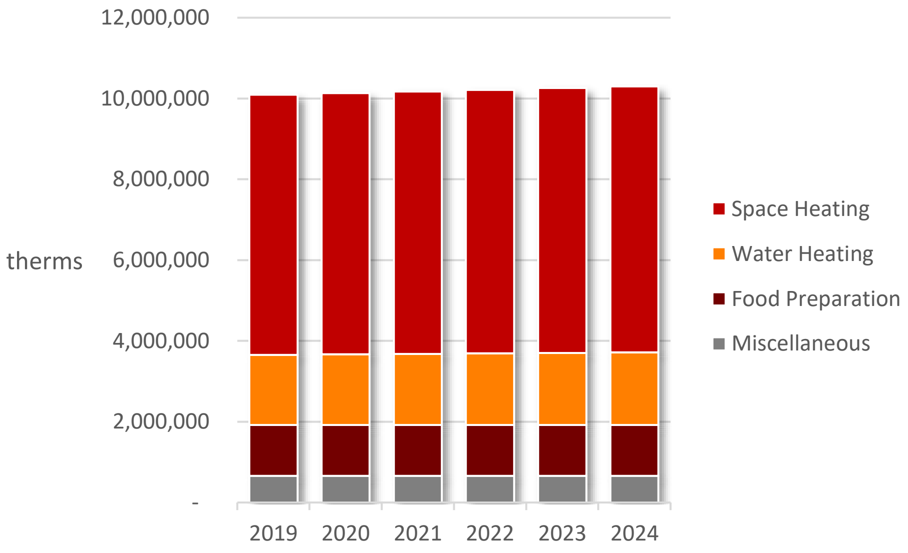
[17] As noted elsewhere above, this is the counterfactual, no-DSM projection based on market growth assumptions provided by Unitil

Table 4-10 Unitil Commercial Natural Gas Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	6,434,243	6,434,243	6,463,611	6,493,738	6,524,194	6,554,604
Water Heating	1,737,064	1,737,064	1,748,911	1,761,013	1,773,091	1,784,911
Food Preparation	1,262,181	1,262,181	1,262,181	1,262,181	1,262,181	1,262,181
Miscellaneous	655,866	655,866	655,866	655,866	655,866	655,866
Total	**10,089,354**	**10,130,569**	**10,172,798**	**10,215,333**	**10,257,563**	**10,298,968**

Figure 4-12 Unitil Gas Commercial Baseline Projection by End Use



Commercial Potential

Table 4-11 presents the commercial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 81,964 therms, or 0.8% of the baseline projection.

Table 4-11 Unitil Summary of Commercial Natural Gas Potential (Therms)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**10,215,333**	**10,257,563**	**10,298,968**
Potential Savings			
Achievable BAU	81,964	82,962	83,240
Achievable BAU Plus	92,907	93,936	94,175
Achievable Max	116,025	117,341	117,612
Economic	232,503	236,845	237,576
Technical	325,400	329,186	331,553
Potential Savings as % of Baseline			
Achievable BAU	0.80%	0.81%	0.81%
Achievable BAU Plus	0.91%	0.92%	0.91%
Achievable Max	1.14%	1.14%	1.14%
Economic	2.28%	2.31%	2.31%
Technical	3.19%	3.21%	3.22%

The education segment accounts for 21% of the commercial savings in 2022 through 2024 followed by lodging (19%), retail (18%), and miscellaneous (17%) (Figure 4-13).

Figure 4-13 Unitil Commercial Natural Gas Achievable BAU Potential by Segment

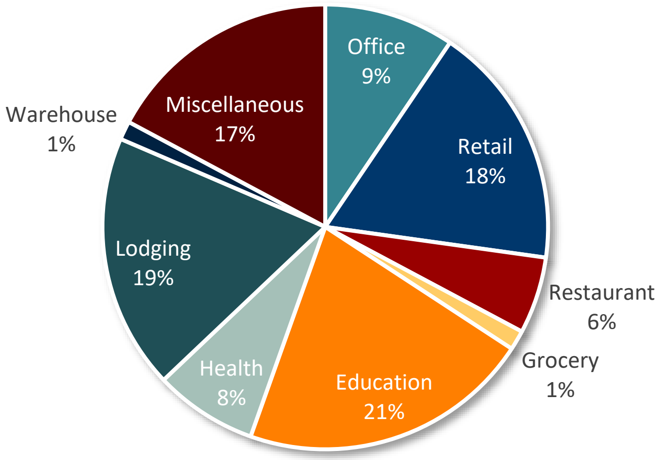


Table 4-12 shows commercial potential by segment for each potential case and for each year of the planning cycle.

Table 4-12 Commercial Natural Gas Potential by Segment and Case

Case	Segment	2022	2023	2024
BAU	Office	7,892	7,876	7,876
	Retail	14,727	14,740	14,773
	Restaurant	4,319	4,501	4,654
	Grocery	1,097	1,144	1,187
	Education	18,140	18,228	17,656
	Health	6,050	6,141	6,227
	Lodging	14,438	14,979	15,444
	Warehouse	1,100	1,111	1,122
	Miscellaneous	14,199	14,241	14,302
BAU Plus	Office	9,073	9,045	9,035
	Retail	16,430	16,428	16,450
	Restaurant	4,796	4,995	5,163
	Grocery	1,269	1,320	1,365
	Education	21,095	21,168	20,515
	Health	6,908	7,001	7,090
	Lodging	16,195	16,788	17,295
	Warehouse	1,234	1,245	1,257
	Miscellaneous	15,908	15,946	16,004
BAU Max	Office	11,092	11,054	11,036
	Retail	19,746	19,735	19,751
	Restaurant	6,274	6,534	6,753
	Grocery	1,586	1,654	1,714
	Education	27,015	27,096	26,228
	Health	8,776	8,895	9,005
	Lodging	20,934	21,706	22,366
	Warehouse	1,547	1,562	1,577
	Miscellaneous	19,055	19,107	19,181
Economic	Office	22,285	22,301	22,296
	Retail	37,515	37,842	38,092
	Restaurant	15,085	15,811	16,394
	Grocery	4,531	4,754	4,940
	Education	54,234	54,692	52,268
	Health	16,708	17,059	17,344
	Lodging	47,996	49,959	51,571
	Warehouse	4,185	4,232	4,270

	Miscellaneous	29,964	30,196	30,401
Technical	Office	32,224	32,064	31,883
	Retail	44,490	45,043	45,511
	Restaurant	15,085	15,811	16,394
	Grocery	5,289	5,507	5,687
	Education	107,848	107,411	106,307
	Health	30,082	30,346	30,541
	Lodging	48,660	50,702	52,391
	Warehouse	6,416	6,538	6,648
	Miscellaneous	35,305	35,765	36,191

Table 4-13 shows potential by case and vintage – new construction or existing buildings.

Table 4-13 Commercial Natural Gas Potential by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	72,016	72,695	72,632
	New	9,948	10,267	10,608
BAU Plus	Existing	81,990	82,687	82,569
	New	10,917	11,249	11,606
BAU Max	Existing	102,012	102,980	102,869
	New	14,013	14,361	14,743
Economic	Existing	197,104	201,202	201,693
	New	35,399	35,643	35,884
Technical	Existing	283,570	285,168	285,397
	New	41,830	44,018	46,156

Industrial Sector

In 2019, Unitil industrial customers used a total of 299,333 Dth (Table 4-14). 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[18] averages. As shown in Figure 4-14, the chemicals segment accounts for approximately 28% of the total natural gas consumed in 2019, followed by paper and printing (18%), petroleum and coal products (13%), other industrial (10%), primary metals (8%), food manufacturing (7%), plastic and rubber products (5%), wood products (6%) and machinery (6%). Textile manufacturers make up less than 1% of natural gas consumed.

Although some of these customer segments are not significant consumers of energy in Unitil'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.

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[18] DOE Manufacturing Energy Consumption Survey

Table 4-14 Unitil Gas Industrial Control Totals, 2019

Segment	Annual Use (Dth)	Annual Use (% of therms)
Chemicals	84,611	28.6%
Food	19,818	6.7%
Paper & Printing	52,850	17.8%
Petroleum & Coal Products	37,239	12.6%
Primary Metals	22,358	7.5%
Textiles	1,824	0.6%
Plastics & Rubber Products	14,045	4.7%
Machinery	16,546	5.6%
Wood Products	18,035	6.1%
Other Industrial	29,012	9.8%
Total	**296,339**	**100.0%**

Figure 4-14 Industrial Use by Segment, 2019

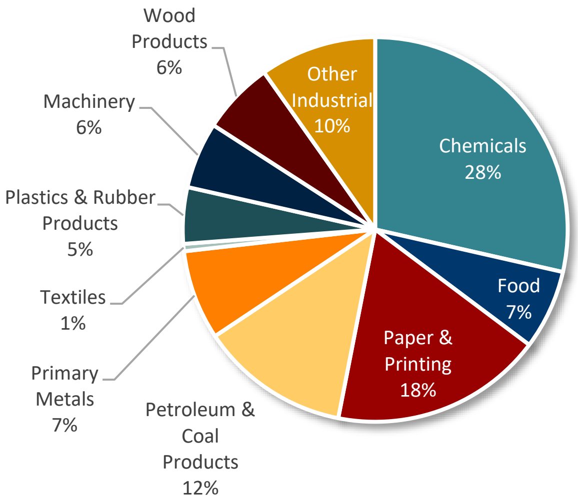
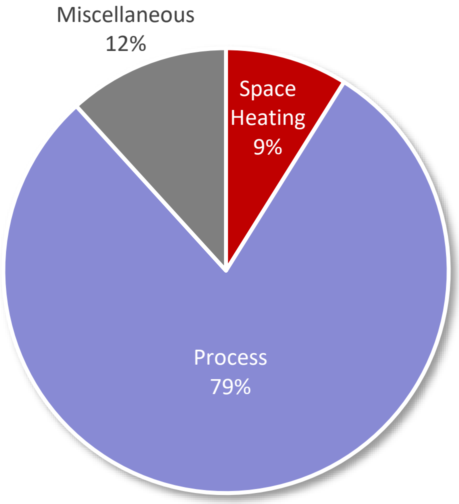


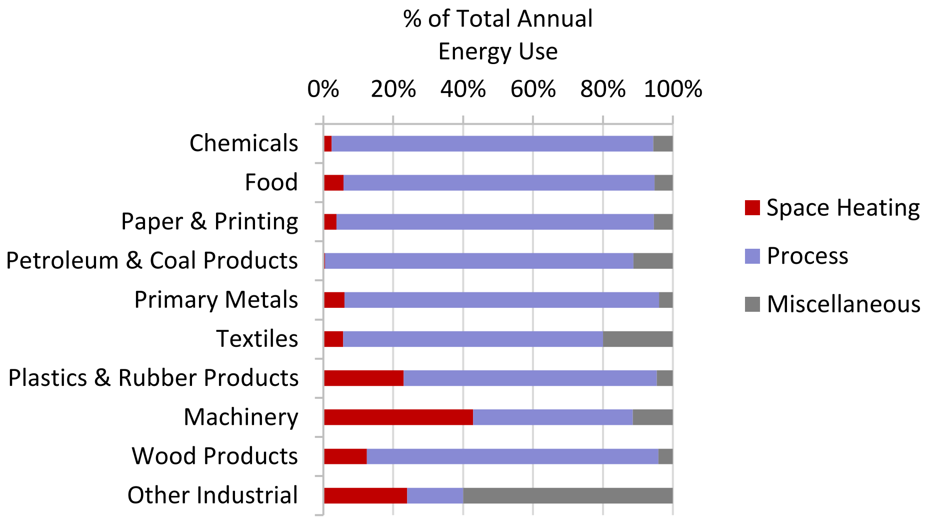
Figure 4-15 shows the distribution of annual natural gas consumption by end use across all industrial facilities. Industrial processes account for the majority of natural gas consumption in this sector.

Figure 4-15 Unitil Industrial Natural Gas Consumption by End Use, 2019



Natural gas intensity is driven largely by process for almost all segments other than Machinery and Other Industrial. Figure 4-16 below shows how natural gas is apportioned across industrial end uses, taken from EIA's Manufacturing Energy Consumption Survey (MECS).

Figure 4-16 Unitil Industrial Natural Gas Intensity by End Use and Segment, 2019



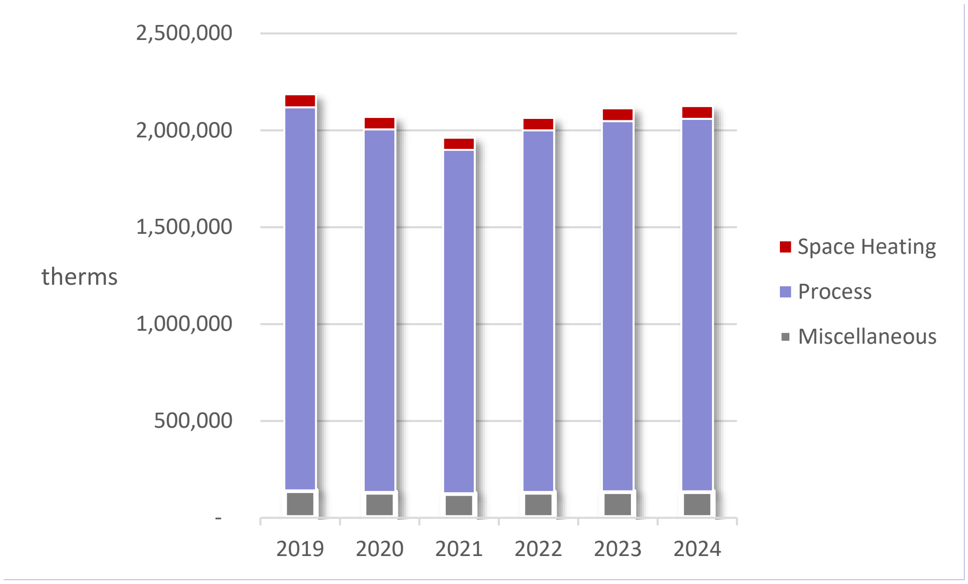
Industrial Baseline Projection

Table 4-15 presents AEG's independent natural gas baseline projection 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 4-15 Unitil Industrial Natural Gas Baseline Projection by End Use (Therms)

Natural Gas Use	2019	2020	2021	2022	2023	2024
Space Heating	68,251	64,584	61,199	64,478	66,066	68,251
Processing	1,977,877	1,871,540	1,773,614	1,866,591	1,912,228	1,977,877
Miscellaneous	140,881	133,261	126,242	132,823	136,030	140,881
Total	**2,187,009**	**2,069,385**	**1,961,055**	**2,063,892**	**2,114,324**	**2,187,009**

Figure 4-17 Unitil Industrial Natural Gas Baseline Projection by End Use



Industrial Potential

Table 4-16 presents the industrial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 13,471 therms, or 0.48% of the baseline projection.

Table 4-16 Unitil Summary of Industrial Natural Gas Potential

First-year Savings Potential	2022	2023	2024
Baseline Projection	**2,798,264**	**2,867,139**	**2,882,321**
Potential Savings			
Achievable BAU	13,471	13,827	13,871
Achievable BAU Plus	15,483	15,875	15,913
Achievable Max	19,367	19,859	19,900
Economic	26,971	26,976	26,819
Technical	27,003	27,008	26,852
Potential Savings as % of Baseline			
Achievable BAU	0.48%	0.48%	0.48%
Achievable BAU Plus	0.55%	0.55%	0.55%
Achievable Max	0.69%	0.69%	0.69%
Economic	0.96%	0.94%	0.93%
Technical	0.97%	0.94%	0.93%

The machinery and other industrial segments each account for almost a quarter (23%) of the industrial achievable BAU potential from 2022 through 2024 (Figure 4-18).

Figure 4-18 Unitil Industrial Natural Gas Achievable BAU Potential by Segment

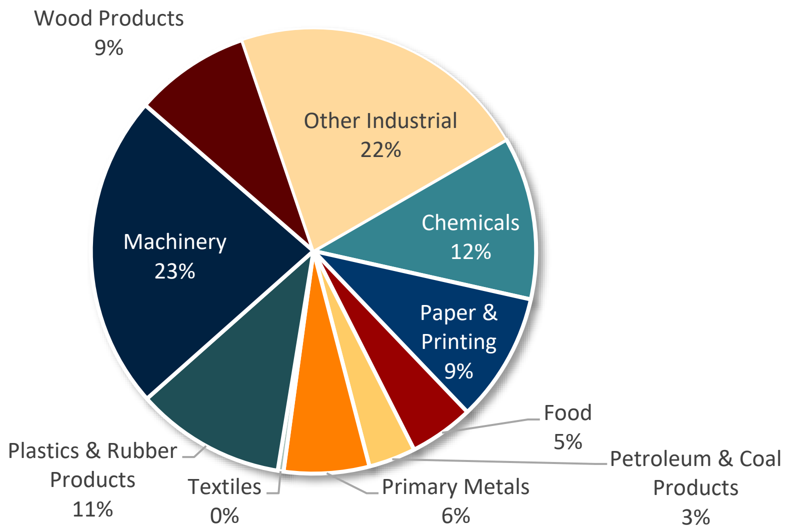


Table 4-17 shows Industrial potential by segment and case.

