2021 NW NATURAL WASHINGTON CONSERVATION POTENTIAL ASSESSMENT

Final Report

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Report prepared for:
NW NATURAL

Energy Solutions. Delivered.

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EXECUTIVE SUMMARY

In early 2021, NW Natural selected Applied Energy Group (AEG) to conduct an assessment of available conservation potential in their Washington service territory. The assessment uses standard industry and northwest regional methodologies to develop reliable estimates of technical, achievable technical, and achievable economic potential from two different cost-effectiveness perspectives for the period from 2022-2051. The assessment was performed in collaboration with NW Natural and Energy Trust of Oregon staff using information specific to NW Natural's customers and existing energy efficiency programs wherever possible.

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, as described in Chapter 4 of this report.

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

Table ES-1-1 summarizes the results of this study at a high level. AEG analyzed potential for NW Natural's sales customers across the residential, commercial, and industrial market sectors. As part of this study, AEG estimated achievable economic potential from both the total resource cost (TRC) and utility cost test (UCT) perspectives. The TRC perspective includes the use of full measure costs, as well as quantified and monetizable non-energy impacts and non-gas fuel impacts (e.g., electric cooling or wood secondary heating) consistent with methodology within the Northwest Power and Conservation Council's Draft 2021 Power Plan (2021 Plan).

Table ES-1-1 Summary of Energy Efficiency Potential (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Baseline Load Projection Absent Future Savings (mTherms)	80,831	82,581	84,282	87,530	95,229	109,312	125,747
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	354	725	1,036	1,827	4,390	9,345	11,392
UCT Achievable Economic Potential	477	992	1,470	2,671	6,523	13,936	16,818
Achievable Technical Potential	874	1,799	2,702	4,808	10,350	19,102	22,321
Technical Potential	2,033	4,189	6,160	10,491	20,957	35,383	42,373
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.4%	0.9%	1.2%	2.1%	4.6%	8.5%	9.1%
UCT Achievable Economic Potential	0.6%	1.2%	1.7%	3.1%	6.8%	12.7%	13.4%
Achievable Technical Potential	1.1%	2.2%	3.2%	5.5%	10.9%	17.5%	17.8%
Technical Potential	2.5%	5.1%	7.3%	12.0%	22.0%	32.4%	33.7%

Key opportunities for savings include residential furnace and water heating equipment upgrades and weatherization, as well as behavioral programs and kitchen equipment.[1]

Table ES-1-2 Cumulative TRC Achievable Economic Potential (mTherms) by Sector

Sector	2022	2023	2024	2026	2031	2040	2050
Residential	182	369	478	837	2,250	5,380	6,612
Commercial	155	323	509	908	1,979	3,713	4,526
Industrial	16	33	49	82	162	253	254
Total	**354**	**725**	**1,036**	**1,827**	**4,390**	**9,3545**	**11,392**

[1] To align with NW Natural's Integrated Resource Plan timeframe, this assessment forecasts savings potential over a 30-year horizon, instead of the typical 20-year period.

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INTRODUCTION

This report documents the results and methodology of the NW Natural Gas Company (NW Natural) 2022-2051 Conservation Potential Assessment (CPA), performed by Applied Energy Group (AEG) for NW Natural's service territory in southwest Washington. Throughout this study, AEG worked with NW Natural to understand the baseline characteristics of their Washington service territory, including a detailed understanding of energy consumption in the territory, the assumptions and methodologies used in NW Natural's official load forecast, and recent programmatic accomplishments. Figure 1-1 presents a map of NW Natural's Washington service territory.[2]

Figure 1-1 NW Natural's Service Territory (courtesy NW Natural)

The primary objective of this study was to develop independent and credible estimates of energy efficiency potential that can be achieved within NW Natural's Washington service territory using accepted regional inputs and methodologies. This included estimating technical, achievable technical, then achievable economic potential using ramp rates from the Northwest Power and Conservation Council's (Council's) Draft 2021 Power Plan as the starting point for all achievability assumptions. The study also utilizes energy efficiency measure assumptions consistent with 2021 Power Plan supply curves, Regional Technical Form

[2] This assessment was specific to NW Natural's Washington service territory and did not attempt to estimate conservation potential for NW Natural's Oregon service territory.

(RTF) measure workbooks, and information from Northwest Energy Efficiency Alliance (NEEA's) market research initiatives where appropriate for use in natural gas planning studies.

To perform this assessment, AEG customized its LoadMAP end-use planning tool with data specific to NW Natural's Washington territory and the Northwest. This includes a detailed snapshot of how NW Natural's Washington customers use energy in the base year of the study, 2019, assumptions on future customer growth from NW Natural's load forecasting team, and measure assumptions using NW Natural primary data, regional research, and other well-vetted industry sources from around the nation. AEG then developed an independent estimate of achievable, cost-effective energy efficiency potential within NW Natural's Washington service territory between 2022 and 2051.

Study Considerations

Below, AEG notes a number of items that came up during the development of this study based on feedback from stakeholders or state policy considerations. These items are discussed throughout the remainder of the report and are summarized here for the benefit of the reader.

- Alignment with Regional Methodology: Because there is no established regional methodology for conducting natural gas CPAs in the Northwest, AEG based the analysis on the methodology established by the Northwest Power and Conservation Council for assessing electric energy efficiency potential. While AEG used a methodology consistent with the Council, certain Council assumptions, particularly ramp rates, were modified to better represent natural gas markets.
- Potential Assessment vs. Program and Portfolio Design: By nature, CPAs rely on the best information available to assess the average cost and impacts of energy efficiency measures for a given group of customers. For example, because it is not possible to get data on the building shell characteristics of each single-family home in NW Natural's Washington service territory, the CPA makes assumptions about the characteristics of the average single-family home and the resulting applicability of energy efficiency upgrades. Because of this, the CPA is able to estimate the total savings potential for a given measure and its average cost-effectiveness, but then makes a binary choice whether to include a measure in the economic potential based on this average cost-effectiveness.

  Energy efficiency programs operate differently, often offering specifically designed prescriptive incentives for measures expected to be cost-effective on average, and a custom measure path for those that may only be cost-effective in certain applications. As such, the CPA can provide a guide for which measures to consider for inclusion in programs, particularly for prescriptive programs, but the identified cost-effective potential should not be viewed as an exhaustive view of all program opportunities.
- Treatment of Transportation Customers: Transportation customers, not to be confused with customers who use natural gas for vehicle transportation, were excluded from consideration in this report, as energy efficiency programs for these customers are currently not available.[3] Though there have been regional conversations surrounding potential for transportation customers, there are additional data needs in estimating this potential, clarification on the appropriate avoided costs to apply for this customer segment and potential challenges in acquiring savings, which would include changing the current tariff to include transportation customers. Assessing the cost-effective potential for transportation customers would require more visibility into the kinds of customers on these rates, how these customers are using natural gas, and an understanding of how these customers view energy

[3] Transportation customers are responsible for purchasing and shipping their own gas to NW Natural's service territory and only pay NW Natural to transport their gas from the interstate pipeline gate stations to their site location via NW Natural's distribution system.

savings and the rate at which they may participate in future programs since there is no past history on which to draw.

- Potential Impacts of Current or Future Legislation: At the time of publication of this report, there is significant activity in the Washington Legislature regarding carbon policy, electrification, and related topics that could impact future natural gas energy efficiency opportunities. For example, House Bill 1084 would have eliminated the use of natural gas for space and water heating in new construction in 2027, also eliminating associated natural gas energy efficiency opportunities.

  Because no new laws explicitly affecting the future consumption of natural gas have currently been passed, potential impacts of this type of legislation have not been considered in the baseline projection or the energy efficiency estimates provided in this report. In future studies, it will be important to review the legislative landscape to determine whether adjustments to the baseline load projection or applicability of energy efficiency measures are required.

- Understanding Residential Potential by Customer Income Level: Given the increased interest in the low-income customer segment specifically, the CPA includes income level analysis for the residential sector, allowing AEG to present results separately for low, moderate, and above-median income groups.

- Potential Implications of the Updated Washington State Energy Code (WSEC): The 2018 WSEC, which took effect in 2021, may affect builders' decisions regarding heating and water heating fuels in residential new construction. However, for consistency with NW Natural's load forecast used to inform the baseline in this assessment, this study does not attempt to project how builders may change their standard practice in response to the new code. This alignment is discussed in additional detail in Chapter 4 of this report.

Summary of Report Contents

The document is divided into five additional chapters, summarizing the approach, assumptions, and results of the EE potential analysis, with additional detail provided in the appendices:

Main Report

- Analysis Approach and Data Development. Detailed description of AEG's approach to conducting NW Natural's 2022-2051 CPA and documentation of primary and secondary sources used.

- Market Characterization and Market Profiles. Characterization of NW Natural's Washington service territory in the base year of the study (2019) including total consumption, number of customers and market units, and energy intensity. This also includes a breakdown of the energy consumption for residential, commercial, and industrial sales customers by end use and technology.

- Baseline Projection. Projection of baseline energy consumption under a naturally occurring efficiency case, described at the end-use level. The LoadMAP models were first aligned with actual sales and NW Natural's official, weather-normalized econometric forecast and then varied to include the impacts of future federal standards, impacts of the 2018 Washington State Energy Code on new construction, and future technology purchasing decisions.

- Energy Efficiency Potential. Summary of energy efficiency potential for NW Natural's entire Washington service territory for selected years between 2022 and 2051.[4] Potential is summarized first

[4] To align with NW Natural's Integrated Resource Plan timeframe, this assessment forecasts savings potential over a 30-year horizon, instead of the typical 20-year period.

across all sectors for sales customers then separately for each market sector within NW Natural's service territory, including residential, commercial, and industrial sales customers.

Appendix

- Alignment with the Council's Methodology. Discussion on how this study aligns with Council electric-centric methodologies, including ramp rates, regional data, and measure assumptions.

Abbreviations and Acronyms

Throughout the report we use several 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
AFUE	Annual Fuel Utilization Efficiency
BEST	AEG's Building Energy Simulation Tool
C&I	Commercial and Industrial
CBSA	NEEA's Commercial Building Stock Assessment
CEF	Combined Energy Factor
Council	Northwest Power and Conservation Council (NWPCC)
DHW	Domestic Hot Water
DSM	Demand-Side Management
EIA	Energy Information Administration
EUL	Estimated Useful Life
EUI	Energy Usage Index
HVAC	Heating Ventilation and Air Conditioning
IFSA	NEEA's Industrial Facilities Site Assessment
IRP	Integrated Resource Plan
LoadMAP	AEG's Load Management Analysis and Planning™ Tool
NEEA	Northwest Energy Efficiency Alliance
O&M	Operations and Maintenance
RBSA	NEEA's Residential Building Stock Assessment
RTF	Regional Technical Forum
RVT	Resource Value Test
TE	Thermal Efficiency
TRC	Total Resource Cost
UCT	Utility Cost Test
UEC	Unit Energy Consumption
UEF	Uniform Energy Factor
UES	Unit Energy Savings
WSEC	Washington State Energy Code

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ANALYSIS APPROACH AND DATA DEVELOPMENT

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

Overview of Analysis Approach

To perform the potential analysis, AEG used a bottom-up approach following the major steps listed below. These analysis steps are described in more detail throughout the remainder of this chapter.

1. Performed a market characterization to describe sector-level natural gas use for the residential, commercial, and industrial sectors for the base year, 2019. This included extensive use of NW Natural data and other secondary data sources from NEEA and the Energy Information Administration (EIA).
2. Developed a baseline projection of energy consumption by sector, segment, end use, and technology for 2022 through 2051.
3. Defined and characterized several hundred EE measures to be applied to all sectors, segments, and end uses.
4. Estimated technical, achievable technical, and achievable economic energy savings at the measure level for 2022-2051. Achievable economic potential was assessed using both the Total Resource Cost (TRC) and Utility Cost Test (UCT) screens.

Comparison with Northwest Power & Conservation Council Methodology

As with other natural gas CPAs AEG has performed in Washington state, this CPA uses the Council's methodology to assess potential and develop ramp rates. It is important to note that the Council's methodology was developed for, and used in, electric CPAs. Natural gas impacts are typically assessed when they overlap with electricity measures (e.g., gas water heating impacts in an electrically heated "Built Green Washington" home). The Council's ramp rates were also developed with electric utility DSM programs in mind, as electricity is the primary focus of the regionwide potential assessed in the Council's Plans. For these reasons, AEG adapted Council methodologies in some cases, rather than using them directly from the source. This is especially relevant in the development of ramp rates when achievability was determined to not be applicable to a specific natural gas measure or program. We discuss this in Appendix A of this report.

Among other aspects, consistent with the Council's methodology, this approach involves using:

- Data Sources: regional surveys, market research, and assumptions
- Measures and Assumptions: Draft 2021 Power Plan supply curves and RTF work products
- Potential Factors: Draft 2021 Power Plan ramp rates
- Levels of Potential: technical, achievable technical, and achievable economic
- Cost-effectiveness Approaches: assessed potential under the UCT as well as the Council's TRC test, including non-energy impacts that have been quantified and monetized within the TRC

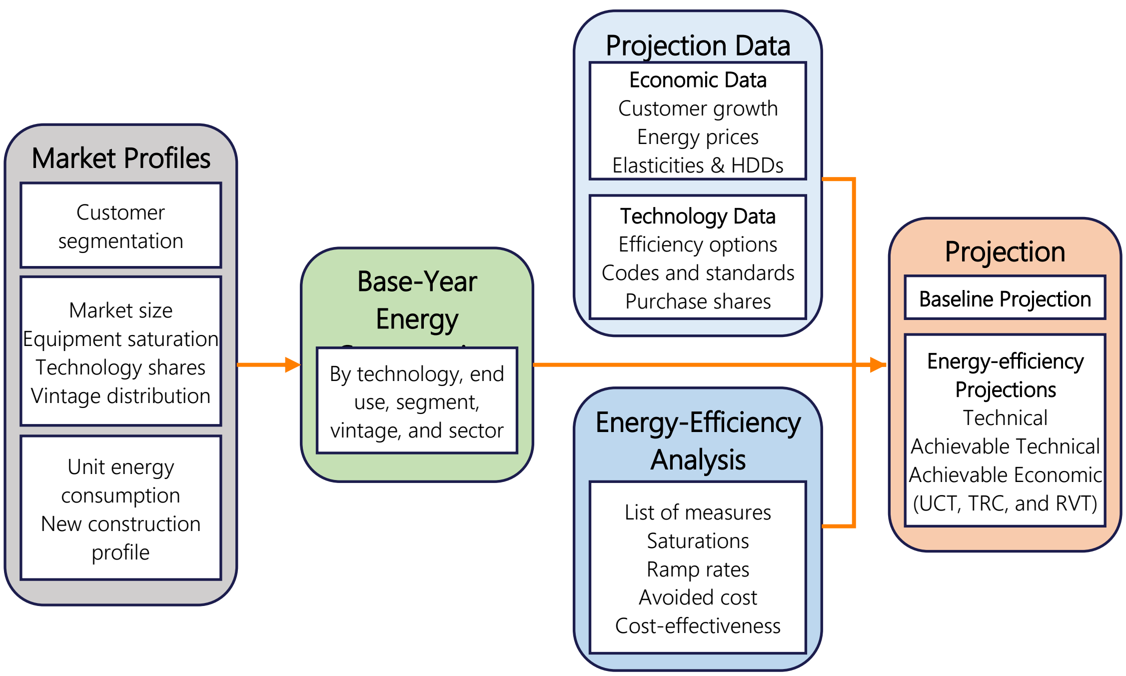
- Conservation Credits: applies a 10% conservation credit to avoided energy costs, consistent with the preference for conservation specified in the Northwest Power Act. This credit was embedded in the avoided costs provided by NW Natural.

LoadMAP Model

For this analysis, AEG used its Load Management Analysis and Planning tool (LoadMAP™) version 5.0 to develop both the baseline projection and the estimates of potential. AEG developed LoadMAP in 2007 and has enhanced it over time, using it for the EPRI National Potential Study and numerous utility-specific forecasting and potential studies since. Built in Excel, the LoadMAP framework (see Figure 2-1) is both accessible and transparent and possesses key features that embody basic principles of rigorous end-use models, accommodates different levels of segmentation, includes algorithms that independently account for new and existing appliances and building stock, and balances the competing needs of simplicity and robustness.

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. [5]

Figure 2-1 LoadMAP Analysis Framework



Types of Potential Included in the Study

AEG market potential studies typically analyze three types of potential: technical, achievable technical and achievable economic. Utilities can customize this analysis to best suit their needs and align with regulatory requirements in reporting energy efficiency potential. Chapter 5 provides more detail on each type of potential and what data informed potential scenarios for this study.

[5] The model computes energy forecasts 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 forecast (e.g., the technical potential forecast).

Table 2-1 Levels of Potential

Potential Type	Definition
Technical	Everyone chooses the most efficient option regardless of cost at time of equipment replacement or measure adoption.
Achievable Technical	A modified technical potential that accounts for likely measure adoption within the market
Achievable Economic	A subset of achievable technical potential that includes only cost-effective measures

Market Characterization

To estimate the savings potential from energy-efficiency measures, it is necessary to understand how much energy is used today and what equipment is currently in service. This market characterization begins with a segmentation of NW Natural's natural gas footprint to quantify energy use by sector, segment, end-use application, and the current set of technologies in use. For this, we rely primarily on information from NW Natural, augmenting with secondary sources as necessary.

Segmentation for Modeling Purposes

This assessment first defined the market segments (building types, end uses, and other dimensions) that are relevant in NW Natural's service territory. The segmentation scheme for this project is presented in Table 2-2.

