the Energy to Lead

gti

GTI-15/0003

TASK REPORT

GTI PROJECT NUMBERS 21853, 21693, and 21754

Technical Analysis of Furnace Sizing for the DOE Notice of Data Availability on Residential Furnace Minimum Efficiencies

Reporting Period:
August 2015 through October 2015

Report Issued:
October 14, 2015

Prepared For:
American Public Gas Association
American Gas Association

GTI Technical Contact:
Neil Leslie
R&D Director
Building Energy Efficiency
847-768-0926
Fax: 847-768-0501
neil.leslie@gastechnology.org

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines, Illinois 60018
www.gastechnology.org

Disclaimer

This information was prepared by Gas Technology Institute ("GTI") for the American Gas Association (AGA) and the American Public Gas Association (APGA).

Neither GTI, the members of GTI, AGA, APGA, nor any person acting on behalf of any of them:

a. Makes any warranty or representation, express or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report. Inasmuch as this project is experimental in nature, the technical information, results, or conclusions cannot be predicted. Conclusions and analysis of results by GTI represent GTI's opinion based on inferences from measurements and empirical relationships, which inferences and assumptions are not infallible, and with respect to which competent specialists may differ.

b. Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this report; any other use of, or reliance on, this report by any third party is at the third party's sole risk.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

This report attempted to examine DOE's Notice of Data Availability (NODA) furnace sizing methodology and the impact of furnace size on lifecycle cost (LCC) savings for impacted consumers at the national level. Due to limited explanatory information in the NODA LCC model and no technical support document accompanying the NODA, the American Gas Association (AGA) and American Public Gas Association (APGA) submitted NODA-related questions and a request for an extension of the comment period on the NODA to DOE on September 15, 2015. DOE did not provide answers to those questions nor did it extend the comment period, both of which limited the opportunity to conduct scenario analyses of NODA algorithms and assumptions. As a result, lifecycle cost (LCC) savings for consumers impacted by separate standards for large and small furnaces were not able to be determined in this report.

The DOE NODA does not effectively address the methodology issues and shortcomings identified in GTI-15/0002 that resulted in overstated national benefits in the March 2015 Notice of Proposed Rulemaking (NOPR). With this caveat, it is noteworthy that, independent of the furnace-size exemption issue, the DOE NODA analysis shows a significant reduction in average benefits for all trial standard levels (TSLs) compared to the original DOE NOPR analysis, as shown in Table 1.

For the first time in the NODA, DOE used a new segmentation grouping of "impacted furnaces" in the LCC savings calculations. Table 1 shows LCC results used in the NODA (for impacted furnaces) as well as in the NOPR (for all furnaces).

As shown in Table 1, GTI's analysis of the NOPR and NODA shows negative average savings for all single standard TSLs (compared to DOE's findings of positive savings). The single standard results in the NODA do not appreciably alter the overall negative average savings findings in the GTI analysis of the NOPR.

Table 1 National Average LCC Savings for DOE NOPR and NODA LCC Models

TSL (% AFUE)	DOE NOPR Analysis	GTI NOPR Analysis	DOE NODA Analysis	GTI NODA Analysis
	NODA (Impacted Furnaces Only)			
90	$441	-$571	$347	-$592
92	$520	-$417	$425	-$442
95	$507	-$631	$420	-$651
98	$443	-$458	$343	-$475
	NOPR (All Furnaces)			
90	$236	-$215	$163	-$225
92	$305	-$181	$225	-$190
95	$388	-$445	$311	-$462
98	$441	-$447	$341	-$466

In summary, the NODA LCC model did not address the technically flawed random Base Case furnace AFUE assignment methodology, and also includes technically flawed furnace sizing algorithms. Based on the additional scenario analyses summarized in this report, there is no economic justification for the single standard described in the NODA. Due to the lack of requested information from DOE, no comparable LCC analysis for a separate standard level for large and small furnaces could be performed in the time DOE allotted for comments. Further, the RECS database information used by DOE in both the NOPR and NODA does not contain either heating load or furnace capacity information and is inadequate to address the furnace AFUE for existing buildings, existing building loads, or existing building furnace capacities.