Table 4-17 Industrial Natural Gas Potential (therms) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Chemicals	1,450	1,593	1,640
	Food	617	642	648
	Paper & Printing	1,199	1,277	1,300
	Petroleum & Coal Products	363	444	474
	Primary Metals	797	846	860
	Textiles	56	58	58
	Plastics & Rubber Products	1,515	1,519	1,509
	Machinery	3,228	3,210	3,179
	Wood Products	1,140	1,168	1,171
	Other Industrial	3,106	3,070	3,032
BAU Plus	Chemicals	3,887	4,366	4,514
	Food	1,143	1,238	1,266
	Paper & Printing	1,625	1,726	1,749
	Petroleum & Coal Products	509	578	598
	Primary Metals	684	686	682
	Textiles	59	60	60
	Plastics & Rubber Products	1,362	1,321	1,296
	Machinery	2,689	2,550	2,483
	Wood Products	996	975	961
	Other Industrial	2,530	2,375	2,304

Case	Segment	2022	2023	2024
BAU Max	Chemicals	4,862	5,462	5,646
	Food	1,429	1,549	1,583
	Paper & Printing	2,032	2,159	2,188
	Petroleum & Coal Products	637	723	748
	Primary Metals	856	858	853
	Textiles	73	75	75
	Plastics & Rubber Products	1,703	1,652	1,621
	Machinery	3,364	3,190	3,105
	Wood Products	1,246	1,220	1,202
	Other Industrial	3,164	2,971	2,881
Economic	Chemicals	7,320	7,921	8,092
	Food	2,091	2,196	2,222
	Paper & Printing	2,917	3,010	3,022
	Petroleum & Coal Products	952	1,039	1,062
	Primary Metals	1,158	1,134	1,118
	Textiles	101	101	100
	Plastics & Rubber Products	2,267	2,148	2,093
	Machinery	4,396	4,072	3,933
	Wood Products	1,665	1,593	1,557
	Other Industrial	4,105	3,763	3,620
Technical	Chemicals	7,320	7,922	8,093
	Food	2,091	2,197	2,223
	Paper & Printing	2,917	3,011	3,022
	Petroleum & Coal Products	952	1,039	1,062
	Primary Metals	1,159	1,134	1,119
	Textiles	101	101	100
	Plastics & Rubber Products	2,268	2,149	2,094
	Machinery	4,399	4,075	3,936
	Wood Products	1,666	1,593	1,558
	Other Industrial	4,129	3,788	3,645

Table 4-18 shows potential by case and vintage – new construction vs existing buildings

Table 4-18 Industrial Natural Gas Potential (therms) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	11,878	11,686	11,473
	New	1,593	2,140	2,398
BAU Plus	Existing	14,222	14,286	14,129
	New	1,260	1,589	1,784
BAU Max	Existing	17,790	17,870	17,669
	New	1,577	1,988	2,231
Economic	Existing	24,900	24,423	23,962
	New	2,071	2,553	2,858
Technical	Existing	24,931	24,454	23,992
	New	2,072	2,554	2,860

C&I Combined Potential by End Use

The following graphic shows the potential for the entire nonresidential by end use. In this view, custom programs have been separated for clarity. Custom HVAC accounts for 66% of the BAU achievable potential savings (Figure 4-19).

Figure 4-19 Unitil Nonresidential Natural Gas Achievable BAU Potential by End Use

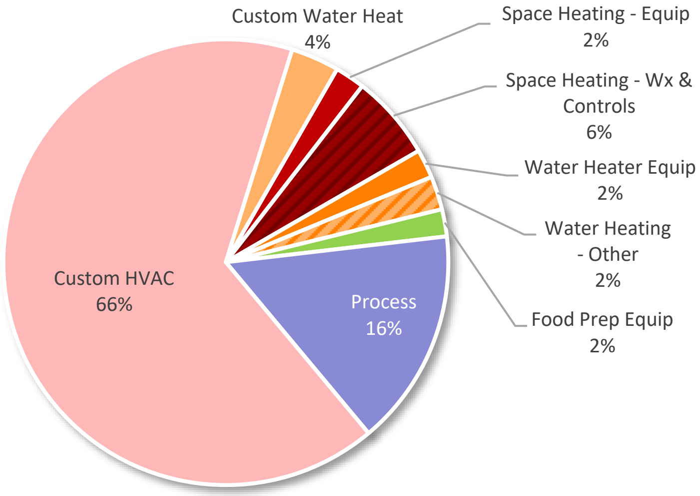
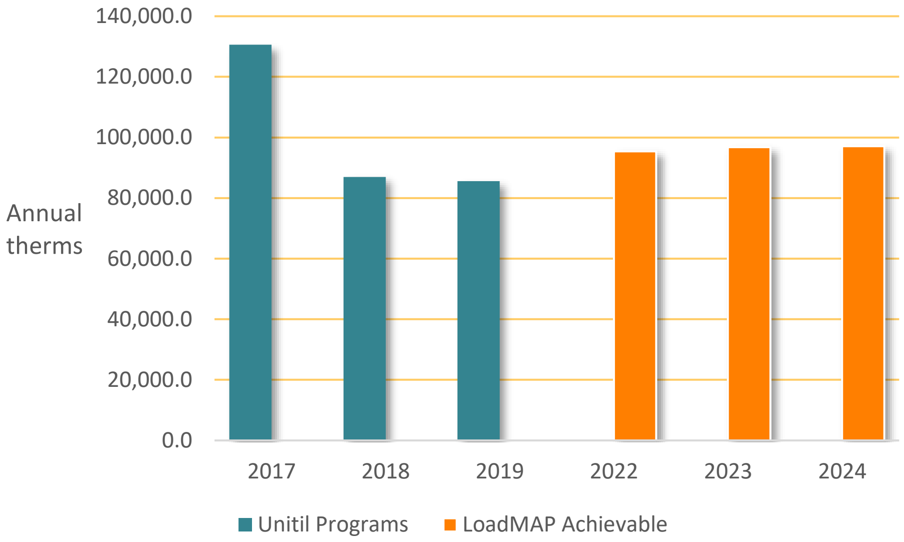


Figure 4-20 compares the nonresidential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. Overall forward savings are similar to past achievements.

Figure 4-20 Unitil Natural Gas Nonresidential Savings Historical Comparison – BAU vs Historic



5

ELECTRIC ENERGY EFFICIENCY ANALYSIS AND RESULTS

Electric Energy Efficiency Potential

This section presents the energy efficiency potential for Unitil's electric territory as a whole and by sector the planning period 2022-2024.

Incremental Potential for Planning Cycle Years

First-year potential savings for 2022 through 2024 and lifetime savings are presented in Table 5-1. The achievable BAU potential is in the range of 3,595 MWh to 4,005 MWh per year, or approximately 1% of the baseline baseline projected in absence of future DSM (see chapter 2 for further details on the baseline case assumptions). BAU Plus is approximately 10% higher, ranging from 4,037 MWh to 4,413 MWh, or ~1.15% of baseline, and the Max case is 25.7% higher than BAU, at 4,574 MWh to 5,037 MWh each year, or 1.3% of baseline.

Notably, the majority of technical potential is passing cost-effectiveness, 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.

The commercial sector accounts for the larger share of savings, approximately 43% of achievable BAU potential savings in each year.

Table 5-1 Unitil First-Year Electric Savings Potential for Planning Cycle (MWh)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**363,639**	**360,980**	**359,488**
Potential Savings			
Achievable BAU	4,005	3,728	3,595
Achievable BAU Plus	4,413	4,147	4,037
Achievable Max	5,037	4,719	4,574
Economic	9,093	8,532	8,307
Technical	10,241	9,658	9,407
Potential Savings as % of Baseline			
Achievable BAU	1.10%	1.03%	1.00%
Achievable BAU Plus	1.21%	1.15%	1.12%
Achievable Max	1.39%	1.31%	1.27%
Economic	2.50%	2.36%	2.31%
Technical	2.82%	2.68%	2.62%

Table 5-2 Unitil First-Year Achievable Electric Savings Potential by Sector (MWh)

Achievable Potential by Sector	2022	2023	2024
Achievable BAU Potential			
Residential	1,480	1,338	1,338
Commercial	1,706	1,629	1,546
Industrial	819	761	711
Achievable BAU Plus Potential			
Residential	1,622	1,479	1,492
Commercial	1,874	1,801	1,720
Industrial	918	867	824
Achievable Max Potential			
Residential	1,830	1,674	1,686
Commercial	2,139	2,051	1,956
Industrial	1,068	994	932
Economic Potential			
Residential	4,590	4,235	4,197
Commercial	3,087	2,994	2,885
Industrial	1,416	1,303	1,225
Technical Potential			
Residential	4,942	4,589	4,549
Commercial	3,507	3,414	3,302
Industrial	1,792	1,655	1,557

Figure 5-1 Unitil Achievable Electric BAU Savings by Sector

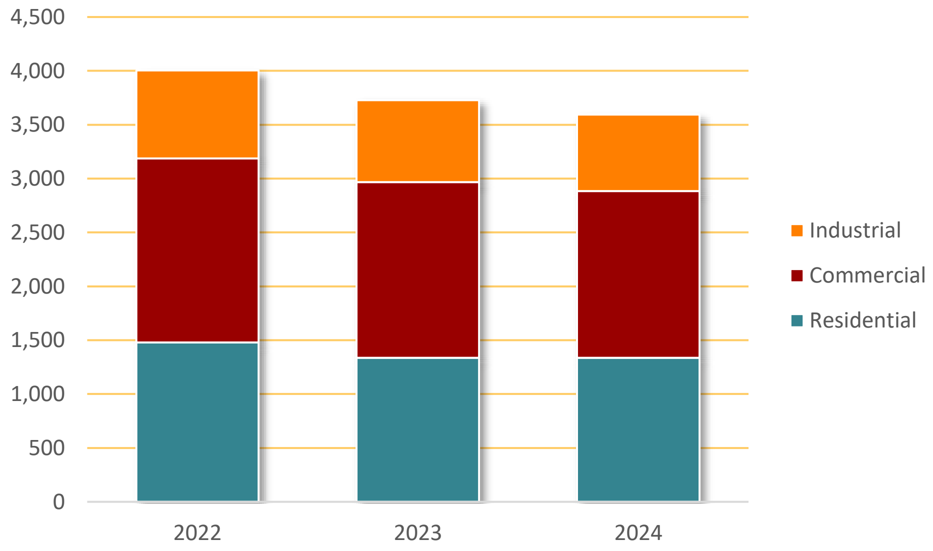


Table 5-3 provides an estimate of the utility cost to achieve the total portfolio savings for each of the three levels of potential. These costs are an estimate only based on sector-average incentive levels and administrative overhead costs from recent program years, and Unitil's actual costs will naturally vary.

Table 5-3 Unitil Electric Total Portfolio Cost to Achieve by Potential Level

Potential Level	2022	2023	2024
Total Portfolio Utility Costs			
BAU	$2,495,185	$2,521,216	$2,424,206
BAU Plus	$3,751,469	$3,799,617	$3,676,743
Max	$5,240,192	$5,285,080	$5,091,788

Residential Sector

In 2019, there were approximately 30,326 households in Unitil's Residential sector that used a total of 172,831 MWh. These numbers are inclusive of estimated multifamily apartment dwellings billed on commercial rate classes[19] .

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[20] average consumption per home and the total consumption of the building

Average use per household was 5,699 kWh (Table 5-4) but there is a large difference between single family homes, which range from 6,148-6,525 kWh depending on income level, and multifamily homes, which have much lower consumption per home. This average use per home also includes both electric heating customers and non-heating customers. Market rate single family customers account for 75% of total usage, and Low-Income Single family customers account for 13% (Figure 5-2). Multi-family and low-income multi-family customers account for the remainder of usage.

Figure 5-2 Unitil Residential Electric Use, 2019

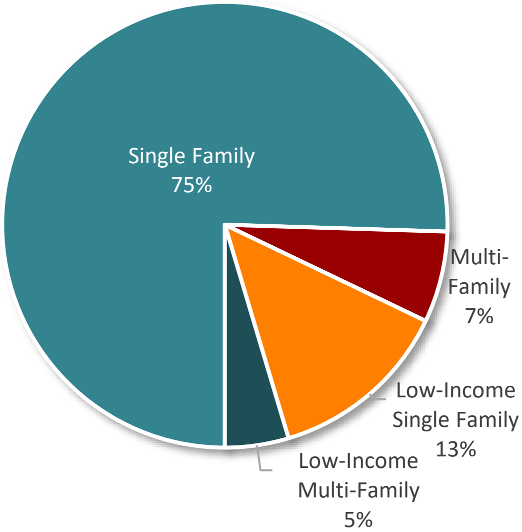


Table 5-4 Unitil Residential Electric Control Totals, 2019

Segment	Households	Annual Use (MWh)	Intensity (kWh / HH)
Single Family	21,223	130,469	6,148
Multi-Family	3,369	11,432	3,393
Low-Income Single Family	3,516	22,943	6,525
Low-Income Multi-Family	2,218	7,988	3,602
Total	**30,326**	**172,831**	**5,699**

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[19] 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 ~56% of multifamily consumption, or ~10% of the overall residential consumption shown here.

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

Figure 5-3 Unitil Residential Electric Consumption by End Use, 2019

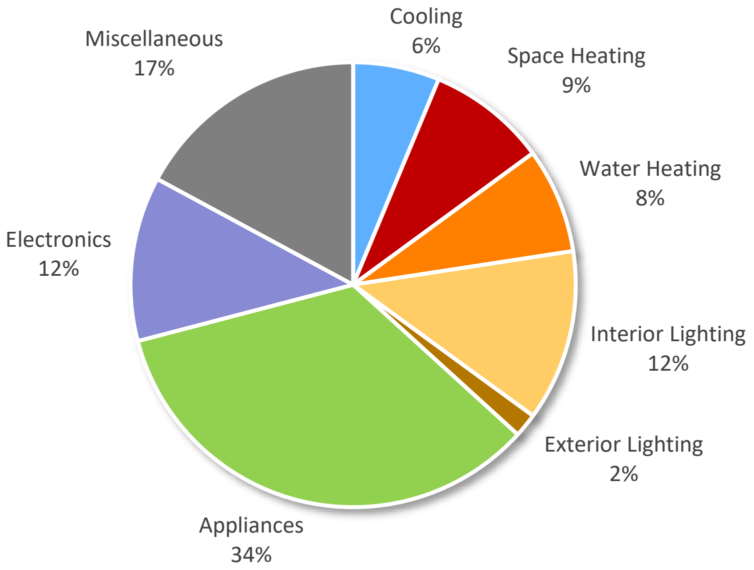
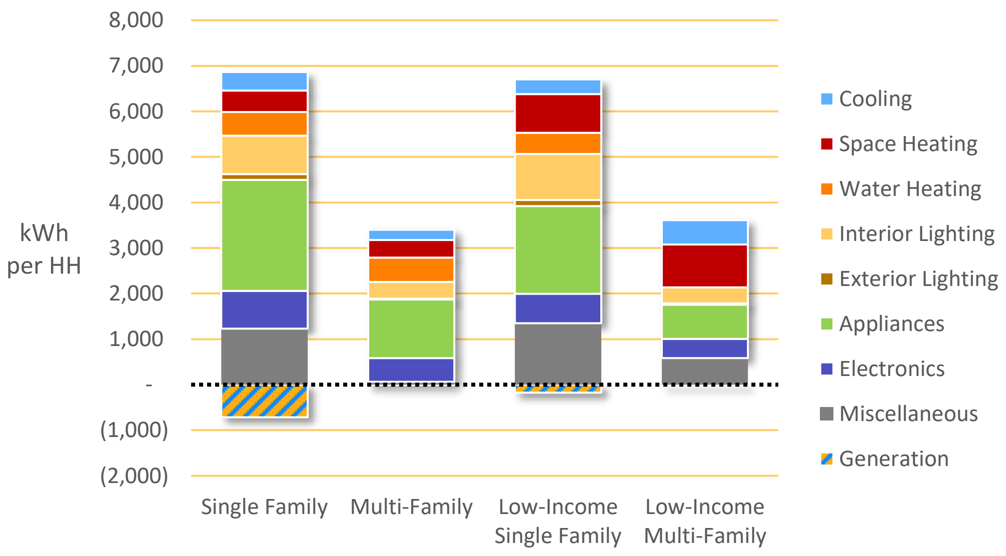


Figure 5-3 shows the average annual electric consumption by end use for all residential customers. Overall electric use per household is on the low end of average, as the majority of Unitil's customers use fuels other than electricity for their household heating, and cooling is not a large element of electricity use in Massachusetts. Among end uses present in Unitil's residential homes, appliances account for the largest portion of total usage.

Figure 5-4 presents the energy intensity by end use and housing type. Single family has the highest intensity at 6,148 kWh per household.

Figure 5-4 Unitil Residential Electric Intensity by End Use and Segment, 2019



Residential Baseline Projection

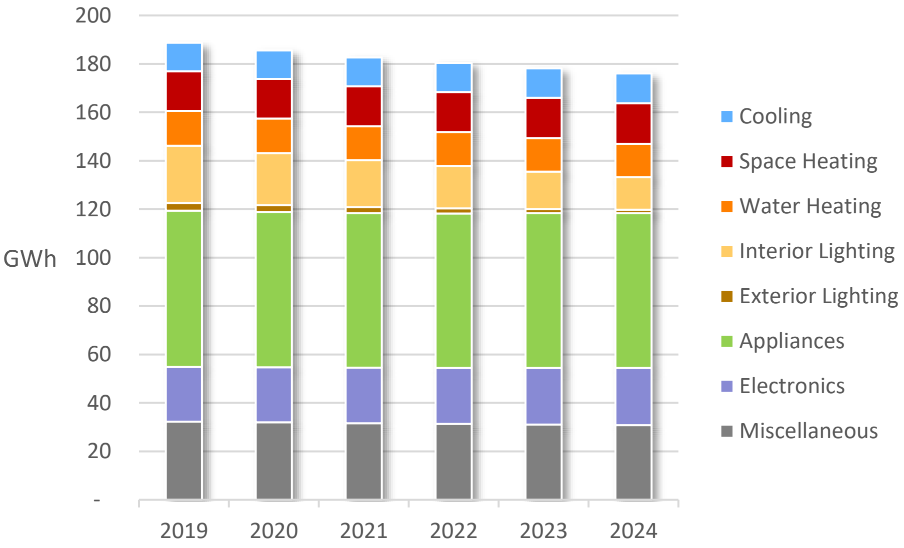
Table 5-5 presents AEG's electric baseline projection at the end use level for the residential sector. The projection includes effects of standards, codes, and naturally occurring conservation, but not future DSM program activity (see Chapter 2 for more details on the development of the baseline). The 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.

The presence of existing solar generation in the models came from Unitil's provided PV data. The portion of customers with solar was held constant throughout the study period.

Table 5-5 Unitil Residential Electric Baseline Projection by End Use (MWh)

Electric Use	2019	2021	2022	2023	2024
Cooling	11,846	11,871	11,917	12,010	12,132
Space Heating	16,344	16,368	16,412	16,511	16,637
Water Heating	14,432	14,238	14,064	13,936	13,834
Interior Lighting	23,499	21,432	19,423	17,539	15,442
Exterior Lighting	3,264	2,847	2,461	2,115	1,757
Appliances	64,476	64,128	63,850	63,776	63,805
Electronics	22,584	22,736	22,911	23,160	23,445
Miscellaneous	32,302	31,972	31,598	31,299	31,032
Generation	(15,916)	(15,924)	(15,945)	(16,016)	(16,109)
Total	**172,831**	**169,667**	**166,961**	**164,330**	**161,975**

Figure 5-5 Unitil Electric Residential Baseline Projection by End Use



Residential Potential

Table 5-6 presents the residential sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 1,480 MWh, or 0.9% of the baseline projection.