Table 2-2 Overview of NW Natural Analysis Segmentation Scheme

Dimension	Segmentation Variable	Description
1	Sector	Residential, Commercial, Industrial (sales customers only)
2	Segment	Residential: Single Family, Multi-Family, Manufactured Home, further divided into 3 income groups Commercial: Office, Retail, Restaurant, Grocery, School, Healthcare, Lodging, Warehouse, Miscellaneous Industrial: Firm and Interruptible, with end uses informed by industries
3	Vintage	Existing and new construction
4	End uses	Heating, secondary heating, water heating, food preparation, process, and miscellaneous (as appropriate by sector)
5	Appliances/End Uses and Technologies	Technologies such as furnaces, water heaters, and process heating by application, etc.
6	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 natural gas sales in the base year, 2019. NW Natural provided detailed energy consumption data along with market segmentation analysis previously conducted by the Energy Trust of Oregon, which AEG combined to produce the final base year totals used in the CPA. These totals for natural gas use and customers are allocated to the various sectors and segments such that the total customer count and energy consumption matched NW Natural's system totals in 2019.[6] This information provided control totals at a sector level for calibrating the LoadMAP model to known data for the base-year.

Market Profiles

The Market Profile is a base-year snapshot of an entire sector. It summarizes energy use for each segment in the study, portioning the annual energy into the various end uses and technologies. The market profile serves as the foundation for the baseline projection by defining the count of stock units that are available, and what the consumption of those units looks like in each segment. Chapter 3 provides detail on the key market profile elements.

Baseline Load Projection

The baseline projection is the foundation for the analysis of savings in future conservation cases and scenarios as well as the metric against which potential savings are measured. AEG developed the reference baseline in alignment with NW Natural's long-term demand forecast, but some modifications to account for known future conditions were also made.

Inputs to the baseline projection include:

- Current economic and load growth forecasts (i.e., customer growth, climate change assumptions)
- Trends in fuel shares and equipment saturations
- Existing and approved changes to building codes and equipment standards
- We present the baseline projection results for the system as a whole and for each sector in Chapter 4

Energy Efficiency Measure Development

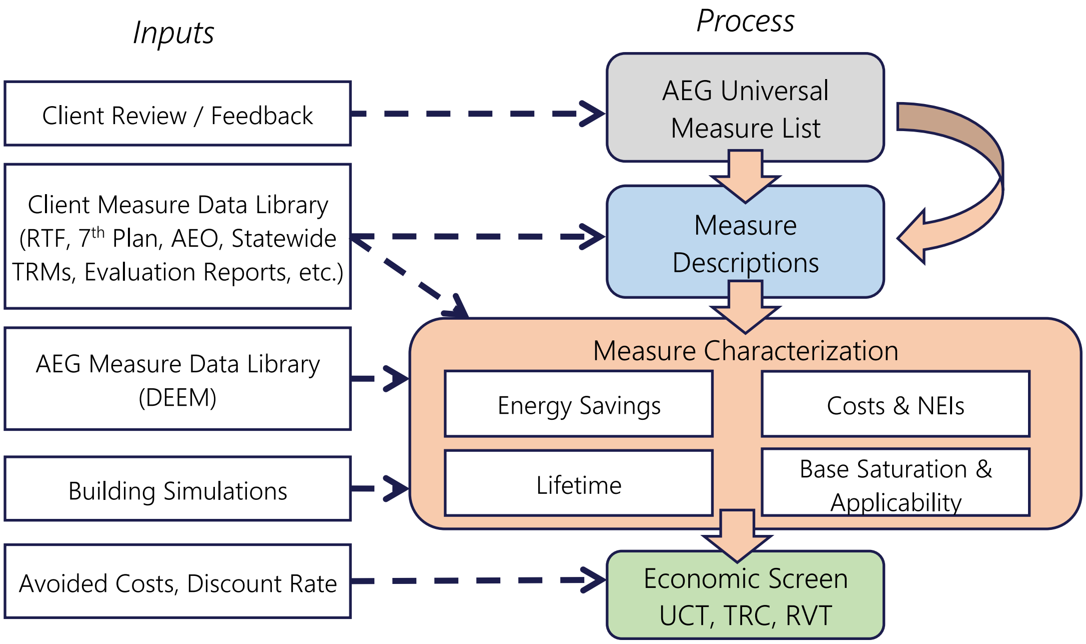
This section describes the framework used to assess the savings, costs, and other attributes of energy efficiency measures. These characteristics form the basis for measure-level cost-effectiveness analyses as well as for determining measure-level savings. To develop NW Natural's measure list, AEG used datasets provided by NW Natural and the Energy Trust of Oregon.

Figure 2-2 outlines the framework for measure characterization analysis. First, the list of measures is identified; each measure is then assigned an applicability for each market sector and segment and is characterized with appropriate savings, costs, and other attributes; then cost-effectiveness screening is performed. NW Natural provided feedback during each step of the process to ensure measure assumptions and results lined up with real-world programmatic experience.

We compiled a robust list of conservation measures for each customer sector, drawing upon NW Natural and the Energy Trust of Oregon's program experience, AEG's own measure databases and building simulation models, and secondary sources, primarily the Regional Technical Forum's (RTF) UES measure workbooks and the Draft 2021 Power Plan's electric power conservation supply curves. This universal list of measures covers all major types of end-use equipment, as well as devices and actions to reduce energy consumption.

[6] 2019 was chosen as the base year as it was deemed to be more reflective of normal conditions than 2020, which was heavily affected by the COVID-19 pandemic.

Figure 2-2 Approach for Energy Efficiency Measure Characterization and 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 a tankless residential water heater (UEF 0.91) that replaces a standard efficiency storage water heater (UEF 0.58). For equipment measures, many efficiency levels may be available for a given technology, ranging from the baseline unit (often determined by a 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 (LO) measures by the Council because once a purchase decision is made, there will not be another opportunity to improve the efficiency of that equipment item until its end of useful life (EUL) is reached once again.
- Non-equipment measures save energy by reducing the need for delivered energy, but do not involve replacement or purchase of major end-use equipment (such as a furnace or water heater). Measure installation is not tied to a piece of equipment reaching the end of useful life, so these are generally categorized as "retrofit" measures. 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 upgraded without waiting for 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 (Built Green homes)
  - Retrocommissioning
  - Behavioral

AEG developed a preliminary list of efficiency measures, which was reviewed with NW Natural's project team and with the Energy Trust of Oregon to ensure a robust field of options and consistency with program activity where applicable. Once we assembled the list of measures, the AEG team assessed their energy-saving characteristics as well as incremental cost, service life, non-energy impacts, and other performance factors.

Calculation of Energy Conservation Potential

The approach we used for this study to calculate the energy conservation potential adheres to the approaches and conventions outlined in the National Action Plan for Energy-Efficiency (NAPEE) *Guide for Conducting Energy Efficiency Potential Studies*.[7] This document represents credible and comprehensive industry best practices for specifying energy conservation potential. Three types of potential were developed as part of this effort: technical potential, achievable technical potential, and achievable economic potential (using UCT and TRC).

Stacking of Measures and Interactive Effects

An important factor when estimating potential is to consider interactions between measures when they are applied within the same space. This is important to avoid double counting and could feasibly result in savings at greater than 100% of equipment consumption if not properly accounted for.

This occurs at the population- or system- level, where multiple DSM actions must be stacked or layered on top of each other in succession, rather than simply summed arithmetically. These interactions are automatically handled within the LoadMAP models where measure impacts are stacked on top of each other, modifying the baseline for each subsequent measure. AEG first computes the total savings of each measure on a standalone basis, then also assign a stacking priority, based on levelized cost, to the measures such that "integrated" or "stacked" savings will be calculated as a percent reduction to the running total of baseline energy remaining in each end use after the previous measures have been applied. This ensures that the available pie of baseline energy shrinks in proportion to the number of DSM measures applied, as it would in reality. The loading order is based on the levelized cost of conserved energy, such that the more economical measures that are more likely to be selected from a resource planning perspective will be the first to be applied to the modeled population.

We also account for the exclusivity of certain measure options when defining measure assumptions. For instance, if an AFUE 95% furnace is installed in a single-family home, the model will not allow that same home to install an AFUE 98% furnace, or any other furnace, until the newly installed AFUE 95% option has reached its end of useful life. For non-equipment measures, which do not have a native applicability limit, we define base saturations and applicability such that measures do not overlap. For example, we model two applications of ceiling insulation. The first assumes the installation of insulation where there previously was none. The second upgrades pre-existing insulation if it falls under a certain threshold. We used regional market research data to ensure exclusivity of these two options. NEEA's RBSA contains information on average R-values of insulation installed. The AEG team used these data to define the percent of homes that could install one insulation measure, but not the other.

Estimating Customer Adoption

Once the technical potential is established, estimates for the market adoption rates for each measure are applied that specify the percentage of customers that will select the highest–efficiency economic option. This potential, phased in over a more realistic time frame, considers barriers such as imperfect information,

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

supplier constraints, technology availability, and individual customer preferences. The intent of market adoption rates is to establish a path to full market maturity for each measure or technology group and ensure resource planning does not overstep acquisition capabilities. We adapted the Northwest Power and Conservation Council's 2021 Plan ramp rates to develop these achievability factors for each measure. Applying these ramp rates as factors leads directly to the achievable technical potential. More details on this process can be found in Chapter 5.

Screening Measures for Cost-Effectiveness

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

This study uses the TRC test as the primary cost-effectiveness metric, which compares the lifetime energy and non-energy benefits of each applicable measure with the measure's incremental costs, lifetime operations and maintenance costs, and administrative costs incurred by the utility. The lifetime energy benefits are calculated by multiplying the annual energy savings for each measure by NW Natural's avoided costs and discounting the dollar savings to the present value equivalent. The analysis uses each measure's values for savings, costs, and lifetimes that were developed as part of the measure characterization process described above.

The LoadMAP model performs this screening dynamically and on an annual basis, considering changing savings and cost data over time. Thus, it is possible for measures to pass the economic screen 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 each measure in the screen is conducted relative to a baseline condition, such as minimum federal standard equipment, or average existing building shell conditions.
- The economic screening was 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.

Data Development

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

Data Sources

The data sources are organized into the following categories:

- NW Natural/Energy Trust of Oregon-provided data
- Pacific Northwest regional data
- AEG's databases and analysis tools
- Other secondary data and reports

NW Natural and Energy Trust of Oregon Data

Our highest priority data sources for this study were those that were specific to NW Natural. This data is specific to NW Natural's Washington service territory and is an important consideration when customizing the model for NW Natural's Washington market. This is best practice when developing CPA baselines when the data are available.

- NW Natural customer and system totals. NW Natural provided billing data summaries and sector-level totals for development of customer counts and energy use for each sector. These data were used to develop a detailed estimate of energy consumption within NW Natural's Washington service territory.
- NW Natural presence of equipment estimates. NW Natural conducted billing-level analysis of its customer databases to screen for the presence of natural gas space and water heating among its residential customers and space heating for commercial customers. This provided an excellent benchmark to adjust NEEA survey data (see below) to better represent NW Natural customers specifically.
- Load forecasts. NW Natural provided forecasts, by sector, of energy consumption, customer counts, weather actuals for 2019, and projected heating degree days (HDDs) for the study period, including assumed climate trends over the period.
- Economic information. NW Natural provided a discount rate and avoided cost forecasts by sector and end use.
- Peak Usage Factors. NW Natural provided the peak day and peak hour usage factors used for calculating peak savings for the day and the hour based on annual savings. These are the same usage factors used for calculating the avoided cost components that vary by end use.
- NW Natural's Washington program data via Energy Trust of Oregon. The Energy Trust of Oregon provided information about past and current programs they operate in NW Natural's Washington service territory, including program descriptions, goals, and measure achievements to date. NW Natural also provided a comprehensive list of measure costs, developed from measure installations within actual NW Natural conservation programs as per guidance they received from a previous third-party program evaluation.

Pacific Northwest Regional Data

The study utilized a variety of local data and research, including research performed by the Northwest Energy Efficiency Alliance (NEEA) and analyses conducted by the Council. Most important among these are:

- Northwest Power and Conservation Council Draft 2021 Power Plan and Regional Technical Forum workbooks. To develop its Power Plan, the Council maintains workbooks with detailed information about measures. This was used as a primary data source when NW Natural-specific program data was not available, and the data was determined to be applicable to natural gas conservation measures. The most recent data and workbooks available were used at the time of this study.
- Northwest Energy Efficiency Alliance, 2016-2017 Residential Building Stock Assessment II, https://neea.org/data/residential-building-stock-assessment
- Northwest Energy Efficiency Alliance, 2011 Residential Building Stock Assessment, https://neea.org/resources/washington-state-report
- Northwest Energy Efficiency Alliance, 2019 Commercial Building Stock Assessment, https://neea.org/resources/cbsa-4-2019-final-report

- Northwest Energy Efficiency Alliance, 2014 Commercial Building Stock Assessment, https://neea.org/resources/2014-cbsa-final-report
- Northwest Energy Efficiency Alliance, 2014 Industrial Facilities Site Assessment, https://neea.org/resources/2014-ifsa-final-report

The NEEA surveys were used extensively to develop base saturation and applicability assumptions for many of the non-equipment measures within the study. Legacy surveys (RBSA 2011 and CBSA 2014) are included because they often provide different granularity of data and/or valuable trend insight when combined with the more recent surveys.

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 10 years, AEG 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 (natural gas and electricity), 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 Conservation 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 60 studies of EE potential in the last five years. We checked our input assumptions and analysis results against the results from these other studies, both within the region and across the country.

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.
- American Community Survey. The US Census American Community Survey is an ongoing survey that provides data every year on household characteristics. http://www.census.gov/acs/www/
- Local Weather Data. Weather data from NOAA's National Climatic Data Center for Vancouver, WA.
- Database for Energy Efficient Resources (DEER). The California Energy Commission and California Public Utilities Commission (CPUC) sponsor this database, which is designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective

useful life (EUL) for the state of California. We used the DEER database to cross check the measure savings we developed using BEST and DEEM.

- Other relevant resources: These include reports from the Consortium for Energy Efficiency, the EPA, and the American Council for an Energy-Efficient Economy. This also includes technical reference manuals (TRMs) from other states. When using data from outside the region, especially weather-sensitive data, AEG adapted assumptions for use within NW Natural's Washington territory.

Application of Data to the Analysis

This section provides additional detail on how each of 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 natural gas consumption and market size units (households for residential, floor space for commercial, and employees for industrial), AEG primarily used NW Natural's customer usage data, secondary data from AEG's Energy Market Profiles database, and Energy Trust measure characterizations.

Data Application for Market Profiles

The specific data elements for the market profiles, together with the key data sources, are shown in Table 2-3. To develop the market profiles for each segment, we used the following approach:

1. Develop control totals for each segment. These include market size, segment-level annual natural gas use, and annual intensity. Control totals were based on NW Natural's actual sales and customer-level information found in NW Natural's customer billing database.
2. Develop existing appliance saturations and the energy characteristics of appliances, equipment, and buildings using NW Natural's end-use analysis, NEEA's 2016 RBSA, 2019 CBSA, and 2014 IFSA, DOE's 2015 RECS, the 2019 edition of the Annual Energy Outlook, AEG's Energy Market Profile (EMP) for the Pacific region, and the American Housing Survey.
3. Ensure calibration to NW Natural control totals for annual natural gas sales in each sector and segment.
4. Compare and cross-check with other recent AEG studies.
5. Work with NW Natural to verify the data aligns with their knowledge and experience.

Table 2-3 Data Applied for the Market Profiles

Model Inputs	Description	Key Sources
Market Size	Base-year residential dwellings, commercial floor space, and industrial employment	– NW Natural 2019 weather normalized sales – NW Natural customer account database
Annual Intensity	Residential: Annual use per household Commercial: Annual use per square foot Industrial: Annual use per employee	– NW Natural customer account database – AEG's Energy Market Profiles – AEO 2019 – Pacific Region – Other recent studies
Appliance/Equipment Saturations	Fraction of dwellings with an appliance/technology Percentage of C&I floor space/employment with equipment/technology	– NW Natural equipment flags in customer account database – 2016 RBSA, 2019 CBSA and 2014 IFSA – 2014 American Community Survey – 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/employee for a technology in floor space that has the technology	– HVAC uses: BEST simulations using prototypes developed for NW Natural – Engineering analysis – AEG DEEM – AEO 2019 – Pacific Region – Recent AEG studies
Appliance/Equipment Age Distribution	Age distribution for each technology	– 2011 RBSA, 2014 CBSA, and recent AEG studies
Efficiency Options for Each Technology	List of available efficiency options and annual energy use for each technology	– Energy Trust of Oregon program data in NW Natural WA service territory – AEG DEEM – AEO 2019 – CA DEER – Recent AEG studies

Data Application for Baseline Projection

Table 2-4 summarizes the LoadMAP model inputs required for the baseline projection. These inputs are required for each segment within each sector, as well as for new construction and existing dwellings/buildings.

Table 2-4 Data Applied for the Baseline Projection in LoadMAP

Model Inputs	Description	Key Sources
Customer Growth Forecasts	Forecasts of new construction and conversions in residential and C&I sectors	– NW Natural load forecast
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	– Shipments data from AEO and ENERGY STAR – AEO 2019 regional forecast assumptions8 – Appliance/efficiency standards analysis
Utilization Model Parameters	Price elasticities, elasticities for other variables (income, weather)	– EPRI's REEPS and COMMEND models

- Equipment Standards. In addition, assumptions were incorporated for known future equipment standards as of July 2020, as shown in Table 2-5 and Table 2-6. These tables extend through 2025, after which all standards are assumed to hold steady.
- Building Codes for New Construction. This CPA assumed new construction would comply with the mandatory portions of the 2018 Washington State Energy Code.

[8] AEG developed baseline purchase decisions using the Energy Information Agency's *Annual Energy Outlook* report (2017), 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.

