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FINAL REPORT

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Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies

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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

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

DOE issued a notice of proposed rulemaking (NOPR) that proposes a single national standard at a minimum efficiency level of 92% annual fuel utilization efficiency (AFUE) for non-weatherized gas furnaces and mobile home gas furnaces. The NOPR was published in the Federal Register on March 12, 2015 and open for a 120 day amended public comment period through July 10, 2015. DOE released an extensive technical support document (TSD) to substantiate the NOPR, which included a detailed review of the effects of the NOPR as well as economic modeling to assess consumer-level cost impacts.

GTI conducted a technical and economic analysis of the DOE furnace NOPR to evaluate the impact of the 92% AFUE minimum furnace efficiency requirements along with other Trial Standard Levels (TSLs) on consumers. The analysis included a detailed examination of the following:

- DOE TSD modeling approach, assumptions, and results;
- DOE NOPR Life Cycle Cost (LCC) analysis spreadsheet and Crystal Ball model;
- Rational Consumer Economic Decision (CED) framework and related methodologies developed by GTI;
- Surveys (e.g., American Home Comfort Study) and data on input variables judged to have potential impact on LCC analysis results; and
- Estimates of consumer benefits and costs associated with the 92% furnace standard as well as other trial standard levels of furnace efficiency.

As a result of this detailed examination, GTI uncovered a serious technical flaw in the methodology DOE used to establish the homes that would be impacted by the proposed rule. Specifically, the Base Case furnace assignment algorithm used by DOE ignores economic decision making by the consumer. Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly in the DOE NOPR LCC model. DOE's baseline furnaces in the 10,000 Crystal Ball trial case homes are intended to be representative of the RECS survey furnace distribution across various locations and categories throughout the country projected out to 2021 (the first year the rule would be enforced). Random assignment of the baseline furnace does not achieve this key objective. The economics of a particular efficiency level selection compared to other levels (e.g., 80% AFUE vs. 92% AFUE) are not considered in DOE's baseline furnace decision making methodology. DOE's methodology assumes that consumers do not consider economics at all when choosing a furnace. This technical flaw results in overstated LCC savings in the proposed rule.

GTI also uncovered a serious technical flaw in the methodology DOE used in its fuel switching analysis. DOE used a single switching payback value of 3.5 years for fuel switching decisions in its algorithm based on an average tolerable payback period for more efficient appliance purchases derived from proprietary American Home Comfort Study (AHCS) survey information. However, more granular inspection of the AHCS information showed that tolerable switching payback periods are a function of income and are dominated by large numbers of very low tolerable payback periods with small numbers of much larger payback periods. This reduces the benefit of the proposed rule compared to DOE's single switching payback period approach whenever the rule induces consumers with low tolerable payback periods to fuel switch to low first cost options despite negative LCC impacts. In addition, the DOE fuel switching analysis includes as a rule benefit cases in which rational fuel switching would accrue incremental benefits to the consumer compared to the TSL furnace. These cases would likely cause fuel switching without the rule in an unregulated market, and would be considered “No Impact” cases when using CED criteria for incremental technology and fuel switching decisions. These technical flaws also result in overstated LCC savings in the proposed rule.

Key input data used in the DOE NOPR LCC model are also inaccurate or outdated. DOE uses an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the EIA 2013 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies’ tariff data to supplement EIA data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data. Taken together, the DOE input information and forecasts associated with using these variables overstate LCC savings compared to more current forecasts and credible market data.

After uncovering these serious technical deficiencies, GTI developed an alternative approach to determine the baseline using a consumer economic decision (CED) framework based on criteria that more accurately depict how rational consumers choose one furnace option over another, through the use of simple payback periods, and the manner in which consumers make fuel switching decisions. GTI also identified a number of improvements to the input data used in the DOE NOPR LCC model. GTI Integrated Scenario Int-5 includes several refinements to the DOE NOPR LCC model, including rational consumer economic decision making and improved input data, and forms the primary basis for comparison to DOE’s analysis of its proposed furnace efficiency standards; other technically defensible scenarios based on different factors are included for reference purposes. GTI Scenario Int-5 was selected based on three key factors:

- Base Case furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions when using a CED framework for Base Case furnace assignment and fuel switching decisions
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices; and more current AEO forecast information

Key findings of the scenario analysis conducted by GTI analysts using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- DOE’s random Base Case furnace AFUE assignment methodology is technically flawed. DOE misallocated 22% of residential trial cases by using a random furnace assignment methodology, resulting in overstated benefits in the NOPR. Replacing DOE’s technically flawed methodology with rational economic decision making criteria substantially shifts both the characteristics and fractions of “Net Benefit” and “No Impact” consumers and appreciably lowers the financial benefit of the proposed rule.

- The DOE NOPR LCC model results combine random decisions and limited application of economic decisions in the fuel switching decision algorithms that overstate LCC savings compared to a CED framework methodology included in GTI Integrated Scenario Int-5.

- The DOE NOPR LCC model results include outdated and lower quality input data than the input data selected for inclusion in GTI Integrated Scenario Int-5. The DOE NOPR LCC model includes an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available furnace price market data; marginal gas prices derived from the EIA 2013 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from the latest AHRI condensing furnace shipment data including 2010 – 2014 statistics. Taken together, the DOE input information and forecasts associated with these parameters overstate LCC savings compared to more current forecasts and available market data, resulting in overstated benefits in the NOPR.
- GTI Integrated Scenario Int-5, based on improved consumer economic decision criteria and refinements to DOE's outdated and lower quality input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace. Based on these findings, the 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the EPCA requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life.
- GTI Integrated Scenario Int-5 results also show increased annual primary energy consumption and greenhouse gas emissions for three of the four condensing furnace trial standard levels (90%, 92%, and 95% AFUE) compared to the 80% AFUE baseline furnace, whereas the DOE NOPR LCC model results show decreased annual source energy consumption and greenhouse gas emissions. This increase in source (or primary) energy and associated greenhouse gas emissions results from fuel switching to electric options that are less efficient on a primary energy basis, especially electric resistance furnaces and electric resistance water heaters, as well as electric heat pumps in northern climates.

Table 1 summarizes the difference in consumer impacts when comparing the DOE NOPR LCC model results to Scenario Int-5. The magnitude of the overall market impact is reduced in Scenario Int-5, with more furnaces in the "No Impact" category. Through application of rational economic decision making criteria and other analytical refinements delineated in this report that are incorporated into GTI Integrated Scenario Int-5, the number of consumers with a "Net Benefit" is reduced from 39% to 17%, and the portion of consumers who experience an increase in "Net Cost" rises from 20% to 27%. Together, these impacts result in negative Life-cycle Cost Savings – that is, an overall increase in consumer life cycle costs.

Table 1: 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%

The DOE NOPR LCC model results provide input information to the DOE NOPR National Impact Analysis (NIA) that is summarized in the DOE NIA spreadsheet. Although GTI was not able to adjust the DOE NIA model inputs to determine the national impact of the DOE NOPR LCC model technical flaws, the LCC analysis provided enough annual energy consumption information to estimate the national impact of the proposed rule. GTI analysts conducted a 30 year analysis of the projected national impact of the proposed furnace rulemaking based on the DOE NOPR LCC model results and the GTI Integrated Scenario Int-5 analysis results.

Figure 1 shows the Crystal Ball trial cases and estimated total number of homes in the country impacted by the rulemaking in the DOE NOPR LCC model analysis, including the portion that choose the TSL furnace or switch to competing electric options. The lower box summarizes the estimated impact of natural gas to electricity fuel switching projected over the entire market (5.28 million homes from a total 53.8 million homes with natural gas furnaces) and summed over a thirty-year time horizon. The top box shows similar information for 30-year impacts of affected consumers switching to higher-efficiency gas furnaces.

Figure 2 illustrates findings based on the GTI Scenario Int-5 results, which include rational consumer economic decision making and other refinements that address perceived shortcomings in the DOE NOPR LCC model results. Differences in the affected home outcomes compared to the DOE NOPR LCC model include:

- The number of affected homes is 26 percentage points less, reducing projected natural gas energy savings
- Fewer homes that opt for relatively efficient electric heat pumps
- An increase in homes that are induced to choose low-first cost, source energy inefficient electric resistance space and water heating systems over more source energy efficient natural gas equipment.

The fuel switching impacts result in appreciable reduction of the primary (or source) energy savings and CO_2 equivalent (CO_2e) emission reduction benefits of the proposed rule under both scenarios, as consumers choose electric options that increase primary energy use and associated CO_2e emissions compared to direct natural gas use for space heating or water heating. The GTI Scenario Int-5 analysis shows a significant net increase in total primary energy use and CO_2e emissions resulting from the proposed rule. In this scenario, the negative societal impacts of fuel switching caused by the DOE rule outweigh the natural gas primary energy savings and associated CO_2e emissions.

Table 2 through Table 6 provide a more detailed comparison of the DOE NOPR LCC model results with the GTI Integrated Scenario Int-5 results. These data reflect composite national average impacts per furnace.

Based on the findings of GTI Scenario Int-5, there are three key changes compared to the DOE NOPR:

(1) The number of homes affected by the proposed rulemaking is reduced by 26%:

(2) Different homes fuel switch to different electric options compared to the DOE NOPR LCC model; and

(3) Improved input data show a higher baseline penetration of condensing furnaces, lower forecasted energy price changes, higher price differential between condensing and non-condensing furnaces, and lower marginal gas prices compared to the DOE NOPR LCC model.

Combined, these changes lead to negative economic and societal impacts caused by the proposed rule, including higher primary energy consumption, higher greenhouse emissions, and negative LCC savings.

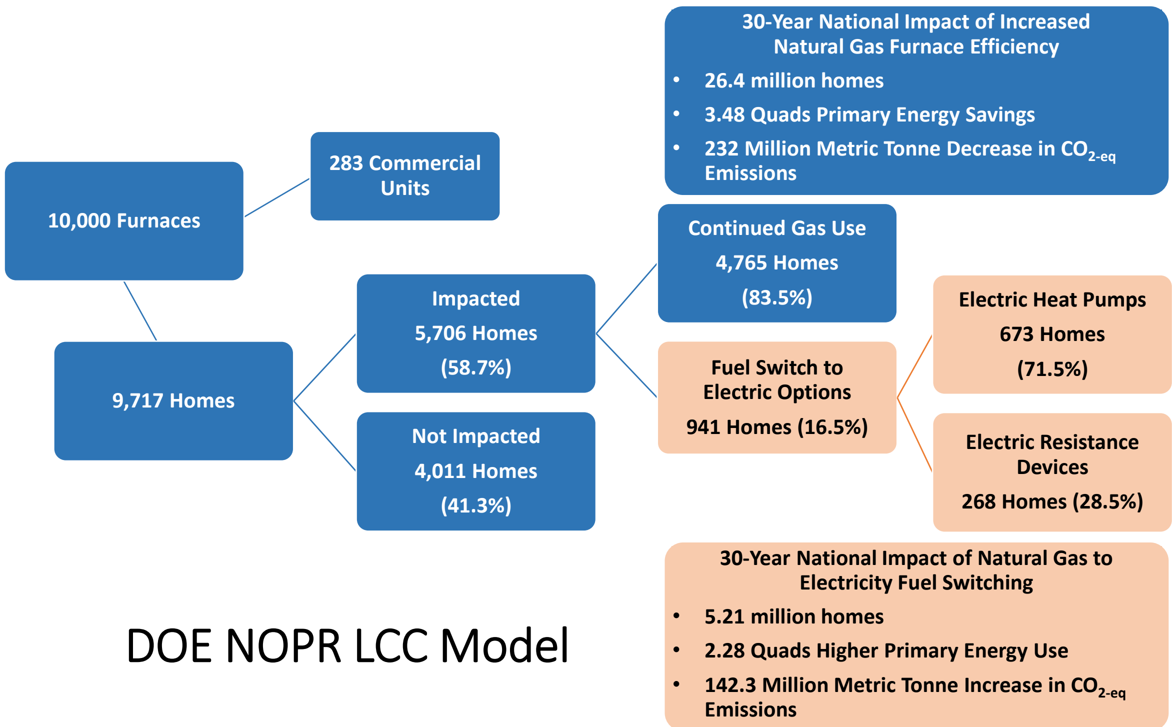

Figure 1: DOE NOPR LCC Model Impacts

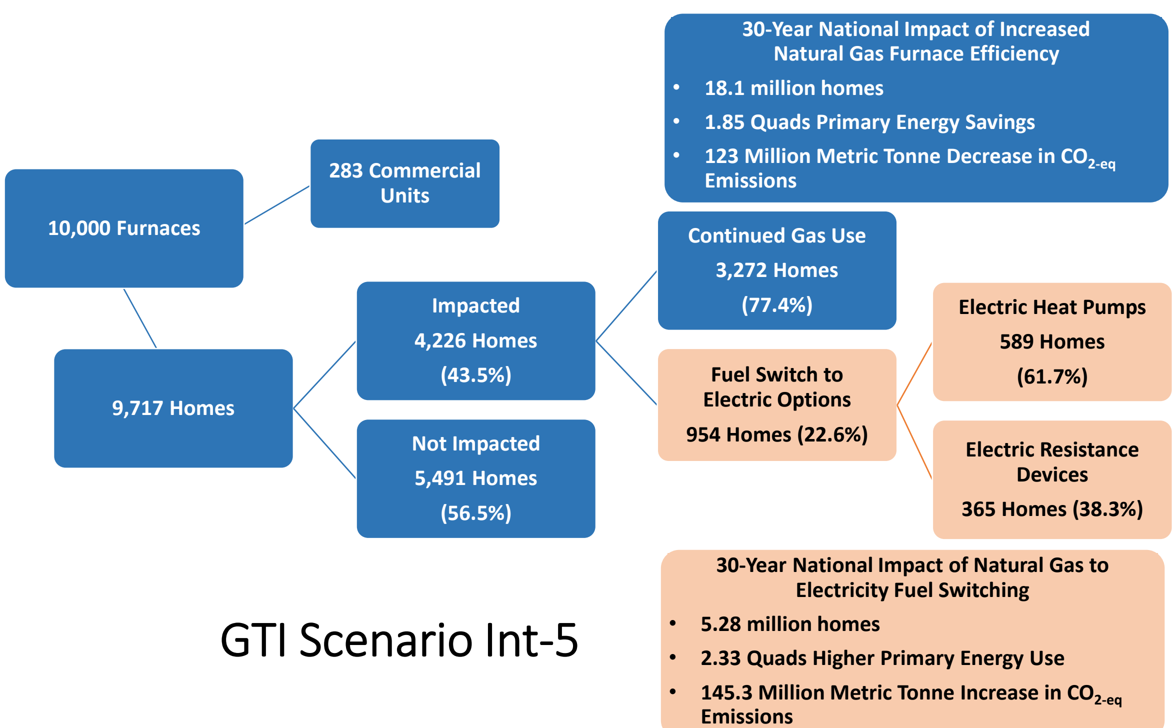

Figure 2: GTI Scenario Int-5 Impacts

Table 2 LCC Savings – DOE NOPR vs. GTI Integrated Scenario Int-5

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Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
LCC Savings Summary - 90% TSL											
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
GTI Scenario Int-5	-$215	-$159	-$278	-$266	-$184	-$355	-$68	-$93	-$39	-$212	-$555
LCC Savings Summary - 92% TSL											
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
GTI Scenario Int-5	-$181	-$131	-$237	-$233	-$161	-$310	-$36	-$55	-$14	-$183	-$533
LCC Savings Summary - 95% TSL											
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
GTI Scenario Int-5	-$445	-$520	-$361	-$443	-$458	-$427	-$430	-$687	-$126	-$302	-$804
LCC Savings Summary - 98% TSL											
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
GTI Scenario Int-5	-$447	-$497	-$390	-$443	-$420	-$469	-$456	-$755	-$102	-$261	-$743

Table 3 Fuel Switching – DOE NOPR vs. GTI Integrated Scenario Int-5

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
Percent of Impacted Buildings Switching - 90% TSL											
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
GTI Scenario Int-5	25.6%	20.8%	27.6%	25.6%	21.5%	27.0%	26.4%	19.7%	32.3%	33.5%	36.6%
Percent of Impacted Buildings Switching - 92% TSL											
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
GTI Scenario Int-5	22.4%	15.7%	25.9%	22.9%	17.0%	25.2%	21.3%	13.2%	31.1%	27.7%	33.1%
Percent of Impacted Buildings Switching - 95% TSL											
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
GTI Scenario Int-5	28.2%	16.3%	35.9%	30.2%	17.9%	36.8%	23.2%	13.3%	32.8%	27.4%	35.8%
Percent of Impacted Buildings Switching - 98% TSL											
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
GTI Scenario Int-5	23.4%	9.9%	38.5%	23.3%	9.0%	38.8%	24.1%	12.4%	37.8%	20.6%	26.9%

Table 4 Energy and GHG Emissions – DOE NOPR vs. GTI Integrated Scenario Int-5

Scenario	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs CO_{2e})
Impacted Buildings - 90% TSL								
DOE NOPR (GTI Scenario 0)	37.2	28.8	312.4	1,045.3	-22%	235%	-1.2	-158.5
GTI Scenario Int-5	29.2	20.4	266.4	1,256.1	-30%	371%	1.0	145.4
Impacted Buildings - 92% TSL								
DOE NOPR (GTI Scenario 0)	37.4	29.3	314.1	960.7	-22%	206%	-2.0	-258.2
GTI Scenario Int-5	30.1	21.9	272.1	1,138.6	-27%	318%	0.3	51.8
Impacted Buildings - 95% TSL								
DOE NOPR (GTI Scenario 0)	37.9	29.9	317.4	911.8	-21%	187%	-2.3	-301.7
GTI Scenario Int-5	32.4	22.9	288.6	1,340.3	-29%	364%	0.9	130.3
Impacted Buildings - 98% TSL								
DOE NOPR (GTI Scenario 0)	39.4	31.1	322.7	952.4	-21%	195%	-2.3	-308.4
GTI Scenario Int-5	38.4	29.9	319.2	1,179.4	-22%	270%	-0.1	-9.1

Table 5 DOE NOPR LCC Analysis Summary Results (GTI Scenario 0)

Simulation Results NATIONAL - 10000 samples		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,218	$10,314	$12,533						
1	NWGF 90%	$2,654	$9,388	$12,042	$236	22%	47%	32%	18.0	10.6
2	NWGF 92%	$2,669	$9,228	$11,897	$305	20%	41%	39%	13.9	7.7
3	NWGF 95%	$2,788	$8,985	$11,773	$388	24%	23%	53%	12.9	8.9
4	NWGF 98%	$2,948	$8,771	$11,718	$441	40%	0%	60%	16.8	12.0

Simulation Results NORTH		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,410	$12,923	$15,333						
1	NWGF 90%	$2,985	$11,761	$14,746	$208	11%	67%	22%	13.9	8.8
2	NWGF 92%	$3,000	$11,555	$14,556	$277	10%	60%	30%	10.3	5.3
3	NWGF 95%	$3,133	$11,251	$14,385	$374	14%	40%	46%	10.2	7.8
4	NWGF 98%	$3,311	$10,979	$14,290	$467	37%	1%	62%	15.5	11.8

Simulation Results Rest of Country		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,003	$7,374	$9,376						
1	NWGF 90%	$2,280	$6,714	$8,994	$267	33%	24%	42%	20.1	11.8
2	NWGF 92%	$2,295	$6,606	$8,901	$336	31%	20%	49%	16.1	9.5
3	NWGF 95%	$2,398	$6,430	$8,828	$404	35%	5%	60%	14.8	10.1
4	NWGF 98%	$2,539	$6,281	$8,820	$412	43%	0%	57%	18.3	12.4

Simulation Results Low Income Only		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,983	$10,641	$12,625						
1	NWGF 90%	$2,498	$9,720	$12,218	$176	26%	43%	31%	19.6	12.8
2	NWGF 92%	$2,512	$9,562	$12,074	$247	23%	38%	39%	16.2	10.0
3	NWGF 95%	$2,618	$9,328	$11,945	$330	26%	24%	51%	13.1	9.5
4	NWGF 98%	$2,776	$9,012	$11,789	$485	43%	1%	56%	17.4	12.7

Table 6 GTI Scenario Int-5 LCC Analysis Summary Results

Simulation Results NATIONAL - 10000 samples		Scenario Int 5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,016	$9,984	$12,001						
1	NWGF 90%	$2,634	$9,266	$11,900	-$215	28%	62%	10%	39.2	28.0
2	NWGF 92%	$2,649	$9,123	$11,772	-$181	27%	57%	17%	28.0	19.8
3	NWGF 95%	$3,139	$9,017	$12,156	-$445	57%	29%	14%	40.4	32.5
4	NWGF 98%	$3,283	$8,882	$12,165	-$447	68%	2%	30%	30.8	24.6

Simulation Results NORTH		Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,219	$12,304	$14,523						
1	NWGF 90%	$2,986	$11,337	$14,323	-$159	15%	79%	6%	38.3	31.0
2	NWGF 92%	$3,001	$11,158	$14,159	-$131	15%	72%	13%	23.9	17.1
3	NWGF 95%	$3,598	$11,090	$14,688	-$520	47%	48%	5%	45.5	41.2
4	NWGF 98%	$3,763	$10,920	$14,683	-$497	66%	3%	32%	27.6	23.3

Simulation Results Rest of Country		Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,788	$7,370	$9,158						
1	NWGF 90%	$2,238	$6,931	$9,168	-$278	42%	44%	14%	39.7	27.0
2	NWGF 92%	$2,252	$6,829	$9,080	-$237	40%	39%	21%	30.3	21.0
3	NWGF 95%	$2,622	$6,681	$9,303	-$361	68%	9%	23%	36.9	27.4
4	NWGF 98%	$2,743	$6,583	$9,326	-$390	71%	2%	27%	34.7	25.9

Simulation Results Low Income Only		Scenario Int 5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,771	$10,201	$11,972						
1	NWGF 90%	$2,413	$9,873	$12,286	-$555	31%	61%	8%	39.1	28.1
2	NWGF 92%	$2,427	$9,737	$12,164	-$533	30%	56%	14%	29.0	21.1
3	NWGF 95%	$2,795	$9,743	$12,538	-$804	51%	36%	13%	36.6	30.1
4	NWGF 98%	$2,933	$9,575	$12,507	-$743	69%	2%	28%	31.5	25.1

1 Background

The Energy Policy and Conservation Act of 1975 (EPCA) requires the Department of Energy (DOE) to establish energy conservation standards for select consumer products and equipment and to update these standards when it is determined that in addition to yielding energy savings, the updated standards are technologically feasible and economically justified. Among other provisions, EPCA includes the following seven criteria for DOE to consider in its assessment of economic justification for proposed energy conservation standards:

a. The economic impact of the standard on the manufacturers and consumers of the products subject to the standard;
b. The savings in operating costs throughout the estimated average life of the products in the type (or class) compared to any increases in the price, initial charges, or maintenance expense for the products that are likely to result from the imposition of the standard;
c. The total projected amount of energy savings likely to result directly from the imposition of the standard;
d. Any lessening of the utility or the performance of the products likely to result from the imposition of the standard;
e. The impact of any lessening of competition, as determined in writing by the attorney general, that is likely to result from the imposition of the standard;
f. The need for national energy conservation; and
g. Other factors the Secretary considers relevant.

A DOE Direct Final Rule (DFR), published in the Federal Register on June 27, 2011, proposed to increase the minimum energy efficiency standards for non-weatherized residential gas furnaces to 90% AFUE in 30 states in the North Region of the United States. Under the DFR, these 90% AFUE standards were to take effect in 2013. For the DFR, DOE did not explicitly quantify the impact of fuel switching from gas furnaces to electric heating equipment. Nor did it consider the impact of related fuel switching from gas water heaters to electric water heaters. Based on concerns with the DFR, the American Public Gas Association (APGA) filed a petition challenging the 2011 DFR in court. The APGA petition requested that the court vacate the direct final rule as it applied to residential gas furnaces and remand the matter to DOE for further rulemaking proceedings to establish new efficiency standards. On April 24, 2014, the court ordered that the joint unopposed motion to vacate in part and remand for further rulemaking, filed March 11, 2014, be granted. Following the court approval of the joint motion, DOE committed to using best efforts to issue a notice of proposed rulemaking regarding new efficiency standards for gas furnaces within one year of the issuance of the remand and to issue a final rule within the later of two years of the issuance of the remand or one year of the issuance of the proposed rule.

Because of their concerns about the impact of a new furnace standard on fuel switching and DOE's failure to investigate fuel switching in the DFR, the American Gas Association (AGA) and APGA funded research conducted by GTI to develop and publish information on current and expected fuel switching behavior related to residential heating and water heating systems in new construction and replacement markets at national, regional, and state levels. The survey response data and accompanying spreadsheet and report, published in 2014 (https://www.aga.org/gas-technology-institute-fuel-switching-study), were intended for use in evaluating the impact of fuel switching on the technical feasibility and economic justification for increasing federal minimum efficiency requirements from non-condensing furnace efficiency levels to condensing furnace efficiency levels.

Fuel switching survey responses indicate that incremental fuel switching from gas to electric technology options is expected if the future federal minimum efficiency requirement precludes the availability of non-condensing natural gas furnaces. Fuel switching is expected to occur in both space heating and water heating systems. Differences in behavior are anticipated between builders (new construction) and contractors (new and replacement installations), with differences across regions and states. Compared to builders, contractors expect more fuel switching caused by a DOE condensing furnace rule due to additional perceived cost and system retrofit issues in the replacement market.

During the interim period between the settlement agreement in the DFR appeal and the issuance of a proposed rule by DOE, the gas industry used the published fuel switching survey information and related impact analysis to educate stakeholders on the potential negative societal impacts of fuel switching that would be caused by a condensing furnace minimum efficiency level. At the same time, GTI analysts evaluated the DOE life-cycle cost (LCC) analysis methodology and input parameters in detail to gain a more textured understanding of the DOE LCC model. This included an evaluation of a preliminary LCC analysis spreadsheet provided by DOE in September 2014 as well as participation in a public meeting held by DOE in November 2014 to answer questions about the new LCC spreadsheet application and methodology. With input from GTI and other stakeholders, DOE included fuel switching considerations and marginal gas prices for the first time in the preliminary LCC spreadsheet.

DOE issued a notice of proposed rulemaking (NOPR), published in the Federal Register on March 12, 2015, that proposes a single national standard at a minimum efficiency level of 92% AFUE for non-weatherized gas furnaces and mobile home gas furnaces, as shown in Table 7. Under the DOE NOPR, these 92% AFUE standards would take effect in 2021.

Table 7: DOE Proposed Standards for Residential Furnaces

Product Class	National Standard
Non-weatherized gas	92% AFUE 8.5 W Standby/Off Mode
Mobile home gas	92% AFUE 8.5 W Standby/Off Mode

A technical support document (TSD) prepared for DOE by Lawrence Berkeley National Laboratory (LBNL) provides the technical rationale for DOE's determination that the proposed standard is technologically feasible, economically justified, and will save significant amounts of energy. The technical basis of the TSD is a complicated LCC spreadsheet tool developed by LBNL for DOE over a period of several years for use in several rulemakings, including this NOPR. The LCC model uses an Excel® spreadsheet that invokes the Oracle® Crystal Ball predictive modeling and forecasting software. DOE used this spreadsheet modeling tool to predict the LCC and payback periods (PBP) for the proposed efficiency increases. Figure 3 shows the flow chart for the DOE TSD analysis. Figure 4 and Figure 5 below show the summary tables of the results included in the NOPR for non-weatherized gas furnaces and mobile home gas furnaces.

The underlying methodology and multiple inter-related variables in the DOE predictive LCC model strongly affect the results of LCC and PBP analyses, which jointly serve as the technical basis for DOE's determination that the proposed rule is economically justified. The methodologies and input data used within the DOE predictive LCC spreadsheet tool to justify the 92% AFUE furnace standard for non-weatherized gas furnaces are the primary focus of this report and accompanying spreadsheets.

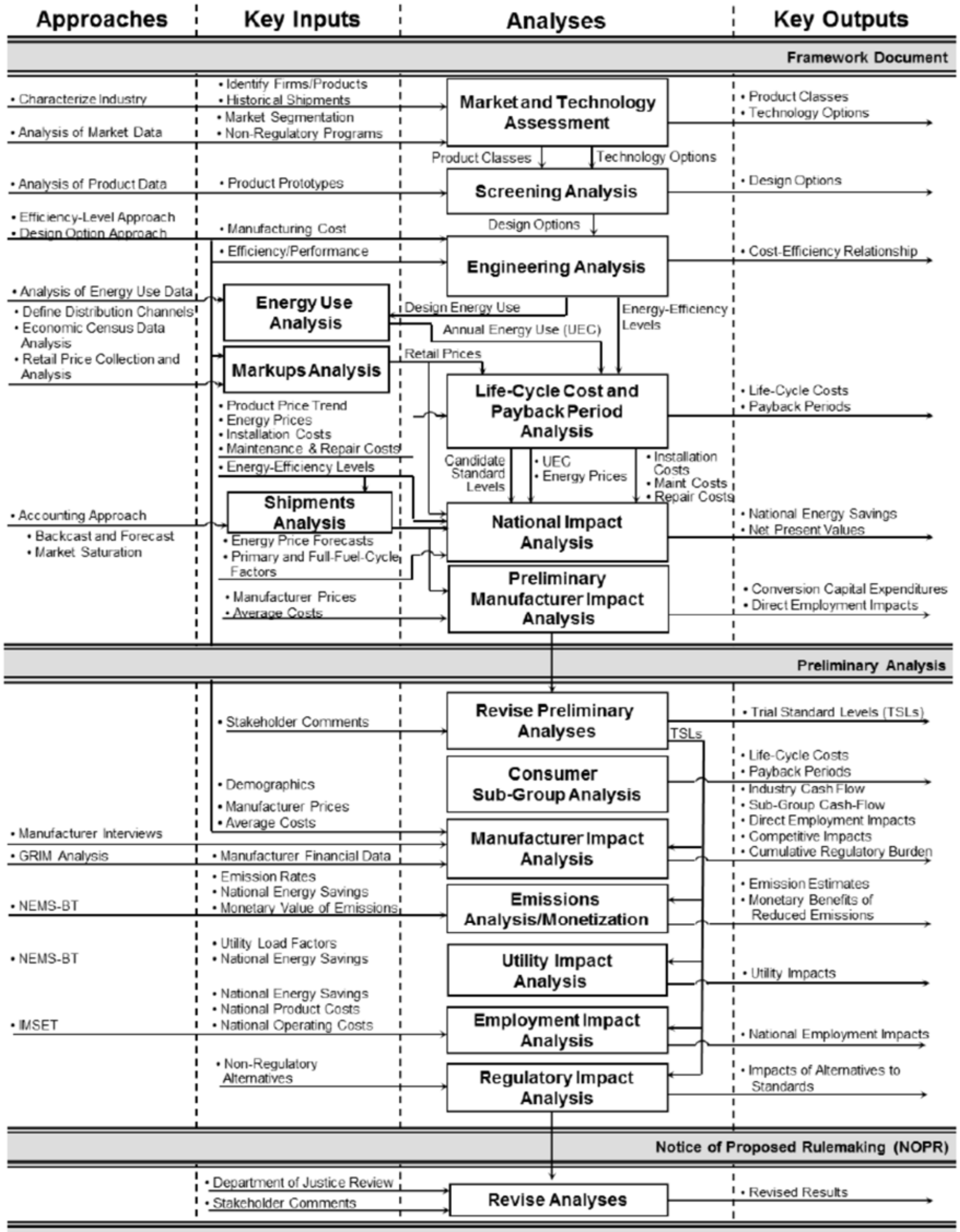

Figure 3: NOPR Technical Support Document Analysis Methodology

Source: DOE Notice of Proposed Rulemaking, Technical Support Document Chapter 2[1]

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1 U.S. Department of Energy Docket website. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Chapter 2. Analytical Framework. http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0031-0027

Efficiency Level	AFUE	Average Costs 2013$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
National						
0	80%	$2,218	$642	$10,314	$12,533	--
1	90%	$2,654	$589	$9,388	$12,042	8.2
2	92%	$2,669	$579	$9,228	$11,897	7.2
3	95%	$2,788	$565	$8,985	$11,773	7.4
4	98%	$2,948	$554	$8,771	$11,718	8.3
North						
0	80%	$2,410	$807	$12,923	$15,333	--
1	90%	$2,985	$737	$11,761	$14,746	8.3
2	92%	$3,000	$724	$11,555	$14,556	7.2
3	95%	$3,133	$706	$11,251	$14,385	7.2
4	98%	$3,311	$690	$10,979	$14,290	7.7
Rest of Country						
0	80%	$2,003	$456	$7,374	$9,376	--
1	90%	$2,280	$422	$6,714	$8,994	8.1
2	92%	$2,295	$415	$6,606	$8,901	7.1
3	95%	$2,398	$406	$6,430	$8,828	7.9
4	98%	$2,539	$401	$6,281	$8,820	9.6

Figure 4 DOE Lifecycle Cost and Payback Period Results for Non-Weatherized Gas Furnaces

Source: DOE Notice of Proposed Rulemaking, Technical Support Document Chapter 8[2]

Efficiency Level	AFUE	Average Costs 2013$				Simple Payback years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC	
National						
0	80%	$1,551	$700	$10,887	$12,438	--
1	92%	$1,721	$623	$9,694	$11,415	2.2
2	95%	$1,864	$607	$9,440	$11,304	3.3
3	97%	$1,979	$599	$9,319	$11,298	4.2
North						
0	80%	$1,590	$832	$12,829	$14,418	--
1	92%	$1,760	$740	$11,415	$13,175	1.8
2	95%	$1,902	$719	$11,103	$13,005	2.8
3	97%	$2,017	$709	$10,949	$12,966	3.5
Rest of Country						
0	80%	$1,489	$489	$7,762	$9,251	--
1	92%	$1,658	$436	$6,926	$8,584	3.2
2	95%	$1,802	$426	$6,766	$8,568	5.0
3	97%	$1,918	$422	$6,696	$8,614	6.4

Figure 5 DOE Lifecycle Cost and Payback Period Results for Mobile Home Gas Furnaces

Source: DOE Notice of Proposed Rulemaking, Technical Support Document Chapter 8[3]

2 U.S. Department of Energy Docket website. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Chapter 8. Life-Cycle Cost and Payback Period Analysis. http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0031-0027

3 U.S. Department of Energy Docket website. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Chapter 8.

2 LCC Analysis Methodology

2.1 Overview

Energy efficiency regulations for consumer products are legislatively authorized market interventions in response to perceived market failures that may cause consumers not to purchase higher efficiency products even though the consumer would benefit financially. Examples of possible unregulated market or market transformation failures include:

- Split incentives (e.g., home builder vs. homeowner; landlord vs. tenant)
- Ignorance (e.g., consumer is unaware of benefits or costs)
- Limited access to capital (e.g., consumer charges large investments on high interest credit cards)
- Ineffective wealth transfer (e.g., poorly implemented incentives by regulated entities)

Energy efficiency regulations are a powerful tool with no recourse for those impacted, so it is important to ensure that each regulation positively addresses a known market failure not addressed adequately by another means, without the imposition of inordinate costs or unintended consequences. To provide net societal benefits, it is important to ensure that each regulation provides overall financial benefit and minimizes financial loss to consumers negatively impacted by the regulatory intervention.

Under DOE's LCC analysis methodology, financial benefits accrue when the present value of future savings is sufficient to offset the first cost premium of the more efficient product through lower operating costs over the life of the product. Otherwise financial losses accrue. LCC analysis is extremely complex to apply to large populations due to the likelihood of significant differences in LCC benefits across various segments of the impacted population. Variables of interest for the non-weatherized gas furnace LCC analysis include:

- Baseline furnace design
- Higher efficiency furnace designs
- Fuel switching options
- Energy prices
- Furnace prices
- Installation costs
- Furnace life
- Maintenance costs
- Discount rates
- Local and regional factors
- Differences in consumer subcategories

To account for these and other variables, the DOE LCC analysis spreadsheet model methodology uses complex algorithms that include interactive impacts among a large number of input parameters. Some algorithms, such as manufacturer component costs and consumer decision making logic, use proprietary or confidential technical and cost information. DOE's

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Life-Cycle Cost and Payback Period Analysis. http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0031-0027 methodology includes a combination of fixed values, partial or full distributions, and random assignments to conduct its forecasting analysis. After incorporating all these various distributions and random assignments, the DOE LCC analysis model provides a single answer for key parameters rather than a probability distribution of possible results with error bars or other indicator of accuracy, precision, and confidence level.

Parametric analyses presented in this report incorporate a higher degree of granularity than was provided in the DOE LCC spreadsheet model output files and published results. Additional detail was required to conduct the desired analyses on individual trial cases, base case assignment decisions, and subcategory impacts (e.g., state-level, low income, senior citizen, or housing type subcategories).

To explore the impact of various parameters on LCC results, GTI analysts added Excel Visual Basic for Applications (VBA) code to the DOE LCC spreadsheet. The VBA code extracted outputs of interest from each of the 10,000 Crystal Ball trial cases and enabled a detailed analysis of the DOE LCC spreadsheet as well as GTI's parametric scenarios. The code that was used to extract outputs of interest did not affect any calculations in the DOE NOPR LCC model (referred to as Scenario 0 in this report) or any of the GTI parametric runs that examined the decision making methodology, input data modifications, and integrated scenarios.

GTI analysts conducted parametric scenario analyses to evaluate the impact of changes to the DOE NOPR LCC model in three topical areas:

- Decision Making Algorithms
- Input Data Modifications
- Integrated Scenarios

Table 8 shows the matrix of parametric scenarios that GTI explored under this project. Appendix A, Sections A.2 through A.10, provide descriptions of these parametric runs and associated results. The main body of this report describes and summarizes results of GTI Scenario Int-5 and its constituent parametrics, one of several GTI scenarios that integrate several reasonable and technically defensible parameters into a single scenario for comparison with the DOE LCC model results. GTI Scenario Int-5 was selected for comparisons in this report based on three key factors:

- Baseline furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices; and more current AEO forecast information

Other GTI scenarios are technically defensible as well based on different factors and assumptions. For instance, GTI Scenario Int-6 includes technically defensible assumptions about consumer decision making, with a fuel switching fraction that is significantly higher than the DOE fuel switching fraction. Other scenarios, such as GTI Scenario 1, were intended to examine the incremental impact of changing a single parametric, and would need to be integrated with other parametric scenarios to allow comparison with the DOE LCC model.

Table 8: Parametric Analysis Scenarios

	DOE NOPR	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14
Scenario 0	X																											
Scenario 1			X																									
Scenario 2				X																								
Scenario 3					X																							
Scenario 4						X	X																					
Scenario 5						X		X																				
Scenario 6						X			X																			
Scenario 7										X																		
Scenario 8			X							X																		
Scenario 9				X		X		X		X																		
Scenario 10						X		X		X																		
Scenario 11						X	X			X																		
Scenario 12						X			X	X																		
Scenario 13			X			X			X																			
Scenario 14			X			X			X	X																		
Scenario 15											X																	
Scenario 16												X																
Scenario 17										X	X																	
Scenario 18										X		X																
Scenario 19	X	X																										
Scenario 20		X				X	X																					
Scenario 21		X				X		X																				
Scenario 22		X				X			X																			
Scenario 23			X			X	X			X																		
Scenario 24				X		X	X			X																		
Scenario 25					X	X	X			X																		
Scenario 26				X						X			X															
Scenario 27				X						X				X														
Scenario I-1															X													
Scenario I-2																X												
~~Scenario I-3~~																												
~~Scenario I-4~~																												
Scenario I-5																			X									
Scenario I-6																				X								
~~Scenario I-7~~																												
Scenario I-8																						X						
~~Scenario I-9~~																												
Scenario I-10																								X				
Scenario I-11																									X			
~~Scenario I-12~~																												
Scenario I-13																											X	
~~Scenario I-14~~																												
Scenario I-15																				X		X					X	
Scenario I-16																X				X		X					X	
Scenario Int 1 (Scenarios 24 & I-15)				X		X	X			X										X		X					X	
Scenario Int 2 (Scenario 23 & I-15)			X			X	X			X										X		X					X	
Scenario Int 3 (Scenarios 18 & I-15)										X		X								X		X					X	
Scenario Int 4 (Scenarios 17 & I-15)										X	X	X								X		X					X	
Scenario Int 5 (Scenarios 24 & I-16)				X		X	X			X						X				X		X					X	
Scenario Int 6 (Scenario 23 & I-16)			X			X	X			X						X				X		X					X	
Scenario Int 7 (Scenarios 18 & I-16)										X		X				X				X		X					X	
Scenario Int 8 (Scenarios 17 & I-16)										X	X	X				X				X		X					X	
Scenario Int 9 (Scenarios 26 & I-16)				X						X			X			X				X		X					X	
Scenario Int 10 (Scenarios 27 & I-16)				X						X				X		X				X		X					X	

2.2 Consumer Economic Decision Analysis Framework

To demonstrate economic justification for a condensing furnace efficiency rule, the DOE NOPR LCC analysis methodology needs to show overall financial benefit to those consumers that would otherwise not have selected the condensing furnace without the rule. The use of rational consumer economic decision making and payback principles provides a consistent framework for evaluating the impact of new rulemaking on consumers.

A Consumer Economic Decisions (CED) analysis framework places consumer furnace purchase decisions into four categories based on financial benefit or financial loss:

Category 1: Consumers that choose a condensing furnace and accrue financial benefit
Category 2: Consumers that choose a condensing furnace and suffer financial loss
Category 3: Consumers that do not choose a condensing furnace and do not accrue financial benefit
Category 4: Consumers that do not choose a condensing furnace and do not suffer financial loss

Table 9 characterizes CED categories related to furnace purchasing decisions based on unregulated market factors, market transformations, and regulatory interventions. Based on unregulated market economics, consumers in Categories 1 and 4 are considered market successes, and consumers in Categories 2 and 3 are considered market failures under the CED framework. It is challenging to determine whether a consumer choosing a condensing furnace is in Category 1 or 2, and equally challenging to determine whether an individual consumer not choosing a condensing furnace is in Category 3 or 4.

Market transformation initiatives succeed when they address Category 3 unregulated market failures through incentives coupled with education and outreach, shifting them to Category 1. However, there is also the potential for free riders in Categories 1 and 2 if those consumers would have purchased the condensing furnace without the incentive. Market transformation incentives may also induce consumers in Category 4 based on unregulated market economics to shift to Category 1 or 2, an undesirable outcome for the market transformation initiative. For these reasons, market transformation initiatives such as utility energy efficiency programs receive a great deal of scrutiny and regulatory oversight before such incentive programs are approved.