Table 5-6 Unitil Summary of Residential Electric Potential (MWh)

First-year Savings Potential	2022	2023	2024
Baseline Projection	**164,330**	**161,975**	**159,879**
Potential Savings			
Achievable BAU	1,480	1,338	1,338
Achievable BAU Plus	1,622	1,479	1,492
Achievable Max	1,830	1,674	1,686
Economic	4,590	4,235	4,197
Technical	4,942	4,589	4,549
Potential Savings as % of Baseline			
Achievable BAU	0.90%	0.83%	0.84%
Achievable BAU Plus	0.99%	0.91%	0.93%
Achievable Max	1.11%	1.03%	1.05%
Economic	2.79%	2.61%	2.63%
Technical	3.01%	2.83%	2.85%

The single family segment accounts for most of the residential savings (72%). The low-income single family segment represents 16% of the savings with the multi-family segments representing 12% of the savings combined. Single family dwellings include buildings with 2-4 units (Figure 5-6).

Figure 5-6 Unitil Residential Electric Potential by Segment

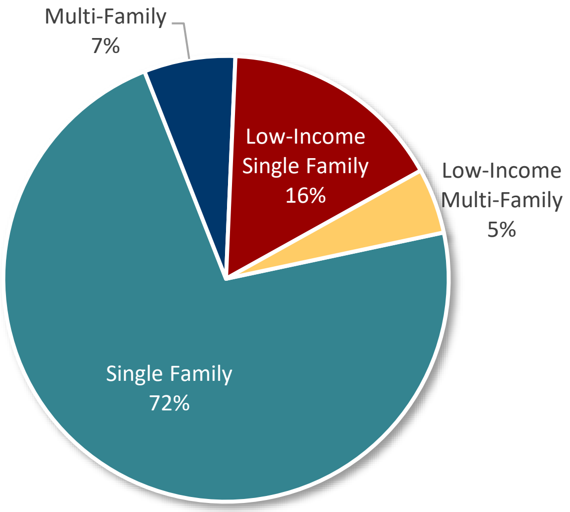


Table 5-7 shows residential potential by segment for all cases and for each year of the planning cycle.

Table 5-7 Residential Electric Potential (MWh) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Single Family	969	970	968
	Multi-Family	89	89	89
	Low-Income Single Family	333	215	218
	Low-Income Multi-Family	88	63	63
BAU Plus	Single Family	1,056	1,066	1,072
	Multi-Family	109	114	118
	Low-Income Single Family	358	228	231
	Low-Income Multi-Family	99	72	72
BAU Max	Single Family	1,222	1,232	1,237
	Multi-Family	125	130	133
	Low-Income Single Family	380	238	241
	Low-Income Multi-Family	104	74	75
Economic	Single Family	3,137	3,141	3,116
	Multi-Family	282	282	278
	Low-Income Single Family	954	655	647
	Low-Income Multi-Family	217	157	157
Technical	Single Family	3,391	3,398	3,372
	Multi-Family	307	306	302
	Low-Income Single Family	992	693	683
	Low-Income Multi-Family	252	192	191

Space heating non-equipment measures (27%), appliances (20%), water heating equipment (13%) and miscellaneous (17%) account for a combined 77% of the BAU achievable potential savings (Figure 5-7).

Figure 5-7 Unitil Residential Electric Potential by End Use

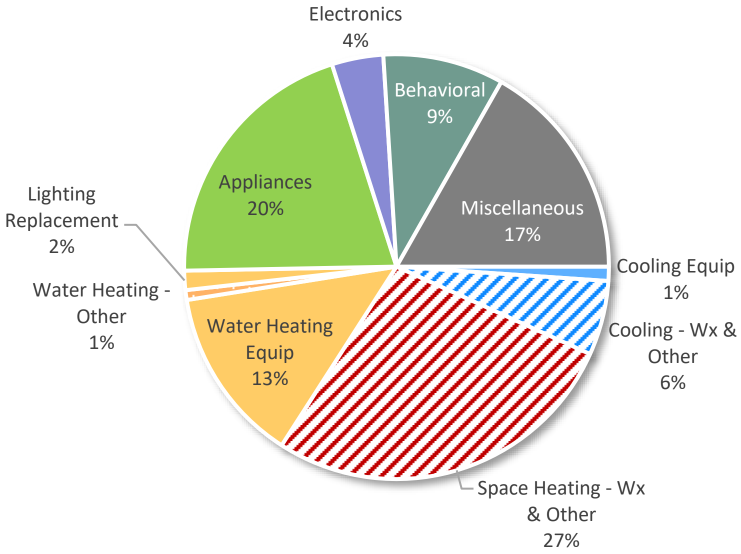


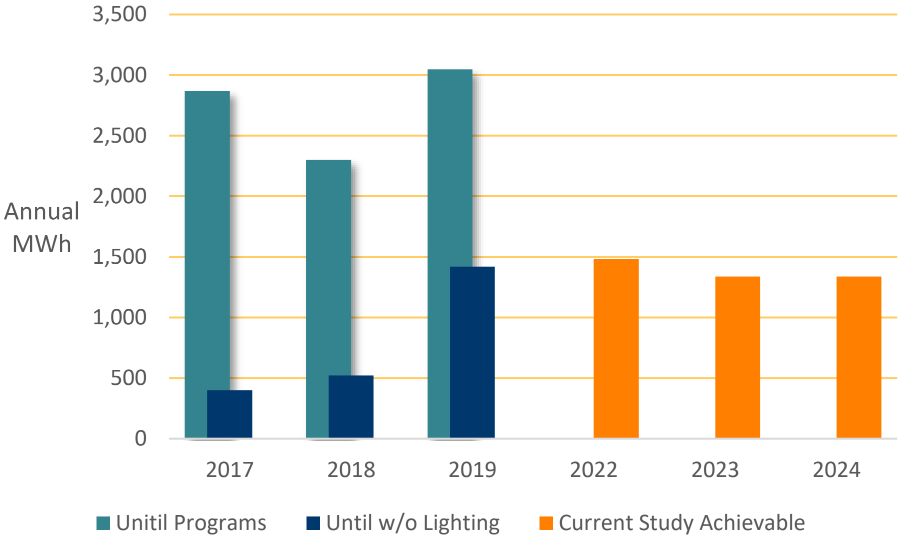
Table 5-8 shows potential broken out by vintage – new construction vs existing buildings – and case.

Table 5-8 Residential Electric (MWh) Potential by Segment and Case

Case	Segment	2022	2023	2024
BAU	Existing	1,438	1,295	1,288
	New	42	43	51
BAU Plus	Existing	1,571	1,427	1,432
	New	51	52	60
BAU Max	Existing	1,769	1,610	1,613
	New	61	64	72
Economic	Existing	4,367	3,989	3,938
	New	223	246	260
Technical	Existing	4,694	4,311	4,256
	New	248	278	292

Figure 5-8 compares the residential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. The historical savings are displayed as both the total program achievements and the total program achievements without lighting savings. This view allows for a more meaningful comparison to potential savings in the upcoming plan years where lighting savings have significantly lower potential due to baseline changes. The residential BAU achievable potential is higher than historic achievements without lighting in 2022-2024.

Figure 5-8 Unitil Electric Residential Savings Historical Comparison – BAU vs Historic



Commercial Sector

In 2019, Unitil commercial customers used a total of 107,962 MWh. We allocated this usage to 9 commercial segments, shown in Table 5-9 using identifiers provided in Unitil's 2019 customer data, which was enhanced with tax assessor data and industry codes provided by DNV. As shown in Figure 5-9, the education segment used approximately 32% of the total electricity consumed in 2019, followed by retail (17%), office (13%), warehouse (13%), lodging (11%), miscellaneous (6%), healthcare (3%), restaurant (3%), and grocery (2%). Please note that industrial customers are segmented separately later in this section.

Table 5-9 Unitil Commercial Electric Control Totals, 2019

Segment	Annual Use (MWh)	Intensity (kWh/sqft)	Floor Space (Million Sq. Ft.)
Office	13,446	9.57	1.40
Retail	23,433	11.15	2.10
Restaurant	7,879	37.30	0.21
Grocery	9,329	54.38	0.17
Healthcare	25,404	10.19	2.49
Education	5,494	16.82	0.33
Lodging	16,144	17.24	0.94
Warehouse	2,839	2.40	1.18
Misc.	3,994	7.14	0.56
Total	**107,962**	**11.50**	**9.39**

Figure 5-9 Unitil Commercial Electric Use by Segment, 2019

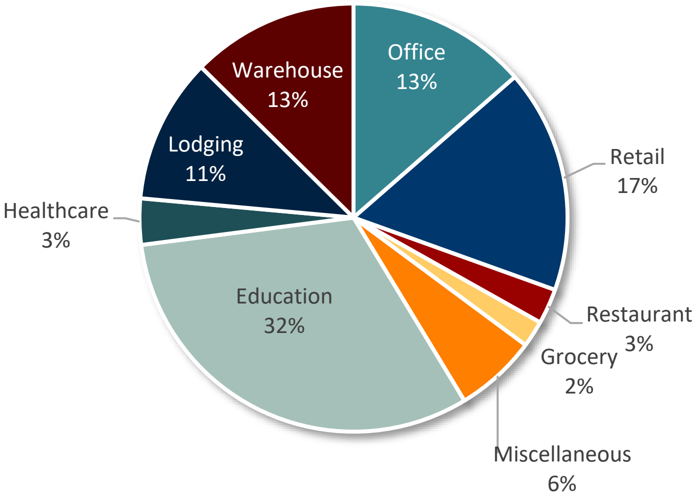
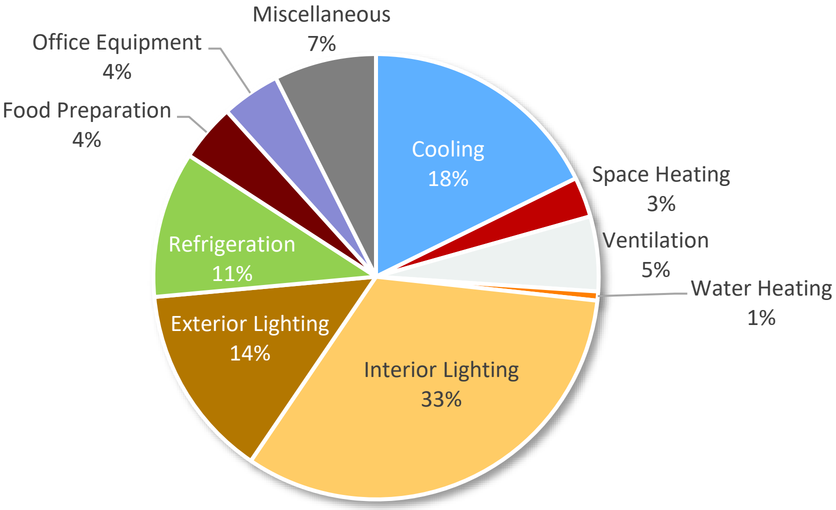


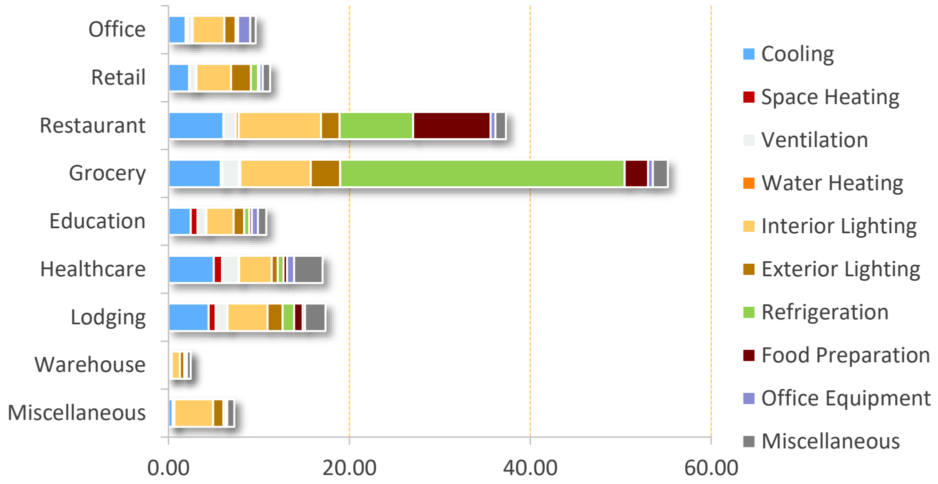
Figure 5-10 shows the distribution of annual electric consumption by end use across all commercial buildings. Lighting accounts for the highest proportion of consumption followed by cooling.

Figure 5-10 Unitil Commercial Electric Consumption by End Use, 2019



As shown in Figure 5-11, electric intensity by end use varies significantly across segments. For example, due to refrigeration equipment consumption, the grocery segment is the most energy intensive, with significantly higher usage per square foot than any other segment due to refrigeration and lighting needs but not necessarily large spaces.

Figure 5-11 Unitil Commercial Electric Intensity by End Use and Segment, 2019



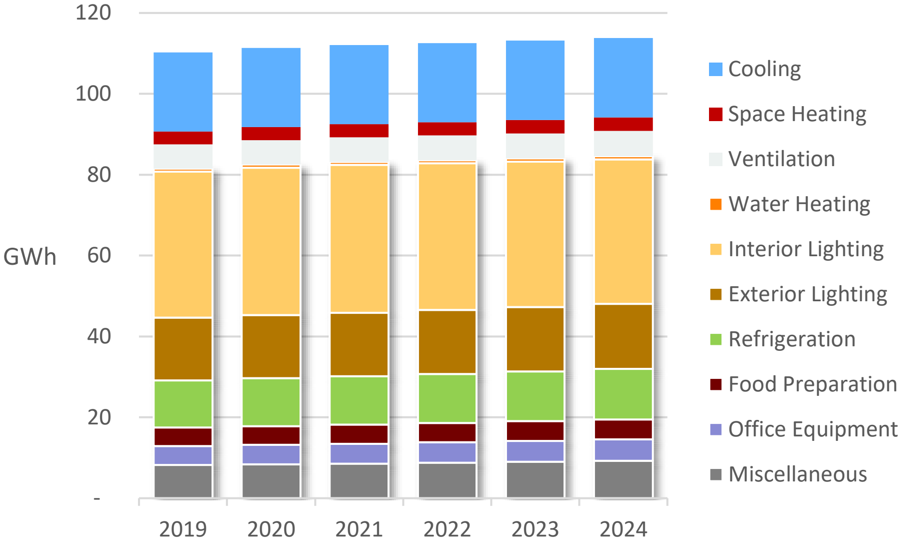
Commercial Baseline Projection

Table 5-10 presents AEG's independent electric baseline projection at the end use level for the commercial sector. Market growth contributes to slight increases in load, while general intensity (use per sq.ft) remains nearly constant. Commercial lighting is largely in long-lived fixtures, and there is significant existing LED penetration even in these, so the natural turnover does not show the dramatic falloff as visible in the residential sector.

Table 5-10 Unitil Commercial Baseline Electric Projection by End Use (MWh)

Electric Use	2019	2020	2021	2022	2023	2024
Cooling	19,523	19,571	19,557	19,573	19,617	19,671
Space Heating	3,213	3,240	3,262	3,291	3,325	3,359
Ventilation	5,984	6,036	6,078	6,136	6,202	6,269
Water Heating	726	733	738	745	753	761
Interior Lighting	36,130	36,447	36,592	36,297	35,997	35,748
Exterior Lighting	15,487	15,623	15,695	15,789	15,902	16,033
Refrigeration	11,699	11,848	11,977	12,138	12,316	12,497
Food Preparation	4,591	4,657	4,715	4,786	4,865	4,945
Office Equipment	4,680	4,792	4,898	5,020	5,150	5,285
Miscellaneous	8,189	8,388	8,578	8,797	9,034	9,280
Generation	-2,255	-2,275	-2,291	-2,313	-2,337	-2,363
Total	**107,967**	**109,060**	**109,799**	**110,260**	**110,822**	**111,485**

Figure 5-12 Unitil Electric Commercial Baseline Projection by End Use (GWh)



Commercial Potential

Table 5-11 presents the commercial sector energy savings potential estimates. In 2022, achievable BAU potential energy savings are 1,706 MWh, or 1.55% of the counterfactual baseline projection[21].

Table 5-11 Unitil Summary of Commercial Electric Potential (MWh)

First-year Savings Potential	2022	2023	2024
Baseline Projection	110,260	110,822	111,485
Potential Savings			
Achievable BAU	1,706	1,629	1,546
Achievable BAU Plus	1,874	1,801	1,720
Achievable Max	2,139	2,051	1,956
Economic	3,087	2,994	2,885
Technical	3,507	3,414	3,302
Potential Savings as % of Baseline			
Achievable BAU	1.55%	1.47%	1.39%
Achievable BAU Plus	1.70%	1.62%	1.54%
Achievable Max	1.94%	1.85%	1.75%
Economic	2.80%	2.70%	2.59%
Technical	3.18%	3.08%	2.96%

The education segment accounts for 27% of the commercial savings in 2022 through 2024 followed by office (16%), retail (16%), lodging (12%) and grocery (10%).

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[21] Inclusive of codes & standards and market growth but without DSM programs. See chapter 2 for more details.