Table 2-5 Residential Natural Gas Equipment Federal Standards[9]

End Use	Technology	2019	2020	2021	2022	2023	2024	2025
Space Heating	Furnace – Direct Fuel	AFUE 80%					AFUE 92%*	
	Boiler – Direct Fuel	AFUE 82%	AFUE 84%					
Secondary Heating	Fireplace	N/A						
Water Heating	Water Heater <= 55 gal.	UEF 0.58						
	Water Heater > 55 gal.	UEF 0.76						
Appliances	Clothes Dryer	CEF 3.30						
	Stove/Oven	N/A						
Miscellaneous	Pool Heater	TE 0.82						
	Miscellaneous	N/A						

* This code was originally set to take effect in 2021 but exempts smaller systems. The comment period lasted through 2017, with the standard not expected to take effect until at least 5 years after that time. There has been no update since the comment period expired, so the analysis retains the previous assumption that this standard will come online officially in 2024.

Table 2-6 Commercial and Industrial Natural Gas Equipment Standards

End Use	Technology	2019	2020	2021	2022	2023	2024	2025
Space Heating	Furnace	AFUE 80% / TE 0.80						
	Boiler	Average around AFUE 80% / TE 0.80 (varies by size)						
	Unit Heater	Standard (intermittent ignition and power venting or automatic flue damper)						
Water Heater	Water Heating	TE 0.80						
Food Preparation	Fryer	N/A			Min. heavy load efficiency ≥50%, idle ≤ 9 kBtu/hr.			
	Steamer	N/A			Min. heavy load efficiency ≥38%, idle ≤ 9.3 kBtu/hr.			

[9] The assumptions tables here extend through 2025, after which all standards are assumed to hold steady.

Energy Conservation Measure Data Application

Table 2-7 details the energy-efficiency data inputs to the LoadMAP model. It describes each input and identifies the key sources used in the NW Natural analysis.

Table 2-7 Data Inputs 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.	– Energy Trust of Oregon program data in NW Natural WA service territory – NWPCC workbooks, RTF – AEG BEST – AEG DEEM – AEO 2017 – CA DEER – 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, commercial, and industrial 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.	– NW Natural/Energy Trust of Oregon program data – NWPCC workbooks, RTF – AEG DEEM – AEO 2017 – CA DEER – RS Means – Other secondary sources
Measure Lifetimes	Estimates derived from the technical data and secondary data sources that support the measure demand and energy savings analysis.	– NWPCC workbooks, RTF – AEG DEEM – AEO 2017 – CA DEER – Other secondary sources
Applicability	Estimate of the percentage of dwellings in the residential sector, square feet in the commercial sector, or employees in the industrial sector where the measure is applicable and where it is technically feasible to implement.	– 2011/2016 RBSA, 2014/2019 CBSA; 2021 Plan applicability guidelines – 2015 WSEC for limitations on new construction – AEG DEEM – CA DEER – 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 perform the cost-effectiveness screening, a number of economic assumptions were needed. All cost and benefit values were analyzed in real dollars. The analysis applied NW Natural's long-term real discount rate of 4.8% equal to NW Natural's real after-tax weighted average cost of capital (WACC) for Washington.

Estimates of Customer Adoption

To estimate the timing and rate of customer adoption in the potential forecasts, two sets of parameters are needed:

- Technical diffusion curves for non-equipment measures. Equipment measures are installed when existing units fail. Non-equipment measures do not have this natural periodicity, so rather than installing all available non-equipment measures in the first year of the projection (instantaneous potential), they are phased in according to adoption schedules that generally align with the diffusion of similar equipment measures. For this analysis, we used the Council's retrofit ramp rates, applied before the achievability adjustment.
- 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 best-practice portfolio of well-operated efficiency programs under a reasonable policy or regulatory framework. Information channels are assumed to be established and efficient for marketing, educating consumers, and coordinating with trade allies and delivery partners. The primary barrier to adoption reflected in this case is customer preferences. Again, these are based on the ramp rates from the Council's Draft 2021 Power Plan

The ramp rates referenced above were adapted for use for assessing natural gas measure potential, as described in Appendix A.

3

MARKET CHARACTERIZATION AND MARKET PROFILES

In this section, we describe how customers in NW Natural's Washington service territory use natural gas in the base year of the study, 2019, beginning with a high-level summary of energy use across all sectors and then delving into each sector in more detail.

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 we use is number of households. In the commercial sector, it is floor space measured in square feet. For the industrial sector, it is number of employees.
- Saturations indicate the share of the market that is served by a particular end-use technology. Three types of saturation definitions are commonly used:
    - The conditioned space approach accounts for the fraction of each building that is conditioned by the end use (i.e., space heating).
    - The whole-building approach measures shares of space in a building with an end use regardless of the portion of each building that is served by the end use. Examples are commercial refrigeration and food service, and domestic water heating and appliances.
    - The 100% saturation approach applies to end uses that are generally present in every building or home and are simply set to 100% in the base year.
- UEC (Unit Energy Consumption) or EUI (Energy Usage Index) define consumption for a given technology. UEC represents the amount of energy a given piece of equipment is expected to use in one year. EUI is a UEC indexed to a non-building market unit, such as per square foot or per employee.
    - These are indices that refer to a measure of average annual energy use per market unit (home, floor space, or employee in the residential, commercial, and industrial sector, respectively) that are served by an end-use technology. UECs and EUIs embody an average level of service and average equipment efficiency for the market segment.
- 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 as therms/household for natural gas. For the commercial and industrial sectors, intensity, computed as the product of the saturation and the EUI, represents the average use for the technology across all floor space or all employees 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 therms or mTherms.

Overall Energy Use Summary

Total weather normalized natural gas consumption for sales customers across all sectors for NW Natural's Washington service territory in 2019 was 80,319 mTherms. As shown in Figure 3-1 and Table 3-1, the residential sector accounts for the largest share of annual energy use at 66%, followed by the commercial sector at 28%. Sales customers within the industrial sector account for 6% of usage.

Figure 3-1 Sector-Level Natural Gas Use in Normalized Base Year 2019 (annual therms, percent)

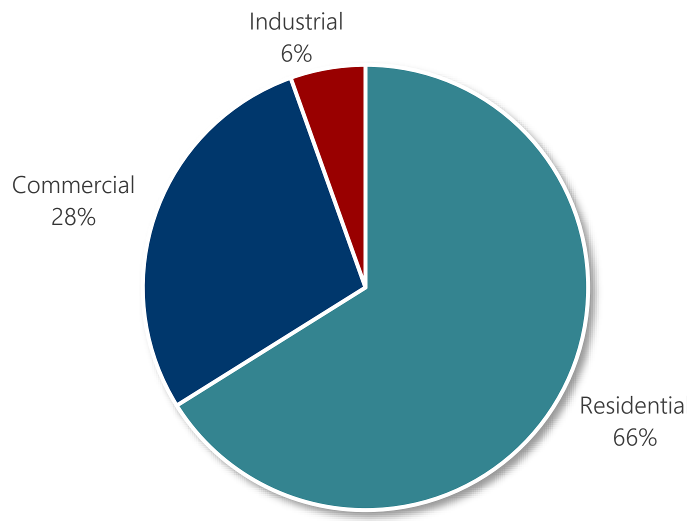


Table 3-1 NW Natural Sector Control Totals, 2019 Weather Normalized

Sector	2019 Normalized Gas Sales (mTherms)	% of Total Usage
Residential	53,096	66%
Commercial	22,840	28%
Industrial	4,382	6%
Total	**80,319**	**100%**

Considerations for Transportation Customers

Transportation customers were excluded from consideration in this report, as energy efficiency programs for these customers are currently not available. Though there have been regional conversations surrounding potential for transportation customers, there are additional data needs in estimating this potential, clarifications to be made on the appropriate avoided costs to apply for this customer segment and potential challenges in acquiring savings, which would include changing the current tariff to include transportation customers. Assessing the cost-effective potential for transportation customers would require more visibility into the kinds of customers on these rates, how these customers are using natural gas, and an understanding of how these customers view energy savings and the rate at which they may participate in future programs since there is no past history on which to draw.

Residential Sector

The total number of households and gas sales for the service territory were obtained from NW Natural's actual sales for 2019. Details, including number of households and 2019 natural gas consumption for the residential sector can be found in Table 3-2 below. In 2019, there were 78,764 households in the NW Natural territory that used a total of over 53 mTherms, resulting in an average use per household of 674 therms per year. This is an important number for the calibration process.

These values have been weather normalized to account for differences in the actual heating degree days for 2019 compared to normal weather. Degree days for the conversion were provided by NW Natural's forecast department.

Table 3-2 Residential Natural Gas Use by Segment, 2019 Weather Normalized

Segment	Households	Gas Sales (mTherms)	% of Total Usage	Avg. Use / Household (therms)
Single Family	70,323	49,724	94%	707
Multi-Family	8,045	3,093	6%	384
Manufactured Home	395	280	1%	708
Total	**78,764**	**53,096**	**100%**	**674**

Residential Income Group Analysis

Given increased interest in reaching low-income customer segments in NW Natural's Washington service territory, income-level analysis for the residential sector was included in the scope of this assessment. To protect customer privacy, data on NW Natural's specific customers was limited to their ZIP code and household natural gas use.

Income Group Definitions

AEG worked with NW Natural to develop suitable definitions of each income group to align with program eligibility and other income eligibility criteria in alignment with low-income programs in Washington. The thresholds of household income for low- and moderate-Income designations are shown in Table 3-3 below. The low-income threshold corresponds with 200% of the Federal Poverty Level (FPL) which is also the eligibility cutoff for the Washington weatherization assistance program. Households in the moderate-income group are above the 200% FPL level, but below the Washington state median income by household size. Households with income above the Washington state median income were included in a third "Above Median Income" group.

Table 3-3 Definitions of Income Groups by Household Size (up to)

HH Size (persons)	Low Income	Moderate Income
1	$25,520	$28,931
2	$34,480	$57,863
3	$43,440	$86,794
4	$52,400	$115,725
5	$61,360	$144,657
6	$70,320	$173,588
7	$79,280	$202,520
8	$88,240	$231,451

Customer Segmentation by Income Group

To estimate the number of NW Natural customers in each of the income groups, AEG mapped address data or NW Natural residential accounts back to corresponding geographic "blocks" in the census data. Each of these blocks was then processed to analyze average household size and income, producing a distribution of households into income buckets for places where NW Natural customers reside. These distributions by housing type and income level serve to split apart the housing types from the original 2019 market profile.

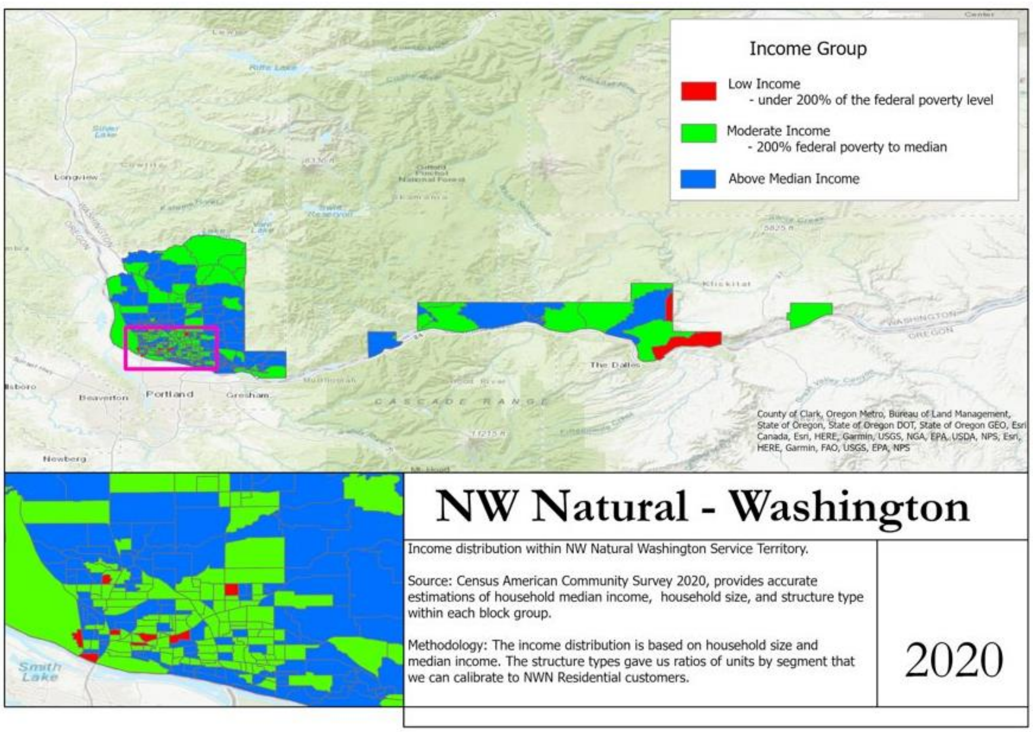
As shown in Table 3-4 below, slightly more than half of NW Natural's Washington residential customers have household incomes at or above the median for Washington. The moderate-income group is the next largest with 46.2% of households, while just 1.9% of households fall into the low-income group.

Table 3-4 Customer Distribution by Income Groupings and Housing Type (% of households)

Segment	Above Median	Moderate	Low Income	Total
Single Family	54.0%	44.6%	1.4%	**100.0%**
Multi-Family	35.1%	59.0%	5.9%	**100.0%**
Manufactured Homes	38.8%	59.8%	1.4%	**100.0%**
Total	**52.0%**	**46.2%**	**1.9%**	**100.0%**

The map in Figure 3-2 shows the distribution of different income groups through NW Natural's service territory.

Figure 3-2 Income Group Map



Energy Consumption by Income Group

Once the percent of customers in each housing type and income group was known, AEG used RBSA data to investigate differences in home characteristics and energy consumption by these same groupings. This allowed AEG to compare natural gas usage per household across categories. AEG was also able to identify some adjustments to the base market profile and building assumptions to reflect differences by income level, including:

- Low-income customers with gas service from NW Natural have lower presence of gas water heat, but greater presence of gas space heat compared to moderate or above median income customers.
- Low- and moderate-income homes are smaller than above median income homes, however, use per square foot of home is similar across all three categories, despite RBSA data showing that low- and moderate-income homes have lower insulation values and would be expected to use more energy (per square foot) to maintain similar levels of comfort in the home. This suggests that while home size is a factor in reduced consumption, it is not the sole explanation.
- Income level does not appear to correlate with the age of the home.

Combining the geographic/demographic analysis with RBSA data on usage differences by income level, AEG was able to produce an expanded residential profile with data-driven variation by income group.

Table 3-5 shows the residential control totals from above after distributing base-year households and natural gas consumption based on the income group analysis.

Table 3-5 Residential Natural Gas Use by Income Level, 2019 Weather Normalized

Segment	Income Group	Households	% of All Homes	mTherms	Therms / HH
Single Family	Above Median	37,941	48.2%	28,378	748
	Moderate Income	31,375	39.8%	20,803	663
	Low Income	1,008	1.3%	542	538
Multi-Family	Above Median	2,826	3.6%	1,185	419
	Moderate Income	4,744	6.0%	1,764	372
	Low Income	475	0.6%	143	302
Manufactured Homes	Above Median	153	0.2%	117	762
	Moderate Income	236	0.3%	160	676
	Low Income	5	0.0%	3	548
Total		**78,764**	**100.0%**	**53,096**	**674**

Figure 3-3 shows the distribution of annual natural gas consumption by end use for an average residential household. Space heating (primary and secondary) comprises a majority of the load at 78% followed by water heating at 20%. Miscellaneous loads make up a very small portion of the total. This is expected for a natural gas profile as there are few miscellaneous technologies. Natural gas backyard grills and pool heaters fall into this category.

Figure 3-3 Residential Natural Gas Use by End Use, 2019

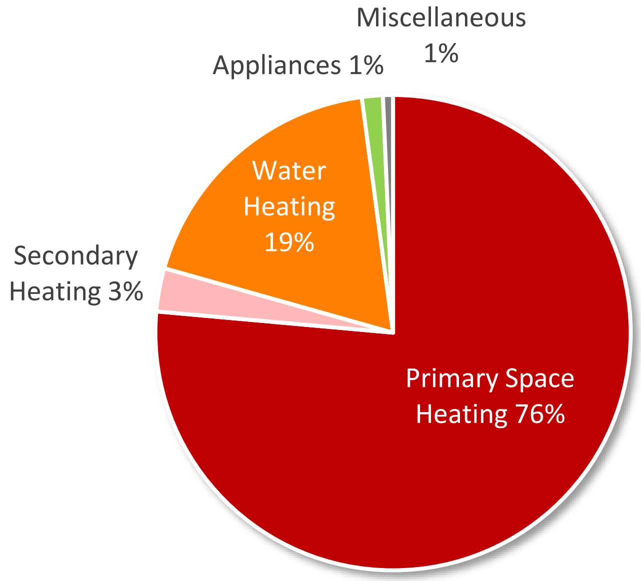
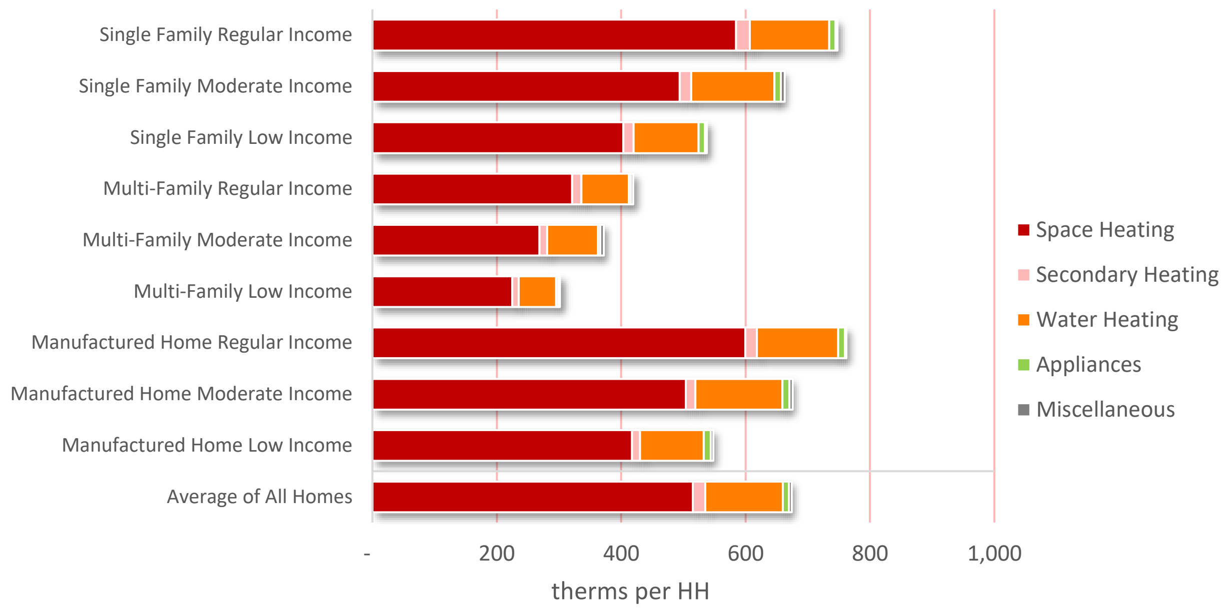


Figure 3-4 presents average residential natural gas intensities by end use and housing type. Manufactured homes consume more energy than other segments, primarily due to an older housing stock with inefficient building envelopes and heating systems. Prior to 1976, no energy code for manufactured homes existed to ensure a minimum level of efficiency, resulting in poorly constructed energy intensive homes. Single family regular income homes also consume substantially more natural gas for space heating, primarily due to two factors. The first is that single family homes are larger. The second is that more walls are exposed to the outside environment, compared to multifamily dwellings with many shared walls. This increases heat transfer, resulting in greater heating loads. Higher water heating consumption can often be attributed to having more people in the household, which increases the demand for hot water.