1 Background

The U.S. Department of Energy (DOE) issued a notice of data availability (NODA), published in the Federal Register on September 14, 2015, containing a provisional analysis of the potential economic impacts and energy savings that could result from promulgating amended energy conservation standards for residential non-weatherized gas furnaces (NWGFs) that include two product classes defined by input capacity. The NODA does not consider mobile home gas furnaces. In the NODA, DOE outlines a potential alternative furnace efficiency standard that would differentiate between larger furnaces (which would be subject to more stringent minimum efficiency levels) and smaller furnaces (which would be subject to existing minimum efficiency requirements). The NODA analysis estimated impacts for several potential standard level combinations for condensing furnaces and various maximum sizes for non-condensing furnaces.

This task report is a follow-up to GTI-15/0002, "Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies." The prior GTI-15/0002 report included a comprehensive technical and economic analysis of the original March 2015 NOPR proposal to promulgate a minimum national furnace efficiency of 92% AFUE. The GTI-15/0002 report pointed to significant deficiencies in the NOPR LCC analysis, including:

- A flawed random furnace assignment methodology which deviated from a rational economic decision framework,
- A flawed fuel switching analysis methodology, and
- Use of outdated and lower quality input data.

Addressing these deficiencies and shortcomings, GTI's scenario analyses showed the proposed standard, instead of yielding positive national benefits, would instead result in: 1) negative average lifecycle cost savings and 2) increased primary energy consumption and greenhouse gas emissions (from fuel switching from natural gas to electric options that are less efficient on a primary energy basis). Table 2 provides a recap of the comparison of the NOPR and GTI scenario analysis findings, underscoring the average negative costs, higher proportion of consumers faced with a net cost (27% of the population), and reduced level of consumers who would experience a net benefit (only 17% of the population).

Table 2: Lifecycle Cost and Rulemaking Market Impact

LCC Model	Average Furnace Life-cycle Cost (LCC) Savings	Fraction of Furnace Population (%)		
		Net Cost	No Impact	Net Benefit
DOE NOPR LCC Model	$305	20%	41%	39%
GTI Integrated Scenario Int-5	-$181	27%	57%	17%

2 Furnace Sizing Analysis Methodology

2.1 AGA/APGA Data Request to DOE

Due to limited explanatory information in the NODA LCC model and no technical support document accompanying the NODA, the American Gas Association (AGA) and American Public Gas Association (APGA) submitted NODA-related questions and a request for an extension of the comment period on the NODA to DOE on September 15, 2015. DOE did not provide answers to those questions, nor did it extend the comment period, both of which limited the opportunity to conduct scenario analyses of NODA algorithms and assumptions. As a result, lifecycle cost (LCC) savings for consumers impacted by separate standards for large and small furnaces were not able to be determined in this report. The data requests are summarized below.

2.1.1 NODA LCC Spreadsheet Data Request

The AGA/APGA September 15, 2015, data request sought the following information related to the NODA LCC spreadsheet:

1) An updated version of input spreadsheet “rf_nopr_analysis_inputs_2014-02-06.xlsm” that was released with the NOPR LCC spreadsheet. The input spreadsheet contains key information on the LCC calculations and methodology for:
   - contractor markups
   - implementation of the new AHRI shipment data
   - implementation of the new AEO forecast
   - implementation of the new EIA pricing data
   - implementation of updated NWGF input capacity percentiles
2) Supporting data and detailed descriptions of changes in building shell efficiency calculations in the NODA LCC spreadsheet as mentioned on page 16 of “Res Furnace_NODA_2015-09-04.pdf.” This is currently referenced in general terms as “described in the LCC spreadsheet.”
3) Supporting data and detailed descriptions of changes in climate indices used to adjust energy use as mentioned on page 16 of “Res Furnace_NODA_2015-09-04.pdf.” This is currently referenced in general terms as “described in the LCC spreadsheet.”
4) Supporting data and detailed descriptions of the “updated engineering analysis” that is referenced in the “NODA Analysis Update” sheet under the “Prod Price” changes.
5) Clarification as to whether or not changes have been made to the “NWGF Switching” sheet that was omitted from the descriptions of changes in the “NODA Analysis Updates” Sheet of the NODA LCC spreadsheet.