Figure 5-13 Unitil Commercial Electric Potential by Segment

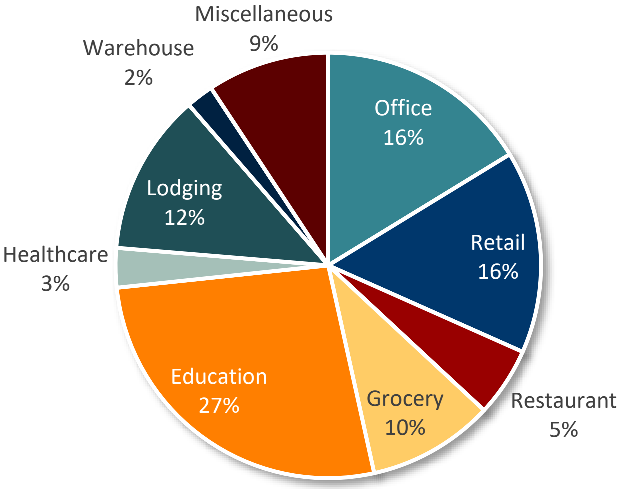


Table 5-12 Commercial Electric Potential (MWh) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Office	282	267	251
	Retail	270	254	238
	Restaurant	83	82	81
	Grocery	154	152	149
	Education	51	49	46
	Health	455	436	414
	Lodging	211	201	190
	Warehouse	37	35	32
	Miscellaneous	164	154	144
BAU Plus	Office	290	277	262
	Retail	307	291	274
	Restaurant	110	110	109
	Grocery	177	175	173
	Education	57	56	53
	Health	486	467	447
	Lodging	235	226	216
	Warehouse	44	42	39
	Miscellaneous	167	158	148
BAU Max	Office	301	286	270
	Retail	405	382	358
	Restaurant	143	142	140
	Grocery	215	212	209
	Education	64	62	59
	Health	520	500	478
	Lodging	262	252	241
	Warehouse	58	55	51
	Miscellaneous	171	161	150
Economic	Office	402	387	369
	Retail	522	496	468
	Restaurant	240	239	237
	Grocery	311	309	306
	Education	515	503	489
	Health	342	331	317
	Lodging	442	434	422
	Warehouse	119	113	107
	Miscellaneous	193	183	171
Technical	Office	441	426	408

Case	Segment	2022	2023	2024
	Retail	551	526	498
	Restaurant	292	290	287
	Grocery	398	395	390
	Education	632	621	605
	Health	355	344	330
	Lodging	498	490	478
	Warehouse	128	123	117
	Miscellaneous	212	200	189

Table 5-13 Commercial Electric Potential (MWh) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	1,288	1,191	1,105
	New	419	438	441
BAU Plus	Existing	1,413	1,318	1,232
	New	460	483	489
BAU Max	Existing	1,622	1,511	1,410
	New	516	540	546
Economic	Existing	2,332	2,203	2,085
	New	754	791	800
Technical	Existing	2,671	2,529	2,398
	New	836	886	904

Industrial Sector

In 2019, Unitil industrial customers used a total of 96,801 MWh[22] (Table 5-14). We allocated this usage to 6 industrial segments. As shown in Figure 5-14, the plastics & rubber products segment used approximately 36% of the total electricity consumed in 2019, followed by paper (19%), agriculture (18%), other industrial (16%), chemicals (6%), and fabricated metal products (5%).

Table 5-14 Unitil Industrial Control Totals, 2019

Segment	Annual Use (MWh)	Annual Use (% of Total)
Plastics & Rubber Products	15,707	36.0%
Paper	25,191	19.2%
Agriculture	6,265	18.1%
Chemicals	6,653	5.8%
Fabricated Metal Products	4,590	5.0%
Other Industrial	10,771	15.9%
Total	**96,801**	**100.0%**

Figure 5-14 Unitil Industrial Use by Segment, 2019

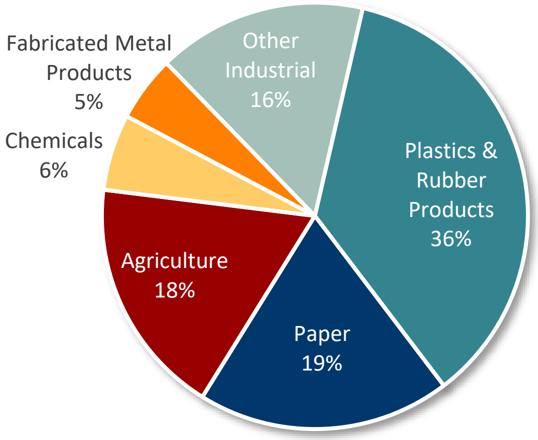
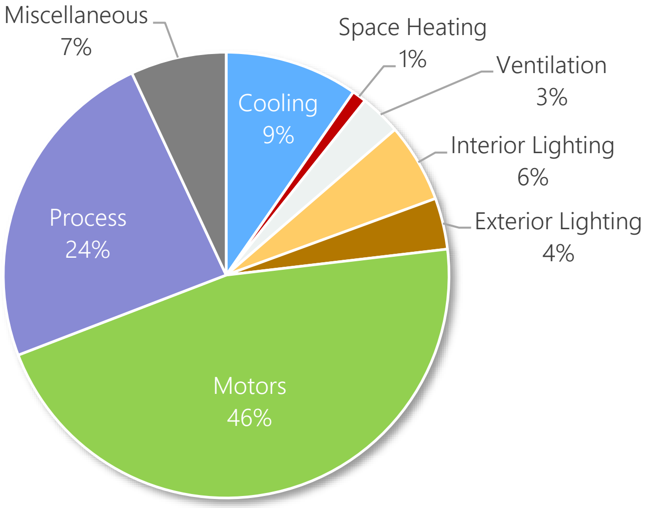


Figure 5-15 shows the distribution of annual electric consumption by end use across all commercial buildings.

Figure 5-15 Unitil Industrial Electric Consumption by End Use, 2019



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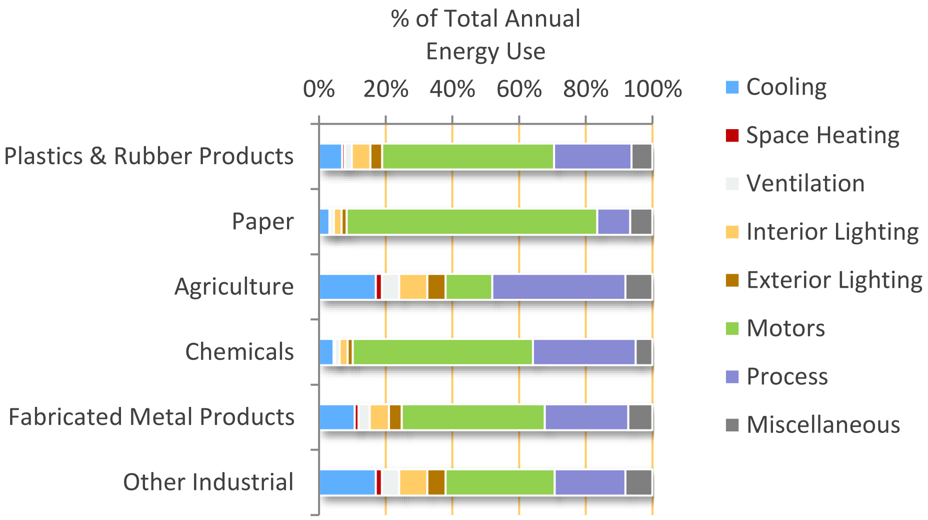
[22] There is a singular large special contract account in Unitil's industrial load that is not included in this total or in this study. As a potential study operates on averages and across populations, modeling single large customers like this is difficult at best and likely to produce erroneously high estimates of potential by attempting to smooth a single large customer's activity into a regularly meted out annual delivery schedule. Aside from that, Unitil has engaged many times with this customer for multiple rounds of projects and believes there is very little left they will be able to modify in the near future.

As shown in Figure 5-16, electric intensity by end use varies by segment, although motors and process tend to account for the most electric use.

Figure 5-16 Unitil Industrial Electric Intensity by End Use and Segment, 2019



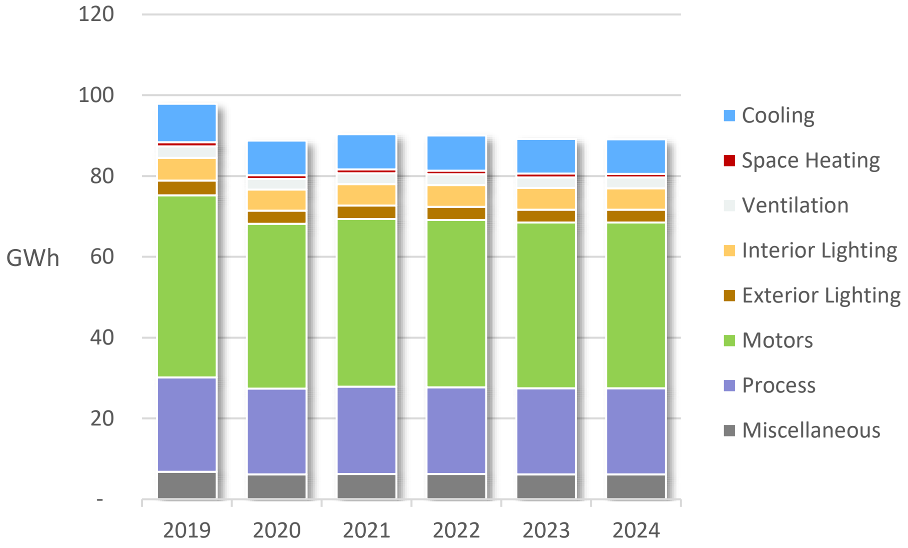
Industrial Baseline Projection

Table 5-15 presents AEG's electric baseline projection at the end use level for the commercial sector, including codes & standards impacts but not future DSM efforts. Industrial load tends to be variable, but here the market growth assumptions follow Unitil's nonresidential forecast as a driver, and within the model intensity is modestly affected by equipment turnover.

Table 5-15   Unitil Industrial Electric Baseline Projection by End Use (MWh)

Electric Use	2019	2020	2021	2022	2023	2024
Cooling	9,460	8,569	8,713	8,673	8,562	8,533
Space Heating	1,013	919	935	931	922	922
Ventilation	2,912	2,639	2,686	2,675	2,650	2,650
Interior Lighting	5,619	5,178	5,333	5,357	5,335	5,349
Exterior Lighting	3,641	3,290	3,326	3,283	3,216	3,175
Motors	45,036	40,822	41,539	41,377	40,992	40,991
Process	23,381	21,193	21,565	21,481	21,281	21,281
Miscellaneous	6,804	6,168	6,276	6,251	6,193	6,193
Generation	-1,066	-966	-983	-980	-970	-970
Total	**204,767**	**196,871**	**199,188**	**199,309**	**199,005**	**199,609**

Figure 5-17 Unitil Electric Industrial Baseline Projection by End Use (GWh)



Industrial Potential

Table 5-16 presents the industrial sector electric savings potential estimates. In 2022, achievable BAU potential energy savings are 819 MWh, or 0.92% of the counterfactual baseline projection[23].

Table 5-16 Unitil Summary of Industrial Electric Potential

First-year Savings Potential	2022	2023	2024
Baseline Projection	**89,049**	**88,183**	**88,124**
Potential Savings			
Achievable BAU	819	761	711
Achievable BAU Plus	918	867	824
Achievable Max	1,068	994	932
Economic	1,416	1,303	1,225
Technical	1,792	1,655	1,557
Potential Savings as % of Baseline			
Achievable BAU	0.92%	0.86%	0.81%
Achievable BAU Plus	1.03%	0.98%	0.94%
Achievable Max	1.20%	1.13%	1.06%
Economic	1.59%	1.48%	1.39%
Technical	2.01%	1.88%	1.77%

The plastics & rubber products segment accounts for almost a third of the industrial potential (52%) in 2022 through 2024 (Figure 5-18).

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[23] See chapter 2

Figure 5-18 Unitil Industrial Electric Potential by Segment

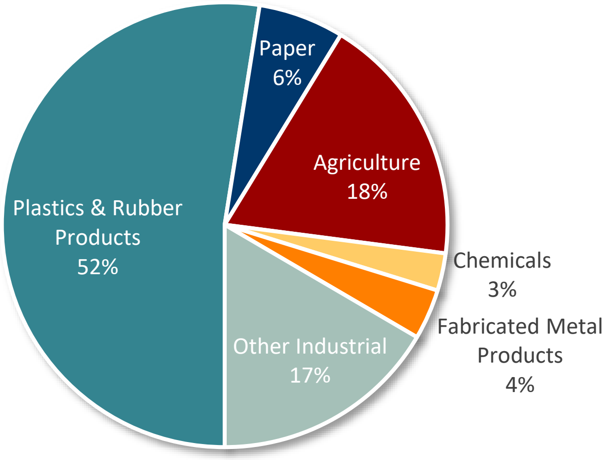


Table 5-17 Industrial Electric Potential (MWh) by Segment and Case

Case	Segment	2022	2023	2024
BAU	Plastics & Rubber Products	398	385	373
	Paper	53	48	44
	Agriculture	167	147	130
	Chemicals	21	20	19
	Fabricated Metal Products	32	29	26
	Other Industrial	149	132	118
BAU Plus	Plastics & Rubber Products	427	415	403
	Paper	60	57	54
	Agriculture	195	177	163
	Chemicals	24	24	25
	Fabricated Metal Products	38	35	32
	Other Industrial	174	158	147
BAU Max	Plastics & Rubber Products	500	483	468
	Paper	69	63	58
	Agriculture	227	202	181
	Chemicals	27	26	25
	Fabricated Metal Products	44	39	36
	Other Industrial	202	180	163
Economic	Plastics & Rubber Products	628	599	578
	Paper	96	87	81
	Agriculture	314	277	253

Case	Segment	2022	2023	2024
	Chemicals	40	38	37
	Fabricated Metal Products	60	54	50
	Other Industrial	279	247	226
Technical	Plastics & Rubber Products	702	666	639
	Paper	155	144	136
	Agriculture	413	371	341
	Chemicals	65	62	60
	Fabricated Metal Products	84	76	71
	Other Industrial	373	336	310

Table 5-18 Industrial Electric Potential (MWh) by Vintage and Case

Case	Segment	2022	2023	2024
BAU	Existing	684	625	574
	New	135	136	137
BAU Plus	Existing	774	724	682
	New	144	142	142
BAU Max	Existing	896	821	757
	New	172	173	175
Economic	Existing	1,202	1,091	1,012
	New	214	211	213
Technical	Existing	1,520	1,386	1,289
	New	272	269	268

C&I Combined Results

The following graph shows the potential for the C&I combined by end use. Lighting replacement and custom HVAC account for just over half of the BAU achievable potential savings (Figure 5-19).

Figure 5-19 Unitil Nonresidential Electric Potential by End Use

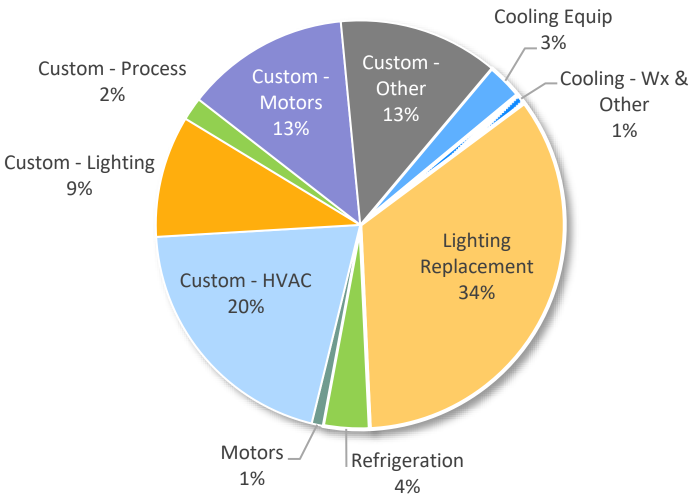
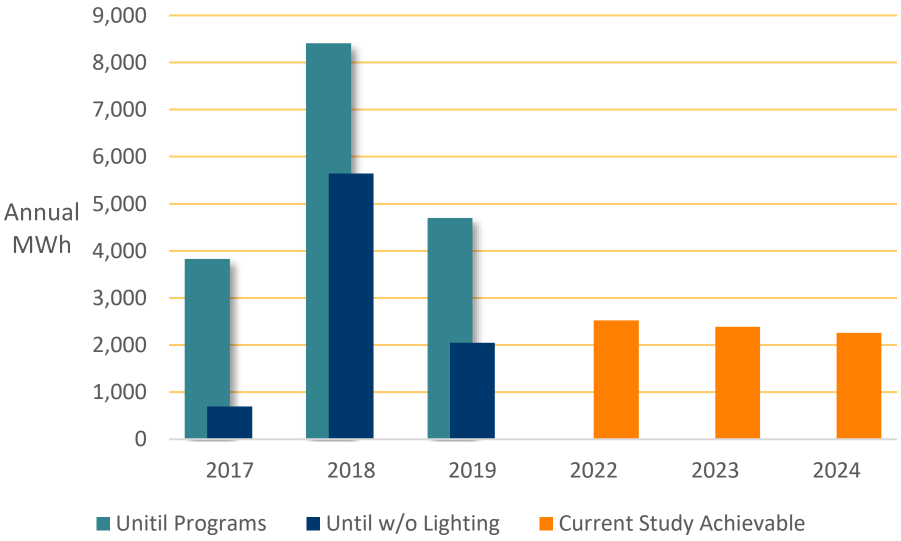


Figure 5-20 below compares the nonresidential savings achieved in 2017-2019 with the BAU achievable potential over the next 3-year planning cycle. The historical savings are displayed as both the total program achievements and the total program achievements without lighting savings. This view allows for a more meaningful comparison to potential savings in the upcoming plan years where lighting savings have significantly lower potential due to baseline changes.

Figure 5-20 Unitil Electric Nonresidential Savings Historical Comparison – BAU vs Historic



6

ELECTRIC DEMAND RESPONSE ANALYSIS AND RESULTS

Unitil has a small demand response portfolio available to eligible residential, commercial, and industrial customers operating within Massachusetts. These programs work in coordination with ISO New England, where complementary demand response programs reduce electricity consumption in the market during peak hours and provide permanent load reduction contingent on requirements from specific state utility commissions. Other regional utilities, such as National Grid and Eversource, offer similar demand response programs through ConnectedSolutions, a branded program that Unitil also offers to its residential and C&I customers. Collectively these programs contribute or provide value to the regional peak energy demand savings, flatten system ramps, firm intermittent energy resources, and relieve network congestion stress providing savings and benefits to the energy providers' ratepayers.

DR Market Characterization

The first step in the analysis is to segment customers by service class and develop characteristics for each sector. The three primary characteristics for the analysis are the number of customers by sector, coincident peak demand by sector, and saturations by end use within each sector.

Customer Counts by Sector

Once the customer sectors were defined, AEG developed customer counts and coincident peak demand values for each sector. Unitil provided a forecast of meters in their territory by meter type. AEG used the average number of meters per year as a proxy for the number of customers per sector matching the number of customers that were used in the energy efficiency analysis. Table 6-1 below shows the number of customers by sector for the forecasted years 2022-2024.

Table 6-1 Unitil Customer Counts by Sector

	2022	2023	2024
Sector			
Residential	29,440	29,611	29,787
Commercial	9,029	9,126	9,224
Industrial	863	872	882

Coincident Peak Demand by Sector

To develop the coincident peak demand forecast for each sector, AEG started with electricity sales by customer class. AEG used the electricity forecasts by meter type that were provided by Unitil to summarize the electricity use by year. The total annual MWh for each sector were multiplied by an estimated load factor,[24] then calibrated so that the total peak MW matched the Until-provided peak hour for the system.