U.S. natural gas utilities currently manage energy efficiency and market transformation programs in excess of $1.44 billion in 2014 (according to the Consortium for Energy Efficiency). Of this total, $830 million is aimed at adoption of more energy efficient options for residential ($541 million) and low income consumers ($289 million). A new Federal condensing furnace efficiency standard would curtail the ability of natural gas energy efficiency programs to positively influence consumer selection of high-efficiency furnaces. The loss of consumer incentives could also result in a shift to less source energy efficient electric heating options such as electric resistance furnaces.

Table 9 Consumer Economic Decision Making Framework

Consumer Economic Decision Making Based on Unregulated Market Factors, Market Transformations, and Regulatory Interventions		
Unregulated Market (Based on Economic Factors)	Financial Benefit (Acceptable Payback)	Financial Loss (Unacceptable Payback)
Select Condensing Furnace (48.5% of purchases in 2014).	**Category 1** Rational decision.	**Category 2** Irrational decision.
Do Not Select Condensing Furnace (51.5% of purchases in 2014).	**Category 3** Irrational decision.	**Category 4** Rational decision.
Market Transformation (Energy Efficiency Incentives)	Financial Benefit (Acceptable Payback or LCC)	Financial Loss (Unacceptable Payback or LCC)
Select Condensing Furnace.	Rational decision. Incentives may induce Category 3 or Category 4 consumers to make rational decision. May also have Category 1 free riders.	Irrational decision. Incentives may induce Category 4 consumers to make irrational decision. May also have Category 2 free riders.
Do Not Select Condensing Furnace.	Irrational decision. Incentives do not induce Category 3 consumers to make rational decision.	Rational decision. Incentives do not induce Category 4 consumers to make irrational decision.
Regulatory Intervention (Codes, DOE Rule, Legislation)	Financial Benefit (Acceptable LCC)	Financial Loss (Unacceptable LCC)
Select Condensing Furnace.	Intervention does not impact Category 1 consumers. May force Category 3 consumers to make rational decision.	Intervention does not impact Category 2 consumers. May force Category 4 consumers to make irrational decision.
Do Not Select Condensing Furnace.	May force Category 3 consumers to fuel switch.	May force Category 4 consumers to fuel switch.

It is possible that the combination of unregulated market factors and market transformation initiatives still do not induce consumers in Category 3 to make energy efficiency decisions that accrue financial benefit. Codes, regulations, and legislation are intended to override those approaches and force Category 3 consumers to shift to Category 1 to accrue the financial benefit. However, these interventions are mandatory, and will force Category 4 consumers to shift to Category 2 and incur financial losses. The interventions may also induce them to switch to electric heating options (that may or may not have financial losses) to mitigate financial losses associated with the higher first cost condensing furnace. They may also induce Category 3 consumers to switch to lower first cost electric heating options (that may or may not have financial losses) to mitigate perceived financial losses associated with the higher first cost condensing furnace.

The implications for the DOE NOPR are significant. The unregulated market and market transformation shortcomings that the DOE rule overrides are confined to Category 3 consumers, but the DOE rule also impacts consumers in other categories, especially Category 4. However, it is not easy to determine who is actually in Category 3 or Category 4. Numerous financial and operational parameters impact consumers' decisions, and desired analytical information is often scarce or difficult to obtain. Given the myriad options for information, it is also important to prioritize the sources of information for the LCC analysis, and to use the best sources of information that are publicly available whenever possible.

Objective and credible market data, such as AHRI shipment data, furnace prices, installation costs, and marginal natural gas and electricity prices, is the top priority to obtain and use in the LCC analysis if possible. It is critical for economic parameter calculations such as equipment and installation costs, baseline conditions, and energy prices. Where such market data and statistics are not available, topical consumer and industry surveys such as the American Home Comfort Study and the nationwide fuel-switching survey of builders and installing contractors are valuable in helping understand expected behavior. If these sources of information are not available, construction and engineering principles may be useful, but are prone to systematic and random errors, especially when aggregating component level engineering estimates to system level costs. Finally, if none of the above information is available for a topic, persuasive anecdotal information may also have a role.

Consumers make purchase decisions based primarily on economics, but consider factors other than economics as well, including product performance or reliability, manufacturer reputation, intangible societal benefits, and perceived risks and rewards associated with the decision. Table 10 characterizes consumer decision making related to condensing furnaces, including economic and non-economic factors, based on unregulated market factors, market transformations, and regulatory interventions. This is a more complete decision making analytical framework because it acknowledges the value consumers attach to differentiating attributes such as delivered air temperature or risk-based decisions due to unique financial circumstances. However, it is difficult to model and is not considered in the DOE NOPR LCC methodology or the GTI parametric scenarios in this report. The CED framework in this report is a proxy for the more complete economic and non-economic framework and aligns with the DOE LCC analysis framework that focuses only on economic decisions.

Table 10 Consumer Economic and Non-Economic Decision Making Framework

Consumer Economic and Non-Economic Decision Making Based on Unregulated Market Factors, Market Transformations, and Regulatory Interventions		
Unregulated Market (Based on Economic and Non-Economic Factors)	Financial Benefit (Acceptable Payback)	Financial Loss (Unacceptable Payback)
Select Condensing Furnace (48.5% of purchases in 2014).	**Category 1** Rational decision based on economic and non-economic factors.	**Category 2** Irrational decision based on economics. Rational decision based on non-economic factors.
Do Not Select Condensing Furnace (51.5% of purchases in 2014).	**Category 3** Irrational decision based on favorable economics. Driven by non-economic factors or market imperfections. Incentives may or may not improve decision.	**Category 4** Rational decision based on unfavorable economics coupled with non-economic factors. Incentives may impact decision.
Market Transformation (Energy Efficiency Incentives)	Financial Benefit (Acceptable Payback or LCC)	Financial Loss (Unacceptable Payback or LCC)
Select Condensing Furnace.	Incentive may have changed rational or irrational Category 3 decision. May also have changed Category 2 or Category 4 economics. May also have Category 1 free riders.	Irrational economic decision. May also have changed Category 4 decision based on non-economic factors. May also be a Category 2 free rider based on non-economic factors.
Do Not Select Condensing Furnace.	Incentives do not induce Category 3 consumers to make a rational economic decision. May also be a rational decision due to non-economic factors.	Rational decision based on unfavorable economics coupled with non-economic factors. Incentives do not induce Category 4 consumers to change their decision.
Regulatory Intervention (Codes, DOE Rule, Legislation)	Financial Benefit (Acceptable LCC)	Financial Loss (Unacceptable LCC)
Select Condensing Furnace.	Intervention does not impact Category 1 consumers. May force Category 3 consumers to make rational economic decision, or may force irrational decision based on rational non-economic factors.	Intervention does not impact Category 2 consumers. May force Category 4 consumers to make irrational decision.
Do Not Select Condensing Furnace.	May force Category 3 consumers to fuel switch.	May force Category 4 consumers to fuel switch.

2.3 Base Case Furnace Assignment Methodology

The DOE NOPR LCC model includes economic criteria and a distribution of allowable cost recovery times in its trial standard level (TSL) furnace analysis and fuel switching decision algorithm. However, DOE's Base Case furnace assignment algorithm ignores economic decision making parameters. Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly to each of the 10,000 trial cases in the DOE LCC model. The economics of a particular efficiency level selection compared to other levels (e.g., 80% AFUE vs. 92% AFUE) are not considered in DOE's baseline furnace decision for any of the 10,000 Crystal Ball trial cases. Figure 6 illustrates the DOE random base case furnace assignment algorithm. Appendix A, Section A.2 provides further details on the DOE random Base Case furnace assignment methodology.

DOE's decision to use a random assignment methodology to assign base case furnace efficiency to each of the trial cases in the Crystal Ball simulation is a significant technical flaw with meaningful impact on the DOE NOPR LCC results. A random assignment methodology misallocates a random fraction of consumers that use economic criteria for their decisions and results in higher LCC savings compared to rational economic decision making criteria. DOE's Base Case furnaces in the 10,000 Crystal Ball trial case homes are intended to be representative of the RECS survey furnace distribution across various locations and categories. Random assignment of the Base Case furnace does not achieve this key objective and is not a technically defensible proxy for rational residential decision making processes. Figure 7 shows GTI's Base Case furnace assignment algorithm that incorporates a CED framework into the trial case assignments to provide a reasonable, technically defensible Base Case furnace assignment algorithm for the LCC analysis.

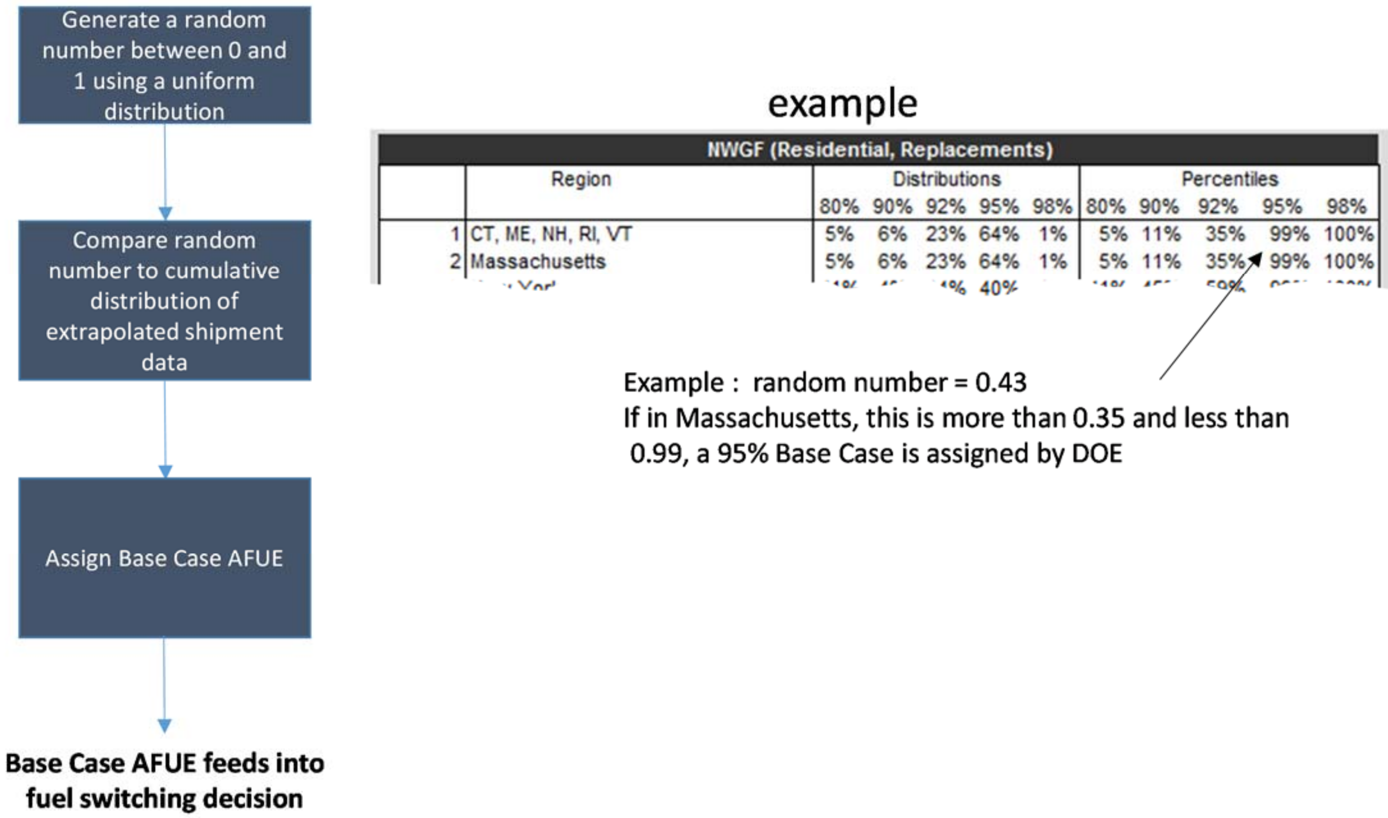

Figure 6 GTI Illustration of DOE Random Base Case Furnace Assignment Algorithm

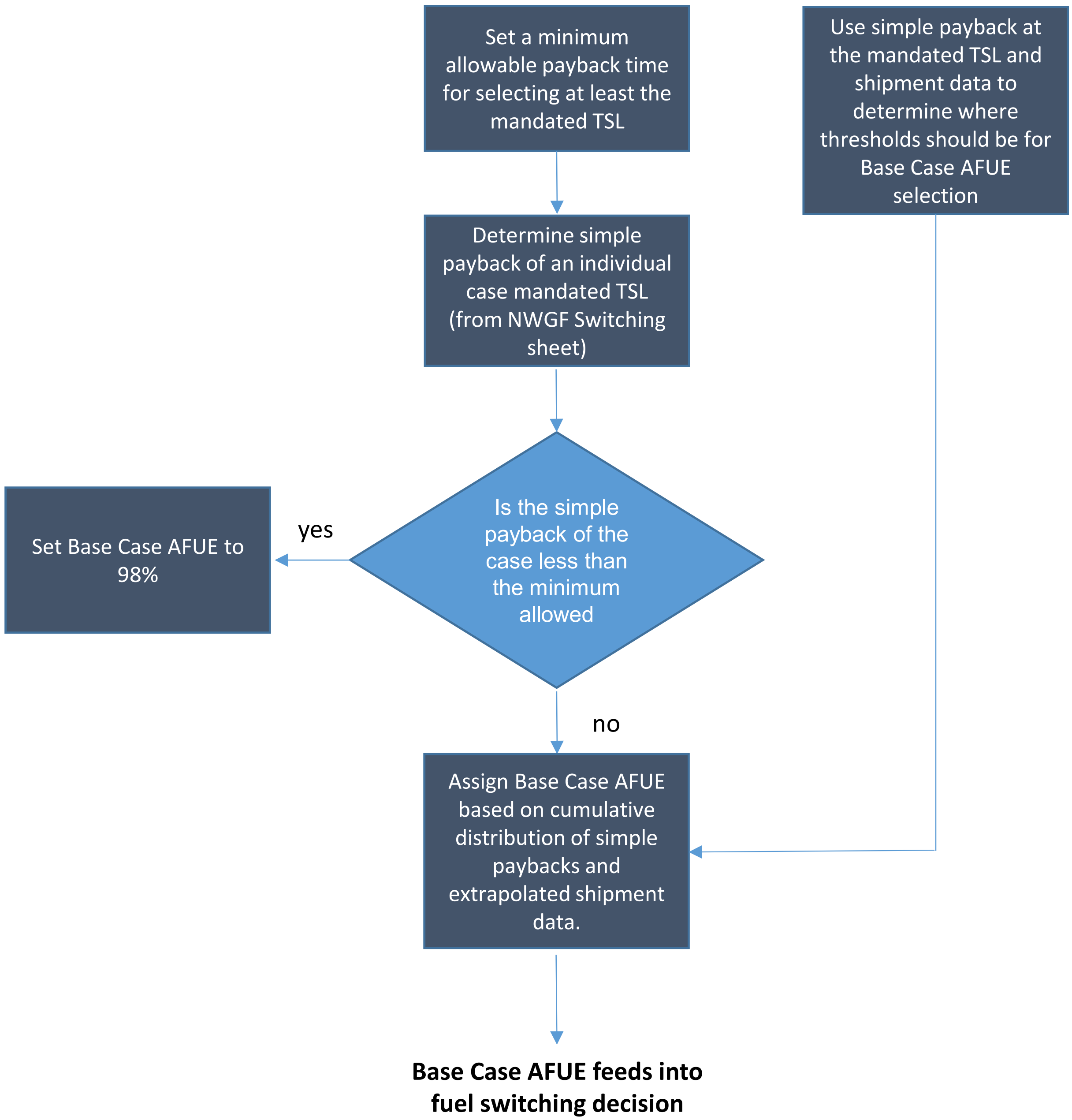

Figure 7 GTI Economic Decision Base Case Furnace Assignment Flow Chart

Table 11 and Table 12 provide illustrative examples of Crystal Ball trial case homes that result in overstated savings under the DOE random base case furnace assignment methodology compared to economic decision making criteria. The overstated savings in the DOE NOPR LCC model occur for two different reasons:

- DOE's random assignment puts non-condensing furnaces in buildings that would purchase condensing furnaces based on economic criteria; and
- DOE's random assignment puts condensing furnaces in buildings that would not purchase condensing furnaces based on economic criteria.

Table 11 illustrates a subset of trial cases classified by DOE as positively affected by the rule ("Net Benefit") that would likely not be impacted by the rule and would be excluded from the LCC analysis ("No Impact") under rational CED criteria.

Table 11 Cases Included as "Net Benefit" in the DOE NOPR LCC model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
7067	-$1,656	$76	$2,702	No Impact	North/ New York	Single Family New	-22
8749	-$457	$315	$8,659	No Impact	North/ New York	Single Family New	-1
1886	-$690	$360	$6,961	No Impact	North/ New York	Single Family Replacement	-2
138	-$856	$56	$2,165	No Impact	South/ AL, KY, MS	Single Family Replacement	-15
5327	-$741	$379	$6,917	No Impact	North/ Pacific	Commercial New	-2
8042	-$876	$155	$5,934	No Impact	South/ Tennessee	Single Family New	-6

Table 12 shows a subset of trial cases excluded from DOE's LCC analysis as not affected by the rule ("No Impact") that would likely be negatively impacted by the rule ("Net Cost") and would be included in the LCC analysis if decisions were based on CED criteria rather than assigned by a random number.

Table 12 Cases Considered "No Impact" in the DOE NOPR LCC Model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
287	$1,055	$1	No Impact	No Impact	North/ IA, MN, ND, SD	Single Family Replacement	1,323
5872	$1,118	$3	No Impact	-$809	North/ IN, OH	Single Family Replacement	382
8906	$810	$2	No Impact	-$59	North/ OR, WA	Single Family Replacement	340
6467	$4,620	$23	No Impact	-$3,792	North/ Illinois	Multifamily Replacement	201
8377	$3,287	$27	No Impact	-$3,035	South/ California	Multifamily Replacement	90
7147	$1,891	$10	No Impact	-$1,680	South/ California	Single Family Replacement	189

The first case in Table 12, Crystal Ball trial 287, highlights an important point. Both DOE and GTI consider this trial to be "No Impact," but for entirely different reasons. DOE considers it "No Impact" because the random number generated was high enough that a 95% AFUE furnace was selected in the Base Case AFUE assignment. GTI considers this trial "No Impact" because a fuel switching option was available that had lower first costs than either an 80% or the mandated 92% TSL and had lower operating costs than the 92% TSL. DOE excludes this option in its methodology.

Table 13 provides comparative results of the base case furnace assignments using DOE's random assignment methodology versus a rational CED framework. Of all new installation trial cases in the DOE NOPR LCC model, 69% (1,709/2,476) have a negative payback period (i.e., negative first cost premium divided by positive annual energy savings). In 62% of the trial cases for residential new construction with negative payback periods (1,061 cases representing 11% of total residential trial cases), DOE's random assignment methodology caused the trial cases to be considered "Net Benefit" when they would have been "No Impact" under a CED framework. For replacements, 25% of the long payback period trial cases (794 cases representing 8% of total trial cases) are considered "No Impact" in the DOE NOPR LCC analysis, when they would have been "Net Cost" under CED. Table 13 also shows the 266 "No Impact" fuel switching cases in the GTI scenarios with payback periods greater than 15 years. Overall, DOE misallocated 2,179 cases – representing 22% of all residential trial cases – by using a technically flawed random base case furnace assignment methodology instead of the rational CED methodology used in GTI decision making scenarios.

Table 13 DOE Random Base Case Assignment Compared to GTI Scenarios

Characteristics of Crystal Ball Trial Cases at 92% TSL	DOE LCC Model		GTI Scenarios	
	Number of Cases	Percent of Total	Number of Cases	Percent of Total
Number of Residential	9,717	100%	9,717	100%
Replacements	7,241	75%	7,241	75%
- Payback Period ≤ 0 years	530	5%	526	5%
- Impacted by Rule	324	3%	0	0%
- Payback Period >15 years	3,062	32%	3,065	32%
- No Impact	1,053	11%	264	3%
New Installations	2,476	25%	2,476	25%
- Payback Period ≤ 0 years	1,709	18%	1,707	18%
- Impacted by Rule	1,061	11%	0	0%
- Payback Period >15 years	21	0%	28	0%
- No Impact	7	0%	2	0%
Total Residential Trial Cases	9,717	100%	9,717	100%
- Payback Period ≤ 0 years	2,239	23%	2,233	23%
- Impacted by Rule	1,385	14%	0	0%
- Payback Period >15 years	3,083	32%	3,093	32%
- No Impact	1,060	11%	266	3%

Figure 8 shows the full distribution of payback periods for new installations in the DOE NOPR LCC model. DOE's input data and assumptions result in lower relative installed cost condensing furnaces compared to non-condensing furnaces in new construction 69% of the time, often with significant negative payback periods that result in overstated savings when included in the LCC analysis as "Net Benefit" cases rather than "No Impact" cases.

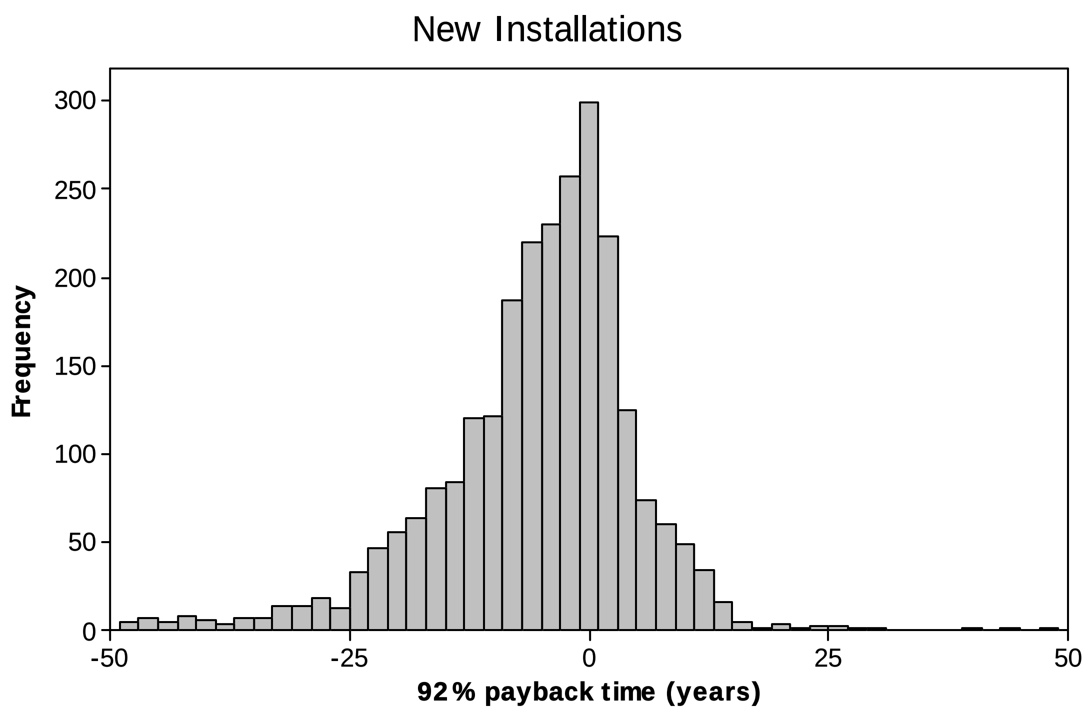

Figure 8 DOE LCC Analysis 92% AFUE New Construction Payback Period Distribution

2.4 DOE Fuel Switching Decision Making Methodology

Unlike the random decisions in the Base Case AFUE assignment, decisions on whether or not a consumer will choose a fuel switching option are based on consumer economics in the baseline DOE LCC model. Figure 9 describes GTI's understanding of the DOE LCC fuel switching decision-making process flow chart. The flow chart aligns with the process that is coded into the LCC spreadsheet rather than the limited description in the TSD. Cases that have selected a furnace with efficiency higher than 80% in the Base Case AFUE sheet are excluded from fuel switching in the LCC&PB Calcs sheet in a large range of cells in columns P through DG using statements like "=IF(AND(optSwitch=1, Index(iBase,1=0),…" which has the effect of verifying that fuel switching in the DOE model is turned on and that the selected furnace is an 80% AFUE furnace. Cells D63 through D66 in the DOE NWGF switching sheet look for cases that have negative payback and cases that have payback periods above the 3.5 year "switching payback period" (a term explained below) set in cells D48 and D49 in the same sheet. They are coded by DOE such that negative payback options will be selected first, followed by those with the largest switching payback period over the 3.5 year payback period threshold.

The TSD includes a confusing definition of payback period as applied to the LCC spreadsheet fuel switching algorithms. The TSD states (at pages 8J-5 and 8J-6): "DOE calculated a PBP [payback period] of the potential switching options relative to the NWGF at the specified EL." However, the fuel switching PBP definition actually used by DOE in the LCC spreadsheet differs from traditional PBP applied elsewhere in the DOE LCC analysis. The spreadsheet "payback" calculation in column AH of the NWGF Switching sheet calculates the time after which the first cost advantage of a switching option relative to a NWGF is offset by the higher operating cost of the switching option. Thus, the "payback period" used in the DOE fuel switching analysis calculations (versus the PBP described in the TSD) is actually the period after which a consumer begins losing money due to higher operating costs of the lower first cost option. This report refers to the DOE fuel switching version of "payback" as the "switching payback." This term is needed to distinguish the "switching payback period" from the usual definition of "payback period," which is the period after which a consumer begins saving money due to the lower operating costs of the higher first cost option.

DOE's random assignment algorithm in the Base Case AFUE assignment also affects its fuel switching analysis, resulting in higher savings compared to rational economic decision making criteria. There are cases that DOE does not consider in its consumer economics fuel switching algorithm because they are randomly excluded from the LCC analysis before the fuel switching payback calculations are performed. Some of these excluded cases are candidates for fuel switching caused by the rule and would be included in the LCC analysis using CED criteria. There are also cases that DOE has randomly determined will be "Net Benefit" cases due to fuel switching caused by the rule that would likely have fuel switched without the rule based on compelling economic benefits. Such cases would be considered "No Impact" in the LCC analysis using CED criteria.

Also, the LCC spreadsheet algorithm for switching options with higher first cost than the baseline furnace is not explicitly stated in the TSD. Switching options with a negative energy savings payback period relative to the baseline furnace have both a higher first cost and a higher operating cost than the specified NWGF. In the DOE LCC spreadsheet, calculations by the formulas in column AH in the NWGF Switching sheet remove any options where there is no first cost advantage of the switching option compared to the baseline furnace.

The DOE fuel switching model also excludes fuel switching in cases where there is a first cost advantage for the electric technology when comparing to an 80% furnace and an operating cost advantage for the electric technology compared to the TSL furnace. Instead, the DOE LCC analysis chooses the TSL furnace as a "Net Benefit" case, even though fuel switching would accrue incremental benefits to the consumer compared to the TSL furnace. These cases would likely cause fuel switching without the rule in the unregulated market, and would be considered "No Impact" cases when using CED criteria for incremental technology and fuel switching decisions. This results in overstated LCC savings compared to rational fuel switching under a CED framework methodology.

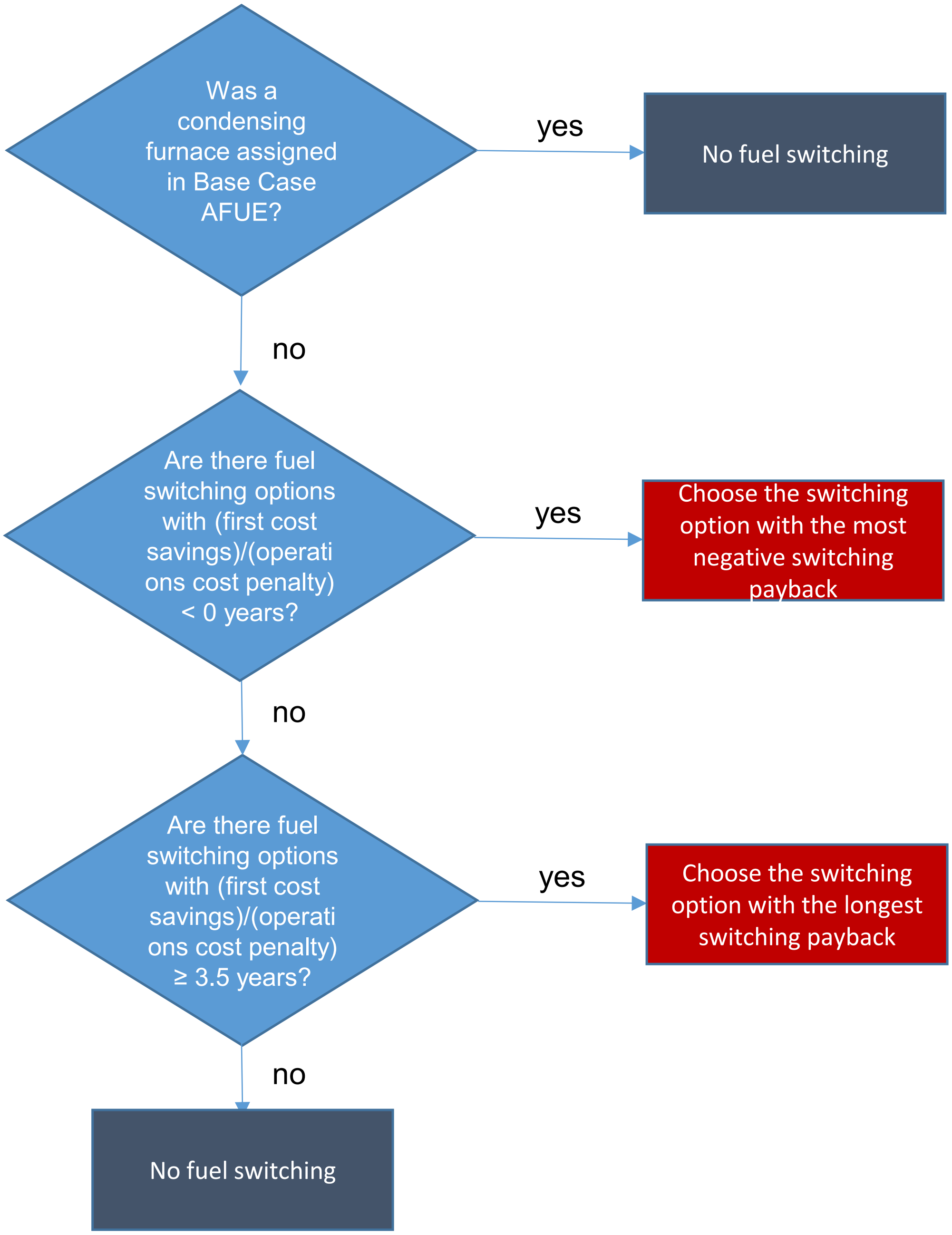

Figure 9 GTI Illustration of DOE Fuel Switching Logic Flow Chart

The distribution of LCC savings for individual trial cases is a non-linear function of switching payback period in the DOE LCC model. LCC savings drop significantly as the switching payback period falls below 4 years, but rise only slightly, with flat LCC savings for longer switching payback periods. Since DOE uses a single 3.5 year switching payback period in its fuel switching decision methodology, savings associated with fuel switching are overstated in the DOE LCC model compared to consideration of the full distribution of fuel switching payback periods. Parametrics D1 through D3 along with D8 through D10 explore various approaches to incorporating the distribution of fuel switching payback periods in the fuel switching analysis. Figure 10 shows GTI's fuel switching decision logic algorithm used in Scenario 24 that incorporates a CED framework into the LCC analysis. Appendix A, Section A.2.2, provides further details on the DOE fuel switching decision methodology.

2.5 American Home Comfort Study Application

The DOE fuel switching decision algorithm chooses the option with the longest switching payback if more than one option's switching payback period is over 3.5 years. DOE selected the 3.5 year switching payback period as the decision point based on analysis of four versions (2006, 2008, 2010, and 2013) of the American Home Comfort Study (AHCS) published by Decision Analyst.[4] The derivation of the 3.5 year switching payback period criterion used by DOE is described in section 8J.2.2 of the TSD. It comes from the amount consumers responding to the AHCS reported being willing to pay for a 25 percent improvement in the efficiency of their HVAC system and the space conditioning costs determined from the 2001, 2005, and 2009 RECS information. The average amount consumers were willing to pay from the AHCS was divided by 25% of the energy costs for space conditioning derived from the RECS information to arrive at 3.5 years.

The AHCS is a proprietary report available only through private purchase and contains detailed consumer preference information not generally available to the public. According to Decision Analyst, the AHCS is the largest knowledge base of homeowner behavior, perceptions, and attitudes related to energy efficiency, home comfort, and HVAC. Topics include:

- The level of consumers' interest in energy efficiency
- How consumers balance rising energy costs with home comfort
- Consumers' willingness to spend money on options to achieve energy efficiency
- Home comfort differences by region and demographics

Detailed consumer behavior information available in the AHCS allowed GTI to explore fuel switching decision parametric scenarios that were not considered by DOE in its fuel switching decision algorithm. The AHCS contains between 2,849 and 3,803 respondents in each of the years 2006, 2008, 2010, and 2013. It includes enough survey response information to produce distributions of switching payback periods as a function of income groups. Decision Analyst provided this detailed survey response information to GTI, allowing GTI analysts to conduct a more granular evaluation of fuel switching behavior than DOE incorporated into its analysis using the single point average switching payback period algorithm. Appendix A, Section A.3.2, provides additional information on the use of the AHCS information in the GTI scenarios.

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4 Decision Analyst. 2006, 2008, 2010, and 2013. American Home Comfort Study. Arlington, TX. http://www.decisionanalyst.com/Syndicated/HomeComfort.dai

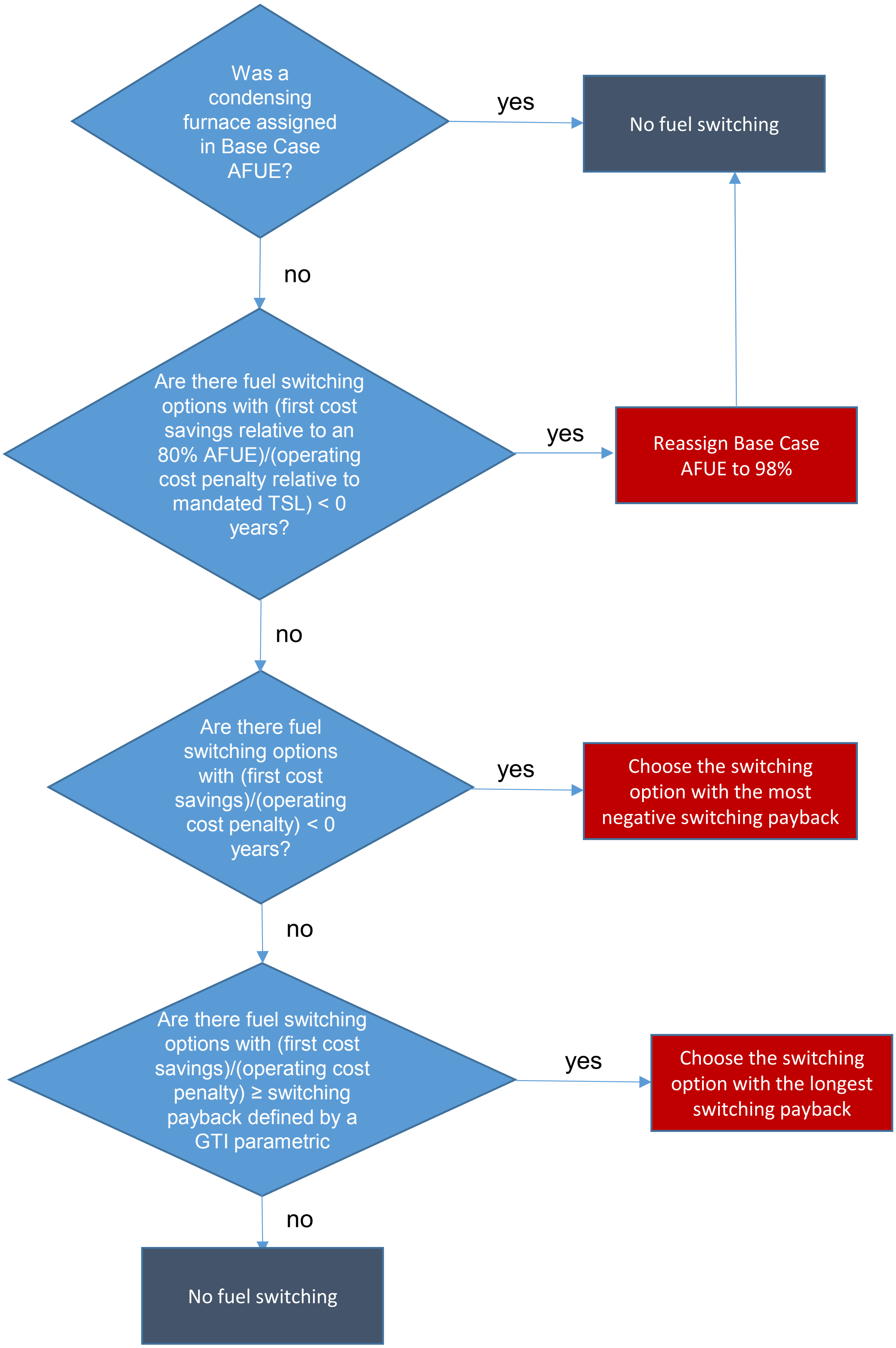


Figure 10 GTI Scenario 24 Fuel Switching Logic Flow Chart

2.6 GTI Decision Making Analysis Methodology

To examine the impact of DOE's random baseline decision making and fuel switching algorithms on modeling results, GTI analysts developed several parametric scenarios that investigate the impact of economic decision making criteria on LCC model results. The scenarios GTI analysts developed and evaluated include various combinations of data, surveys, studies, and engineering principles to incorporate consumer economic and non-economic decision making processes into the LCC analysis. The CED framework, coupled with the availability of detailed information from the AHCS, permitted consideration of a wide range of decision making scenarios under different allowable payback period and "switching payback period" parametrics. Parametrics D1 through D12 explore options for substituting various approaches to incorporating CED factors to address the DOE technical flaws. Appendix A, Sections A.3 and A.4, provides detailed descriptions of these parametrics and associated scenarios.

Decision making scenarios evaluated by GTI analysts incorporate individual and combined parametrics that modify, in the manner specified for each parameter, the DOE LCC model decision making parameters (Scenarios 0 and 19), focusing on base case furnace assignment and fuel switching decision algorithms. Each of the GTI parametric scenarios includes one or more approaches to incorporating the CED framework into the LCC analysis algorithms. Some scenarios modify a single DOE parameter (Scenarios 1, 2, 3, 7, 15, and 16) and show only the individual impact of the revised parameter on LCC savings. Other scenarios modify a combination of parameters in the DOE LCC analysis and show the impact of the revised combined parameters on LCC savings (for example, Scenarios 4 through 6, 8 through 14, 17, 18, and 23 through 27). Others addressed the impact of ignoring fuel switching on analysis results (Scenarios 20 through 22).

It is important to identify and justify the alternative scenario or scenarios that produce credible and technically defensible results for comparisons with the DOE LCC model results. Integrated scenarios that include combinations of scenarios that address economic decision making (GTI Decision Making Scenarios 1 through 18 and 23 through 27) and substitution of improved input data for those used by DOE (GTI Input Variable Scenarios I-1 through I-16), as diagrammed in Table 8, are most suited to that purpose. As noted in Section 2.1, GTI analysts selected Integrated Scenario Int-5 for that purpose. Since Scenario 24 is included in Scenario Int-5 (along with Input Variable Scenario I-16), the methodology description below focuses on Scenario 24, comprising decision making parametrics D2, D4, D5, and D8, which are also summarized below.

Scenario 24 is a reasonable and technically defensible decision making scenario based on overall analytical constraints and assumptions. It corrects random Base Case AFUE assignment with rational consumer economic decision making, thereby avoiding extremely unlikely consumer behavior caused by the random assignment technical flaw in the DOE NOPR LCC analysis. It also incorporates household income into the fuel switching decision based on analysis of data contained in the AHCS. Finally, it generates fuel switching fractions that are reasonably consistent with the DOE baseline fuel switching fractions as well as the 2014 builder and contractor fuel switching survey. It is possible that fuel switching driven by the DOE NOPR will actually exceed this level and be more similar to the levels generated by Scenario 23, but to date GTI has received only anecdotal information to validate this higher level of fuel switching.

The objective of Scenario 24 was to incorporate the CED framework into the LCC analysis for both baseline furnace assignment decisions and fuel switching decisions. Scenario 24 parametrics included substituting a distribution of switching payback periods for the single average 3.5 year switching payback period used by DOE (Parametric D2); assignment of base case furnace using regional shipment data and payback period rather than random assignment (Parametric D4); eliminating negative payback period trial cases from the LCC analysis (Parametric D5); and removing exceptionally rational fuel switching trial cases from the LCC analysis (Parametric D8).

Parametric D2 assigns switching payback periods according to household income rather than the single average value used by DOE. It uses the average payback period for each income group included in detailed survey information collected by Decision Analyst that was summarized in the 2006, 2008, 2010, and 2013 AHCS. Parametric D2 provides a survey-based approach to differentiate the fuel switching decision making across income groups and changes the type and impact of trial cases that are induced to fuel switch by the rule compared to the DOE single point average switching payback methodology that results in overstated LCC savings compared to application of Parametric D2.

Parametric D4 replaces DOE’s random Base Case AFUE assignment with rational economic decision making assignments based on simple payback periods. Base Case AFUE assignments in Parametric D4 couple the payback period for the TSL furnace relative to an 80% AFUE furnace with the cumulative distribution of TSL furnace payback periods in the DOE LCC model. GTI analysts used individual trial case information extracted from the DOE LCC model to develop cumulative distributions of TSL furnace payback periods for each region, installation type (new or replacement), and building type (residential or commercial). Parametric D4 combined these cumulative distributions with the extrapolated shipment data provided by DOE to assign payback periods for furnaces at different efficiencies. By matching the condensing furnace fractions with the associated payback period, D4 provided a pathway to incorporating the CED framework into GTI decision making scenarios, and is included in Scenario 24.

Parametric D5 sets the minimum allowed payback to 0 years to avoid negative payback periods from being considered as part of the “Impacted” group. This is done by assigning trial cases with negative payback periods a 98% AFUE furnace, thereby excluding them from further analysis as “No Impact” trial cases. Parametric D5 is combined with Parametric D4 in Scenario 24 to constrain the Parametric D4 CED framework trial cases that are considered for each TSL furnace in the LCC analysis. It is the most conservative of the three similar CED constraint Parametrics (D5, D6, and D7) explored by GTI analysts.