2.1.2 Technical Support Documentation

Information requested in this section of the AGA/APGA data request focuses on descriptions typically included in a DOE technical support document that are needed for a reasonable understanding of changes included in the NODA LCC spreadsheet.

1) Describe the “bug” in the “AFUE Existing” assignment and what was done to correct the bug, with references to specific locations in the NODA LCC spreadsheet.
2) Describe the methodology and rationale for choosing 1.3 vs. 1.7 oversizing factors in the “Furnace & AC Sizing” Sheet of the NODA LCC spreadsheet.

3) Describe the methodology used to arrive at the Net Cost percentages included in Tables III.2 and III.3 of "Res Furnace_NODA_2015-09-04.pdf."
4) Describe the methodology/logic of implementing dual standard scenario, and downsizing options.
5) The NODA LCC spreadsheet provides a dropdown box (see cell D23 in the Summary tab of the LCC spreadsheet) that provides options for various Standard Scenarios. The options in the dropdown box include Dual Standard selections for input capacities for small furnaces with thresholds of less than or equal to 70, 75, 80, 85 and 90 kBtus/hr. However, the tables included in the NODA do not include the LCC or the NIA spreadsheet results for these scenarios. Please provide the LCC and NIA spreadsheet results for each of these scenarios in a similar fashion that the other scenario results were presented in the NODA.

2.2 DOE NODA Sizing Methodology

DOE describes its methodology for furnace sizing beginning on page 7B-18 of the NOPR Technical Support Document (TSD). The steps DOE took to assign furnace size in the NODA LCC model appear to be the same as in the NOPR LCC model described in the NOPR TSD as follows:

1) The Department ranked all the RECS housing units in ascending order by size (heating square foot) multiplied by a scaling factor to account for the outdoor design temperature and calculated the percentile rank of each housing unit using the statistical weight of each of the sample records. The scaling factor is given by: $SF_{design,h} = (65 - T_{design,\,h}) / (65 - 42)$, where $SF_{design,h}$ = heating design scaling factor, and

$T_{design,\,h}$ = average 1 percent ASHRAE design dry bulb temperature (°F) for heating.

2) The Department constructed percentile tables by input capacity of furnaces based on the historical shipment information and number of models in AHRI Directory (TSD Table 7B.2.13).

3) After selecting a housing unit from the Residential Energy Consumption Survey (RECS) database during each Monte Carlo iteration, DOE noted the size of the selected housing unit and determined the percentile rank from Step 1.

4) To avoid a one-to-one deterministic relation between the housing unit size and input capacity, DOE added a random term to the percentile identified in Step 3 so that the correlation was not perfect. The Department used a normal distribution to characterize the random term. The random term has a mean of zero and a standard deviation of 8 percent.

5) Using the percentile from Step 4, DOE looked up the input capacity from the input capacity percentile table in Step 2.

In the procedure for furnace sizing described in the NOPR TSD, the distribution of furnace input capacity used in Step 2 was used to split the 10 kBtu/hr size bins based on AHRI shipment numbers for the year 2000 in each size bin. As indicated in footnote 6 of the NODA (80 Fed. Reg. 55041), furnaces were binned into 5 kBtu/hr size bins for the NODA analysis. GTI was unable to find any location in the NODA LCC model where the random term described in Step 4 is either generated or used.

Consistent with the steps above, DOE also does not appear to consider the size of an AC system when determining furnace size. Correct furnace fan sizing is important to ensure that the furnace/AC system will provide adequate space conditioning during summer cooling periods in conventional forced air systems with an evaporator coil located adjacent to the furnace. This issue is especially important in warmer climates dominated by cooling demand. Furnace capacity in those cases will not be based on the peak heating load, but on the furnace fan capacity linked to the AC system capacity. As a result, the furnace capacity will often be oversized to maintain adequate delivered air temperature in heating mode based on the fan output. The amount of oversizing varies, but can limit the minimum furnace capacity in those cases to a higher capacity than calculated based on peak heating load. ACCA Manual S acknowledges this application and permits additional oversizing in those cases.