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[24] The relationship between the average hourly energy use and peak load

The forecast of future peak demand is then assumed to follow the same trend as the provided energy forecast. Table 6-2 shows the summer demand forecasts by sector that were used in the analysis while

Table 6-3 shows the winter demand forecasts.

Table 6-2 Unitil Summer Coincident Peak Demand by Sector (MW @ Meter)

	2022	2023	2024
Sector			
Residential	38.0	38.2	38.2
Commercial	23.7	23.7	23.7
Industrial	25.6	25.7	25.6
Total	**87.3**	**87.5**	**87.6**

Table 6-3 Unitil Winter Coincident Peak Demand by Sector (MW @ Meter)

	2022	2023	2024
Sector			
Residential	30.2	30.3	30.4
Commercial	20.1	20.1	20.1
Industrial	24.5	24.5	24.5
Total	**74.8**	**75.0**	**75.0**

Equipment End Use Saturation

Another key component of the market characterization is end use saturation data. This is required to further segment the market and identify eligible customers for direct control of different equipment options. Saturations by end use and building type were taken from the market characterization performed for the energy efficiency analysis mainly relying on Massachusetts Baseline Studies[25]. Since the saturations in the statewide data don't reflect the Unitil territory specifically, there may be some potential limitations. The saturations of WIFI technology may be greater on a statewide level than Unitil's relatively older building stock. In addition, since the Unitil territory is in the Northern portion of MA, there may be less Cooling Degree Days and potentially less demand response available for cooling DR offerings. Since demand response can be widely available across different housing/business types, the saturations for the demand response analysis were weighted across all building types in the Unitil territory.

To calculate the saturations, there were several special cases. For residential appliances, AEG used a weighted average of the saturations across three appliance types that can be used for DR (pool pumps, clothes washers, and clothes dryers). Pool pumps were considered as a separate measure in two other recent studies performed for PAs near Unitil, however there is a great deal of uncertainty regarding saturations in the Unitil territory since it has not been specifically canvassed. Therefore, to get an estimate for potential DR from appliances, AEG grouped several appliances together as one option. Lastly, the saturation of Solar PV for DR purposes reflects the systems that include a battery, enabling DR.

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[25] For end-use saturations, AEG relied on Massachusetts Baseline Studies, American Community Survey (ACS), previous Unitil MPS, and AEG's Energy Market Profiles

Table 6-4 Unitil Demand Response Saturation of Base Equipment Available

	2022	2023	2024
Residential			
Appliances	54.4%	54.4%	54.5%
Central AC	26.2%	26.6%	27.1%
Electric Vehicles	0.3%	0.3%	0.3%
Solar PV Batteries	0.9%	0.9%	0.9%
Water Heaters <= 55 Gal	16.1%	16.1%	16.2%
Commercial			
Central AC	2.8%	2.8%	2.8%
Solar PV Batteries	0.2%	0.2%	0.2%
Industrial			
Solar PV Batteries	0.3%	0.3%	0.3%

Demand Response Offerings

The next step in the analysis is to characterize the available demand response options for the Unitil territory. AEG considered the characteristics and applicability of a comprehensive list of options available in the marketplace today as well as those projected into the three-year study time horizon. Working closely with Unitil, AEG included for quantitative analysis those options which have been deployed at scale such that reliable estimates exist for cost, lifetime, and performance. Each selected option is described briefly below.

Smart Thermostats DLC Cooling

This offering uses the two-way communicating ability of smart thermostats to cycle air conditioning equipment on and off during events. Unitil's Smart Thermostat offering targets Unitil's residential and commercial sectors. We assume this will be a Bring your own Thermostat (BYOT) program and therefore assume no installation costs to Unitil. Thermostats can provide DR solutions during summer and winter periods however this offering was only developed as a cooling program as much of the territory relies on gas heating. Currently, Unitil has a Residential Smart Thermostat Program in place through their Residential WIFI program.

Direct Load Control of Domestic Hot Water Heaters

The DLC Domestic Hot Water Heater offering targets Unitil's residential customers only. The emphasis for Energy Efficiency is mostly on heat pump water heaters which are not well-designed for participation in DR offerings. Discussion with the Unitil team led to the conclusion that imposing DR on commercial water heaters would likely disrupt business operations and would form a significant barrier to entry. Therefore, AEG did not calculate the DR potential for commercial water heaters. This offering directly controls water heating load throughout the year for these customers through a load control switch. Water heaters would be completely turned off during the DR event period. Water heaters of all sizes are eligible for control however AEG assumed Water Heaters under 55 gallons would be an appropriate proxy for this analysis. Since this offering requires a switch to be installed on a unit, this offering wasn't eligible for a Bring Your Own Device (BYOD) program. AEG assumed a $130 cost to Unitil for each switch, with a $200 installation fee performed by a licensed contractor ($330 total equipment costs per unit).

Smart Appliances DLC

The Smart Appliances DLC offering uses a Wi-Fi hub to connect smart Wi-Fi enabled appliances such as washers, dryers, pool pumps. During events throughout the year, the smart appliances will be cycled on and off. The Smart Appliances DLC offering targets Unitil's residential and commercial customers. AEG assumes a low steady-state participation rate of 5% for this offering.

Third Party Contracts (currently ConnectedSolutions)

Third Party Contracts are assumed to be available for commercial and industrial customers year-round. For the Industrial customers, it is assumed they will engage in firm curtailment. Under this offering, it is assumed that participating customers will agree to reduce demand by a specific amount or curtail their consumption to a predefined level at the time of an event. Unitil currently offers an industrial curtailment program through ConnectedSolutions. This offering provides $25 per kW reduced during events with no penalty for non-participation. Events are three hours in length and occur during summer months (June-September) for up to eight events.

As an expansion to the current offering, AEG holds the industrial customers at their current participation level (three participants), but simulates a demand buyback program for commercial customers. In a demand buyback program, customers volunteer to reduce what they can on a day-ahead or day-of basis during a predefined event window. Customers then receive an energy payment based on their performance during the events.

Electric Vehicle DLC Smart Chargers

DLC Smart Chargers for electric vehicles can be switched off during on-peak hours throughout the year to shift demand to off-peak hours. This offering is assumed to be a BYOD offering with no equipment costs to Unitil.

Battery Energy Storage

This offering provides the ability to shift peak loads using stored electrochemical energy. Currently the main battery storage equipment uses lithium-ion batteries, the most cost-effective battery type on the market today. We assume the battery energy storage option will be available for all service classes with the size and cost of the battery varying depending upon the level of demand of the building. For residential, AEG used the 2019 Residential Energy Storage Demand Response Pilot (BLU). Interestingly, Unitil has tried a Battery Energy Storage Program in the past in their residential sector, but the vendor stopped communicating with Unitil staff and the offering lost steam.

Other Offerings Considered

Several other offerings were considered but ended up being excluded from the analysis. In the case of direct load control of central air conditioners, smart thermostats were selected as the more favorable option in the territory. In addition, the current Unitil ConnectedSolutions offering already uses smart thermostats for demand response.

CTA-2045 water heater modules are becoming a popular option across the United States where some states (Washington for example) are mandating these be phased in over the next few years. These modules attach to a customer's water heater to make it grid-enabled where it can be communicated with directly, and be able to shed during DR events. These were not considered for the Unitil territory due to lack of saturation and no plans for Massachusetts to mandate them in the future.

Behavioral demand response was not considered in the Unitil territory due to a lack of AMI saturation.

Program Assumptions and Characteristics

This section includes the key assumptions used for potential impacts, TRC tests, and levelized costs for each offering selected for this study. Levelized costs provide another way to examine and compare the cost-effectiveness of the offerings in the form of $/kW reduced. The development of these assumptions is based on findings from research and review of available information on the topic, including national program survey databases, evaluation studies, program reports, and regulatory filings. Wherever possible, AEG used assumptions from similar offerings run in the state of Massachusetts. The key parameters required to estimate potential for a demand response program are steady-state participation rate, per-participant load reduction, and program costs. We have described below our assumptions of these parameters.

Participation Rate Assumptions

Table 6-6 shows the steady-state participation rate assumptions for each offering as well as the basis for the assumptions. As more DR offerings are implemented around the country and results become available, AEG picks the most recent reliable program data available to use for the offering assumptions. Where available, AEG used offering assumptions based on historical program performance in MA. For current offerings, a recent robust study of DR program participation rates and impacts was performed by the Northwest Power and Conservation Council (NWPCC) in 2019. These assumptions formed the basis for most of the offering assumptions used in this study. However, where NWPCC assumptions didn't exist, AEG used the next best available sourcing that would best represent the Unitil territory.

Most offerings follow a participation ramp rate of five years to reach steady-state participation levels, but Third-Party Contracts follow a three-year ramp rate due to the third-party implementer's ability to expedite the program rollout. Table 6-5 shows the ramp rate schedules for three- and five-year ramping offerings. All offerings are expected to be slightly front-loaded with most of the marketing occurring early on. Since this study focuses on a three-year window, the offerings which have a five-year ramp rate will only reach 70% of their expected steady-state participation rate by 2024.

Table 6-5 Offering Ramp Rate Schedules

	Year 1	Year 2	Year 3	Year 4	Year 5
Offering Ramp Years					
3	50%	80%	100%	100%	100%
5	10%	30%	70%	90%	100%

Table 6-6 Unitil Offering Steady-State Participation Rates

DSM Option	Ramp Years	Residential	Commercial	Industrial	Sourcing
DLC Smart Thermostats - Cooling	5	20%[26]	10%		NWPCC Smart Thermostat cooling assumption. Residential participation calibrated to start at 325 customers in 2022 according to numbers provided by Unitil.
DLC Water Heating	5	15%			Best estimate based on industry experience – in line with other DR offerings
DLC Electric Vehicle Charging	5	25%			NWPCC Electric Resistance Grid-Ready Participation
DLC Smart Appliances	5	5%	5%		2015 ISACA IT Risk Reward Barometer - US Consumer Results. October 2015.
Battery Energy Storage	5	5%	5%	5%	Best estimate based on industry experience.
Third Party Contracts	3		5%	3	Best estimate based on industry experience. Industrial participation based on Unitil's current Industrial Curtailment participation level of 3 customers.[27]

Load Reduction Assumptions

Table 6-7 presents the per-participant load reductions for each demand response option and explains the basis for these assumptions. The load reductions are shown on a kW basis for technology-based options and a percent load reduction otherwise.

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[26] Residential steady-state participation was lowered to 10% in the BAU Plus scenario to be more in line with the current Residential WIFI participants. Participation reaches 820 by 2024 under this scenario. Maximum Achievable steady-state participation is set to 20% and reaches 1640 participants by 2024.

[27] For Technical Potential, industrial steady-state participation was maxed at 5%.

Table 6-7 Unitil Summer Load Reduction Assumptions (kW except as noted)

DSM Option	Residential	Commercial	Industrial	Sourcing
DLC Smart Thermostats - Cooling	0.5	1.3		NWPCC DLC Central AC Cooling Assumption
DLC Water Heating	0.5			NWPCC Electric Resistance Switch Impact
DLC Electric Vehicle Charging	0.5			Based on Avista EVSE program (2019)
DLC Smart Appliances	0.1	0.1		Ghatikar, Rish. Demand Response Automation in Appliance and Equipment. Lawrence Berkley National Laboratory, 2015.
Battery Energy Storage	1.3	2.0	15.0	Residential uses the average kW impact per customer from the MA TRM. Commercial and Industrial kW values are based on average size of battery per segment
Third Party Contracts		10%	297.0	Commercial is the weighted average impacts from report: Impact Estimates from Aggregator Programs in California (Source: 2019 Statewide Load Impact Evaluation of California Aggregator Demand Response Programs). Industrial is calibrated to average customer on current curtailment program

Program Costs

Table 6-8 shows the annual O&M and equipment costs per offering used in the analysis. Table 6-9 presents the annual marketing and incentive costs per participant as well as the full offering administrative and development costs that AEG estimates it would take to run each offering. Incentives are shown for the BAU and BAU Plus cases, however to achieve greater participation for the Maximum Achievable and Technical Potential offerings, incentives were increased by 50% in the Maximum Achievable scenario and 100% for the Technical Potential scenario. When available, offering costs were based on the current cost of running Unitil's Residential WIFI and Industrial Curtailment Programs but rely on other similar offerings around the country for equipment and other specific offering costs. For Third Party Contracts, AEG calibrated the total offering cost it took to achieve 1 MW of savings using all offering costs (including incentives) it took to achieve 890 MW of savings on the current Industrial Curtailment Program. Since this is a performance-based offering, all costs are represented as O&M costs per MW.

Table 6-8 Unitil O&M and Equipment Costs Per Offering

DSM Option	Annual O&M Cost Per Participant	Annual O&M Cost per MW	Cost of Equip + Install Per Participant
DLC Smart Thermostats - Cooling	$8		
DLC Water Heating	$26		$330
DLC Electric Vehicle Charging	$10		
DLC Smart Appliances	$26		
Battery Energy Storage	$44	$10,000	
Third Party Contracts		$38,776	

Table 6-9 Unitil Marketing, Incentive, Development, and Administrative Costs Per Offering

DSM Option	Annual Marketing/ Recruitment Cost Per Participant	Annual Incentive Per Participant[28]	Offering Development Cost	Offering Admin Cost
DLC Smart Thermostats - Cooling	$35	$40	$30,000	$50,000
DLC Water Heating	$30	$15	$27,000	$32,400
DLC Electric Vehicle Charging	$50	$22	$27,000	$32,400
DLC Smart Appliances	$30	$15	$27,000	$32,400
Battery Energy Storage	$50	$50	$18,000	$32,400
Third Party Contracts[29]	N/A	N/A	N/A	N/A

Other Cross-Cutting Assumptions

In addition to the above offering-specific assumptions, there are two that affect all offerings:

- Discount rate. We used a real discount rate of 0.81%[30] to calculate the net present value (NPV) of costs over the useful life of each DR offering. All cost results are shown in real dollars.
- Line losses. Unitil provided a line loss factor of 8.00% to convert estimated demand savings at the customer meter level to demand savings at the generator level. In the next section, we report our analysis results at the generator level.

Overall Potential Results by Season

AEG presents the following potential savings for the BAU, BAU Plus, and Maximum Achievable scenarios.[31] Overall demand response summer potential savings for 2022 through 2024 are presented in Table 6-10. The projected baseline values are in terms of MW @ Generation and are based on the MW @ Meter baseline calculation in Table 6-2 and applying the 8% line loss. BAU potential is made up solely of the current Unitil offerings holding the current participation levels constant for the remainder of the planning cycle. With 325 customers expected on the residential offering in 2022 at an average impact of 0.5 kW, and three industrial customers with an average impact of 297 kW, the current offerings are expected to reach 1.14 MW per year, or 2.8% of the baseline projection. The inclusion of all offerings in the BAU Plus and Maximum Potential options represent a slight increase from BAU in 2022 but each grow to nearly triple the MW of the BAU scenario by 2024.

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[28] Incentives are increased by 50% for the Maximum Achievable scenario

[29] For Third Party Contracts all costs are shown as O&M costs per MW of demand reduced. Costs per MW were calibrated to current Unitil C&I curtailment program.

[30] 2021 Avoided Energy Supply Components (AESC) final draft results for the state of Massachusetts

[31] Technical potential was also evaluated but the results are not included in this report due to the unrealistic nature of 100% participation. Please see the supplemental DR workbook for Technical Potential Results.

Table 6-10 Unitil Overall Demand Response Summer Potential for Planning Cycle

DSM Option	2022	2023	2024
Baseline Forecast (MW)	**94.3**	**94.5**	**94.6**
Annual Savings (MW)			
Achievable BAU Potential	1.14	1.14	1.14
Achievable BAU Plus Potential	1.30	1.71	2.63
Achievable Maximum Potential	1.33	1.86	2.96
Energy Savings (% of baseline)			
Achievable BAU Potential	1.2%	1.2%	1.2%
Achievable BAU Plus Potential	1.4%	1.8%	2.8%
Achievable Maximum Potential	1.4%	2.0%	3.1%

The overall costs and benefits for the potential shown in Table 6-10 in terms of net present value are presented in Table 6-11. Costs increase under each scenario as more participants are included on the offerings. Costs are highest in the first year due to initial marketing and recruitment costs. In the case of Water Heating, there is also a one-time fixed equipment cost for the DLC switch installed on the unit. In each scenario, the benefits outweigh the costs however, the cost tests by offering shown in the "Offering Costs and Tests" section below show that most offerings are not cost-effective when examined individually.

Table 6-11 Unitil Overall Summer Net Present Value of Costs and Benefits for Planning Cycle

	2022	2023	2024
NPV Costs			
BAU	$77,820	$66,534	$66,530
BAU Plus	$277,460	$324,714	$431,734
Maximum Achievable	$294,254	$362,138	$552,837
NPV Benefits			
BAU	$517,652	$510,124	$505,121
BAU Plus	$566,681	$651,677	$784,946
Maximum Achievable	$576,486	$685,848	$1,006,828

Demand response overall winter potential savings for 2022 through 2024 are presented in Table 6-12. It should be noted that under the current AESC avoided costs, there are no benefits from winter curtailment and these results are presented for illustrative purposes only. The achievable BAU potential is 0.97 MW per year, or 1.2% of the baseline projection which represents the industrial curtailment program only as the thermostat program drops off during winter. The BAU Plus and Maximum Achievable options represent a slight increase from 2022 BAU savings but grow to over 150% of BAU savings by 2024. Since the only difference between the summer and winter options is the inclusion or exclusion respectively of the Smart Thermostats - Cooling Program, the rest of the results reflect summer-only impacts so show all offerings evaluated. Costs and Benefits in terms of NPV are not shown for winter in this report but it should be noted that they are very similar to the summer costs and benefits.