Parametric D8 removes trial cases where a fuel switching option, such as a low-cost electric heat pump, has a lower first cost than an 80% furnace and operating costs savings relative to a TSL furnace that is included as an “Impacted” trial case in the DOE LCC analysis. Such fuel switching occurrences would likely occur in the absence of a rule, thereby excluding them from further analysis as “No Impact” trial cases. Cases are removed from the “Impacted” group by assigning a Base Case AFUE at 98% so they become “No Impact” cases at all TSLs.

2.7 GTI Input Data Analysis Methodology

To examine the impact of DOE’s input data assumptions on modeling results, GTI analysts developed several parametric scenarios using alternative input data with the potential for significant impact on the DOE LCC model results. In priority order, the GTI Input Data scenarios were based on publicly available market data, targeted surveys, construction and engineering principles, and persuasive anecdotal information. Appendix A, Section A.5, provides a detailed description of these scenarios.

Similar to the GTI decision making scenarios, the input data scenarios evaluated by GTI analysts incorporate individual and combined parametrics that modify, in the manner specified for each parameter, the DOE LCC model input data parameters. Similar to the approach taken in the GTI decision making scenarios, GTI analysts evaluated alternative input parameters with the potential to produce credible and technically defensible results for comparisons with the DOE LCC model results. Since Input Data Scenario I-16 is included in Scenario Int-5 (along with Decision Making Scenario 24), the methodology description below focuses on Scenario I-16, comprising Input Data parametrics I2, I6, I8, and I13, which are also summarized.

The objective of Scenario I-16 was to incorporate furnace pricing data from the 2013 Furnace Price Guide (Parametric I2); substitute marginal gas prices derived from AGA tariff analysis for the DOE marginal gas prices (Parametric I6); incorporate updated AEO 2015 forecasts (Parametric I8), and use condensing furnace market penetration data from AHRI to revise the DOE 2021 forecast of condensing furnace market share (Parametric I13). These substitutions used superior data and forecasts compared to the information used in the DOE NOPR LCC model.

Parametric I2 replaces DOE's retail furnace prices that are derived through a tear down analysis of furnaces with a database of actual offered prices of furnaces. GTI tabulated retail prices provided in the 2013 Furnace Price Guide (https://www.furnacecompare.com/furnaces/price-guide.html), segregated models by efficiency level, adjusted the furnace prices to account for the use of BPM motors in place of PSC motors, and used the adjusted "delivered to home" furnace prices as inputs to the model.

Parametric I6 replaces the DOE NOPR LCC model marginal gas price factors with the marginal price factors developed by AGA using gas companies' tariff data. Similar to DOE, AGA relied on EIA residential natural gas sales and revenues by state (EIA 2013 NG Navigator). However, in contrast to the DOE methodology described in the TSD, AGA developed a fixed cost component of natural gas rates for each state and applied it to the EIA data to develop state level residential marginal price factors. These state level data were then weighted according to furnace shipments in the same manner that DOE uses to generate marginal rates on a regional basis.

Parametric I8 replaces the older 2014 EIA AEO forecasts and utility prices used in the DOE NOPR LCC model with the current 2015 EIA AEO forecasts for energy price trends and updated 2012 gas and electric utility prices.

Parametric I13 uses newly released NWGF condensing and non-condensing furnace shipment data provided to DOE by AHRI to revise the DOE 2021 forecast of base case condensing furnace shipment fraction. AHRI provided updated information in May 2015 regarding NWGF shipment data for the years 2010 through 2014. However, GTI analysts used only AHRI 2014 data to avoid concerns with possible perturbations caused by federal energy credits phased out in 2013 that may have influenced shipment numbers between 2010 and 2013. To create a 2021 forecast trend line that matched actual 2014 shipment data, GTI used 1998 to 2005 trending years. This combined approach resulted in a 2014 condensing furnace shipment fraction of 48%, which is slightly lower than the actual fraction of 48.5% reported by AHRI.

Based on this trend line, Parametric I13 uses a 58.3% condensing furnace shipment fraction for the 2021 baseline instead of DOE's 2021 furnaces shipment fraction of 46.7%, which is an 11.6% increase in the Base Case condensing furnace fraction.

2.8 GTI Integrated Scenario Analysis Methodology

GTI analysts developed and evaluated integrated scenarios comprising technically defensible decision making and input parametrics and scenarios to examine the impact of these combinations on LCC results and fuel switching fractions. The integrated scenarios were cross-checked with the 2014 fuel switching survey results and the DOE NOPR LCC spreadsheet fuel switching fractions to identify scenario combinations that were both technically defensible and consistent with other technical information and data sources. Appendix A, Section A7, provides a detailed description of the integrated scenarios developed and evaluated.

GTI analysts selected Integrated Scenario Int-5, comprising Decision Making Scenario 24 and Input Data Scenario I-16, as the integrated scenario considered most reasonable and technically defensible for comparison with the DOE NOPR LCC model results. Other scenarios may be useful as well based on different factors and purposes. For instance, Scenario Int-6 includes technically defensible assumptions about consumer decision making, but its resulting fuel switching fraction is significantly higher than the DOE fuel switching fraction. Scenarios Int-7 and Int-8 provide interesting analytical results, but their economic decision criteria do not use the AHCS methodology, and their fuel switching fractions differ from the DOE fuel switching fractions.

Scenario Int-5 was preferred over the other integrated scenarios evaluated based in three key factors:

- Baseline furnace assignment that aligns with historical AHRI condensing furnace fractions and consumer economic decision making criteria;
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions;
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices; and more current AEO forecast information.

These factors increase the confidence that GTI Integrated Scenario Int-5 produces credible and technically defensible results that are well-suited for direct comparisons with the DOE NOPR LCC model results.

3 LCC Parametric Scenario Analysis Results

3.1 GTI Decision Making Scenario 24 Results

Table 14 shows relative LCC savings for each TSL based on Scenario 24 as compared to the DOE NOPR LCC analysis results.

Table 15 shows fuel switching percentages in homes impacted by the rule for each TSL under Scenario 24 as compared to the DOE NOPR LCC analysis results.

To facilitate comparisons of LCC analysis results, Table 16 summarizes LCC analysis results for the DOE NOPR LCC model. In this table and similar GTI scenario tables, the asterisk in the "Lifetime Operating Cost" header refers to the operating cost discounted and summed over lifetime of the product.

Table 17 summarizes LCC analysis results under Scenario 24, using the same categories as in Table 16.

Key findings of the decision making scenario analysis conducted by GTI analysts using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- DOE's random baseline furnace assignment methodology is technically flawed. Replacing DOE's methodology with economic decision making criteria changes both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and significantly reduces the financial benefit of the rule nationally, regionally, and by subgroup.
- DOE's predictive LCC model results combine random decisions and limited application of economic decisions that overstate LCC savings compared to a CED framework methodology.

Table 14 LCC Savings – DOE NOPR vs. GTI Decision Making Scenario 24

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
GTI Scenario 24	-$80	-$117	-$40	-$117	-$167	-$64	$37	$29	$46	-$73	-$279
	LCC Savings Summary - 92% TSL										
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
GTI Scenario 24	-$30	-$66	$10	-$65	-$120	-$4	$75	$85	$63	-$21	-$237
	LCC Savings Summary - 95% TSL										
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
GTI Scenario 24	$25	-$9	$63	-$14	-$69	$45	$140	$149	$129	$10	-$208
	LCC Savings Summary - 98% TSL										
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
GTI Scenario 24	$50	$42	$58	$5	$9	$0	$159	$91	$240	$75	-$182

Table 15 Fuel Switching Results – DOE NOPR vs. GTI Decision Making Scenario 24

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	Percent of Impacted Buildings Switching - 90% TSL										
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
GTI Scenario 24	21.0%	18.0%	22.6%	21.4%	17.4%	23.2%	18.1%	20.1%	13.2%	23.9%	29.7%
	Percent of Impacted Buildings Switching - 92% TSL										
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
GTI Scenario 24	19.3%	15.1%	21.9%	20.1%	15.3%	22.5%	14.1%	14.7%	12.2%	21.1%	28.3%
	Percent of Impacted Buildings Switching - 95% TSL										
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
GTI Scenario 24	18.5%	11.7%	24.0%	19.3%	11.6%	24.2%	15.3%	11.9%	23.1%	19.3%	24.9%
	Percent of Impacted Buildings Switching - 98% TSL										
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
GTI Scenario 24	19.2%	9.1%	31.2%	19.6%	8.0%	32.5%	18.4%	14.1%	25.1%	18.2%	25.1%

Table 16 DOE NOPR LCC Analysis Summary Results (GTI Scenario 0)

Simulation Results NATIONAL - 10000 samples		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,218	$10,314	$12,533						
1	NWGF 90%	$2,654	$9,388	$12,042	$236	22%	47%	32%	18.0	10.6
2	NWGF 92%	$2,669	$9,228	$11,897	$305	20%	41%	39%	13.9	7.7
3	NWGF 95%	$2,788	$8,985	$11,773	$388	24%	23%	53%	12.9	8.9
4	NWGF 98%	$2,948	$8,771	$11,718	$441	40%	0%	60%	16.8	12.0

Simulation Results NORTH		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,410	$12,923	$15,333						
1	NWGF 90%	$2,985	$11,761	$14,746	$208	11%	67%	22%	13.9	8.8
2	NWGF 92%	$3,000	$11,555	$14,556	$277	10%	60%	30%	10.3	5.3
3	NWGF 95%	$3,133	$11,251	$14,385	$374	14%	40%	46%	10.2	7.8
4	NWGF 98%	$3,311	$10,979	$14,290	$467	37%	1%	62%	15.5	11.8

Simulation Results Rest of Country		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,003	$7,374	$9,376						
1	NWGF 90%	$2,280	$6,714	$8,994	$267	33%	24%	42%	20.1	11.8
2	NWGF 92%	$2,295	$6,606	$8,901	$336	31%	20%	49%	16.1	9.5
3	NWGF 95%	$2,398	$6,430	$8,828	$404	35%	5%	60%	14.8	10.1
4	NWGF 98%	$2,539	$6,281	$8,820	$412	43%	0%	57%	18.3	12.4

Simulation Results Low Income Only		DOE NOPR LCC Model (GTI Scenario 0)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,983	$10,641	$12,625						
1	NWGF 90%	$2,498	$9,720	$12,218	$176	26%	43%	31%	19.6	12.8
2	NWGF 92%	$2,512	$9,562	$12,074	$247	23%	38%	39%	16.2	10.0
3	NWGF 95%	$2,618	$9,328	$11,945	$330	26%	24%	51%	13.1	9.5
4	NWGF 98%	$2,776	$9,012	$11,789	$485	43%	1%	56%	17.4	12.7

Table 17 GTI Scenario 24 LCC Analysis Summary Results

Simulation Results NATIONAL - 10000 samples		Scenario 24 (D2, D4, D5, D8)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,218	$10,441	$12,659						
1	NWGF 90%	$2,648	$9,563	$12,211	-$80	28%	56%	16%	28.2	20.0
2	NWGF 92%	$2,662	$9,402	$12,064	-$30	26%	52%	23%	21.5	15.8
3	NWGF 95%	$2,779	$9,183	$11,962	$25	27%	37%	36%	17.0	12.1
4	NWGF 98%	$2,931	$9,031	$11,962	$50	36%	16%	48%	17.2	12.7

Simulation Results NORTH		Scenario 24 (D2, D4, D5, D8)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,408	$13,165	$15,573						
1	NWGF 90%	$2,974	$12,042	$15,016	-$117	20%	70%	10%	27.6	22.5
2	NWGF 92%	$2,989	$11,831	$14,820	-$66	18%	65%	17%	19.6	16.3
3	NWGF 95%	$3,118	$11,543	$14,661	-$9	21%	47%	32%	14.9	11.3
4	NWGF 98%	$3,286	$11,329	$14,614	$42	35%	14%	52%	15.2	12.6

Simulation Results Rest of Country		Scenario 24 (D2, D4, D5, D8)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,004	$7,371	$9,375						
1	NWGF 90%	$2,280	$6,770	$9,049	-$40	37%	39%	23%	28.6	18.5
2	NWGF 92%	$2,294	$6,663	$8,958	$10	34%	37%	30%	22.8	15.3
3	NWGF 95%	$2,397	$6,522	$8,919	$63	34%	25%	41%	18.7	12.6
4	NWGF 98%	$2,530	$6,442	$8,972	$58	38%	18%	44%	19.8	12.9

Simulation Results Low Income Only		Scenario 24 (D2, D4, D5, D8)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,975	$10,773	$12,747						
1	NWGF 90%	$2,450	$10,111	$12,561	-$279	33%	52%	15%	25.9	20.8
2	NWGF 92%	$2,464	$9,958	$12,422	-$237	30%	49%	21%	20.4	17.0
3	NWGF 95%	$2,567	$9,772	$12,339	-$208	32%	35%	33%	16.8	13.0
4	NWGF 98%	$2,696	$9,658	$12,355	-$182	45%	10%	45%	17.6	13.4

3.2 GTI Input Data Scenario I-16 Results

Table 18 shows the relative LCC savings for each TSL under Scenario I-16 compared to the DOE NOPR LCC analysis results.

Table 19 shows fuel switching percentages in homes impacted by the rule for each TSL under Scenario I-16 compared to the DOE NOPR LCC analysis results.

Table 20 summarizes LCC analysis results under Scenario I-16.

Key findings of the input variable scenario analysis conducted by GTI analysts using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- DOE's predictive LCC model results include an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the EIA 2013 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data. Taken together, the DOE input information and forecasts associated with these parameters increase LCC savings compared to more current forecasts and available market data.

Table 18 LCC Savings – DOE NOPR vs. GTI Input Data Scenario I-16

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
GTI Scenario I-16	$54	$77	$28	-$36	$13	-$90	$306	$246	$376	$76	$7
	LCC Savings Summary - 92% TSL										
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
GTI Scenario I-16	$105	$124	$85	$12	$55	-$36	$361	$298	$437	$128	$59
	LCC Savings Summary - 95% TSL										
DOE NOPR (GTI Scenario 0)	$388	$388	$388	$388	$388	$388	$388	$388	$388	$388	$388
GTI Scenario I-16	-$100	-$100	-$100	-$100	-$100	-$100	-$100	-$100	-$100	-$100	-$100
	LCC Savings Summary - 98% TSL										
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
GTI Scenario I-16	-$83	-$66	-$103	-$123	-$67	-$185	$34	-$93	$185	$116	$0

Table 19 Fuel Switching – DOE NOPR vs. GTI Input Data Scenario I-16

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	Percent of Impacted Buildings Switching - 90% TSL										
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
GTI Scenario I-16	18.2%	12.7%	20.4%	17.8%	11.3%	20.0%	20.3%	16.4%	22.2%	22.2%	16.5%
	Percent of Impacted Buildings Switching - 92% TSL										
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
GTI Scenario I-16	16.0%	9.6%	19.0%	15.9%	8.8%	18.8%	17.1%	11.9%	20.3%	19.6%	14.7%
	Percent of Impacted Buildings Switching - 95% TSL										
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
GTI Scenario I-16	23.0%	10.0%	31.4%	23.6%	8.9%	31.7%	22.2%	12.3%	31.0%	21.8%	22.1%
	Percent of Impacted Buildings Switching - 98% TSL										
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
GTI Scenario I-16	19.6%	6.0%	34.7%	18.9%	4.6%	34.3%	22.2%	9.9%	36.6%	17.1%	19.4%

Table 20 GTI Input Data Scenario I-16 LCC Analysis Summary Results

Simulation Results NATIONAL - 10000 samples					Scenario I-16 (I2, I6, I8, I13)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,016	$10,032	$12,048						
1	NWGF 90%	$2,653	$9,219	$11,872	$54	22%	58%	20%	24.9	15.3
2	NWGF 92%	$2,668	$9,069	$11,737	$105	20%	52%	28%	18.1	10.0
3	NWGF 95%	$3,186	$8,860	$12,046	-$100	51%	28%	21%	37.2	27.2
4	NWGF 98%	$3,335	$8,693	$12,029	-$83	66%	1%	33%	31.7	22.8

Simulation Results NORTH					Scenario I-16 (I2, I6, I8, I13)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,219	$12,366	$14,585						
1	NWGF 90%	$3,001	$11,332	$14,333	$77	10%	78%	12%	18.2	12.6
2	NWGF 92%	$3,017	$11,142	$14,159	$124	9%	71%	20%	12.1	6.3
3	NWGF 95%	$3,655	$10,922	$14,577	-$120	40%	47%	13%	37.4	28.4
4	NWGF 98%	$3,829	$10,693	$14,521	-$66	65%	1%	34%	28.0	21.4

Simulation Results Rest of Country					Scenario I-16 (I2, I6, I8, I13)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,788	$7,401	$9,189						
1	NWGF 90%	$2,260	$6,839	$9,099	$28	35%	36%	29%	27.6	16.6
2	NWGF 92%	$2,275	$6,733	$9,007	$85	33%	30%	36%	21.1	12.4
3	NWGF 95%	$2,658	$6,537	$9,194	-$78	63%	7%	29%	37.1	26.2
4	NWGF 98%	$2,780	$6,439	$9,219	-$103	68%	0%	32%	36.4	25.3

Simulation Results Low Income Only					Scenario I-16 (I2, I6, I8, I13)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,771	$10,279	$12,050						
1	NWGF 90%	$2,469	$9,497	$11,966	$7	24%	58%	19%	27.4	18.0
2	NWGF 92%	$2,484	$9,347	$11,831	$59	23%	52%	26%	20.4	13.0
3	NWGF 95%	$2,876	$9,162	$12,038	-$78	48%	30%	22%	30.1	24.2
4	NWGF 98%	$3,023	$8,936	$11,959	$0	65%	1%	34%	30.1	23.4

3.3 GTI Integrated Scenario Int-5 Results

Table 21 shows LCC savings for each TSL under GTI Scenario Int-5 compared to the DOE NOPR LCC analysis results.

Table 22 shows fuel switching percentages in homes impacted by the rule for each TSL under GTI Scenario Int-5 compared to the DOE NOPR LCC analysis results.

Table 23 provides information on energy and environmental impacts in homes impacted by the rule for each TSL under GTI Scenario Int-5 compared to the DOE NOPR LCC analysis results.

Table 24 summarizes LCC analysis results under GTI Scenario Int-5.

Key findings of the integrated scenario analysis conducted by GTI analysts using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- GTI Integrated Scenario Int-5, based on rational consumer economic decision criteria and modifications to DOE's input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace, indicating that the 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the EPCA requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life.
- GTI Integrated Scenario Int-5 also shows increased annual primary energy consumption and greenhouse gas emissions for three of the four condensing furnace trial standard levels (90%, 92%, and 95% AFUE) compared to the 80% AFUE baseline furnace, whereas DOE's LCC model results show decreased annual primary energy consumption and greenhouse gas emissions.

Table 21 LCC Savings – DOE NOPR vs. GTI Integrated Scenario Int-5

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
					LCC Savings Summary - 90% TSL						
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
GTI Scenario Int-5	-$215	-$159	-$278	-$266	-$184	-$355	-$68	-$93	-$39	-$212	-$555
					LCC Savings Summary - 92% TSL						
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
GTI Scenario Int-5	-$181	-$131	-$237	-$233	-$161	-$310	-$36	-$55	-$14	-$183	-$533
					LCC Savings Summary - 95% TSL						
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
GTI Scenario Int-5	-$445	-$520	-$361	-$443	-$458	-$427	-$430	-$687	-$126	-$302	-$804
					LCC Savings Summary - 98% TSL						
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
GTI Scenario Int-5	-$447	-$497	-$390	-$443	-$420	-$469	-$456	-$755	-$102	-$261	-$743

Table 22 Fuel Switching – DOE NOPR vs. GTI Integrated Scenario Int-5

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
					Percent of Impacted Buildings Switching - 90% TSL						
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
GTI Scenario Int-5	25.6%	20.8%	27.6%	25.6%	21.5%	27.0%	26.4%	19.7%	32.3%	33.5%	36.6%
					Percent of Impacted Buildings Switching - 92% TSL						
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
GTI Scenario Int-5	22.4%	15.7%	25.9%	22.9%	17.0%	25.2%	21.3%	13.2%	31.1%	27.7%	33.1%
					Percent of Impacted Buildings Switching - 95% TSL						
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
GTI Scenario Int-5	28.2%	16.3%	35.9%	30.2%	17.9%	36.8%	23.2%	13.3%	32.8%	27.4%	35.8%
					Percent of Impacted Buildings Switching - 98% TSL						
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
GTI Scenario Int-5	23.4%	9.9%	38.5%	23.3%	9.0%	38.8%	24.1%	12.4%	37.8%	20.6%	26.9%

Table 23 Energy and GHG Emissions – DOE NOPR vs. GTI Integrated Scenario Int-5

Scenario	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
				Impacted Buildings - 90% TSL				
DOE NOPR (GTI Scenario 0)	37.2	28.8	312.4	1,045.3	-22%	235%	-1.2	-158.5
GTI Scenario Int-5	29.2	20.4	266.4	1,256.1	-30%	371%	1.0	145.4
				Impacted Buildings - 92% TSL				
DOE NOPR (GTI Scenario 0)	37.4	29.3	314.1	960.7	-22%	206%	-2.0	-258.2
GTI Scenario Int-5	30.1	21.9	272.1	1,138.6	-27%	318%	0.3	51.8
				Impacted Buildings - 95% TSL				
DOE NOPR (GTI Scenario 0)	37.9	29.9	317.4	911.8	-21%	187%	-2.3	-301.7
GTI Scenario Int-5	32.4	22.9	288.6	1,340.3	-29%	364%	0.9	130.3
				Impacted Buildings - 98% TSL				
DOE NOPR (GTI Scenario 0)	39.4	31.1	322.7	952.4	-21%	195%	-2.3	-308.4
GTI Scenario Int-5	38.4	29.9	319.2	1,179.4	-22%	270%	-0.1	-9.1

Table 24 GTI Scenario Int-5 LCC Analysis Summary Results

Simulation Results NATIONAL - 10000 samples		Scenario Int 5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,016	$9,984	$12,001						
1	NWGF 90%	$2,634	$9,266	$11,900	-$215	28%	62%	10%	39.2	28.0
2	NWGF 92%	$2,649	$9,123	$11,772	-$181	27%	57%	17%	28.0	19.8
3	NWGF 95%	$3,139	$9,017	$12,156	-$445	57%	29%	14%	40.4	32.5
4	NWGF 98%	$3,283	$8,882	$12,165	-$447	68%	2%	30%	30.8	24.6

Simulation Results NORTH		Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$2,219	$12,304	$14,523						
1	NWGF 90%	$2,986	$11,337	$14,323	-$159	15%	79%	6%	38.3	31.0
2	NWGF 92%	$3,001	$11,158	$14,159	-$131	15%	72%	13%	23.9	17.1
3	NWGF 95%	$3,598	$11,090	$14,688	-$520	47%	48%	5%	45.5	41.2
4	NWGF 98%	$3,763	$10,920	$14,683	-$497	66%	3%	32%	27.6	23.3

Simulation Results Rest of Country		Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,788	$7,370	$9,158						
1	NWGF 90%	$2,238	$6,931	$9,168	-$278	42%	44%	14%	39.7	27.0
2	NWGF 92%	$2,252	$6,829	$9,080	-$237	40%	39%	21%	30.3	21.0
3	NWGF 95%	$2,622	$6,681	$9,303	-$361	68%	9%	23%	36.9	27.4
4	NWGF 98%	$2,743	$6,583	$9,326	-$390	71%	2%	27%	34.7	25.9

Simulation Results Low Income Only		Scenario Int 5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)								
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
NWGF										
0	NWGF 80%	$1,771	$10,201	$11,972						
1	NWGF 90%	$2,413	$9,873	$12,286	-$555	31%	61%	8%	39.1	28.1
2	NWGF 92%	$2,427	$9,737	$12,164	-$533	30%	56%	14%	29.0	21.1
3	NWGF 95%	$2,795	$9,743	$12,538	-$804	51%	36%	13%	36.6	30.1
4	NWGF 98%	$2,933	$9,575	$12,507	-$743	69%	2%	28%	31.5	25.1

4 National Primary Energy and Emissions Impact Assessment

The DOE NOPR LCC model results provide input information to the DOE NOPR National Impact Analysis (NIA) that is summarized in the DOE NIA spreadsheet. The underlying model used to estimate national impacts of the proposed rule is the NEMS model, an economic and energy model of U.S. energy markets created and maintained by EIA (http://www.eia.gov/oiaf/aeo/overview/index.html). NEMS projects the production, consumption, conversion, import, and pricing of energy. The model relies on assumptions for economic variables, including world energy market interactions, resource availability (which influences costs), technological choice and characteristics, and demographics. DOE's NIA spreadsheet summarizes the results of the NEMS model, but provides no opportunity to adjust impacts based on different LCC model results.

Although GTI was not able to adjust the DOE NIA model inputs to determine the national impact of the DOE NOPR LCC model technical flaws, the LCC analysis provided enough annual energy consumption information to estimate the national impact of the proposed rule. GTI analysts conducted a 30 year analysis of the projected national impact of the proposed furnace rulemaking based on the DOE NOPR LCC model results and the GTI Integrated Scenario Int-5 analysis results.

The GTI national primary energy and emissions impact assessment described below focused on residential consumers based on a total of 53,780,000 U. S. residences with natural gas furnaces. The assessment started with collection of output information from the 10,000 Crystal Ball trial cases, of which 9,717 are residential cases. The VBA code developed by GTI analysts enabled capture of the distribution of annual energy consumption by energy form along with the "Net Benefit," "Net Cost," and "No Impact" category for each of the 9,717 representative residential cases. This approach allowed a direct comparison of aggregated representative results between the DOE NOPR LCC model and the GTI Integrated Scenario Int-5 analysis. The 9,717 representative case results were then extrapolated over the entire U.S. residential furnace population to derive an estimate of the national primary (or source) energy use and CO_2e emissions impacts.

Figure 11 and Figure 12 summarize the results of GTI's national primary energy and emissions impact assessment. In the DOE NOPR the number of affected homes was 5,706, while the GTI Scenario Int-5 analysis concluded that 4,226 homes would be affected. This nearly 26% reduction in the number of homes impacted by DOE's proposed rule represents one of the key national impact differences between the DOE NOPR LCC model and GTI Scenario Int-5.

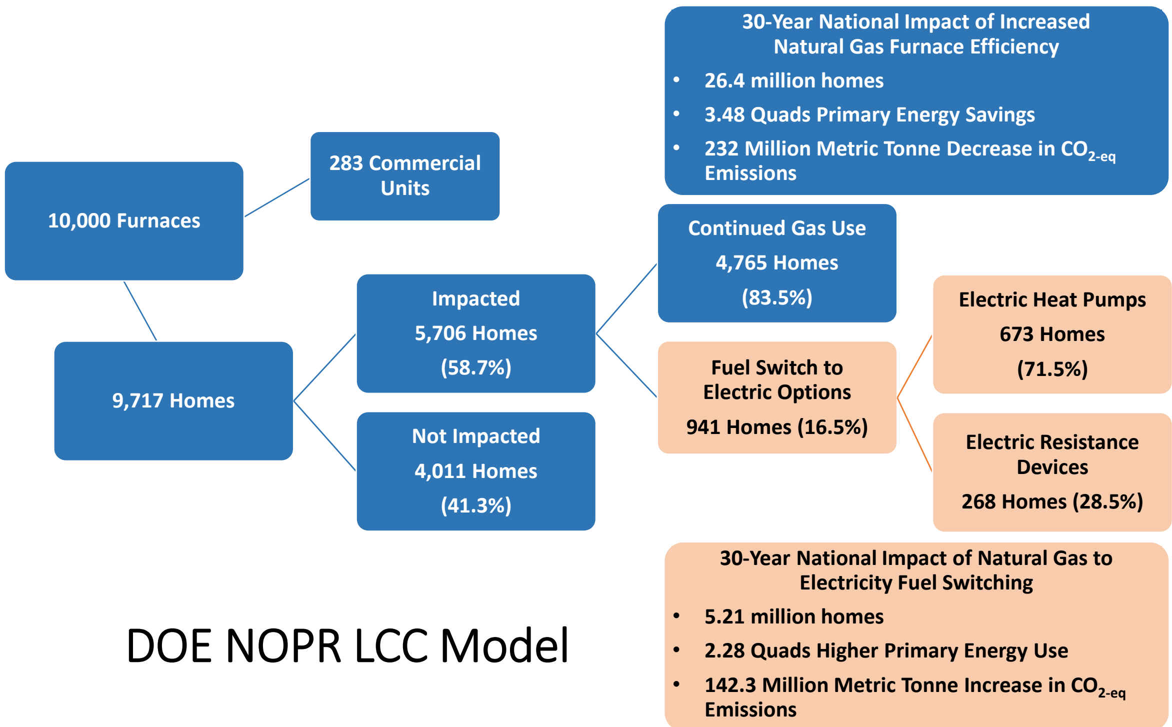


Figure 11: DOE NOPR LCC Model Impacts

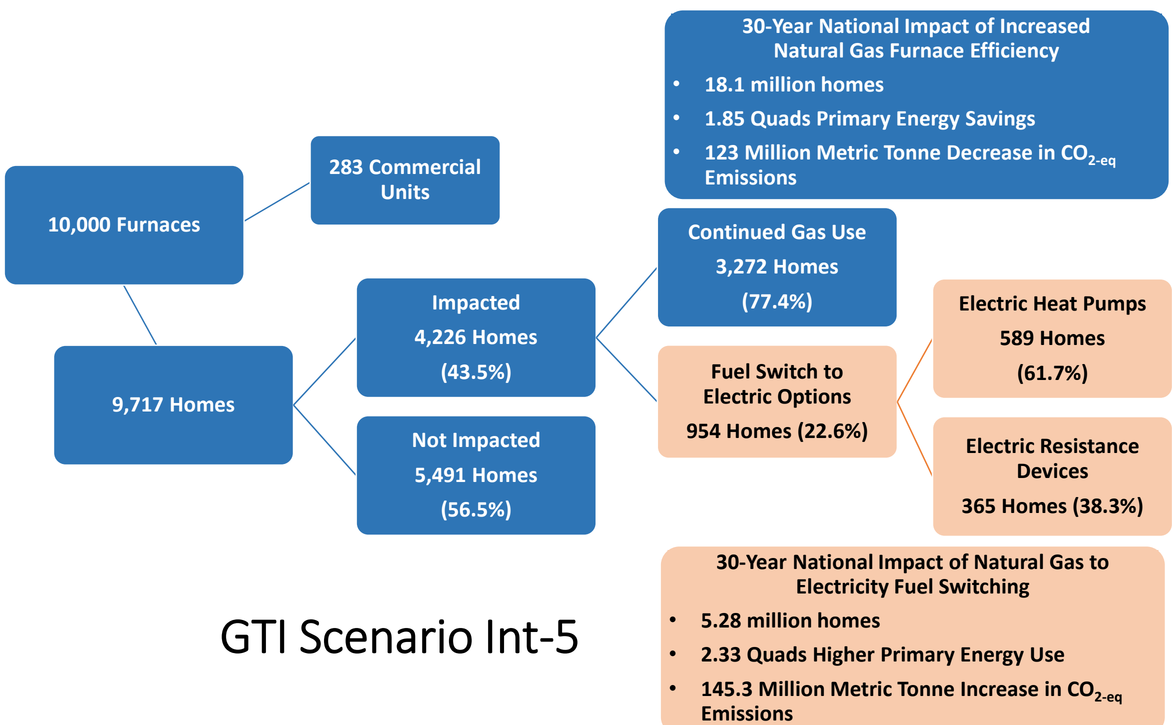


Figure 12: GTI Scenario Int-5 Impacts

There are two categorical decision outcomes for homes impacted by DOE's proposed rule:

1. Continued use of natural gas (with a higher efficiency furnace); or
2. Fuel switch to an electric option.

For the first decision outcome (continued use of natural gas), GTI calculated the estimated 30-year full market impact of this shift of natural gas customers to higher-efficiency natural gas furnaces. The DOE NOPR LCC model results show that 49% of homes – about 26.4 million homes – would incrementally adopt high-efficiency furnaces [(4,765/9,717)*53,780,000]. The analytical results show an average per home annual savings of 4.4 MMBtu/year for this population subset. This results in annal savings of 116 Trillion Btu/year, which is about 2.4% of average residential natural gas use over the past five years, and a projected 3.48 Quads of primary energy saved over a thirty-year time horizon, using a primary energy conversion factor of 1.09 derived from GTI's Source Energy and Emissions Analysis Tool (SEEAT) available to the public for free (at www.cmictools.com). This translates into a thirty-year CO_2e emission reduction of 232 million metric tonnes, using a CO_2e emission factor of 147 lb per MMBtu for natural gas derived from SEEAT. CO_2e includes the direct CO_2 and methane emissions of natural gas, plus upstream energy and related methane losses.

In contrast, the GTI Scenario Int-5 results show that 34% of homes – about 18.1 million homes – would incrementally adopt high-efficiency furnaces [(3,272/9,717)*53,780,000]. This is a 31% reduction compared to the DOE NOPR LCC model. Further, the analytical results show the average per home annual savings is 3.4 MMBtu/year for this population subset. This value is 23% less than the DOE NOPR analysis of 4.4 MMBtu/year and reflects a more realistic correlation with homes in warmer climates that use less natural gas for space heating on an annual basis. This results in annal savings of 61.6 Trillion Btu/year, which is about 1.3% of average residential natural gas use over the past five years. This is a projected 1.85 Quads of energy saved over a thirty-year time horizon. Importantly, this value is 47% less than is estimated in the DOE NOPR LCC model. This also translates into a thirty-year carbon dioxide equivalent savings of 123 million metric tonnes, using a primary energy emission factor of 147 lb CO_2e per MMBtu for natural gas.

The shift of natural gas consumers to higher efficiency furnaces is the intended focus of the proposed rulemaking. However, both the DOE NOPR LCC model and GTI Scenario Int-5 show that a significant proportion of homes would be induced to fuel switch to electric options that are often less source energy-efficient than the natural gas furnace or water heater.

For the second decision outcome noted above (fuel switch to an electric option), GTI calculated the estimated 30-year full market impact of this shift of natural gas customers to electric options, including heat pumps and electric resistance furnaces and water heaters using a primary energy conversion factor of 3.14 and a CO2e emission factor of 1,454 lb/MWh derived from SEEAT for electricity . For the DOE NOPR LCC model, the results show that 9.7% of homes – about 5.21 million homes – would fuel switch to electric options [(941/9,717)*53,780,000]. This includes electric heat pumps and electric furnaces, with attendent secondary impact on water heater selections also occurring.

Both the DOE NOPR LCC model and GTI Scenario Int-5 fuel switching results show an overall increase in primary energy use and CO_2e emissions due to fuel switching caused by DOE's proposed rule. GTI Scenario Int-5 results indicate incrementally higher negative fuel switching outcomes due to a higher proportion of consumers choosing primary energy-inefficient electric resistance equipment to meet their space and water heating needs.

Table 25 provides a detailed breakdown of the five different pathways that fuel switching from natural gas to electric options were projected under the DOE NOPR LCC model analysis and the impacts in terms of increased primary energy use and greater CO_2e emissions. The greatest increases in primary energy and CO_2e emissions per home result from a shift to electric resistance space and water heating devices.

Table 25: Residential Case Fuel Switching Details – DOE NOPR LCC Model

DOE NOPR LCC Model	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Total Homes	580	93	188	62	18
Change in Gas Use (MMBtu)	-25.1	-36.4	-20.4	-41.3	-8.9
Change in Electric Use (kWh)	3,140.4	4,886.8	4,953.4	8,873.9	1,230.9
Change in Source energy (MMBtu)	6.2	12.7	30.8	49.9	3.5
Change in emissions (lbs CO_{2e})	869.9	1,760.4	4,201.6	6,824.5	484.9

Table 26 provides an expanded breakdown of the five different pathways for natural gas to electricity fuel switching extended over the entire market for the DOE NOPR LCC model analysis. This shows annual and thirty-year full market impact in terms of increased primary energy use and greater CO_2e emissions.

Table 26: National Fuel Switching Impact Details – DOE NOPR LCC Model

DOE NOPR LCC Model	Annual National Impacts	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Number of Homes	5,208,087	3,210,085	514,721	1,040,510	343,147	99,623
Primary Energy (TBtu)	76.0	19.9	6.5	32.0	17.1	0.3
Carbon Emissions (MMT CO_2e)	4.7	1.3	0.4	2.0	1.1	0.0
	Thirty Year National Impacts	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Primary Energy (TBtu)	2,279.5	598.3	195.9	960.8	514.0	10.5
Carbon Emissions (MMT CO_2e)	142.3	38.0	12.3	59.5	31.9	0.7

GTI Scenario Int-5 results show that 9.8% of homes – about 5.28 million homes – would fuel switch to electric options [(954/9,717)*53,780,000]. In this scenario, there is a larger portion of homes that select a low first cost electric resistance device (36% more than in the DOE NOPR LCC model).

Table 27 provides a detailed breakdown of the five different pathways that fuel switching from natural gas to electric options were projected under the GTI Scenario Int-5 analysis along with the impacts in terms of increased primary energy use and greater CO_2e emissions. The greatest increases in primary energy and CO_2e emissions result from a shift to electric resistance space and water heating devices.

Table 27: Residential Case Fuel Switching Details – GTI Scenario Int-5

GTI Scenario Int-5	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Total Homes	489	100	284	71	10
Change in Gas Use (MMBtu)	-25.8	-43.9	-15.6	-26.5	-4.8
Change in Electric Use (kWh)	3,254.0	6,064.1	3,777.9	5,771.2	696.5
Change in Source energy (MMBtu)	6.8	17.1	23.4	32.9	2.3
Change in emissions (lbs CO_{2e})	944.5	2,370.5	3,197.9	4,492.5	312.5

Table 28 provides an expanded breakdown of the five different pathways for natural gas to electricity fuel switching extended over the entire market for GTI Scenario Int-5. This shows annual and thirty-year full market impact in terms of increased primary energy use and greater CO_2e emissions.

Table 28: National Fuel Switching Impact Details – GTI Scenario Int-5

GTI Scenario Int-5	Annual National Impacts	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Number of Homes	5,280,037	2,706,434	553,463	1,571,835	392,959	55,346
Primary Energy (TBtu)	77.6	18.3	9.5	36.8	12.9	0.1
Carbon Emissions (MMT CO_2	4.8	1.2	0.6	2.3	0.8	0.0
	Thirty Year National Impacts	Gas Furnace To Electric Heat Pump	Gas Furnace & Water Heater To Electric Heat Pump & Water Heater	Gas Furnace To Electric Furance	Gas Furnace & Water Heater To Electric Furnace & Water Heater	Gas Water Heater to Electric Water Heater
Primary Energy (TBtu)	2,328.9	548.7	284.2	1,104.7	387.6	3.8
Carbon Emissions (MMT CO_2	145.3	34.8	17.9	68.4	24.0	0.2

5 Conclusions

DOE issued a NOPR that proposes a single national standard at a minimum efficiency level of 92% AFUE for non-weatherized gas furnaces and mobile home gas furnaces. DOE released an extensive TSD to substantiate the NOPR, which included a detailed review of the effects of the NOPR as well as economic modeling to assess consumer-level cost impacts.

GTI conducted a technical and economic analysis of the NOPR to evaluate the impact of the 92% AFUE minimum furnace efficiency requirements along with other TSLs on consumers. The analysis included a detailed examination of the following:

- DOE TSD modeling approach, assumptions, and results;
- DOE NOPR Life Cycle Cost (LCC) analysis spreadsheet and Crystal Ball model;
- Rational Consumer Economic Decision framework and related methodologies developed by GTI;
- Surveys (e.g., American Home Comfort Study) and data on input variables judged to have potential impact on LCC analysis results; and
- Estimates of consumer benefits and costs associated with the 92% furnace standard as well as other trial standard levels of furnace efficiency.

As a result of this detailed examination, GTI uncovered a serious technical flaw in the methodology DOE used to establish the homes that would be impacted by the proposed rule. Specifically, the Base Case furnace assignment algorithm used by DOE ignores economic decision making by the consumer. Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly in the DOE NOPR LCC model. This technical flaw results in overstated LCC savings in the proposed rule.

GTI also uncovered a serious technical flaw in the methodology DOE used in its fuel switching analysis. DOE used a single switching payback value of 3.5 years for fuel switching decisions in its algorithm based on an average tolerable payback period for more efficient appliance purchases derived from proprietary American Home Comfort Study (AHCS) survey information. In addition, the DOE fuel switching analysis includes as a rule benefit cases in which rational fuel switching would accrue incremental benefits to the consumer compared to the TSL furnace. These technical flaws also result in overstated LCC savings in the proposed rule.

Key input data used in the DOE NOPR LCC model are also inaccurate or outdated. DOE uses an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the EIA 2013 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data. Taken together, the DOE input information and forecasts associated with using these data overstate LCC savings compared to more current forecasts and credible market data.

After uncovering these serious technical deficiencies, GTI developed an alternative approach to determine the baseline using a consumer economic decision (CED) framework based on criteria that more accurately depict how consumers choose one furnace option over another and the manner in which consumers make fuel switching decisions. GTI also identified a number of improvements to the input data used in the DOE NOPR LCC model. GTI Integrated Scenario Int-5 includes several refinements to the DOE NOPR LCC model, including rational consumer economic decision making and improved input data, and forms the primary basis for comparison to proposed furnace efficiency rulemaking. Other scenarios are technically defensible as well based on different factors and are included for reference purposes. GTI Scenario Int-5 was selected based on three key factors:

- Baseline furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions when using a CED framework for Base Case furnace assignment and fuel switching decisions
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices; and more current AEO forecast information

Key findings of the scenario analysis conducted by GTI analysts using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- DOE's random Base Case furnace assignment methodology is technically flawed. DOE misallocated 22% of residential trial cases by using a random furnace assignment methodology, resulting in overstated benefits in the NOPR. Replacing DOE's technically flawed methodology with rational economic decision making criteria substantially shifts both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and appreciably lowers the financial benefit of the proposed rule.

- The DOE NOPR LCC model results combine random decisions and limited application of economic decisions in the fuel switching decision algorithms that overstate LCC savings compared to a CED framework methodology included in GTI Integrated Scenario Int-5.

