Baseline or Bust: Calculating Savings for a Residential Heating Equipment Program

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ABSTRACT

Evaluators have struggled with developing a solid and defensible method to estimate savings for gas heating equipment in residential equipment replacement programs. On-site measurement of the baseline equipment is not feasible, as the standard efficiency system was not actually installed. Since these programs typically rely on rebates rather than detailed audits, program implementers frequently use deemed values to estimate savings. In the New York State program discussed in this paper, the program savings were calculated using full load hours developed from simulation modeling.

In this paper, we present an approach to establishing the equipment replacement baseline develop for the statewide impact evaluation of the Residential High Efficiency Heating Equipment (HEHE) program in New York State. The evaluation team conducted a billing analysis using the post installation period to estimate the full load hours of the heating equipment. The full load hours are a function of the output capacity and heating efficiency of the heating plant (from the program tracking data) and the annual heating consumption (from the billing records).

This approach has two major advantages: savings reflect actual residential energy consumption patterns and they are correctly based on post-only operating conditions. The pre/post billing analysis provided a reference point to assess the direct impacts of the program in relation to the pre-installation consumption levels. The information from this study may also be used to update the average full load hours for heating system measures in the New York State Technical Manual (NYTM) and improve the estimation of savings going forward.

Introduction

The baseline assumptions used to estimate savings for efficiency measures have two components: 1) the efficiency of the baseline equipment and 2) the operating conditions. Both components are equally important to the calculation of savings and are dependent on the type of measure, i.e., retrofit, equipment replacement or new construction. While these terms may be used differently from jurisdiction to jurisdiction, for the purposes of this paper, these terms are described below:

- Retrofit measure: replacement of existing inefficient equipment in current operation with new, efficiency equipment to be used under the same conditions, primarily for the purposes of savings energy
- Equipment replacement: purchase of new, efficient equipment to replace equipment that has failed or to address new operating conditions

For retrofit measures, the baseline is the existing equipment prior to the installation, sometimes adjusted to energy code, federal standards or standard practice at the time that the existing equipment is expected to be replaced (dual baseline). For equipment replacement measures, the baseline is the equivalent "standard efficiency" equipment, typically defined by state energy code, federal standards or, less often, standard practice. Thus, the baseline is a theoretical construct based on equipment that was never actually installed.

Operating conditions are the other key part of the equation. For retrofit measures, the pre-installation operating conditions are used to estimate savings with the assumption that the pre- and post-installation periods are reasonably consistent. In contrast, equipment replacement savings are the difference between the baseline and efficient equipment operating under the same operating conditions. Thus, the conditions in the post installation period should be the basis for establishing savings.

Establishing the baseline operating condition is problematic from a number of different perspectives:

- Although specific equipment that meets the baseline criteria can be identified, it cannot be directly measured on site as it was never installed.
- A pre/post billing analysis incorporates the pre-installation operating conditions, which may introduce impacts of behavioral changes or other factors that are not directly relevant to the equipment replacement savings.
- Theoretical calculations that are not calibrated to actual consumption patterns tend to overstate actual savings.
- A representative, nonparticipant comparison group is difficult to define as there is often no easy way to identify homeowners who installed new equipment without the program and the comparison group would need to be quite large as wide variations in house-to-house energy consumption make it difficult to isolate the savings.

These issues highlight the tension between two conflicting aspects of estimating the savings: 1) since the baseline is a theoretical construct, savings are typically estimated using modelling, but 2) experience with residential billing analysis demonstrates that actual energy consumption is often less than modeled. In addition, wide variations in house-to-house energy consumption make it difficult to separate energy savings from the noise and suggest that large sample sizes are needed.

This conundrum has left impact evaluators with few options: estimating savings from a pre/post billing model, attempting to identify a representation nonparticipant comparison group where possible, or relying on deemed savings. To address these issues, we developed a hybrid approach that uses accepted engineering equations and inputs and incorporates actual residential heating consumption. Billing records were combined with program tracking data and assumed baseline efficiency to estimate full load hours. Savings were then calculated using standard engineering algorithms. Use of the post installation billing records ensured that the savings were calibrated to post period operating conditions.

