CASCADE NATURAL GAS RESIDENTIAL SPACE HEATING, WATER HEATING, AND APPLIANCE IMPACTS

SUBMITTED DATE: May 6, 2024

SUBMITTED BY: ADM ASSOCIATES, INC.

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ACKNOWLEDGEMENTS

ADM Associates, Inc. (ADM) would like to acknowledge the many talented individuals who contributed to this report.

Cascade Natural Gas Company (CNGC) staff participated in a debrief, attended regular meetings, and responded to follow-up questions, data requests and document requests. They are an ongoing partner in our evaluation efforts.

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ACRONYMS/ABBREVIATIONS

Table 0-1. Acronyms and Abbreviations

Acronym	Term
AFUE	Annual Fuel Utilization Efficiency
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
CNGC	Cascade Natural Gas Corporation
DHW	Domestic Hot Water
DOE	Department of Energy
EFLH	Equivalent Full-Load Hours
EM&V	Evaluation, Measurement, and Verification
ES	ENERGY STAR®
EVO	Efficiency Valuation Organization
HDD	Heating Degree Days
IPMVP	International Performance Measurement and Verification Protocols
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
PY	Program Year
RTF	Regional Technical Forum
Sqft	Square footage
TMY	Typical Meteorological Year
TRM	Technical Reference Manual
UES	Unit Energy Savings
UMP	Uniform Methods Project

1 EXECUTIVE SUMMARY

This report is a summary of the Cascade Natural Gas Company (CNGC) Impact Evaluation for the space heating, water heating, thermostat, and clothes washer measures offered to CNGC residential customers in their Washington service territory. The evaluation was administered by ADM Associates, Inc. (herein referred to as the “Evaluators”).

The Evaluators found the impact evaluation results for combination heating, furnaces, programmable thermostats, smart thermostats, and tankless water heaters all closely match CNGC’s savings estimates. Boilers, meanwhile, have verified savings that are nearly double the ex-ante estimate. In contrast, clothes washers, hearths, and storage water heaters all have realization rates below 50%. Explanations for deviations in savings impacts in comparison to CNGC’s expected savings claims can be found in Section 3. The impact evaluation resulted in a 121.1% realization rate, which is primarily driven by the 130.0% realization rate for furnaces. The Evaluators provide recommendations for improving program documentation, savings algorithm applications, and recommended unit energy savings to reference moving forward to improve accuracy of residential claimed savings.

1.1 Evaluation Findings

The Evaluators conducted an impact evaluation for CNGC’s space heating, water heating, thermostat, and clothes washer measures between program years 2018 and 2022 (PY2018-PY2022). The total verified savings amounted to 1,293,451 therms with a 121.1% realization rate. The Evaluators summarize the channel and measure-level verified savings in Table 1-1 and Table 1-2, respectively. Table 1-3 meanwhile outlines results by both measure and year.

The Evaluators conducted the following evaluation tasks for the measure offerings impact evaluation:

- Database review
- Deemed savings analysis
- Billing analysis
- Heating load analysis
- Measure recommendation development

Table 1-1. Verified Impact Savings by Channel

End Use	Projects	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Clothes Washer	63	479	183	38.1%
Space Heating	8,814	778,756	968,885	124.4%
Thermostat	5,577	114,755	140,149	122.1%
Water Heating	2,699	173,711	184,234	106.1%
Total	**17,153**	**1,067,702**	**1,293,451**	**121.1%**

Table 1-2. Verified Impact Savings by Measure

Measure	Projects	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Boiler	77	6,518	11,667	179.0%
Clothes Washer	63	479	183	38.1%
Combination Heating	178	35,920	29,756	82.8%
Furnace	7,966	703,426	914,501	130.0%
Hearth	593	32,892	12,962	39.4%
Programmable Thermostat	5,101	99,139	123,863	124.9%
Smart Thermostat	476	15,616	16,286	104.3%
Storage Water Heater	2	66	25	37.3%
Tankless Water Heater	2,697	173,645	184,209	106.1%
Total	**17,153**	**1,067,702**	**1,293,451**	**121.1%**

Table 1-3. Verified Impact Savings by Measure and Year

Measure	Program Year	Projects	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Boiler	2018	1	106	211	198.8%
Boiler	2019	10	761	1,649	216.6%
Boiler	2020	20	1,513	3,527	233.1%
Boiler	2021	25	1,908	3,690	193.4%
Boiler	2022	21	2,230	2,591	116.2%
Clothes Washer	2022	63	479	183	38.1%
Combination Heating	2018	9	4,268	1,394	32.7%
Combination Heating	2019	63	15,058	9,965	66.2%
Combination Heating	2020	44	6,993	7,314	104.6%
Combination Heating	2021	38	6,032	6,431	106.6%
Combination Heating	2022	24	3,569	4,652	130.3%
Furnace	2018	367	40,679	50,340	123.7%
Furnace	2019	2,232	195,742	289,595	147.9%
Furnace	2020	2,045	171,520	213,844	124.7%
Furnace	2021	1,761	149,734	189,391	126.5%
Furnace	2022	1,561	145,751	171,330	117.5%
Hearth	2018	60	3,378	1,164	34.4%
Hearth	2019	173	9,717	4,002	41.2%
Hearth	2020	140	7,871	3,099	39.4%
Hearth	2021	122	6,850	2,652	38.7%
Hearth	2022	98	5,076	2,045	40.3%
Programmable Thermostat	2018	283	5,398	6,595	122.2%
Programmable Thermostat	2019	1,693	32,007	40,686	127.1%
Programmable Thermostat	2020	1,647	31,134	39,645	127.3%
Programmable Thermostat	2021	939	17,650	23,443	132.8%
Programmable Thermostat	2022	539	12,951	13,494	104.2%
Smart Thermostat	2022	476	15,616	16,286	104.3%
Storage WH	2019	2	66	25	37.3%
Tankless WH	2018	132	7,128	9,418	132.1%
Tankless WH	2019	1,014	66,066	68,466	103.6%
Tankless WH	2020	748	49,455	50,131	101.4%
Tankless WH	2021	540	34,566	37,726	109.1%
Tankless WH	2022	263	16,431	18,469	112.4%
Total		**17,153**	**1,067,702**	**1,293,451**	**121.1%**

1.2 Conclusions and Recommendations

The Evaluators provide the following conclusions and recommendations. Cross-cutting database recommendations are presented first and followed by channel specific ones.

Table 1-4. Cross-cutting Database Recommendations

Scope	Recommendations
Billing and Tracking Database	1. Include a unique customer or premise identifier in tracking data (such as Premise ID) so that billing data and tracking data can be matched with greater accuracy. 2. Standardize reporting of efficiency in tracking data. Efficiency was reported as a value (e.g., 85.0) and percentage (e.g., 0.85) at different points in tracking data. 3. Utilize a database structure that limits each address/premise ID to only one square footage value and each measure installation to only one model number, brand name, and efficiency value. This could help identify and address duplicate measures. 4. Identify and remove duplicates in billing data. Evaluators identified several duplicates with one instance being an estimated bill and the other being an actual bill.

Table 1-5. Space Heating Recommendations

Equipment	Recommendations
All Space Heating Measures	1. Include the input Btu/h capacity of all space heating equipment in tracking data. Furnace tracking data included capacity; however, this data would facilitate fast and accurate verification efforts for boilers, combination heating, and hearths.
Boilers	2. Based on billing data analysis results, the Evaluators recommend CNGC estimate boiler savings as verified boiler capacity by 1.49 therms per input kBtu/h.
Combination Heating	3. Based on billing data analysis results, the Evaluators recommend CNGC estimate combination heating savings as verified combination heating capacity by 1.37 therms per input kBtu/h.
Furnaces	4. Based on billing data analysis results, the Evaluators recommend CNGC estimate furnace savings as verified furnace heating capacity by 2.22 therms per input kBtu/h.
Hearths	5. To estimate expected savings for residential hearths, Evaluators recommend CNGC multiply verified hearth capacity by 0.694 therms per input kBtu/h.

Table 1-6. Water Heating Recommendations

Equipment	Recommendations
All Water Heating Measures	1. Include the Btu/h capacity of all water heating equipment in tracking data. Btu/h capacity data was not necessary for deemed savings calculations, but capacity is a key metric that affects billing analysis savings calculations.
Storage Water Heaters[1]	2. Use region-specific water temperature and hot water usage data in deemed savings calculations, such as values from the RTF.[2] 3. Instead of applying a single savings value across all systems, incorporate system specific UEF values in deemed savings calculations. 4. Consider employing a deemed savings equation, as outlined in Equation 3-1, to calculate annual storage water heater savings.
Tankless Water Heaters	5. Based on billing data analysis results, the Evaluators recommend CNGC estimate tankless water heater savings as 0.372 therms per kBtu/h.

Table 1-7. Thermostat Recommendations

Equipment	Recommendations
Programmable Thermostats	1. Based on billing data analysis results, the Evaluators recommend CNGC estimate programmable thermostats savings as 11.9 therms per 1000 conditioned square feet.
Smart Thermostats	2. Based on billing data analysis results, the Evaluators recommend CNGC estimate smart thermostats savings as 15.9 therms per 1000 conditioned square feet. 3. Consider rerunning savings analyses in PY2025-PY2026 with more than one year of tracking data.

Table 1-8. Clothes Washer Recommendations

Equipment	Recommendations
Clothes Washers	1. Include clothes washer quantity, tub volume, and configuration as well as clothes dryer type (if possible) in tracking data to facilitate savings calculations. 2. Consider employing a deemed savings equation, as outlined in Equation 3-2, to calculate annual clothes washer savings. Such deemed savings equations will help differentiate savings between top-load and front-load washers.

[1] Storage water heaters have not been offered for many years and only two were included in this evaluation.
[2] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/

2 GENERAL METHODOLOGY

The Evaluators completed an impact evaluation on each of the measures summarized in Table 1-1. Our activities estimate and verify annual savings and identify whether the program is meeting its goals. Our activities also provide conclusions to inform changes to the methodology towards claiming savings for each measure evaluated. This is aimed to provide guidance for continuous program improvement.

The Evaluators used the following approaches to accomplish the impact-related research goals listed above and calculate impacts defined by the International Performance Measurement and Verification Protocols (IPMVP)[3] and the Uniform Methods Project (UMP)[4]:

- Deemed savings (RTF UES input values and engineering algorithms developed by ASHRAE, ENERGY STAR [ES], and other industry bodies)
- Pre/Post billing analysis
- Heating load estimation

The methodologies are determined by the methodologies employed in similar programs in the region as well as the relative contribution of a given measure to the overall impacts. In addition to drawing on IPMVP, the Evaluators reviewed relevant information on infrastructure, framework, and guidelines set out for EM&V work in several guidebook documents that have been published over the past several years. These include the following:

- Northwest Power & Conservation Council Regional Technical Forum (RTF)[5]
- Regional Technical Forum (RTF) Unit Energy Savings Workbooks[6]
- National Renewable Energy Laboratory (NREL), United States Department of Energy (DOE) The Uniform Methods Project (UMP): Methods for Determining Energy Efficiency Savings for Specific Measures, April 2013
- IPMVP maintained by the Efficiency Valuation Organization (EVO) with sponsorship by the U.S. Department of Energy (DOE)[7]
- Energy Star
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- National Renewable Energy Laboratory (NREL)

The Evaluators kept data collection instruments, calculation spreadsheets, programming code, and survey data available for CNGC records. The Pre/Post billing analysis complies with the IPMVP Option C procedures while the heating load estimation follows IPMVP Option A.

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[3] https://www.nrel.gov/docs/fy02osti/31505.pdf
[4] https://www.nrel.gov/docs/fy18osti/70472.pdf
[5] https://rtf.nwcouncil.org
[6] https://rtf.nwcouncil.org/measures
[7] Core Concepts: International Measurement and Verification Protocol. EVO 100000 – 1:2016, October 2016.

2.1 Glossary of Terminology

As a first step to detailing the evaluation methodologies, the Evaluators have provided a glossary of terms to follow:

- Deemed Savings – An estimate of a savings outcome for a single unit of an installed energy efficiency measure. This estimate (a) has been developed from data sources and analytical methods that are widely accepted for the measure and purpose and (b) are applicable to the situation being evaluated.
- Expected Savings – Calculated savings used for program and portfolio planning purposes.
- Verified Savings – Savings estimates after the unit-level savings values have been updated and impact evaluation has been completed, integrating results from billing analyses and appropriate RTF UES and New Mexico TRM values.
- Pre-Period – The period of time prior to installation of energy efficient equipment or upgrade.
- Post-Period – The period of time after installation of energy efficient equipment or upgrade.
- HDD – Heating degree days (HDD) are a measurement used to estimate the amount of energy required to heat a building or space during a specific period, typically a day or a month. It is primarily used in regions with cold climates to assess the demand for heating and to evaluate energy consumption.
- TMY –A Typical Meteorological Year (TMY) is a synthesized set of weather data representing the long-term climatic conditions for a specific location. It is constructed using historical weather data collected over a period of 30 years, typically obtained from weather stations in the vicinity of the location of interest. The purpose of a TMY is to provide a standardized dataset that represents the "typical" weather conditions for a particular location.
- Dummy variable - A dummy variable, also known as an indicator variable or binary variable, is a categorical variable that takes on one of two values to represent the presence or absence of a characteristic or condition. It is commonly used in statistical analysis and regression modeling to represent qualitative factors and typically takes the value of 0 or 1, where 0 represents the absence or reference category, and 1 represents the presence or alternative category.