- The DOE NOPR LCC model results include outdated and lower quality input data than the input data selected for inclusion in GTI Integrated Scenario Int-5. The DOE NOPR LCC model includes an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available furnace price market data; marginal gas prices derived from the EIA 2013 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data available in May 2015. Taken together, the DOE input information and forecasts associated with these parameters overstate LCC savings compared to more current forecasts and available market data, resulting in overstated benefits in the NOPR.

- GTI Integrated Scenario Int-5, based on improved consumer economic decision criteria and refinements to DOE's outdated and lower quality input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace. Based on these findings, the 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the EPCA requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life.

- GTI Integrated Scenario Int-5 results also show increased annual primary energy consumption and greenhouse gas emissions for three of the four condensing furnace trial standard levels (90%, 92%, and 95% AFUE) compared to the 80% AFUE baseline furnace, whereas the DOE NOPR LCC model results show decreased annual primary energy consumption and greenhouse gas emissions. This increase in primary (or source) energy and associated greenhouse gas emissions results from fuel switching to electric options that are less efficient on a primary energy basis, especially electric resistance furnaces and electric resistance water heaters, as well as electric heat pumps in northern climates.

Appendix A Parametric and Scenario Analysis Details

A.1 Overview

This report contains a higher degree of granularity than exists in the DOE LCC spreadsheet model and published results. Many of the desired outputs of DOE's model were not provided in sufficient detail to conduct analysis on individual case and subcategory results. The addition of Visual Basic for Application (VBA) code that exported outputs of interest to a new spreadsheet enabled this level of detailed analysis. The VBA code used for this purpose stepped the baseline model through each of the 10,000 individual trials while the Crystal Ball simulation was running and enabled capture of key information related to individual trial cases. The VBA code to capture data output did not affect the calculation of any parameters for the DOE LCC Model (referred to as Scenario 0 in this report and accompanying spreadsheets). Nor did it affect the calculations in any of the GTI parametric runs that examined the decision making methodology, input data assumptions, and integrated scenarios. However, additional VBA code was added as necessary to apply GTI parametric decision making methodology algorithms described in this Appendix.

The following Excel spreadsheets accompany this report:

21693 Short LCC tables - all EL - Decisions & Summaries - 2015-07-07.xlsx,
21693 Short LCC tables - all EL - Inputs and Integrated Only - 2015-07-07.xlsx,
21693 Short Switching Tables - Decisions & Summaries - 2015-07-07.xlsx,
21693 Short Switching Tables - Inputs and Integrated Only - 2015-07-07.xlsx,
21693 Energy Use Tables - Decisions & Summaries - 2015-07-07.xlsx, and
21693 Energy Use Tables - Inputs and Integrated Only - 2015-07-07.xlsx.

These spreadsheets provide detailed results tables and supporting information for each of the scenarios evaluated in this report, along with the shorter summary tables included in this report.

A.2 DOE LCC/Crystal Ball Spreadsheet Model Decision Making Analysis

A.2.1 DOE Base Case Furnace Efficiency Levels

The DOE LCC Model includes economic criteria and a distribution of allowable cost recovery times in its trial standard level (TSL) furnace analysis and fuel switching decision algorithm. However, DOE's baseline furnace decision algorithm ignores economic decision making by the consumer and is in conflict with its other analysis and decision making algorithms. Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly in the baseline model. This random assignment occurs in the "Base Case AFUE" sheet in cell D12. A random number between 0 and 1 with a uniform distribution is generated by Crystal Ball for each of the 10,000 trials, representing an individual consumer choice. The random number is compared to the cumulative distribution of extrapolated shipment data for geographic regions, residential vs. commercial, and new vs. replacement. If the random number is smaller than the percentage of furnaces that are expected to be 80% AFUE furnaces, an 80% AFUE furnace is assigned as the Base Case AFUE. If the random number generated is above the expected fraction of 80% AFUE furnaces but below the expected cumulative 80% plus 90% AFUE fraction, then a 90% furnace is assigned as the Base Case AFUE. If the random number exceeds this level, a 92% AFUE furnace is selected in the 92% AFUE TSL case. This process continues through the 98% AFUE TSL. A flow chart and example of this process can be seen in Figure 13. The favorable economics of a particular TSL compared to other levels (e.g., 80% vs. 92% AFUE) are not considered in the decision making.

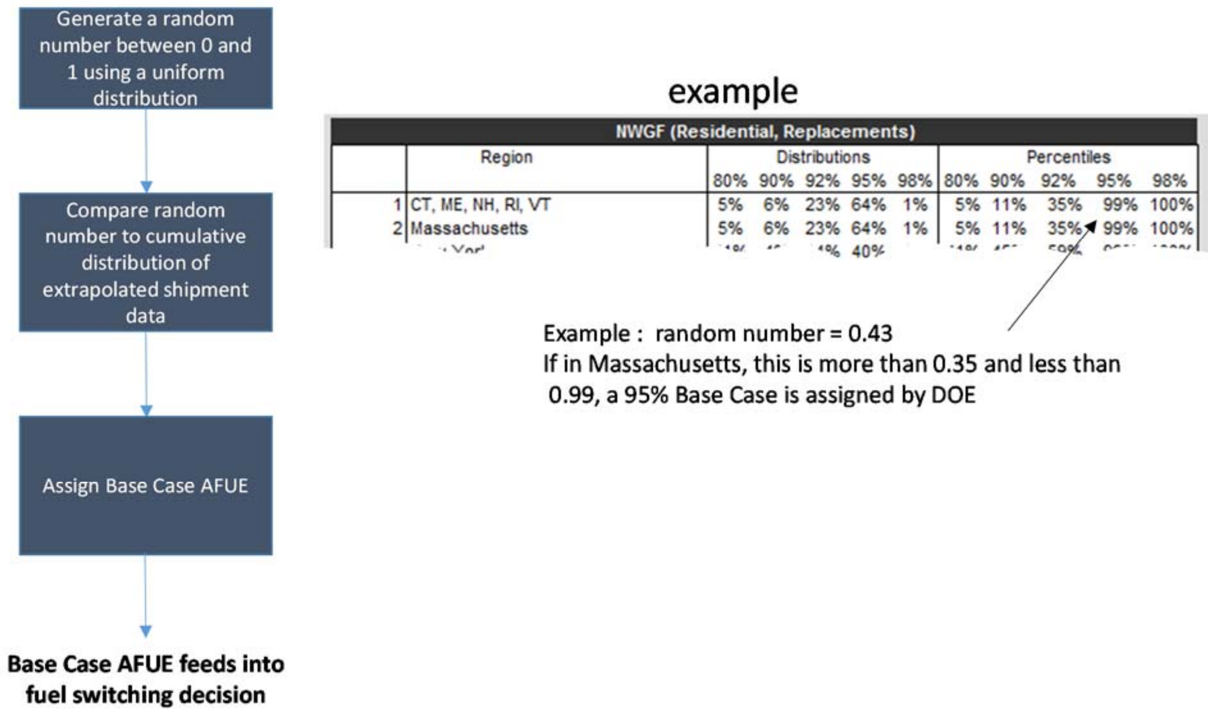


Figure 13 GTI Illustration of DOE Random Base Case Furnace Assignment Algorithm

DOE includes two conflicting assumptions in its NOPR LCC model that combine to overstate the number and type of impacted trial cases. DOE assumes that it is reasonable to linearly extrapolate condensing furnace shipments into the future, while simultaneously assuming that condensing furnace installed costs will drop relative to non-condensing furnaces. The combination of these two assumptions causes more cases to be considered "Net Benefit" than would experience first cost increases when selecting a condensing furnace. Using DOE's combined assumptions, some base cases choose lower efficiency furnaces even when higher efficiency ones are less expensive. This is especially true in new construction.

Table 29 and Table 30 provide examples of cases that increase the LCC savings generated by the DOE model toward higher savings by including cases as "Impacted" that would likely not be affected by the rule under economic decision making, and excluding cases as "Not Impacted" that would likely be affected by the rule if decisions were based on economics rather than assigned by a random number.

Table 29 Cases Included as "Net Benefit" in the DOE NOPR LCC model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
7067	-$1,656	$76	$2,702	No Impact	North/ New York	Single Family New	-22
8749	-$457	$315	$8,659	No Impact	North/ New York	Single Family New	-1
1886	-$690	$360	$6,961	No Impact	North/ New York	Single Family Replacement	-2
138	-$856	$56	$2,165	No Impact	South/ AL, KY, MS	Single Family Replacement	-15
5327	-$741	$379	$6,917	No Impact	North/ Pacific	Commercial New	-2
8042	-$876	$155	$5,934	No Impact	South/ Tennessee	Single Family New	-6

Table 30 Cases Considered "No Impact" in the DOE NOPR LCC Model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
287	$1,055	$1	No Impact	No Impact	North/ IA, MN, ND, SD	Single Family Replacement	1,323
5872	$1,118	$3	No Impact	-$809	North/ IN, OH	Single Family Replacement	382
8906	$810	$2	No Impact	-$59	North/ OR, WA	Single Family Replacement	340
6467	$4,620	$23	No Impact	-$3,792	North/ Illinois	Multifamily Replacement	201
8377	$3,287	$27	No Impact	-$3,035	South/ California	Multifamily Replacement	90
7147	$1,891	$10	No Impact	-$1,680	South/ California	Single Family Replacement	189

Figure 14 illustrates cases for new installations where there was a first cost savings and an operating cost savings for a 92% AFUE furnace, shown as negative payback periods. Using DOE's random assignment algorithm, some consumers with negative payback periods were randomly assigned an 80% AFUE furnace and were therefore considered by DOE to be "Net Benefit" cases by the rule. The cases highlighted in Table 29 are not the only cases in the baseline model where this occurs, but just these six cases (0.06% of the total cases) represent 1% of the total LCC savings asserted by DOE. Under an economic decision making algorithm, such as any of the scenarios that contain parametric D4, D5, D6, D7, D9, D10, D11, or D12, these consumers would have been considered "No Impact" and would have been excluded from the LCC calculations, reducing the overall benefit of the rule. Note that in one commercial building trial case (trial case 5327), the replacement cost for an 80% furnace is higher than shifting to the 92% furnace. This case required relining, so the total installed cost of the condensing furnace is lower, making it a rational economic decision without the rule for that consumer. It would be excluded from the analysis under a CED framework.

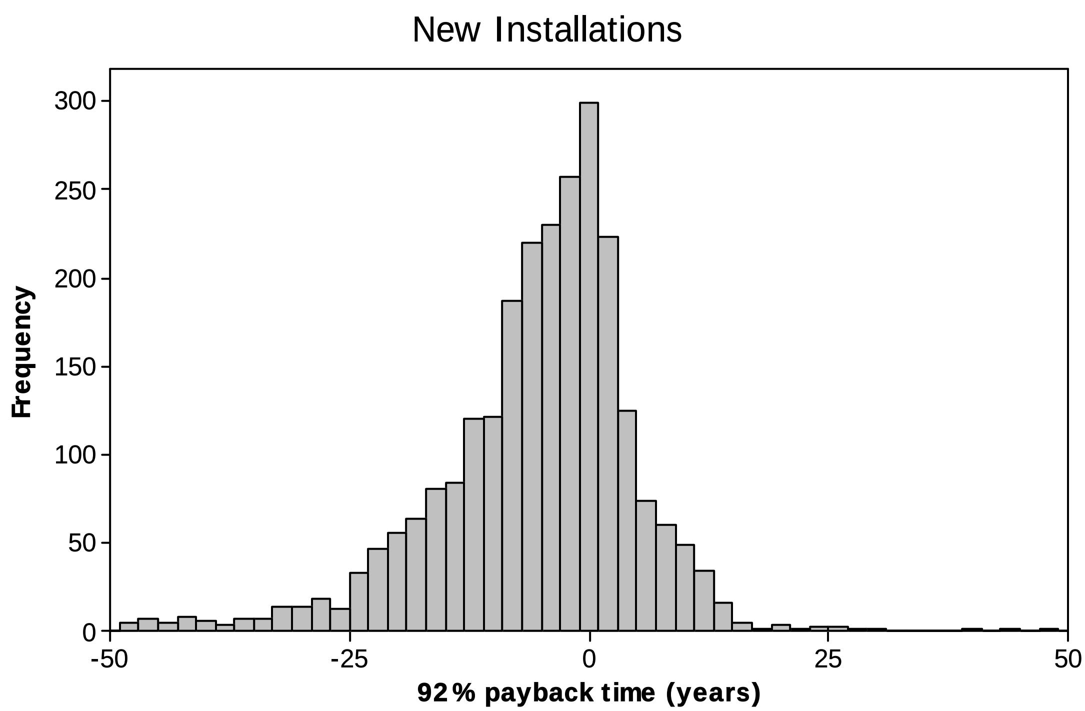


Figure 14 DOE LCC Analysis 92% AFUE New Construction Payback Period Distribution

Similarly, as shown in Table 30, in cases where the payback for the 92% AFUE furnace was very poor, DOE's random assignment algorithm selected these cases as "No Impact," i.e., not affected by the DOE rule. According to DOE's random assignment methodology, the consumer would have freely chosen a 92% or higher efficiency furnace even though the simple payback period exceeds 100 years, causing that consumer to incur a financial loss. Under an economic decision making algorithm, such as Scenario 24, most consumers with long payback periods would have been considered "Net Cost," i.e., negatively affected by the DOE rule, and would have been included in the LCC calculations, reducing the overall benefit of the rule. Another flaw in the random assignment methodology is the rational fuel switching that would be expected to occur if the fuel switch to a low cost (compared to an 80% AFUE furnace), efficient electric technology is a superior choice to the 92% furnace, as is the case in Crystal Ball trial case 287. In that case, rational fuel switching is considered unregulated market behavior and is excluded from the economic decision making scenarios as "No Impact" as well, but for economic reasons, not by random assignment.

Further evidence that there is no economic decision making in used when determining Base Case AFUE is shown in the histograms in Figure 15 and Figure 16. The affected group was assigned an 80% or 90% AFUE furnace and the unaffected group was assigned a 92% or higher AFUE furnace. The shape of the distributions of first cost differences between the 92% and 80% furnace are extremely similar, with minor differences resulting from variations in the distribution of new/replacement installations and condensing furnace market penetration across different regions of the country. This is consistent with a random assignment, but would not be expected when economic decision making is considered.

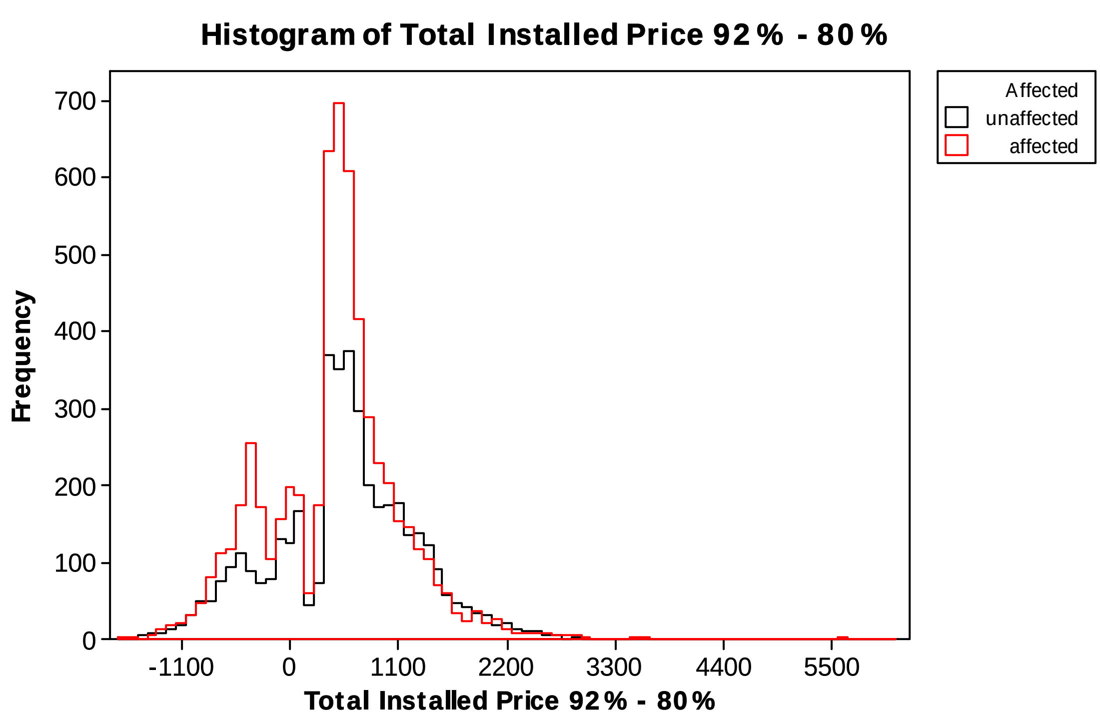


Figure 15 DOE LCC Model Price Differential for 92% and 80% AFUE Furnaces

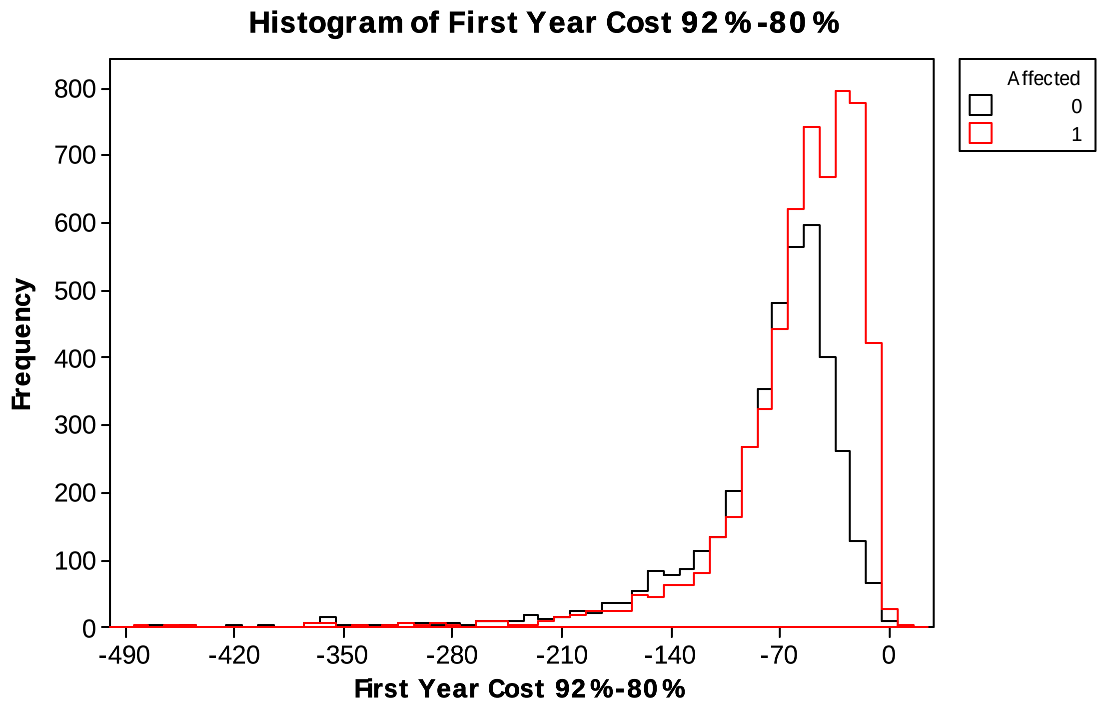


Figure 16 DOE LCC Model Energy Cost Differential for 92% and 80% AFUE Furnaces

A.2.2 DOE Fuel Switching Decision Making Methodology

Unlike the random decisions in the Base Case AFUE assignment, decisions on whether or not a consumer will choose a fuel switching option are based on consumer economics in the baseline DOE LCC model. Figure 9 describes GTI's understanding of the DOE LCC fuel switching decision-making process flow chart. The flow chart aligns with the process that is coded into the LCC spreadsheet rather than the limited description in the TSD. Cases that have selected a furnace with efficiency higher than 80% in the Base Case AFUE sheet are excluded from fuel switching in the LCC&PB Calcs sheet in a large range of cells in columns P through DG using statements like "=IF(AND(optSwitch=1, Index(iBase,1=0),…" which has the effect of verifying that fuel switching in the DOE model is turned on and that the selected furnace is an 80% AFUE furnace. Cells D63 through D66 in the DOE NWGF switching sheet look for cases that have negative payback and cases that have payback periods above the 3.5 year "switching payback period" (a term explained below) set in cells D48 and D49 in the same sheet. They are coded by DOE such that negative payback options will be selected first, followed by those with the largest switching payback period over the 3.5 year payback period threshold.

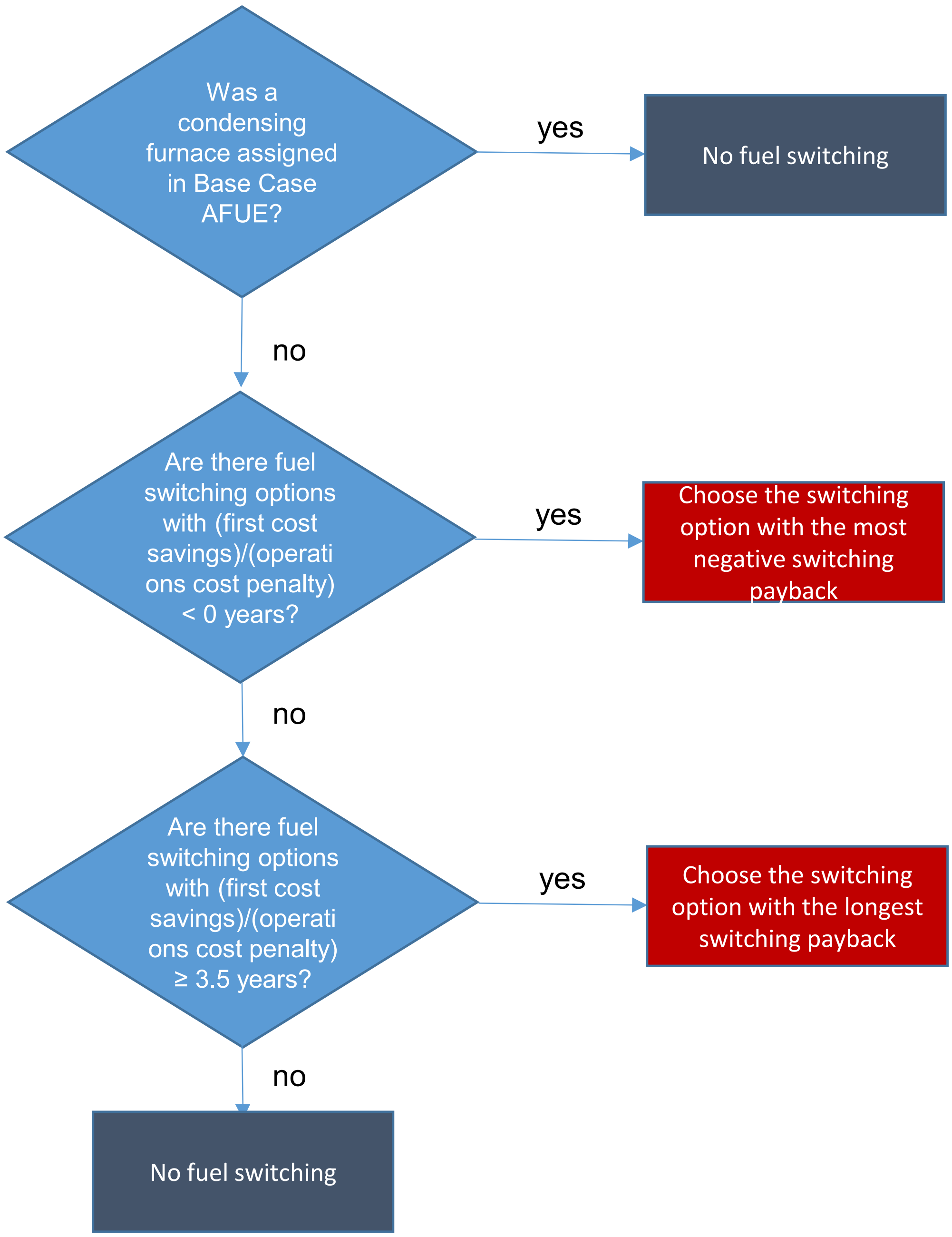


Figure 17 GTI Illustration of DOE Fuel Switching Logic Flow Chart

The TSD includes a confusing definition of payback period as applied to the LCC spreadsheet fuel switching algorithms. The TSD states (at pages 8J-5 and 8J-6): "DOE calculated a PBP [payback period] of the potential switching options relative to the NWGF at the specified EL." However, the fuel switching PBP definition actually used by DOE in the LCC spreadsheet differs from traditional PBP applied elsewhere in the DOE LCC analysis. The spreadsheet "payback" calculation in column AH of the NWGF Switching sheet calculates the time after which the first cost advantage of a switching option relative to a NWGF is offset by the higher operating cost of the switching option. Thus, the "payback period" used in the DOE fuel switching analysis calculations (versus the PBP described in the TSD) is actually the period after which a consumer begins losing money due to higher operating costs of the lower first cost option. This report refers to the DOE fuel switching version of "payback" as the "switching payback." This term is needed to distinguish the "switching payback period" from the usual definition of "payback period," which is the period after which a consumer begins saving money due to the lower operating costs of the higher first cost option.

If DOE's Base Case AFUE assignment were based in economics, the first decision point in the flow chart would be reasonable. A consumer that freely chooses a condensing furnace based on its economic benefits, even if below the TSL (e.g., chooses a 90% furnace instead of either the 80% furnace or a 92% furnace), is unlikely to instead switch to an electric option. Because DOE has chosen to use a random assignment algorithm in the Base Case AFUE assignment, there are likely to be cases that DOE does not consider in its fuel switching algorithm that may actually be candidates for fuel switching, and other cases that DOE has determined will benefit from fuel switching that would have fuel switched without the rule and should not be included in the analysis.

The second decision evaluates whether or not there are electric options that have both lower first cost and lower operating cost (options that do not have lower first cost are not allowed) relative to a non-weatherized gas furnace (NWGF) at the TSL. If there is such a case, its switching payback will be negative (i.e., "negative" first cost penalty divided by positive energy savings), and the model will select it. The DOE model does not look for cases where there is a first cost advantage when comparing to an 80% furnace and an operating cost advantage compared to the TSL. These cases should cause fuel switching that would happen in the unregulated market, and should be removed from the Base Case and not be considered fuel switching due to the rule. This flaw motivated a GTI decision making parametric that removes these cases from the subset that are affected by the rule in the model.

The final decision looks for cases where the switching payback period is at least 3.5 years. The DOE algorithm chooses the option with the longest switching payback if more than one option's switching payback period is over 3.5 years. DOE selected the 3.5 year switching payback period as the decision point based on analysis of four versions (2006, 2008, 2010, and 2013) of the American Home Comfort Study (AHCS) published by Decision Analyst. The AHCS is a proprietary report available only through private purchase and contains detailed consumer preference information not generally available to the public. Some of the more granular information available in the AHCS used in GTI's fuel switching and decision methodology analyses was not used by DOE in its algorithm. The derivation of the 3.5 year payback period criterion is described in section 8J.2.2 of the TSD. It comes from the amount consumers responding to the AHCS reported being willing to pay for a 25 percent improvement in the efficiency of their HVAC system and the space conditioning costs determined from the

RECS 2001, 2005, and 2009. The average amount consumers were willing to pay from the AHCS was divided by 25% of the energy costs for space conditioning derived from the RECS to arrive at 3.5 years. The 3.5 year average value used by DOE can be found in the DOE NOPR LCC model spreadsheet in the Labels sheet at cell G38. It is also referenced by cells D48 and D49 in the NWGF Switching sheet, where it is used in fuel switching decision making.

Interpreting condensing to non-condensing cost differentials from DOE's top level LCC spreadsheet can be misleading as well. A more textured understanding of the modeled consumer choice requires extracting and analyzing data from all 10,000 cases. For instance, LCC spreadsheet Summary, Statistic and Forecast Cells sheets labeled NWGF 90 to 98% report composite numbers for NWGF and fuel switching equipment impacts. Based on individual cases, DOE considers fuel switching to heat pumps to be quite inexpensive because DOE discounts the delivered price and installation cost of the heat pump by assuming replacement of an equivalent air conditioner irrespective of the age of the air conditioner. This overstates the benefit of fuel switching considerably for homes with newer air conditioners that otherwise would not have been replaced when the furnace was replaced.

A.3 GTI Decision Making Parametrics

To examine the impact of DOE's random baseline decision making algorithms on modeling results, GTI analysts developed several parametrics that improve the logical processes in the LCC model. There is a distinction made here between a parametric and a scenario. Parametrics alter aspects of the model as described below. Scenarios are the output of the model run with the alterations described by the parametrics. In some cases parametrics are run by themselves as a scenario and in some cases they are combined with other parametrics in a scenario to see the combined impact. Also, in some cases a parametric cannot be run by itself because its logic cannot stand on its own (such as parametric D4) or because it conflicts with other parametrics (such as D0 with D1, D2, D3, D8, D9, or, D10).

A.3.1 Parametric D0

This parametric uses the flag available in the LCC model at cell D16 in the Summary sheet to turn off fuel switching entirely. This allows the impact of allowing fuel switching to be determined by comparing to equivalent scenarios with switching turned on. Any scenario not containing parametric D0 allows fuel switching.

A.3.2 Parametrics D1, D2, and D3

Figure 18 shows the effect of the switching payback period on LCC savings in the DOE model. This was generated simply by changing the values of cells D48 and D49 in the NWGF Switching sheet. The distribution of LCC savings is non-linear. Because of the shape of the response, any distribution of switching payback periods with an average of 3.5 years will have lower LCC savings than the use of a single 3.5 year switching payback period. The data available in the AHCS contains a wide distribution of payback periods that are a function of household income. These factors motivated the development of parametric modifications to the baseline model which represent more thoroughly the detailed distribution of consumer preferences in the AHCS.

DOE used the AHCS to determine its switching payback period by converting the average amount consumers were willing to pay for an efficiency improvement combined with the average HVAC energy costs to arrive at a single switching payback period. However, the AHCS contains significantly more detailed information than simple averages. According to Decision Analyst, the AHCS is the largest knowledge base of homeowner behavior, perceptions, and attitudes related to energy efficiency, home comfort, and HVAC. Topics covered in the AHCS include:

- The level of consumers' interest in energy efficiency
- How consumers balance rising energy costs with home comfort
- Consumers' willingness to spend money on home improvements to achieve energy efficiency
- Home comfort differences by region and demographics

It contains between 2,849 and 3,803 respondents in each of the years 2006, 2008, 2010, and 2013. It includes enough data to produce distributions of switching payback periods as a function of income groups to produce a more granular evaluation of fuel switching behavior than DOE incorporated into their analysis using the single point average switching payback period.

Figure 19 shows the full distribution of switching payback periods from the AHCS for each income group, calculated following the DOE methodology described in the TSD but for the whole distribution of data from the AHCS instead of an average. The distribution of responses reported by Decision Analyst was used to simulate 5,000 data points for each income group in each of the four years (2006, 2008, 2010, and 2013) of the AHCS. Data from all four years were combined to yield the distributions shown.

Several features stand out in the AHCS distribution. First there is a clear trend with income; lower income households are more tolerant of short switching payback periods than higher income groups. The AHCS distribution information shows that low income households are more first cost sensitive on average than higher income households. Also the distributions are not normal distributions that would align reasonably well with an average value. The distributions are instead skewed, with a large number of consumers having very short switching payback periods, and a small number of consumers having very long switching payback periods. Averaging these disparate distributions into a single value results in an average switching payback period of 3.5 years.

Histograms shown in Figure 20 for the highest and lowest income groups from the 2010 AHCS data further illustrate the skewed allowable switching payback distribution. As shown in Figure 18, switching payback periods much shorter than 3.5 years have a significant negative effect on LCC savings while switching payback periods much greater than 3.5 years have little positive incremental effect on LCC savings. Application of a single average value to this skewed distribution as DOE chose to do in its NOPR LCC model overstates LCC savings compared to using the full distribution of switching payback periods as was done in the GTI scenarios.

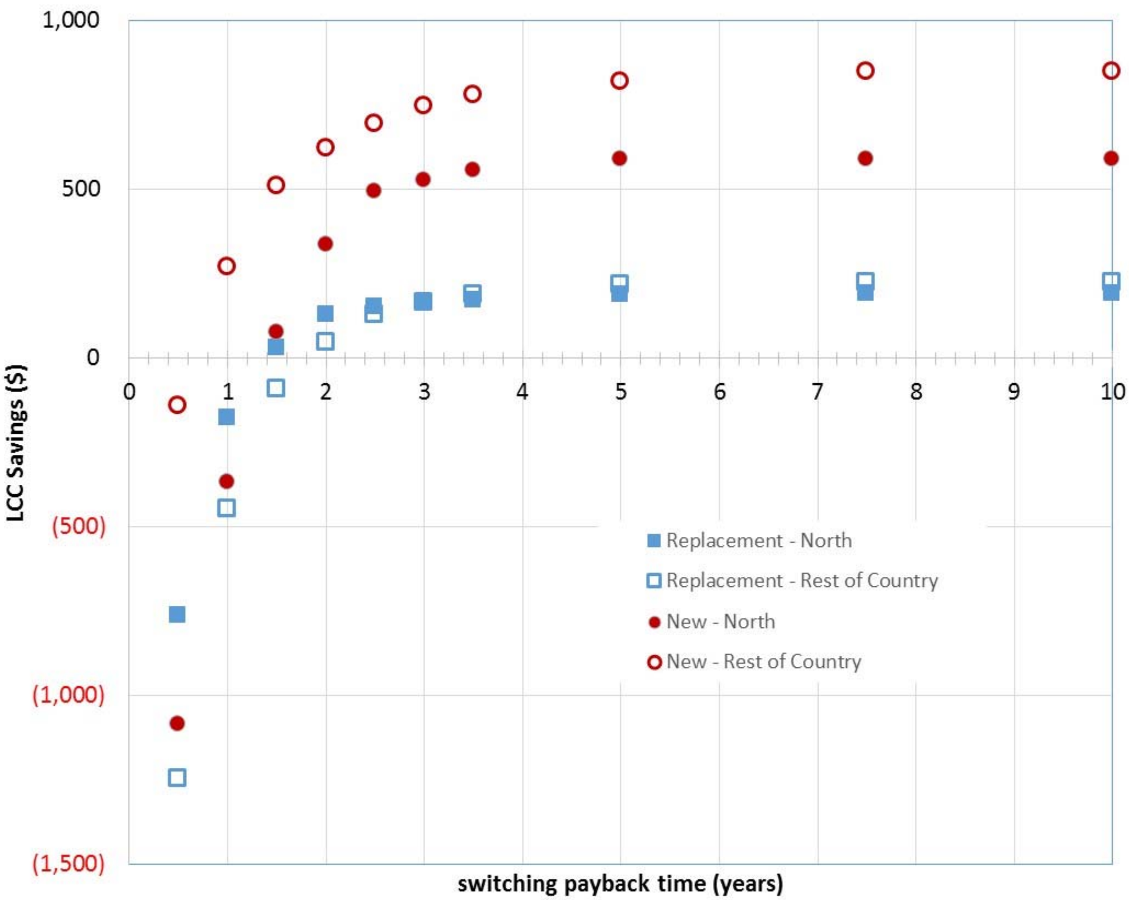


Figure 18 Non-linear LCC Savings Distribution as a Function of Switching Payback Period

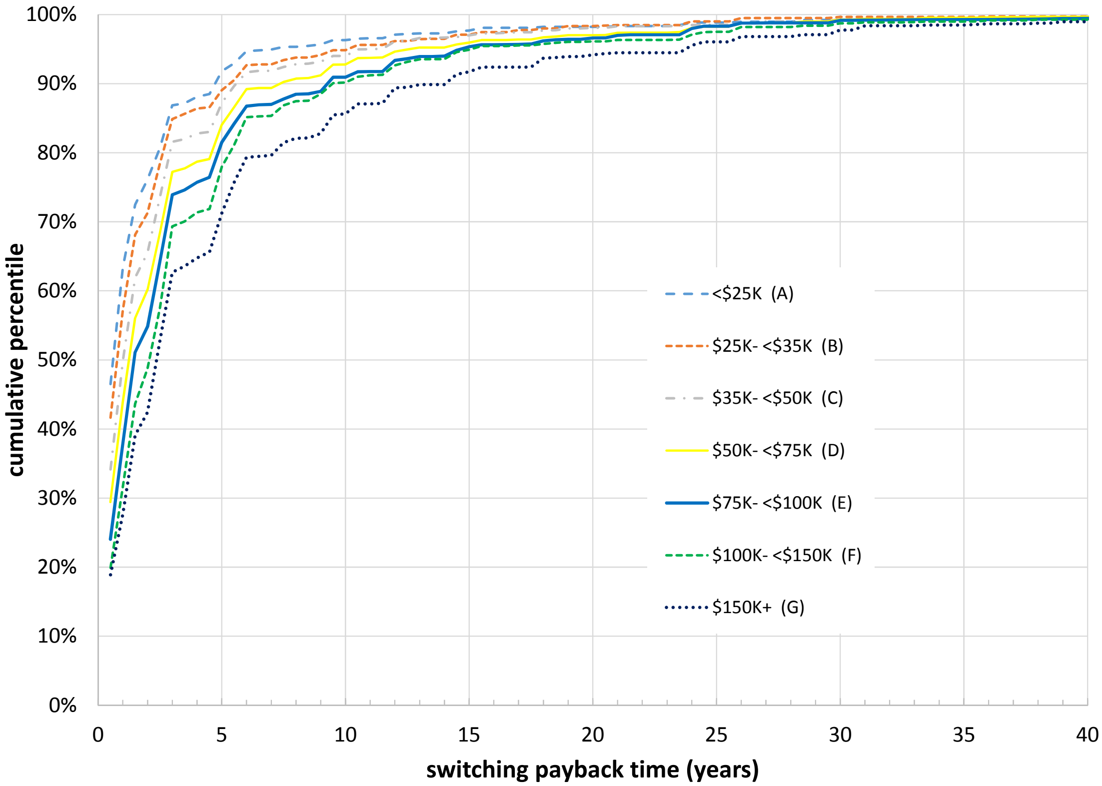


Figure 19 Switching Payback Distribution for Different Income Levels

Source: American Home Comfort Study[5]

5 Decision Analyst. 2006, 2008, 2010, and 2013. American Home Comfort Study. Arlington, TX. http://www.decisionanalyst.com/Syndicated/HomeComfort.dai

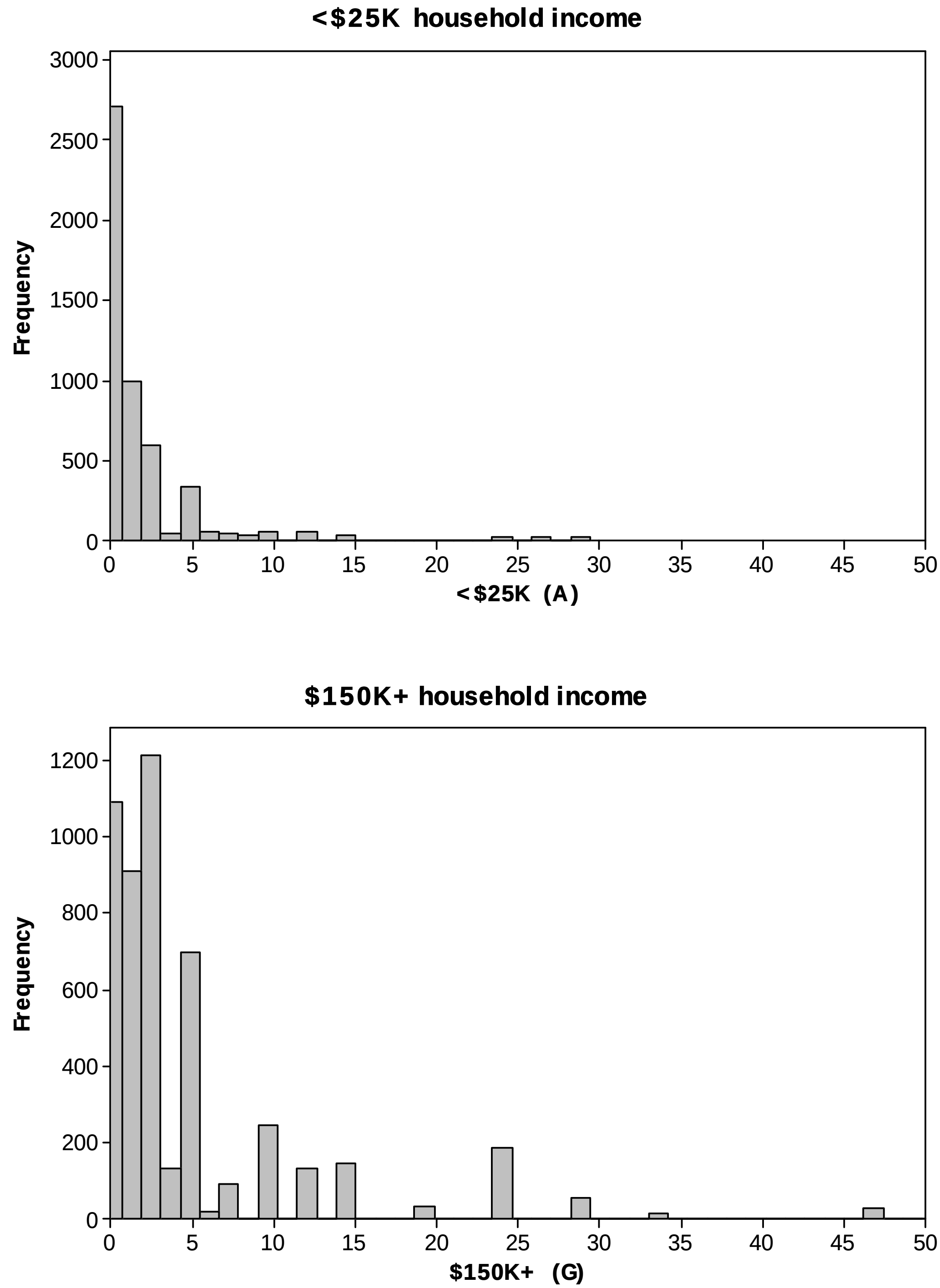


Figure 20 Allowable Switching Payback Distribution by Income Group

Source: American Home Comfort Study[6]

6 Decision Analyst. 2010. American Home Comfort Study. Arlington, TX. http://www.decisionanalyst.com/Syndicated/HomeComfort.dai

Decision making parametric D1 uses the cumulative distributions shown in Figure 20 combined with income data from the RECS 2009 data available in the DOE LCC model and a random number generator to replace the 3.5 year single switching payback period given in the baseline LCC model.