This approach was applied in a recent impact evaluation of the statewide High Efficiency Heating Equipment program implemented by seven utilities in New York State. For comparison purposes, the team also conducted a full pre/post billing analysis. In addition, further analyses were conducted to investigate the strength of the relationship between the heating degree days and annual heating consumption and the implications for the full load hours by weather zone.

The following sections cover the background and context, approach, results and conclusions.

Background and Context

In 2009, the New York State Public Service Commission (PSC) approved Residential Gas HVAC (Gas High-Efficiency Heating) programs for implementation between 2009 and 2011.[1] These high efficiency heating equipment (HEHE) Programs are open to all residential customers and are

[1] Some of these programs were authorized prior to 2009.

funded by those customers' System Benefit Charges (SBC). The programs promote the purchase and installation of energy-efficient heating and water heating equipment, including natural gas furnaces, boilers, indirect water heaters, and related add-on measures such as programmable thermostats, boiler reset controls, and air sealing. Rebates are available to qualifying customers for the purchase of qualifying high-efficiency equipment.

Seven natural gas utilities implemented HEHE programs during this period and were included in this statewide evaluation.[2] Qualifying equipment is largely the same across utilities. Through a competitive bid process, Opinion Dynamics was selected to carry out a statewide impact evaluation. The evaluation team also included West Hill Energy & Computing and Analytical Evaluation Consultants.[3] The time period evaluated covers all projects installed in 2009 to 2011.

This paper focuses on the impact evaluation of the efficient furnaces and boilers, which account for about three quarters of the total program savings. The utilities claim deemed savings based on the geographic region as defined in the New York Technical Manual. Table 1: Minimum Qualifying Heating System EfficiencyTable 1 below shows a summary of program-qualifying efficiency levels by heating system type.

Table 1: Minimum Qualifying Heating System Efficiency

Measure	Program Requirement	Federal Standard
ECM Furnace	0.92	0.78
Furnace	0.90	0.78
Water Boiler	0.85	0.80
Steam Boiler	0.82	0.75
* One utility had a minimum qualifying efficiency of 0.90 for ECM furnaces and 0.81 for steam boilers.		

Initially, the evaluators intended to use contractor surveys to estimate a market-based estimate of standard efficiency equipment. While the evaluation design was changed and this component was dropped, the net-to-gross component was designed to adjust savings to account for those who would have installed a higher efficiency heating plant without the rebate.

Two other impact evaluations of HEHE programs in the Northeast have been conducted in the last several years:

- Massachusetts HEHE by NMR and Cadmus in 2010 (Mass)
- New York State Electric and Gas (NYSEG) by DNV KEMA in 2013

Both of these other studies covered the measures listed in Table 1. For comparison purposes, we reviewed the methods and results from these studies.

Approach

Our approach is different from other studies in that we adjusted the inputs into the standard engineering algorithm for estimating the savings to reflect actual residential consumption patterns. The key inputs to calculate deemed savings are the full load hours, the capacity of the new heating system, the efficiency of the new system and the efficiency of the standard efficiency baseline system. These inputs came from the following sources:

- Full load hours (FLH) were estimated from the post-installation billing records.

[2] The seven utilities were Consolidated Edison, National Grid, National Fuel, Orange and Rockland, Central Hudson Gas and Electric, Corning and Enbridge.

[3] Analytical Evaluation Consultants was formerly known as Megdal and Associates.

- The capacity and efficiency of the new system were available in the program data.
- The standard efficiency equipment was assumed to meet the federal standards.[4]

By using the post-installation billing records to estimate the FLH, the actual residential consumption patterns were incorporated into the analysis without relying on a pre/post billing model as the primary method of estimating savings. In addition, this approach correctly bases the savings on the post-installation operating conditions.