Figure 3-4 Residential Energy Intensity by End Use and Segment, 2019 (Annual Therms/HH)



The market profile for an average home in the residential sector is presented in Table 3-6 below. An important step in the profile development process is model calibration. All consumption within an average home must sum up to the intensity extracted from billing data. This is necessary so estimates of consumption for a piece of equipment do not exceed the actual usage in a home.

Table 3-6 Average Market Profile for the Residential Sector, 2019

End Use	Technology	Saturation	UEC (therms)	Intensity (therms/HH)	Usage (000 therms)
Space Heating	Furnace	78%	624	484	38,131
	Boiler	5%	471	25	1,952
Secondary Heating	Fireplace	19%	112	22	1,698
Water Heating	Water Heater (<= 55 gal)	76%	166	126	9,946
	Water Heater (> 55 gal)	2%	166	4	298
Appliances	Clothes Dryer	14%	18	3	204
	Stove/Oven	38%	18	7	553
Miscellaneous	Pool Heater	0%	77	0	21
	Miscellaneous	100%	4	4	293
	Total			**674**	**53,096**

Commercial Sector

The total number of commercial accounts and natural gas sales for the service territory were obtained from NW Natural's customer account data, distributed according to segment tags in the billing system and Energy Trust's prior analysis of non-residential segmentation for previous NW Natural studies.

Table 3-7 below shows the final allocation of energy to each segment in the commercial sector, as well as the energy intensity on a square-foot basis. Intensities for each segment were derived from a combination of the 2019 CBSA and equipment saturations extracted from NW Natural's database. The CBSA intensities corresponded to spaces with slightly lower natural gas saturations than NW Natural's database, so AEG increased intensities proportionally based on the additional presence of natural gas-consuming equipment.

Table 3-7 Commercial Sector Control Totals, 2019

Segment	Description	Intensity (therms/Sq Ft)	2019 Natural Gas Normalized Use (mTherms)
Office	Traditional office-based businesses including finance, insurance, law, government buildings, etc.	0.38	3,878
Retail	Department stores, services, boutiques, strip malls etc.	0.29	5,513
Restaurant	Sit-down, fast food, coffee shop, food service, etc.	5.44	4,267
Grocery	Supermarkets, convenience stores, market, etc.	0.30	1,034
College	College, university, trade schools, etc.	0.69	437
School	Day care, pre-school, elementary, secondary schools	0.69	3,105
Hospital	Hospital, urgent care centers, etc.	0.66	1,863
Other Health	Doctor/Dental office, therapy clinics, health practitioner office, etc.	0.66	1,121
Lodging	Hotel, motel, bed and breakfast, etc.	1.08	780
Warehouse	Large storage facility, refrigerated/unrefrigerated warehouse	0.25	197
Miscellaneous	Catchall for buildings not included in other segments, includes churches, recreational facilities, public assembly, correctional facilities, etc.	0.33	646
Total		**0.49**	**22,840**

Figure 3-5 shows each segment's natural gas consumption as a percentage of the entire commercial sector energy consumption. The four segments with the highest natural gas usage in 2019 are retail, restaurant, offices, and schools, in descending order. As expected, the highest intensity segment is restaurant. This is based on the high presence of food preparation equipment.

Figure 3-5 Commercial Natural Gas Use by Segment, 2019

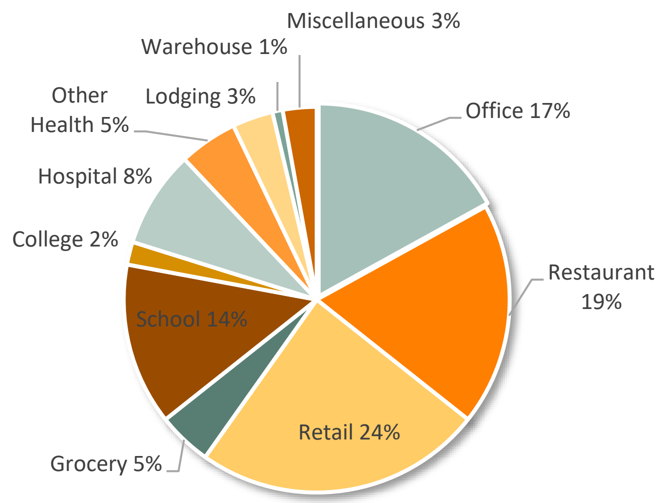


Figure 3-6 shows the distribution of natural gas consumption by end use for the entire commercial sector. Space heating is the largest end use, followed by water heating and food preparation. The miscellaneous end use is quite small, as expected.

Figure 3-6 Commercial Sector Natural Gas Use by End Use, 2019

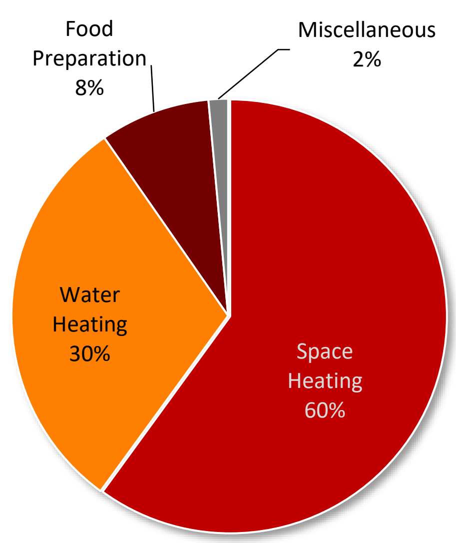
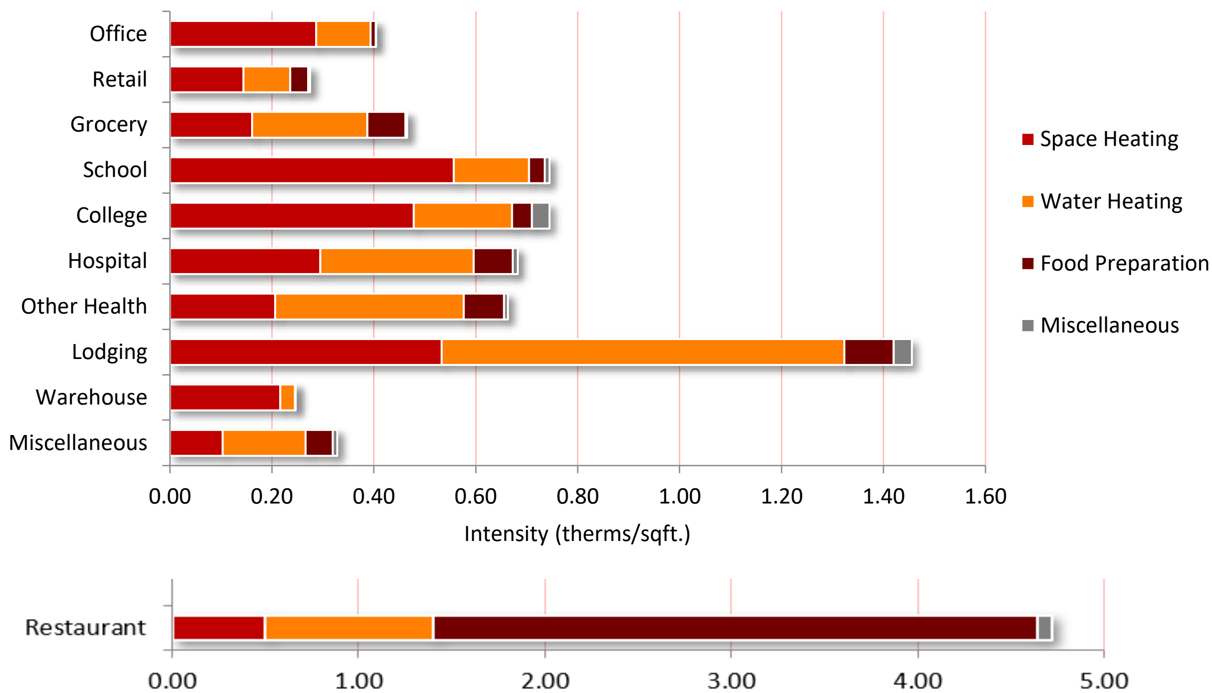


Figure 3-7 presents average commercial natural gas intensities by end use and segment. Due to large food preparation loads, the restaurant segment has a significantly higher intensity than other commercial segments. To allow the distribution of end uses to be visible for all segments, restaurant is displayed on a separate axis.

Figure 3-7 Commercial Energy Usage Intensity by End Use and Segment, 2019 (Annual Therms/Sq. Ft)



The total market profile for an average building in the commercial sector is presented in Table 3-8 below. NW Natural customer account data informed the market profile by providing information on saturation of key equipment types. Secondary data was used to develop estimates of energy intensity and square footage, and to fill in saturations for any equipment types not included in the database.

Table 3-8 Average Market Profile for the Commercial Sector, 2019

End Use	Technology	Saturation	EUI (therms/sq. ft.)	Intensity (therms/sq. ft.)	Usage (mTherms)
Space Heating	Furnace	53.9%	0.17	0.09	4,201
	Boiler	24.6%	0.55	0.13	6,260
	Unit Heater	4.4%	0.09	0.00	184
Water Heating	Water Heater	58.6%	0.27	0.16	7,285
Food Preparation	Oven	4.7%	0.09	0.00	205
	Conveyor Oven	2.4%	0.16	0.00	175
	Double Rack Oven	2.4%	0.24	0.01	266
	Fryer	9.0%	0.33	0.03	1,388
	Broiler	5.1%	0.37	0.02	884
	Griddle	9.0%	0.18	0.02	743
	Range	10.9%	0.16	0.02	795
	Steamer	1.7%	0.14	0.00	111
	Commercial Food Prep Other	0.2%	0.02	0.00	1.6
Miscellaneous	Pool Heater	0.2%	0.01	0.00	1.0
	Miscellaneous	100.0%	0.01	0.01	342
Total				**0.49**	**22,840**

Industrial Sector

The total sum of natural gas used in 2019 by NW Natural's industrial sales customers in Washington was 4,382 mTherms. As in the commercial sector, customer account data were used to allocate usage among segments. Energy intensity was derived from AEG's Energy Market Profiles database. We cross-referenced this data with Bureau of Labor Statistics employment data by industry. Number of employees is calculated by dividing total usage by intensity. For the industrial sector, the unit of measure chosen is employment. This is because floor area is not as indicative of process loads, which may be constrained to one portion of a larger warehouse/storage facility. AEG chose to capture usage on an employment basis rather than customer since NEEA's 2014 IFSA reports in a similar metric, and it allows us to compare intensities with those estimated for the region as a whole. Most industrial measures are installed through custom programs, where the unit of measure is not as necessary to estimate potential. This analysis breaks Industrial customers into two groups; firm customers, who receive a guarantee of their gas delivery, and interruptible customers, who's gas service can be interrupted when the system becomes constrained to ensure firm customers are served first. Interruptible industrial customers receive a cheaper gas rate and are a form of demand response on the natural gas system.

Table 3-9 Industrial Sales Sector Control Totals (2019)

Segment	Natural Gas Sales (mTherms)	% of Total Usage	Intensity (therms/empl.)
Industrial - Firm	3,989	91%	4,213
Industrial - Interruptible	393	9%	385
Total	**4,382**	**100%**	**2,227**

Error! Reference source not found.8 summarizes industrial natural gas consumption by segment.

Figure 3-8 Industrial Sales Natural Gas Use by Segment, 2019

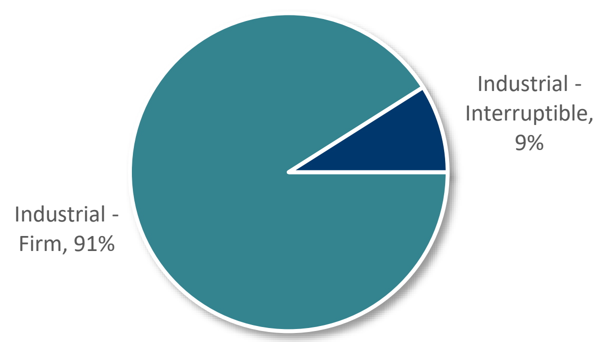


Figure 3-9 shows the distribution of annual natural gas consumption by end use for all industrial customers. Two major sources were used to develop this consumption profile. The first was AEG's analysis of warehouse usage as part of the commercial sector. We begin with this prototype as a starting point to represent non-process loads. We then added in process loads using our Energy Market Profiles database, which summarizes usage by end use and process type. Accordingly, process is the largest overall end use for the industrial sector, accounting for 82% of energy use. Space heating is the second largest end use, and miscellaneous, non-process industrial uses round out consumption.

Figure 3-9 Industrial Sales Natural Gas Use by End Use, 2019

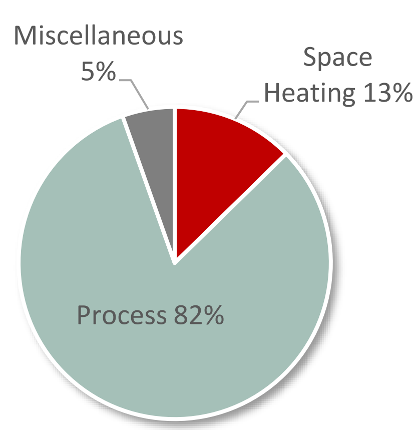


Figure 3-10 summarizes industrial energy intensities by industry type.

Figure 3-10 Industrial Sales Energy Usage Intensity by End Use and Segment, 2019 (Annual Therms/Employee)

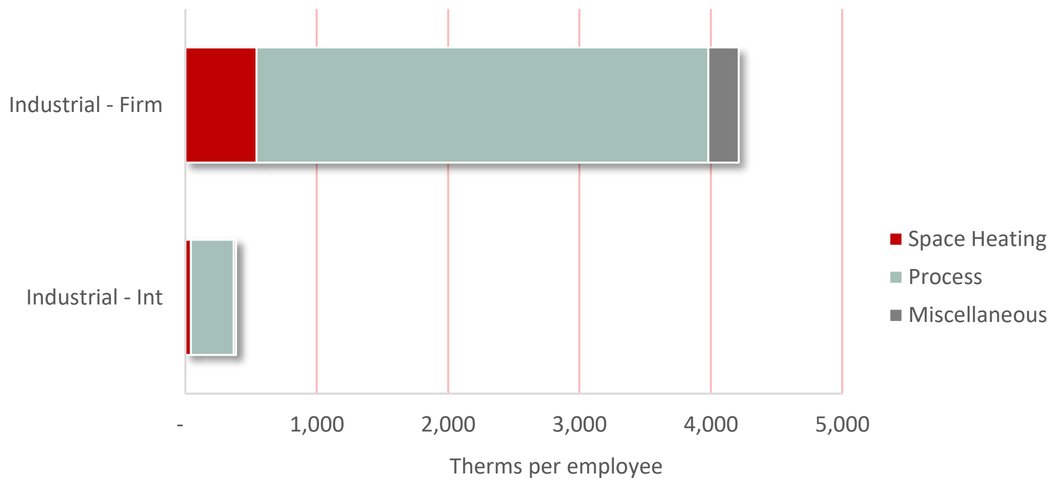


Table 3-10 shows the composite market profile for the industrial sector. Process cooling is very small and represents technologies such as gas-driven absorption chillers.

Table 3-10 Average Natural Gas Market Profile for the Industrial Sector, 2019

End Use	Technology	Saturation	EUI (mTherms/ employee)	Intensity (mTherms/ employee)	Usage (mTherms)
Space Heating	Furnace	70.6%	0.54	0.38	392
	Boiler	14.0%	0.54	0.08	78
	Unit Heater	15.4%	0.54	0.08	86
Process	Process Boiler	100.0%	1.81	1.81	1,851
	Process Heating	100.0%	1.61	1.61	1,645
	Process Cooling	100.0%	0.01	0.01	12
	Other Process	100.0%	0.08	0.08	81
Miscellaneous	Miscellaneous	100.0%	0.23	0.23	238
Total				**4.30**	**4,382**

4

BASELINE PROJECTION

Prior to developing estimates of energy conservation potential, baseline projections of annual natural gas use for 2022 through 2051 by customer segment and end use in the absence of new utility energy-efficiency programs were developed. The savings from past programs are embedded in the forecast, but the baseline projection assumes that those past programs cease to exist in the future to avoid double counting potential opportunities. Thus, the potential analysis captures all possible savings from future programs.