Two other parametrics were based on a less complete analysis of the AHCS data than parametric D1, but still more complete than the DOE analysis. As shown in Figure 21, there is a consistent trend in all years of the AHCS between tolerable payback periods for consumers and household income. Decision making scenario D2 assigns payback periods according to household income using the average payback period calculated for all 4 years of the AHCS data (2006, 2008, 2010, and 2013). Tolerable payback periods in the 2013 AHCS were somewhat lower than in previous years. Decision making scenario D3 uses a linear fit to the 2013 AHCS data only.

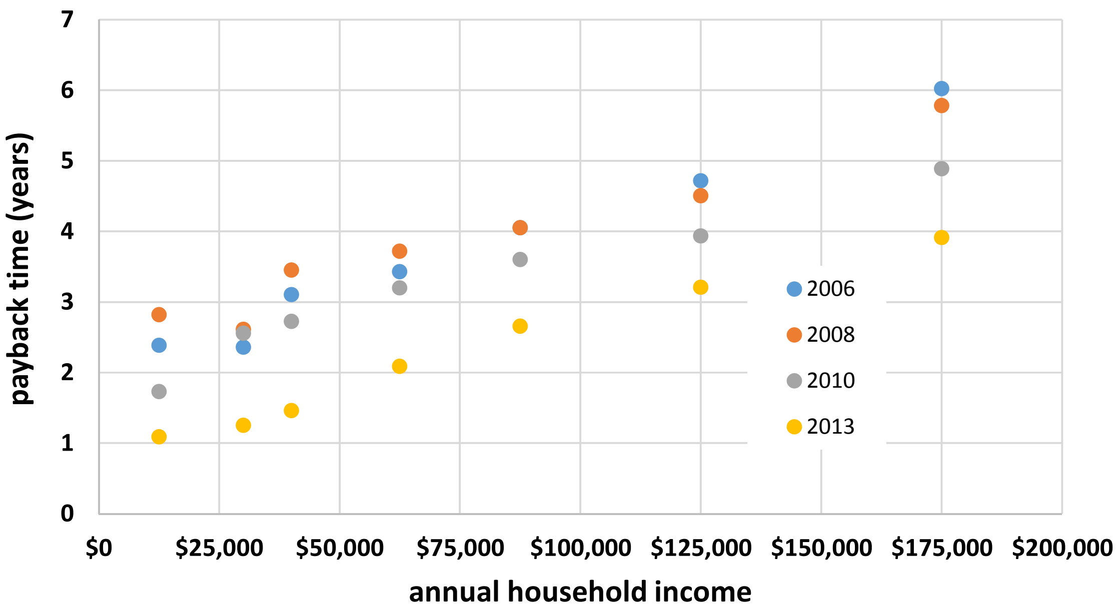
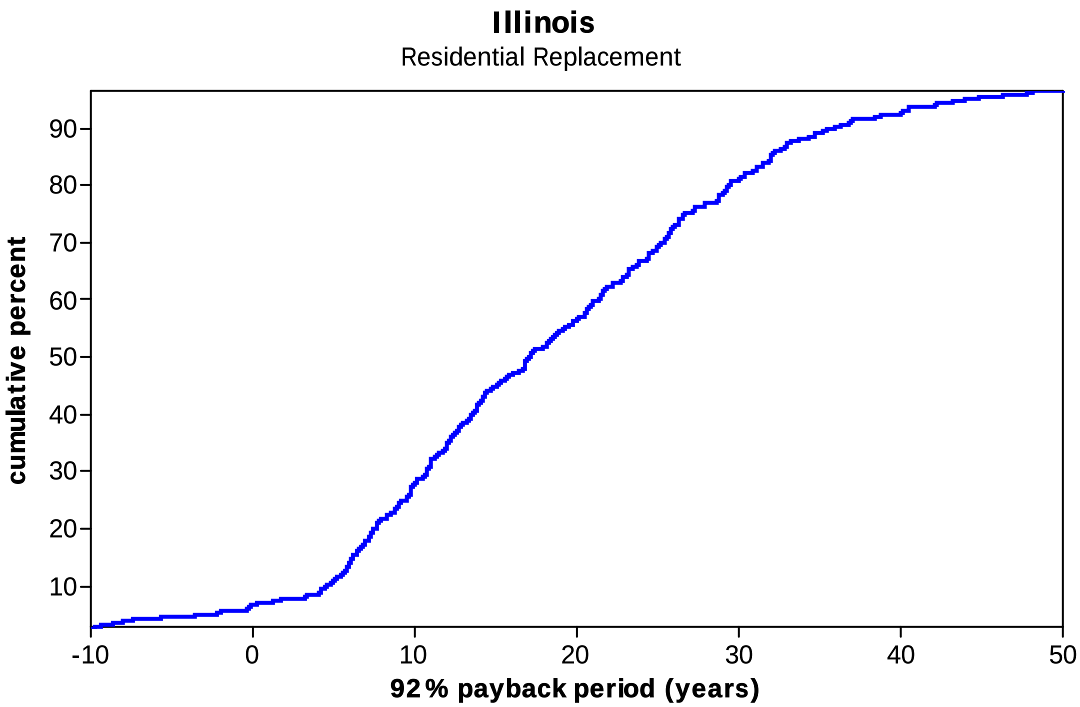


Figure 21 Tolerable Switching Payback Periods for Lower and Higher Income Households

A.3.3 Parametric D4

This parametric replaces DOE's random Base Case AFUE assignment with economic decision making. Base Case AFUE assignment by this parametric is based on the payback period for the TSL furnace relative to an 80% AFUE furnace. This payback period is already calculated and available in the LCC model in the NWGF Switching sheet in column AI (specifically in cell AI13 in the case of a 92% AFUE TSL). The DOE LCC model calculates in for every case whether the case is affected by the rule or not. GTI analysts ran the baseline model and collected data on all payback periods so that cumulative distributions could be produced for each region, installation type (new or replacement), and building type (residential or commercial). Figure 22 shows two example cumulative distributions of payback periods for Illinois and Georgia. Parametric D4 combines these cumulative distributions with the extrapolated shipment data provided by DOE to assign payback periods for furnaces at different efficiencies.



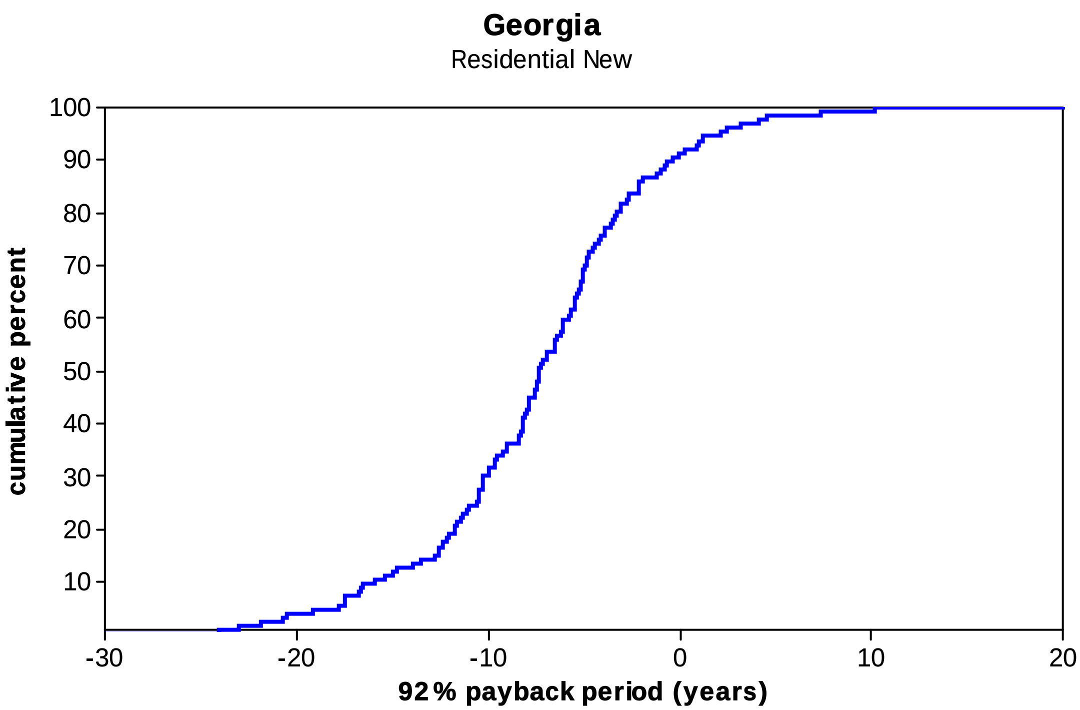


Figure 22 Cumulative Distribution of Payback Periods in DOE Model

The method of assigning payback periods is illustrated for Illinois residential replacements and Georgia residential new construction. For Illinois residential replacements, the extrapolated shipment data available in the Base Case AFUE sheet indicates that 49% of furnaces will be 80% AFUE while 3% of furnaces will be 90% furnaces, as shown in Figure 23. This means that, based on the DOE NOPR LCC model, 52% of furnaces will be affected by the 92% minimum efficiency rule. Following this logic, cases that have the best economics, ones with payback periods less than 16.7 years, will be assigned a 92% or higher Base Case AFUE and will therefore not be affected by the rule. Cases with 16.7 – 17.7 years will be assigned a Base Case AFUE of 90% and cases with greater than 17.7 year paybacks will be assigned an 80% AFUE.

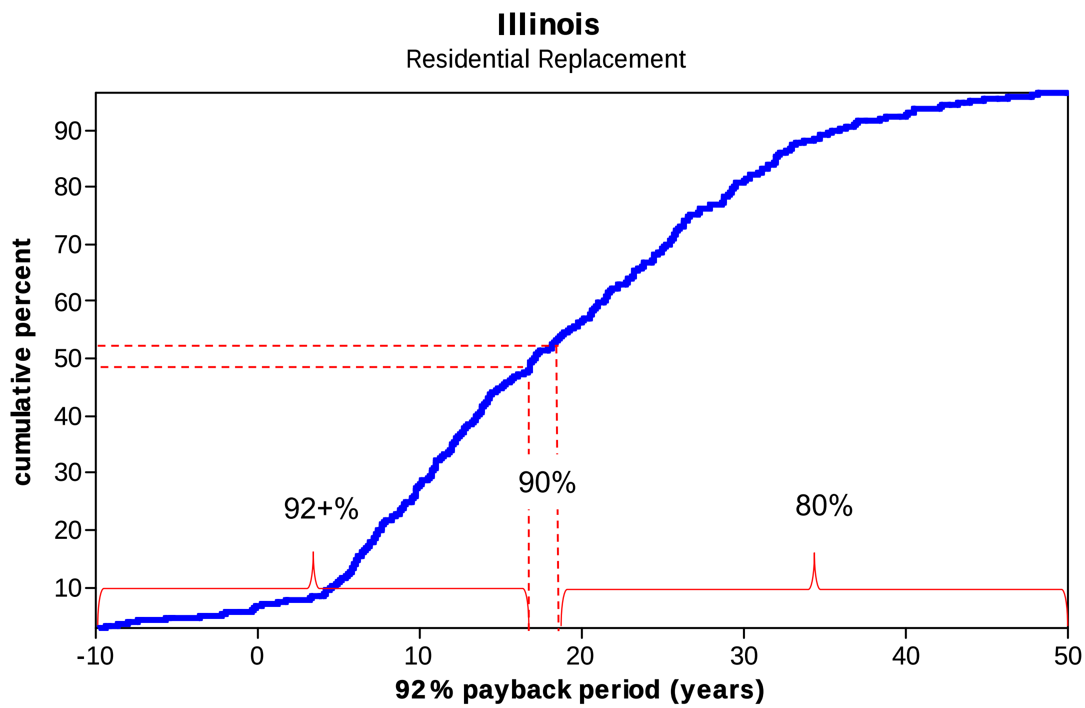


Figure 23 Baseline Furnace Payback Distribution for Illinois Replacements

In Georgia for new installations 88% of installations are projected to be 80% AFUE and 2% are projected to be 90% AFUE. This translates to payback periods less than -16.2 years to be assigned to the 92+% AFUE group, and between -16.2 and -14.9 years to be assigned to the 90% AFUE group. This implies that large fractions of the new construction market in Georgia will choose lower efficiency furnaces even though they cost more than higher efficiency furnaces. This represents a logical problem. Negative paybacks for new construction should shift the market to condensing furnace technology in new construction in Georgia, which is inconsistent with market behavior asserted by DOE using AHRI state-level shipment data.

The cause of the logical problem is that DOE used shipment data from 1994 to 2004 and linearly extrapolated this to 2021 to determine the base case efficiency distributions. DOE also forecasts condensing furnace price reductions relative to non-condensing furnaces between now and 2021. The combination of equipment price decreases and extrapolation of linear market adoption 17 to 27 years into the future causes unrealistic behavior in the DOE model.

Specifically, in the example of Georgia new construction, the DOE model projects that approximately 80% of builders will choose to purchase 80% AFUE furnaces even though 90+% AFUE furnaces are less expensive to purchase and install. This is an improbable scenario for homeowners and contractors, and an extremely improbable scenario for builders based on economic decision making criteria.

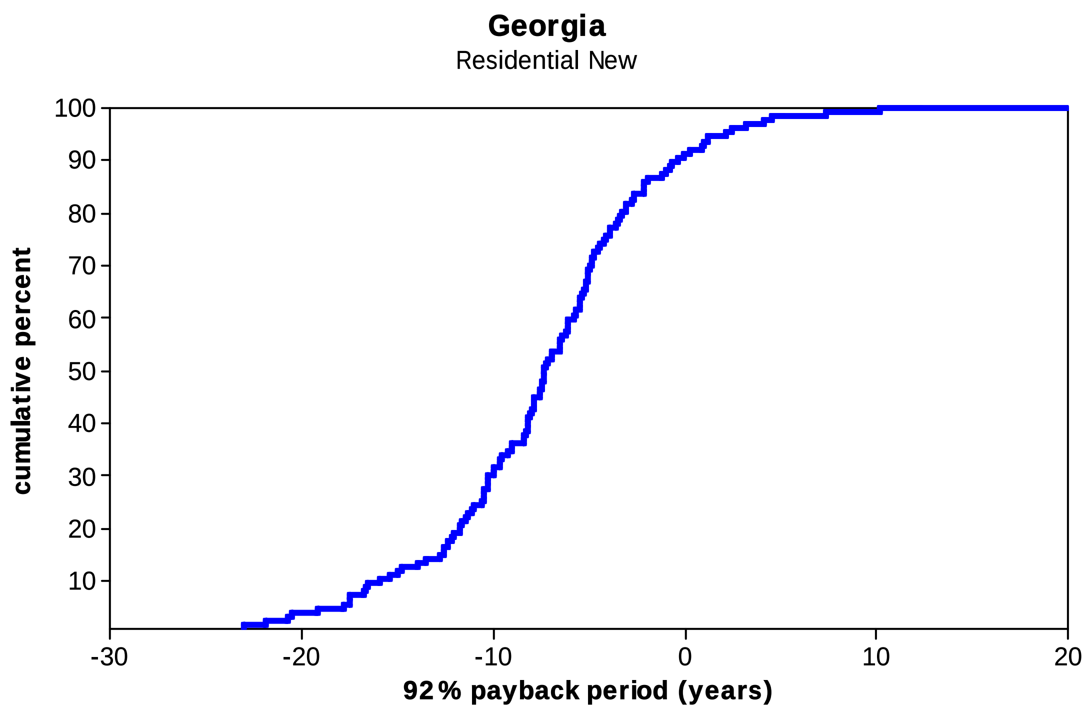


Figure 24 Baseline Furnace Payback Distribution for Georgia New Construction

This improbable situation is not isolated to Georgia new construction. The payback periods for each region are given in Table 31 and Table 32 below for residential and commercial buildings. Because of the prevalence of negative payback periods within the DOE model caused by caused by DOE's projections that condensing furnace total installed costs will drop relative to non-condensing furnaces, even applying CED will result in substantial numbers of consumers being considered Impacted when they would experience first cost savings by choosing a furnace at the mandated TSL. Therefore, Parametric D4 was never run alone. It was always combined with another scenario to remove these highly improbable negative and extremely low payback period cases from the "Net Benefit" category.

The Parametric 4 methodology was also performed for 90%, 95%, and 98% TSLs. The 95% and 98% levels require more payback criteria because furnaces need to be divided into more groups. For example, in the 98% TSL case, a payback period for 90%, 92%, 95% and 98% AFUE groups had to be calculated to determine the base case distribution of AFUEs.

Table 31 Regional and State Baseline Residential Furnace Payback Periods

Residential				
Region	replacement		new	
	payback required for		payback required for	
	92+% AFUE	90% AFUE	92+% AFUE	90% AFUE
CT, ME, NH, RI, VT	11.7	13.7	1.3	3.0
Massachusetts	15.5	19.5	0.1	1.1
New York	15.4	16.4	-1.6	-1.2
New Jersey	18.0	18.8	0.4	1.9
Pennsylvania	26.5	32.2	2.0	4.9
Illinois	16.7	17.7	0.6	1.3
Indiana, Ohio	14.4	15.3	0.6	1.9
Michigan	11.7	12.8	1.2	2.1
Wisconsin	25.5	32.6	7.4	10.5
IA, MN, ND, SD	33.5	46.3	7.4	14.4
Kansas, Nebraska	11.9	12.9	-4.7	-2.6
Missouri	12.1	13.3	0.5	1.3
Virginia	12.9	15.9	-4.8	-3.8
DE, DC, MD	10.3	11.4	-13.4	-7.8
Georgia	2.4	3.3	-16.2	-14.9
NC, SC	7.2	9.4	-3.6	-1.9
Florida	-66.1	-66.1	-116.0	-116.0
AL, KY, MS	8.1	9.5	-6.9	-6.0
Tennessee	8.6	9.9	-8.8	-7.5
AR, LA, OK	-1.3	2.5	-16.1	-16.0
Texas	-26.8	-23.9	-70.5	-62.1
Colorado	10.4	10.9	-5.4	-2.0
ID, MT, UT, WY	9.8	10.2	-3.0	-2.4
Arizona	6.8	8.3	-21.5	-18.4
NV, NM	3.5	7.4	-27.6	-27.4
California	5.1	7.5	-42.1	-32.9
OR, WA	7.9	8.5	-7.6	-6.1
Alaska	-9.8	-9.8	-4.3	-4.3
Hawaii	0.0	0.0	0.0	0.0
West Virginia	16.7	18.4	-1.7	-1.7

Table 32 Regional and State Baseline Commercial Furnace Payback Periods

Commercial				
Region	replacement		new	
	payback required for		payback required for	
	92+% AFUE	90% AFUE	92+% AFUE	90% AFUE
New England	34.7	34.7	0.0	0.0
Middle Atlantic	27.1	31.7	-1.2	-1.2
East North Central	10.9	12.7	-0.8	-0.1
West North Central	13.2	13.4	-2.0	-1.4
South Atlantic	8.8	9.8	-5.5	-4.8
East South Central	9.1	9.1	-8.2	-6.4
West South Central	0.2	0.2	-24.0	-24.0
Mountain	1.4	2.9	-2.0	-2.0
Pacific	11.7	12.6	-20.0	-20.0

A.3.4 Parametric D5, D6, and D7

Parametrics D5, D6, and D7 set the minimum allowed payback period for Base Case furnace assignment to 0 years, 3.5 years, and the full distribution of payback periods from the AHCS respectively. The three parametrics allow a comparison of impacts of different allowable payback period options (single value or distribution) on both Base Case furnace assignment and fuel switching impacts. A 0 year minimum payback period would result in more consumers being considered impacted by the rule than a 3.5 year allowable payback period for decisions. The distribution function is more aligned with the full AHCS survey information and permits a more granular evaluation of low income impacts.

To avoid negative and very short payback periods from being incorrectly assigned to the "Net Benefit" group, parametrics D5, D6, or D7 are combined with parametric D4. The full flow chart for Base Case AFUE assignment, including both parametric D4 and one of D5, D6, or D7 (as well as Parametrics D9 or D10), is shown in Figure 25. The cumulative distribution functions (CDFs) for Georgia and Illinois referenced in Figure 25 illustrate the linkage of these parametrics with Parametric D4 for CED framework scenarios.

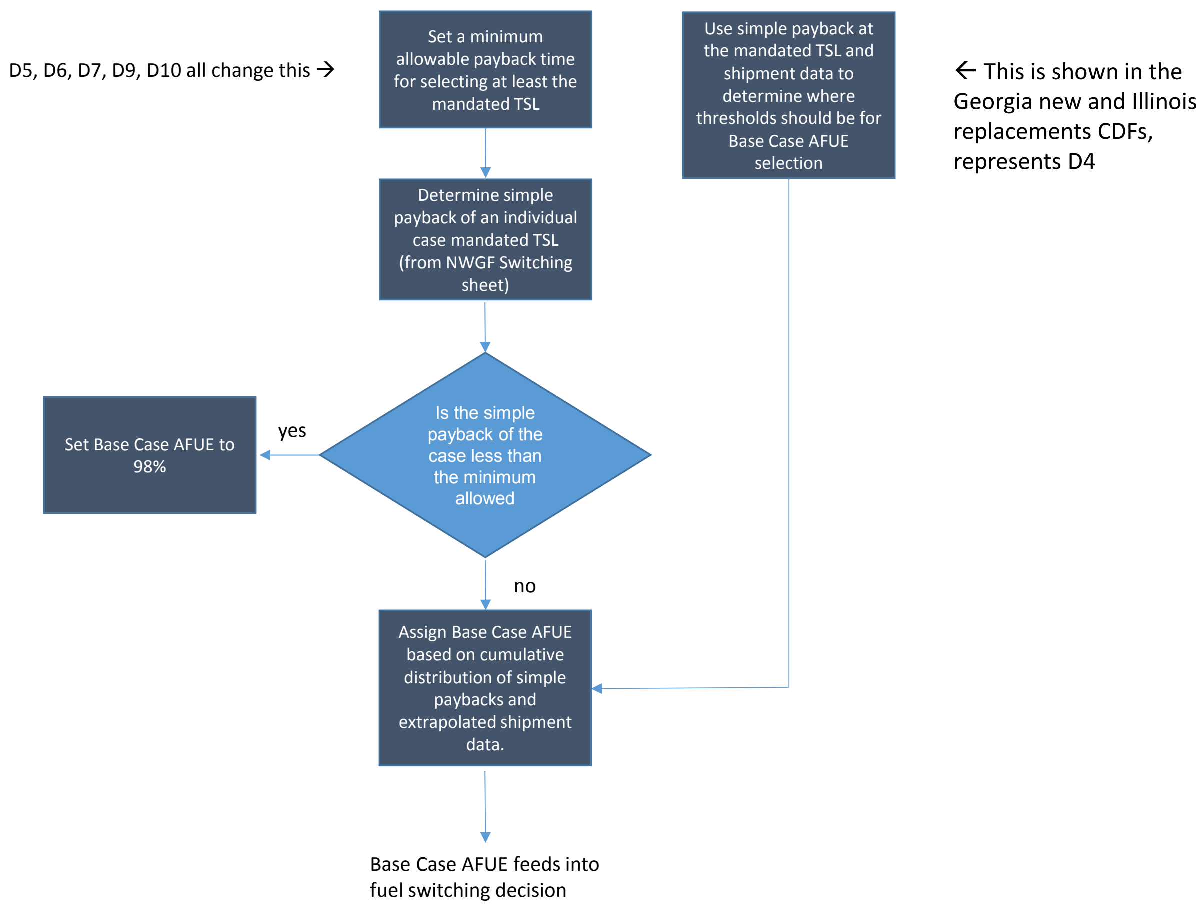


Figure 25 GTI Base Case Furnace AFUE Assignment Flow Chart

A.3.5 Parametric D8

This parametric removes cases where a fuel switching option has a lower first cost than an 80% furnace and operating costs savings relative to a TSL furnace. Those switching occurrences should occur in the absence of a rule. Cases are removed from the affected group by assigning a Base Case AFUE high enough that the case becomes considered not affected by the rule. The addition of parametric D8 to the fuel switching decision making is illustrated in Figure 26.

A.3.6 Parametric D9 and D10

Parametric D4 in combination with any of its minimum threshold criterion parametrics (D5, D6, and D7) incorporates economic decision making into the Base Case AFUE decision. In any case where fuel switching is allowed to occur there is an additional economic decision being made which includes a switching payback period. The DOE NOPR LCC model uses an inconsistent logic in its decision algorithm. DOE assumes that consumers do not consider economics at all in the Base Case AFUE furnace assignment, but do consider economics when choosing fuel switching options. When applying parametric D4 to introduce economic decision making into the model, consumers will end up with one payback period for Base Case AFUE selection, and a different switching payback period for switching decisions.

Parametrics D9 and D10 use parametric D4 with a minimum of threshold of 3.5 and 0.5 years, respectively, and assign as a switching payback period either the payback period calculated for D4 or the minimum threshold, whichever is longer. These parametrics align the condensing furnace Base Case AFUE assignment decision and fuel switching payback periods.

A.3.7 Parametric D11 and D12

While parametric D4 does not preclude economically poor decisions, it does make decisions based on economic criteria according to the simple payback period of a NWGF at the mandated TSL relative to an 80% NWGF. A household with a shorter payback period will always be more likely to choose a condensing furnace of a particular TSL compared to a household with a longer payback period under Parametric D4. This brings up the possibility that even though one household has better economics than another for a particular decision, it may not act accordingly.

Parametrics D11 and D12 use the same simple payback periods used in D4, but only remove trial cases as “No Impact” from the LCC analysis if their payback periods are below 0 and 3.5 years, respectively. Both parametrics also force trial cases to choose an 80% AFUE furnace if the TSL furnace has a payback period over 15 years. If the payback periods fall between these extremes, Base Case AFUE is assigned randomly, the same way as in the DOE algorithm. These parametrics provide an upper limit on LCC savings compared to the Base Case furnace. In these two parametrics, trial cases that have extremely good economics will definitely choose a furnace at the mandated TSL, while trial cases with extremely poor economics for a condensing furnace will definitely choose an 80% AFUE furnace. All other trial cases will be assigned a baseline furnace efficiency randomly without considering economics.

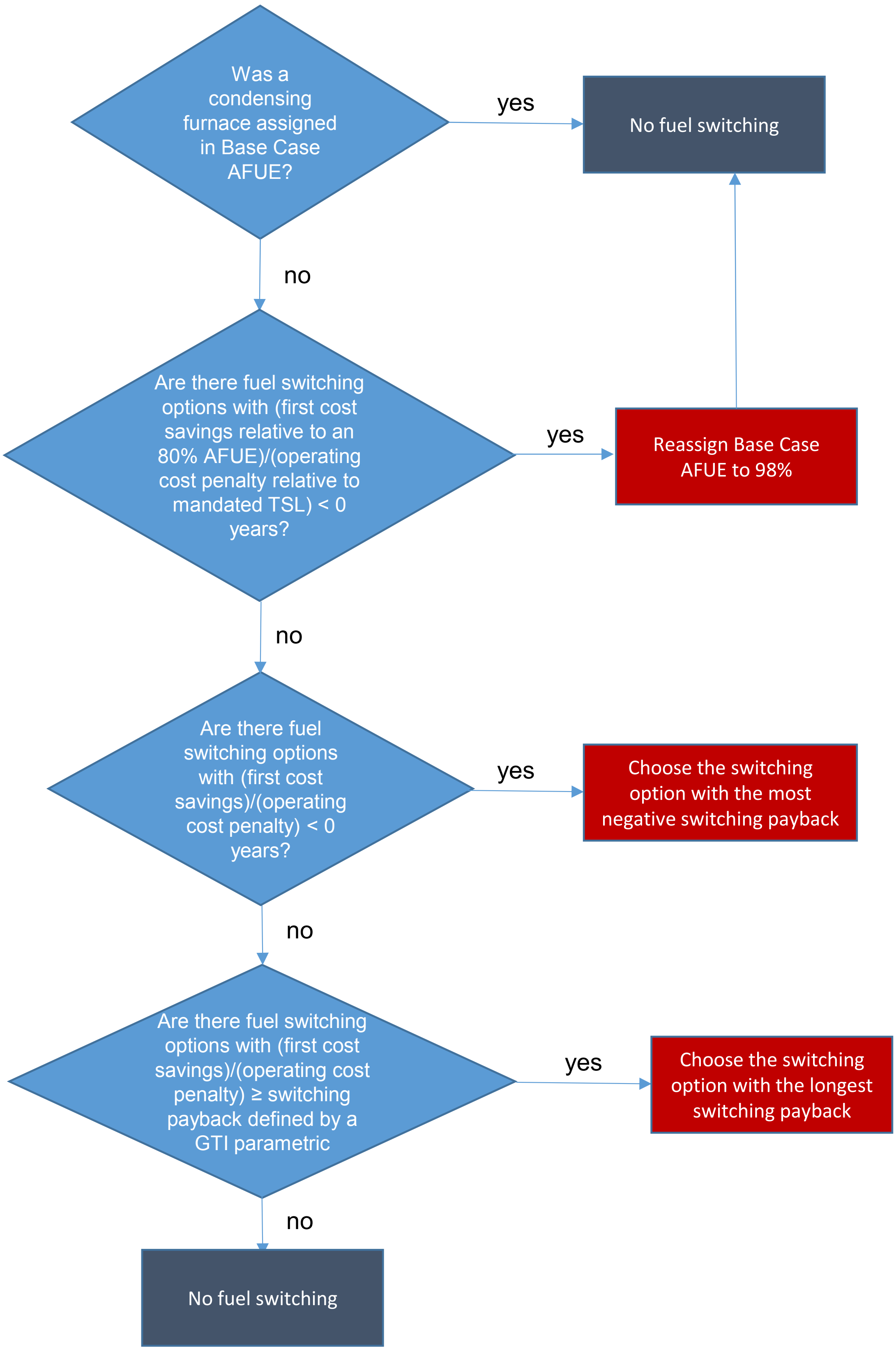


Figure 26 GTI Fuel Switching Logic Flow Chart

A.4 GTI Decision Making Scenarios

As described in the preceding section, scenarios represent the outputs of the LCC model when one or more parametric modifications are included in the LCC model. The parametrics were incorporated into scenarios according to the matrix in Table 33. Some of these scenarios were run only to illustrate the impact of the selected parametrics, whether or not they are technically defensible on their own. This section describes the rationale for inclusion of each scenario in this analysis. Summaries of LCC savings, fuel switching for affected buildings, and energy use for affected buildings can be found at the end of this section in Table 34 through Table 45.

The DOE and GTI LCC analysis results include information on energy consumption by fuel type. GTI analysts used this information to evaluate the impact of the rule on site energy consumption, primary energy consumption, and greenhouse gas emissions (CO_2e emissions). Energy use and emissions results tables below, for the decision making, input, and integrated scenarios, summarize national level average results using national values for primary energy conversion factors and CO_2e emissions for natural gas and electricity. GTI's Source Energy and Emissions Analysis Tool (available at: www.cmictools.com) was used for this analysis. These results are helpful to gain an understanding of the environmental impacts of the proposed rule, including the impact of fuel switching. Where primary energy consumption or CO_2e emissions increase (positive values), fuel switching caused by the proposed rule makes the proposed rule worse for the environment, irrespective of the LCC model results.

Table 33 Decision Making Parametric Matrix

	DOE NOPR	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Scenario 0	X													
Scenario 1			X											
Scenario 2				X										
Scenario 3					X									
Scenario 4						X	X							
Scenario 5						X		X						
Scenario 6						X			X					
Scenario 7										X				
Scenario 8			X							X				
Scenario 9				X		X		X		X				
Scenario 10						X		X		X				
Scenario 11						X	X			X				
Scenario 12						X			X	X				
Scenario 13			X			X			X					
Scenario 14			X			X			X	X				
Scenario 15											X			
Scenario 16												X		
Scenario 17										X	X			
Scenario 18										X		X		
Scenario 19	X	X												
Scenario 20		X				X	X							
Scenario 21		X				X		X						
Scenario 22		X				X			X					
Scenario 23			X			X	X			X				
Scenario 24				X		X	X			X				
Scenario 25					X	X	X			X				
Scenario 26				X						X			X	
Scenario 27				X						X				X

A.4.1 Scenarios 1, 2, and 3

These scenarios illustrate the impact of changing the fuel switching payback periods using a more comprehensive analysis of the AHCS than provided by DOE. They do not address any other decision making in the LCC model. Scenario 1 includes the full distribution of the AHCS. However, when run by itself it produces fuel switching percentages, shown in Table 38, Table 39, Table 40, and Table 41, that are quite high compared to the 2014 GTI fuel switching survey results and other scenarios. Scenarios 2 and 3 show fuel switching percentages that are similar to the DOE NOPR LCC model and the GTI fuel switching survey results. While future market behavior in response to the DOE NOPR cannot be known in advance, the GTI fuel switching survey that informed the DOE NOPR LCC model is the most recent market information available, and may be useful as a metric for comparing the scenario results.

All three scenarios show reduced LCC savings relative to the DOE NOPR LCC Model as shown in Table 34, Table 35, Table 36, and Table 37. Low income households show a particularly large reduction in LCC savings compared to other categories. This result is expected because parametrics D1, D2, and D3 all produce shorter switching payback periods, especially for low income trial cases, compared to the DOE NOPR LCC Model. Scenario 1, with its high level of fuel switching, results in higher primary energy consumption and CO_2e emissions compared to the DOE NOPR LCC Model, as do all scenarios that include parametric D1 across all TSLs as shown in Table 42, Table 43, Table 44, and Table 45.

A.4.2 Scenarios 4, 5, and 6

These scenarios apply different CED thresholds for decision making. Table 34, Table 35, Table 36, and Table 37 all show significant reduction in LCC savings compared to the DOE NOPR LCC Model, though there is not much difference among the three. The largest differences among the three scenarios is in new construction. This is expected because they differ only in their minimum thresholds for CED. In most cases, these minimum thresholds are not approached by replacements, but can be approached in new construction. None of these scenarios alters fuel switching decision making and are thus primarily included to illustrate the effects of adding CED to the Base Case AFUE assignment and the sensitivity to the setting of minimum thresholds for CED.

A.4.3 Scenario 7

Scenario 7 incorporates only parametric D8 that eliminates as "No Impact" any cases where fuel switching would have been economically driven without the proposed rule. It serves to illustrate the impact of that single adjustment. Also, as shown in Table 38, Table 39, Table 40, and Table 41, it significantly reduces fuel switching at all TSLs because it is removing fuel switching that would have occurred in the absence of a rule from being considered in the model.

A.4.4 Scenario 8

Scenario 8 combines two alterations to the fuel switching logic, parametrics D1 and D8. This removes cases where fuel switching would have been economically driven without any rule from being affected and uses the full distribution of AHCS data to set switching payback periods. Even with the addition of parametric D8, fuel switching is still high relative to the DOE NOPR LCC Model.

A.4.5 Scenarios 9, 11, 12, 13, 14, 15, and 16

These scenarios illustrate the effects of their respective CED parametrics incorporated in various combinations, including single parametrics and multiple parametrics. These scenarios were candidates for integrated scenarios based on fuel switching decision and Base Case assignment impacts.

A.4.6 Scenario 10

Scenario 10 combines parametrics D4, D6, and D8. It uses the CED framework for Base Case AFUE assignment, thereby removing cases that should not have been included as potentially impacted by the proposed rule. It does not address fuel switching logic. It illustrates the impact of removing cases that should not be considered to be impacted by the rule, either because of unregulated market fuel switching, or because the TSL furnace has a sufficiently short payback period under CED that it would have been chosen without the proposed rule.

It also illustrates the impact of including trial cases that DOE randomly considers "Not Impacted" even though payback periods are very long and LCC savings are negative. Scenarios such as Scenario 10, that alter the decision making for condensing furnace efficiency so that economics plays a role in decision making, still result in a significant fraction of buildings with positive LCC savings under the proposed rule. Under a CED framework, there are still consumers that make rational payback decisions that are considered poor decisions under the LCC savings metric used in the DOE NOPR. For example, in the DOE NOPR LCC model using random Base Case furnace assignment, almost 40% of trial cases experience a "Net Benefit" at the 92% TSL, implying that 40% or the population, in the absence of a rule, would make payback decisions that are not the best for themselves from a life cycle cost perspective. In Scenario 10 the fraction of trial cases experiencing a "Net Benefit" due to the proposed rule drops to ~20% as shown in Figure 27. Thus poor LCC decisions are not eliminated by these scenarios. What Scenario 10 eliminates from the "Net Benefit" category are cases where extremely large LCC savings occur due to negative payback periods where condensing furnaces most likely would have been adopted in the absence of a rule. What Scenario 10 adds to the "Net Cost" category are cases that the DOE NOPR LCC model considered to be "No Impact," even though the LCC economics are extremely poor for that case, and a rule would likely have been required to force adoption of a furnace at the mandated TSL at a "Net Cost" to that consumer.

Scenario 10, where the minimum threshold for potential inclusion in the impacted category was set to 0 years, shows negative LCC savings at a national level for the 90 and 92% TSLs and LCC savings under $40 nationally for the 95 and 98% TSLs.

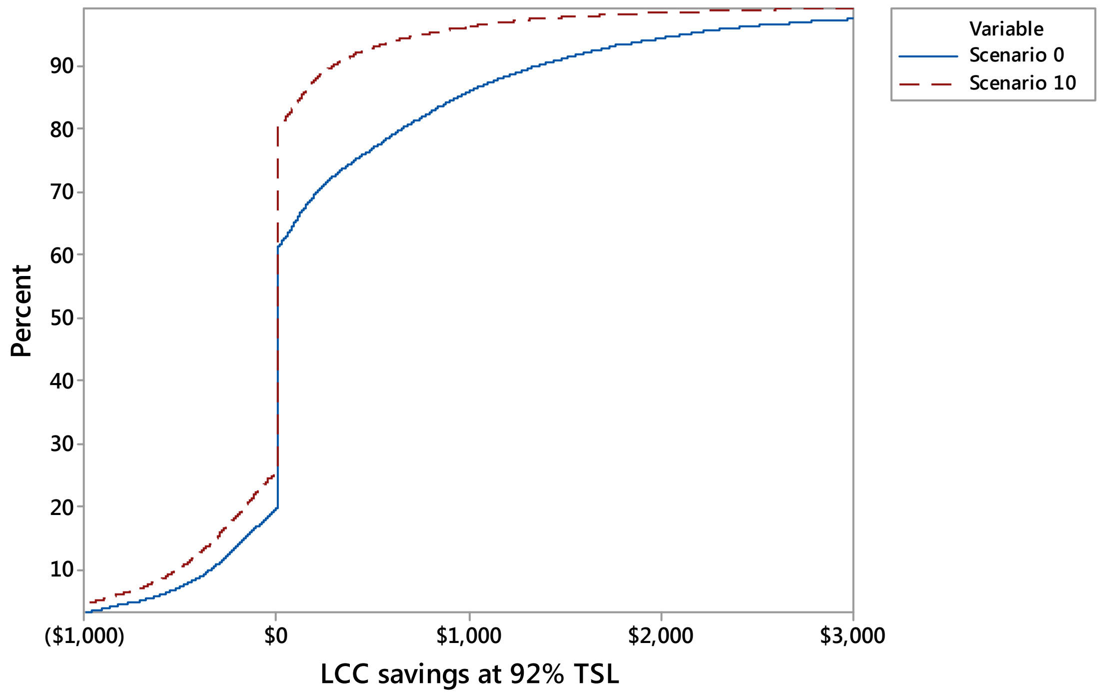


Figure 27 LCC Savings Distribution for Scenarios 0 and 10

A.4.7 Scenarios 17 and 18

Scenarios 17 and 18 differ significantly from other GTI decision scenarios. They include economics in the decision making for condensing furnaces and prevent payback periods below 3.5 and 0.5 years, respectively, from being considered impacted by the rule. However, unlike other GTI scenarios that use the AHCS for switching payback periods, Scenarios 17 and 18 align the furnace decision making time horizon with the fuel switching decision, preventing a single decision from being made with two separate tolerable payback periods. Finally, they do not consider fuel switching due to a first cost advantage relative to an 80% furnace and operating cost advantage relative to a TSL furnace a "Net Benefit" caused by the rule. These scenarios do not use the AHCS data in the fuel switching decision. In doing this, the model moves from relying on survey data from the AHCS to a linked combination of decision making logic. These scenarios acknowledge that consumers will pay for energy cost savings leading to a 0.5 or 3.5 year payback while recognizing that forecasted furnace shipment data in some cases indicates that the decision payback period can be much longer than 3.5 years.

Scenarios 17 and 18 also have significantly different LCC savings. This is the result of a tradeoff between very short allowable switching payback periods causing economically poor fuel switching decisions, and long payback periods avoiding these poor switching decisions but excluding a larger fraction of buildings as condensing furnaces are adopted without the proposed rule. These two effects are shown at a national level for the 92% TSL furnace case in Figure 28. Scenario 17 LCC savings, based on a minimum condensing and switching payback period of 3.5 years, are very close to the maximum achievable LCC savings based on payback period. At lower minimum payback periods, LCC savings drop very quickly as some consumers make switching decisions and start losing money very quickly. LCC savings fall slowly as minimum payback periods are increased beyond approximately 4 years as the result of greater adoption of condensing furnaces without the proposed rule.

For replacements, the short payback periods have less effect, as shown in Figure 29. This is because replacements in most regions have a relatively high tolerance for long payback periods, so the minimum allowable payback period does not affect as many buildings. In contrast, new construction has a low tolerance for long payback periods, so switching decisions are often at or near the minimum payback period, driving large negative LCC savings, as shown in Figure 30.

For long payback period cases, the replacement market shows a steeper decrease in LCC savings than the new installations market. This is occurring because a much larger fraction of replacements are impacted by the rule. Also, reducing the number of trial cases impacted by the proposed rule has a significant effect. New construction has only about 12% impacted homes, even with a minimum payback of 3.5 years. Replacements have negative LCC savings across the entire range of minimum payback periods.