2.2 Summary of Approach

This section presents our approach to accomplishing the impact and process evaluation of CNGC's measures listed in Table 1-1. Section 2.2.3 describes the Evaluators' measure-specific impact evaluation methods and results in further detail.

The Evaluators outline the approach for verifying, measuring, and reporting the residential portfolio impacts as well as summarizing potential program and portfolio improvements. The primary objective of the impact evaluation is to determine verified savings and to recommend unit energy savings (UES) values for claiming measure-level savings in future program cycles. On-site verification and equipment monitoring was not conducted during this impact evaluation.

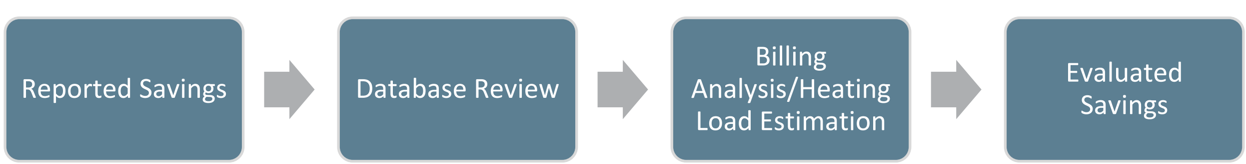
The Evaluators employed the following approach to complete impact evaluation activities for the program. The Evaluators define three major approaches to determining net savings:

- A *Deemed Savings* approach involves using stipulated savings for energy conservation measures for which savings values are well-known and documented. These prescriptive savings may also include an adjustment for certain measures, such as lighting measures in which site operating hours may differ from RTF values.
- A *Billing Analysis* approach involves using monthly consumption bills within a regression analysis to estimate the average daily heating load decrease in consumption due to the installation of the energy efficiency upgrade equipment.
- A *Heating Load Estimation* involves calculating customer heating load from monthly consumption bills and employing engineering equations to calculate average heating equipment savings.

The Evaluators accomplished the following quantitative goals as part of the impact evaluation:

- Verify savings with 10% precision at the 90% confidence level;
- Where appropriate, apply the RTF values or engineering algorithms to verify measure impacts; and,
- Where appropriate, conduct billing analysis with Pre/Post consumption data or heating load estimation to estimate measure savings.

The Evaluators calculated verified savings for each measure based on the engineering algorithms or based on billing analysis results.



The Evaluators also completed billing analyses to support estimation of savings for the space heating and envelope measures in which interactive effects are prominent. Further methodology for the additional research objectives for these measures are provided in each of the channel-level sections in Section 3.

2.2.1 DATA COLLECTION

To complete the objectives defined for this work, the Evaluators requested the following documents from CNGC:

- Tracking databases for PY2018 through PY2022 for each of the measures being evaluated
- Customer-level monthly billing consumption data between the start of 2018 and the end of 2022
- A list of documents/key assumptions included in expected savings calculations

2.2.2 DATABASE REVIEW

At the outset of the evaluation, the Evaluators reviewed the databases to ensure that each program tracking database conforms to industry standards and adequately tracks key data required for evaluation. As necessary, the Evaluators added missing customer data, such as heating equipment capacity (e.g., Btu/h) and household square footage, via online research. Product specification PDFs or equipment databases such as the AHRI directory[8] were used to identify equipment capacity while Zillow and Redfin were used for household square footage.

Measure-level net savings were evaluated primarily by reviewing measure algorithms and values in the tracking system to assure that they are appropriately applied using the appropriate unit energy savings and engineering algorithms defined in CNGC's program plan and in accordance with industry best practices. The Evaluators then aggregated and cross-checked program and measure totals.

2.2.3 IMPACT APPROACH

The Evaluators completed the steps outlined below to complete the impact evaluation.

1. Deliver a detailed data request outlining the information we require for each rebated equipment type.
2. Complete a thorough and comprehensive summary of program tracking data.
3. Validate the appropriate inputs to deemed savings and engineering algorithms were used for each measure.
4. Verify the gross energy (therms) savings that are a result of the program either via a deemed savings, billing analysis, or heating load estimation methodology.
5. Summarize and integrate the impact evaluation findings into the final report.

The Evaluators detail measure-specific impact evaluation methodologies in Section 3.

2.2.3.1 Deemed Savings

This section summarizes the deemed savings analysis method the Evaluators employed for clothes washer and storage water heater measures. The Evaluators ensured the proper measure unit savings were recorded and used in the calculation of expected measure savings. The Evaluators used regional inputs from RTF workbooks and engineering algorithms to calculate expected measure savings. The Evaluators documented any cases where recommend values differed from the specific unit energy

[8] https://www.ahridirectory.org/

savings workbooks used by CNGC. The Evaluators reviewed and applied savings values derived from the following TRMs/workpapers:

- ASHRAE and NREL for engineering algorithms
- RTF for region-specific inputs (water source temperature, etc.)

2.2.3.2 Billing Analysis

This section describes the billing analysis methodology employed by the Evaluators as part of the impact evaluation and measurement of energy savings for measures with sufficient participation. A billing analysis approach was used to calculate savings for the tankless water heater, programmable thermostat, and smart thermostat measures. The Evaluators performed billing analyses using pre-period and post-period data. The pre-period identifies the period prior to measure installation while the post-period refers to the period following measure installation.

For the purposes of this analysis, a household is considered a treatment household if it has received a program incentive. To isolate measure impacts, treatment households are eligible to be included in the billing analysis if they installed only one measure in the tracking data CNGC provided. Isolation of individual measures is necessary to provide valid measure-level savings. Households that installed more than one measure may display interactive energy savings effects across multiple measures that are not feasibly identifiable. Therefore, instances where households installed isolated measures were used in the billing analyses.

After isolating households to those installing a single measure, the treatment group's pre-period and post-period billing data are compared, as detailed in IPMVP Option C. The Evaluators fit regression models to estimate weather-dependent daily consumption differences for each household between the period of time prior to the efficiency upgrade, and the period of time after the efficiency upgrade has been installed.

2.2.3.2.1 Cohort Creation

The Evaluators created each measure cohort by compiling billing data from the census of participants for each measure between PY2018 and PY2022. This allowed the Evaluators to evaluate the maximum number of participants within the service territory. With this information, the Evaluators conducted cleaning steps to ensure sufficient data is displayed for each participant.

After cohort creation and data cleaning, the Evaluators calculated heating load consumption (total gas usage for space heating end uses) for each customer and ran a Pre/Post billing analysis[9] regression for each measure.

Further details on regression model specifications can be found below.

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[9] National Renewable Energy Laboratory (NREL) Uniform Methods Project (UMP) Chapter 17 Section 4.4.7.

2.2.3.2.2 Data Collected

The following data were collected for the billing analysis:

1. Monthly billing data for program participants (treatment customers)
2. Program tracking data, including customer identifiers, address, household square footage, Btu/h of equipment (if applicable), and date of measure installation
3. National Oceanic and Atmospheric Administration (NOAA) weather data between January 1, 2017, and December 31, 2023)
4. Typical Meteorological Year (TMY3) data[10]

Billing and weather data were obtained for the entire evaluation period and for one year prior to measure install dates (2017-2022). CNGC delivered billing and tracking data to the Evaluators in October 2023, so the most recent full year of data for this analysis was 2022. The Evaluators mapped customer zip codes to the nearest weather station and extracted temperature data from those weather stations via NOAA's Global Hourly Integrated Surface Database.[11]

TMY weather stations were assigned to NOAA weather stations by geocoding the minimum distance between each set of latitude and longitude points. This data is used for extrapolating savings to long-run, 30-year average weather.

2.2.3.2.3 Data Preparation

The following steps were taken to prepare the billing data:

1. Excluded bills missing address information.
2. Cleaned billing data and tracking data address information by converting addresses to lowercase and removing whitespace.
3. Subset billing data to only include customers included in the tracking data. Billing and tracking data did not include matching identifiers (e.g., premise ID), so the Evaluators matched the datasets based on cleaned customer address information.
4. Removed bills missing fuel type/Unit of Measure (UOM).
5. Removed bills missing usage, billing start date, or billing end date.
6. Merged equipment capacity, equipment efficiency, and household square footage from the tracking data with the billing data by clean address.
7. Removed all bills prior to customer move-in date or after customer move-out date.
8. Removed all bills prior to service start date.
9. Removed duplicates from tracking and billing data.
10. Adjusted estimated bills based on proximal actual bills using a true-up process.
11. Calendarized bills (recalculates bill dates, usage, and total billed days such that bills begin and end at the start and end of each month).

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[10] Typical Meteorological Year (TMY) 3 is a set of weather data synthesized by NREL representing the long-term climatic conditions for specific locations. The TMY3 dataset was constructed using historical weather data collected from 1976-2005, typically obtained from weather stations in the vicinity of the location of interest.

[11] https://www.ncei.noaa.gov/products/land-based-station/integrated-surface-database

12. Remove bills with outlier durations after calendarization (<9 days).
13. Obtained weather data from nearest NOAA weather station using 5-digit zip code per household.
14. Computed Heating Degree Days (HDD) for a range of setpoints. The Evaluators assigned a setpoint of 65°F for both HDD.
15. Subset billing data to only include customers with only one measure installed during the analysis years and merged customer measure install dates with billing data (to define pre- and post-periods).
16. Removed customers with incomplete post-period bills (<5 months total, <2 months of bills in winter).
17. Removed customers with incomplete pre-period bills (<5 months total, <2 months of bills in winter).
18. Calculate customer baseload consumption by averaging summer month (June – August) gas consumption.
19. Calculate heating load consumption by subtracting customer-specific baseload from gas consumption

2.2.3.2.4 Regression Model

The Evaluators ran the Pre/Post regression model for the tankless water heater, programmable thermostat, and smart thermostat measures. The results of each regression model were summarized and utilized for extrapolation of verified savings for each participant. The following equation displays the model specification to estimate the average daily savings due to the measure evaluated.

Equation 2-1. Pre/Post Regression Model Specification

$$ADC_{it} = \alpha_0 + \beta_1(Post)_{it} + \beta_2(HDD)_{it} + \beta_3(Post \times HDD)_{it} + \beta_4(COVID19)_i + \beta_5(Customer\ Dummy)_i + \varepsilon_{it}$$

Where:

- *i* = the *i*th household
- *t* = the first, second, third, etc. month of the post-treatment period
- ADC_{it} = Either average daily gas usage per Btu/h or average daily heat load per square foot for month *t* for household *i*
- $Post_{it}$ = A dummy variable indicating pre- or post-period designation during period *t* at facility *i*
- HDD_{it} = Average heating degree days (base with optimal Degrees Fahrenheit) during period *t* at facility *i*
- $COVID19$ = a dummy variable to control for the impact of the COVID-19 pandemic. COVID19 was set to 1 from April 1, 2020, through April 30, 2022
- $Customer\ Dummy_i$ = a customer-specific dummy variable isolating individual household effects
- ε_{it} = The error term
- α_0= The model intercept

- β_{1-5} = Coefficients determined via regression

ADC_{it} was calculated as either monthly gas usage or monthly heating load divided by the duration of the bill month. For the tankless water heater measure, average daily gas usage was divided by the input Btu/h of the equipment. Average daily gas usage was used for tankless water heater calculations because water heater use is not dependent on heating load. In contrast, for both smart and programmable thermostat measures, average daily heating load was divided by household square footage. ADC_{it} was calculated on a per input Btu/h or per household square footage to standardize savings calculations across different households. β_1 is the coefficient representing the impact of measure installation on average daily gas usage per Btu/h or heating load per square foot. Meanwhile, β_2 represents the impact of weather on energy usage and β_3 is the coefficient associated with the interaction between measure installation and weather. Typical annual gas savings were estimated by adding β_1 to the product of β_3 and the average daily Typical Meteorological Year (TMY) HDD data and then multiplying that sum by the days in a year (365.25) and by 1000 (to convert from per Btu/h to per kBtu/h, or from per square foot to per 1000 square feet).

The equation below displays how savings per capacity (i.e., per input kBtu/h or per 1000 Sqft) were extrapolated for a full year utilizing the coefficients in the regression model and TMY data. TMY data was weighted by the number of households assigned to each weather station. Regression results are multiplied by -1 to present results as gas savings instead of the change in gas usage.

Equation 2-2. Savings Extrapolation

$$Annual\ Savings\ per\ capacity\ = -1 * 1000 * 365.25 * (\beta_1 + \beta_3 * Avg\ Daily\ TMY\ HDD)$$

2.2.3.3 Heating Load Analysis

The Evaluators estimated heating load for gas space heating participants in the post-period. The heating load estimation billing analysis was employed for furnaces, boilers, hearths, and combination heating (i.e., hydronic heating) measures. A heating load estimate provides a way to calculate therms savings for space heating measures using TRM-based engineering equations, under various scenarios for pre- and post-efficiency factors and space heating capacities.