Table 6-12 Unitil Overall Demand Response Winter Potential for Planning Cycle

DSM Option	2022	2023	2024
Baseline Forecast (MW)	**80.7**	**81.0**	**81.0**
Annual Savings (MW)			
Achievable BAU Potential	0.97	0.97	0.97
Achievable BAU Plus Potential	1.08	1.24	1.50
Achievable Maximum Potential	1.10	1.29	1.61
Energy Savings (% of baseline)			
Achievable BAU Potential	1.2%	1.2%	1.2%
Achievable BAU Plus Potential	1.3%	1.5%	1.9%
Achievable Maximum Potential	1.4%	1.6%	2.0%

Residential Demand Response Potential

Table 6-13 presents the residential demand response potential. This includes the incremental savings from 2022 through 2024 for each offering. The BAU case only shows the Smart Thermostats - Cooling offering which is held constant at 0.177 kW. The BAU Plus potential savings for all residential DR offerings in 2022 is .230 MW and grows to 0.680 MW by 2024 with most of the savings' contributions coming from Water Heaters and Smart Thermostats. Battery Energy Storage, DLC Electric Vehicle Charging, and DLC Smart Appliances make up a small portion of the total potential savings. With the increase in participation levels, the Maximum Achievable potential scenario reaches 1.059 MW by 2024.

Table 6-13 Unitil Residential Demand Response Summer Potential for Planning Cycle

DSM Option	2022	2023	2024
Battery Energy Storage (MW)			
Achievable BAU Plus Potential	0.002	0.005	0.012
Achievable Maximum Potential	0.002	0.006	0.014
DLC Electric Vehicle Charging (MW)			
Achievable BAU Plus Potential	0.001	0.003	0.006
Achievable Maximum Potential	0.001	0.003	0.007
DLC Smart Appliances (MW)			
Achievable BAU Plus Potential	0.012	0.036	0.086
Achievable Maximum Potential	0.014	0.044	0.103
DLC Smart Thermostats – Cooling (MW)			
Achievable BAU Potential	0.177	0.177	0.177
Achievable BAU Plus Potential	0.177	0.234	0.304
Achievable Maximum Potential	0.177	0.255	0.609
DLC Water Heating (MW)			
Achievable BAU Plus Potential	0.038	0.116	0.272
Achievable Maximum Potential	0.046	0.139	0.326
Total Achievable BAU	**0.177**	**0.177**	**0.177**
Total Achievable BAU Plus	**0.230**	**0.393**	**0.680**
Total Achievable Maximum Potential	**0.240**	**0.447**	**1.059**

C&I Demand Response Potential

Table 6-14 presents the C&I demand response potential. This includes the incremental savings from 2022 through 2024 for each type of offering. The BAU case represents the three industrial customers currently on Unitil's Industrial Curtailment Program. The BAU Plus and Maximum Potential scenarios project commercial customers to participate at 10% of their average peak demand. These results mostly reflect commercial impacts as industrial customers are only projected to participate in Battery Storage and Third Party Contract Programs due to barriers to entry such as the current C&I building infrastructure in the Unitil territory, and program design and start up challenges. The total achievable BAU Plus potential savings for all C&I DR offerings in 2022 is 1.031 MW which is mostly driven by Third Party Contracts. BAU Plus and Maximum Potential reach 1.33 and 1.4 MW by 2024 respectively.

Table 6-14 Unitil C&I Demand Response Summer Potential for Planning Cycle

DSM Option	2022	2023	2024
Battery Energy Storage (MW)			
Achievable BAU Plus Potential	0.000	0.001	0.003
Achievable Maximum Potential	0.001	0.002	0.004
DLC Smart Appliances (MW)			
Achievable BAU Plus Potential	0.007	0.021	0.049
Achievable Maximum Potential	0.008	0.025	0.058
DLC Smart Thermostats – Cooling (MW)			
Achievable BAU Plus Potential	0.026	0.079	0.186
Achievable Maximum Potential	0.031	0.095	0.223
Third Party Contracts (MW)			
Achievable BAU Potential	0.967	0.968	0.968
Achievable BAU Plus Potential	1.031	1.070	1.095
Achievable Maximum Potential	1.044	1.090	1.120
Total Achievable BAU	**0.967**	**0.968**	**0.968**
Total Achievable BAU Plus	**1.064**	**1.170**	**1.333**
Total Achievable Maximum Potential	**1.084**	**1.211**	**1.406**

Offering Costs and Tests

After determining potential under each scenario over the study window, AEG performed a Total Resource Cost (TRC) test for each scenario and calculated levelized costs per kW of equivalent generation capacity over 2022-2026 for all offerings by sector grouping (residential, C&I). A five-year horizon was used to calculate the cost results as that ensures all offerings are fully ramped by the end of the time frame as opposed to partially ramped by the end of the three-year study window and will provide a better sense of full offering costs and benefits.

The TRC test includes all offering costs to Unitil including incentive costs. The benefits are calculated using avoided costs from the 2021 AESC final draft results for the state of Massachusetts which are then multiplied by the impacts for each program year[32]. The net present value (NPV) is then taken on the five-year cost/benefit outlay to get both into terms of present value. The final TRC ratio is the NPV of benefits over the NPV of costs. A ratio greater than one passes the test.

$$Benefits = NPV(Program\ Impacts * Avoided\ Costs)$$

$$Costs = NPV(NonIncentive\ Program\ Costs)$$

$$TRC\ Ratio = Benefits/Costs$$

For DR, levelized costs represent the total cost it would require reducing demand by one kW given the total cost of an offering over the five-year outlay mentioned above. The same NPV Costs that were used for the TRC Ratio are used for the levelized cost calculations. The levelized costs are shown in conjunction with the TRC test to show the cost per kW of savings for each offering while removing the aspect of avoided costs from the equation. Levelized costs are captured as the ratio of the five-year offering potential outlay over the five-year offering cost outlay as shown in the equation below. The net present value is taken on each impact/cost outlay to get each in terms of present value prior to the final calculation.

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[32] The one exception to this was for Smart Thermostats where the current Residential WIFI program's avoided costs calculated to be $600/kW were used to calculate the benefits

$$Levelized\ Costs\ (\$/kW) = NPV(Program\ Costs)/NPV(Program\ Potential)$$

Cost Effectiveness Results by Scenario

For the cost results, we present the cost-effectiveness tables for the BAU, BAU Plus, and Maximum Achievable scenarios which incorporate the costs and benefits used for the TRC test as well as the levelized costs of each offering. In addition, each table shows the NPV of the offering impact over the five-year horizon. While demand potential is viewed as an instantaneous value on an annual basis, in order to view the total program potential over the full five years, the net present value is taken on the full five year potential horizon.

BAU

Table 6-15 shows the cost-effectiveness results for residential offerings under the BAU scenario. Over the planning period, the benefits are projected to outweigh the costs for the current Residential Smart Thermostats- Cooling offering if participation remained constant at the projected 2022 levels (325 participants). Based on the TRC test, Unitil's current Residential WIFI offering passes with a ratio of 3.04. The levelized costs of the offering are $197 per kW.

Table 6-15 Unitil BAU Residential Offering Cost-Effectiveness

	NPV of Impact (MW)	**NPV of Costs**	**NPV of Benefits**	**B/C Ratio (TRC)**	**Levelized Costs ($/kW)**
DLC Smart Thermostats-Cooling	0.86	$170,168	$517,025	**3.04**	$197

Table 6-16 shows the cost-effectiveness results for C&I offerings under the BAU scenario. Under the BAU scenario, the current industrial curtailment offering is held constant at Pre-COVID participation levels. This offering passes the TRC test with a B/C ratio of 11.50. The levelized costs of the offering are $36 per kW.

Table 6-16 Unitil BAU C&I Offering Cost-Effectiveness

	NPV of Impact (MW)	**NPV of Costs**	**NPV of Benefits**	**B/C Ratio (TRC)**	**Levelized Costs ($/kW)**
Third Party Contracts	4.72	$168,456	$1,937,724	**11.50**	$36

BAU Plus

Table 6-17 presents the Total Resource Cost (TRC) test and levelized costs per kW of equivalent generation capacity over 2022-2026 for the residential offerings in the BAU Plus scenario. Under this scenario, all offerings are considered and grow to the steady-state participation levels found in Table 6-6.[33] The DLC Smart Thermostats- Cooling Offering passes the TRC test with a ratio of 3.72 with a levelized cost of $161 per kW. As additional customers participate in the Smart Thermostat offering each year, the overall DR impact increases while costs to the utility remain fairly stable. New participants require a one-time marketing/recruitment cost however offering and administrative costs remain constant leading the impacts to grow at a faster rate than costs.

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[33] The mechanism for the increased participation from Unitil's current Residential WIFI and Industrial Curtailment (BAU to BAU Plus scenario) is through additional marketing and recruitment with no increase to incentives. Incentives are increased by 50% in the Maximum Achievable Scenario.

Table 6-17 Unitil BAU Plus Residential Offering Cost Effectiveness

	NPV of Impact (MW)	NPV of Costs	NPV of Benefits	B/C Ratio (TRC)	Levelized Costs ($/kW)
Battery Energy Storage	0.05	$127,545	$6,930	0.05	$2,554
DLC Electric Vehicle Charging	0.03	$177,830	$4,935	0.03	$6,889
DLC Smart Appliances	0.36	$252,626	$74,561	0.30	$707
DLC Smart Thermostats-Cooling	1.52	$245,017	$911,084	**3.72**	$161
DLC Water Heating	1.13	$432,932	$339,879	0.79	$382

Table 6-18 shows the results of the C&I TRC test and levelized costs by offering. In the case of C&I, both the DLC Smart Thermostat – Cooling and Third Party Contract Programs pass the TRC test. Third Party Contracts have both the lowest levelized costs ($34 per kW) and the highest B/C ratio of 12.10.

Table 6-18 Unitil BAU Plus C&I Offering Cost Effectiveness

	NPV of Impact (MW)	NPV of Costs	NPV of Benefits	B/C Ratio (TRC)	Levelized Costs ($/kW)
Battery Energy Storage	0.01	$39,705	$2,590	0.07	$2,767
DLC Smart Appliances	0.20	$110,512	$42,569	0.39	$542
DLC Smart Thermostats-Cooling	0.78	$218,073	$140,753	0.65	$280
Third Party Contracts	5.25	$176,938	$2,153,457	12.17	$34

Maximum Achievable

Table 6-19 presents the Total Resource Cost (TRC) test and levelized costs per kW of equivalent generation capacity over 2022-2026 for the residential offerings in the Maximum Achievable scenario. Under this scenario, participation is increased by 20% over the BAU Plus scenario. To achieve this, incentives were increased by 50% over the BAU Plus case. For the Maximum Achievable scenario, the DLC Smart Thermostats- Cooling Program passes the TRC test with a ratio of 3.38 and a levelized cost of $177 per kW.

Table 6-19 Unitil Maximum Achievable Residential Offering Cost Effectiveness

	NPV of Impact (MW)	NPV of Costs	NPV of Benefits	B/C Ratio (TRC)	Levelized Costs ($/kW)
Battery Energy Storage	0.06	$129,105	$8,103	0.06	$2,211
DLC Electric Vehicle Charging	0.03	$179,345	$5,923	0.03	$5,790
DLC Smart Appliances	0.43	$297,730	$89,473	0.30	$695
DLC Smart Thermostats-Cooling	2.65	$470,759	$1,591,708	**3.38**	$177
DLC Water Heating	1.36	$519,444	$407,855	0.79	$382

Table 6-20 shows the results of the C&I TRC test and levelized costs by offering. In the case of C&I, Third Party Contracts pass the TRC test with a ratio of 12.30. Third Party Contracts also have the lowest levelized costs of $33 per kW.

Table 6-20 Unitil Maximum Achievable C&I Offering Cost Effectiveness

	NPV of Impact (MW)	**NPV of Costs**	**NPV of Benefits**	**B/C Ratio (TRC)**	**Levelized Costs ($/kW)**
Battery Energy Storage	0.02	$39,880	$3,103	0.08	$2,319
DLC Smart Appliances	0.24	$136,295	$51,083	0.37	$557
DLC Smart Thermostats-Cooling	0.94	$240,280	$168,904	0.70	$257
Third Party Contracts	5.36	$178,635	$2,196,603	**12.30**	$33

7

ENERGY OPTIMIZATION

AEG assessed the potential for customer energy optimization (a.k.a. fuel switching) separately from the broader energy efficiency analysis to avoid confusion from overlapping *savings* from energy efficiency measures with *increased* consumption from conversions. When reported together, this can produce a distorted view of overall energy potential.

AEG used the same market characterization data that served as the foundation for the energy efficiency results to provide a baseline for energy optimization as well. However, unlike electricity and natural gas, Unitil does not have customer billing data for oil, distillates, or propane, so there is no calibration step to match actual consumption. Instead, values for the share of customers using these fuels and the expected MMBTU savings per conversion come directly from the Massachusetts statewide baseline studies and Massachusetts Technical Reference Manual, respectively.

Methodology and data sources for the energy optimization analysis including market characterization are described in Chapter 2, as is the description of how the different achievable cases and participation rates were defined for energy optimization.

Energy Optimization Available Market

As noted above, the base population for energy optimization was based partly on analysis completed for the energy efficiency study and partly on available MA statewide data. The following table summarizes the number of market units (residential - households, commercial – served floor space) using each fuel for the specified end use.

Table 7-1 Energy Optimization Eligible Market Size

End Use	Fuel	Residential Households	Commercial Square Feet
Space Heating	Natural Gas	17,068	13,307,348
	Oil	9,414	704,529
	Propane	1,924	0
Water Heating	Natural Gas	12,032	9,198,586
	Oil	208	784,531
	Propane	104	223,346

Energy Optimization Results

The achievable potential presented here is organized by the existing fuel being converted. Top measures across fuels are shown following the individual fuel tables.

Natural Gas Conversions

AEG's analysis found that conversion of residential natural gas space heating equipment to either central or ductless heating equipment is not cost-effective. However, residential water heating does have cost-effective energy optimization potential. On the commercial side, conversion from gas furnaces is not cost-effective, however converting from gas boilers (either full or partial) is cost-effective for some customer segments.

Only totals are shown here for brevity, but measure level results across all fuels are shown later.

Note that throughout this section, *savings* are shown as positive values, and *increased load* is shown as negative values.

Table 7-2 Natural Gas Conversion Potential

Natural Gas Conversion Measures	Business as Usual			BAU Plus			Max Achievable		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Natural Gas Impact (Annual MMBTU)	328	328	328	2,163	2,163	2,163	5,912	5,912	5,912
Electric Impact (Annual MWh)	-18.2	-18.2	-18.2	-42.4	-42.4	-42.4	-74.0	-74.0	-74.0
Summer Peak (kW)	-4.1	-4.1	-4.1	-11.4	-11.4	-11.4	-22.9	-22.9	-22.9
Winter Peak (kW)	-4.1	-4.1	-4.1	-11.2	-11.2	-11.2	-22.2	-22.2	-22.2

Fuel Oil Conversions

Fuel oil dominates Unitil's current fuel switching programs, accounting for more than 117 of the 131 conversion projects achieved over the past two years, most of which have been partial or supplemental conversions using ductless mini-split systems. Our analysis shows that converting oil water heaters is also cost effective, though there has not been participation in this measure yet. Our projection assumes a small number of oil water heater customers will participate during the planning period. For commercial, conversion from oil-fired boiler heating is cost effective for all customer segments, however total savings are limited by the relatively low amount of commercial buildings with oil-fired heating in Unitil's territory. Again, for brevity only totals are shown here, and measure level results across fuels are shown later.

Table 7-3 Fuel Oil Conversion Potential

Fuel Oil Conversion Measures	Business as Usual			BAU Plus			Max Achievable		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Fuel Oil Impact (Annual MMBTU)	3,351	3,351	3,351	3,754	3,754	3,754	5,244	5,244	5,244
Electric Impact (Annual MWh)	-250	-250	-250	-276	-276	-276	-379	-379	-379
Summer Peak (kW)	-15.5	-15.5	-15.5	-17.9	-17.9	-17.9	-25.9	-25.9	-25.9
Winter Peak (kW)	-33.0	-33.0	-33.0	-36.8	-36.8	-36.8	-51.0	-51.0	-51.0

Propane Conversions

Customers converting from propane heating to electric have been fewer in number than those converting from oil in Unitil's past program participation. Like fuel oil conversions, these have heavily favored partial conversions using ductless mini-split systems. Also similar to fuel oil, converting from a propane water heater to an electric HPWH is cost effective, but has not had participation since the incentive has been offered. Our projection assumes a small number of propane water heater customers will participate during the planning period. Propane space heat conversions were not evaluated for the commercial sector due to the minimal presence of this customer configuration. Again, for brevity only totals are shown here, and measure level results across fuels are shown later.

Table 7-4 Propane Conversion Potential

Propane Conversion Measures	Business as Usual			BAU Plus			Max Achievable		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Propane Impact (Annual MMBTU)	425	425	425	468	468	468	639	639	639
Electric Impact (Annual MWh)	-28.4	-28.4	-28.4	-31.4	-31.4	-31.4	-42.8	-42.8	-42.8
Summer Peak (kW)	-1.8	-1.8	-1.8	-2.0	-2.0	-2.0	-2.7	-2.7	-2.7
Winter Peak (kW)	-3.7	-3.7	-3.7	-4.1	-4.1	-4.1	-5.6	-5.6	-5.6

Total Energy Optimization Potential

Total potential for the energy optimization is shown in Table 7-5.

Table 7-5 Total Energy Optimization Potential – All Fuels, 2022-2024 total annual savings

Potential Case	Gas MMBTU	Oil MMBTU	Propane MMBTU	Electric MWh Impact	Summer Peak	Winter Peak
BAU Potential	985	1,005	127	-891	-0.1	-0.1
BAU Plus Potential	6,490	1,126	141	-1,051	-0.1	-0.2
Max Achievable	17,737	1,573	192	-1,486	-0.2	-0.2
Economic Potential	156,716	7,846	1,898	-12,744	-1.9	-2.5
Technical Potential	292,247	8,248	2,070	-18,268	-5.9	-6.1

Table 7-6 shows the estimated utility costs associated with the above potential. As on the energy efficiency side, these are estimates only based on the average incentives provided during 2019 and 2020 program activity, and Unitil's actual costs will necessarily vary.

Table 7-6 Energy Optimization Estimated Utility Costs

Case	Sector	2022	2023	2024
BAU	Residential	$206,835	$206,835	$206,835
	Commercial	$0	$0	$0
BAU Plus	Residential	$463,129	$463,129	$463,129
	Commercial	$86,209	$86,209	$86,209
BAU Max	Residential	$1,267,985	$1,267,985	$1,267,985
	Commercial	$563,967	$563,967	$563,967
BAU	**Total**	**$206,835**	**$206,835**	**$206,835**
BAU Plus	**Total**	**$549,339**	**$549,339**	**$549,339**
BAU Max	**Total**	**$1,831,951**	**$1,831,951**	**$1,831,951**

Potential by measure for the achievable cases case is shown in Table 7-7, Table 7-8, and Table 7-9 that follow.