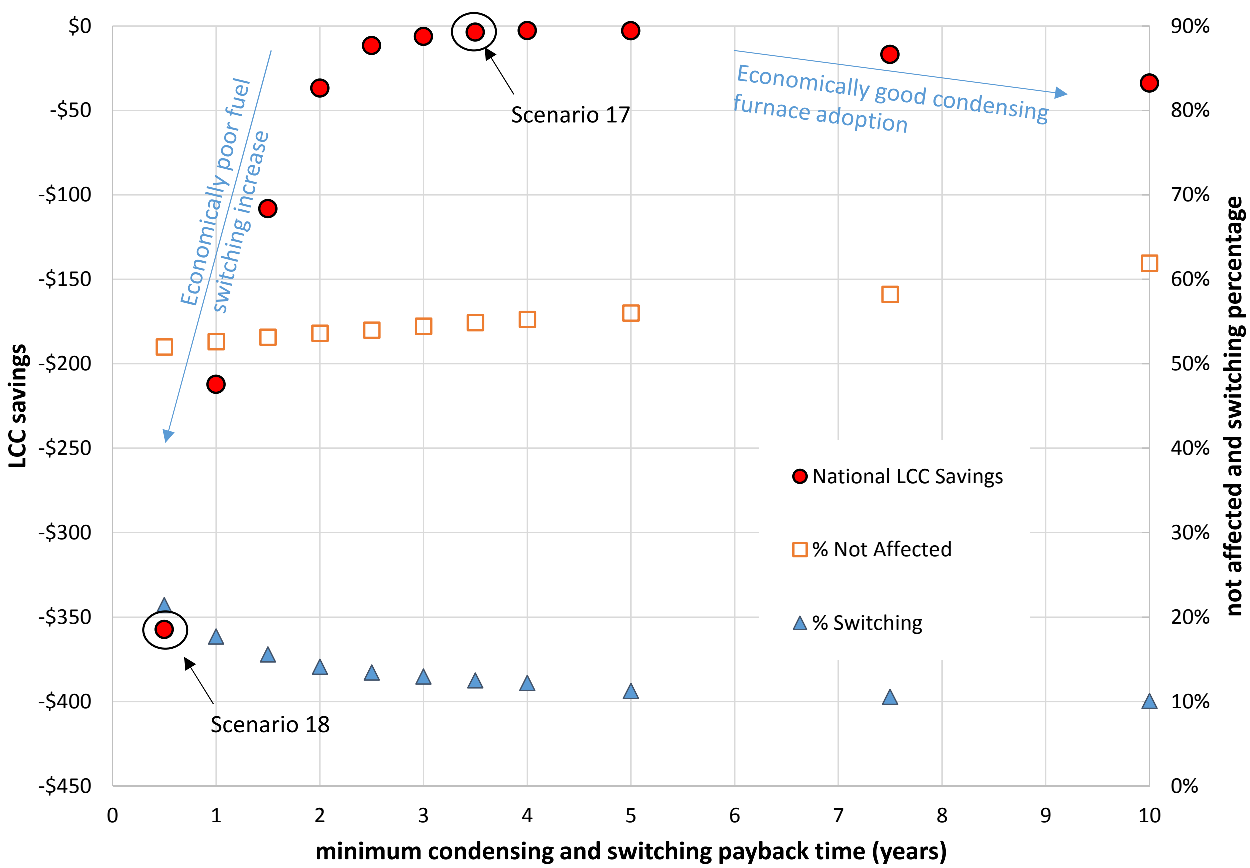


Figure 28 GTI Model Paybacks for LCC Savings and Fuel Switching Decisions – National Average – 92% AFUE TSL Furnace

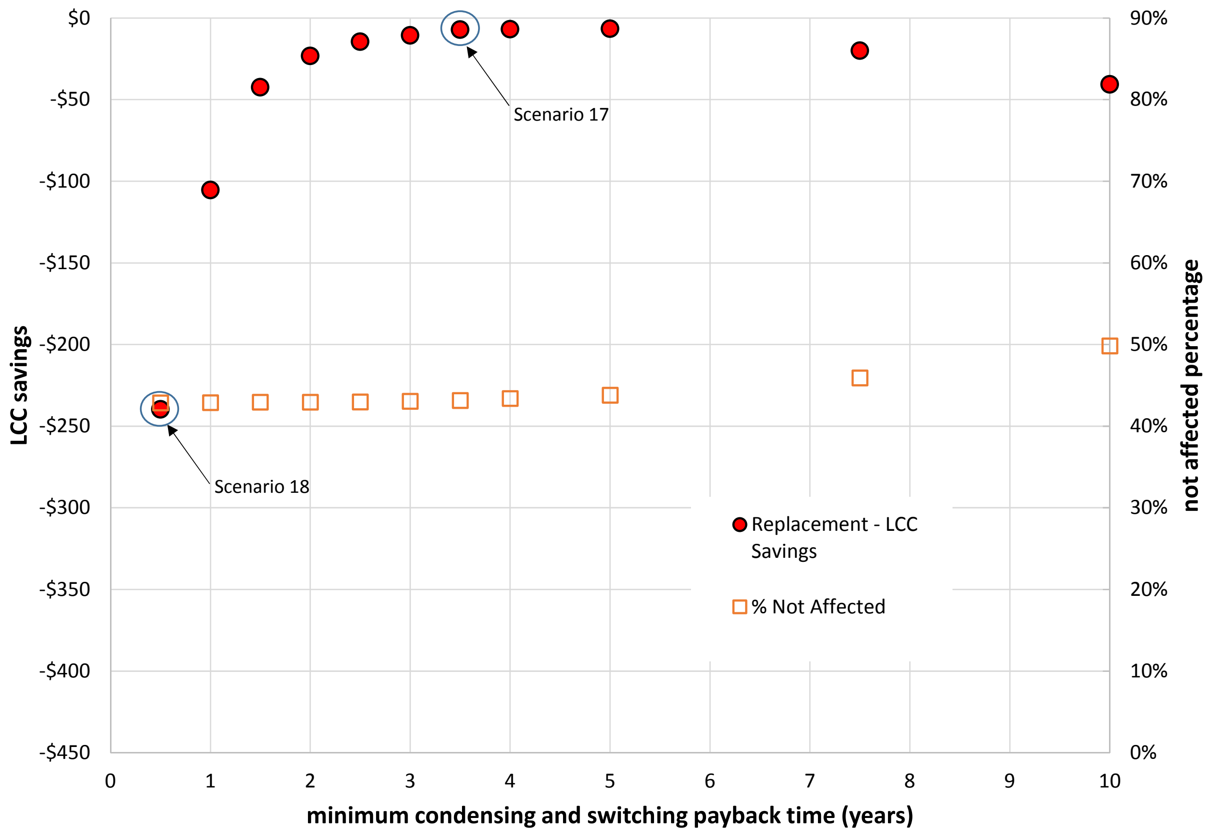


Figure 29 GTI Model Paybacks for LCC Savings and Fuel Switching Decisions – National Average Replacements – 92% AFUE TSL Furnace

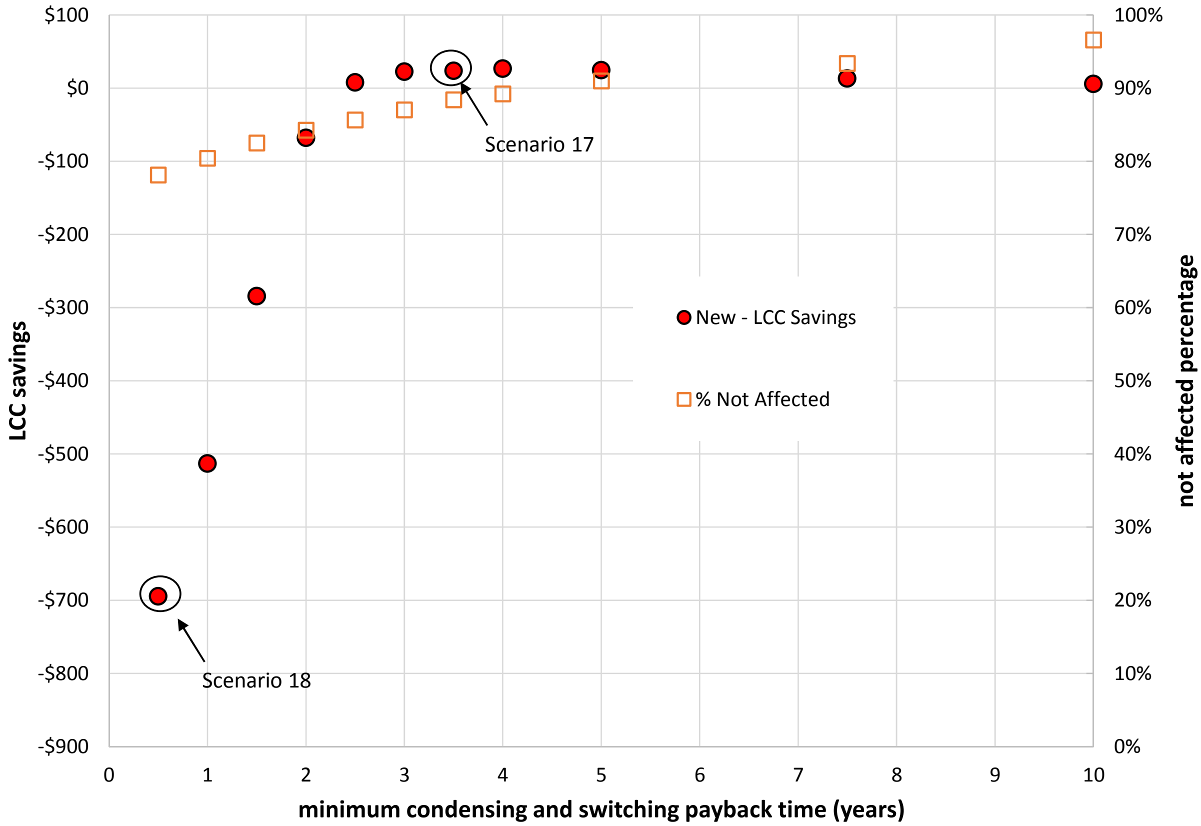


Figure 30 GTI Model Paybacks for LCC Savings and Fuel Switching Decisions – National Average New Construction – 92% AFUE TSL Furnace

A.4.8 Scenario 19

This scenario is the DOE NOPR LCC Model with fuel switching turned off. Turning off fuel switching decreases the DOE LCC savings from $305 to $238, indicating that fuel switching provides a "Net Benefit" to consumers. This counterintuitive result occurs because the DOE NOPR LCC model takes credit for fuel switching cases that would have occurred without the proposed rule because of their extremely positive economics. GTI Parametric D8 addresses these cases based on the CED framework, considering them "No Impact." Another reason that fuel switching is a benefit in this scenario is because DOE includes as "Net Benefit" cases that have very bad economics for a condensing furnace that switch to electrical options to avoid the poor economics. Finally, DOE eliminates many economically poor fuel switching decisions by limiting the switching payback period to a single value of 3.5 years. As a result, economically poor fuel switching cases are underrepresented in the DOE NOPR LCC model.

A.4.9 Scenarios 20, 21, and 22

These scenarios replicate GTI Scenarios 4, 5, and 6, but with fuel switching turned off. In all three scenarios, the LCC savings are smaller (more negative) compared to equivalent scenarios in which fuel switching is allowed. This is similar to the results in scenario 19, and for the same counterintuitive reasons, though the magnitude of the difference is smaller.

A.4.10 Scenarios 23, 24, and 25

These scenarios combine CED in the Base Case AFUE assignment with a minimum threshold of zero years, removal of fuel switching cases that are unrelated to the rule, and modification to the fuel switching payback periods. The difference among the three scenarios is the parametric used for the switching payback assignment. Scenarios 23, 24, and 25 include parametric D1, D2, and D3, respectively. All show very significant decreases in LCC savings relative to the DOE NOPR LCC Model. Only scenario 24 yields fuel switching levels that are similar to the DOE NOPR LCC Model and the 2014 GTI fuel switching survey. Scenarios 23 and 25 have substantially larger fuel switching.

A.4.11 Scenarios 26 and 27

These scenarios are included to demonstrate the effects of confining the boundary for CED in the Base Case AFUE assignment. Both scenarios include parametric D2, which makes switching behavior a function of income according to the AHCS, and parametric D8, which prevents fuel switching that would have occurred in the absence of a rule. They also each contain parametrics that set a minimum threshold for payback time and prevent cases with a simple payback of less than 0 or 3.5 years from being impacted by a rule in Scenario 26 and 27, respectively. Also both scenarios contain a maximum threshold of 15 years for random base case furnace assignment. If the simple payback period for a furnace at the mandated TSL is longer than 15 years, an 80% furnace is assigned, and these trial cases will be “Impacted.” Any payback periods between these extremes are treated randomly as they are treated by the DOE NOPR LCC Model. Trial cases are assumed to not consider economics if payback periods are between the minimum and maximum thresholds of 0 and 15 years payback.

A.4.12 Results Summaries for Decision Making Scenarios

Table 34 LCC Savings for Decision Making Scenarios – 90% TSL

LCC Savings Summary - 90% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
Scenario 1 (D1)	-$115	-$135	-$92	-$293	-$222	-$370	$359	$56	$717	-$122	-$359
Scenario 2 (D2)	$220	$193	$252	$93	$104	$80	$585	$430	$767	$251	$6
Scenario 3 (D3)	$126	$112	$141	-$20	$19	-$62	$531	$353	$742	$106	-$340
Scenario 4 (D4, D5)	-$31	-$65	$8	-$80	-$143	-$12	$129	$164	$87	-$14	-$56
Scenario 5 (D4, D6)	-$31	-$65	$8	-$80	-$143	-$12	$129	$164	$87	-$14	-$56
Scenario 6 (D4, D7)	-$51	-$83	-$15	-$85	-$141	-$23	$65	$95	$30	-$32	-$56
Scenario 7 (D8)	$198	$179	$219	$99	$106	$92	$476	$361	$611	$190	$162
Scenario 8 (D1, D8)	-$197	-$198	-$196	-$380	-$319	-$447	$281	$64	$538	-$135	-$472
Scenario 9 (D2, D4, D6, D8)	-$95	-$132	-$54	-$118	-$167	-$65	-$15	-$25	-$3	-$81	-$270
Scenario 10 (D4, D6, D8)	-$31	-$65	$8	-$80	-$143	-$12	$129	$164	$87	-$14	-$56
Scenario 11 (D4, D5, D8)	-$50	-$87	-$8	-$87	-$146	-$23	$71	$86	$54	-$42	-$59
Scenario 12 (D4, D7, D8)	-$65	-$98	-$26	-$92	-$146	-$35	$34	$47	$19	-$49	-$59
Scenario 13 (D1, D4, D7)	-$522	-$632	-$398	-$621	-$708	-$526	-$267	-$476	-$21	-$472	-$897
Scenario 14 (D1, D4, D7, D8)	-$567	-$657	-$466	-$636	-$667	-$603	-$405	-$688	-$71	-$484	-$796
Scenario 15 (D9)	-$35	-$70	$5	-$54	-$113	$10	$37	$62	$9	-$14	-$44
Scenario 16 (D10)	-$367	-$337	-$400	-$275	-$113	-$453	-$622	-$981	-$199	-$159	-$463
Scenario 17 (D8, D9)	-$46	-$83	-$5	-$61	-$116	-$1	$11	$19	$2	-$30	-$44
Scenario 18 (D8, D10)	-$384	-$358	-$415	-$282	-$116	-$463	-$674	-$1,053	-$227	-$185	-$466
Scenario 19 (D0)	$164	$169	$158	$31	$67	-$8	$537	$438	$655	$144	$110
Scenario 20 (D0, D4, D5)	-$92	-$96	-$88	-$158	-$180	-$134	$108	$145	$64	-$104	-$112
Scenario 21 (D0, D4, D6)	-$110	-$116	-$103	-$159	-$180	-$135	$44	$74	$9	-$113	-$117
Scenario 22 (D0, D4, D7)	-$107	-$110	-$103	-$160	-$180	-$139	$62	$94	$23	-$110	-$116
Scenario 23 (D1, D4, D5, D8)	-$572	-$687	-$442	-$645	-$697	-$588	-$405	-$730	-$21	-$474	-$797
Scenario 24 (D2, D4, D5, D8)	-$80	-$117	-$40	-$117	-$167	-$64	$37	$29	$46	-$73	-$279
Scenario 25 (D3, D4, D5, D8)	-$226	-$271	-$176	-$279	-$315	-$240	-$81	-$165	$19	-$229	-$812
Scenario 26 (D2,D8,D11)	-$43	-$65	-$19	-$66	-$96	-$33	$19	$12	$26	-$1	-$237
Scenario 27 (D2,D8,D12)	-$75	-$110	-$36	-$87	-$127	-$43	-$32	-$57	-$2	-$34	-$272

Table 35 LCC Savings for Decision Making Scenarios – 92% TSL

LCC Savings Summary - 92% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
Scenario 1 (D1)	-$85	-$112	-$54	-$267	-$205	-$335	$390	$79	$757	-$71	-$475
Scenario 2 (D2)	$289	$262	$319	$159	$168	$148	$654	$506	$830	$323	$79
Scenario 3 (D3)	$189	$179	$201	$41	$82	-$4	$597	$422	$803	$168	-$273
Scenario 4 (D4, D5)	$21	-$14	$61	-$25	-$95	$50	$168	$219	$107	$40	-$8
Scenario 5 (D4, D6)	-$13	-$53	$32	-$27	-$95	$46	$51	$84	$11	$16	-$21
Scenario 6 (D4, D7)	-$7	-$42	$33	-$32	-$97	$39	$89	$131	$39	$25	-$13
Scenario 7 (D8)	$266	$248	$287	$168	$173	$163	$537	$426	$669	$261	$232
Scenario 8 (D1, D8)	-$148	-$153	-$142	-$314	-$248	-$387	$275	$27	$567	-$114	-$369
Scenario 9 (D2, D4, D6, D8)	-$54	-$93	-$11	-$67	-$120	-$8	-$2	-$3	-$1	-$32	-$233
Scenario 10 (D4, D6, D8)	-$24	-$66	$22	-$35	-$98	$35	$24	$41	$4	-$1	-$21
Scenario 11 (D4, D5, D8)	$1	-$36	$43	-$33	-$98	$39	$108	$141	$69	$11	-$11
Scenario 12 (D4, D7, D8)	-$19	-$57	$24	-$39	-$100	$28	$56	$79	$30	$1	-$13
Scenario 13 (D1, D4, D7)	-$523	-$615	-$420	-$634	-$696	-$566	-$237	-$443	$7	-$413	-$892
Scenario 14 (D1, D4, D7, D8)	-$493	-$575	-$401	-$583	-$633	-$528	-$267	-$464	-$35	-$414	-$703
Scenario 15 (D9)	$8	-$31	$52	-$0	-$66	$72	$51	$84	$11	$38	-$1
Scenario 16 (D10)	-$338	-$304	-$377	-$233	-$66	-$414	-$638	-$988	-$225	-$124	-$436
Scenario 17 (D8, D9)	-$4	-$44	$42	-$7	-$69	$61	$24	$41	$4	$22	-$1
Scenario 18 (D8, D10)	-$357	-$326	-$393	-$240	-$69	-$426	-$695	-$1,066	-$256	-$151	-$439
Scenario 19 (D0)	$238	$244	$232	$103	$137	$65	$613	$518	$726	$219	$186
Scenario 20 (D0, D4, D5)	-$38	-$45	-$31	-$101	-$133	-$66	$148	$202	$84	-$55	-$62
Scenario 21 (D0, D4, D6)	-$66	-$75	-$54	-$103	-$133	-$71	$58	$97	$11	-$69	-$72
Scenario 22 (D0, D4, D7)	-$59	-$66	-$52	-$106	-$133	-$76	$89	$134	$35	-$65	-$64
Scenario 23 (D1, D4, D5, D8)	-$532	-$617	-$436	-$621	-$664	-$574	-$324	-$560	-$45	-$517	-$867
Scenario 24 (D2, D4, D5, D8)	-$30	-$66	$10	-$65	-$120	-$4	$75	$85	$63	-$21	-$237
Scenario 25 (D3, D4, D5, D8)	-$182	-$225	-$134	-$234	-$274	-$190	-$44	-$111	$35	-$185	-$784
Scenario 26 (D2,D8,D11)	$20	$9	$33	$9	-$10	$31	$43	$47	$39	$76	-$176
Scenario 27 (D2,D8,D12)	$90	$74	$109	$126	$110	$145	-$18	-$32	-$1	$129	$13

Table 36 LCC Savings for Decision Making Scenarios – 95% TSL

LCC Savings Summary - 95% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
Scenario 1 (D1)	-$53	-$53	-$53	-$225	-$162	-$295	$379	$163	$633	$29	-$354
Scenario 2 (D2)	$362	$351	$375	$237	$256	$216	$706	$587	$847	$392	$114
Scenario 3 (D3)	$232	$232	$232	$93	$140	$41	$601	$442	$790	$249	-$332
Scenario 4 (D4, D5)	$89	$52	$131	$28	-$45	$107	$276	$323	$220	$102	$60
Scenario 5 (D4, D6)	$36	-$6	$83	$24	-$45	$100	$91	$120	$57	$59	$30
Scenario 6 (D4, D7)	$42	$8	$81	$12	-$49	$79	$152	$184	$114	$67	$41
Scenario 7 (D8)	$335	$335	$336	$244	$262	$223	$576	$490	$678	$343	$304
Scenario 8 (D1, D8)	-$135	-$101	-$173	-$310	-$230	-$397	$296	$156	$462	-$142	-$378
Scenario 9 (D2, D4, D6, D8)	-$15	-$53	$29	-$18	-$69	$39	$9	-$0	$21	-$13	-$233
Scenario 10 (D4, D6, D8)	$21	-$21	$68	$16	-$49	$87	$54	$73	$33	$37	$26
Scenario 11 (D4, D5, D8)	$61	$23	$103	$19	-$49	$94	$187	$222	$145	$60	$53
Scenario 12 (D4, D7, D8)	$30	-$8	$73	$11	-$51	$80	$106	$131	$77	$44	$41
Scenario 13 (D1, D4, D7)	-$517	-$606	-$417	-$601	-$656	-$540	-$315	-$527	-$65	-$447	-$877
Scenario 14 (D1, D4, D7, D8)	-$547	-$633	-$450	-$594	-$624	-$561	-$455	-$727	-$134	-$563	-$784
Scenario 15 (D9)	$65	$26	$109	$61	-$5	$134	$95	$126	$57	$88	$51
Scenario 16 (D10)	-$284	-$127	-$461	-$201	-$5	-$416	-$516	-$462	-$579	-$89	-$159
Scenario 17 (D8, D9)	$50	$10	$94	$53	-$9	$121	$58	$79	$33	$66	$47
Scenario 18 (D8, D10)	-$308	-$150	-$487	-$210	-$9	-$429	-$587	-$537	-$645	-$126	-$166
Scenario 19 (D0)	$311	$343	$276	$174	$230	$112	$683	$620	$757	$305	$264
Scenario 20 (D0, D4, D5)	$28	$29	$28	-$52	-$79	-$23	$263	$325	$189	$5	-$2
Scenario 21 (D0, D4, D6)	-$15	-$19	-$11	-$56	-$79	-$30	$115	$161	$61	-$22	-$29
Scenario 22 (D0, D4, D7)	-$14	-$14	-$14	-$64	-$82	-$45	$146	$188	$98	-$21	-$25
Scenario 23 (D1, D4, D5, D8)	-$566	-$641	-$482	-$623	-$645	-$599	-$468	-$722	-$168	-$552	-$846
Scenario 24 (D2, D4, D5, D8)	$25	-$9	$63	-$14	-$69	$45	$140	$149	$129	$10	-$208
Scenario 25 (D3, D4, D5, D8)	-$177	-$248	-$97	-$223	-$288	-$152	-$65	-$178	$68	-$203	-$869
Scenario 26 (D2,D8,D11)	$87	$83	$91	$85	$77	$94	$77	$74	$80	$126	-$168
Scenario 27 (D2,D8,D12)	$133	$113	$156	$183	$164	$204	-$10	-$28	$11	$166	$28

Table 37 LCC Savings for Decision Making Scenarios – 98% TSL

LCC Savings Summary - 98% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
Scenario 1 (D1)	-$119	-$116	-$121	-$302	-$228	-$383	$320	$62	$624	$10	-$404
Scenario 2 (D2)	$398	$429	$364	$273	$339	$201	$726	$620	$852	$472	$168
Scenario 3 (D3)	$229	$267	$187	$92	$187	-$11	$572	$408	$767	$271	-$338
Scenario 4 (D4, D5)	$155	$143	$168	$80	$55	$108	$362	$358	$368	$238	$249
Scenario 5 (D4, D6)	$64	$28	$105	$38	-$19	$100	$164	$174	$153	$127	$45
Scenario 6 (D4, D7)	$73	$41	$109	$37	-$5	$83	$202	$184	$223	$125	$94
Scenario 7 (D8)	$387	$441	$326	$312	$382	$236	$561	$526	$603	$440	$459
Scenario 8 (D1, D8)	-$220	-$199	-$242	-$356	-$287	-$431	$66	-$120	$285	-$238	-$348
Scenario 9 (D2, D4, D6, D8)	$1	-$31	$36	-$27	-$59	$8	$97	$52	$150	$35	-$340
Scenario 10 (D4, D6, D8)	$39	$2	$81	$28	-$26	$86	$92	$89	$96	$80	$38
Scenario 11 (D4, D5, D8)	$117	$107	$129	$70	$48	$94	$240	$233	$249	$172	$224
Scenario 12 (D4, D7, D8)	$48	$20	$80	$29	-$12	$74	$123	$120	$126	$91	$63
Scenario 13 (D1, D4, D7)	-$484	-$558	-$400	-$565	-$592	-$536	-$286	-$529	$2	-$420	-$674
Scenario 14 (D1, D4, D7, D8)	-$568	-$684	-$438	-$603	-$663	-$538	-$516	-$829	-$147	-$513	-$795
Scenario 15 (D9)	$118	$93	$145	$93	$38	$153	$213	$264	$153	$173	$80
Scenario 16 (D10)	-$142	$100	-$415	-$122	$81	-$343	-$207	$147	-$627	$49	$43
Scenario 17 (D8, D9)	$92	$67	$121	$83	$32	$139	$141	$179	$96	$126	$73
Scenario 18 (D8, D10)	-$178	$63	-$450	-$132	$74	-$357	-$322	$22	-$728	-$8	$31
Scenario 19 (D0)	$332	$435	$215	$197	$329	$53	$675	$664	$687	$358	$375
Scenario 20 (D0, D4, D5)	$73	$127	$12	-$24	$28	-$80	$329	$364	$286	$78	$149
Scenario 21 (D0, D4, D6)	-$10	$18	-$41	-$66	-$46	-$87	$164	$204	$117	-$16	-$42
Scenario 22 (D0, D4, D7)	-$0	$38	-$43	-$66	-$33	-$101	$203	$248	$148	$4	$1
Scenario 23 (D1, D4, D5, D8)	-$541	-$597	-$478	-$603	-$616	-$589	-$451	-$674	-$186	-$339	-$695
Scenario 24 (D2, D4, D5, D8)	$50	$42	$58	$5	$9	$0	$159	$91	$240	$75	-$182
Scenario 25 (D3, D4, D5, D8)	-$192	-$252	-$125	-$245	-$276	-$212	-$89	-$273	$128	-$163	-$822
Scenario 26 (D2,D8,D11)	$136	$142	$129	$119	$138	$98	$154	$100	$218	$201	-$95
Scenario 27 (D2,D8,D12)	$181	$160	$204	$236	$222	$252	$19	-$17	$62	$232	$63

Table 38 Fuel Switching for Decision Making Scenarios – 90% TSL

Percent of Affected Buildings Swithcing - 90%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
Scenario 1 (D1)	25.9%	20.9%	28.3%	29.9%	21.5%	33.8%	15.3%	21.6%	11.7%	29.6%	28.4%
Scenario 2 (D2)	16.8%	12.4%	19.0%	18.8%	12.1%	21.9%	11.5%	13.9%	10.0%	20.1%	20.6%
Scenario 3 (D3)	21.3%	15.7%	24.0%	24.5%	16.2%	28.3%	12.7%	15.6%	10.9%	26.6%	30.1%
Scenario 4 (D4, D5)	19.8%	17.7%	21.0%	19.4%	15.8%	21.1%	23.5%	24.4%	21.2%	22.1%	16.6%
Scenario 5 (D4, D6)	19.8%	17.7%	21.0%	19.4%	15.8%	21.1%	23.5%	24.4%	21.2%	22.1%	16.6%
Scenario 6 (D4, D7)	20.2%	18.1%	21.4%	19.6%	16.1%	21.3%	26.6%	26.8%	26.0%	21.9%	16.7%
Scenario 7 (D8)	12.4%	7.9%	14.5%	15.1%	9.2%	17.8%	3.2%	4.4%	2.6%	13.2%	11.6%
Scenario 8 (D1, D8)	23.4%	18.0%	26.1%	28.6%	20.5%	32.4%	7.1%	12.3%	4.3%	24.1%	29.9%
Scenario 9 (D2, D4, D6, D8)	21.7%	18.7%	23.3%	21.4%	17.4%	23.2%	26.4%	25.6%	29.8%	24.5%	30.2%
Scenario 10 (D4, D6, D8)	19.8%	17.7%	21.0%	19.4%	15.8%	21.1%	23.5%	24.4%	21.2%	22.1%	16.6%
Scenario 11 (D4, D5, D8)	18.5%	15.7%	20.0%	18.9%	15.3%	20.5%	14.9%	16.6%	10.9%	20.1%	16.4%
Scenario 12 (D4, D7, D8)	19.1%	16.1%	20.7%	19.1%	15.3%	20.8%	18.7%	18.9%	18.1%	20.6%	16.7%
Scenario 13 (D1, D4, D7)	35.4%	34.6%	35.9%	35.0%	32.4%	36.2%	44.4%	46.7%	37.3%	37.9%	40.8%
Scenario 14 (D1, D4, D7, D8)	35.3%	33.8%	36.2%	35.0%	31.8%	36.4%	45.1%	46.9%	39.4%	36.7%	40.3%
Scenario 15 (D9)	15.0%	11.7%	16.8%	14.0%	8.1%	16.6%	32.0%	31.9%	32.7%	15.8%	13.1%
Scenario 16 (D10)	26.4%	19.7%	30.2%	22.3%	8.1%	28.7%	63.7%	63.6%	63.7%	23.2%	25.1%
Scenario 17 (D8, D9)	13.9%	9.7%	16.1%	13.4%	7.6%	16.0%	24.0%	23.7%	25.5%	14.4%	13.1%
Scenario 18 (D8, D10)	25.3%	17.7%	29.4%	21.8%	7.6%	28.2%	59.7%	59.9%	59.1%	21.5%	24.9%
Scenario 19 (D0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
Scenario 20 (D0, D4, D5)	19.8%	17.7%	21.0%	19.4%	15.8%	21.1%	23.5%	24.4%	21.2%	22.1%	16.6%
Scenario 21 (D0, D4, D6)	20.3%	18.5%	21.3%	19.4%	15.8%	21.1%	32.0%	31.9%	32.7%	21.8%	16.8%
Scenario 22 (D0, D4, D7)	20.0%	17.7%	21.3%	19.4%	15.7%	21.2%	26.3%	26.6%	25.4%	22.3%	16.7%
Scenario 23 (D1, D4, D5, D8)	34.4%	33.1%	35.1%	34.5%	31.1%	36.0%	38.0%	43.5%	24.8%	36.1%	40.5%
Scenario 24 (D2, D4, D5, D8)	21.0%	18.0%	22.6%	21.4%	17.4%	23.2%	18.1%	20.1%	13.2%	23.9%	29.7%
Scenario 25 (D3, D4, D5, D8)	28.0%	25.1%	29.6%	28.5%	24.6%	30.3%	25.4%	28.2%	18.6%	32.9%	44.4%
Scenario 26 (D2, D8, D11)	18.6%	13.5%	23.0%	19.0%	13.4%	23.5%	14.1%	15.0%	11.9%	19.5%	22.4%
Scenario 27 (D2, D8, D12)	19.2%	14.1%	23.5%	19.2%	13.6%	23.6%	23.2%	22.1%	27.6%	20.2%	23.5%

Table 39 Fuel Switching for Decision Making Scenarios – 92% TSL

Percent of Affected Buildings Swithcing - 92%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
Scenario 1 (D1)	24.3%	18.5%	27.6%	28.4%	19.0%	33.3%	14.0%	18.7%	10.7%	27.6%	29.3%
Scenario 2 (D2)	15.2%	10.4%	18.0%	17.4%	10.3%	21.0%	9.7%	11.1%	8.7%	18.4%	19.3%
Scenario 3 (D3)	19.4%	13.1%	23.0%	22.7%	13.6%	27.4%	10.9%	12.8%	9.5%	24.4%	27.9%
Scenario 4 (D4, D5)	18.2%	14.9%	20.3%	18.2%	13.8%	20.4%	18.7%	18.3%	19.8%	19.6%	16.3%
Scenario 5 (D4, D6)	19.0%	16.1%	20.7%	18.2%	13.8%	20.5%	28.6%	27.4%	34.6%	19.7%	16.8%
Scenario 6 (D4, D7)	18.9%	15.4%	20.9%	18.5%	13.9%	20.8%	21.9%	21.3%	24.1%	19.6%	16.7%
Scenario 7 (D8)	11.1%	6.4%	13.6%	14.0%	7.7%	17.1%	2.0%	3.1%	1.3%	11.4%	11.5%
Scenario 8 (D1, D8)	21.6%	15.5%	24.9%	26.8%	18.0%	31.2%	6.5%	10.2%	4.0%	21.2%	28.7%
Scenario 9 (D2, D4, D6, D8)	20.3%	16.3%	22.6%	20.1%	15.3%	22.5%	23.0%	21.6%	30.4%	22.1%	29.3%
Scenario 10 (D4, D6, D8)	17.9%	14.4%	20.0%	17.7%	13.2%	19.9%	20.9%	19.9%	26.1%	18.5%	16.8%
Scenario 11 (D4, D5, D8)	16.9%	13.0%	19.2%	17.6%	13.2%	19.8%	11.2%	12.1%	8.8%	17.7%	16.1%
Scenario 12 (D4, D7, D8)	17.5%	13.6%	19.9%	17.8%	13.4%	20.0%	13.8%	13.6%	14.3%	18.5%	16.5%
Scenario 13 (D1, D4, D7)	34.6%	30.8%	36.9%	34.8%	29.7%	37.4%	36.1%	37.1%	32.6%	35.7%	38.5%
Scenario 14 (D1, D4, D7, D8)	32.9%	29.0%	35.3%	33.2%	28.3%	35.7%	33.6%	33.7%	33.3%	33.8%	38.5%
Scenario 15 (D9)	14.2%	10.3%	16.6%	13.3%	7.3%	16.3%	28.6%	27.4%	34.6%	14.5%	13.0%
Scenario 16 (D10)	25.3%	17.2%	30.4%	21.5%	7.3%	28.5%	53.3%	49.2%	65.8%	21.8%	24.0%
Scenario 17 (D8, D9)	13.1%	8.4%	15.8%	12.7%	6.6%	15.7%	20.9%	19.9%	26.1%	13.2%	13.0%
Scenario 18 (D8, D10)	24.1%	15.4%	29.5%	21.0%	6.6%	28.0%	49.2%	45.3%	61.5%	20.1%	23.8%
Scenario 19 (D0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
Scenario 20 (D0, D4, D5)	18.2%	14.9%	20.3%	18.2%	13.8%	20.4%	18.7%	18.3%	19.8%	19.6%	16.3%
Scenario 21 (D0, D4, D6)	19.0%	16.1%	20.7%	18.2%	13.8%	20.5%	28.6%	27.4%	34.6%	19.7%	16.8%
Scenario 22 (D0, D4, D7)	18.6%	15.0%	20.7%	18.4%	13.9%	20.6%	20.2%	19.2%	24.1%	19.6%	16.7%
Scenario 23 (D1, D4, D5, D8)	32.2%	28.3%	34.6%	33.1%	28.3%	35.4%	29.3%	30.3%	26.5%	32.1%	39.6%
Scenario 24 (D2, D4, D5, D8)	19.3%	15.1%	21.9%	20.1%	15.3%	22.5%	14.1%	14.7%	12.2%	21.1%	28.3%
Scenario 25 (D3, D4, D5, D8)	25.9%	21.3%	28.8%	27.0%	21.8%	29.6%	20.0%	20.6%	18.4%	29.6%	41.7%
Scenario 26 (D2, D8, D11)	17.9%	12.6%	22.5%	18.5%	12.7%	23.1%	11.3%	11.9%	9.8%	19.1%	21.5%
Scenario 27 (D2, D8, D12)	12.1%	7.9%	15.2%	11.8%	6.5%	15.3%	18.6%	17.7%	22.2%	10.4%	13.8%

Table 40 Fuel Switching for Decision Making Scenarios – 95% TSL

Percent of Affected Buildings Swithcing - 95%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
Scenario 1 (D1)	22.2%	14.6%	27.6%	25.9%	15.4%	32.5%	14.3%	14.1%	14.4%	22.9%	27.3%
Scenario 2 (D2)	14.5%	8.0%	19.1%	16.7%	7.8%	22.2%	9.9%	8.8%	10.9%	16.8%	19.4%
Scenario 3 (D3)	18.7%	11.1%	24.1%	21.9%	11.6%	28.3%	11.9%	11.0%	12.7%	21.1%	28.2%
Scenario 4 (D4, D5)	18.1%	11.8%	23.1%	17.9%	10.6%	22.5%	19.6%	15.0%	29.5%	17.6%	16.1%
Scenario 5 (D4, D6)	19.2%	12.8%	24.0%	18.1%	10.6%	23.0%	29.7%	23.9%	42.3%	18.1%	17.0%
Scenario 6 (D4, D7)	18.8%	12.2%	23.9%	18.2%	10.6%	23.2%	23.1%	18.0%	33.8%	18.5%	16.1%
Scenario 7 (D8)	10.9%	4.9%	15.1%	13.7%	6.1%	18.6%	3.6%	2.7%	4.5%	9.5%	11.6%
Scenario 8 (D1, D8)	20.1%	11.9%	26.0%	25.3%	14.4%	32.3%	7.6%	7.6%	7.5%	18.7%	26.0%
Scenario 9 (D2, D4, D6, D8)	20.1%	13.1%	25.3%	19.5%	11.6%	24.7%	26.3%	20.7%	38.9%	20.7%	26.2%
Scenario 10 (D4, D6, D8)	18.2%	11.6%	23.1%	17.6%	10.2%	22.4%	24.3%	18.5%	37.1%	16.7%	16.8%
Scenario 11 (D4, D5, D8)	16.7%	10.3%	21.8%	17.4%	10.2%	22.0%	13.6%	10.5%	20.7%	15.5%	15.8%
Scenario 12 (D4, D7, D8)	17.8%	11.1%	22.9%	17.9%	10.5%	22.7%	17.1%	12.8%	27.1%	16.2%	16.3%
Scenario 13 (D1, D4, D7)	32.1%	24.1%	38.2%	31.7%	22.5%	37.7%	37.4%	31.6%	50.5%	30.2%	35.8%
Scenario 14 (D1, D4, D7, D8)	31.6%	23.4%	37.8%	31.5%	21.9%	37.8%	34.9%	31.0%	44.1%	31.5%	37.1%
Scenario 15 (D9)	14.9%	8.3%	19.7%	13.4%	5.6%	18.5%	29.5%	23.6%	42.3%	14.0%	13.6%
Scenario 16 (D10)	24.1%	11.9%	33.8%	20.4%	5.6%	29.8%	44.3%	30.4%	74.8%	19.8%	20.6%
Scenario 17 (D8, D9)	13.8%	7.0%	18.8%	12.9%	5.1%	17.9%	24.1%	18.3%	37.1%	12.6%	13.4%
Scenario 18 (D8, D10)	23.0%	10.5%	32.7%	19.9%	5.1%	29.3%	40.4%	27.1%	71.7%	17.8%	20.3%
Scenario 19 (D0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
Scenario 20 (D0, D4, D5)	18.1%	11.8%	23.1%	17.9%	10.6%	22.5%	19.6%	15.0%	29.5%	17.6%	16.1%
Scenario 21 (D0, D4, D6)	19.2%	12.8%	24.0%	18.1%	10.6%	23.0%	29.7%	23.9%	42.3%	18.1%	17.0%
Scenario 22 (D0, D4, D7)	18.8%	12.0%	24.0%	18.3%	10.8%	23.1%	22.8%	16.4%	37.0%	17.4%	16.4%
Scenario 23 (D1, D4, D5, D8)	30.2%	21.6%	37.0%	31.0%	21.1%	37.2%	28.9%	24.3%	39.8%	30.0%	36.3%
Scenario 24 (D2, D4, D5, D8)	18.5%	11.7%	24.0%	19.3%	11.6%	24.2%	15.3%	11.9%	23.1%	19.3%	24.9%
Scenario 25 (D3, D4, D5, D8)	24.7%	17.1%	30.8%	25.6%	17.1%	31.1%	21.9%	18.0%	31.1%	26.7%	39.2%
Scenario 26 (D2, D8, D11)	18.2%	11.3%	24.5%	19.4%	12.0%	25.3%	11.6%	8.3%	17.7%	19.1%	22.7%
Scenario 27 (D2, D8, D12)	11.2%	6.0%	15.9%	10.7%	5.1%	15.1%	15.7%	10.1%	26.4%	9.3%	13.6%