2.3 Furnace Size and Heating Load Analysis Methodology

Furnace size calculated using the above methodology is located in the Furnace & AC Sizing Sheet in Cell D19 for each Crystal Ball trial case. The annual heating load (i.e., furnace output) for each Crystal Ball trial case is located in the Energy Use Sheet in Cell F78. GTI extracted both furnace size and heating load from each trial case for post-processing and analysis using Visual Basic for Application (VBA) code as described in GTI-15/0002 Section 2.1. This permitted an evaluation of the correlation between furnace size and heating load for the 10,000 trial cases in the NODA LCC model.

Figure 1 shows heating load vs. furnace size along with a best fit line for all furnaces, whether impacted by the rule or not. The correlation between heating load and furnace size is weak. Also, the best fit line has an intercept at zero heating load near 75 kBtu/hr. An intercept above zero is expected because even homes with very low heating loads may be expected to install a furnace in the event of infrequent cold weather. The relatively high value of the intercept is consistent with the idea that furnaces are generally oversized for the heating load and that therefore furnace size is only weakly related to heating load, which will tend to make this intercept close to the average furnace size. In this case the average furnace size for all trials is 85.9 kBtu/hr. The lack of a strong relationship between heating load and furnace size may help to explain the lack of a consistent trend in LCC savings with furnace size. To better show the distribution of heating loads within the furnace size bins, Figure 2 and Figure 3 show the distribution of heating loads for a range of kBtu/hr furnace size bins. The distributions overlap substantially, and all of the distributions contain a significant fraction of buildings with very low heating loads.

As noted above in Section 2.2, the DOE sizing methodology does not appear to consider AC requirements when sizing furnaces. Thus, the lack of correlation between heating load and furnace size does not appear to be driven to any meaningful extent by AC size and associated fan requirements.