Table 7-7 BAU Energy Optimization Potential by Measure

Sector	Measure	Gas Impact (MMBTU)	Fuel Oil Impact (MMBTU)	Propane Impact (MMBTU)	Electricity Impact (MWh)	Summer Peak Impact (kW)	Winter Peak Impact (kW)
Res	Ductless Mini Split HP Partially displacing Oil space heating	0	8,027	0	-616.3	-38.0	-61.8
Res	Ductless Mini Split HP Fully displacing Oil space heating	0	1,335	0	-75.8	-4.7	-28.8
Res	Ductless Mini Split HP Partially displacing Propane space heating	0	0	730	-56.8	-3.5	-5.7
Res	Electric Heat Pump Water Heater replacing Natural Gas water heater	985	0	0	-54.7	-12.3	-12.3
Res	ASHP Partially displacing Oil space heating	0	556	0	-50.0	-3.1	-5.0
Res	ASHP Partially displacing Propane space heating	0	0	389	-19.4	-1.2	-1.9
Res	Ductless Mini Split HP Fully displacing Propane space heating	0	0	150	-8.6	-0.5	-3.3
Res	ASHP Fully displacing Oil space heating	0	127	0	-8.5	-0.5	-3.2
Res	Electric Heat Pump Water Heater replacing Oil-fired water heater	0	8	0	-0.7	-0.2	-0.2
Res	Electric Heat Pump Water Heater replacing Propane-fired water heater	0	0	4	-0.4	-0.1	-0.1
	Total	**985**	**10,053**	**1,274**	**-891.2**	**-64.0**	**-122.3**

Table 7-8 BAU+ Energy Optimization Potential by Measure

Sector	Measure	Gas Impact (MMBTU)	Fuel Oil Impact (MMBTU)	Propane Impact (MMBTU)	Electricity Impact (MWh)	Summer Peak Impact (kW)	Winter Peak Impact (kW)
Res.	Ductless Mini Split HP Partially displacing Oil space heating	0	8,829	0	-677.9	-41.8	-68.0
Res.	Electric Heat Pump Water Heater replacing Natural Gas water heater	1,971	0	0	-109.4	-24.5	-24.5
Res.	Ductless Mini Split HP Fully displacing Oil space heating	0	1,469	0	-83.4	-5.1	-31.7
Res.	Ductless Mini Split HP Partially displacing Propane space heating	0	0	803	-62.4	-3.8	-6.3
Res.	ASHP Partially displacing Oil space heating	0	612	0	-55.0	-3.4	-5.5
Res.	ASHP Partially displacing Propane space heating	0	0	428	-21.4	-1.3	-2.1
Res.	Ductless Mini Split HP Fully displacing Propane space heating	0	0	165	-9.5	-0.6	-3.6
Res.	ASHP Fully displacing Oil space heating	0	140	0	-9.3	-0.6	-3.5
Res.	Electric Heat Pump Water Heater replacing Oil-fired water heater	0	17	0	-1.5	-0.3	-0.3
Res.	Electric Heat Pump Water Heater replacing Propane-fired water heater	0	0	9	-0.8	-0.2	-0.2
Com.	ASHP fully replacing Natural Gas Boiler	2,329	0	0	-14.6	-9.1	-7.2
Com.	ASHP partially displacing Natural Gas Boiler	106	0	0	-1.6	-0.5	-1.3
Com.	ASHP fully replacing Oil-fired Boiler	0	143	0	-1.5	-1.2	-0.8
Com.	Electric Heat Pump water heating replacing Natural Gas water heating	2,083	0	0	-1.4	-0.1	-0.6
Com.	ASHP fully replacing Oil-fired Furnace	0	17	0	-0.6	-0.9	-0.3
Com.	ASHP partially displacing Oil-fired Boiler	0	36	0	-0.3	-0.2	-0.2
	Total	**6,490**	**11,262**	**1,405**	**-1,050.6**	**-93.8**	**-156.2**

Table 7-9 BAU Max Energy Optimization Potential by Measure

Sector	Measure	Gas Impact (MMBTU)	Fuel Oil Impact (MMBTU)	Propane Impact (MMBTU)	Electricity Impact (MWh)	Summer Peak Impact (kW)	Winter Peak Impact (kW)
Res.	Ductless Mini Split HP Partially displacing Oil space heating	0	12,040	0	-924.4	-57.0	-92.8
Res.	Electric Heat Pump Water Heater replacing Natural Gas water heater	2,956	0	0	-164.2	-36.8	-36.8
Res.	Ductless Mini Split HP Fully displacing Oil space heating	0	2,003	0	-113.7	-7.0	-43.2
Res.	Ductless Mini Split HP Partially displacing Propane space heating	0	0	1,095	-85.1	-5.2	-8.5
Res.	ASHP Partially displacing Oil space heating	0	834	0	-75.0	-4.6	-7.5
Res.	ASHP Partially displacing Propane space heating	0	0	583	-29.1	-1.8	-2.9
Res.	Ductless Mini Split HP Fully displacing Propane space heating	0	0	225	-13.0	-0.8	-4.9
Res.	ASHP Fully displacing Oil space heating	0	191	0	-12.7	-0.8	-4.8
Res.	Electric Heat Pump Water Heater replacing Oil-fired water heater	0	25	0	-2.2	-0.5	-0.5
Res.	Electric Heat Pump Water Heater replacing Propane-fired water heater	0	0	13	-1.2	-0.3	-0.3
Com.	ASHP fully replacing Natural Gas Boiler	7,619	0	0	-47.8	-29.9	-23.4
Com.	ASHP partially displacing Natural Gas Boiler	347	0	0	-5.2	-1.6	-4.3
Com.	ASHP fully replacing Oil-fired Boiler	0	467	0	-4.8	-4.1	-2.6
Com.	Electric Heat Pump water heating replacing Natural Gas water heating	6,814	0	0	-4.7	-0.4	-1.9
Com.	ASHP fully replacing Oil-fired Furnace	0	55	0	-1.9	-3.0	-1.1
Com.	ASHP partially displacing Oil-fired Boiler	0	118	0	-1.1	-0.7	-0.6
	Total	**17,737**	**15,733**	**1,917**	**-1,486.2**	**-154.4**	**-236.2**

8

INSIGHTS AND CONCLUSIONS

Unitil 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 Unitil has areas of strong success and that, in several cases, acquiring additional potential beyond current performance may be challenging.

High Performing Programs

- Residential Weatherization. (Electric and Natural Gas) Unitil'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. (Electric and Natural Gas) Activity for this offering is modestly higher than AEG's typical take rates, indicating a mature, robust program.
- Commercial Water Savings. (Natural Gas) This category includes measure such as faucet aerators, restaurant sprayer valves, and low flow showerheads. Unitil's program activity in these measures is much higher than AEG commonly sees in other territories.
- Ductless Mini-Split Heat Pumps (displacing or replacing electric resistance heat) and Smart Power Strips also show high activity.

Possible Opportunities for Growth

- Residential Gas Water Heating Equipment. Current participation levels are low compared to modeled equipment turnover rates based on generally accepted equipment lifetimes, suggesting there may be additional units that require replacement but are not coming through the program, possibly due to the often emergent nature of these replacements.
- Residential Refrigerators and Other ENERGY STAR Appliances. Unitil's offerings to date have focused on retirement of aging but still functional equipment, where there are significant savings. However, there is cost effective potential even in offering customers a rebate for choosing ENERGY STAR appliances over current standard models.

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[34] 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.

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[34] Pre-Weatherization Barrier analysis, data taken from RISE and provided by Unitil

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.[35]

Elimination of Lighting from the Portfolio

Another factor significantly impacting future portfolio savings for Unitil's electric programs is that the lighting market is now assumed to be fully transformed. These measures have provided the bulk of portfolio savings in past years, and as yet a new "magic bullet" that can so easily and aggressively change the landscape of energy efficiency has not been found.

Conclusions

Energy Efficiency

The measure level savings potential estimated in this study support diverse future savings for electricity and natural gas in all three customer sectors. Existing programs such as weatherization and smart thermostats continue to show strong potential over the planning period, however electric programs in particular may be challenged to find a replacement set of measure to compensate for the updated lighting baseline that removes lighting from future potential opportunities.

There is room for 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.

Demand Response

Unitil's current DR portfolio includes a residential Wi-Fi offering as well as a C&I curtailment offering. As the programs stand now, only the C&I program is cost-effective. However, if participation in the residential Wi-Fi program continues to grow as shown in the BAU Plus and Maximum Achievable scenarios, the impact from the additional participants outweighs the marketing and recruitment cost of getting them on the program. In addition, AEG found that DLC Smart Thermostats are cost-effective for small commercial customers so the offering could be expanded beyond the residential sector as well. After extensive analysis, other DR programs considered are not cost-effective in the Unitil territory.

Energy Optimization

There is still significant remaining potential to convert oil and propane heating systems to highly efficient electric models, mainly on the residential side. However, uptake of these offerings has been limited, even in the face of large incentives, and most activity in this area remains in partial displacement, not complete elimination of fossil fuels on site.

Natural gas, which has not historically been part of Unitil's fuel conversion portfolio, appears to have some limited cost-effective conversion potential for residential water heating and possibly some commercial segments, but none in residential space heating.

Use of this Potential Study

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

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

- 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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Appendix A: Adoption Rates
Unitil Gas

Sector	**Ramp Name**	**Business as Usual (BAU)**			**BAU Plus**			**BAU Max**		
		2022	***2023***	***2024***	***2022***	***2023***	***2024***	***2022***	***2023***	***2024***
Residential	LostOpp_Heating	29%	29%	29%	31%	31%	31%	46%	46%	46%
Residential	LostOpp_DHW	8%	8%	8%	9%	9%	9%	13%	13%	13%
Residential	LostOpp_Cooking	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_OtherAppliance	21%	21%	21%	23%	23%	23%	34%	34%	34%
Residential	Retro_ResWx	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	Retro_Custom	3%	3%	3%	3%	3%	3%	5%	5%	5%
Residential	Retro_Duct_Seal/Ins	7%	7%	7%	8%	8%	8%	12%	12%	12%
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	42%	42%	42%	46%	46%	46%	67%	67%	67%
Residential	Retro_Pipe_Wrap	53%	53%	53%	58%	58%	58%	85%	85%	85%
Residential	Retro_DHW_Conservation	22%	22%	22%	24%	24%	24%	35%	35%	35%
Residential	LostOpp_Heating_LI	12%	12%	12%	14%	14%	14%	15%	15%	15%
Residential	LostOpp_DHW_LI	6%	6%	6%	6%	6%	6%	7%	7%	7%
Residential	LostOpp_Cooking_LI	0%	0%	0%	88%	88%	88%	97%	97%	97%
Residential	LostOpp_OtherAppliance_LI	21%	21%	21%	23%	23%	23%	25%	25%	25%
Residential	Retro_ResWx_LI	89%	89%	89%	95%	95%	95%	100%	100%	100%
Residential	Retro_Custom_LI	2%	2%	2%	3%	3%	3%	3%	3%	3%
Residential	Retro_Duct_Seal/Ins_LI	5%	5%	5%	6%	6%	6%	6%	6%	6%
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	24%	24%	24%	26%	26%	26%	29%	29%	29%
Residential	Retro_Pipe_Wrap_LI	39%	39%	39%	43%	43%	43%	47%	47%	47%
Residential	Retro_DHW_Conservation_LI	12%	12%	12%	14%	14%	14%	15%	15%	15%
Commercial	LostOpp_HVAC_Office	6%	6%	6%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_Water heating_Office	6%	6%	6%	6%	6%	6%	8%	8%	8%
Commercial	LostOpp_Food Prep_Office	13%	13%	13%	15%	15%	15%	19%	19%	19%
Commercial	LostOpp_Other_Office	0%	0%	0%	32%	32%	32%	42%	42%	42%
Commercial	Retro_Weatherization_Office	24%	24%	24%	26%	26%	26%	34%	34%	34%
Commercial	Retro_Thermostats_Office	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Office	0%	0%	0%	17%	17%	17%	23%	23%	23%
Commercial	Retro_Process_Office	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Office	86%	86%	86%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Office	29%	29%	29%	32%	32%	32%	42%	42%	42%
Commercial	Retro_RCx_Office	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Office	17%	17%	17%	19%	19%	19%	25%	25%	25%
Commercial	LostOpp_HVAC_Retail	11%	11%	11%	12%	12%	12%	16%	16%	16%
Commercial	LostOpp_Water heating_Retail	16%	16%	16%	18%	18%	18%	23%	23%	23%
Commercial	LostOpp_Food Prep_Retail	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	LostOpp_Other_Retail	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Retail	30%	30%	30%	32%	32%	32%	43%	43%	43%
Commercial	Retro_Thermostats_Retail	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Retail	0%	0%	0%	26%	26%	26%	34%	34%	34%
Commercial	Retro_Process_Retail	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Retail	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Retail	82%	82%	82%	90%	90%	90%	90%	90%	90%
Commercial	Retro_RCx_Retail	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Retail	26%	26%	26%	28%	28%	28%	37%	37%	37%
Commercial	LostOpp_HVAC_Restaurant	13%	13%	13%	14%	14%	14%	18%	18%	18%

Appendix A: Adoption Rates

Unitil Gas

Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	***2023***	***2024***	***2022***	***2023***	***2024***	***2022***	***2023***	***2024***
Commercial	LostOpp_Water heating_Restaurant	4%	4%	4%	4%	4%	4%	5%	5%	5%
Commercial	LostOpp_Food Prep_Restaurant	14%	14%	14%	16%	16%	16%	20%	20%	20%
Commercial	LostOpp_Other_Restaurant	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Restaurant	28%	28%	28%	31%	31%	31%	41%	41%	41%
Commercial	Retro_Thermostats_Restaurant	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Restaurant	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Process_Restaurant	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Restaurant	58%	58%	58%	64%	64%	64%	83%	83%	83%
Commercial	Retro_Steam Trap_Restaurant	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	Retro_RCx_Restaurant	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Restaurant	22%	22%	22%	24%	24%	24%	31%	31%	31%
Commercial	LostOpp_HVAC_Grocery	13%	13%	13%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_Water heating_Grocery	12%	12%	12%	13%	13%	13%	17%	17%	17%
Commercial	LostOpp_Food Prep_Grocery	9%	9%	9%	10%	10%	10%	13%	13%	13%
Commercial	LostOpp_Other_Grocery	0%	0%	0%	7%	7%	7%	9%	9%	9%
Commercial	Retro_Weatherization_Grocery	22%	22%	22%	24%	24%	24%	32%	32%	32%
Commercial	Retro_Thermostats_Grocery	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Grocery	0%	0%	0%	17%	17%	17%	22%	22%	22%
Commercial	Retro_Process_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Grocery	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Grocery	61%	61%	61%	67%	67%	67%	87%	87%	87%
Commercial	Retro_RCx_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Grocery	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Education	13%	13%	13%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_Water heating_Education	12%	12%	12%	13%	13%	13%	17%	17%	17%
Commercial	LostOpp_Food Prep_Education	9%	9%	9%	10%	10%	10%	13%	13%	13%
Commercial	LostOpp_Other_Education	0%	0%	0%	7%	7%	7%	9%	9%	9%
Commercial	Retro_Weatherization_Education	22%	22%	22%	24%	24%	24%	32%	32%	32%
Commercial	Retro_Thermostats_Education	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Education	0%	0%	0%	17%	17%	17%	22%	22%	22%
Commercial	Retro_Process_Education	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Education	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Education	61%	61%	61%	67%	67%	67%	87%	87%	87%
Commercial	Retro_RCx_Education	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Education	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Health	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	LostOpp_Water heating_Health	12%	12%	12%	14%	14%	14%	18%	18%	18%
Commercial	LostOpp_Food Prep_Health	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Other_Health	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Health	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	Retro_Thermostats_Health	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Health	0%	0%	0%	17%	17%	17%	22%	22%	22%
Commercial	Retro_Process_Health	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Health	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Health	63%	63%	63%	70%	70%	70%	90%	90%	90%
Commercial	Retro_RCx_Health	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Health	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Lodging	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	LostOpp_Water heating_Lodging	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Food Prep_Lodging	20%	20%	20%	22%	22%	22%	29%	29%	29%
Commercial	LostOpp_Other_Lodging	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Lodging	39%	39%	39%	43%	43%	43%	56%	56%	56%
Commercial	Retro_Thermostats_Lodging	20%	20%	20%	22%	22%	22%	28%	28%	28%

Appendix A: Adoption Rates
Unitil Gas

Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	***2023***	***2024***	***2022***	***2023***	***2024***	***2022***	***2023***	***2024***
Commercial	Retro_Controls_Lodging	0%	0%	0%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Process_Lodging	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Lodging	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Lodging	66%	66%	66%	73%	73%	73%	90%	90%	90%
Commercial	Retro_RCx_Lodging	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Lodging	16%	16%	16%	17%	17%	17%	23%	23%	23%
Commercial	LostOpp_HVAC_Warehouse	10%	10%	10%	11%	11%	11%	15%	15%	15%
Commercial	LostOpp_Water heating_Warehouse	14%	14%	14%	16%	16%	16%	21%	21%	21%
Commercial	LostOpp_Food Prep_Warehouse	2%	2%	2%	2%	2%	2%	3%	3%	3%
Commercial	LostOpp_Other_Warehouse	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Warehouse	8%	8%	8%	9%	9%	9%	12%	12%	12%
Commercial	Retro_Thermostats_Warehouse	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Warehouse	0%	0%	0%	7%	7%	7%	9%	9%	9%
Commercial	Retro_Process_Warehouse	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Warehouse	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Warehouse	73%	73%	73%	80%	80%	80%	90%	90%	90%
Commercial	Retro_RCx_Warehouse	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Warehouse	7%	7%	7%	7%	7%	7%	9%	9%	9%
Commercial	LostOpp_HVAC_Miscellaneous	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	LostOpp_Water heating_Miscellaneous	14%	14%	14%	16%	16%	16%	20%	20%	20%
Commercial	LostOpp_Food Prep_Miscellaneous	16%	16%	16%	18%	18%	18%	23%	23%	23%
Commercial	LostOpp_Other_Miscellaneous	0%	0%	0%	18%	18%	18%	24%	24%	24%
Commercial	Retro_Weatherization_Miscellaneous	31%	31%	31%	34%	34%	34%	45%	45%	45%
Commercial	Retro_Thermostats_Miscellaneous	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Controls_Miscellaneous	0%	0%	0%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Process_Miscellaneous	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Miscellaneous	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	Retro_Steam Trap_Miscellaneous	73%	73%	73%	80%	80%	80%	90%	90%	90%
Commercial	Retro_RCx_Miscellaneous	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Miscellaneous	16%	16%	16%	18%	18%	18%	23%	23%	23%
Industrial	LostOpp_HVAC_Industrial	7%	7%	7%	8%	8%	8%	11%	11%	11%
Industrial	LostOpp_Water heating_Industrial	6%	6%	6%	7%	7%	7%	9%	9%	9%
Industrial	LostOpp_Food Prep_Industrial	3%	3%	3%	3%	3%	3%	4%	4%	4%
Industrial	LostOpp_Other_Industrial	0%	0%	0%	4%	4%	4%	5%	5%	5%
Industrial	Retro_Weatherization_Industrial	4%	4%	4%	5%	5%	5%	6%	6%	6%
Industrial	Retro_Thermostats_Industrial	20%	20%	20%	22%	22%	22%	28%	28%	28%
Industrial	Retro_Controls_Industrial	0%	0%	0%	4%	4%	4%	5%	5%	5%
Industrial	Retro_Process_Industrial	0%	0%	0%	24%	24%	24%	31%	31%	31%
Industrial	Retro_Water Saving_Industrial	91%	91%	91%	91%	91%	91%	90%	90%	90%
Industrial	Retro_Steam Trap_Industrial	31%	31%	31%	34%	34%	34%	44%	44%	44%
Industrial	Retro_RCx_Industrial	0%	0%	0%	24%	24%	24%	31%	31%	31%
Industrial	Retro_Custom_Industrial	4%	4%	4%	4%	4%	4%	6%	6%	6%