For comparison purposes, the study also included a pre/post billing analysis using a fixed-effects regression model to estimate retrofit savings for comparison purposes. In addition, the evaluators performed an analysis of the heating degree days and energy consumption by geographic region to validate the full load hours. This multi-pronged approach provided internal cross-checking and robust estimation of savings. The evaluation approach is explained graphically in

Figure **1**. The next sections describe the data and data sources, followed by methods, results and conclusions.

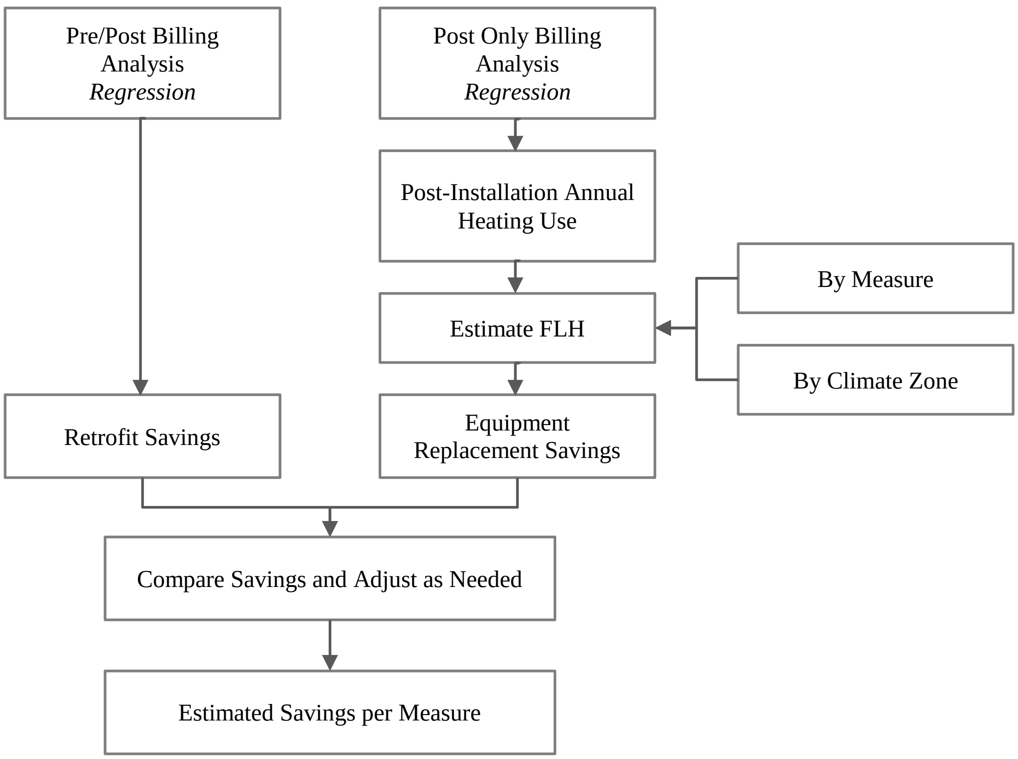

Figure 1**:** Evaluation Approach

Data and Data Sources

Three major sources of data were combined for use in the billing analyses: program data on measures installed, consumption history from the utilities, and weather data from the National Oceanic and Atmospheric Administration. After the combining and cleaning the data, we included 44% of all participants with a heating system installation in the final analysis. The weather data was selected from the station that was geographically closest to each participant's home, from among 32 weather stations in New York and surrounding states. To model the relationship between weather

[4] Use of the federal standards as the baseline is clearly not an ideal choice, but it was the only viable option for this evaluation. The net-to-gross component was carefully designed to use this baseline as the comparison.

and natural gas use for each home, we calculated the heating degree days (HDD) for each billing cycle for each home using actual weather data from the nearest weather station and a base temperature of 65°F.