Table 41 Fuel Switching for Decision Making Scenarios – 98% TSL

Percent of Affected Buildings Swithcing - 98%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
Scenario 1 (D1)	21.2%	10.5%	33.2%	23.2%	9.7%	37.8%	17.1%	13.6%	21.3%	21.4%	25.7%
Scenario 2 (D2)	15.4%	6.2%	25.7%	16.6%	5.3%	28.9%	12.7%	9.1%	17.0%	16.2%	19.7%
Scenario 3 (D3)	18.7%	8.3%	30.4%	20.5%	7.5%	34.5%	14.8%	11.0%	19.2%	19.6%	26.3%
Scenario 4 (D4, D5)	18.4%	8.5%	30.0%	17.9%	7.1%	30.0%	21.9%	15.2%	31.6%	16.5%	16.4%
Scenario 5 (D4, D6)	20.1%	9.4%	32.1%	18.8%	7.6%	30.7%	29.9%	20.0%	47.0%	18.0%	17.6%
Scenario 6 (D4, D7)	19.7%	9.2%	31.7%	18.7%	7.6%	30.6%	26.8%	17.6%	41.0%	17.1%	17.0%
Scenario 7 (D8)	12.1%	4.0%	21.3%	14.2%	4.2%	25.2%	6.1%	3.6%	9.1%	9.6%	12.6%
Scenario 8 (D1, D8)	19.6%	9.5%	31.2%	22.8%	10.0%	36.9%	11.2%	9.0%	14.0%	18.1%	23.8%
Scenario 9 (D2, D4, D6, D8)	22.1%	10.7%	34.8%	20.9%	8.8%	33.8%	31.4%	22.2%	47.3%	21.9%	27.1%
Scenario 10 (D4, D6, D8)	19.2%	8.7%	31.1%	18.5%	7.4%	30.2%	25.2%	16.4%	41.4%	16.3%	17.3%
Scenario 11 (D4, D5, D8)	17.3%	7.8%	28.6%	17.6%	6.9%	29.5%	16.8%	11.8%	24.3%	14.6%	15.8%
Scenario 12 (D4, D7, D8)	18.6%	8.3%	30.5%	18.3%	7.4%	30.2%	20.9%	13.1%	35.1%	15.5%	16.5%
Scenario 13 (D1, D4, D7)	28.8%	16.4%	43.1%	27.7%	14.0%	42.5%	38.2%	30.2%	52.2%	27.2%	30.8%
Scenario 14 (D1, D4, D7, D8)	29.1%	16.7%	43.3%	28.2%	14.4%	43.2%	37.2%	30.8%	47.9%	26.1%	31.9%
Scenario 15 (D9)	15.1%	5.2%	26.2%	13.6%	3.6%	24.3%	27.2%	15.9%	47.0%	13.8%	14.0%
Scenario 16 (D10)	20.6%	6.3%	37.4%	17.7%	3.3%	33.6%	37.0%	19.8%	63.6%	16.9%	18.0%
Scenario 17 (D8, D9)	14.1%	4.5%	25.1%	13.2%	3.4%	23.7%	22.4%	12.1%	41.4%	12.0%	13.8%
Scenario 18 (D8, D10)	19.5%	5.5%	36.2%	17.3%	3.1%	33.2%	32.9%	16.5%	59.7%	15.0%	17.6%
Scenario 19 (D0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
Scenario 20 (D0, D4, D5)	18.4%	8.5%	30.0%	17.9%	7.1%	30.0%	21.9%	15.2%	31.6%	16.5%	16.4%
Scenario 21 (D0, D4, D6)	20.1%	9.4%	32.1%	18.8%	7.6%	30.7%	29.9%	20.0%	47.0%	18.0%	17.6%
Scenario 22 (D0, D4, D7)	19.7%	9.2%	31.8%	18.8%	7.5%	30.8%	26.4%	17.6%	41.1%	17.5%	16.7%
Scenario 23 (D1, D4, D5, D8)	26.6%	14.7%	40.7%	26.8%	13.1%	42.0%	28.5%	23.4%	36.3%	24.5%	29.9%
Scenario 24 (D2, D4, D5, D8)	19.2%	9.1%	31.2%	19.6%	8.0%	32.5%	18.4%	14.1%	25.1%	18.2%	25.1%
Scenario 25 (D3, D4, D5, D8)	24.1%	12.9%	37.3%	24.4%	11.4%	38.8%	24.7%	20.3%	31.4%	22.2%	34.1%
Scenario 26 (D2, D8, D11)	19.7%	9.9%	31.3%	21.2%	10.2%	33.4%	13.5%	8.8%	20.4%	19.3%	24.4%
Scenario 27 (D2, D8, D12)	10.9%	4.8%	20.8%	10.3%	3.6%	20.7%	14.3%	9.9%	23.5%	8.1%	12.2%

Table 42 Energy Use and GHG Emissions for Decision Making Scenarios – 90% TSL

Energy Use Summary - 90% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.2	28.8	312	1,045	-22.4%	234.6%	-1.2	-158.5
Scenario 1 (D1)	37.2	25.9	312	1,751	-30.2%	460.4%	3.2	443.2
Scenario 2 (D2)	37.2	29.0	312	1,038	-22.1%	232.3%	-1.2	-151.3
Scenario 3 (D3)	37.2	27.7	312	1,317	-25.5%	321.6%	0.4	67.5
Scenario 4 (D4, D5)	32.9	24.5	286	1,069	-25.6%	274.4%	-0.8	-100.9
Scenario 5 (D4, D6)	32.9	24.5	286	1,069	-25.6%	274.4%	-0.8	-100.9
Scenario 6 (D4, D7)	32.1	23.8	280	1,057	-25.9%	277.2%	-0.8	-95.8
Scenario 7 (D8)	37.4	30.4	314	794	-18.6%	153.2%	-2.5	-325.9
Scenario 8 (D1, D8)	37.4	26.7	314	1,672	-28.5%	433.2%	2.9	407.1
Scenario 9 (D2, D4, D6, D8)	32.4	23.6	282	1,147	-27.1%	306.3%	-0.3	-32.0
Scenario 10 (D4, D6, D8)	32.9	24.5	286	1,069	-25.6%	274.4%	-0.8	-100.9
Scenario 11 (D4, D5, D8)	33.1	25.1	286	987	-24.2%	244.9%	-1.2	-158.8
Scenario 12 (D4, D7, D8)	32.3	24.3	282	994	-24.7%	252.7%	-1.1	-140.4
Scenario 13 (D1, D4, D7)	32.2	18.8	281	2,247	-41.7%	700.1%	6.4	884.2
Scenario 14 (D1, D4, D7, D8)	32.4	18.9	282	2,267	-41.6%	705.3%	6.6	909.3
Scenario 15 (D9)	32.3	25.1	282	846	-22.2%	200.3%	-1.8	-233.4
Scenario 16 (D10)	32.9	21.8	285	1,706	-33.8%	498.4%	3.1	433.0
Scenario 17 (D8, D9)	32.4	25.5	282	789	-21.2%	179.5%	-2.1	-272.2
Scenario 18 (D8, D10)	33.0	22.3	286	1,640	-32.6%	473.7%	2.8	387.6
Scenario 19 (D0)	37.2	33.1	312	307	-10.9%	-1.9%	-4.5	-601.7
Scenario 20 (D0, D4, D5)	32.9	29.4	286	282	-10.9%	-1.2%	-3.9	-531.5
Scenario 21 (D0, D4, D6)	32.3	28.7	282	279	-10.9%	-0.8%	-3.9	-519.4
Scenario 22 (D0, D4, D7)	32.3	28.8	281	279	-10.9%	-0.8%	-3.9	-519.7
Scenario 23 (D1, D4, D5, D8)	33.1	19.7	286	2,222	-40.5%	676.0%	6.1	845.8
Scenario 24 (D2, D4, D5, D8)	33.1	24.4	286	1,132	-26.4%	295.5%	-0.5	-52.9
Scenario 25 (D3, D4, D5, D8)	33.1	22.3	286	1,576	-32.6%	450.4%	2.1	290.0
Scenario 26 (D2, D8, D11)	38.1	29.3	310	1,114	-23.1%	259.5%	-1.0	-128.0
Scenario 27 (D2, D8, D12)	36.6	27.9	301	1,112	-23.9%	269.3%	-0.9	-107.4

Table 43 Energy Use and GHG Emissions for Decision Making Scenarios – 92% TSL

Energy Use Summary - 92% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.4	29.3	314	961	-21.8%	205.9%	-2.0	-258.2
Scenario 1 (D1)	37.4	26.3	314	1,692	-29.8%	438.6%	2.6	363.0
Scenario 2 (D2)	37.4	29.4	314	963	-21.6%	206.8%	-1.9	-243.5
Scenario 3 (D3)	37.4	28.2	314	1,220	-24.7%	288.6%	-0.4	-38.9
Scenario 4 (D4, D5)	33.5	25.2	289	992	-24.7%	243.0%	-1.5	-192.0
Scenario 5 (D4, D6)	32.4	24.2	283	992	-25.5%	250.6%	-1.4	-184.0
Scenario 6 (D4, D7)	32.5	24.3	283	989	-25.2%	249.1%	-1.4	-179.2
Scenario 7 (D8)	37.5	30.5	314	736	-18.6%	134.3%	-3.1	-410.1
Scenario 8 (D1, D8)	37.5	27.1	314	1,552	-27.8%	393.6%	1.9	269.2
Scenario 9 (D2, D4, D6, D8)	32.6	23.9	284	1,073	-26.5%	278.1%	-1.0	-122.4
Scenario 10 (D4, D6, D8)	32.6	24.6	284	940	-24.5%	231.3%	-1.7	-220.6
Scenario 11 (D4, D5, D8)	33.6	25.8	290	914	-23.4%	215.2%	-1.9	-247.4
Scenario 12 (D4, D7, D8)	32.7	24.9	284	904	-23.9%	218.5%	-1.9	-245.7
Scenario 13 (D1, D4, D7)	32.4	19.0	282	2,189	-41.2%	675.5%	5.9	814.2
Scenario 14 (D1, D4, D7, D8)	32.6	19.8	284	2,083	-39.3%	633.4%	5.3	731.8
Scenario 15 (D9)	32.4	25.2	283	798	-22.2%	181.9%	-2.3	-310.8
Scenario 16 (D10)	33.3	22.3	288	1,643	-32.9%	470.3%	2.5	356.7
Scenario 17 (D8, D9)	32.6	25.6	284	743	-21.2%	161.8%	-2.6	-349.0
Scenario 18 (D8, D10)	33.5	22.8	289	1,578	-31.8%	445.8%	2.2	310.1
Scenario 19 (D0)	37.4	33.1	314	304	-11.7%	-3.1%	-4.9	-659.2
Scenario 20 (D0, D4, D5)	33.5	29.5	289	282	-11.8%	-2.5%	-4.4	-590.1
Scenario 21 (D0, D4, D6)	32.4	28.5	283	277	-11.9%	-2.1%	-4.3	-578.1
Scenario 22 (D0, D4, D7)	32.5	28.7	283	278	-11.9%	-2.1%	-4.3	-576.3
Scenario 23 (D1, D4, D5, D8)	33.6	20.7	290	2,078	-38.3%	616.4%	5.1	704.2
Scenario 24 (D2, D4, D5, D8)	33.6	25.1	290	1,051	-25.4%	262.6%	-1.2	-147.4
Scenario 25 (D3, D4, D5, D8)	33.6	23.2	290	1,470	-31.1%	407.0%	1.3	180.8
Scenario 26 (D2, D8, D11)	38.3	29.3	312	1,068	-23.5%	242.3%	-1.7	-222.9
Scenario 27 (D2, D8, D12)	46.5	37.0	364	1,123	-20.5%	208.4%	-2.2	-293.9

Table 44 Energy Use and GHG Emissions for Decision Making Scenarios – 95% TSL

Energy Use Summary - 95% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.9	29.9	317	912	-20.9%	187.2%	-2.3	-301.7
Scenario 1 (D1)	37.9	27.4	317	1,551	-27.7%	388.7%	1.8	250.0
Scenario 2 (D2)	37.9	30.0	317	910	-20.8%	186.6%	-2.2	-294.2
Scenario 3 (D3)	37.9	28.8	317	1,179	-24.0%	271.3%	-0.7	-83.3
Scenario 4 (D4, D5)	34.9	26.7	299	972	-23.6%	225.5%	-1.8	-230.3
Scenario 5 (D4, D6)	33.8	25.4	292	987	-24.8%	237.7%	-1.7	-223.3
Scenario 6 (D4, D7)	33.8	25.5	292	966	-24.3%	231.4%	-1.7	-225.6
Scenario 7 (D8)	38.2	31.3	319	716	-17.9%	124.5%	-3.2	-427.8
Scenario 8 (D1, D8)	38.2	28.3	319	1,454	-25.8%	355.9%	1.4	200.0
Scenario 9 (D2, D4, D6, D8)	34.0	25.3	293	1,057	-25.6%	260.4%	-1.3	-168.9
Scenario 10 (D4, D6, D8)	34.0	25.8	293	946	-24.1%	222.3%	-1.9	-254.1
Scenario 11 (D4, D5, D8)	35.1	27.2	300	901	-22.4%	200.6%	-2.1	-283.1
Scenario 12 (D4, D7, D8)	34.0	26.0	294	923	-23.6%	214.3%	-2.0	-265.7
Scenario 13 (D1, D4, D7)	34.0	21.3	293	2,024	-37.2%	591.5%	4.7	658.1
Scenario 14 (D1, D4, D7, D8)	33.9	21.4	293	2,004	-36.9%	584.9%	4.7	646.6
Scenario 15 (D9)	33.8	26.4	292	808	-21.9%	176.2%	-2.6	-341.4
Scenario 16 (D10)	34.7	24.4	298	1,498	-29.8%	403.5%	1.6	227.6
Scenario 17 (D8, D9)	34.0	26.8	293	764	-21.2%	160.3%	-2.8	-373.7
Scenario 18 (D8, D10)	34.9	24.9	289	1,578	-31.8%	445.8%	2.2	310.1
Scenario 19 (D0)	37.4	33.1	314	304	-11.7%	-3.1%	-4.9	-659.2
Scenario 20 (D0, D4, D5)	33.5	29.5	289	282	-11.8%	-2.5%	-4.4	-590.1
Scenario 21 (D0, D4, D6)	32.4	28.5	283	277	-11.9%	-2.1%	-4.3	-578.1
Scenario 22 (D0, D4, D7)	32.5	28.7	283	278	-11.9%	-2.1%	-4.3	-576.3
Scenario 23 (D1, D4, D5, D8)	33.6	20.7	290	2,078	-38.3%	616.4%	5.1	704.2
Scenario 24 (D2, D4, D5, D8)	33.6	25.1	290	1,051	-25.4%	262.6%	-1.2	-147.4
Scenario 25 (D3, D4, D5, D8)	33.6	23.2	290	1,470	-31.1%	407.0%	1.3	180.8
Scenario 26 (D2, D8, D11)	38.3	29.3	312	1,068	-23.5%	242.3%	-1.7	-222.9
Scenario 27 (D2, D8, D12)	46.5	37.0	364	1,123	-20.5%	208.4%	-2.2	-293.9

Table 45 Energy Use and GHG Emissions for Decision Making Scenarios – 98% TSL

Energy Use Summary - 98% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	39.4	31.1	323	952	-21.1%	195.1%	-2.3	-308.4
Scenario 1 (D1)	39.4	28.9	325	1,514	-26.8%	366.4%	1.2	178.0
Scenario 2 (D2)	39.4	31.1	323	975	-21.3%	202.3%	-2.1	-283.2
Scenario 3 (D3)	39.4	30.0	323	1,220	-24.0%	278.2%	-0.7	-86.7
Scenario 4 (D4, D5)	39.7	31.0	324	1,005	-21.7%	210.5%	-2.1	-277.4
Scenario 5 (D4, D6)	37.2	28.4	309	1,034	-23.7%	235.2%	-1.8	-238.6
Scenario 6 (D4, D7)	37.7	29.0	312	1,021	-23.0%	227.6%	-1.9	-243.4
Scenario 7 (D8)	39.9	32.4	325	787	-18.7%	141.9%	-3.2	-427.8
Scenario 8 (D1, D8)	39.9	29.7	325	1,446	-25.5%	344.4%	0.9	135.0
Scenario 9 (D2, D4, D6, D8)	37.2	27.8	309	1,156	-25.1%	274.7%	-1.1	-140.1
Scenario 10 (D4, D6, D8)	37.4	28.8	310	991	-22.9%	220.2%	-2.0	-266.0
Scenario 11 (D4, D5, D8)	39.9	31.6	325	945	-20.8%	190.8%	-2.4	-319.6
Scenario 12 (D4, D7, D8)	38.0	29.7	313	959	-21.9%	206.1%	-2.2	-283.8
Scenario 13 (D1, D4, D7)	37.7	25.9	311	1,789	-31.2%	474.5%	3.0	417.2
Scenario 14 (D1, D4, D7, D8)	37.9	26.1	313	1,812	-31.2%	479.4%	3.1	439.4
Scenario 15 (D9)	37.2	29.5	309	824	-20.6%	167.1%	-2.8	-377.2
Scenario 16 (D10)	39.3	29.9	321	1,261	-23.8%	292.5%	-0.2	-11.8
Scenario 17 (D8, D9)	37.4	30.0	310	779	-19.8%	151.5%	-3.0	-406.1
Scenario 18 (D8, D10)	39.6	30.5	289	1,578	-31.8%	445.8%	2.2	310.1
Scenario 19 (D0)	37.4	33.1	314	304	-11.7%	-3.1%	-4.9	-659.2
Scenario 20 (D0, D4, D5)	33.5	29.5	289	282	-11.8%	-2.5%	-4.4	-590.1
Scenario 21 (D0, D4, D6)	32.4	28.5	283	277	-11.9%	-2.1%	-4.3	-578.1
Scenario 22 (D0, D4, D7)	32.5	28.7	283	278	-11.9%	-2.1%	-4.3	-576.3
Scenario 23 (D1, D4, D5, D8)	33.6	20.7	290	2,078	-38.3%	616.4%	5.1	704.2
Scenario 24 (D2, D4, D5, D8)	33.6	25.1	290	1,051	-25.4%	262.6%	-1.2	-147.4
Scenario 25 (D3, D4, D5, D8)	33.6	23.2	290	1,470	-31.1%	407.0%	1.3	180.8
Scenario 26 (D2, D8, D11)	38.3	29.3	312	1,068	-23.5%	242.3%	-1.7	-222.9
Scenario 27 (D2, D8, D12)	46.5	37.0	364	1,123	-20.5%	208.4%	-2.2	-293.9

A.5 GTI Input Data Parametrics

In addition to improving decision making over the Baseline AFUE assignment in DOE LCC Model, input parameters were also changed to more technically defensible ones when such information was available. Several input parameters were evaluated and are included in the parametric matrix, but they were not incorporated into scenarios if more technically defensible inputs compared to the DOE LCC model could not be found. For this reason, input data parametrics I3, I4, I5, I7, I9, I12, and I14 were not incorporated into scenarios for further evaluation.

A.5.1 Parametric I1

Between the LCC Model that DOE released in 2011 and the one released in 2014 NWGF manufacturer production costs (MPC) substantially increased for non-condensing NWGF while only marginally increased or even decreased for condensing versions. This parametric uses the inflation adjusted (http://www.bls.gov/cpi/cpid1405.pdf) MPC from the 2011 LCC Model in the more recent LCC Model. NWGF MPC were adjusted according to Table 46.

Table 46 Manufacturer Production Cost Comparison – 2014 vs. 2011 LCC Model

2014 LCC MPC 2013$

EL	MPC			
	60 kBtu/hr	80 kBtu/hr	100 kBtu/hr	120 kBtu/hr
NWGF 80%	$349.23	$359.98	$381.62	$406.74
NWGF 90%	$427.90	$443.29	$471.10	$507.01
NWGF 92%	$435.67	$450.89	$484.78	$511.88
NWGF 95%	$476.44	$504.98	$541.02	$583.62
NWGF 98%	$610.50	$626.73	$661.30	$711.27

2011 LCC MPC 2013$

EL	MPC			
	60 kBtu/hr	80 kBtu/hr	100 kBtu/hr	120 kBtu/hr
NWGF 80%	$281.24	$288.84	$306.21	$331.19
NWGF 90%	$398.51	$411.54	$437.60	$472.35
NWGF 92%	$431.09	$447.37	$478.86	$513.61
NWGF 95%	$491.89	$523.38	$573.33	$616.77
NWGF 98%	$631.97	$646.09	$684.09	$744.90

A.5.2 Parametric I2

This parametric replaces DOE's retail prices that are derived through a tear down analysis of furnaces with a database of actual offered prices of furnaces. GTI tabulated retail prices provided in the 2013 Furnace Price Guide (https://www.furnacecompare.com/furnaces/price-guide.html), segregated models by efficiency level, adjusted the furnace prices to account for the use of BPM motors in place of PSC motors, and used the adjusted "delivered to home" furnace prices as inputs to the model. The list of actual direct-to-consumer prices offered over the Internet listed in the 2013 Furnace Price Guide covers 25 brands and a wide range of efficiencies and capacities. A total of 1,222 records were extracted from 2013 Price Guide (569 for 80% AFUE NWGF, 29 for 90%, 215 for 92%, 409 for 95%, and none for 98%). A linear curve fit was derived only for the 80%, 92% and 95% AFUE NWGFs.

There was not sufficient data for 90% AFUE furnaces in the 2013 Furnace Price Guide for a reasonable curve fit, and there were no 98% AFUE furnaces in the 2013 Furnace Price Guide. To estimate prices for 90% and 98% AFUE furnaces, differential prices between 92% and 90% as well as 95% and 98% from the DOE 2014 LCC spreadsheet were applied to 92% and 95% AFUE groups from 2013 Furnace Price Guide as inputs to the model.

Price decreases over time followed the DOE learning curve baseline assumptions. This parametric represents real offered prices rather than a large number of manufacturing cost estimates for every component and assembly where each aggregation is subject to error.

Figures Figure 31, Figure 32, and Figure 33 illustrate the 2013 Furnace Price Guide curve fitted data for 80%, 92% and 95% AFUE NWGF.

As illustrated in Figure 34, the curve fitted 2013 Price Guide numbers show a $363 differential between 92% and 80% 80,000 Btu/h furnace. DOE 92% AFUE retail prices were similar, but DOE's 80% AFUE furnace price is much higher than the 2013 Price Guide numbers. Also, 2013 Price Guide 95% AFUE has a much steeper price change with capacity than DOE's numbers.

To make the 2013 Price Guide compatible with 2021 fan motor assumptions, the 2013 Price Guide numbers were adjusted by adding the upgrade cost from a PSC motor to a BPM motor based on percentages of PSC motors being installed in each AFUE efficiency group in equipment currently available per the rf_nopr_analysis_inputs_2014-02-06.xlsm sheet "Furnace Fan Motor Types."

Current Fractions of PSC and BPM Motors are shown in Table 47 and 2021 motor type fractions used in the DOE NOPR LCC model are shown in Table 48. The cost of the motor upgrade is based on DOE numbers listed on page 5-22 of 2014 LCC TSD, shown in Table 49.

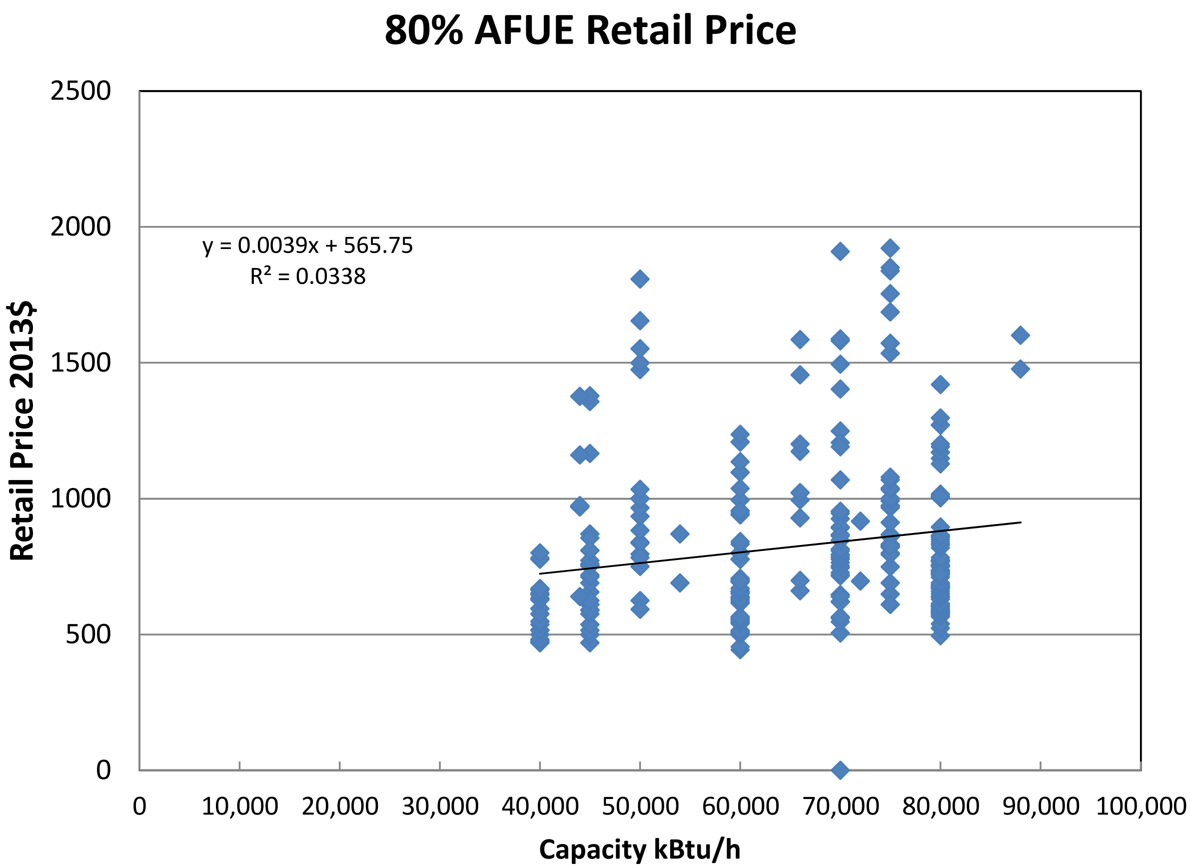


Figure 31 Retail Price vs. Capacity at 80% AFUE

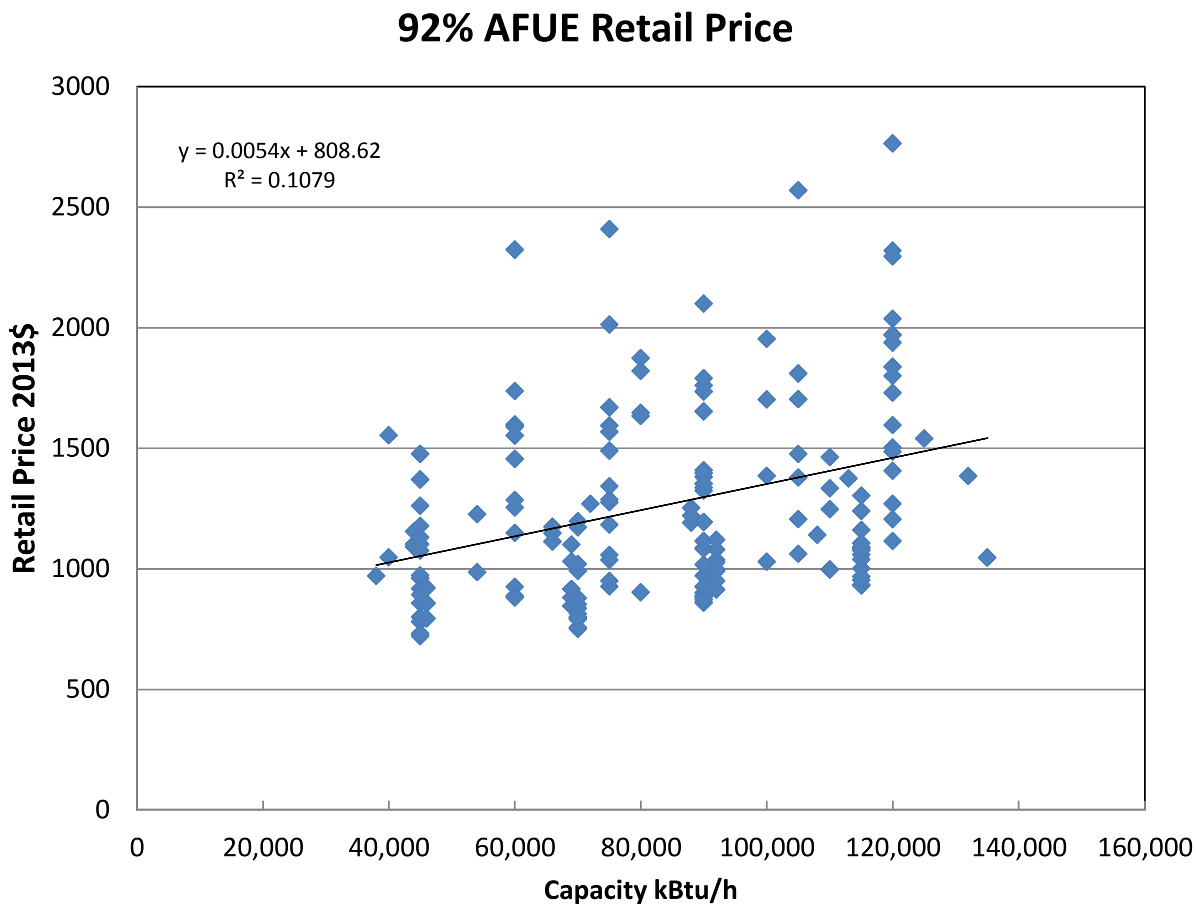


Figure 32 Retail Price vs. Capacity at 92% AFUE

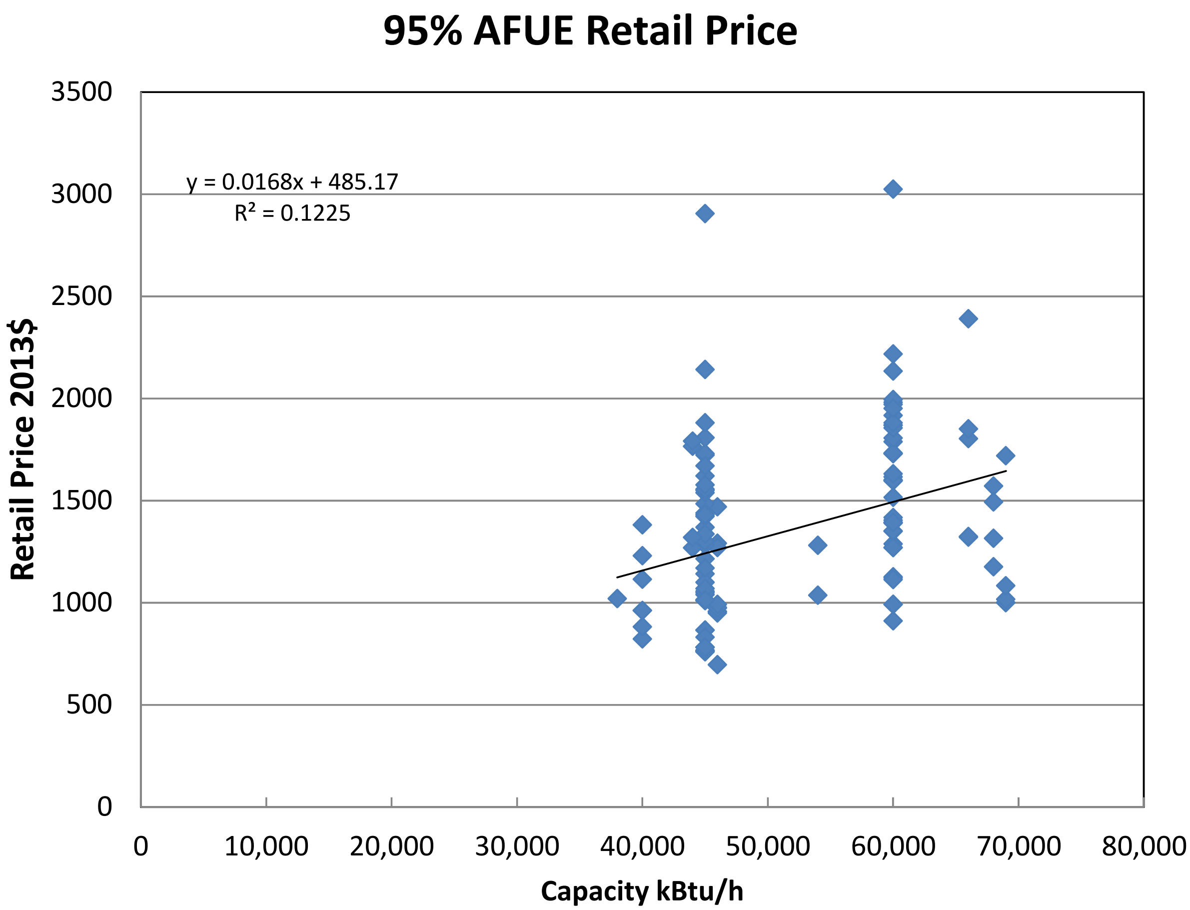


Figure 33 Retail Price vs. Capacity at 95% AFUE

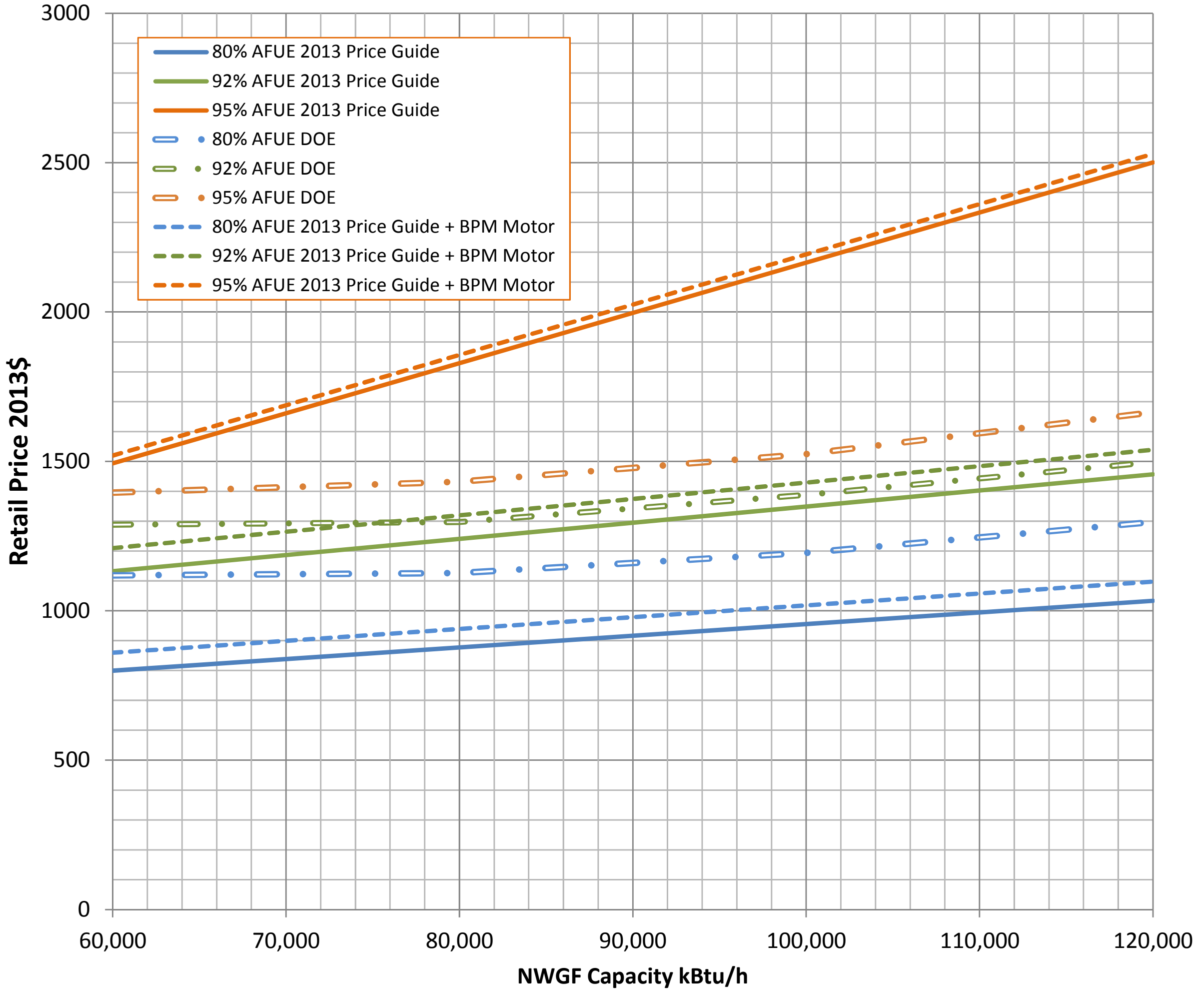


Figure 34 Retail Price Comparison –DOE LCC Model vs. 2013 Price Guide

Table 47 Current Fractions of PSC and BPM Motors

Fraction of Furnaces by Motor Type (Based on Model Data)

	PrdClass	AFUE	PSC	BPM Constant Torque (Single Stage)	BPM Constant Torque (Two-Stage)	BPM Constant Airflow
0	NWGF	80	67%	14%	4%	15%
1	NWGF	90	78%	5%	0%	16%
2	NWGF	92	86%	1%	0%	13%
3	NWGF	95	29%	12%	11%	47%
4	NWGF	98	0%	0%	0%	100%
0	MHGF	80	100%	0%	0%	0%
1	MHGF	92	100%	0%	0%	0%
2	MHGF	95	53%	40%	0%	7%
3	MHGF	97	0%	0%	0%	100%

Table 48 2021 Motor Type Fractions

Crystal Ball Assumptions

Description	NWGF 80%		NWGF 90%		NWGF 92%		NWGF 95%		NWGF 98%		MHGF 80%		MHGF 92%		MHGF 95%		MHGF 97	
Improved PSC	1		1		1		1		1		1	100%	1	100%	1	50%	1	50%
X13, Single Stage	2		2		2		2		2		2	0%	2	0%	2	40%	2	40%
X13, Multi-Stage	3	85%	3	85%	3	85%	3	50%	3	0%	3	0%	3	0%	3	0%	3	0%
ECM, Multi-Stage	4	15%	4	15%	4	15%	4	50%	4	100%	4	0%	4	0%	4	10%	4	10%

Table 49 Additional Cost for Motor Upgrades

Table 5.8.1 Additional Cost (Including Motor, Controls, and Wiring) to Switch from PSC to Improved PSC or BPM Blower Motor

Product Class	Input Capacity (kBtu/h)	Incremental Cost Increase for Improved PSC ($)	Incremental Cost Increase for Constant-torque BPM ($)	Incremental Cost Increase for Constant-airflow BPM ($)
Non-weatherized Gas	60	-	37.29	89.60
	80	-	41.29	91.60
	100	-	45.29	93.60
	120	-	49.29	95.60
Mobile Home Gas	80	6.11	41.29	91.60

A.5.3 Parametric I3

This parametric was intended to modify NWGF installation costs based on an installing contractor survey conducted by other stakeholders in 2015. However, survey information was not publicly available in time for this analysis, so this parametric was not run.

A.5.4 Parametric I4

This parametric was intended to apply actual installation cost data to electric switching options and would have been a necessary addition to parametric I3. However, no data of this type was available, so this parametric was not run.

A.5.5 Parametric I5

This parametric examines the effects of consumer discount rate on LCC savings. Discount rate is expected to have a significant effect on the life cycle cost calculation of long lifetime equipment such as residential furnaces. In its analysis, DOE used the Federal Reserve Board’s Survey of Consumer Finances (SCF) to estimate consumer opportunity cost of funds (TSD 8-23). DOE used information in the SCF to determine equity and debt percentages of income groups which were then used to determine distributions of discount rates for each income group. (for a full description, see TSD 8-24). Table 50 shows the types of debt or equity by percentage for each income group.

As indicated in Table 50, mortgages represent a very significant portion of consumer debt – more than 24% for the top five income groups defined in Table 51. Mortgage debt is also a very low interest debt type. It becomes especially low interest when DOE considers the tax deductibility of mortage and home equity loan interest and inflation (TSD 8-25). DOE does not appear to account for the observation that the mortgage interest tax deduction is only available to taxpayers with more than the standard deduction of $6,200 for single taxpayers or $12,400 for married tax payers that itemize deductions. Many taxpayers in the lower income groups may not qualify for the itemized mortgage interest deduction if they have no other significant itemized deductions. In that regard, in testimony before the Committee on Ways and Means, Eric J. Toder submitted that 24% of tax units (married couples or singles) will beneift from the deduction while 47% of those tax units pay home secured debt interest. (Eric J. Toder, Testimony before the Committee on Ways and Means April 25, 2013 http://www.taxpolicycenter.org/UploadedPDF/1001677-Toder-Ways-and-Means-MID.pdf). Toder’s testimony indicates that 49% of mortgage holders do not qualify for the tax deduction. DOE’s tax deductibility assumption reduces the effective discount rate, particularly for lower income households, and overstates the resulting LCC savings in the DOE NOPR LCC model.

In addition, the inclusion of the mortgage interest debt type may not be reasonable in all cases. Mortgages may be a reasonable debt type to consider when a furnace is included in the price of a new home, but it may not be reasonable to include it when considering replacements.

Table 50 Types of Household Debt and Equity by Percentage Shares

Type of Debt or Equity	Income Group					
	1	2	3	4	5	6
Debt:						
Mortgage	18.9%	24.1%	33.1%	38.1%	39.3%	25.0%
Home equity loan	3.1%	3.3%	2.6%	3.6%	4.5%	7.2%
Credit card	15.3%	13.0%	11.8%	8.7%	6.0%	2.7%
Other installment loan	25.1%	20.6%	17.3%	13.2%	9.6%	4.7%
Other residential loan	0.7%	0.6%	0.6%	0.7%	1.0%	1.2%
Other line of credit	1.6%	1.5%	1.3%	1.5%	2.1%	1.8%
Equity:						
Savings account	18.5%	16.0%	12.7%	10.6%	10.4%	7.9%
Money market account	3.6%	4.5%	4.0%	4.5%	5.0%	8.6%
Certificate of deposit	7.0%	7.8%	5.5%	5.0%	4.4%	4.2%
Savings bond	1.8%	1.7%	1.9%	2.2%	1.7%	1.1%
Bonds	0.2%	0.4%	0.5%	0.7%	0.8%	3.8%
Stocks	2.3%	3.1%	4.4%	5.7%	7.6%	15.8%
Mutual funds	2.1%	3.5%	4.3%	5.7%	7.6%	15.9%
Total	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, and 2010.

Source: DOE Notice of Proposed Rule Making TSD Table 8.2.19

Table 51 Definition of Income Groups

Income Group	Percentile of Income
1	1st to 20th
2	21st to 40th
3	41st to 60th
4	61st to 80th
5	81st to 90th
6	91th to 99th

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, and 2010.

Source: DOE Notice of Proposed Rulemaking TSD Table 8.2.18

DOE has not provided tabular data or spreadsheets containing each of their full distributions of consumer discount rates for each debt and asset class and for each income group. Without this information, discount rate parametric analysis such as removal of mortgages from consideration on replacement furnaces would require repeating the entire DOE discount rate analysis. There is also an apparent inconsistency in rates listes in the TSD. Table 8.2.20 in the TSD shows average real effective interest rates for mortgages from 1995-2012 with a range of values between 2.1 and 4.3%, but Table 8.2.21 shows average real effective interest rates for mortgages ranging from 4.0 to 6.6 %.

Even if repeating the DOE discount rate analysis were feasible, the fundamental rationale for the DEO methodology is arguably flawed. Aggregating debt and equity together to determine a discount rate based on opportunity cost appears to ignore that the purchase of a furnace, particularly in the replacement market, is not likely well represented by an aggregate of all debt and equity for a particular consumer. A marginal rate that is specific to the financial instrument used to purchase the furnace would be a more defensible value. For example, a homeowner with a mortgage of $100,000 and savings of $1,000 that needs to purchase a new furnace which costs $3,000 will not experience the weighted average rate of 99% mortgage interest rate and 1% savings interest rate. They will more likely experience a rate represented by 1/3 savings and 2/3 credit card, yielding a rate closer to 12% than to 3%.