This approach complies with the IPMVP maintained by the EVO with sponsorship by the U.S. DOE[12]. It is often used to calculate deemed savings for gas furnace retrofits.

2.2.3.3.1 Data Collection

CNGC provided the Evaluators with the necessary data to compute heating load estimates for the space heating equipment installed within the CNGC service territory. The heating load was estimated separately for each household because space heating runtimes vary depending on customer preferences as well as weather zone and associated heating degree days (HDDs). The information required to conduct this analysis included:

- Efficient space heating capacity (Btu/h)

[12] Core Concepts: International Measurement and Verification Protocol. EVO 100000 – 1:2016, October 2016.

- Efficient space heating AFUE/efficiency (%)
- Monthly billing data for furnace, boiler, hearth, and combination heating participants
- Heating Degree Days from local weather stations
- Typical Meteorological Year (TMY3) data
- The Evaluators conducted the same data cleaning steps outlined in Section 2.2.3.2.3 for the heating load estimation analysis. However, step 17 of that list was ignored, as the heating load analysis only involves post-period data.

2.2.3.3.2 Heating Load Estimation Methodology

The first step in heating load estimation is calculating TMY3 weather normalized average daily consumption. To do so, customer-specific regressions are run to determine the effect of daily HDD on average daily consumption. This is a straightforward regression of the form:

Equation 2-3. Heating Load Regression

$$ADC_i = \alpha_0 + \beta_1 (HDD)_i$$

Where:

- *i* = the *i*th household
- ADC_i = Average daily usage for household *i* during the post-treatment period
- HDD_i = Average heating degree days (base with optimal Degrees Fahrenheit) at home *i*
- β_1 = Coefficient determined via regression

This regression is run separately for each customer to determine β_1, impact of HDD on average daily consumption (i.e., the change in therms usage per HDD). From there, β_1 multiplied by HDD is subtracted from ADC and $\beta_1$multiplied by TMY_HDD is added back to ADC to calculate TMY3 weather normalized average daily consumption. The actual HDD attributable therms usage is subtracted from average daily consumption and the TMY_HDD attributable therms are added back in, as outlined in the following equation.

Equation 2-4. Normalized Average Daily Consumption

$$NADC_i = ADC_i - \beta_1 * (HDD)_i + \beta_1 * (TMY\_HDD)_i$$

Where:

- *i* = the *i*th household
- $NADC_i$ = TMY normalized average daily usage for household *i* during the post-treatment period
- β_1 = Customer-specific therms usage per HDD
- ADC_i = Average daily usage for household *i* during the post-treatment period
- HDD_i = Average heating degree days (base with optimal Degrees Fahrenheit) at home *i*
- TMY_HDD_i = Average TMY heating degree days at home *i*

Once TMY normalized average daily usage (NADC) was calculated, the Evaluators performed the following calculations to determine customer heating load savings:

- Calculated post-period normalized baseload usage (therms) for each participant, where baseload is equal to average NADC in June, July, and August.
- Calculated TMY weather normalized average daily heating load (NHL) for each participant in the post-period by taking the difference between NADC (therms) and normalized baseload usage.
- Set any negative heating loads to zero (assumed to be deviations from average baseload usage).
- Divided NHL by equipment Btu/h to determine the NHL per Btu/h.
- Calculated the average NHL per Btu/h in each heating zone. Customer heating zones are determined by the RTF and are assigned based on zip code.[13] See Figure 4-1 for a map of RTF heating zones.
- Merged heating zone average NHL per Btu/h with tracking data by heating zone.

With a weather normalized heating load per Btu/h included in the tracking data for each space heating measure, the Evaluators calculated annual therms savings as follows. This equation is outlined in page 43 of the Arkansas TRM version 9.1.[14]

Equation 2-5. Heating Load Annual Savings

$$Savings = NHLperBtuh * 365.25 * Btuh * (\frac{1}{BaseEff} - \frac{1}{InstallEff})$$

Where:

- $Savings$ = Annual therms savings associated with gas space heating measure
- $NHLperBtuh$ = Average TMY normalized daily heating load usage per Btu/h for participants in the post period
- 365.25 = Average number of days per year
- $Btuh$ = Heating equipment input capacity in Btu/h
- $BaseEff$ = The federal baseline efficiency standard for the given measure at the time of installation
- $InstallEff$ = The installed measure efficiency per tracking data, for furnaces this is the Annual Fuel Utilization Efficiency (AFUE) factor

Of note, all references to kBtu/h or Btu/h in this report refer to the input kBtu/h or Btu/h of installed equipment. The Evaluators removed projects from inclusion in heating load estimation that did not have sufficient bills to calculate average summertime baseload. Only post-period (post-installation) billing data was used in this estimation.

In addition to calculating annual savings, the same heating load methodology outlined above can be used to calculate customer Equivalent Full Load Hours (EFLH). In turn, EFLH can then be used to calculate annual savings. Equation 2-5 simplifies those two steps into one, allowing the Evaluators to directly calculate annual therms savings.

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[13] https://rtf.nwcouncil.org/work-products/supporting-documents/climate-files/

[14] https://apsc.arkansas.gov/wp-content/uploads/AR_TRM_V9.1_Volume_1_2_and_3_on_8-31-22.pdf

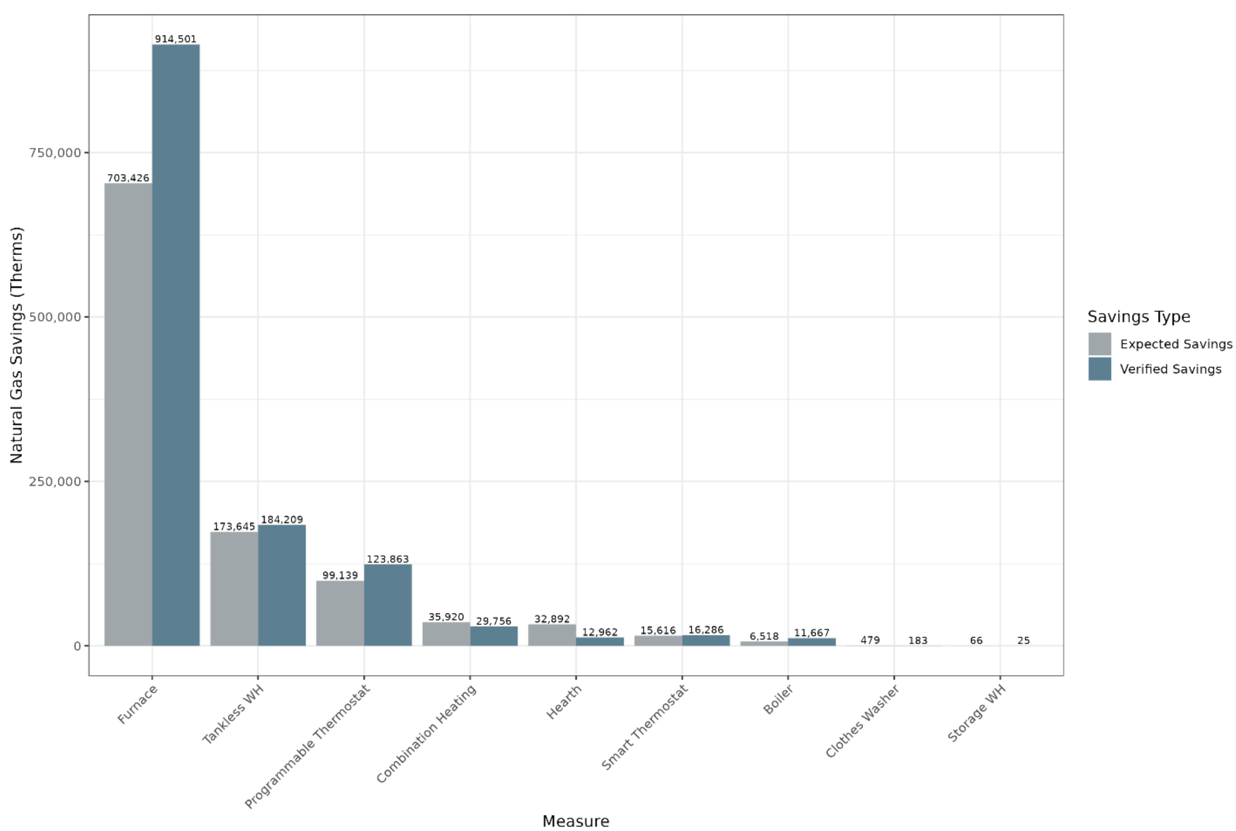
3 MEASURE-LEVEL IMPACT EVALUATION RESULTS

The following sections summarize findings for the residential gas impact evaluation of the space heating, water heating, and thermostat channels within the Washington service territory. The Evaluators used data collected and reported in the tracking database, applicable TRMs, and workpapers to evaluate savings. Table 3-1 and Figure 3-1 summarize verified impact savings by measure offering.

Table 3-1. CNGC Channel and Offering Verified Impact Savings

Channel	Measure	Number of Units	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Clothes Washer	Clothes Washer	63	479	183	38.1%
Space Heating	Boiler	77	6,518	11,667	179.0%
Space Heating	Combination Heating	178	35,920	29,756	82.8%
Space Heating	Furnace	7,966	703,426	914,501	130.0%
Space Heating	Hearth	593	32,892	12,962	39.4%
Thermostat	Programmable Thermostat	5,101	99,139	123,863	124.9%
Thermostat	Smart Thermostat	476	15,616	16,286	104.3%
Water Heating	Storage WH	2	66	25	37.3%
Water Heating	Tankless WH	2,697	173,645	184,209	106.1%
Total		**17,153**	**1,067,702**	**1,293,451**	**121.1%**

Figure 3-1. Expected and Verified Savings by Measure



The Evaluators summarize the channel and offer-specific activities, results, conclusions, and recommendations in the section below.

3.1 Space Heating

The Evaluators assessed savings for four types of space heating measures: boilers, combination heating (also known as hydronic heating), furnaces, and hearths. Combination heating systems also provide households with hot water, but the Evaluators have chosen to present findings for this measure under the space heating header. To be eligible for a rebate, residential boilers, combination heaters, furnaces must have at least a 95% AFUE.[15] Hearths meanwhile must have at least a 70% EnerGuide Fireplace Efficiency rating.[16]

The Evaluators conducted a thorough analysis of gas savings associated with these measures and developed a methodology to utilize in future savings estimates. To calculate savings for each of these the Evaluators employed a post-only, heating load estimation methodology. The outline of the calculation process, findings, and general recommendations below. The following subsections present the Evaluators' methodology and findings as well as key recommendations based on the analyses.

3.1.1 OVERVIEW

The following subsections outline the methodology the Evaluators employed to calculate gas savings associated with the residential space heating measures. Prior to exploring the savings calculation methodology, the Evaluators summarize the expected therms usage by program year and measure for the space heating channel below.

[15] https://www.cngc.com/energy-efficiency/residential-rebate-offerings/

[16] https://www.cngc.com/wp-content/uploads/PDFs/Conservation/2022_rebates/Incentive-Sheet-2022-UPDATED-English-1.pdf

Table 3-2. Space Heating Channel Savings by Measure and Year

Measure	Program Year	Projects	Incentives	Expected Savings (therms)
Boiler	2018	1	$500	106
	2019	10	$7,500	761
	2020	20	$15,000	1,513
	2021	25	$18,750	1,908
	2022	21	$18,150	2,230
Combination Heating	2018	9	$22,500	4,268
	2019	63	$98,750	15,058
	2020	44	$55,000	6,993
	2021	38	$47,500	6,032
	2022	24	$35,000	3,569
Furnace	2018	367	$146,800	40,679
	2019	2,232	$892,400	195,742
	2020	2,045	$818,000	171,520
	2021	1,761	$704,400	149,734
	2022	1,561	$937,650	145,751
Hearth	2018	60	$15,000	3,378
	2019	173	$50,900	9,717
	2020	140	$42,000	7,871
	2021	122	$36,600	6,850
	2022	98	$29,400	5,076
Total		**8,814**	**$3,991,800**	**778,756**

3.1.1.1 Data Received

The Evaluators received tracking data and billing data. The tracking data included all relevant information on residential rebate measures installed between January 1, 2018, and December 31, 2022. The dataset included data such as measure type, installation date, input Btu/h, and customer address. The billing data tracked monthly residential gas usage between November 29, 2018, and October 31, 2023, across 11,102 unique premise IDs.

The Evaluators' approach estimated the impacts of the efficient measure installation for each space heating measure. Table 3-3 displays customer counts for customers included in billing analyses and identifies measures that met the requirements for a billing analysis.

Table 3-3. Space Heating Measures Considered for Billing Analysis

Measure	Measure Considered for Billing Analysis	Customers Included in Billing Analysis	Sufficient Participation for Billing Analysis
Boiler	✓	53	✓
Combination Heating	✓	104	✓
Furnace	✓	2,401	✓
Hearth	✓	383	✓

3.1.1.2 Preprocessing

While the tracking and billing datasets contained nearly all data necessary for the Evaluators to conduct savings calculations, minor preprocessing was required. A full list of the data preparation steps employed for the billing analysis is presented in Section 2.2.3.2.3. The following paragraphs provide additional details on the data preprocessing required for space heating measures.