Estimation of Equipment Replacement Savings

The following equation gives the standard engineering algorithm for estimating the savings for replacing the heating plant, as used in the New York Technical Manual (NYTM) and elsewhere.

Equation 1: $$Savings = FLH \; x \; Capacity_{new} \; x \; \frac{\eta_{efficient} - \eta_{baseline}}{\eta_{baseline}}$$

where

$Capacity_{new}$ = the input capacity of the high-efficiency (HE) heating system

FLH = full load hours

$\eta_{baseline}$ = the AFUE of the baseline equipment
$\eta_{efficient}$ = the AFUE of the new equipment

The program savings and evaluated savings were calculated using the inputs as shown in Table 2.

Table 2: Source of Inputs into Savings Calculations

Input	Source	
	Program Reported Savings	Evaluated Savings
Capacity	Program Records*	
Baseline Efficiency	Federal Standards**	
New Efficiency	Program Records	
Full Load Hours	NYTM	Billing Analysis

* One utility did not record this information in their program tracking database in some of its service territory and used average values instead.

**Primary research into market based baseline efficiency was beyond the scope of this evaluation, and the minimum federal code-compliant efficiency was used as the best available baseline. The net-to-gross component of the study reflected the likelihood that some participants would have installed more efficient heating plants even without program incentives.

Savings are the difference in natural gas consumption between the installed heating system and a baseline efficiency heating system of the same type, assuming both were operating under the same conditions. The FLH were calculated as follows.

Equation 2: $$FLH = \frac{Annual\ Heating\ Use_{Post}\ (Btu)}{Input\ Capacity\ \left(\frac{Btu}{hr}\right)}$$

where

Annual Heating Use_{post} = the annual Btu used for heating the home, estimated from the post-installation billing data

Input Capacity = the AFUE of the new heating system from program tracking data

As can be seen in the equation above, the annual natural gas consumption during the post-installation period is a key input for estimating equipment savings. To calculate annual heating consumption for each home, we conducted separate linear regression models for each home, using only post-installation billing data. We tested models with and without intercepts (reflecting therms of base use) for each home, and selected the model that fit each home the best. The primary output from this analysis was the heating slope (therms/HDD). Normalized heating use was estimated by multiplying the heating slope by the 10-year average annual HDD.

The analysis included all participants with natural gas primary or secondary space heat fuel (R^2 of 0.3 or greater) as the basis for analysis. In general, homes identified as having primary natural gas space heat (R^2 over 0.70) had higher annual heating use than homes with lower R^2 values, providing empirical support for this method. About 94% of the homes had heating consumption patterns consistent with natural gas primary space heat. To reflect the distribution of homes with each type of space heat, we calculated a weighted average between the two groups for each climate zone.

We recognize that billing data is a proxy for our variable of interest, i.e., the annual heating load. However, billing records incorporate non-program factors that are not germane to our analysis, such as behavioral changes and changes in occupancy. In addition, separating space heating consumption from base (water heating) use is not an exact science.[5] While billing analysis is an imperfect tool and introduces some degree of measurement error, it is still the best method for ensuring that our savings estimates are grounded in the reality of residential consumption patterns. Due to the volume of activity in the HEHE programs, we were able to develop large models with thousands of homes, which reduce the impacts of non-program effects and improves the reliability of the results.

Estimation of Retrofit Savings

Retrofit savings were estimated to validate the FLH model approach. Assuming that participants are replacing older equipment that is less efficient than the federal standard, the retrofit savings would be expected to provide an upper limit for the evaluated equipment replacement savings. However, prior to the recent change, the federal minimum standards had been in place for many years and it is possible that the existing heating plants were more recent installations and were more efficient than the federal standard.

The evaluation team applied a generalized linear, fixed effects model to the billing data, and tested multiple specifications of this model. The model included weather effects and dummy variables for the installed measures as the predictor variables and the resulting coefficients reflect the savings for the measures. The monthly consumption in therms was the response variable.