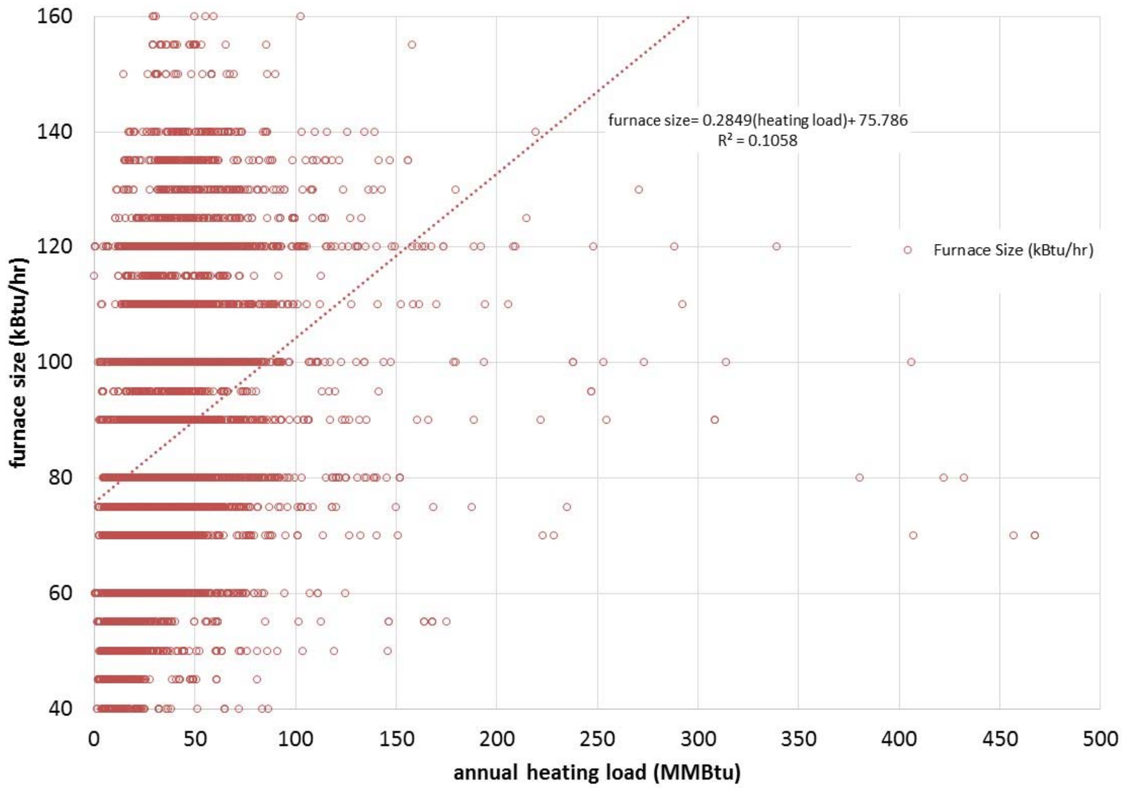

Figure 1: Furnace Size vs. Annual Heating Load

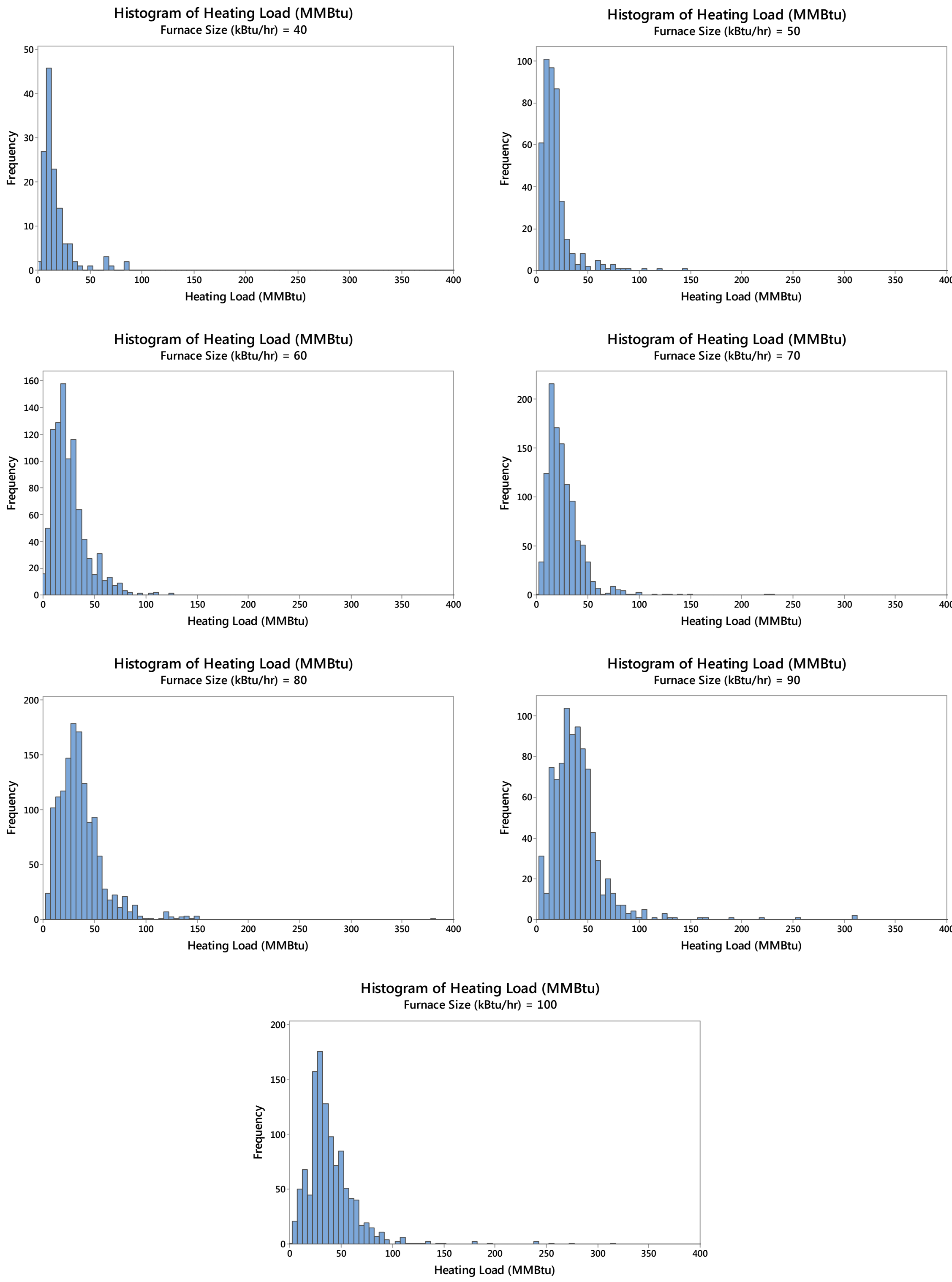

Figure 2: Heating Load Distribution for