First, the Evaluators converted addresses in both the billing and tracking data to lowercase and removed any extra whitespace. Since the tracking data did not include a customer or premise identifier (such as Premise ID) that matched with the billing data, the Evaluators had to match the datasets based on cleaned household address.

Second, the Evaluators conducted research to impute missing household square footage and equipment capacity. While the tracking data included household square footage for nearly all customers, the Evaluators imputed square footage for five furnace customers via Zillow searches. In addition, while Btu/h capacity data was included in furnace tracking data, the Evaluators conducted online searches to identify installed equipment capacity for all other space heating measures.

Next, before merging tracking data information (such as household square footage) with billing data, the Evaluators removed duplicates from both the tracking and billing data. Tracking data duplicates were often due to multiple different model numbers, efficiency ratings, and/or square footage values being reported for a single measure installation. The Evaluators reviewed AFUE certification documents to identify correct efficiency ratings and reviewed realtor sites (such as Zillow.com) to identify correct household square footage and removed all erroneous duplicates. If multiple model numbers were reported, then the most specific one was selected. For example, if both “S9X2” and “S9X2C080U5PSB**” were reported furnace types, the latter was selected and the former was removed.

After removing duplicates, the Evaluators used household zip codes to assign the closest possible United States Air Force (USAF) code to each customer in the billing data. USAF codes are 6-digit codes that correspond to USAF weather stations. USAF stations are used by the National Oceanic and Atmospheric Administration (NOAA) for weather data collection. Evaluators used publicly available NOAA temperature data to calculate the average daily HDDs across each billing period. After adding daily HDDs to the dataset, the Evaluators also calculated average daily therms usage by dividing monthly bills by bill duration. The final preprocessing step was to use those daily bills and daily HDDs to calculate weather-normalized therms usage. To do so the Evaluators followed the calculations outlined in Equation 2-4. Lastly, the Evaluators used TMY weather normalized average daily consumption to calculate TMY normalized heating load, which in turn was used to calculate annual savings per Equation 2-5.

3.1.2 ANALYSIS METHODOLOGY

The Evaluators employed a post-only, heating load estimation methodology to estimate verified savings for each of the four space heating technologies. The formulae used across the four space heating technologies were similar; however, different baseline equipment efficiency assumptions were employed. Federal baseline equipment efficiency and compliance dates are presented in Table 3-4.

Table 3-4. Space Heating Measures Considered for Billing Analysis

Measure	Baseline Efficiency	Compliance Date	End Date for Analyses	Source
Boiler	82%	09/01/2012	01/14/2021	10 CFR § 430.32[17]
Boiler	84%	01/15/2021	12/31/2023	10 CFR § 430.32
Combination Heating	80%	11/19/2015	12/31/2023	10 CFR § 430.32[18]
Furnace	80%	11/19/2015	12/31/2023	10 CFR § 430.32
Hearth	64%	04/16/2010	12/31/2023	Energy Conservation Standards for Direct Heating Equipment[19]

The general methodology outlined in Section 2.2.3.3 was employed to calculate the savings associated with furnaces and boilers; however, combination heating and hearth savings calculations were slightly distinct.

Since combination heating effectively involves using a water heater for space heating, combination heating calculations must account for both space and water heating savings. Space heating savings were calculated using the heating load estimate methodology. Water heating savings meanwhile were calculated based on the results of the pre-period vs. post-period regression analysis for tankless water heaters. Full tankless water heater savings results are outlined below in Section 3.2.3; however, the key detail is that efficient tankless water heaters were found to be associated with 0.372 therms savings per kBtu/h. As such, combination heating water heating savings were calculated by multiplying combination heater capacities (in kBtu/h) by 0.372. The combination heating savings outlined below are equal to the sum of space heating and water heating savings.

Hearth savings calculations also required adjustment. The heating load methodology assumes that 100% of space heating therms are attributable to a single primary space heating technology. In the case of furnaces or boilers this is a reasonable assumption; however, hearths are often used as secondary heating equipment.[20] To account for this, the Evaluators multiplied customer heating load by 20.85%, the percentage of gas heating consumption used on fireplaces in 2021 per the American Gas Association.[21] It is possible that customers who installed hearths may use it as a primary heating source or alternatively they may use it only for aesthetic purposes. The 20.85% multiplier (calculated as 8.8/[8.8+33.4]) is a reasonable, region-specific estimate that could be adjusted in the future based on additional data regarding CGC customer gas consumption habits.

After calculating savings for these four measures using the heating load estimate methodology or an adjusted version of it, the Evaluators then aggregated all project-level annual savings to produce the program year savings for PY2018 through PY2022. While the billing data were subset to ensure each customer had at least six post-period monthly bills, the tracking data were only subset to remove duplicates. For example, while 383 customers were included in the hearth billing analysis to determine

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[17] https://www.govinfo.gov/content/pkg/CFR-2023-title10-vol3/pdf/CFR-2023-title10-vol3-sec430-32.pdf
[18] Furnace baseline standards were used for the space heating portion of combination heating savings calculations
[19] https://www.govinfo.gov/content/pkg/FR-2022-06-16/pdf/2022-12787.pdf
[20] https://escholarship.org/content/qt3dp1m0fw/qt3dp1m0fw.pdf
[21] https://www.aga.org/wp-content/uploads/2023/01/Table10-1.pdf

heating load, heating load savings calculations were extrapolated to 593 hearths installed from 2018-2022.

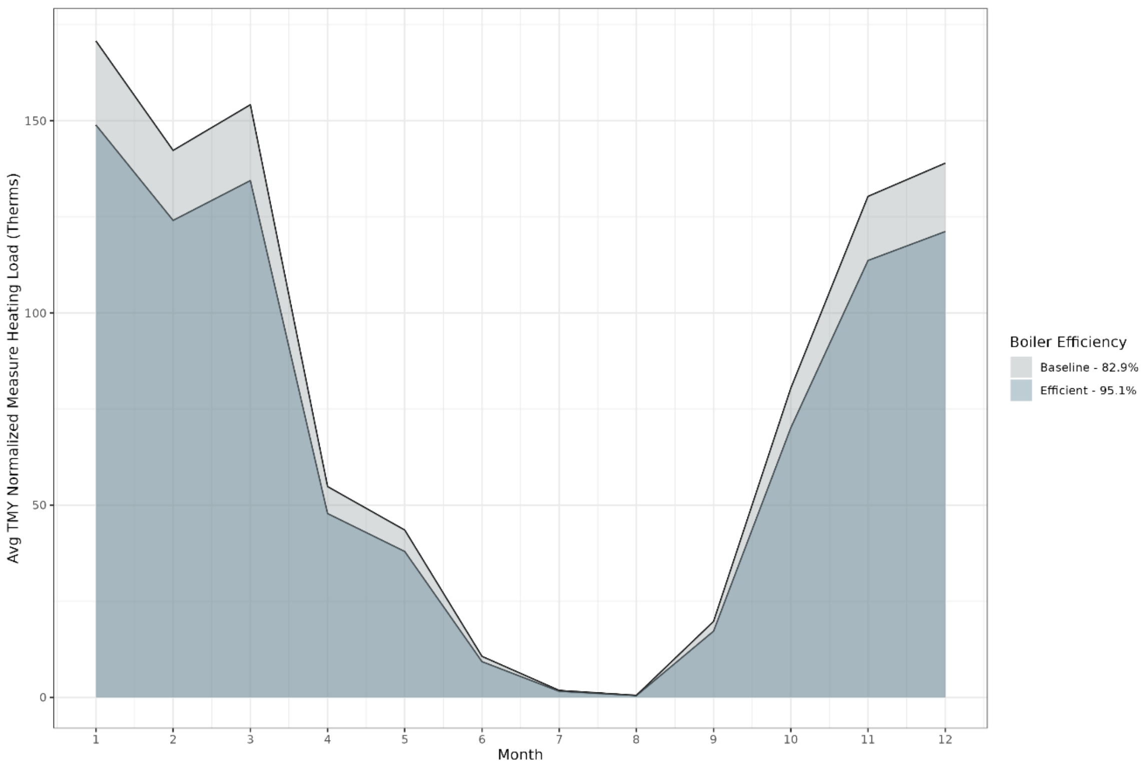
3.1.3 FINDINGS

In this section, the Evaluators summarize findings for each of the four space heating measures.

3.1.3.1 Boilers

Figure 3-2 highlights the monthly difference in average TMY normalized heating load with baseline and efficient boilers. The baseline boiler efficiency of 82.9% is weighted based on boiler installation date.

Figure 3-2. Boiler Heating Load Visualization by Month



After conducting the post-only analysis, the Evaluators found that on average households in the tracking data installed a 100.73 kBtu/h boiler (the subset of households included in the billing data meanwhile installed a 98.49 kBtu/h boiler on average). All references to “kBtu/h” or “Btu/h” in this report refer to the input kBtu/h or Btu/h of installed equipment. Customers in the boiler billing analysis were found to have an average daily usage of 3.11 therms which equates to an average annual usage of 1,136 therms. After running the heating load calculation, the Evaluators found that boilers were associated with average daily savings of 0.415 therms which equates to average annual savings of 152 therms (13.3%).

Table 3-5 displays comprehensive per-customer summary statistics based on the boiler analysis.

Table 3-5. Boiler Summary Statistics

Summary Statistics	Value
Average Billing Analysis Capacity (kBtu/h)	98.49
Average Tracking Data Capacity (kBtu/h)	100.73
Daily Usage per kBtu/h (therms)	0.0382
Daily Usage per Household (therms)	3.11
Yearly Usage per Household (therms)	1,136
Daily Savings per kBtu/h (therms)	0.00408
Yearly Savings per kBtu/h (therms)	1.49
Daily Savings per Household (therms)	0.415
Yearly Savings per Household (therms)	152
Savings as a Percent of Therms Usage	13.3%

In order to estimate expected savings for boilers, the Evaluators recommend CNGC multiply the verified boiler capacity in kBtu/h by 1.49, which is equal to 365.25 times the daily savings per kBtu/h value.

When aggregating per-customer savings, the Evaluators found that 77 installed boilers yielded 11,667 therms verified savings and a realization rate of 179.0%. These findings are presented below in Table 3-9. It is difficult to determine why the verified boiler savings are substantially higher than CNGC's ex-ante savings; however, it is possible that customers installing boilers use substantially more gas than normal, meaning improving boiler efficiency leads to substantially higher savings. Indeed, the American Gas Association outlines that the average residential household in Washington used 765 therms annually.[22] This statewide average is 67.3% of the 1,136 therms average annual usage observed in the 53 customers included in the boiler billing analysis. Furthermore, as outlined in the following tables, the annual usage per household observed in the billing data for other space heating measures was far lower than 1,136 therms as well. A combination of a relatively small size for the boiler billing analysis paired with elevated natural gas consumption in that cohort likely explains at least a portion of the 179.0% realization rate.

For future analyses and evaluations, the Evaluators would recommend CNGC collect and share data on the Btu/h capacity of boilers. Including measure capacity in savings calculations can dramatically improve the accuracy of savings calculations.

3.1.3.2 Combination Heating

Figure 3-3 highlights the monthly difference in average TMY normalized space heating load with baseline and efficient combination heating. The increased efficiency associated with combination heating decreases the average space heating gas load in winter months.