Climate Effects by Weather Station

In the analysis above, the FLH were averaged by type of heating system installed and then by

[5] We understand that there are many approaches to estimating space heating consumption from billing records. This paper is focused on the use of full load hours to estimate savings and is not intended to provide a comprehensive discussion on approaches to selecting the base temperature for heating degree days or other aspects of estimating the space heating use.

climate zone. For comparison purposes, an alternative approach was explored to estimate average FLH values at the weather station level, allowing the team to assess the impact of climate on the energy consumption patterns. Households were binned by climate from the weather station data, and the average heating slope was calculated over all homes in the climate bin. Having carried out this analysis, the team concluded there was too much variability in heating slopes to reasonably estimate total program savings by applying an average heating slope to all homes. Nonetheless, this analysis provided some interesting insights into differing residential heating use, as explained in the results section.

Comparison of Approach to Other Studies

Evaluators have different perspectives and may tackle the same problem using a variety of strategies. Thus, looking at impact evaluation reports for similar programs can provide context and help to assess when and where specific methods are more applicable. In evaluation planning, key factors are the available information, cost of acquiring additional information and budget. Table 3 compares the NY statewide evaluation to two other recent evaluations of similar programs conducted for NYSEG and Massachusetts, with a discussion below.

Table 3: Comparison of HEHE Impact Evaluation Approaches

		NY Statewide HEHE	NYSEG HEHE	Mass HEHE
Program data	Existing	None	AFUE or model number for most homes	None
	Efficient	Input capacity, efficiency (AFUE) by home for most utilities	AFUE or model number for most homes	Model numbers
Primary data collection		Contractor and homeowner net-to-gross surveys	Contractor and homeowner net-to-gross surveys	Contractor and homeowner surveys, including behavioral questions
Equipment replacement savings estimation approach		FLH from post model	Adjusted pre/post savings	Averaged 5 models, excludes post only model
Standard Efficiency		Federal standard	Federal standard (NYTM)	Unknown, close to federal standard, reference to "code"
Models		Post only as primary/ pre-post for validation	Pre/post only	5 pre/post models; 1 post only
Modeled FLH		Yes	Yes	No
Nonparticipants		No	No	Yes (oil-to-gas conversions)

Both the NYSEG and Massachusetts studies relied on pre/post billing as the primary method of estimating savings. However, pre/post analysis introduces the possibility of incorporating behavioral or other non-program changes into the results. As these are equipment replacement measures, the analysis should reflect the post installation usage patterns. The inclusion of multiple pre/post models does not mitigate this issue.

In the Massachusetts study, there was access to billing records for homeowners who purchased new natural gas heating equipment when converting from oil to natural gas but did not receive a rebate through the program.[6] This group could be a valuable source of information about efficiency of the new equipment and energy related choices made by nonparticipants. A potential downside is that the direct inclusion of nonparticipants in the billing analysis could possibly introduce net effects into the analysis: the results are likely to be somewhere between net and gross impacts.[7]

Results

The results of the hybrid analysis undertaken for the NY combined utilities evaluation indicate that the FLH approach is workable and provides reasonable and robust results. Table 4 below presents the FLH estimates by climate zone. For most climate zones, there were over 500 homes in the model. The relative precision is less than 10% for all climate zones and less than 5% for all except one, suggesting that the variability is relatively low for this type of analysis.

Table 4: Evaluated Full Load Hours by Climate Zone

Climate Zone	Number of Homes	Annual FLH	Standard Error	Lower Confidence Limit*	Upper Confidence Limit*	Relative Precision*
Albany	1,619	978	9.0	964	993	2%
Binghamton	239	1,136	30.6	1,085	1,186	4%
Buffalo	16,319	1,032	3.0	1,027	1,037	0%
Massena	266	889	21.7	853	925	4%
NYC	2,513	786	7.2	774	797	2%
O&R	815	879	13.7	856	901	3%
Poughkeepsie	245	804	27.5	759	850	6%
Syracuse	1,558	1,042	9.6	1,026	1,058	2%
* Confidence intervals and precision are reported at the 90% confidence level.						