Appendix A: Adoption Rates

Unitil Electric

Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	*2023*	*2024*	*2022*	*2023*	*2024*	*2022*	*2023*	*2024*
Residential	LostOpp_Cooling	9%	9%	9%	10%	10%	10%	14%	14%	14%
Residential	LostOpp_Heating	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_DHW	30%	30%	30%	33%	33%	33%	48%	48%	48%
Residential	LostOpp_Lighting	55%	55%	55%	61%	61%	61%	89%	89%	89%
Residential	LostOpp_Cooking	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_Fridge	6%	6%	6%	6%	6%	6%	9%	9%	9%
Residential	LostOpp_OtherAppliance	15%	15%	15%	16%	16%	16%	24%	24%	24%
Residential	LostOpp_Electronics	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_Pump	5%	5%	5%	6%	6%	6%	8%	8%	8%
Residential	Retro_ResWx	39%	39%	39%	43%	43%	43%	63%	63%	63%
Residential	Retro_DMSHP	63%	63%	63%	69%	69%	69%	100%	100%	100%
Residential	Retro_Custom	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	Retro_Conversion	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	Retro_App_Recycle	18%	18%	18%	20%	20%	20%	29%	29%	29%
Residential	Retro_Duct_Seal/Ins	0%	0%	0%	95%	95%	95%	100%	100%	100%
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	64%	64%	64%	70%	70%	70%	100%	100%	100%
Residential	Retro_Circ_Pump	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	Retro_Pipe_Wrap	69%	69%	69%	76%	76%	76%	100%	100%	100%
Residential	Retro_DHW_Conservation	8%	8%	8%	9%	9%	9%	13%	13%	13%
Residential	Retro_Light_Controls	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	Retro_Smart_Powerstrip	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_Cooling_LI	4%	4%	4%	5%	5%	5%	5%	5%	5%
Residential	LostOpp_Heating_LI	0%	0%	0%	50%	50%	50%	55%	55%	55%
Residential	LostOpp_DHW_LI	22%	22%	22%	24%	24%	24%	27%	27%	27%
Residential	LostOpp_Lighting_LI	64%	64%	64%	70%	70%	70%	77%	77%	77%
Residential	LostOpp_Cooking_LI	0%	0%	0%	88%	88%	88%	97%	97%	97%
Residential	LostOpp_Fridge_LI	4%	4%	4%	5%	5%	5%	5%	5%	5%
Residential	LostOpp_OtherAppliance_LI	15%	15%	15%	16%	16%	16%	18%	18%	18%
Residential	LostOpp_Electronics_LI	0%	0%	0%	95%	95%	95%	100%	100%	100%
Residential	LostOpp_Pump_LI	5%	5%	5%	6%	6%	6%	6%	6%	6%
Residential	Retro_ResWx_LI	31%	31%	31%	34%	34%	34%	37%	37%	37%
Residential	Retro_DMSHP_LI	27%	27%	27%	30%	30%	30%	32%	32%	32%
Residential	Retro_Custom_LI	0%	0%	0%	83%	83%	83%	91%	91%	91%
Residential	Retro_Conversion_LI	66%	66%	66%	72%	72%	72%	79%	79%	79%
Residential	Retro_App_Recycle_LI	14%	14%	14%	15%	15%	15%	16%	16%	16%
Residential	Retro_Duct_Seal/Ins_LI	0%	0%	0%	83%	83%	83%	91%	91%	91%
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	36%	36%	36%	40%	40%	40%	44%	44%	44%
Residential	Retro_Circ_Pump_LI	90%	90%	90%	95%	95%	95%	100%	100%	100%
Residential	Retro_Pipe_Wrap_LI	51%	51%	51%	56%	56%	56%	62%	62%	62%
Residential	Retro_DHW_Conservation_LI	5%	5%	5%	5%	5%	5%	6%	6%	6%
Residential	Retro_Light_Controls_LI	0%	0%	0%	83%	83%	83%	91%	91%	91%
Residential	Retro_Smart_Powerstrip_LI	90%	90%	90%	95%	95%	95%	100%	100%	100%
Commercial	LostOpp_HVAC_Office	7%	7%	7%	7%	7%	7%	10%	10%	10%
Commercial	LostOpp_Water heating_Office	0%	0%	0%	12%	12%	12%	16%	16%	16%

Appendix A: Adoption Rates

Unitil Electric

Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	*2023*	*2024*	*2022*	*2023*	*2024*	*2022*	*2023*	*2024*
Commercial	LostOpp_Lighting_Gen_Office	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Office	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Office	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Office	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Office	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Office	0%	0%	0%	32%	32%	32%	42%	42%	42%
Commercial	Retro_Weatherization_Office	0%	0%	0%	17%	17%	17%	22%	22%	22%
Commercial	Retro_Thermostats_Office	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Office	20%	20%	20%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Sensors_Office	9%	9%	9%	10%	10%	10%	13%	13%	13%
Commercial	Retro_Motors_Office	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Office	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Office	0%	0%	0%	12%	12%	12%	16%	16%	16%
Commercial	Retro_Steam Trap_Office	0%	0%	0%	12%	12%	12%	16%	16%	16%
Commercial	Retro_RCx_Office	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Office	17%	17%	17%	19%	19%	19%	25%	25%	25%
Commercial	LostOpp_HVAC_Retail	11%	11%	11%	12%	12%	12%	16%	16%	16%
Commercial	LostOpp_Water heating_Retail	0%	0%	0%	35%	35%	35%	45%	45%	45%
Commercial	LostOpp_Lighting_Gen_Retail	66%	66%	66%	73%	73%	73%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Retail	54%	54%	54%	59%	59%	59%	77%	77%	77%
Commercial	LostOpp_Food Prep_Retail	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commercial	LostOpp_Fridge_Retail	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Retail	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Retail	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Retail	0%	0%	0%	21%	21%	21%	28%	28%	28%
Commercial	Retro_Thermostats_Retail	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Retail	30%	30%	30%	34%	34%	34%	44%	44%	44%
Commercial	Retro_Sensors_Retail	16%	16%	16%	17%	17%	17%	23%	23%	23%
Commercial	Retro_Motors_Retail	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Retail	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Retail	0%	0%	0%	35%	35%	35%	45%	45%	45%
Commercial	Retro_Steam Trap_Retail	0%	0%	0%	35%	35%	35%	45%	45%	45%
Commercial	Retro_RCx_Retail	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Retail	26%	26%	26%	29%	29%	29%	37%	37%	37%
Commercial	LostOpp_HVAC_Restaurant	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Water heating_Restaurant	0%	0%	0%	8%	8%	8%	11%	11%	11%
Commercial	LostOpp_Lighting_Gen_Restaurant	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Restaurant	66%	66%	66%	72%	72%	72%	90%	90%	90%
Commercial	LostOpp_Food Prep_Restaurant	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Restaurant	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Restaurant	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Restaurant	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Restaurant	0%	0%	0%	20%	20%	20%	27%	27%	27%
Commercial	Retro_Thermostats_Restaurant	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Restaurant	26%	26%	26%	28%	28%	28%	37%	37%	37%
Commercial	Retro_Sensors_Restaurant	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	Retro_Motors_Restaurant	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Restaurant	0%	0%	0%	24%	24%	24%	31%	31%	31%

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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_Water Saving_Restaurant	0%	0%	0%	8%	8%	8%	11%	11%	11%
Commercial	Retro_Steam Trap_Restaurant	0%	0%	0%	8%	8%	8%	11%	11%	11%
Commercial	Retro_RCx_Restaurant	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Restaurant	22%	22%	22%	24%	24%	24%	32%	32%	32%
Commercial	LostOpp_HVAC_Grocery	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Water heating_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	LostOpp_Lighting_Gen_Grocery	89%	89%	89%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Grocery	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Grocery	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Grocery	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Grocery	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Grocery	0%	0%	0%	7%	7%	7%	9%	9%	9%
Commercial	Retro_Weatherization_Grocery	0%	0%	0%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Thermostats_Grocery	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Grocery	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Sensors_Grocery	10%	10%	10%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Motors_Grocery	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_Steam Trap_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_RCx_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Grocery	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Grocery	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Water heating_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	LostOpp_Lighting_Gen_Grocery	89%	89%	89%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Grocery	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Grocery	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Grocery	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Grocery	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Grocery	0%	0%	0%	7%	7%	7%	9%	9%	9%
Commercial	Retro_Weatherization_Grocery	0%	0%	0%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Thermostats_Grocery	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Grocery	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Sensors_Grocery	10%	10%	10%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Motors_Grocery	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_Steam Trap_Grocery	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_RCx_Grocery	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Grocery	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Education	13%	13%	13%	14%	14%	14%	19%	19%	19%
Commercial	LostOpp_Water heating_Education	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	LostOpp_Lighting_Gen_Education	89%	89%	89%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Education	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Education	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Education	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Education	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Education	0%	0%	0%	7%	7%	7%	9%	9%	9%

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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_Weatherization_Education	0%	0%	0%	16%	16%	16%	21%	21%	21%
Commercial	Retro_Thermostats_Education	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Education	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Sensors_Education	10%	10%	10%	12%	12%	12%	15%	15%	15%
Commercial	Retro_Motors_Education	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Education	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Education	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_Steam Trap_Education	0%	0%	0%	26%	26%	26%	33%	33%	33%
Commercial	Retro_RCx_Education	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Education	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Healthcare	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Water heating_Healthcare	0%	0%	0%	27%	27%	27%	35%	35%	35%
Commercial	LostOpp_Lighting_Gen_Healthcare	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Healthcare	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Healthcare	1%	1%	1%	1%	1%	1%	1%	1%	1%
Commercial	LostOpp_Fridge_Healthcare	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Healthcare	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Healthcare	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Healthcare	0%	0%	0%	14%	14%	14%	18%	18%	18%
Commercial	Retro_Thermostats_Healthcare	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Healthcare	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	Retro_Sensors_Healthcare	8%	8%	8%	8%	8%	8%	11%	11%	11%
Commercial	Retro_Motors_Healthcare	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Healthcare	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Healthcare	0%	0%	0%	27%	27%	27%	35%	35%	35%
Commercial	Retro_Steam Trap_Healthcare	0%	0%	0%	27%	27%	27%	35%	35%	35%
Commercial	Retro_RCx_Healthcare	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Healthcare	17%	17%	17%	18%	18%	18%	24%	24%	24%
Commercial	LostOpp_HVAC_Lodging	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Water heating_Lodging	0%	0%	0%	28%	28%	28%	36%	36%	36%
Commercial	LostOpp_Lighting_Gen_Lodging	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Lodging	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Lodging	1%	1%	1%	1%	1%	1%	2%	2%	2%
Commercial	LostOpp_Fridge_Lodging	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Lodging	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Lodging	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Lodging	0%	0%	0%	28%	28%	28%	37%	37%	37%
Commercial	Retro_Thermostats_Lodging	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Lodging	19%	19%	19%	20%	20%	20%	27%	27%	27%
Commercial	Retro_Sensors_Lodging	14%	14%	14%	15%	15%	15%	20%	20%	20%
Commercial	Retro_Motors_Lodging	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Lodging	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Lodging	0%	0%	0%	28%	28%	28%	36%	36%	36%
Commercial	Retro_Steam Trap_Lodging	0%	0%	0%	28%	28%	28%	36%	36%	36%
Commercial	Retro_RCx_Lodging	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Lodging	16%	16%	16%	17%	17%	17%	23%	23%	23%
Commercial	LostOpp_HVAC_Warehouse	10%	10%	10%	12%	12%	12%	15%	15%	15%
Commercial	LostOpp_Water heating_Warehouse	0%	0%	0%	31%	31%	31%	40%	40%	40%

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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_Lighting_Gen_Warehouse	39%	39%	39%	43%	43%	43%	56%	56%	56%
Commercial	LostOpp_Lighting_HID_Warehouse	26%	26%	26%	28%	28%	28%	37%	37%	37%
Commercial	LostOpp_Food Prep_Warehouse	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commercial	LostOpp_Fridge_Warehouse	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Warehouse	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Warehouse	0%	0%	0%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Weatherization_Warehouse	0%	0%	0%	6%	6%	6%	8%	8%	8%
Commercial	Retro_Thermostats_Warehouse	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Warehouse	8%	8%	8%	9%	9%	9%	11%	11%	11%
Commercial	Retro_Sensors_Warehouse	3%	3%	3%	3%	3%	3%	4%	4%	4%
Commercial	Retro_Motors_Warehouse	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Warehouse	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Warehouse	0%	0%	0%	31%	31%	31%	40%	40%	40%
Commercial	Retro_Steam Trap_Warehouse	0%	0%	0%	31%	31%	31%	40%	40%	40%
Commercial	Retro_RCx_Warehouse	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Warehouse	7%	7%	7%	7%	7%	7%	10%	10%	10%
Commercial	LostOpp_HVAC_Miscellaneous	20%	20%	20%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Water heating_Miscellaneous	0%	0%	0%	31%	31%	31%	40%	40%	40%
Commercial	LostOpp_Lighting_Gen_Miscellaneous	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Lighting_HID_Miscellaneous	90%	90%	90%	90%	90%	90%	90%	90%	90%
Commercial	LostOpp_Food Prep_Miscellaneous	1%	1%	1%	1%	1%	1%	2%	2%	2%
Commercial	LostOpp_Fridge_Miscellaneous	0%	0%	0%	21%	21%	21%	27%	27%	27%
Commercial	LostOpp_Electronics_Miscellaneous	0%	0%	0%	22%	22%	22%	28%	28%	28%
Commercial	LostOpp_Other_Miscellaneous	0%	0%	0%	19%	19%	19%	24%	24%	24%
Commercial	Retro_Weatherization_Miscellaneous	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Thermostats_Miscellaneous	0%	0%	0%	22%	22%	22%	29%	29%	29%
Commercial	Retro_Controls_Miscellaneous	19%	19%	19%	21%	21%	21%	28%	28%	28%
Commercial	Retro_Sensors_Miscellaneous	9%	9%	9%	10%	10%	10%	13%	13%	13%
Commercial	Retro_Motors_Miscellaneous	64%	64%	64%	70%	70%	70%	90%	90%	90%
Commercial	Retro_Process_Miscellaneous	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Water Saving_Miscellaneous	0%	0%	0%	31%	31%	31%	40%	40%	40%
Commercial	Retro_Steam Trap_Miscellaneous	0%	0%	0%	31%	31%	31%	40%	40%	40%
Commercial	Retro_RCx_Miscellaneous	0%	0%	0%	24%	24%	24%	31%	31%	31%
Commercial	Retro_Custom_Miscellaneous	16%	16%	16%	18%	18%	18%	24%	24%	24%
Industrial	LostOpp_HVAC_Industrial	8%	8%	8%	8%	8%	8%	11%	11%	11%
Industrial	LostOpp_Water heating_Industrial	0%	0%	0%	15%	18%	21%	17%	17%	17%
Industrial	LostOpp_Lighting_Gen_Industrial	62%	62%	62%	68%	68%	68%	90%	90%	90%
Industrial	LostOpp_Lighting_HID_Industrial	46%	46%	46%	51%	52%	53%	66%	66%	66%
Industrial	LostOpp_Food Prep_Industrial	0%	0%	0%	3%	7%	10%	0%	0%	0%
Industrial	LostOpp_Fridge_Industrial	0%	0%	0%	23%	25%	27%	27%	27%	27%
Industrial	LostOpp_Electronics_Industrial	0%	0%	0%	24%	26%	28%	28%	28%	28%
Industrial	LostOpp_Other_Industrial	0%	0%	0%	7%	10%	13%	5%	5%	5%
Industrial	Retro_Weatherization_Industrial	0%	0%	0%	6%	9%	12%	4%	4%	4%
Industrial	Retro_Thermostats_Industrial	0%	0%	0%	24%	26%	29%	29%	29%	29%
Industrial	Retro_Controls_Industrial	5%	5%	5%	8%	11%	14%	7%	7%	7%
Industrial	Retro_Sensors_Industrial	9%	9%	9%	13%	16%	18%	13%	13%	13%
Industrial	Retro_Motors_Industrial	64%	64%	64%	70%	70%	69%	90%	90%	90%

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Sector	Ramp Name	Business as Usual (BAU)			BAU Plus			BAU Max		
		2022	*2023*	*2024*	*2022*	*2023*	*2024*	*2022*	*2023*	*2024*
Industrial	Retro_Process_Industrial	0%	0%	0%	26%	28%	30%	31%	31%	31%
Industrial	Retro_Water Saving_Industrial	0%	0%	0%	15%	18%	21%	17%	17%	17%
Industrial	Retro_Steam Trap_Industrial	0%	0%	0%	15%	18%	21%	17%	17%	17%
Industrial	Retro_RCx_Industrial	0%	0%	0%	26%	28%	30%	31%	31%	31%
Industrial	Retro_Custom_Industrial	4%	4%	4%	7%	10%	14%	6%	6%	6%