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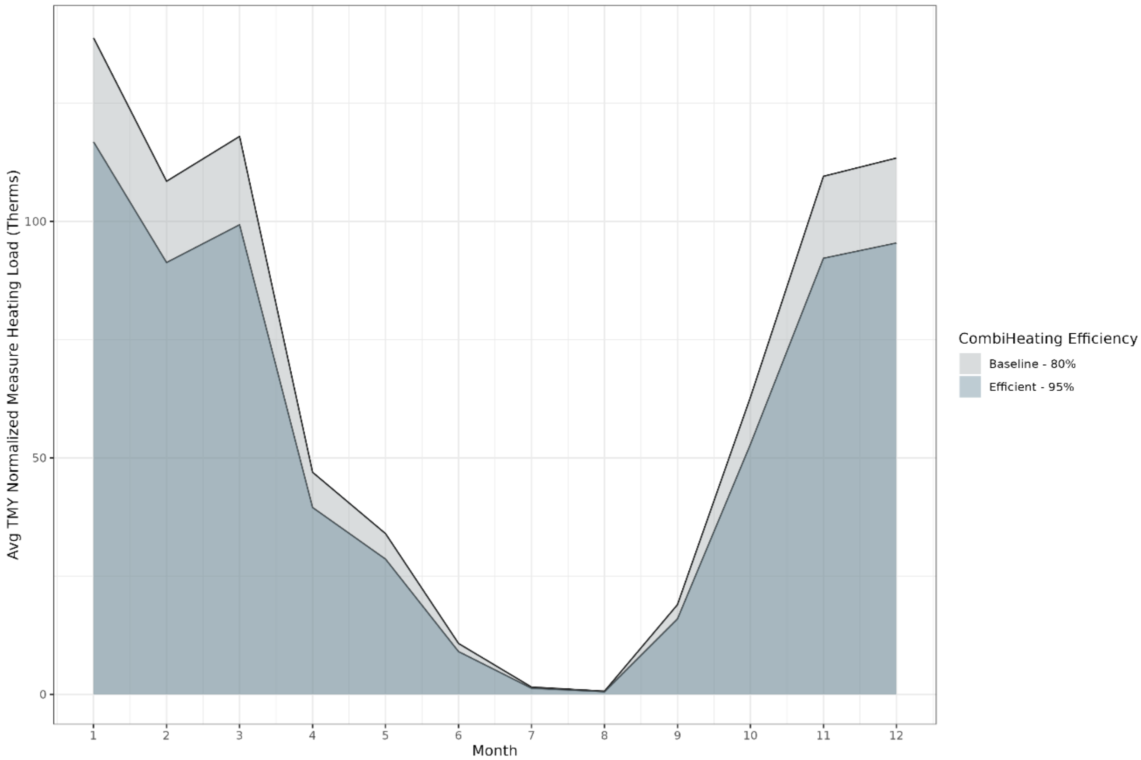
[22] https://www.aga.org/wp-content/uploads/2023/01/Table6-14.pdf

Figure 3-3. Combination Heating Space Heating Load Visualization by Month



After conducting the post-only analysis, the Evaluators found that on average households in the tracking data installed a 122.21 Btu/h combination heater (the subset of households included in the billing data meanwhile installed a 125.62 Btu/h combination heater on average). Customers in the combination heater billing analysis were found to have an average daily usage of 2.35 therms which equates to an average annual usage of 860 therms. After running the heating load calculation, the Evaluators found that combination heaters were associated with average daily savings of 0.458 therms which equates to average annual savings of 167 therms (19.4%). Of those 167 therms savings, 72.9% (122 therms) were attributable to space heating while the remaining 27.1% (45 therms) were due to water heating. Table 3-6 displays comprehensive per-customer summary statistics based on the combination heater analysis.

Table 3-6. Combination Heating Summary Statistics

Summary Statistics	Value
Average Billing Analysis Capacity (kBtu/h)	125.62
Average Tracking Data Capacity (kBtu/h)	122.21
Daily Usage per kBtu/h (therms)	0.0194
Daily Usage per Household (therms)	2.35
Yearly Usage per Household (therms)	860
Daily Savings per kBtu/h (therms)	0.00375
Yearly Savings per kBtu/h (therms)	1.37
Daily Savings per Household (therms)	0.458
Yearly Savings per Household (therms)	167
Savings as a Percent of Therms Usage	19.4%

In order to estimate expected savings for combination heaters, the Evaluators recommend CNGC multiply the verified combination heater capacity in kBtu/h by 1.37, which is equal to 365.25 times the daily savings per kBtu/h value.

When aggregating per-customer savings, the Evaluators found that 178 installed combination heaters yielded 29,756 therms verified savings and a realization rate of 82.8%. These findings are presented below in Table 3-9. Upon investigating the tracking data, combination heaters labelled “90+% AFUE Hydronic Space Heating & DHW”, as opposed to “95+% AFUE Hydronic Space Heating & DHW” seem to be the driving force behind this low realization rate. The 95+% AFUE combination heaters all have ex-ante savings ranging between 136 and 160 therms; however, the 90+% AFUE ones have ex-ante savings of 468 or 475 therms.

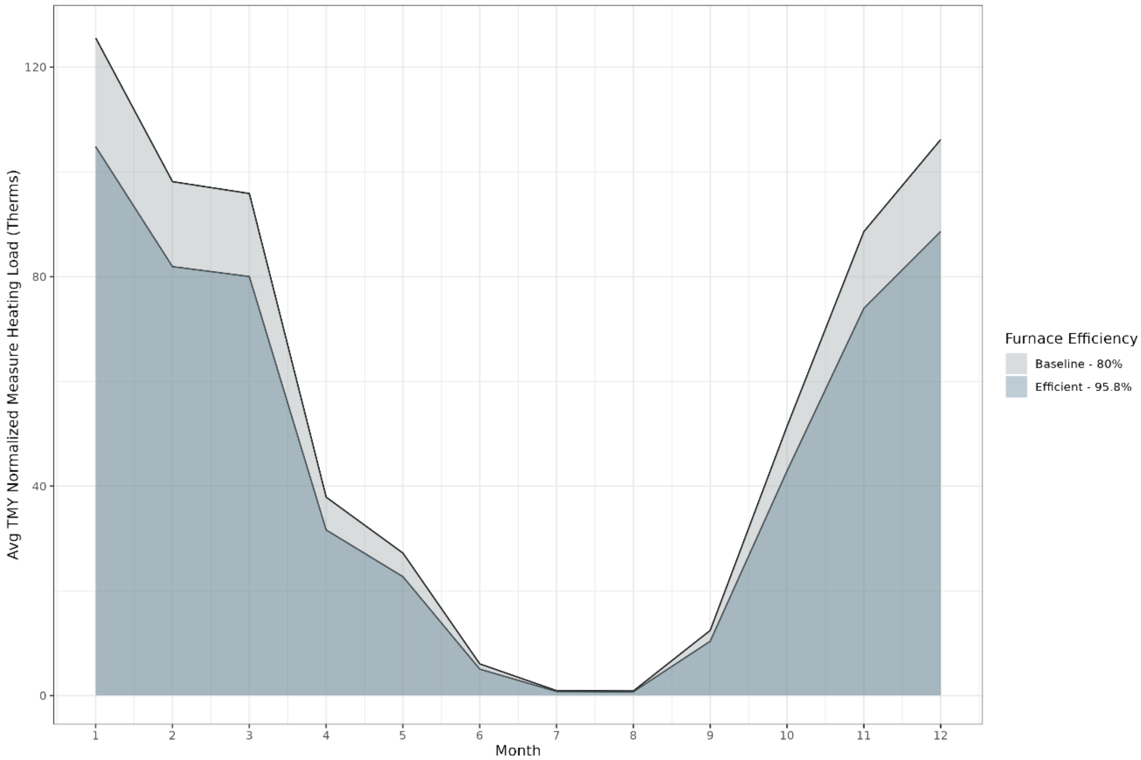
When the Evaluators subset the tracking data to only include 95+% AFUE combination heaters, the 153 measures yielded 26,008 therms verified savings and a realization rate of 108.1%. This slightly elevated realization rate is likely caused by differences in between CNGC’s and the Evaluator’s baseline assumptions. The aforementioned CNGC Excel workbook outlines the baseline condition for combination heaters as 80% AFUE gas space heating and a 40-gallon storage tank water heater. The Evaluators meanwhile assumed an 80% baseline for space heating calculations, but calculated water heating savings based on a tankless water heater regression. The tankless water heater regression yielded average water heating savings of 47 therms. However, if we apply the 33 therms ex-ante savings that CNGC uses for storage water heaters to the combination heater savings calculation we get 23,994 therms verified savings across the 153 measures for a realization rate of 99.7%. While exploring the implications of these different baseline assumptions is interesting, the Evaluators would ultimately suggest CNGC use the savings values presented in Table 3-6 for future savings calculations.

For future analyses and evaluations, the Evaluators would recommend CNGC collect and share data on the Btu/h capacity of combination heaters. Including measure capacity in savings calculations can dramatically improve the accuracy of savings calculations.

3.1.3.3 Furnaces

Figure 3-4 highlights the monthly difference in average TMY normalized heating load with baseline and efficient furnaces. On average, customers included in the furnace heating load analysis installed a 95.8% efficient furnace. As with other space heating measures, furnace savings are driven by a lower heating load in winter months.

Figure 3-4. Furnace Heating Load Visualization by Month



The Evaluators found that the average customer in the tracking data installed a 51.47 kBtu/h furnace. Customers in the furnace billing analysis were found to have an average daily usage of 1.96 therms which equates to an average annual usage of 716 therms. After running the heating load calculation, the Evaluators found that furnaces were associated with average daily savings of 0.314 therms which equates to average annual savings of 115 therms (16.0%). Table 3-7 displays the per-customer summary statistics based on the furnace billing data analysis.

Table 3-7. Furnace Summary Statistics

Summary Statistics	Value
Average Billing Analysis Capacity (kBtu/h)	51.12
Average Tracking Data Capacity (kBtu/h)	51.47
Daily Usage per kBtu/h (therms)	0.0411
Daily Usage per Household (therms)	1.96
Yearly Usage per Household (therms)	716
Daily Savings per kBtu/h (therms)	0.00609
Yearly Savings per kBtu/h (therms)	2.22
Daily Savings per Household (therms)	0.314
Yearly Savings per Household (therms)	115
Savings as a Percent of Therms Usage	16.0%

To estimate expected savings for furnaces, the Evaluators recommend multiplying the verified facility capacity in kBtu/h by 2.22, which is 365.25 times the daily savings per kBtu/h value.

When aggregating per-customer savings, the Evaluators found that 7,966 installed furnaces yielded 914,501 therms verified savings and a realization rate of 130.0%. These findings are presented below in Table 3-9. Furnaces are the most installed measure in the tracking data CNGC provided, and furnace ex-ante savings make up 66% of all ex-ante savings in this analysis. As such, this 130.0% furnace realization rate is a key driving force in the overall 121.1% realization rate across all measures.

The Evaluators' furnace savings calculation methodology is similar to CNGC's in several ways. Both methodologies account for the impact of weather and furnace efficiency on savings. CNGC's methodology differentiates savings by the CNGC weather zone of the household and the efficiency bracket (95+% AFUE or 98+% AFUE) of the installed furnace. The Evaluators' methodology uses weather-normalized billing data and installed furnace efficiency in heating load estimation calculations. However, the Evaluators' calculation of verified furnace savings considers furnace capacity (in input kBtu/h), while CNGC's methodology for ex-ante savings calculations seem not to. For example, CNGC assigns ex-ante annual savings of 111 therms for one customer installing a 95% AFUE, 40 kBtu/h furnace in 2019 and another installing a 95% AFUE, 120 kBtu/h furnace in 2019. In contrast, the Evaluators' methodology assigns annual savings of 83 therms to the first customer and 250 therms to the second. Furnace capacity (which is correlated with household square footage) has a direct impact on both overall gas usage and annual savings. As such, the Evaluators would recommend CNGC consider furnace capacity in future savings calculations.

3.1.3.4 Hearths

Figure 3-5 highlights the monthly difference in average TMY normalized heating load with baseline and efficient hearths. Hearth heating load is equal to the heating load calculated using customer billing data multiplied by 20.85% to account for hearths being used as secondary heating equipment.

The Evaluators found that the average customer in the tracking data installed a 31.58 kBtu/h hearth. Customers in the hearth billing analysis were found to have an average daily usage of 1.96 therms which equates to an average annual usage of 717 therms. After running the heating load calculation, the Evaluators found that hearths were associated with average daily savings of 0.0609 therms which equates to average annual savings of 21.9 therms (3.0%). Table 3-8 displays the per-customer summary statistics based on the hearth billing data analysis.

Figure 3-5. Hearth Heating Load Visualization by Month

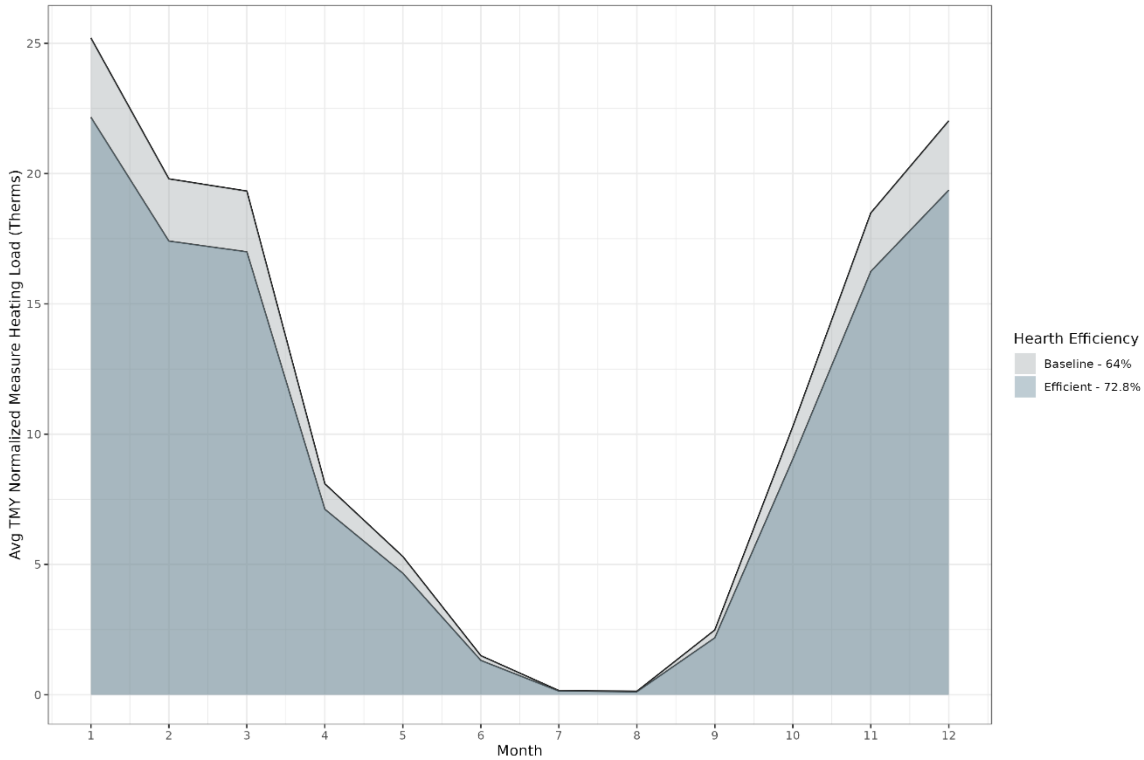


Table 3-8. Hearth Summary Statistics

Summary Statistics	Value
Average Billing Analysis Capacity (kBtu/h)	31.05
Average Tracking Data Capacity (kBtu/h)	31.58
Daily Usage per kBtu/h (therms)	0.0662
Daily Usage per Household (therms)	1.96
Yearly Usage per Household (therms)	717
Daily Savings per kBtu/h (therms)	0.00190
Yearly Savings per kBtu/h (therms)	0.694
Daily Savings per Household (therms)	0.0609
Yearly Savings per Household (therms)	21.9
Savings as a Percent of Therms Usage	3.0%

To estimate expected savings for hearths, the Evaluators recommend multiplying the verified facility capacity by 0.694, which is 365.25 times the daily savings per kBtu/h value.