Table 5 shows the FLH by type of heating system. The FLH for the ECM furnaces and furnaces without ECM are not statistically different. The boilers have lower FLH than the furnaces. Boilers were primarily installed in the NYC area which has a milder climate than more northern parts of the state.

Table 5: Evaluated Full Load Hours by Heating System Type

Climate Zone	Number of Homes	Annual FLH	Standard Error	Lower Confidence Limit*	Upper Confidence Limit*	Relative Precision*
ECM Furnace	7,683	1,016	19.2	984	1,048	3%
Furnace	11,783	1,041	14.5	1,017	1,065	2%
Steam Boiler	917	822	45.4	748	897	9%

[6] This option was considered for the NY combined utilities evaluation, but there were too few homes with oil-to-gas conversions.
[7] TecMarket Works. 2004 California Evaluation Framework, prepared for the California Public Utilities Commission and the Project Advisory Group, September 2004, page 143.

Water Boiler	3,191	946	28.5	899	993	5%
* Confidence intervals and precision are reported at the 90% confidence level.						

Table 6 shows the comparison of the evaluated FLH estimates with the FLH assumptions in the NYTM. This analysis indicates that the FLH values from the billing analysis range from 16% to 41% lower. The climate zone with the greatest variation is Massena. The reasons for such a large difference are not clear.

Table 6: Comparison of Evaluated and NYTM FLH

NYTM Climate Zone	Normalized Annual Heating Degree-Days [a]	Number of Homes	Evaluated FLH	NYTM Assumption for Average Single-Family Home [b]	
				FLH	Evaluated FLH % Difference
NYC	4,961	2,513	786	934	-16%
Poughkeepsie	5,501	1,060	862	1,157	-26%
Buffalo	6,502	16,319	1,032	1,473	-30%
Albany	6,580	1,619	978	1,379	-29%
Syracuse	6,636	1,558	1,042	1,391	-25%
Binghamton	6,797	239	1,136	1,450	-22%
Massena	7,718	266	889	1,496	-41%
Statewide Average [c]	6,324	23,574	995	1,389	-28%

[a] Normalized HDD are weighted to reflect the location of participants in the FLH analysis.
[b] The NYTM allows administrators to select among multiple FLH values for each climate zone. These values are differentiated by single-family/multifamily and home vintage (old, average, or new)
[c] Averages are weighted by the number of participants in FLH analysis

There are a number of reasons for the differences between the NYTM and evaluated FLH. The NYTM values are based on modeling using a DOE-2.2 simulation of prototypical residential buildings, assuming natural gas was the only heating source, and that energy use was entirely linear with heating degree-days. The linear approach does not account for behavioral effects, such as using lower set points or minimizing heating use during the relatively warmer shoulder periods. In addition, our modeling showed that about 5% of homes exhibited heating consumption patterns that were consistent with having a secondary heating source.

Pre/Post Billing Analysis

The results from the pre/post billing model provide an estimate of the retrofit savings, which would be expected to result in higher savings than the FLH approach if the existing heating equipment was less efficient than the federal standards. A brief summary of the pre/post model findings for heating systems is provided below.

- High-Efficiency Furnaces: The pre/post analysis shows savings that are quite close to the estimated savings using the FLH approach.
- High-Efficiency Furnaces with ECM: The estimated pre/post savings for ECM furnaces are lower than the FLH analysis; this result may indicate that the existing furnaces prior to replacement were of a higher efficiency than the current federal standards.
- Water Boilers: The pre/post model shows substantially higher savings than the FLH

approach, possibly indicating that the efficiency of the existing equipment prior to the installation was much lower than the current federal standards. As older boilers tend to have a longer measure life than many of the newer ones, it is possible that some very old and low-efficiency equipment was removed.