The baseline projection incorporates assumptions about:

- 2019 energy consumption based on the market profiles
- Customer population growth
- Appliance/equipment standards and building codes already mandated
- Appliance/equipment purchase decisions
- NW Natural's customer forecast
- Trends in fuel shares and appliance saturations and assumptions about miscellaneous natural gas growth

Although it aligns closely, the baseline projection presented in this chapter is not NW Natural's official load forecast. Rather, it was developed by AEG as an integral component of the modeling construct to serve as the metric against which energy conservation potentials are measured. To align the baseline projection as closely as possible with NW Natural's load forecast, AEG incorporated the same assumptions and data where available. For example, NW Natural's heating degree days (base 58°F) were incorporated into the LoadMAP model to align the baseline projection with NW Natural's forecast. The end-use projection includes impacts of future federal standards that were effective as of July 2020, which drive energy consumption down through the study period.

NW Natural's load forecast informing this assessment uses the base case load forecasting methodology discussed in NW Natural's 2018 IRP. The 2018 IRP base case load forecast primarily relies on historical data and trends to forecast usage into the future. Structural changes from historical trends, such as the new Washington residential building code, will likely require an end use load forecasting methodology NW Natural employs to develop some of its load sensitivities to be used for the base case in the upcoming IRP. NW Natural will discuss this methodology with stakeholders through the upcoming technical working group process. Any structural changes from historical trends are likely to have a larger impact on the long-term savings potential than in the near-term (i.e., the next two years before another CPA is conducted).

Naturally occurring energy conservation, that is, energy conservation that is realized within the service area independent of utility-sponsored programs, is incorporated into the baseline projection consistent with the US Energy Information Administration's Annual Energy Outlook for the Pacific region. Results of the primary market research were used to calibrate these assumptions to ensure the secondary sources were relevant to NW Natural customers. For example, some customers will purchase and install energy conservation measures that are available in the market without a utility incentive. Please note this is not the "Frozen Efficiency" case defined by the Council, which is used for comparison with electricity savings from the Draft 2021 Power Plan.

Below, are the baseline projections for each sector, which include projections of annual use in mTherms. We also present a summary across all sectors.

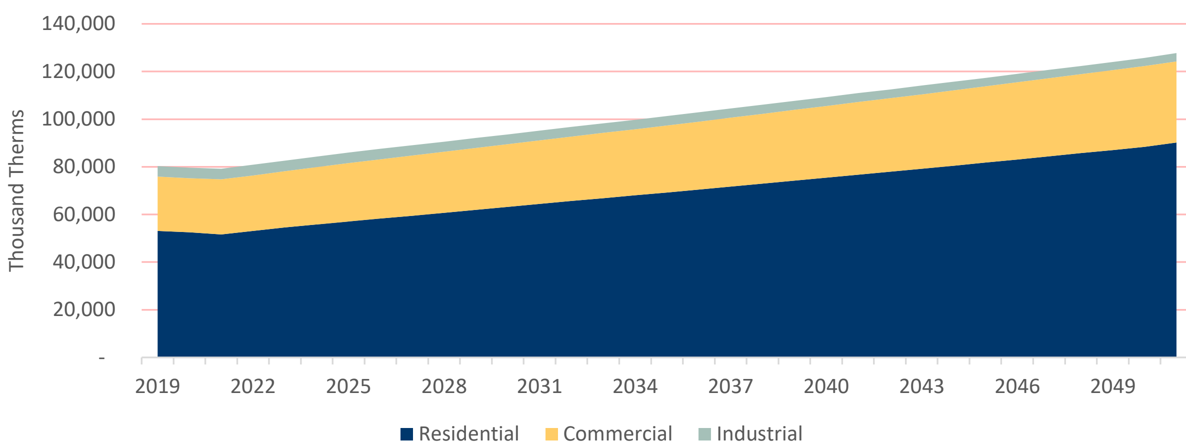
Summary of Overall Baseline Projection

Table 4-1 and Figure 4-1 provide a summary of the baseline projection for annual use by sector for the entire NW Natural Washington service territory. Base year (2019) values[10] are weather normalized using HDD data provided by NW Natural's load forecast department. Years 2021 forward include the impact of climate trends through projected heating degree days (HDDs) supplied by NW Natural. Overall, the forecast shows modest growth in natural gas consumption, at an average rate of about 1.4% per year.

Table 4-1 Baseline Projection Summary by Sector, Selected Years (mTherms)

Sector	2019	2020	2021	2022	2023	2024	2031	2040	2050	% Change ('19-'50)	Avg. Growth
Residential	53,096	52,500	51,552	53,041	54,507	55,765	64,452	75,477	88,376	66.4%	1.6%
Commercial	22,840	22,754	23,213	23,350	23,623	24,112	26,657	30,083	33,935	48.6%	1.3%
Industrial	4,382	4,379	4,400	4,440	4,450	4,405	4,120	3,753	3,435	-21.6%	-0.8%
Total	**80,319**	**79,633**	**79,166**	**80,831**	**82,581**	**84,282**	**95,229**	**109,312**	**125,747**	**56.6%**	**1.4%**

Figure 4-1 Baseline Projection Summary by Sector (mTherms)



[10] NW Natural also provided 2020 consumption data for AEG's consideration in aligning the baseline projection with NW Natural's forecast

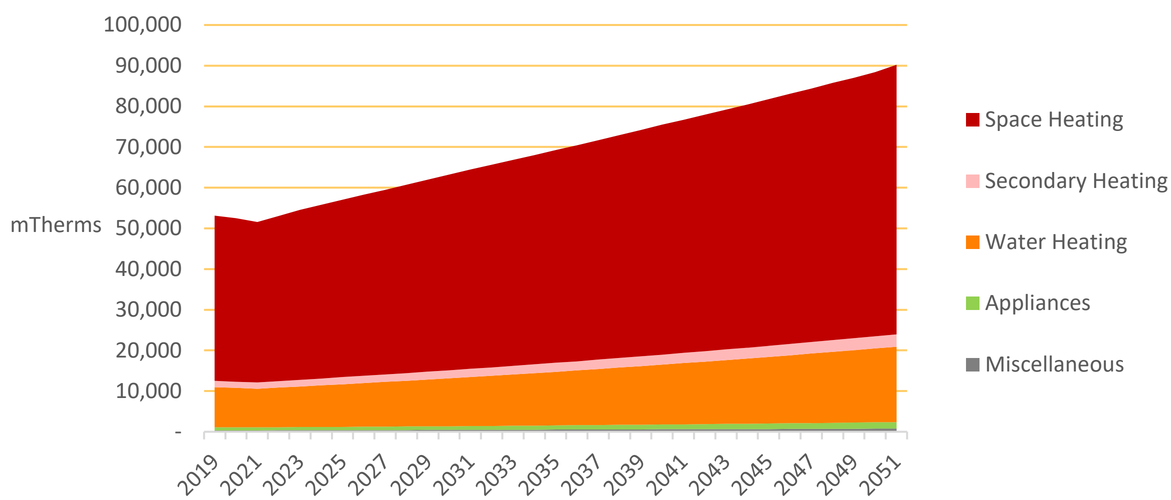
Residential Sector Baseline Projection

Table 4-2 and Figure 4-2 present the baseline projection for natural gas at the end-use level for the residential sector, as a whole. Overall, residential use increases from 53,096 mTherms in 2019 to 88,376 mTherms in 2050, an increase of 66%. There are two high-level factors affecting growth. The first is a moderate increase in number of households and customers. The second is a decrease in equipment consumption due to future standards and naturally occurring efficiency improvements (notably the upcoming AFUE 92% furnace standard). We model gas-fired fireplaces as secondary heating because these units consume energy and may heat a space but are rarely relied on to be a primary heating technology. As such, they are estimated to be more aesthetic and less weather-dependent than gas furnaces. This end- use grows faster than others since new homes are more likely to install a unit, increasing fireplace stock. Miscellaneous is a very small end-use in natural gas studies and includes technologies with low penetration, such as gas barbeques.

Table 4-2 Residential Baseline Projection by End Use (mTherms)

End Use	2019	2020	2022	2023	2024	2031	2040	2050	% Change ('19-'50)	Avg. Growth Rate
Space Heating	40,578	41,486	40,594	41,716	42,654	48,986	56,513	64,888	60%	1.5%
Secondary Heating	1,564	1,620	1,584	1,636	1,683	2,012	2,464	3,014	93%	2.1%
Water Heating	9,835	9,950	9,745	10,005	10,247	12,038	14,702	18,155	85%	2.0%
Appliances	757	777	749	769	788	938	1,198	1,564	107%	2.3%
Miscellaneous	362	375	368	381	393	478	600	756	109%	2.4%
Total	**53,096**	**54,209**	**53,041**	**54,507**	**55,765**	**64,452**	**75,477**	**88,376**	**66%**	**1.6%**

Figure 4-2 Residential Baseline Projection by End Use (mTherms)



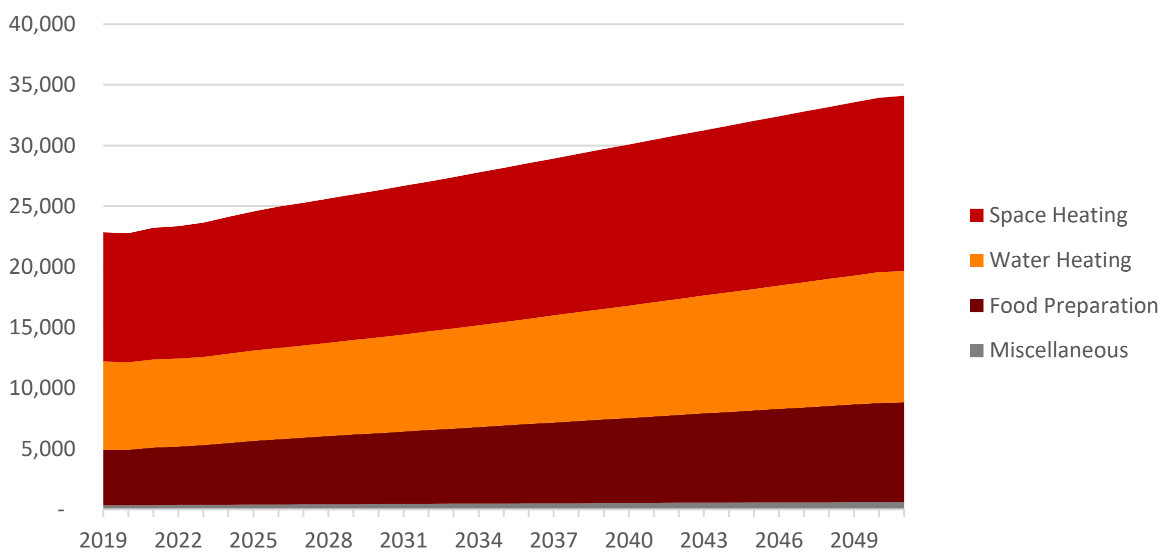
Commercial Sector Baseline Projection

Annual natural gas use in the commercial sector grows at an average rate of 1.3% per year during the overall forecast horizon, starting at 22,840 mTherms in 2019, and increasing to 33,935 mTherms in 2050. Table 4-3 and Figure 4-3 present the baseline projection at the end-use level for the commercial sector, as a whole. Similar to the residential sector, market size is increasing and usage per square foot is decreasing slightly.

Table 4-3 Commercial Baseline Projection by End Use (mTherms)

End Use	2019	2020	2022	2023	2024	2031	2040	2050	% Change ('19-'50)	Avg. Growth Rate
Space Heating	10,644	10,628	10,912	11,041	11,265	12,229	13,278	14,382	35%	1.0%
Water Heating	7,285	7,201	7,260	7,281	7,370	8,011	9,267	10,775	48%	1.3%
Food Preparation	4,568	4,581	4,816	4,931	5,095	5,969	7,011	8,166	79%	1.9%
Miscellaneous	343	344	361	370	382	448	526	613	79%	1.9%
Total	**22,840**	**22,754**	**23,350**	**23,623**	**24,112**	**26,657**	**30,083**	**33,935**	**49%**	**1.3%**

Figure 4-3 Commercial Baseline Projection by End Use



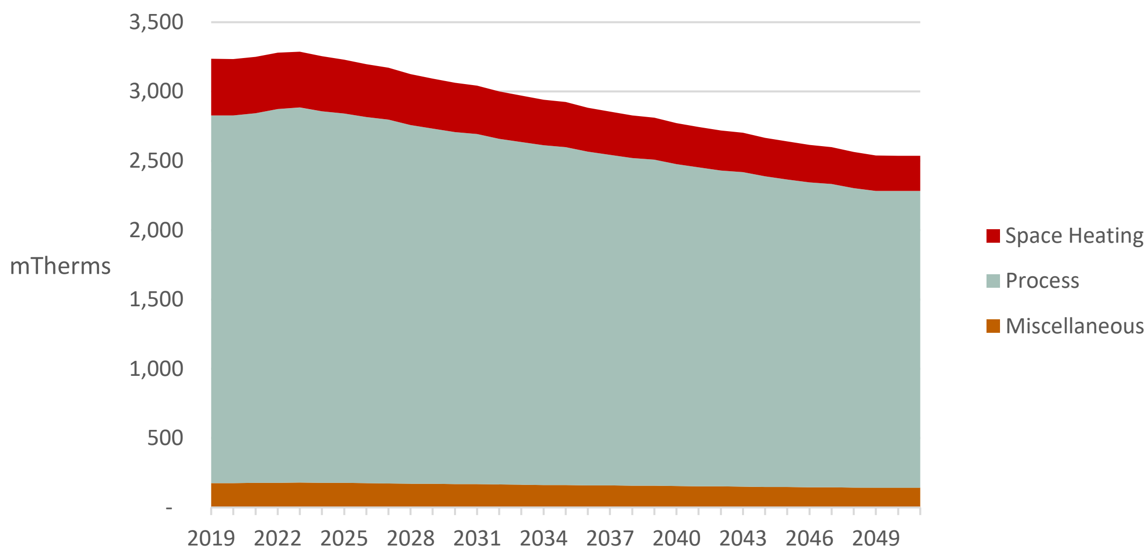
Industrial Sales Sector Baseline Projection

Industrial sector usage increases throughout the planning horizon. Table 4-4 and Figure 4-4 present the projection at the end-use level. Overall, industrial annual natural gas use decreases from 4,382 mTherms in 2019 to 3,435 mTherms in 2050. Growth in most end-uses is consistent at around -0.8% per year but impacts of naturally occurring efficiency lowers consumption slightly in the space heating end-use.

Table 4-4 Industrial Sales Baseline Projection by End Use (mTherms)

End Use	2019	2020	2022	2023	2024	2031	2040	2050	% Change ('19-'50)	Avg. Growth Rate
Space Heating	555	552	549	546	536	472	402	344	-38.0%	-1.5%
Process	3,589	3,589	3,649	3,662	3,629	3,421	3,143	2,898	-19.2%	-0.7%
Miscellaneous	238	238	242	243	241	227	208	192	-19.2%	-0.7%
Total	**4,382**	**4,379**	**4,440**	**4,450**	**4,405**	**4,120**	**3,753**	**3,435**	**-21.6%**	**-0.8%**

Figure 4-4 Industrial Sales Baseline Projection by End Use (mTherms)



5

ENERGY EFFICIENCY POTENTIAL

This chapter presents the identified energy conservation potential across all sectors. This includes every possible measure that is considered in the measure list, regardless of program implementation concerns. Year-by-year savings for annual energy usage are available in the LoadMAP model and measure assumption summary, which were provided to NW Natural at the conclusion of the study. Note that all savings are provided at the customer site. This section includes potential from the residential, commercial, and industrial analyses.

Summary of Overall Energy Efficiency Potential

Table 5-1 and Figure 5-1 summarize the energy conservation savings in terms of annual energy use for all measures for four levels of potential relative to the baseline projection. Figure 5-2 displays the energy conservation forecasts. Savings are represented in cumulative terms, reflecting the effects of persistent savings in prior years in addition to new savings. This allows for the reporting of annual savings impacts as they actually impact each year of the forecast.

- Technical Potential reflects the adoption of all conservation measures regardless of cost-effectiveness. Technical potential is useful as a theoretical construct, applying an upper bound to the potential that may be realized in any one year. Other levels of potential are based off this level which makes it an important component in the estimation of potential. In this potential case, efficient equipment makes up all lost opportunity installations and all retrofit measures are installed, regardless of achievability. 2022 first-year savings are 2,033 mTherms, or 2.5% of the baseline projection. Cumulative savings in 2031 are 20,957 mTherms, or 22% of the baseline. By 2050, cumulative technical potential reaches 42,373 mTherms, or 33.7% of the baseline.
- Achievable Technical Potential refines technical potential by applying customer participation rates that account for market barriers, customer awareness and attitudes, program maturity, and other factors that affect market penetration of conservation measures. For the 2022-2051 CPA, ramp rates from the Draft 2021 Power Plan were customized for use in natural gas programs. These ramp rates are provided in Appendix A. In 2022, first-year savings are 874 mTherms, or 1.1% of the baseline projection. Cumulative savings in 2031 are 10,350 mTherms, or 10.9% of the baseline. By 2050 cumulative achievable technical potential reaches 22,321 mTherms, or 17.8% of the baseline.
- TRC Achievable Economic Potential further refines achievable technical potential by applying an economic cost-effectiveness screen. In this analysis, the cost-effectiveness is measured by the total resource cost (TRC) test, which compares lifetime energy benefits to the total customer and utility costs of delivering the measure through a utility program, including monetized non-energy impacts. AEG also applied benefits for non-gas energy savings, such as electric HVAC savings for weatherization and lighting savings for retrocommissioning. We also applied the Council's calibration credit to space heating savings to reflect the fact that additional fuels may be used as a supplemental heat source within an average home and may be accounted for within the TRC. Avoided costs of energy were provided by NW Natural, including 10% conservation credit per the Council's methodology. In 2022, first-year savings are 354 mTherms, or 0.4% of the baseline projection. Cumulative savings in 2031 are 4,390 mTherms, or 4.6% of the baseline. By 2050 cumulative TRC achievable economic potential reaches 11,392 mTherms, or 9.1% of the baseline. Potential under the

TRC test is lower than UCT due to the inclusion of full measure costs rather than solely the utility portion.