When aggregating per-customer savings, the Evaluators found that 593 installed hearths yielded 12,962 therms verified savings and a realization rate of 39.4%. These findings are presented below in Table 3-9. As with furnaces, this deviation from a 100% realization rate seems to be caused by CNGC savings calculations not considering equipment capacity. Regardless of hearth capacity, CNGC reports nearly all ex-ante hearth savings as 56 or 57 therms annually. These estimates correspond closely to the Evaluators verified savings for a 50 kBtu/h capacity hearth with 80% efficiency. However, most hearths included in the tracking data have capacities lower than 50,000 Btu/h, and as such ex-post verified savings are substantially lower than ex-ante estimates. It is also possible that the American Gas Association's estimate that 20.85% of space heating gas is spent on hearths may be an underestimate for CNGC customers, especially if many CNGC customers use hearths for primary heating. The Evaluators tested using 50% instead of 20.85% and found 31,079 therms savings for a realization rate of 94.5%. Given this, additional research on hearth usage patterns among CNGC customers may be worthwhile.

For future analyses and evaluations, the Evaluators would recommend CNGC collect and share data on the kBtu/h capacity of hearths. Including measure capacity in savings calculations can dramatically improve the accuracy of savings calculations.

Table 3-9. Space Heating Verified Savings by Measure

Measure	Installed Measures	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Boilers	77	6,518	11,667	179.0%
Combination Heating	178	35,920	29,756	82.8%
Furnaces	7,966	703,426	914,501	130.0%
Hearths	593	32,892	12,962	39.4%
Total	**8,814**	**778,756**	**968,886**	**124.4%**

3.1.4 CONCLUSIONS AND RECOMMENDATIONS

The Evaluators provide overall conclusions and recommendations for the space heating channel below.

Table 3-10. Space Heating Recommendations

Equipment	Recommendations
All Space Heating Measures	1. Include a unique customer or premise identifier in tracking data (such as Premise ID) so that billing data and tracking data can be matched with greater accuracy. 2. Include the input Btu/h capacity of all space heating equipment in tracking data. Furnace tracking data included capacity; however, this data would facilitate fast and accurate verification efforts for boilers, combination heating, and hearths in the future. 3. Standardize reporting of efficiency in tracking data. Efficiency was reported as a value (e.g., 85.0) and percentage (e.g., 0.85) at different points in tracking data. 4. Utilize a database structure that limits each address/premise ID to only one square footage value and each measure installation to only one model number, brand name, and efficiency value. This could help identify and address duplicate measures. 5. Identify and remove duplicates in billing data. Evaluators identified several duplicates with one instance being an estimated bill and the other being an actual bill.
Boilers	6. Based on billing data analysis results, the Evaluators recommend CNGC estimate boiler savings as verified boiler capacity by 1.49 therms per input kBtu/h.
Combination Heating	7. Based on billing data analysis results, the Evaluators recommend CNGC estimate combination heating savings as verified combination heating capacity by 1.37 therms per input kBtu/h.
Furnaces	8. Based on billing data analysis results, the Evaluators recommend CNGC estimate furnace savings as verified furnace heating capacity by 2.22 therms per input kBtu/h.
Hearths	9. To estimate expected savings for residential hearths, Evaluators recommend CNGC multiply verified hearth capacity by 0.694 therms per input kBtu/h.

3.2 Water Heating

3.2.1 OVERVIEW

CNGC offers incentives towards tankless water heaters and high efficiency storage tank water heaters. The Evaluators conducted an impact evaluation analysis for all incentivized tankless water heaters and storage tank water heaters between the program years of 2018 and 2022. This section provides further details of the Evaluators' objectives, data collection, methodology, and findings for this offering. Prior to exploring savings calculation methodologies, the Evaluators provide an outline of expected savings by year and measure below.

Table 3-11. Water Heating Channel Savings by Measure and Year

Measure	Program Year	Projects	Incentive	Expected Savings (therms)
Storage WH	2019	2	$90	66
Tankless WH	2018	132	$33,000	7,128
	2019	1,014	$331,500	66,066
	2020	748	$248,100	49,455
	2021	540	$188,000	34,566
	2022	263	$91,700	16,431
Total		**2,699**	**$892,390**	**173,711**

The Evaluators estimated verified measure-level energy savings through two different methodologies. Storage water heater savings were calculated via a deemed savings approach while tankless water heater savings were calculated through a pre-period vs. post-period regression billing analysis. The dependent variable in this regression was average daily gas usage per Btu/h because water heating affects year-round gas usage. For the deemed savings analysis, engineering algorithms and inputs were sourced from industry standard sources such as TRMs and RTF UES measure workbooks.

3.2.1.1 Data Received

The tracking data provided for tankless and storage tank water heaters included the following relevant fields:

- Uniform energy factor (UEF)
- Water heater model number
- Household address
- Household square footage
- Ex-ante expected therms savings
- Customer incentive

The following fields were missing from the tracking data:

- Water heater quantity
- Storage water heater tank size
- Baseline UEF
- Customer estimated annual hot water usage

- The Evaluators also received billing data for customers who installed water heater customers from X to Y. These billing data were used for a pre-period vs. post-period regression billing analysis to assess the annual savings associated with tankless water heaters. The full billing data tracked monthly residential gas usage between December 1, 2018, and October 31, 2023, across 11,102 unique premise IDs. Of those premise IDs, 874 were linked to tankless water heater installations.

3.2.1.2 Preprocessing

As part of the impact evaluation work, the Evaluators reviewed tracking data inputs for water heating offerings and imputed missing data via research. For storage tank water heaters, the Evaluators used water heater model number to identify storage tank heater size, which was used to assign baseline UEF according to the “Analysis Inputs” worksheet of the RTF’s residential gas water heater version 2.1 workbook.[23] Other region-specific inputs used in the deemed savings calculation of storage water heater savings were also identified in the RTF workbook. These inputs included estimated annual hot water use, the water heater set point ($T_{setpoint}$), and the average water supply temperature (T_{supply}). Since quantity was not included in the tracking data, the Evaluators assumed that one water heater was installed per residence.

Prior to running the pre-period vs. post-period regression billing analysis for tankless water heaters, the Evaluators completed the preprocessing steps outlined in Section 2.2.3.2.3. As with the space heating billing analysis, the Evaluators converted addresses in the billing and tracking data to lowercase and removed extra whitespace to identify premises where tankless water heaters were installed in the billing data. In addition, tankless water heater capacity in Btu/h was identified for all model numbers in the tracking data based on product specifications and the AHRI directory website. Lastly, duplicates were removed from both the billing and tracking data.

3.2.2 STORAGE WATER HEATER ANALYSIS METHODOLOGY

The results of the billing analysis for the tankless water heater installation and the deemed savings analysis for storage tank water heater measures are provided in this section. The Evaluators used a regression analysis to determine tankless water heater savings and the following engineering algorithm to calculate storage water heater savings*:*

Equation 3-1. Storage Water Heater Annual Savings Equation

$$Therms\ Savings = \frac{p * Cp * V * \left(T_{Setpoint} - T_{Supply}\right) * \left(\frac{1}{UEF_{Baseline}} - \frac{1}{UEF_{Efficient}}\right)}{100{,}000}$$

Where:

- p = Water density = 8.33 lb/gal
- Cp = Specific heat of water = 1 BTU/lb. °F

[23] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/

- V = Estimated annual hot water use (gal) = 15,085[24]
- $T_{Setpoint}$ = Water heater set point (°F) = 128[25]
- T_{Supply} = Average supply water temperature (°F) = 56[26]
- $UEF_{Baseline}$ = Baseline Uniform Energy Factor, which is between 0.614 and 0.633 depending on storage water heater tank size[27]
- $UEF_{Efficient}$ = Uniform Energy Factor of installed water heater
- $100{,}000$ = Conversion Factor Btu/Therm

This industry standard deemed savings equation for estimating annual water heater savings was sourced from page 131 and 132 of the Arkansas TRM version 9.1.[28] The Evaluators used this equation to calculate verified savings for the two customers who installed storage tank water heaters in the CNGC tracking data. Those results as well as the findings from the tankless water heater billing regression analysis are presented below.

3.2.3 FINDINGS

3.2.3.1 Storage Water Heaters

Savings results for the two installed storage water heaters can be found in Table 3-12. CNGC reported ex-ante savings of 33 therms per storage water heater. Only two storage water heaters were incentivized from 2019 to 2022. This offering is no longer available to CNGC customers and savings results should not be interpreted to be significant or impactful to the future of the program.

The CNGC Cost Effectiveness Excel workbook does not include storage water heaters, it only references "0.87 UEF tankless water heaters" and "condensing high-efficiency natural gas tankless water heaters". As such, the Evaluators were not able to investigate CNGC's calculation methodology. However, the Evaluators did test the impact of using a 0.58 baseline UEF (the baseline UEF CNGC outlines for tankless water heaters) for storage water heaters.

Using a 0.58 baseline UEF increased average verified savings from 12.5 to 23.9 therms per storage water heater and increased the realization rate from 37.3% to 72.3%. This suggests that CNGC likely assumes a lower baseline UEF than the Evaluators in their ex-ante savings calculations. The Evaluators used baseline UEF values from the RTF residential water heater UES workbook for final calculations.

One other distinction between CNGC's and the Evaluators' methodologies seems to be accounting for the UEF of the installed storage tank water heater. Per Equation 3-1, the Evaluators' savings calculation is dependent on the installed UEF; however, CNGC reported 33 therms ex-ante savings for both water heaters irrespective of system specific UEFs (one has a UEF of 0.67 and the other 0.70). The Evaluators would recommend CNGC account for installed UEF in their calculation of storage water heater savings.

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[24] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/
[25] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/
[26] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/
[27] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/
[28] https://apsc.arkansas.gov/wp-content/uploads/AR_TRM_V9.1_Volume_1_2_and_3_on_8-31-22.pdf

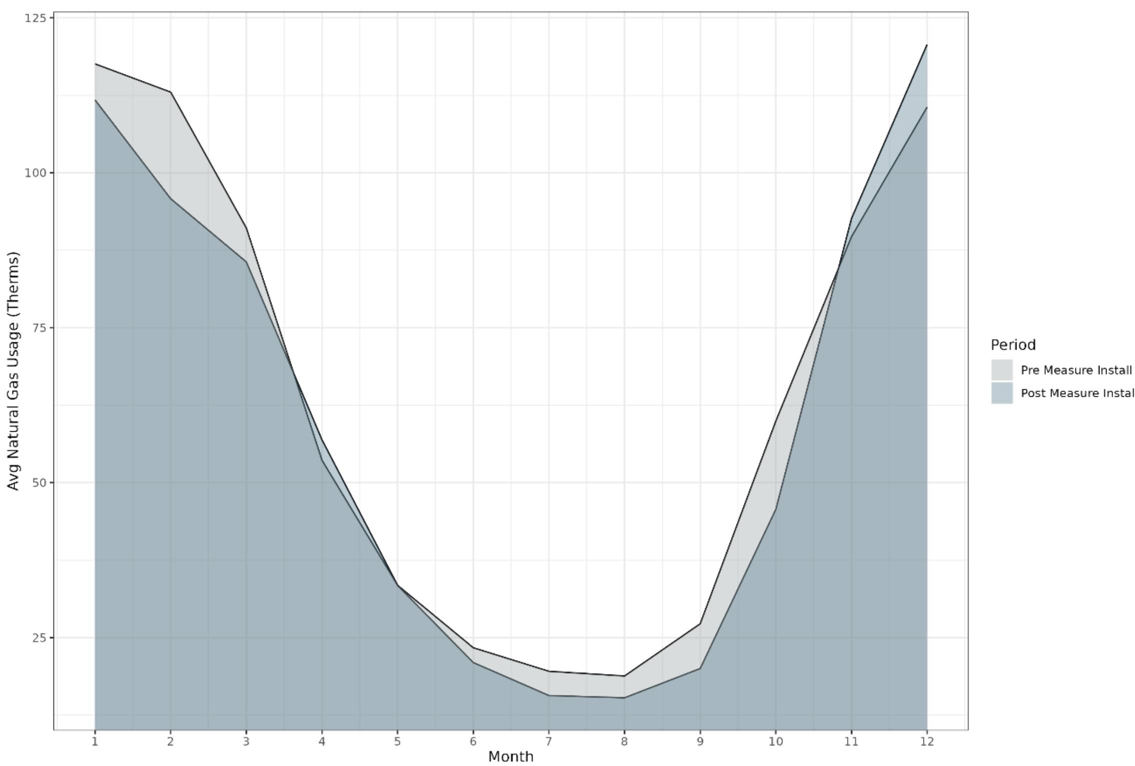
Table 3-12. Storage Tank Water Heater Verified Savings by Program Year

Program Year	Installed Measures	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
2019	2	66	25	37.3%
Total	**2**	**66**	**25**	**37.3%**

3.2.3.2 Tankless Water Heaters

The CNGC tracking data included substantially more tankless water heaters than storage water heaters. As such, the pre-period vs. post-period billing regression analysis was successful and yielded statistically significant results for tankless water heaters. Figure 3-6 outlines the difference in average pre-period and post-period monthly natural gas usage. Data in this figure are not weather normalized, as the regression includes HDD as a predictor variable to control for differences in temperature.