Selected Furnace Size Bins (40 to 100 kBtu/hr)

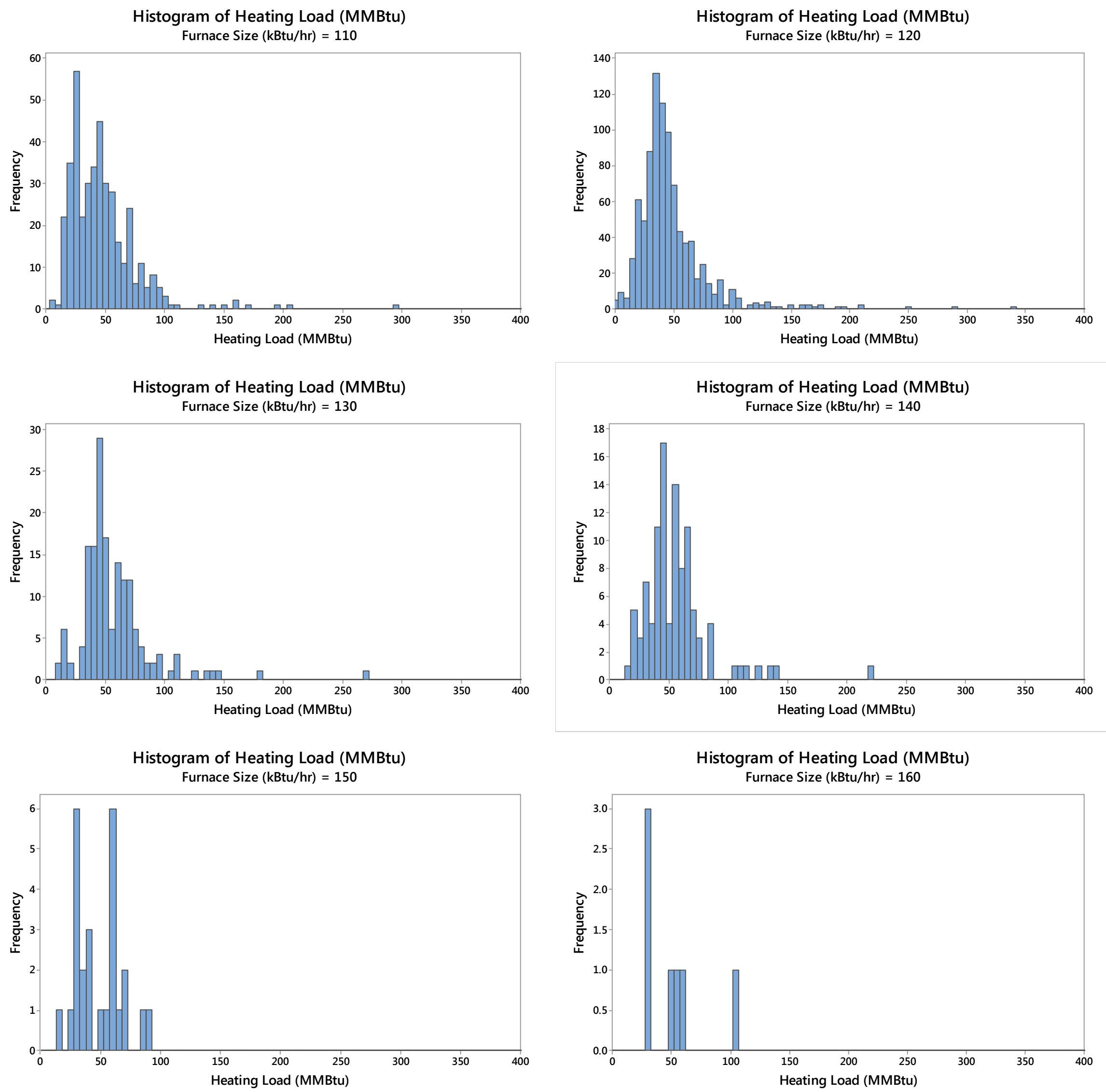

Figure 3: Heating Load Distribution for Selected Furnace Size Bins (110 to 160 kBtu/hr)