- UCT Achievable Economic Potential further refines achievable technical potential by applying an economic cost-effectiveness screen. In this analysis, the cost-effectiveness is measured by the utility cost test (UCT), which compares lifetime energy benefits to the total utility costs of delivering the measure through a utility program, excluding monetized non-energy impacts. Avoided costs were provided by NW Natural with a 10% conservation credit embedded per Council methodologies. In 2022c first-year savings are 477 mTherms, or 0.6% of the baseline projection. Cumulative savings in 2031 are 6,523 mTherms, or 6.8% of the baseline. By 2050 cumulative savings reach 16,818 mTherms, or 13.4% of the baseline.

Table 5-1 Summary of Energy Efficiency Potential (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Baseline Load Projection (mTherms)	80,831	82,581	84,282	87,530	95,229	109,312	125,747
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	354	725	1,036	1,827	4,390	9,345	11,392
UCT Achievable Economic Potential	477	992	1,470	2,671	6,523	13,936	16,818
Achievable Technical Potential	874	1,799	2,702	4,808	10,350	19,102	22,321
Technical Potential	2,033	4,189	6,160	10,491	20,957	35,383	42,373
Cumulative Savings (% of Baseline)							
TRC Achievable Economic Potential	0.4%	0.9%	1.2%	2.1%	4.6%	8.5%	9.1%
UCT Achievable Economic Potential	0.6%	1.2%	1.7%	3.1%	6.8%	12.7%	13.4%
Achievable Technical Potential	1.1%	2.2%	3.2%	5.5%	10.9%	17.5%	17.8%
Technical Potential	2.5%	5.1%	7.3%	12.0%	22.0%	32.4%	33.7%

Figure 5-1 Summary of Annual Cumulative Energy Efficiency Potential (mTherms)

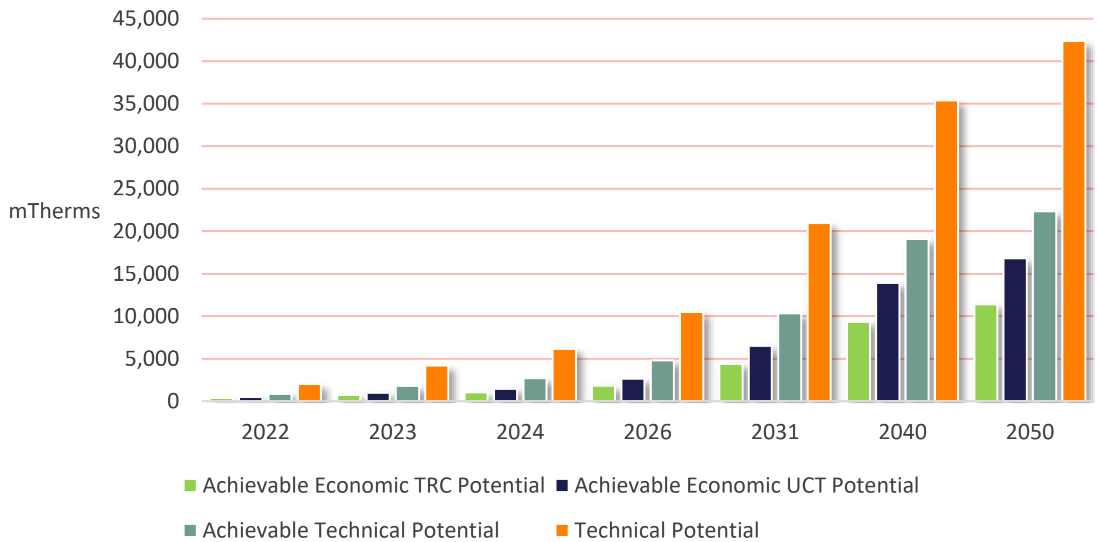


Figure 5-2 Baseline Projection and Annual Energy Efficiency Forecasts (mTherms)

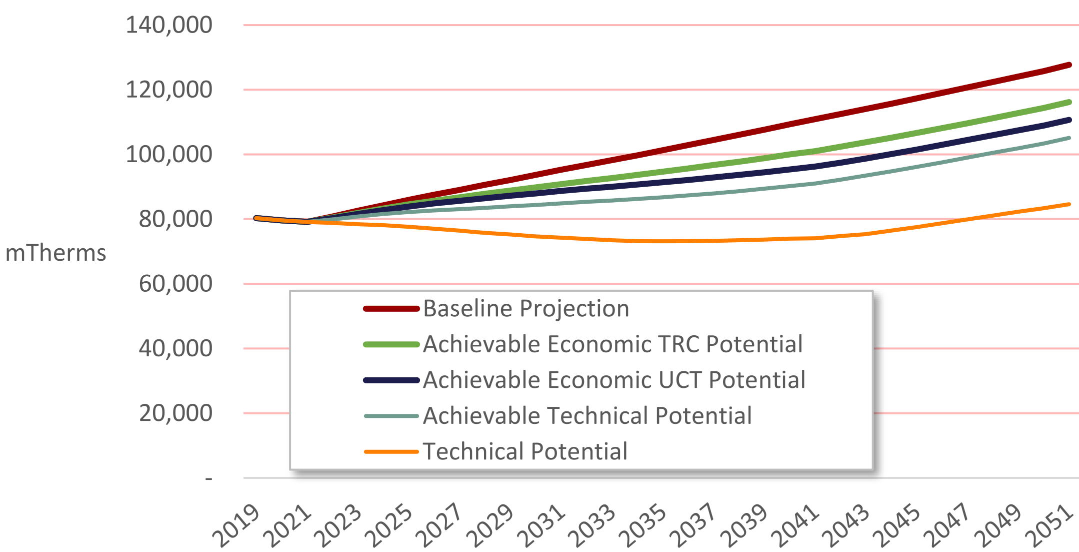


Figure 5-3 shows the cumulative TRC achievable potential by sector for the full timeframe of the analysis as a percent of total savings. Table 5-2 summarizes TRC achievable potential by market sector for selected years.

While the precise distribution of savings among sectors shifts slightly over the course of the study, in general residential and commercial potential are well balanced. Since industrial sales customer consumption represents a small percentage of the baseline, potential for this sector makes up a lower percentage of the total. While residential and commercial potential ramps up, industrial potential is mainly retrofit in nature, and is much flatter. This is because process equipment is highly custom and most potential comes from controls modifications or process adjustments rather than high-efficiency equipment upgrades. Additionally, we model retrocommissioning to phase in evenly over the next twenty years. This measure has a maintenance component, and not all existing facilities may be old enough to require the tune-up immediately but will be eligible at some point over the course of the study.

There is a notable downtick in residential savings around 2024. This is due to the impacts of the residential forced-air furnace standard, which raises the baseline from AFUE 80% to AFUE 92%, a substantial change relative to the efficient option of an AFUE 95% unit.

Figure 5-3 Cumulative TRC Achievable Economic Potential by Sector (% of Total)

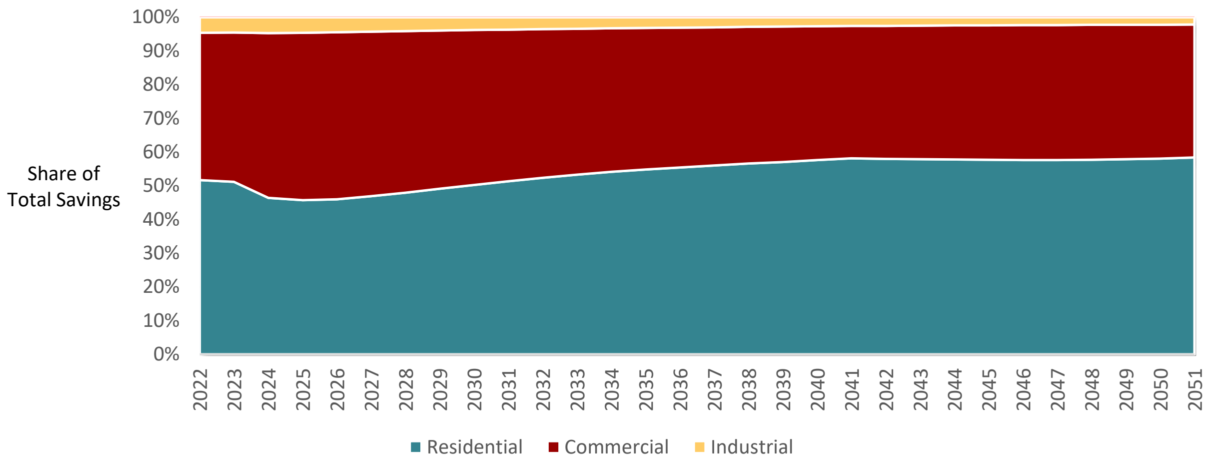


Table 5-2 Cumulative TRC Achievable Economic Potential by Sector, Selected Years (mTherms)

Sector	2022	2023	2024	2026	2031	2040	2050
Residential	182	369	478	837	2,250	5,380	6,612
Commercial	155	323	509	908	1,979	3,713	4,526
Industrial	16	33	49	82	162	253	254
Total	**354**	**725**	**1,036**	**1,827**	**4,390**	**9,345**	**11,392**

Residential Sector Potential

Table 5-3 and Figure 5-4 summarize the energy efficiency potential for the residential sector. In 2022, TRC achievable economic potential is 182 mTherms, or 0.3% of the baseline projection. By 2050, cumulative savings are 6,612 mTherms, or 7.5% of the baseline.

Table 5-3 Residential Potential Summary (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Baseline Projection (mTherms)	53,041	54,507	55,765	58,258	64,452	75,477	88,376
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	182	369	478	837	2,250	5,380	6,612
UCT Achievable Economic Potential	293	610	872	1,614	4,265	9,808	11,887
Achievable Technical Potential	432	908	1,346	2,505	6,165	12,932	15,450
Technical Potential	1,356	2,810	4,045	6,938	14,593	26,662	32,793
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.3%	0.7%	0.9%	1.4%	3.5%	7.1%	7.5%
UCT Achievable Economic Potential	0.6%	1.1%	1.6%	2.8%	6.6%	13.0%	13.5%
Achievable Technical Potential	0.8%	1.7%	2.4%	4.3%	9.6%	17.1%	17.5%
Technical Potential	2.6%	5.2%	7.3%	11.9%	22.6%	35.3%	37.1%

Figure 5-4 Residential Cumulative Potential by Case (mTherms)

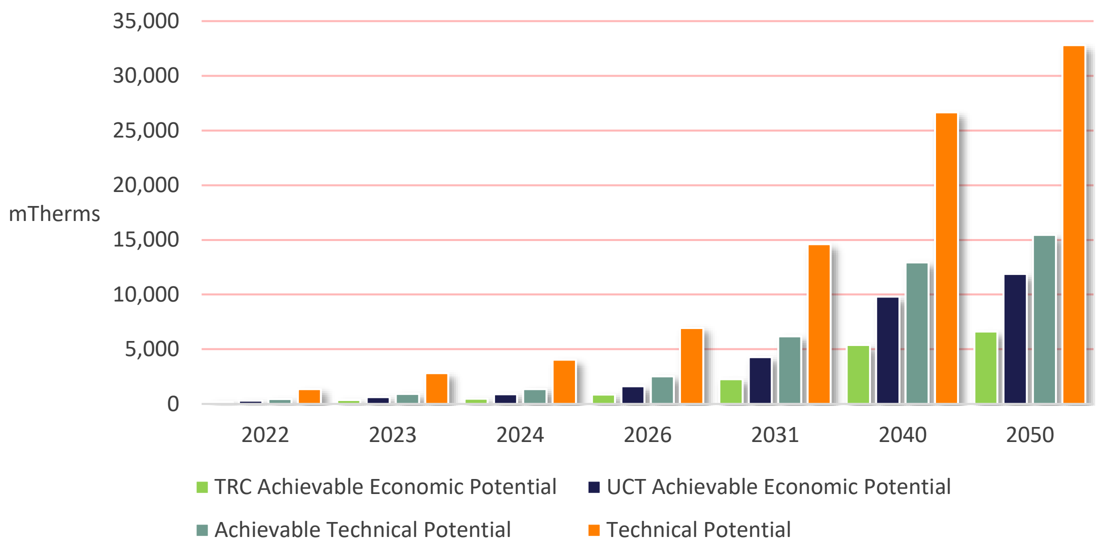
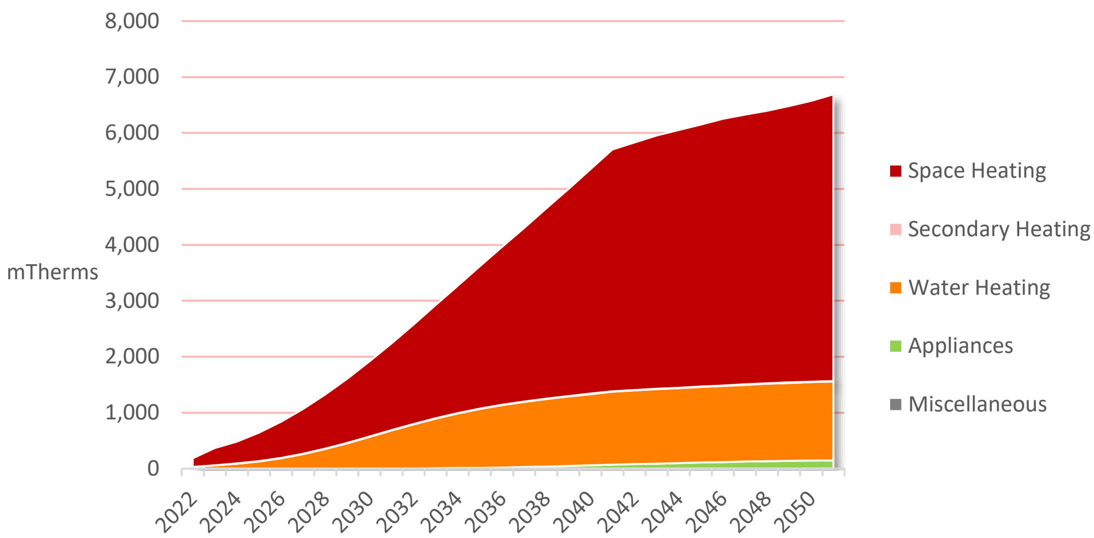


Figure 5-5 presents forecasts of energy savings by end use as a percent of total annual savings and cumulative savings. Space heating makes up a majority of potential throughout the study horizon.

Figure 5-5 Residential TRC Achievable Economic Potential – Cumulative Potential by End Use (mTherms, % of total)



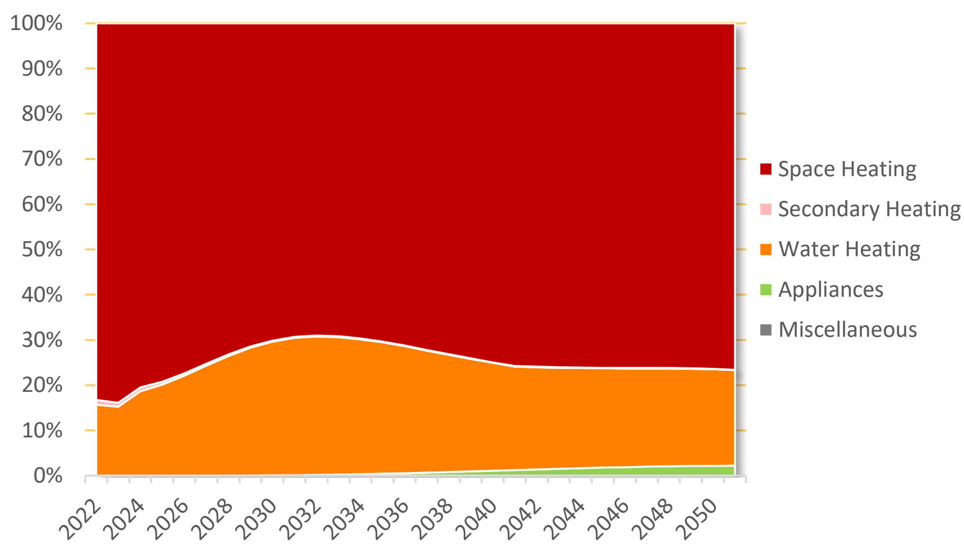


Table 5-4 identifies the top 20 residential measures by cumulative 2023 and 2050 savings. Furnaces (98% AFUE), Connected Thermostats, Low Flow Showerheads (1.5 GPM), and Ceiling Insulation (retrofit only) are the top measures. Behavioral Programs, which are not currently part of NW Natural's portfolio but were of interest in the CPA analysis, show up in early years with a large amount of savings potential.