Figure 3-6. Tankless Water Heater Pre vs. Post Period Gas Usage by Month



The Evaluators followed the steps outlined in Section 2.2.3.2.4 to determine the impact of tankless water heater installation on average daily natural gas consumption. The results of the regression are outlined below in Table 3-13 and the results of the results of the extrapolation to an average annual savings value (per Equation 2-2) are presented in Table 3-14.

Table 3-13. Tankless Water Heater Regression Results

Regression Term	Coefficient	Standard Error	P value
Post	$-8.28*10^{-7}$	$9.27*10^{-8}$	<0.001
HDD	$7.14*10^{-7}$	$3.91*10^{-9}$	<0.001
COVID19	$7.46*10^{-8}$	$4.85*10^{-8}$	0.12
Post*HDD	$-1.26*10^{-8}$	$5.20*10^{-9}$	0.02

Table 3-14. Tankless Water Heater Regression Extrapolation

Summary Statistics	Value
Customers included in analysis	607
Annual savings per kBtu/h (therms)	0.3718
95% CI annual savings per kBtu/h lower bound (therms)	0.3340
95% CI annual savings per kBtu/h upper bound (therms)	0.4095
P value	<0.001
Adjusted R-squared	0.786

The Evaluators multiplied the annual therms savings per kBtu/h value of 0.372 by the kBtu/h capacity of all tankless water heaters included in the tracking data to determine tankless water heater annual savings. The results of this analysis are presented below in Table 3-15. Overall, 2,697 tankless water heaters were associated with 184,209 therms in verified annual savings for a 106.1% realization rate.

Table 3-15. Tankless Water Heater Verified Savings by Program Year

Program Year	Installed Measures	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
2018	132	7,128	9,418	132.1%
2019	1,014	66,066	68,466	103.6%
2020	748	49,455	50,131	101.4%
2021	540	34,566	37,726	109.1%
2022	263	16,431	18,469	112.4%
Total	**2,697**	**173,645**	**184,209**	**106.1%**

The results of the tankless water heater billing analysis are similar to CNGC's ex-ante savings estimates. This seems to suggest that annual savings estimates between 54 and 68 therms per tankless water heater are a slight underestimate of gas savings. For the most accurate savings estimates, the Evaluators would recommend CNGC multiply installed tankless water heater capacity by 0.372 savings per kBtu/h.

3.2.4 CONCLUSIONS AND RECOMMENDATIONS

The Evaluators provide overall conclusions and recommendations for the water heating channel below.

Table 3-16. Water Heating Recommendations

Equipment	Recommendations
All Water Heating Measures	1. Include a unique customer or premise identifier in tracking data (such as Premise ID) so that billing data and tracking data can be matched with greater accuracy. 2. Include the Btu/h capacity of all water heating equipment in tracking data. Btu/h capacity data was not necessary for deemed savings calculations, but capacity is a key metric that affects billing analysis savings calculations. 3. Utilize a database structure that limits each address/premise ID to only one square footage value and each measure installation to only one model number and brand name. This could help identify and address duplicate measures. 4. Identify and remove duplicates in billing data. Evaluators identified several duplicates with one instance being an estimated bill and the other being an actual bill.
Storage Water Heaters[29]	5. Use region-specific water temperature and hot water usage data in deemed savings calculations, such as values from the RTF.[30] 6. Instead of applying a single savings value across all systems, incorporate system specific UEF values in deemed savings calculations. 7. Consider employing a deemed savings equation, as outlined in Equation 3-1, to calculate annual storage water heater savings.
Tankless Water Heaters	8. Based on billing data analysis results, the Evaluators recommend CNGC estimate tankless water heater savings as 0.372 therms per kBtu/h.

[29] Storage water heaters have not been offered for many years and only two were included in this evaluation.
[30] https://rtf.nwcouncil.org/measure/residential-gas-water-heaters-0/

3.3 Thermostats

CNGC offers its customers incentives for installing either programmable or smart thermostats. Customers receive a $25 rebate for programmable thermostats and a $75 one for smart thermostats. The Evaluators conducted a thorough analysis of gas savings associated with these measures and in so doing developed a methodology to utilize in future savings estimates. The following subsections present the Evaluators' methodology and findings as well as key recommendations based on the analyses.

3.3.1 OVERVIEW

The tracking data delivered to the Evaluators included 6,140 installed thermostats; however, after deduplication and limiting tracking data to measures installed between 2018 and 2022, the Evaluators calculated savings for 5,577 thermostats. Before exploring the methodology employed to calculate savings, please find an outline of expected savings by measure and year below.

Table 3-17. Thermostat Channel Savings by Measure and Year

Measure	Program Year	Projects	Incentive	Expected Savings (therms)
Programmable Thermostat	2018	283	$2,830	5,398
	2019	1,693	$39,025	32,007
	2020	1,647	$41,175	31,134
	2021	939	$23,475	17,649
	2022	539	$13,475	12,950
Smart Thermostat	2022	476	$35,700	15,615
Total		**5,577**	**$155,680**	**114,755**

The Evaluators calculated verified savings using a pre-period vs. post-period billing regression analysis methodology as outlined in Section 2.2.3.2. Of note, the dependent variable in both regressions was average daily heating load per square foot. The Evaluators used heating load as opposed to average daily gas usage because thermostat installations should have a direct impact on household heating. Since thermostats, unlike space and water heating equipment, do not have a Btu/h capacity, savings were calculated on a per square foot basis.

3.3.1.1 Preprocessing

Thermostat data preprocessing followed the steps presented in Section 2.2.3.2.3. In addition to the steps outlined in that section, the Evaluators also filled out missing square footage data for two programmable thermostat premises via Zillow searches. Furthermore, the Evaluators conducted deduplication to remove both duplicate bills and duplicate instances of thermostat installation in the tracking data. The Evaluators summarize the measures considered for billing analyses in the table below.

Table 3-18. Thermostat Measures Considered for Billing Analysis

Measure	Measure Considered for Billing Analysis	Customers Included in Billing Analysis	Sufficient Participation for Billing Analysis
Programmable Thermostat	✓	269	✓
Smart Thermostat	✓	133	✓

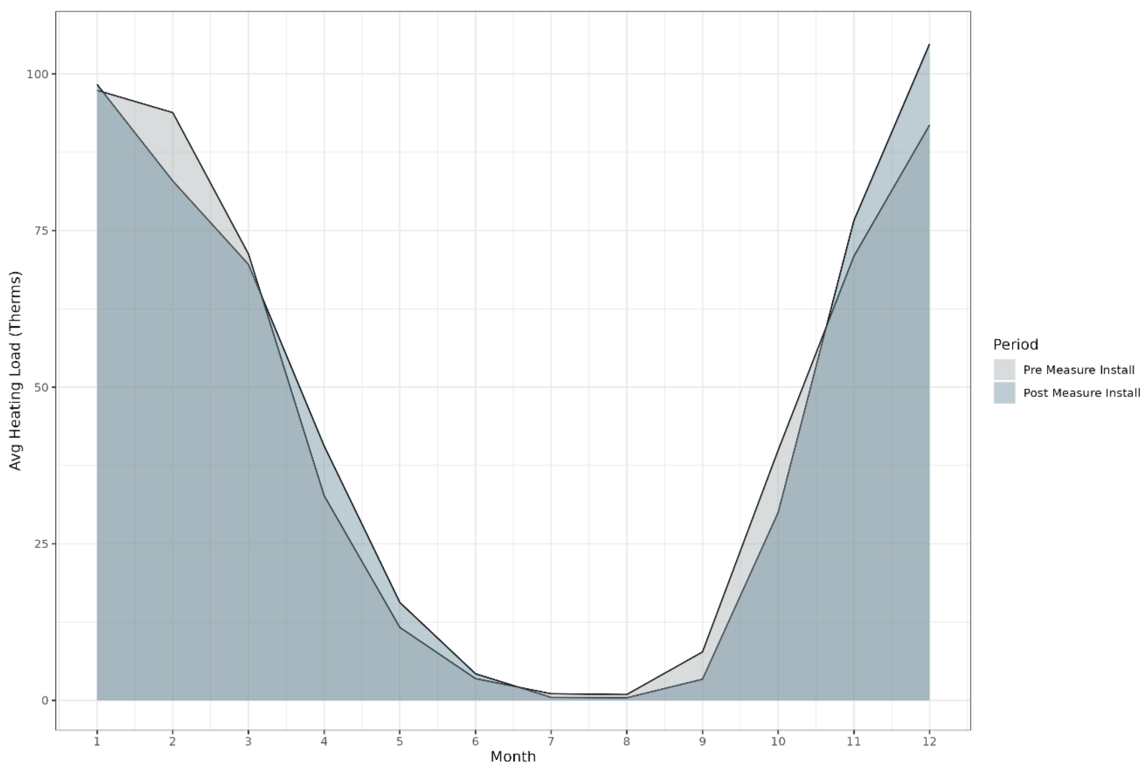
The Evaluators provide additional details on the results of the thermostat regression analyses in the following section.

3.3.2 FINDINGS

3.3.2.1 Programmable Thermostats

Figure 3-7 presents the difference in pre-period and post-period heating load based on the billing data of CNGC customers who installed programmable thermostats. Data in this figure are not weather normalized, as the regression includes HDD as a predictor variable to control for differences in temperature.

Figure 3-7. Programmable Thermostat Pre vs. Post Period Heating Load by Month



The following tables present the results of the programmable thermostat pre-period vs. post-period regression billing analysis. The extrapolation of regression results to a single annual savings per square foot value yielded highly statistically significant results. This suggests that when controlling for the impact of weather (via HDD), installing a programmable thermostat is associated with a clear decrease in natural gas heating load.