2.4 RECS Database Application

In both the NOPR and NODA, DOE derived annual heating load, existing furnace efficiency level, and existing furnace capacity from limited information in the RECS 2009 database. Applicable information in the RECS database includes location, physical size, and gas consumption. Since the RECS database does not include furnace size or annual heating load information, DOE chose to randomly assign existing furnace AFUE and derived the annual heating load from the randomly assigned AFUE. The lack of data in the RECS database on the key values of furnace AFUE and capacity makes it an inadequate source of information for use in the furnace capacity and annual heating load assignments used in the NOPR and NODA, both for the single standard level and for separate standard levels for large and small furnaces evaluated in the NODA. Additional market information is needed for this purpose.

2.5 DOE NODA Furnace Downsizing Methodology

As stated in the NODA, if there is a separate standard for small furnaces, DOE expects that some consumers who would otherwise install a typically-oversized furnace would choose to down-size in order to be able to purchase a non-condensing furnace. For the NODA analysis, DOE identified those sample households that might down-size at the considered small furnace definitions. DOE first determined if a household would install a non-condensing furnace with an input capacity greater than the small furnace size limit without amended standards. In the standards case, DOE assumed that a fraction of such consumers would down-size to the input capacity limit for small furnaces.

The equation for the DOE downsizing algorithm is as follows:

$$Downsizing\ Input\ Size = Original\ Furnace\ Size\left(\frac{Downsizing\ Oversize\ Factor}{Original\ Oversize\ Factor}\right) = Original\ Furnace\ Size\left(\frac{1.35}{1.7}\right)$$

Figure 4 shows the flowchart for the NODA furnace downsizing methodology. The NODA downsizing methodology assumes a rational consumer response to a market constraint to protect their economic interests. This rational consumer behavior methodology is inconsistent with the random furnace sizing and baseline furnace efficiency assignment methodology used by DOE elsewhere in the NOPR and NODA. It also fails to account for the selection of furnace size based on AC size and associated fan requirements.