- Steam Boilers: The model showed modest savings for homes that showed primary natural gas heating during the pre-installation period. There are also relatively few steam boiler installations, and they are largely clustered around the NYC area.

Table 7: Comparison of Savings from Post-Installation FHL and Pre/Post Billing Methods

Measure	Number of Homes in Model	Program-Reported Savings per Home (therms)	Pre/Post Modeled Savings per Home (therms)	FLH Modeled Savings per Home (therms)[a]
ECM Furnace	14,376	240	100 ± 3	143 ± 4
Furnace	15,529	199	129 ± 3	117 ± 3
Water Boiler	3,934	203	160 ± 4	107 ± 5
Steam Boiler - Primary Space Heat Only	781	139	53 ± 7	113 ± 7

a These values are the evaluated savings per measure category among all participants in the pre/post billing model to make a completely equivalent comparison.

Climate Effects by Weather Station

In this analysis, the heating slopes from the individual household regressions were averaged by weather station. The evaluators expected that the heating slope would remain relatively constant, i.e., the energy use would be reasonably linear with temperature. As shown in

Figure **2**, this relationship holds for the colder climates (on the right) where the line representing the relationship between the heating slope and the temperature is relatively flat. However, the warmer climates (on the left) show an inverse relationship between the heating slope and annual HDD, i.e., higher heating slopes at the warmer temperatures (lower annual HDD) than at the colder temperatures. The break between the two trends is around 5,000 annual HDD.

This somewhat counterintuitive result suggests either that homes in the colder climates are substantially more efficient than homes in the warmer areas and/or that usage patterns differ between the two regions. In this case, the warmer weather stations are in the south eastern part of the state, around New York City. This suggests two possible explanations: differences in housing stock related to the relative affluence of the NYC environs or differences in usage patterns, with the NYC residents perhaps less concerned with taking actions to minimize heating costs.