Table 5-4 Residential Top Measures in 2023 and 2050, TRC Achievable Economic Potential (mTherms)

Rank	Measure / Technology	2023 Cumulative Potential Savings (mTherms)	% of Total	2050 Cumulative Potential Savings (mTherms)	% of Total
1	Furnace - AFUE 98%	129.4	35.0%	2,020	30.5%
2	ENERGY STAR - Connected Thermostat - Interactive/Learning Thermostat (i.e., NEST)	78.9	21.4%	1,594	24.1%
3	Water Heater - Low Flow Showerhead - 1.5 GPM Showerhead	5.3	1.4%	398	6.0%
4	Insulation - Ceiling, Installation - R-49 (Retro Only)	6.0	1.6%	382	5.8%
5	Boiler - AFUE 95%	4.0	1.1%	301	4.6%
6	ENERGY STAR Clothes Washers - ENERGY STAR Unit	24.9	6.7%	292	4.4%
7	Water Heater - Pipe Insulation - Insulated 5' of Pipe Between Unit and Conditioned Space	3.1	0.9%	246	3.7%
8	Ducting - Repair and Sealing - 50% Reduction in Duct Leakage	2.6	0.7%	245	3.7%
9	Behavioral Programs - HER-style Customer Awareness Program	105.8	28.7%	207	3.1%
10	Water Heater - Temperature Setback - Setback to 120° F	1.9	0.5%	158	2.4%
11	Stove/Oven - High Efficiency (730 + 1660 IAEC)	0.0	0.0%	143	2.2%
12	Insulation - Wall Cavity, Installation - R-11	2.0	0.5%	122	1.9%
13	Intermittent Ignition System - Installed Switch/Remote on Burner System	0.0	0.0%	115	1.7%
14	Water Heater - Faucet Aerator - 1.5 GPM Aerator	1.5	0.4%	100	1.5%
15	Insulation - Ducting - Duct Thermal Losses Reduced 50%	1.6	0.4%	97	1.5%
16	Insulation - Slab Foundation - R-11 (NC Only)	0.2	0.0%	62	0.9%
17	Water Heater - Drainwater Heat Recovery - Drain Equipped with Heat Recovery System	0.0	0.0%	55	0.8%
18	Insulation - Basement Sidewall - R-15	0.8	0.2%	52	0.8%
19	Insulation - Ceiling, Upgrade - R-49	0.1	0.0%	9	0.1%
20	Thermostatic Radiator Valves - Thermostatic Restriction Valve	0.1	0.0%	9	0.1%
Subtotal		**368.3**	**99.7%**	**6,606**	**99.9%**
Total Savings in Year		**369.3**	**100%**	**6,612**	**100%**

Commercial Sector Potential

Table 5-5 and Figure 5-6 summarize the energy conservation potential for the commercial sector. In 2022, TRC achievable economic potential is 155 mTherms, or 0.7% of the baseline projection. By 2050, cumulative savings are 4,526 mTherms, or 13.7% of the baseline.

Table 5-5 Commercial Potential Summary

Scenario	2022	2023	2024	2026	2031	2040	2050
Baseline Projection (mTherms)	23,287	23,487	23,891	24,573	26,063	29,321	33,019
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	155	323	509	908	1,979	3,713	4,526
UCT Achievable Economic Potential	169	349	549	975	2,096	3,876	4,678
Achievable Technical Potential	424	855	1,303	2,215	4,013	5,906	6,608
Technical Potential	654	1,332	2,046	3,440	6,149	8,399	9,257
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.7%	1.4%	2.1%	3.7%	7.6%	12.7%	13.7%
UCT Achievable Economic Potential	0.7%	1.5%	2.3%	4.0%	8.0%	13.2%	14.2%
Achievable Technical Potential	1.8%	3.6%	5.5%	9.0%	15.4%	20.1%	20.0%
Technical Potential	2.8%	5.7%	8.6%	14.0%	23.6%	28.6%	28.0%

Figure 5-6 Commercial Cumulative Potential by Case (mTherms)

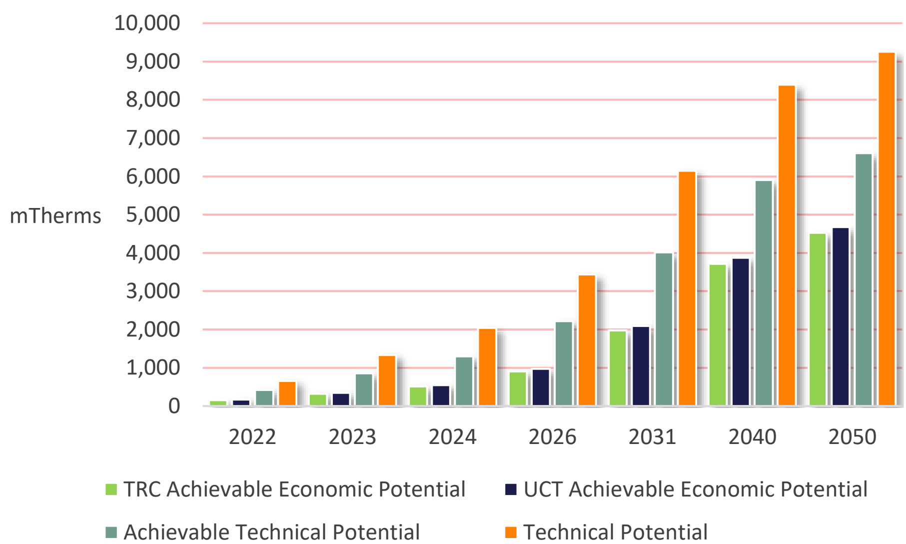
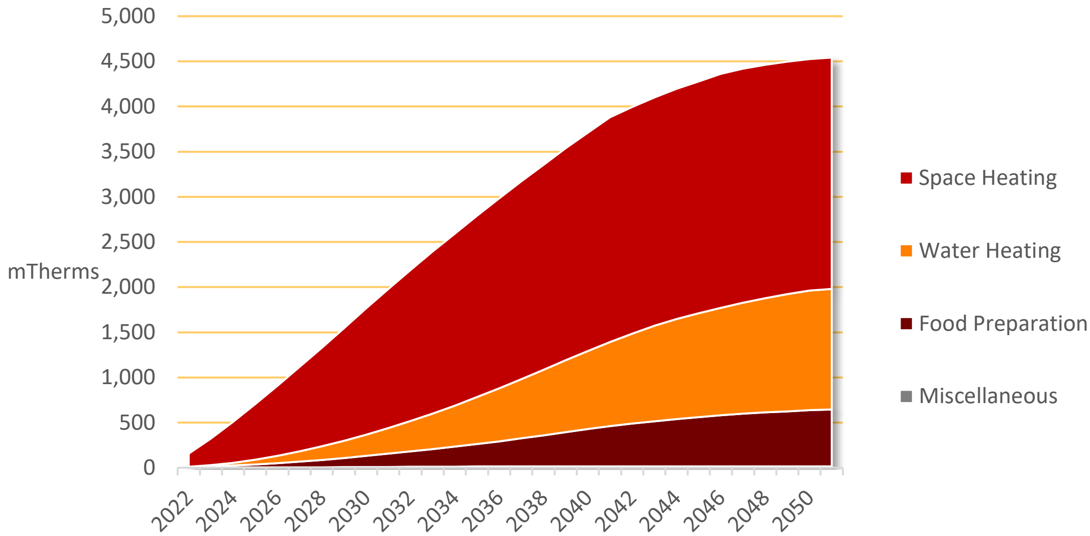


Figure 5-7 presents forecasts of energy savings by end use as a percent of total annual savings and cumulative savings. Space heating makes up a majority of the potential early on, but food preparation equipment upgrades provide substantial savings opportunities in the later years.

Figure 5-7 Commercial TRC Achievable Economic Potential – Cumulative Savings by End Use (mTherms, % of total)



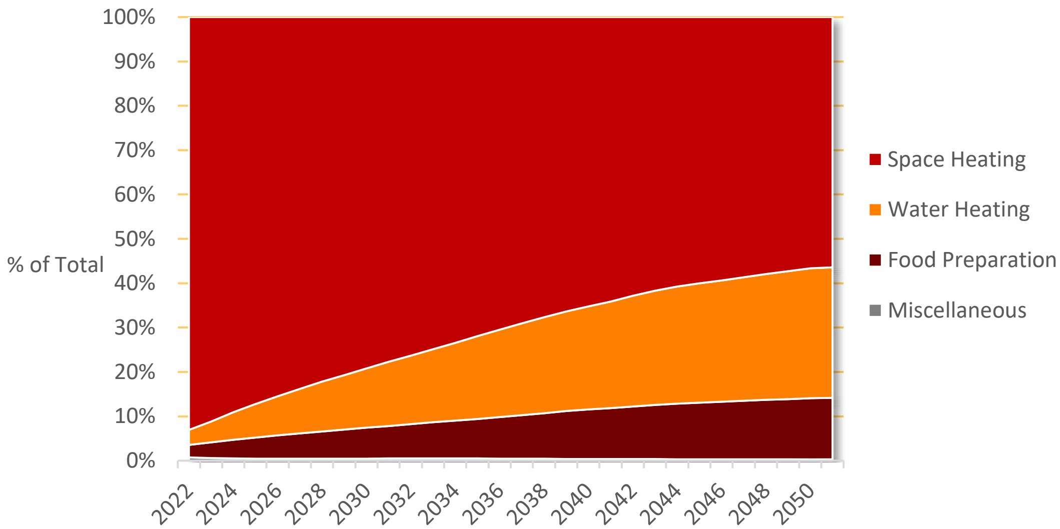


Table 5-6 identifies the top 20 commercial measures by cumulative savings in 2023 and 2050.Condensing Water Heaters (TE 96%) are the top measure, followed by Boilers (AFUE 97%) and Roof/Ceiling Insulation (R-38).

Table 5-6 Commercial Top Measures in 2023 and 2050, TRC Achievable Economic Potential (mTherms)

Rank	Measure / Technology	2023 Cumulative Potential Savings (mTherms)	% of Total	2050 Cumulative Potential Savings (mTherms)	% of Total
1	Water Heater - TE 96% Condensing	11	3.4%	1,225	27.1%
2	Boiler - AFUE 97%	58	18.0%	854	18.9%
3	Insulation - Roof/Ceiling - R-38	94	29.0%	657	14.5%
4	Broiler - Infrared Burners	6	1.9%	352	7.8%
5	Insulation - Wall Cavity - R-21	28	8.8%	149	3.3%
6	Furnace - AFUE 96%	2	0.6%	132	2.9%
7	Range - High Efficiency	3	0.8%	126	2.8%
8	HVAC - Demand Controlled Ventilation - DCV Enabled	3	1.0%	114	2.5%
9	Gas Boiler - Insulate Hot Water Lines - Insulated Water Lines	15	4.7%	103	2.3%
10	Double Rack Oven - FTSC Qualified (>50% Cooking Efficiency)	2	0.5%	94	2.1%
11	ENERGY STAR Connected Thermostat - Wi-Fi/Interactive Thermostat Installed	32	10.1%	93	2.1%
12	Hydronic Heating Radiator Replacement	9	2.7%	70	1.6%
13	Building Automation System - Automation System Installed and Programmed	1	0.2%	62	1.4%
14	Kitchen Hood - DCV/MUA - Vent Hood	5	1.6%	47	1.0%
15	Water Heater - Efficient Dishwasher – ENERGY STAR Unit	1	0.2%	40	0.9%
16	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and Condensate Tank Insulated	6	1.8%	37	0.8%
17	Space Heating - Heat Recovery Ventilator - HRV Installed	5	1.6%	33	0.7%
18	Unit Heater - Infrared Radiant	0	0.1%	33	0.7%
19	Gas Boiler - Hot Water Reset - Reset Control Installed	4	1.4%	33	0.7%
20	Gas Boiler - Burner Control Optimization - Optimized Burner Controls	1	0.2%	30	0.7%
Subtotal		**286**	**88.7%**	**4,282**	**94.6%**
Total Savings in Year		**323**	**100%**	**4,526**	**100%**

Industrial Sales Sector Potential

Table and Figure 5-8 summarize the energy conservation potential for the industrial sales sector. In 2022, TRC achievable economic potential is 16 mTherms, or 0.4% of the baseline projection. By 2050, cumulative savings reach 254 mTherms, or 7.4% of the baseline. Industrial potential is a lower percentage of overall baseline compared to the residential and commercial sectors. While large, custom process optimization and controls measures are present in potential, these are not applicable to all applications which limits potential at the technical level. As seen in Figure 5-8 below, industrial sales potential is substantially lower due to the smaller sector size and process uses.

Table 5-7 Industrial Sales Potential Summary (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Baseline Projection (mTherms)	4,440	4,450	4,405	4,328	4,120	3,753	3,435
Cumulative Savings (mTherms)							
TRC Achievable Economic Potential	16	33	49	82	162	253	254
UCT Achievable Economic Potential	16	33	49	82	162	253	254
Achievable Technical Potential	18	36	53	88	171	263	263
Technical Potential	24	47	69	113	214	322	323
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.4%	0.7%	1.1%	1.9%	3.9%	6.7%	7.4%
UCT Achievable Economic Potential	0.4%	0.7%	1.1%	1.9%	3.9%	6.7%	7.4%
Achievable Technical Potential	0.4%	0.8%	1.2%	2.0%	4.2%	7.0%	7.7%
Technical Potential	0.5%	1.0%	1.6%	2.6%	5.2%	8.6%	9.4%

Figure 5-8 Industrial Sales Cumulative Potential by Case (mTherms)

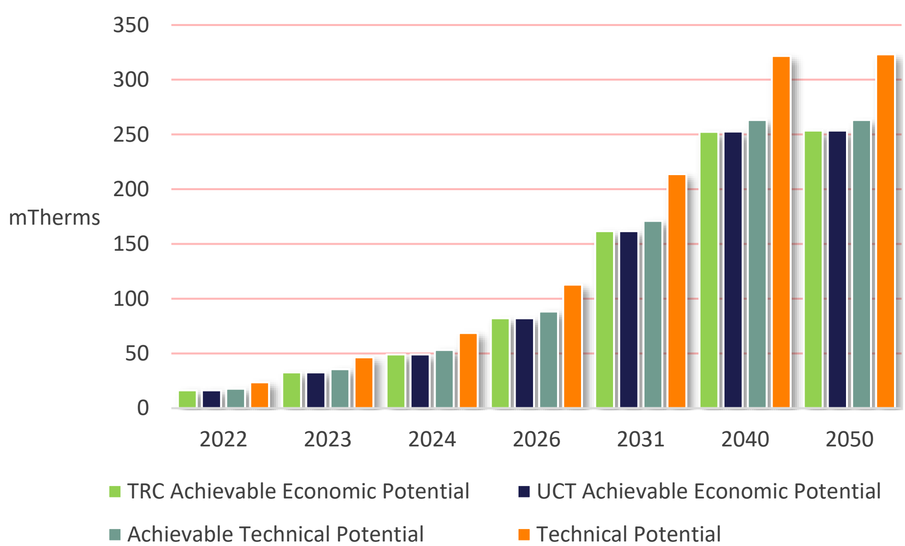
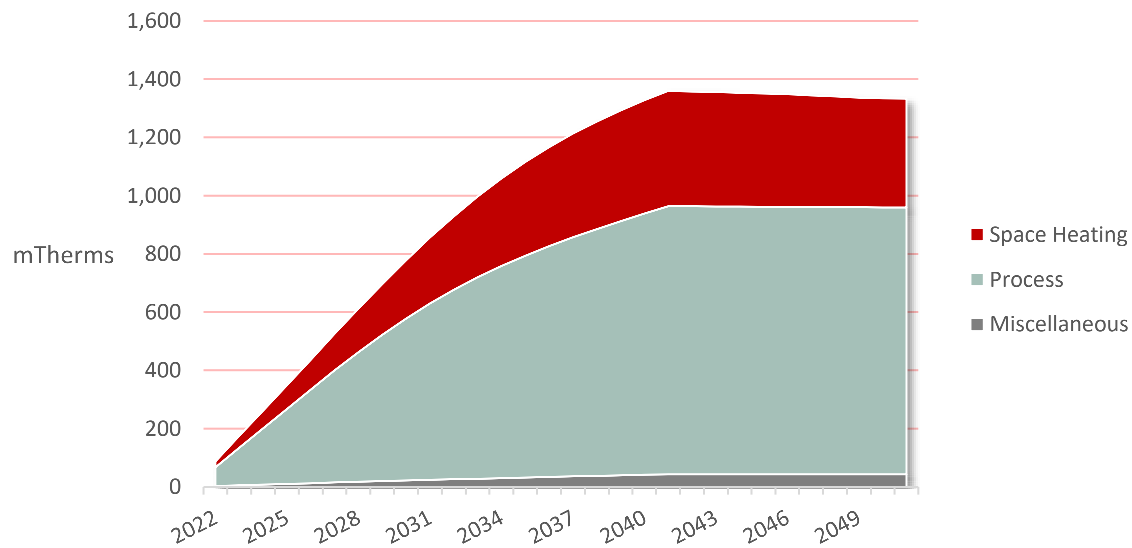


Figure 5-9 presents forecasts of energy savings by end use as a percent of total annual savings and cumulative savings.