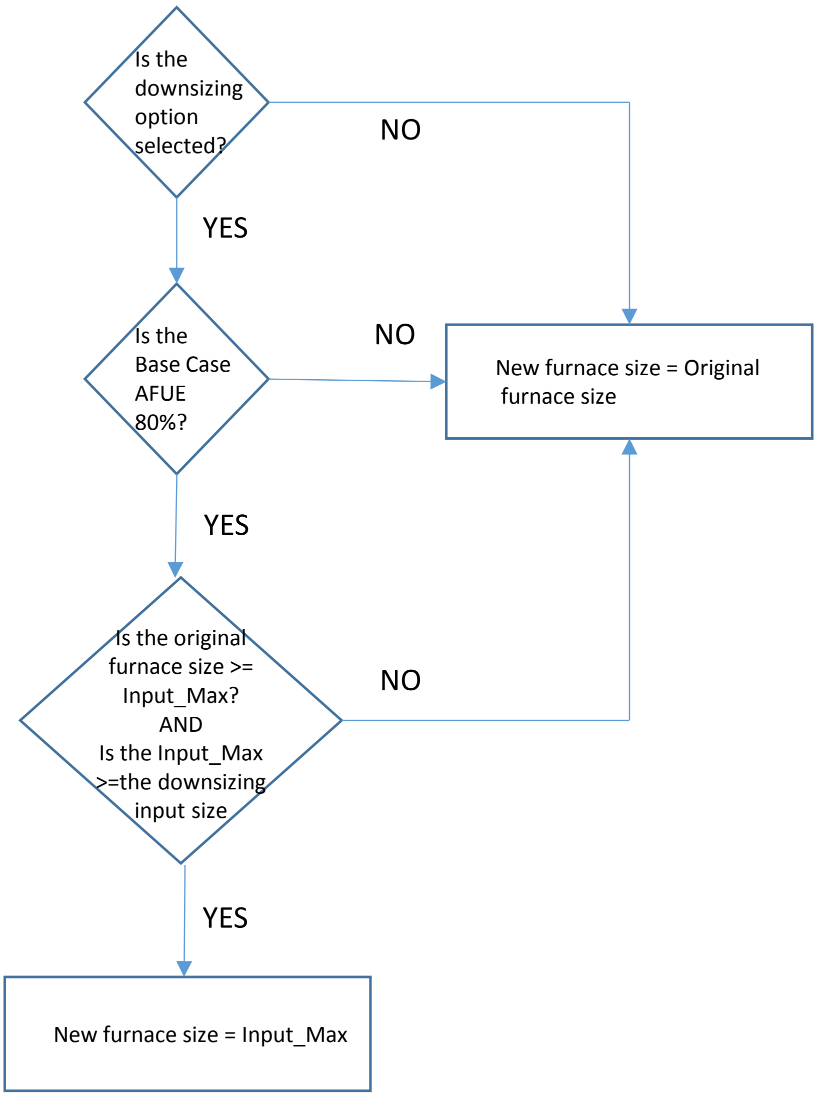

Figure 4 NODA Furnace Down-Sizing Methodology

3 Results

3.1 Incremental changes in the NODA vs. the NOPR LCC Model

The DOE NODA does not effectively address the methodology issues and shortcomings identified in GTI-15/0002 that resulted in overstated LCC savings and national benefits in the March 2015 NOPR. With this caveat, it is noteworthy that, independent of the furnace-size exemption issue, the DOE NODA analysis shows significant reduction in average benefits for all single standard TSLs compared to the original DOE NOPR analysis, as shown in Table 3.

For the first time in the NODA, DOE used a new segmentation grouping of "impacted furnaces" in the LCC savings calculations. In the NODA, the methodology to display average national LCC savings values shifted from an overall average value shown in the NOPR considering all 10,000 trial cases, whether impacted or not, to an average savings value considering only the impacted trial cases. Table 3 shows results for both the NODA (per impacted furnace) as well as the NOPR (per 10,000 furnaces).

Table 3 also summarizes GTI's analysis of the NOPR and NODA. GTI's analysis shows negative average savings for all single standard TSLs in the NODA (compared to DOE's findings of positive savings), and these results are not appreciably different than the overall negative average savings findings in the GTI analysis of the NOPR.

Table 3 National Average LCC Savings for DOE NOPR and NODA LCC Models

TSL (% AFUE)	DOE NOPR Analysis	GTI NOPR Analysis	DOE NODA Analysis	GTI NODA Analysis
	NODA (Impacted Furnaces Only)			
90	$441	-$571	$347	-$592
92	$520	-$417	$425	-$442
95	$507	-$631	$420	-$651
98	$443	-$458	$343	-$475
	NOPR (All Furnaces)			
90	$236	-$215	$163	-$225
92	$305	-$181	$225	-$190
95	$388	-$445	$311	-$462
98	$441	-$447	$341	-$466

3.2 Furnace Size vs. LCC Savings

Due to the lack of requested information from DOE, no comparable LCC analysis for a separate standard level for large and small furnaces could be performed in the time DOE allotted for comments.

4 Conclusions

The DOE NODA LCC model did not address the technically flawed random Base Case furnace AFUE assignment methodology or the technically flawed fuel switching analysis used in the NOPR, and includes technically flawed furnace sizing algorithms. Based on the additional scenario analyses summarized in this report, there is no economic justification for the single standard described in the NODA or the NOPR. Due to the lack of requested information from DOE, no comparable LCC analysis for a separate standard level for large and small furnaces could be performed in the time DOE allotted for comments. Further, the RECS database information used by DOE does not contain either heating load or furnace capacity information and is inadequate to address the furnace AFUE for the existing buildings, the existing building loads, or the existing building furnace capacities.