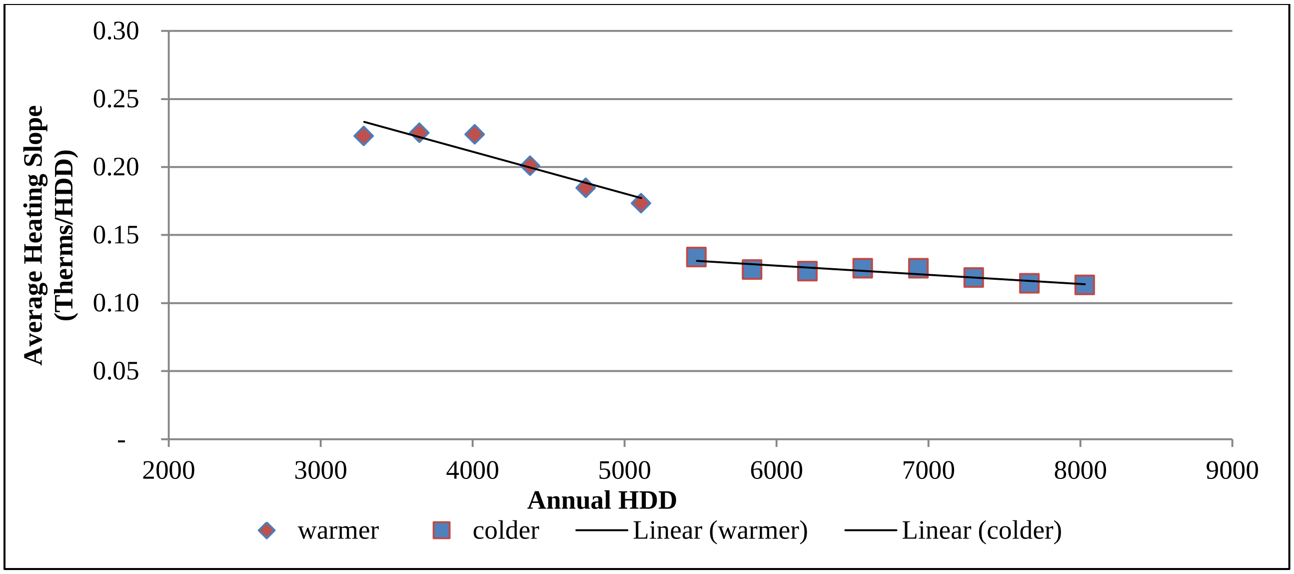

Figure 2: Heating Slope by Weather Station

Comparison of Results to Other HEHE Evaluations

The evaluation results from the three HEHE evaluations are compared in Table 8 below. In spite of the differences in approach, the evaluated savings are reasonably close. For all three programs, it appears that the deemed savings substantially overstated actual impacts.

Table 8: Comparison of Program Reported and Evaluated Savings by Program

<table>
<tr><th rowspan="2">Measure</th><th colspan="2">NY Statewide HEHE</th><th colspan="2">NYSEG/RG&E HEHE</th><th colspan="2">Mass HEHE</th></tr>
<tr><th>Average Program Reported (Therms/ year)</th><th>Average Evaluated (Therms/ year)</th><th>Full TRM Savings (Therms/ year)</th><th>Average Evaluated (Therms/ year)</th><th>Deemed Savings (Therms/ year)</th><th>Average Evaluated (Therms/ year)</th></tr>
<tr><td>Furnaces with ECM</td><td>238</td><td>147</td><td>284</td><td>131</td><td>211</td><td>118</td></tr>
<tr><td>Furnaces without ECM</td><td>198</td><td>119</td><td>246</td><td>128</td><td>196</td><td>127</td></tr>
<tr><td>Water Boilers</td><td>177</td><td>116</td><td rowspan="2">356</td><td rowspan="2">156</td><td>115</td><td>104</td></tr>
<tr><td>Steam Boilers</td><td>134</td><td>93</td><td>123</td><td>109</td></tr>
</table>

Conclusion

The hybrid approach described above provides a reliable estimate of natural gas heating equipment replacement savings by comparing the installed efficient equipment to baseline equipment operating under the post installation operating conditions. In general, equipment replacement savings should be lower than the savings from a pre/post billing analysis, as we would expect older, existing heating equipment to be less efficient than the current federal standard. As equipment replacement savings should be based on comparing the new equipment to a theoretical installation of standard efficiency equipment, relying on the post installation conditions offers the best approach for estimating savings.

The three recent HEHE impact evaluations have taken somewhat different approaches, with two of the studies based on pre/post analyses in contrast to the post only approach used in the NY statewide study. Regardless of the different strategies, the results from the three HEHE impact evaluations are reasonably close for furnaces, which make up the bulk of the purchases, and the Massachusetts and NY statewide evaluations also have similar evaluated savings for boilers. In addition, both the statewide NY and Massachusetts studies conducted both types of analysis and found variability in the results, with some measures having higher savings from the pre/post and others from the post only analyses.

While the conceptual distinction between equipment replacement and retrofit measures is clear and evaluators have gone to great pains to develop evaluation approaches to address the specific concerns, comparing the results from the three HEHE evaluations suggests that the methods yield similar results, at least for these particular measures at this point in time. In theory, absent modeling error, the retrofit and equipment replacement savings will only be different if the efficiency of the baseline equipment is different. The similar results from the different studies suggest that the efficiency of existing heating equipment being replaced may be, on average, relatively close to the federal standard, thus blurring the lines between retrofit and equipment replacement savings.

Regardless of the similarity in the study results, the post only FLH method has some positive features. It seems likely that these types of programs will continue to rely on engineering algorithms with stipulated inputs or deemed savings. The post only FLH approach provides the ability to update the inputs and improve savings estimates on a prospective basis. In addition, the data requirements are lower as only post installation billing records are required. Future research should be directed to developing a more complete understanding of the installation of standard efficiency heating equipment and improving the characterization of the baseline.

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