Figure 5-9 Industrial Sales TRC Achievable Economic Potential – Cumulative Savings by End Use (mTherms, % of total)



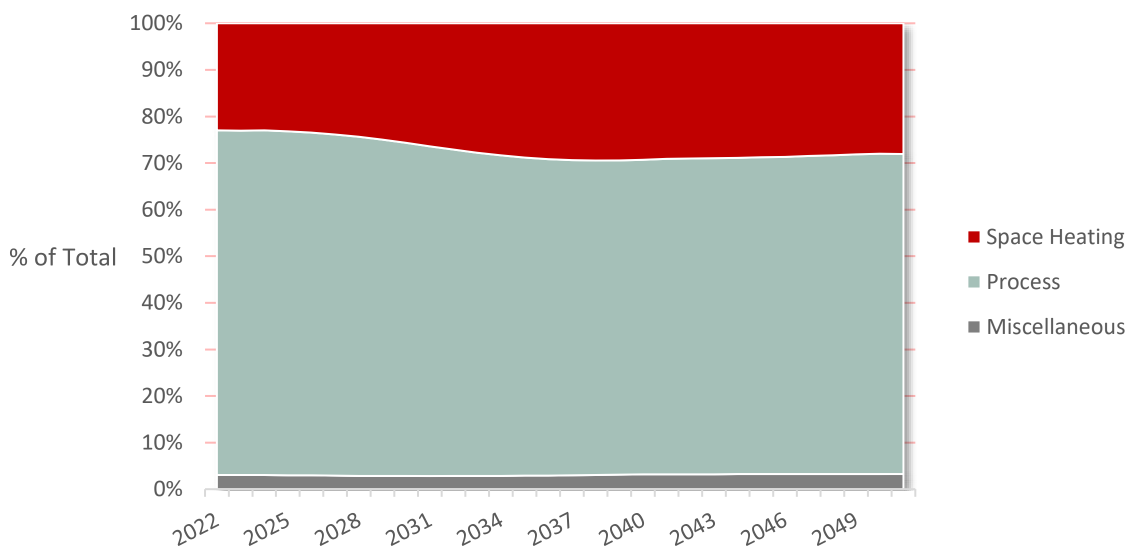


Table 5-7 identifies the top 10 industrial measures by cumulative 2023 and 2051 savings. Strategic energy management of industrial process applications is the highest measure by total savings. For smaller industrial customers, this measure typically involves a cohort of between five to ten customers who form a working group facilitated by an energy management expert. One or more employees at each facility are designated an energy conservation "champion" who work to integrate efficient energy-consuming behavior into the company's culture. Many of these measures are more custom in nature, such as strategic energy management and retrocommissioning. This results in behavior-based and low-cost/no-cost measures, but also results in larger custom projects. We estimate that this potential will be captured within these measures/delivery mechanisms.

Table 5-8 Industrial Sales Top Measures in 2023 and 2050, UCT Achievable Economic Potential (mTherms)

Rank	Measure / Technology	2023 Cumulative Potential Savings (mTherms)	% of Total	2050 Cumulative Potential Savings (mTherms)	% of Total
1	Strategic Energy Management - Energy Management System Installed and Programmed	10	31.7%	77	30.2%
2	Gas Boiler - Insulate Hot Water Lines - Insulated Water Lines	5	14.4%	42	16.4%
3	Building Automation System - Automation System Installed and Programmed	0	0.6%	19	7.5%
4	Gas Boiler - Stack Economizer - Economizer Installed	4	12.6%	18	7.0%
5	Gas Boiler - Hot Water Reset - Reset Control Installed	2	4.9%	16	6.3%
6	Insulation - Roof/Ceiling - R-38	3	8.6%	16	6.3%
7	Gas Boiler - Burner Control Optimization - Optimized Burner Controls	0	0.5%	10	4.1%
8	Gas Boiler - Insulate Steam Lines/Condensate Tank - Lines and Condensate Tank Insulated	1	3.4%	10	3.9%
9	Process - Insulate Heated Process Fluids - Insulated Process Fluid Lines	2	6.5%	9	3.6%
10	Boiler - AFUE 97%	1	2.5%	7	2.9%
Subtotal		**28**	**85.9%**	**223**	**88.1%**
Total Savings in Year		**33**	**100%**	**254**	**100%**

Peak Day and Hour Savings

The potential savings presented above focus on cumulative annual savings. As part of the CPA, NW Natural also asked AEG to estimate potential impacts on the peak day and peak hour. This section presents a summary of potential and top measures on the peak day and peak hour.

Table 5-9 and Table 5-10 present the total reference baseline and potential savings for the peak day and peak hour, respectively. Peak day and hour impacts are estimated using the annual energy savings and conversion factors that relate peak day or hour consumption to annual consumption by end use, which were provided by NW Natural.

Table 5-9 Peak Day Potential Summary (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Peak Day Savings (mTherms)							
TRC Achievable Economic Potential	5	11	16	27	60	124	148
UCT Achievable Economic Potential	7	15	22	38	85	179	208
Achievable Technical Potential	11	23	34	60	127	238	272
Technical Potential	27	55	79	134	265	473	563
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.5%	1.1%	1.4%	2.4%	4.9%	8.9%	9.3%
UCT Achievable Economic Potential	0.7%	1.4%	2.0%	3.4%	6.9%	12.8%	13.0%
Achievable Technical Potential	1.1%	2.2%	3.2%	5.4%	10.3%	17.0%	17.0%
Technical Potential	2.6%	5.2%	7.3%	11.9%	21.6%	33.8%	35.3%

Table 5-10 Peak Hour Potential Summary (mTherms)

Scenario	2022	2023	2024	2026	2031	2040	2050
Peak Hour Savings (mTherms)							
TRC Achievable Economic Potential	0.4	0.7	1.1	1.9	4.5	9.6	11.5
UCT Achievable Economic Potential	0.5	1.0	1.5	2.8	6.8	14.5	17.5
Achievable Technical Potential	0.9	1.9	2.8	5.0	10.9	20.1	23.4
Technical Potential	2.1	4.4	6.5	11.1	22.3	37.4	44.8
Energy Savings (% of Baseline)							
TRC Achievable Economic Potential	0.5%	0.9%	1.3%	2.2%	4.8%	8.8%	9.2%
UCT Achievable Economic Potential	0.6%	1.2%	1.8%	3.2%	7.3%	13.4%	14.0%
Achievable Technical Potential	1.1%	2.3%	3.4%	5.8%	11.6%	18.5%	18.8%
Technical Potential	2.7%	5.4%	7.8%	12.9%	23.6%	34.5%	35.9%

Table 5-11 presents the top measures in terms of their impact on the peak day and hour.

Table 5-11 Top Peak Impact Measures, Day and Hour Potential, Selected Years (therms)

Rank	Measure / Technology (Ranked by 2040 Peak Hour Impact)	Peak Day Potential (therms)			Peak Hour Potential (therms)		
		2023	2031	2040	2023	2031	2040
1	Residential - Behavioral Programs	1,579	2,300	2,634	112.1	163.2	188.7
2	Residential - ENERGY STAR - Connected Thermostat	1,388	9,749	23,710	42.3	85.5	112.7
3	Residential - Furnace	2,277	11,060	25,052	75.5	89.6	103.8
4	Commercial - Water Heater	86	1,095	2,971	19.5	64.4	82.3
5	Residential - Insulation - Ceiling, Installation	106	734	6,309	3.2	6.4	61.5
6	Commercial - Insulation - Roof/Ceiling	1,820	8,109	12,883	52.6	45.8	37.4
7	Commercial - Boiler	1,029	6,135	11,430	33.2	37.8	35.1
8	Residential - Insulation - Wall Cavity, Installation	35	241	2,031	1.1	2.1	19.8
9	Residential - Insulation - Ducting	27	189	1,604	0.8	1.7	15.6
10	Residential - ENERGY STAR Clothes Washers	82	442	909	15.6	19.1	20.3
11	Residential - Intermittent Ignition System	0	11	211	0.0	1.9	12.3
12	Commercial - Insulation - Wall Cavity	552	2,207	3,029	16.0	12.5	8.8
13	Residential - Insulation - Basement Sidewall	15	102	858	0.5	0.9	8.4
14	Residential - Ducting - Repair and Sealing	46	1,877	4,735	1.8	26.9	6.5
15	Commercial - Furnace	35	638	1,602	1.4	5.9	6.8
16	Residential - Insulation - Slab Foundation	3	49	950	0.1	0.6	11.5
17	Commercial - Gas Boiler - Insulate Hot Water Lines	261	1,139	1,865	7.5	6.4	5.4
18	Commercial - Space Heating - Heat Recovery Ventilator	361	1,375	1,818	10.4	7.8	5.3
19	Commercial - Broiler	22	292	840	1.0	3.3	5.1
20	Residential - Water Heater - Low Flow Showerhead	18	759	1,319	4.0	54.9	3.3
	Total of Top 20 Measures	**9,740**	**48,500**	**106,760**	**398.6**	**636.8**	**750.6**

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ALIGNMENT WITH THE COUNCIL'S DRAFT 2021 POWER PLAN METHODOLOGY

While developing potential estimates for NW Natural's CPA, AEG strove to adapt Northwest Power and Conservation Council's Draft 2021 Conservation and Electric Power Plan methodologies wherever appropriate for gas studies and maintain consistency with analysis procedures within the region. To accomplish this, AEG employed the following approach:

- Estimate technical, achievable technical, and achievable economic potential
- Utilize regional market baseline data
- Consider all measures within the 2021 Plan and RTF work products when applicable to gas, and utilize or adapt Council and RTF assumptions wherever possible
- Adapt the 2021 Plan's ramp rates for use in natural gas efficiency programs
- Incorporate all quantified and monetized non-energy impacts into the TRC test

We describe these in more detail below.

Estimate Technical, Achievable Technical, and Achievable Economic Potential

Within the 2021 Plan, the Council estimates three levels of potential, technical, achievable technical, and achievable economic. This is different from best-practice methodology for other parts of the country, where technical, economic, then achievable potential is estimated. The primary advantage of estimating achievable technical potential first is that it allows for a more apples-to-apples comparison with previous studies and other utilities throughout the region. Avoided costs are one of the most likely potential drivers to change and will likely vary by utility, so isolating this impact is important when making comparisons.

Within AEG's LoadMAP model, we estimate potential using the Council's preferred approach of beginning with technical potential, applying ramp rates and achievability factors to estimate achievable technical potential, and finally screening for cost effectiveness to estimate achievable economic potential. Within this study, AEG estimated potential primarily under the TRC, since that is NW Natural's primary cost-effectiveness test, but also estimated potential using the UCT.

Utilize Regional Market Baseline Data

In addition to NW Natural-specific data, which is the best-practice primary source available, AEG relied on NEEA's regional stock and site assessments, the 2016-2017 RBSA, 2014 and 2019 CBSA, and 2014 IFSA. These surveys, which also informed the baseline of the draft 2021 Power Plan, contain detailed home, building, and industrial facility information for customers in the region. While these surveys have primarily been used to inform electric CPAs, AEG identified a list of useful data that is applicable for gas customers in the region as well. For example, AEG utilized detailed home and building shell characteristics to determine the applicable portion of the market for many retrofit opportunities. This included the percentage of customers with no, or very low, ceiling insulation. We also used this to determine things like baseline window types (e.g., single vs. double pane) or number of homes with exterior ductwork.

NEEA's surveys were also used to inform commercial and industrial energy intensities on a square foot and employee basis respectively. This data, particularly the consumption per square foot, is invaluable when determining energy consumption in commercial and industrial facilities. Compared to a residential home, which roughly corresponds one-to-one with customer accounts, a commercial facility may be anywhere from a few thousand square feet to over one million. Utilizing NEEA data allowed AEG an additional benchmark upon which to estimate building energy consumption.

Consider All Measures Within the 2021 Plan and RTF Work Products When Applicable to Gas; Utilize or Adapt Council and RTF Assumptions Wherever Possible

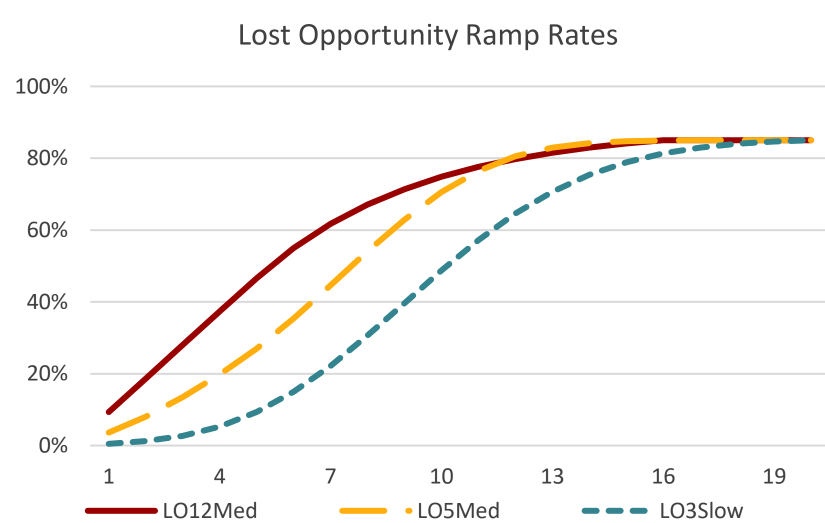
While many of the Council and RTF assumptions were developed with electricity savings in mind, there is data that may be adapted for use in estimating gas potential. For example, weatherization measures may be applied equally to both electric and gas heating systems, so assumptions on lifetime and cost are applicable to both. Additionally, energy savings as percent of baseline consumption may also be adapted if reasonably scrutinized. For example, electric resistance and natural gas direct-fuel furnaces should share similar load shapes and save similar percentages. On the other hand, efficiency of electric air-source heat pumps varies by load and outside temperatures and is not comparable to any commercially available gas technologies and should not be used.

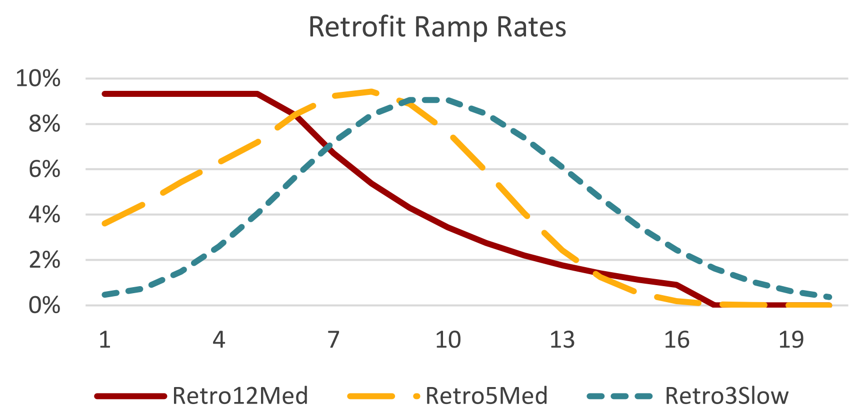
When developing the measure list for this study, AEG began with workbooks from the 2021 Plan and RTF to ensure that all similar measures were captured. We used assumptions from these workbooks when appropriate and substituted gas-specific details as necessary.

Adapt the 2021 Plan's Ramp Rates for Use in Natural Gas Efficiency Programs

Participation rates, also known as ramp rates, are a key driver in estimation of potential. These identify the percentage of an applicable population that will adopt an efficiency measure as part of a utility EE program or other non-utility mechanism within the territory. For CPAs in the Northwest, and particularly the state of Washington, the 2021 Plan's electric ramp rates are a key source of information. While very thorough and straightforward to use, these were developed with electric utilities and electric programs in mind, and reflect assumptions about measure maturity, market acceptance, and existing penetration for electric markets. Because of these embedded assumptions, they may not be appropriate to apply directly to natural gas EE programs or measures.

Figure 5-10 Example Power Council Ramp Rates





AEG utilized these ramp rates as a starting point for estimating potential. We adapted the Council's ramp rate assignments from electric measures to their most similar gas counterparts (e.g., started with identical ramp rates for weatherization). We also applied ramp rates based on similar electric technology categories (e.g., similar food preparation rates). The next step was to adapt these for use in natural gas programs, using observations from programs within the region as well as implementation knowledge provided by the NW Natural team. This information was used to both identify high-performing programs (accelerate potential) and additional market barriers (to possibly delay potential). To apply these ramp rates to a natural gas potential assessment, AEG utilized three of the following approaches:

- Reassign an individual measure's ramp rate. For example, NW Natural's program performance for Furnaces exceeded the default ramp rate values for HVAC equipment, and are moved up to a faster, more mature ramp rate.
- Accelerate or decelerate an existing ramp rate. This involves stepping forward or backward so that the first year of the CPA is aligned with a different "year" of the ramp rate itself. By either delaying the start of a ramp or starting one or two years ahead, a more subtle effect is achieved than a wholesale movement to a new ramp rate. In this study, similar to the previous CPA, NW Natural's robust furnace and water heater programs were accelerated so that projected savings started at a point similar to recent achievements, which were in between the two "fast" lost opportunity ramp rates.
- Design a new ramp rate. It is possible to produce new ramp rates that are still consistent with Council methodology in that they capture the full remaining market (to the limit of achievability) over the twenty-year planning horizon, such as a linear ramp that has consistent year over year growth rather than the bell curve effect seen in retrofit ramps above.

Note that this study identifies cost-effective measures, but it does not adjust ramp rates to account for any potential barriers of new program implementation; for example, the additional lead time to set up and incorporate new measures into existing programs.

Incorporate All Quantified and Monetized Non-Energy Impacts into the TRC Test

The TRC test evaluates impacts for both the utility and customer, while the UCT perspective considers only costs and benefits as they impact the utility. In the TRC, this involves including the full measure cost (incremental for lost opportunities, full cost for retrofits), which is generally substantially higher than the incentive cost included within the UCT. The TRC does include one additional value stream that the UCT does not, non-energy impacts (NEIs).

In accordance with Council methodology, these impacts must be quantified and monetized, which means impacts such as personal comfort, which are difficult to assign a value to, are not included. What this does include are additional savings such as water reductions due to low-flow measures or less detergent required to wash clothes in a high-efficiency clothes washer. AEG has incorporated these impacts as they are available in source documentation, such as RTF UES workbooks. We estimated TRC non-energy impacts in the following ways:

- Include quantified and monetized non-energy impacts present in Council and RTF workbooks
- Incorporate NEIs directly into the avoided cost (e.g., 10% conservation credit, carbon adders, and natural gas risk adders)
- Account for the presence of secondary heating when calibrating energy models (e.g., apply a calibration credit to many space heating savings)
- Account for non-gas impacts, such as cooling savings within a weatherization program or lighting savings from a retrocommissioning program

These impacts are quantified within the LoadMAP models and utilized to assess achievable economic potential under the TRC.

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