Table 3-19. Programmable Thermostat Regression Results

Regression Term	Coefficient	Standard Error	P value
Post	$-5.01*10^{-5}$	$1.18*10^{-5}$	<0.001
HDD	$7.25*10^{-5}$	$5.15*10^{-7}$	<0.001
COVID19	$5.14*10^{-6}$	$6.17*10^{-6}$	0.41
Post*HDD	$1.17*10^{-6}$	$6.60*10^{-7}$	0.08

Table 3-20. Programmable Thermostat Regression Extrapolation

Summary Statistics	Value
Customers included in analysis	269
Annual savings per 1000 Sqft (therms)	11.9
95% CI annual savings per 1000 Sqft lower bound (therms)	7.09
95% CI annual savings per 1000 Sqft upper bound (therms)	16.7
P value	<0.001
Adjusted R-squared	0.815

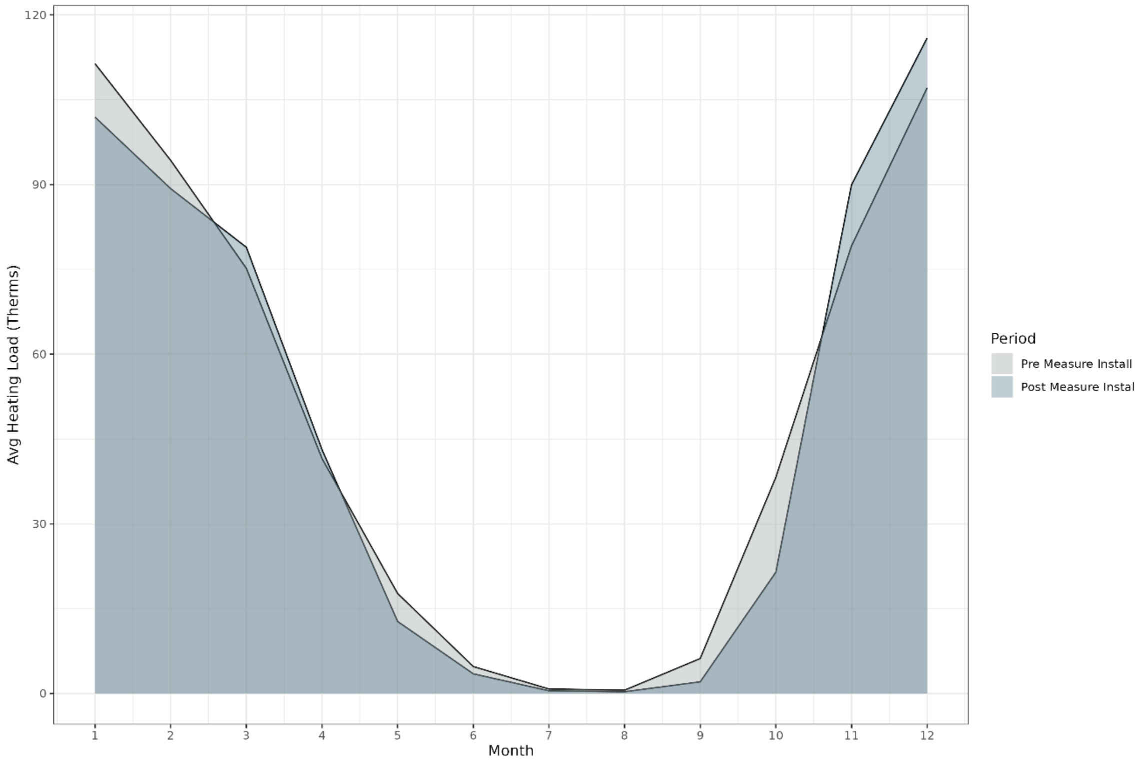
The Evaluators multiplied the annual therms savings per 1000 square feet value of 11.9 by the conditioned square footage, in thousands, of all households included in the tracking data to determine programmable thermostat annual savings. The results of this analysis are presented below in Table 3-23. Overall, 5,101 programmable thermostats were associated with 123,863 therms in verified annual savings for a 124.9% realization rate. The average programmable thermostat installation was associated with annual savings of 24.3 therms.

3.3.2.2 Smart Thermostats

Figure 3-8 highlights the difference in average pre-period and post-period heating load for customers who installed a smart thermostat. Data in this figure are not weather normalized, as the regression includes HDD as a predictor variable to control for differences in temperature.

As expected, summer months (i.e., June, July, and August) have a heating load close to zero, meaning smart thermostat savings are primarily derived from changes in fall, winter, and spring gas heating load. Post-period usage appears to be markedly lower than pre-period usage in January and February, as well as in the fall. The high post-period usage in November and December is likely explained by those post-period winter months being colder (i.e., having a higher HDD) than the corresponding pre-period months. After controlling for HDD, smart thermostat installation was found to be associated with a statistically significant decrease in natural gas heating load.

Figure 3-8. Smart Thermostat Pre vs. Post Period Heating Load by Month



While individual terms in the regression may not have been statistically significant, when combined via a generalized linear hypothesis into an extrapolated output, results were statistically significant. CNGC only provided smart thermostat tracking data from 2022 and 2023. With results in this report limited to the 2018 – 2022 date range, verified savings are only calculated based on a single year of smart thermostat data. While the results of this billing analysis closely match ex-ante estimates, the Evaluator would recommend reassessing savings in the future with additional years of smart thermostat data. The following tables present smart thermostat regression and regression extrapolation findings.

Table 3-21. Smart Thermostat Regression Results

Regression Term	Coefficient	Standard Error	P value
Post	$-2.59*10^{-6}$	$1.73*10^{-5}$	0.88
HDD	$6.82*10^{-5}$	$4.76*10^{-7}$	<0.001
COVID19	$-1.22*10^{-5}$	$9.27*10^{-6}$	0.18
Post*HDD	$-3.11*10^{-6}$	$9.41*10^{-7}$	<0.001

Table 3-22. Smart Thermostat Regression Extrapolation

Summary Statistics	Value
Customers included in analysis	133
Annual savings per 1000 Sqft (therms)	15.9
95% CI annual savings per 1000 Sqft lower bound (therms)	7.92
95% CI annual savings per 1000 Sqft upper bound (therms)	23.9
P value	<0.001
Adjusted R-squared	0.823

The Evaluators multiplied the annual therms savings per 1000 square feet value of 15.9 by the square footage, in thousands, of all households included in the tracking data to determine smart thermostat annual savings. The results of this analysis are presented below in Table 3-23. Overall, 476 tankless water heaters were associated with 16,286 therms in verified annual savings for a 104.3% realization rate. The average smart thermostat installation was associated with annual savings of 34.2 therms. This suggests smart thermostats are substantially more efficient than programmable thermostats, with smart thermostats saving on average 41% more therms annually.

Table 3-23. Thermostat Verified Savings by Measure and Program Year

Measure	Program Year	Installed Measures	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
Programmable Thermostat	2018	283	5,398	6,595	122.2%
	2019	1,693	32,007	40,686	127.1%
	2020	1,647	31,134	39,645	127.3%
	2021	939	17,650	23,443	132.8%
	2022	539	12,951	13,494	104.2%
Smart Thermostat	2022	476	15,616	16,286	104.3%
Total		**5,577**	**114,755**	**140,149**	**122.1%**

Both smart and programmable thermostats have verified savings relatively similar to ex-ante estimates. The Evaluators' average smart thermostat savings of 34.2 therms perfectly matches the smart thermostat weather zone 1 savings outlined in CNGC's Cost Effectiveness Excel workbook. The savings for zones 2 and 3 are also very similar to 34.2 therms. Programmable thermostats meanwhile may have a slightly elevated realization rate due to the fact that CNGC ex-ante estimates do not modify savings based on household square footage. After reviewing programmable thermostat tracking data, households with square footage near 1,700 have realization rates close to 100%. However, the average household square footage in the programmable thermostat tracking data is 2,041. The ex-ante methodology CNGC employs for programmable thermostats might implicitly assume a smaller household square footage (and consequently fewer therms savings) than the reality of the tracking data.

The Evaluators would recommend CNGC calculate savings for programmable and smart thermostats by multiplying household square footage, in thousands, by 11.9 and 15.9 (savings per 1000 square feet), respectively. Not only will these estimates provide region-specific savings estimates based CNGC customer billing data, but they will also help CNGC account for household size in savings calculations.

3.3.3 CONCLUSIONS AND RECOMMENDATIONS

The Evaluators provide overall conclusions and recommendations for the thermostat channel below.

Table 3-24. Thermostat Recommendations

Equipment	Recommendations
All Thermostat Measures	1. Include a unique customer or premise identifier in tracking data (such as Premise ID) so that billing data and tracking data can be matched with greater accuracy. 2. Utilize a database structure that limits each address/premise ID to only one square footage value and each measure installation to only one model number and brand name. This could help identify and address duplicate measures. 3. Identify and remove duplicates in billing data. Evaluators identified several duplicates with one instance being an estimated bill and the other being an actual bill.
Programmable Thermostats	4. Based on billing data analysis results, the Evaluators recommend CNGC estimate programmable thermostats savings as 11.9 therms per 1000 conditioned square feet.
Smart Thermostats	5. Based on billing data analysis results, the Evaluators recommend CNGC estimate smart thermostats savings as 15.9 therms per 1000 conditioned square feet. 6. Consider rerunning savings analyses in PY2025-PY2026 with more than one year of tracking data.

3.4 Clothes Washers

CNGC offers its residential customers a $50 rebate for installing an ES certified clothes washer.[31] The Evaluators conducted a thorough analysis of gas savings associated with efficient clothes washers and in so doing developed a methodology to utilize in future savings estimates. The following subsections present the Evaluators' methodology and findings as well as key recommendations based on the analysis.

3.4.1 OVERVIEW

The tracking data delivered to the Evaluators included 97 installed clothes washers; however, after limiting tracking data to measures installed between 2018 and 2022, the Evaluators calculated savings for 63 clothes washers. Before exploring the methodology employed to calculate savings, please find an outline of expected savings by year below.

Table 3-25. Clothes Washer Savings by Year

Program Year	Projects	Incentive	Expected Savings (therms)
2022	63	$3,100	479
Total	**63**	**$3,100**	**479**

The Evaluators calculated verified savings using a deemed savings analysis methodology. Minimal tracking data are necessary for clothes washer deemed savings calculations, and since CNGC provided clothes washer model number, the Evaluators were able to impute missing data via online research. Additional details on the data preprocessing and analysis methodology are outlined below.

3.4.1.1 Preprocessing

Minimal preprocessing was necessary prior to conducting savings calculations. First, since quantity was not included in the tracking data, the Evaluators assumed that each customer only installed one clothes washer. Outside of that, the only other data that the Evaluators had to source was tub volume (in cubic feet) and clothes washer configuration (top-load or front-load). The RTF residential clothes washer UES workbook outlines that only clothes washers with tub volumes greater than 2.5 cubic feet are eligible for savings, so the Evaluators set savings to zero for two customers who installed 2.2 and 2.4 cubic foot washers. Washer configuration meanwhile was used to assign rated unit electricity consumption (RUEC) values which are used in the deemed savings formula below.

3.4.2 CLOTHES WASHER ANALYSIS METHODOLOGY

The following engineering algorithm was used to calculate clothes washer savings:

Equation 3-2. Clothes Washer Annual Savings Equation

$$Therms\ Savings = \frac{WHCF * LPY}{RLPY * n_{gasWH}} * 0.03412 * (RUEC_{conv} - RUEC_{ES})$$

Where:

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[31] https://www.cngc.com/energy-efficiency/residential-rebate-offerings/

- $WHCF$ = Water heating electricity consumption = 80%
- LPY = Loads per year = 295[32]
- $RLPY$ = Reference loads per year = 311[33]
- n_{gasWH} = Gas water heater efficiency = 75%[34]
- 0.03412 = Conversion factor, therms/kWh
- $RUEC_{conv}$ = Conventional rated unit electricity consumption (kWh/year) = 381 (top loading); 169 (front loading)
- $RUEC_{ES}$ = ES rated unit electricity consumption (kWh/year) = 230 (top loading); 127 (front loading)

This industry standard deemed savings equation for estimating annual clothes washer savings was sourced from page 167 and 168 of the Arkansas TRM version 9.1.[35] Unless otherwise noted, all values in Equation 3-2 are sourced from those pages of the TRM.

3.4.3 FINDINGS

The Evaluators found that 63 gas water heaters installed in 2022 were associated with 183 therms in verified savings, which equates to a 38.1% realization rate. A table containing these savings results is presented below.

Table 3-26. Clothes Washer Verified Savings by Year

Program Year	Installed Measures	Expected Savings (therms)	Verified Savings (therms)	Realization Rate
2022	63	479	183	38.1%
Total	**63**	**479**	**183**	**38.1%**

The CNGC Cost Effectiveness Excel workbook has a clothes washer savings estimate of 7.7 therms annually, which is equal to the savings for a front load gas washer with gas dryer per the RTF residential clothes washer UES measure workbook version 8.0. One issue with this savings estimation methodology is that 25 out of the 63 water heaters in the tracking data are top-load models, meaning applying 7.7 therms savings might not be the most accurate methodology. Furthermore, the CNGC tracking data ADM received does not contain any information on the type of dryer used by any customer. The RTF workbook outlines that customers with a gas washer and electric dryer save 5.3 therms annually instead of 7.7.

Ultimately, the Evaluators found that using Equation 3-2 yielded 5.21 and 1.45 annual therms savings for top-load and front-load models, respectively. Given that CNGC applied annual ex-ante savings of 7.7 therms savings to all clothes washers, the low 38.1% realization rate is not surprising. The Evaluators would suggest CNGC employ Equation 3-2 for future savings calculations, as it differentiates between top-load and front-load models and includes region-specific inputs from the RTF.

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32 https://rtf.nwcouncil.org/measure/clothes-washers-0/
33 https://rtf.nwcouncil.org/measure/clothes-washers-0/
34 https://rtf.nwcouncil.org/measure/clothes-washers-0/
35 https://apsc.arkansas.gov/wp-content/uploads/AR_TRM_V9.1_Volume_1_2_and_3_on_8-31-22.pdf

3.4.4 CONCLUSIONS AND RECOMMENDATIONS

The Evaluators provide overall conclusions and recommendations for clothes washer measures below.

Table 3-27. Clothes Washer Recommendations

Equipment	Recommendations
Clothes Washers	1. Utilize a database structure that limits each address/premise ID to only one square footage value and each measure installation to only one model number and brand name. This could help identify and address duplicate measures. 2. Include clothes washer quantity, tub volume, and configuration as well as clothes dryer type (if possible) in tracking data to facilitate savings calculations. 3. Consider employing a deemed savings equation, as outlined in Equation 3-2, to calculate annual clothes washer savings. Such deemed savings equations will help differentiate savings between top-load and front-load washers.

4 APPENDIX A: REGIONAL TECHNICAL FORUM HEATING ZONE MAP

Figure 4-1. RTF Washington State Heating Zone Map