To look at the impact of discount rate on LCC savings, the distributions of discount rates given in the DOE NOPR LCC model were multiplied by constant factors ranging from 1.0 (the DOE NOPR LCC model distributions) and 4.0 (representative of a purchase predominantly financed by credit card debt). Figure 35 shows the results of this scenario, along with the average discount rate generated by these multipliers. A discount rate of approximately 10% reduces LCC savings by more than half at all TSLs.

Table 8.2.23 in the TSD indicates in that the overall weighted average discount rate used in the DOE NOPR LCC model is 4.5%. However, results shown in Figure 35 based on the 10,000 Crystal Ball trial cases indicate that the weighted average discount rate distribution actually averages 4.0% in the DOE NOPR LCC model. The likely reason for this discrepancy is Crystal Ball random sampling.

Parametric I5 applies the 4.0 discount rate multiplier to compare results with the DOE NOPR LCC model. Discount rate adjustments were made only to residential installations in Parametric I5. Commercial discount rates were left unchanged.

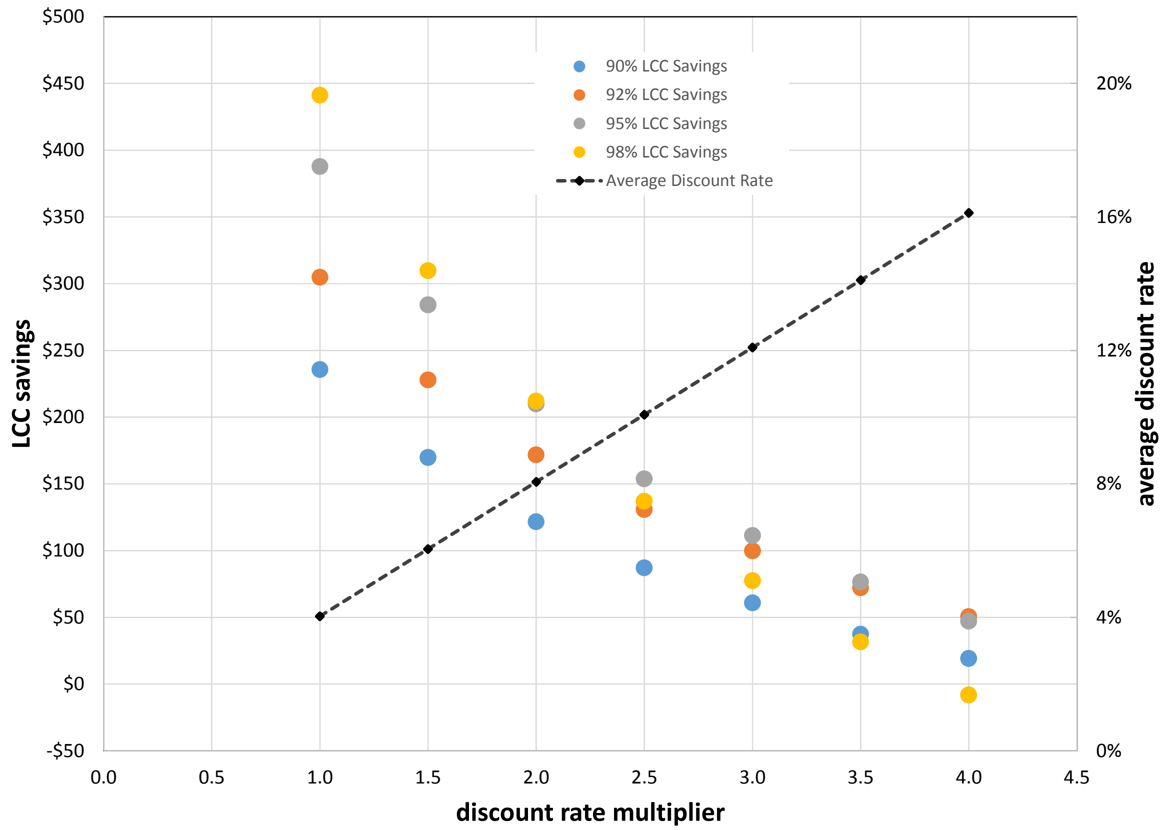


Figure 35 National LCC Savings vs. Discount Rate Multiplier

A.5.6 Parametric I6

The DOE 2014 LCC model marginal gas price factors were replaced with the marginal price factors developed by AGA. Similar to DOE, AGA relied on EIA residential natural gas sales and revenues by state (EIA 2013 NG Navigator). However, in contrast to the DOE methodology described in the TSD, AGA developed a fixed cost component of natural gas rates for each state and applied it to the EIA data to develop state level residential marginal price factors. These state level data were then weighted according to furnace shipments in the same manner that DOE uses to generate marginal rates on a regional basis.

AGA calculated natural gas utility marginal cost by deducting the fixed charge portion from the total bill. The full 12 month residential gas bill was calculated from the reported total monthly residential sales data collected by EIA. AGA conducted an Internet search of utility tariffs to obtain the customer charges for about 200 of the largest utilities (representing roughly 90 percent of the total market). A month's worth of customer charges for all 200 companies was deducted from each total monthly bill or total residential sales. The resulting net monthly bill was divided by the monthly usage to get the marginal cost per Mcf or therm. Dividing the net bill by the total bill yielded the marginal cost factor. The remainder of the calculations followed DOE methodology – seasonal rates, use of shipment data to develop weighting of the state rates.

This approach is conservative in estimating the marginal cost. Use of the customer charge by itself ignores other changes in gas rates as the volume changes. For example, at least 20 large utilities use declining block rates, which if incorporated into the analysis could reduce the marginal cost factor even more. Table 52 shows residential natural gas marginal price factors developed by AGA and percentage change from factors used by DOE.

A.5.7 Parametric I7

This parametric was intended to examine alternative marginal gas price data such as Henry Hub monthly prices to allowed investigation of the impact of a different source of marginal natural gas prices on LCC model results. Based on challenges linking that type of data to the state-level data sets needed for the analysis, this parametric was not investigated further.

A.5.8 Parametric I8

Since the issuance of the NOPR, the EIA released a new 2015 EIA AEO with updated forecasts (http://www.eia.gov/forecasts/aeo/). This parametric replaces the older 2014 EIA AEO forecasts and utility prices used in DOE NOPR LCC model with the current 2015 EIA AEO forecasts for energy price trends and updated 2012 gas and electric utility prices.

This parametric incorporates this data following the DOE methodology. Because DOE uses this as a source of marginal rates, this parametric also slightly alters the marginal rates following the DOE methodology. When run in combination with Parametric I6, the marginal gas rates generated by parametric I6 are used as they are more technically defensible than the approach used in Parametric I8.

A.5.9 Parametric I9

This parametric was intended to include alternative fan power estimates for the condensing and non-condensing furnaces to account for the incremental pressure drop across the secondary heat exchanger in the condensing furnace. However, insufficient technical data on this topic was identified, and this parametric was not investigated further.

A.5.10 Parametric I10

This parameter modifies DOE’s retail price differential between non-condensing and condensing furnaces to match furnace price differentials for the same NWGF types available through Home Depot. Home Depot retail price differential between 80 kBtu/h 80% AFUE and 92% AFUE NWGF was used to adjust the 2014 LCC NWGF retail price differential between these two equipment types. The methodology used was to increase the 2014 LCC retail price of 80 kBtu/h 92% AFUE NWGF to a differential of $361 compared to 80% AFUE to match the differential reported by Home Depot and to use an equivalent percentage increase to all other condensing equipment TSLs and capacities. Similar to parametric I2 these are actual differentials of offered prices with minimal potentially erroneous assumptions.

A.5.11 Parametric I11

This parameter changed the expected average life of an NWGF from 21.5 to 18 years. It is based on industry estimates of furnace life and is useful to explore the impact of a shorter furnace life on LCC analysis results.

Table 52 AGA Marginal Gas Price Factors

Region	AGA NG Residential Marginal Price Factors		DOE Factors vs. AGA	
	Summer	Winter	Summer	Winter
CT, ME, NH, RI, VT	0.58	0.87	141%	105%
MA	0.88	0.97	101%	107%
NY	0.51	0.82	147%	108%
NJ	0.80	0.94	105%	101%
PA	0.68	0.91	107%	102%
IL	0.66	0.88	103%	111%
IN, OH	0.47	0.82	156%	112%
MI	0.70	0.91	111%	102%
WI	0.59	0.88	133%	111%
IA, MN, ND, SD	0.66	0.90	108%	108%
KS, NE	0.59	0.86	116%	108%
MO	0.42	0.80	143%	102%
VA	0.64	0.89	107%	104%
DE, DC, MD	0.66	0.90	104%	102%
GA	0.98	0.99	57%	88%
NC, SC	0.59	0.90	113%	99%
FL	0.72	0.82	89%	100%
AL, KY, MS	0.73	0.92	102%	94%
TN	0.62	0.90	120%	105%
AR ,LA, OK	0.60	0.85	110%	100%
TX	0.49	0.78	119%	109%
CO	0.62	0.85	111%	107%
ID, MT, UT,WY	0.72	0.93	116%	104%
AZ	0.55	0.83	116%	102%
NV, NM	0.54	0.83	136%	106%
CA	0.89	0.95	95%	113%
OR, WA	0.76	0.92	110%	103%
AK	0.79	0.91	109%	105%
HI	0.89	0.90	86%	101%
WV	0.68	0.91	118%	104%
National	0.67	0.89	111%	106%

A.5.12 Parametric I12

This parameter was explored to investigate the impact of changing the expected average life of a gas water heater on LCC analysis results. However, insufficient market data or survey information was identified to support changing the domestic hot water heater lifetime from a mean of 12.3 years to 18 years as this parametric was intended to do, so the parametric run was not performed.

A.5.13 Parametric I13

Parametric run I13 uses newly released NWGF condensing and non-condensing furnace shipment data provided to DOE by AHRI to revise the DOE 2021 forecast of base case condensing furnace shipment fraction. AHRI provided updated information in May 2015 regarding NWGF shipment data for the years 2010 through 2014. However, GTI analysts used only AHRI 2014 data to avoid concerns with possible perturbations caused by federal energy credits phased out in 2013 that may have influenced shipment numbers between 2010 and 2013. To create a 2021 forecast trend line that matched actual 2014 shipment data, GTI used 1998 to

2005 trending years. This combined approach resulted in a 2014 condensing furnace shipment fraction of 48%, which is slightly lower than the actual fraction of 48.5% reported by AHRI. Based on this trend line, Parametric I13 uses a 58.3% condensing furnace shipment fraction for the 2021 baseline instead of DOE's 2021 furnaces shipment fraction of 46.7%, which is an 11.6% increase in the baseline condensing furnace fraction.

DOE chose to use 1994 to 2004 furnace shipment data for its trend line for reasons stated in the TSD. This approach resulted in predicted 2014 condensing furnace shipment fraction of 40%, which is 8.5% lower than the actual fraction of 48.5% reported by AHRI. DOE chose to exclude 2005 data, citing the 2005 tax credit act impact on shipments as the rationale. However, the 2005 tax credit was implemented in 2006 (http://energy.gov/savings/residential-energy-efficiency-tax-credit), so the 2005 shipment data was not influenced by tax credits. GTI also started the data trending two years later than DOE to exclude the earlier time period when condensing furnace technology was less mature. Each of these choices helped align the GTI 2021 forecasting trend line closely with the actual 2014 AHRI condensing furnace fractions. Figure 36 and Figure 37 compare the DOE NOPR condensing furnace shipment forecast trend line with the trend line using the AHRI shipment date.

A.5.14 Parametric I14

This parametric was intended to replace NWGF incremental distribution channel markups with average markups based on industry information. Due to time constraints and limited published information, this parametric was not explored further.

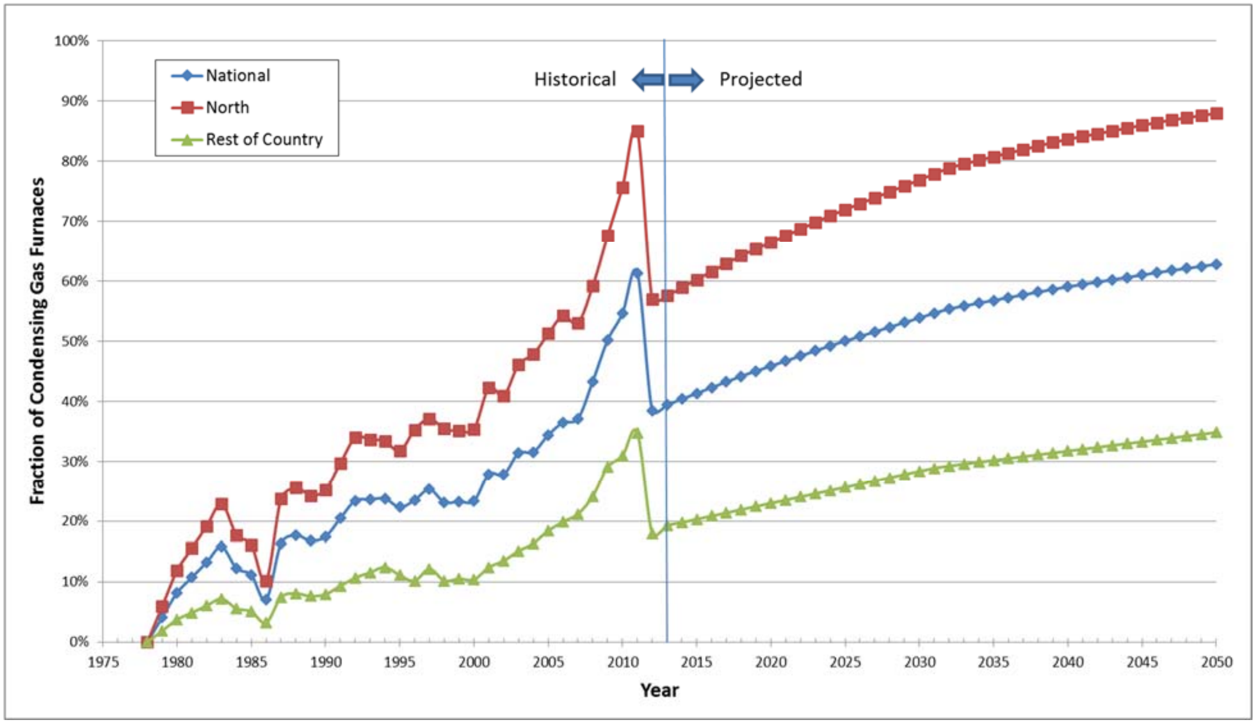


Figure 36 Historical and Projected Condensing Furnace Fractions – DOE NOPR LCC Model

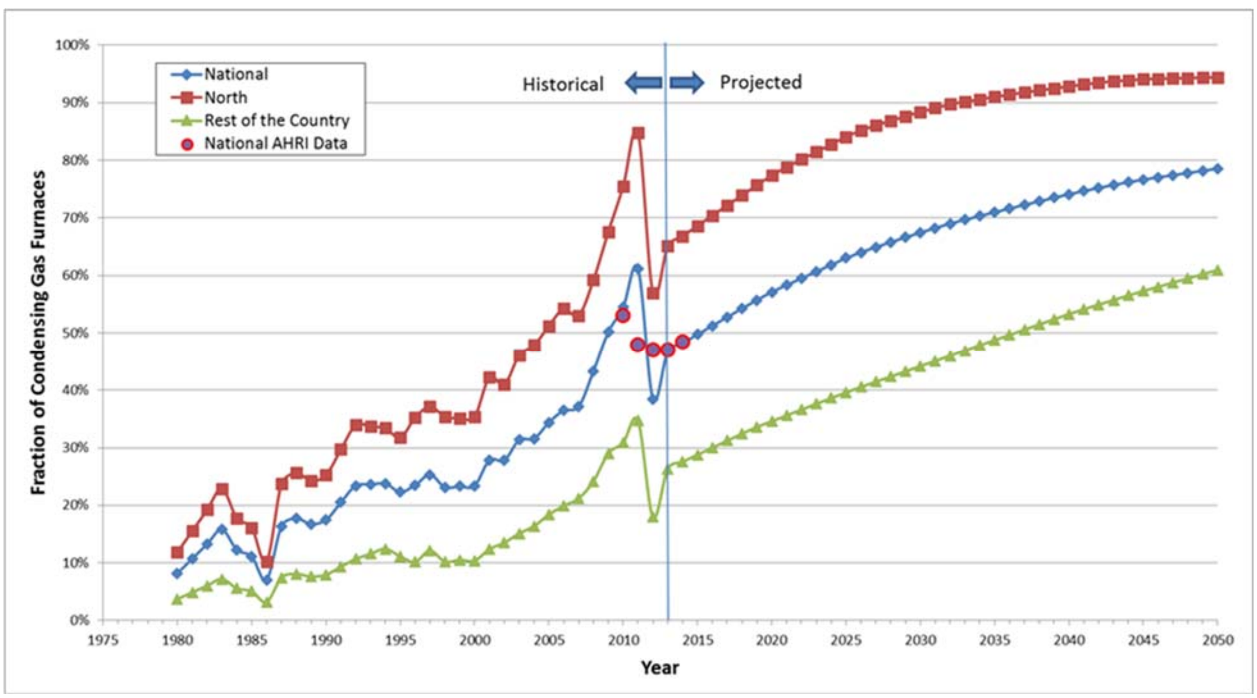


Figure 37 Historical and Projected Condensing Furnace Fractions – GTI Parametric I13

A.6 GTI Input Data Scenarios

The parametrics in the preceding section were incorporated into scenarios according to the matrix shown in Table 53.

Table 53 Input Data Scenario Matrix

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14
Scenario I-1	X													
Scenario I-2		X												
~~Scenario I-3~~														
~~Scenario I-4~~														
Scenario I-5					X									
Scenario I-6						X								
~~Scenario I-7~~														
Scenario I-8								X						
~~Scenario I-9~~														
Scenario I-10										X				
Scenario I-11											X			
~~Scenario I-12~~														
Scenario I-13													X	
~~Scenario I-14~~														
Scenario I-15						X		X					X	
Scenario I-16		X				X		X					X	

A.6.1 Scenarios I-1, I-2, I-5, I-6, I-8, I-10, I-11, and I-13

Each of these scenarios contains a single input parametric modification as described in the previous section. All show the impact of improvements over DOE's baseline inputs and all show reductions in LCC savings compared to the DOE NOPR LCC Model. Compared to the decision making scenarios, impact on fuel switching is relatively small with the exception of GTI Scenarios I-2 and I-10 that examine retail furnace pricing.

A.6.2 Scenario I-15

This scenario combines modifications to energy pricing and condensing furnace market penetration using the updated AEO forecast, billing derived marginal gas prices from AGA, and condensing furnace market penetration from AHRI. These changes decrease the national average LCC savings at the 92% TSL to $207, a decrease of 33% compared to the DOE NOPR LCC model results.

A.6.3 Scenario I-16

This adds the furnace pricing information from the 2013 Furnace Price Guide (parametric I2) to Scenario I-15. This scenario illustrates the importance of obtaining and using furnace price information that aligns with current market data. This additional parametric substantially reduces the LCC savings at the 90% and 92% TSLs, to $54 and $105, respectively, and shifts LCC savings at a national level to negative values at the 95% and 98% TSLs, to -$100 and -$83, respectively.

A.6.4 Results Summaries for Input Scenarios

Summary results for LCC savings, fuel switching, and energy use for the input variable scenarios are given in Table 54 through Table 65.

Table 54 LCC Savings for Input Scenarios – 90% TSL

LCC Savings Summary - 90% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	$163	$175	$149	$44	$78	$7	$502	$439	$576	$173	$86
Scenario I-2 2013 Price Guide	$113	$143	$78	-$3	$45	-$55	$444	$410	$483	$139	$31
Scenario I-5 Increase Discount Rates by 4X	$19	$26	$11	-$114	-$78	-$154	$378	$284	$489	$8	-$15
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	$226	$193	$262	$100	$91	$110	$585	$471	$718	$234	$161
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	$194	$174	$217	$76	$84	$68	$527	$414	$660	$204	$146
Scenario I-10 - Home Depot Pricing	$180	$153	$209	$68	$57	$80	$507	$418	$611	$228	$122
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	$167	$147	$190	$43	$46	$40	$524	$424	$642	$181	$103
Scenario I-13 - Use updated AHRI shipment data	$190	$152	$232	$86	$72	$102	$483	$368	$619	$217	$152
Scenario I-15 (I6, I8, I13)	$155	$125	$189	$54	$55	$53	$439	$311	$590	$173	$118
Scenario I-16 (I2, I6, I8, I13)	$54	$77	$28	-$36	$13	-$90	$306	$246	$376	$76	$7

Table 55 LCC Savings for Input Scenarios – 92% TSL

LCC Savings Summary - 92% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	$207	$226	$185	$87	$128	$43	$543	$487	$609	$226	$129
Scenario I-2 2013 Price Guide	$180	$211	$145	$63	$110	$11	$511	$481	$546	$211	$105
Scenario I-5 Increase Discount Rates by 4X	$51	$60	$40	-$86	-$48	-$128	$409	$319	$516	$38	$22
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	$290	$258	$326	$162	$151	$174	$652	$541	$782	$305	$227
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	$261	$241	$285	$140	$145	$135	$598	$487	$729	$273	$217
Scenario I-10 - Home Depot Pricing	$243	$222	$268	$129	$119	$139	$574	$497	$666	$303	$188
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	$225	$206	$247	$99	$102	$97	$583	$486	$699	$241	$162
Scenario I-13 - Use updated AHRI shipment data	$243	$201	$290	$137	$117	$158	$541	$422	$681	$271	$203
Scenario I-15 (I6, I8, I13)	$207	$170	$248	$103	$95	$111	$493	$363	$647	$223	$173
Scenario I-16 (I2, I6, I8, I13)	$105	$124	$85	$12	$55	-$36	$361	$298	$437	$128	$59

Table 56 LCC Savings for Input Scenarios – 95% TSL

LCC Savings Summary - 95% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	$257	$291	$218	$138	$187	$85	$583	$558	$613	$312	$199
Scenario I-2 2013 Price Guide	-$12	-$47	$29	-$61	-$68	-$53	$154	$16	$316	$145	-$38
Scenario I-5 Increase Discount Rates by 4X	$47	$71	$20	-$90	-$41	-$142	$388	$316	$473	$51	$20
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	$371	$348	$397	$240	$227	$254	$732	$654	$824	$411	$309
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	$345	$335	$356	$223	$226	$220	$675	$605	$759	$381	$305
Scenario I-10 - Home Depot Pricing	$314	$298	$332	$201	$195	$207	$631	$560	$715	$402	$244
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	$283	$278	$290	$161	$168	$152	$626	$561	$703	$316	$221
Scenario I-13 - Use updated AHRI shipment data	$321	$290	$355	$214	$195	$235	$612	$530	$708	$364	$277
Scenario I-15 (I6, I8, I13)	$276	$246	$310	$170	$157	$185	$561	$464	$676	$305	$230
Scenario I-16 (I2, I6, I8, I13)	-$100	-$120	-$78	-$133	-$120	-$147	$5	-$119	$152	$27	-$78

Table 57 LCC Savings for Input Scenarios – 98% TSL

LCC Savings Summary - 98% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	$304	$383	$215	$192	$290	$85	$599	$589	$611	$415	$337
Scenario I-2 2013 Price Guide	$41	$34	$48	-$16	$32	-$68	$222	$22	$458	$260	$121
Scenario I-5 Increase Discount Rates by 4X	-$8	$31	-$52	-$146	-$84	-$214	$311	$238	$396	$24	$13
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	$417	$419	$415	$286	$300	$271	$762	$688	$849	$508	$439
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	$372	$396	$344	$249	$290	$204	$690	$629	$762	$457	$377
Scenario I-10 - Home Depot Pricing	$318	$335	$300	$211	$250	$168	$607	$517	$713	$476	$362
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	$304	$332	$274	$185	$231	$134	$625	$565	$697	$388	$328
Scenario I-13 - Use updated AHRI shipment data	#N/A	$382	$353	$265	$296	$231	$636	$568	$716	$476	$431
Scenario I-15 (I6, I8, I13)	$293	$296	$291	$186	$206	$163	$564	$481	$662	$375	$315
Scenario I-16 (I2, I6, I8, I13)	-$83	-$66	-$103	-$123	-$67	-$185	$34	-$93	$185	$116	$0

Table 58 Fuel Switching for Input Scenarios – 90% TSL

Percent of Impacted Buildings Swithcing - 90%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	16.0%	11.9%	18.1%	15.6%	10.5%	18.0%	18.4%	16.7%	19.3%	19.3%	13.1%
Scenario I-2 2013 Price Guide	19.6%	14.3%	22.2%	19.0%	12.4%	21.9%	22.5%	20.1%	24.0%	22.5%	16.1%
Scenario I-5 - Increase Discount Rate by 4X	17.1%	12.1%	19.6%	16.6%	10.5%	19.3%	20.0%	17.1%	21.7%	20.2%	13.3%
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	17.6%	12.1%	20.3%	17.2%	10.7%	20.2%	19.8%	16.7%	21.6%	20.7%	14.6%
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	16.7%	11.5%	19.3%	16.4%	10.1%	19.3%	18.7%	15.8%	20.4%	20.1%	13.1%
Scenario I-10 - Home Depot Pricing	24.8%	16.8%	28.8%	24.7%	14.7%	29.2%	26.7%	23.7%	28.4%	25.8%	21.3%
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
Scenario I-13 - Use updated AHRI shipment data	18.7%	13.7%	20.6%	18.6%	13.1%	20.5%	19.9%	15.9%	21.9%	22.4%	15.9%
Scenario I-15 (I6, I8, I13)	16.9%	11.7%	19.0%	16.8%	10.7%	18.9%	18.3%	14.4%	20.2%	21.2%	15.1%
Scenario I-16 (I2, I6, I8, I13)	18.2%	12.7%	20.4%	17.8%	11.3%	20.0%	20.3%	16.4%	22.2%	22.2%	16.5%

Table 59 Fuel Switching for Input Scenarios – 92% TSL

Percent of Impacted Buildings Swithcing - 92%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	16.2%	10.6%	19.4%	15.9%	9.6%	19.2%	17.8%	13.8%	20.6%	19.3%	13.6%
Scenario I-2 2013 Price Guide	18.0%	11.7%	21.5%	17.7%	10.4%	21.4%	19.7%	15.3%	22.7%	20.5%	14.9%
Scenario I-5 - Increase Discount Rate by 4X	15.6%	10.0%	18.7%	15.2%	8.7%	18.5%	17.5%	13.5%	20.2%	18.5%	12.4%
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	16.0%	10.0%	19.4%	15.8%	8.9%	19.4%	17.4%	13.1%	20.3%	19.0%	13.4%
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	15.3%	9.7%	18.4%	15.1%	8.6%	18.4%	16.5%	12.8%	19.1%	18.4%	12.2%
Scenario I-10 - Home Depot Pricing	22.8%	14.1%	27.7%	22.9%	12.5%	28.3%	23.5%	18.7%	26.7%	23.9%	19.4%
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
Scenario I-13 - Use updated AHRI shipment data	16.2%	10.2%	19.0%	16.3%	9.8%	19.0%	16.8%	11.7%	19.9%	19.5%	14.2%
Scenario I-15 (I6, I8, I13)	14.9%	8.9%	17.7%	14.9%	8.3%	17.6%	15.5%	10.7%	18.5%	18.5%	13.2%
Scenario I-16 (I2, I6, I8, I13)	16.0%	9.6%	19.0%	15.9%	8.8%	18.8%	17.1%	11.9%	20.3%	19.6%	14.7%

Table 60 Fuel Switching for Input Scenarios – 95% TSL

Percent of Impacted Buildings Swithcing - 95%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	16.1%	8.8%	21.3%	16.4%	8.0%	21.6%	16.2%	10.6%	21.3%	17.2%	14.4%
Scenario I-2 2013 Price Guide	27.5%	14.4%	36.9%	27.9%	12.8%	37.4%	27.5%	18.1%	36.2%	25.6%	25.3%
Scenario I-5 - Increase Discount Rate by 4X	14.5%	7.9%	19.2%	14.9%	7.2%	19.6%	14.4%	9.7%	18.9%	15.6%	12.7%
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	14.8%	7.9%	19.7%	15.3%	7.3%	20.3%	14.2%	9.5%	18.6%	16.0%	13.2%
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	14.0%	7.4%	18.8%	14.6%	6.8%	19.5%	13.3%	8.9%	17.4%	15.3%	12.1%
Scenario I-10 - Home Depot Pricing	21.0%	10.6%	28.4%	22.4%	9.5%	30.3%	18.9%	13.4%	24.1%	21.5%	20.3%
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	15.1%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
Scenario I-13 - Use updated AHRI shipment data	13.3%	6.6%	17.7%	14.0%	6.5%	18.2%	12.4%	7.3%	17.0%	14.3%	12.2%
Scenario I-15 (I6, I8, I13)	12.2%	5.8%	16.3%	12.8%	5.4%	16.9%	11.4%	6.8%	15.5%	13.5%	12.0%
Scenario I-16 (I2, I6, I8, I13)	23.0%	10.0%	31.4%	23.6%	8.9%	31.7%	22.2%	12.3%	31.0%	21.8%	22.1%

Table 61 Fuel Switching for Input Scenarios – 98% TSL

Percent of Impacted Buildings Swithcing - 98%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	16.0%	6.2%	26.9%	16.3%	5.1%	28.4%	16.1%	9.8%	23.4%	15.8%	15.6%
Scenario I-2 2013 Price Guide	24.6%	9.6%	41.5%	23.9%	7.7%	41.4%	27.8%	15.2%	42.6%	21.6%	24.4%
Scenario I-5 - Increase Discount Rate by 4X	14.8%	5.9%	24.9%	14.8%	4.7%	25.8%	15.7%	9.4%	23.2%	14.2%	13.2%
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	15.0%	5.7%	25.4%	15.3%	4.7%	26.9%	15.0%	8.9%	22.2%	14.5%	14.3%
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	14.7%	5.5%	24.9%	14.9%	4.5%	26.1%	14.9%	8.6%	22.2%	14.5%	14.1%
Scenario I-10 - Home Depot Pricing	20.8%	7.5%	35.6%	21.1%	5.9%	37.5%	21.2%	12.5%	31.3%	19.1%	20.6%
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	15.5%	6.1%	26.0%	15.7%	5.0%	27.2%	15.7%	9.4%	23.2%	15.1%	14.6%
Scenario I-13 - Use updated AHRI shipment data	13.0%	4.4%	22.6%	13.2%	3.6%	23.5%	13.3%	6.8%	21.0%	12.6%	12.6%
Scenario I-15 (I6, I8, I13)	12.0%	3.7%	21.3%	12.2%	2.9%	22.3%	12.2%	6.1%	19.4%	11.8%	12.2%
Scenario I-16 (I2, I6, I8, I13)	19.6%	6.0%	34.7%	18.9%	4.6%	34.3%	22.2%	9.9%	36.6%	17.1%	19.4%

Table 62 Energy Use and Greenhouse Gas Emissions for Input Scenarios – 90% TSL

Energy Use Summary - 90% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.2	28.8	312	1,045	-22.4%	234.6%	-1.2	-158.5
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	37.2	29.4	312	1,009	-21.0%	223.0%	-1.0	-133.8
Scenario I-2 2013 Price Guide	37.2	28.5	312	1,158	-23.4%	270.8%	-0.4	-45.4
Scenario I- 5_Increase Disount Rate by 4X	37.2	29.1	312	1,003	-21.6%	221.1%	-1.4	-176.4
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	37.2	28.9	312	1,029	-22.1%	229.5%	-1.3	-164.9
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	37.2	29.1	312	972	-21.6%	211.2%	-1.7	-218.3
Scenario I-10 - Home Depot Pricing	37.2	27.0	312	1,314	-27.2%	320.5%	-0.3	-30.7
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	37.2	28.8	312	1,045	-22.4%	234.5%	-1.2	-158.7
Scenario I-13 - Use updated AHRI shipment data	35.0	26.8	304	1,055	-23.4%	247.4%	-0.9	-112.5
Scenario I-15 (I6, I8, I13)	35.0	27.3	304	958	-22.1%	215.1%	-1.4	-187.6
Scenario I-16 (I2, I6, I8, I13)	35.0	27.0	304	1,058	-22.9%	248.3%	-0.7	-84.1

Table 63 Energy Use and Greenhouse Gas Emissions for Input Scenarios – 92% TSL

Energy Use Summary - 92% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.4	29.3	314	961	-21.8%	205.9%	-2.0	-258.2
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	37.4	29.3	314	1,002	-21.6%	219.0%	-1.5	-191.6
Scenario I-2 2013 Price Guide	37.4	28.9	314	1,082	-22.9%	244.4%	-1.1	-142.1
Scenario I- 5_Increase Disount Rate by 4X	37.4	29.5	314	925	-21.1%	194.6%	-2.1	-272.8
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	37.4	29.4	314	954	-21.6%	203.7%	-2.0	-257.8
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	37.4	29.5	314	911	-21.3%	190.2%	-2.3	-301.9
Scenario I-10 - Home Depot Pricing	37.4	27.6	314	1,227	-26.3%	290.8%	-1.0	-121.8
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	37.4	29.3	314	961	-21.8%	205.9%	-2.0	-258.2
Scenario I-13 - Use updated AHRI shipment data	35.6	27.9	307	942	-21.6%	206.8%	-1.6	-207.5
Scenario I-15 (I6, I8, I13)	35.6	28.2	307	874	-20.7%	184.4%	-2.0	-262.1
Scenario I-16 (I2, I6, I8, I13)	35.6	28.0	307	967	-21.5%	214.8%	-1.3	-169.2

Table 64 Energy Use and Greenhouse Gas Emissions for Input Scenarios – 95% TSL

Energy Use Summary - 95% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.9	29.9	317	912	-20.9%	187.2%	-2.3	-301.7
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	37.9	29.8	317	971	-21.3%	206.0%	-1.8	-233.6
Scenario I-2 2013 Price Guide	37.9	26.5	317	1,475	-30.0%	364.8%	0.0	13.8
Scenario I- 5_Increase Disount Rate by 4X	37.9	30.2	317	877	-20.3%	176.4%	-2.4	-314.9
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	37.9	30.0	317	900	-20.7%	183.6%	-2.3	-305.2
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	37.9	30.2	317	852	-20.3%	168.5%	-2.6	-351.2
Scenario I-10 - Home Depot Pricing	37.9	28.5	317	1,131	-24.7%	256.3%	-1.5	-194.7
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	37.9	29.9	317	911	-20.9%	187.1%	-2.3	-301.9
Scenario I-13 - Use updated AHRI shipment data	36.6	29.8	313	824	-18.5%	163.0%	-1.9	-250.0
Scenario I-15 (I6, I8, I13)	36.6	30.1	313	768	-17.8%	144.9%	-2.2	-294.0
Scenario I-16 (I2, I6, I8, I13)	36.6	27.1	313	1,253	-25.9%	299.7%	-0.3	-24.7

Table 65 Energy Use and Greenhouse Gas Emissions for Input Scenarios – 98% TSL

Energy Use Summary - 98% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	39.4	31.1	323	952	-21.1%	195.1%	-2.3	-308.4
Scenario I-1 - Replace Manufacturers Cost with infl adj 2011 costs	39.4	31.1	323	990	-21.2%	206.7%	-2.0	-261.3
Scenario I-2 2013 Price Guide	39.4	28.6	323	1,365	-27.5%	322.9%	-0.7	-80.4
Scenario I- 5_Increase Disount Rate by 4X	39.4	31.4	323	917	-20.5%	184.3%	-2.4	-322.1
Scenario I-6 - Replace marginal gas rates with AGA marginal rates	39.4	31.2	323	934	-20.8%	189.5%	-2.4	-317.2
Scenario I-8 - Use the 2015 AEO forecast for energy price trends	39.4	31.4	323	894	-20.4%	177.1%	-2.7	-354.0
Scenario I-10 - Home Depot Pricing	39.4	29.8	323	1,156	-24.5%	258.3%	-1.6	-206.8
Scenario I-11 - NWGF lifetime adjusted from 21.5 to 18 years	39.4	31.1	323	952	-21.1%	195.0%	-2.3	-308.6
Scenario I-13 - Use updated AHRI shipment data	38.7	31.8	321	836	-18.0%	160.9%	-2.1	-272.8
Scenario I-15 (I6, I8, I13)	38.7	32.0	321	784	-17.3%	144.6%	-2.3	-310.7
Scenario I-16 (I2, I6, I8, I13)	38.7	30.0	321	1,117	-22.5%	248.5%	-1.0	-125.2

A.7 Integrated Scenarios

GTI analysts combined selected parametrics that comprise technically defensible decision making and input scenarios into integrated scenarios to examine the impact of these combinations. Table 66 below shows the parametric matrix that defines these scenarios. All of the chosen integrated scenarios include parametrics that address Base Case AFUE selection (D4 with D5 or D6, or D9, D10, D11, or D12), remove fuel switching that would occur in the absence of a rule (D8), and modify switching paybacks (D1, D2, D9, or D10). In addition, all of the integrated scenarios include the modified condensing furnace shipment data in alignment with the more recent AHRI data (I13), AGA marginal rates (I6), and the updated AEO forecast (I8) inputs. Several integrated scenarios also include modified retail prices given by the modification of the retail prices found in the 2013 Furnace Price Guide (I2) as this had a larger data set and was considered more defensible than the Home Depot derived cost differentials.

All of the integrated scenarios show a significant reduction in LCC savings relative to the DOE NOPR LCC Model. In most categories LCC savings are negative across the range of TSLs. They also show a higher level of fuel switching than the DOE NOPR LCC Model for impacted buildings. However, in many cases the fuel switching based on total buildings is not significantly higher than the DOE NOPR LCC Model. For example, the DOE NOPR LCC Model has fuel switching between 9.5% and 15.4% depending on TSL while scenario Int-5 has fuel switching between 9.6% and 22.8% based on the total buildings. Due to differences in the number and type of “Impacted” buildings, the DOE NOPR LCC Model has fuel switching between 15.2% and 18.0% based on “Impacted” buildings while scenario Int-5 has fuel switching between 22.4% and 28.2% based on “Impacted” buildings. All of the integrated scenarios show reduced primary energy and CO_2e emissions benefits compared to the DOE NOPR LCC Model, and several GTI Integrated Scenarios show increased primary energy consumption and CO_2e emissions rather than reductions, eliminating the societal benefit asserted by DOE in its NOPR.

Because parametric D4, and therefore D9 and D10, rely on simple payback periods to determine thresholds for condensing furnace adoption, and in the case of D9 and D10 also switching payback periods, it was necessary to generate payback periods following the methodology described in the parametric D4 description using Scenario I-15 and Scenario I-16 to set minimum thresholds for these integrated scenarios.

Table 66 Integrated Decision Making Analysis Scenarios

	DOE NOPR	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14
Scenario Int 1 (Scenarios 24 & I-15)				X		X	X			X										X		X					X	
Scenario Int 2 (Scenario 23 & I-15)			X			X	X			X										X		X					X	
Scenario Int 3 (Scenarios 18 & I-15)										X		X								X		X					X	
Scenario Int 4 (Scenarios 17 & I-15)										X	X	X								X		X					X	
Scenario Int 5 (Scenarios 24 & I-16)				X		X	X			X						X				X		X					X	
Scenario Int 6 (Scenario 23 & I-16)			X			X	X			X						X				X		X					X	
Scenario Int 7 (Scenarios 18 & I-16)										X		X				X				X		X					X	
Scenario Int 8 (Scenarios 17 & I-16)										X	X	X				X				X		X					X	
Scenario Int 9 (Scenarios 26 & I-16)				X						X			X			X				X		X					X	
Scenario Int 10 (Scenarios 27 & I-16)				X						X				X		X				X		X					X	

A.7.1 Scenarios Int-1, Int-2, Int-3, and Int-4

These four integrated scenarios all contain Input Data Scenario I-15, which includes updated input data for energy pricing, energy pricing trends, and condensing furnace shipments, but does not include retail price adjustments for furnaces from Input Parametric I2. These scenarios permit examination of the incremental impact on LCC savings of adjusting furnace prices using the 2013 Furnace Price Guide data by comparing results with Integrated Scenarios Int-5 through Int-8 that contain Input Parametric I2.

These four integrated scenarios also incorporate two different decision making scenarios. Int-1 and Int-2 include Decision Making Scenarios 23 and 24, while Int-3 and Int-4 include Decision Making Scenarios 18 and 17. Scenarios 23 and 24 integrate with Scenario I-15 and use the AHCS information for implementation of Base Case AFUE assignments, with a minimum payback of zero years and alterations to the fuel switching minimum paybacks using either the full distribution of the AHCS data (Int-1) or a linear fit of the AHCS data to income (Int-2). Scenarios 18 and 17 integrate with Scenario I-15 and use internally consistent minimum payback periods of 0.5 years (Int-3) and 3.5 years (Int-4) for implementation of Base Case AFUE assignments and switching payback periods for fuel switching decisions. These scenarios permit an evaluation of the impact of the methodology on LCC results and fuel switching fractions.

Scenarios 23 and 24, and therefore Int-1 and Int-2, use AHCS information for assigning fuel switching paybacks, but as a result have a single purchase decision controlled by two payback times. Scenarios 17 and 18, and therefore Int-3 and Int-4, have a single payback period for both fuel switching and for Base Case AFUE selection but the switching paybacks are not based on the AHCS.

A.7.2 Scenarios Int-5, Int-6, Int-7, and Int-8

These integrated scenarios use the same choices of decision making scenarios as the first set, but use Input Scenario I-16 instead of I-15. These scenarios permit examination of the incremental impact on LCC savings of adjusting furnace prices using the 2013 Furnace Price Guide data by comparing results with Integrated Scenarios Int-1 through Int-4 that do not contain Input Parametric I2.

A.7.3 Scenarios Int-9 and Int-10

These scenarios contain parametrics D11 and D12 coupled with Input Scenario I-16. The scenarios force consumers with payback times less than 0 years (Int-9) or less than 3.5 years (Int-10) to be considered not impacted by the rule and force consumers with payback times over 15 years to be affected by the rule, and leave all consumers between these extremes to make decisions at random. While less technically defensible than the integrated scenarios that apply CED framework for decisions, these scenarios provide an upper boundary on potential LCC savings associated with each TSL furnace.

A.8 Integrated Scenario Results

The summarized results for LCC savings, fuel switching, and energy use and greenhouse gases can be found in Table 67 through Table 78.

Table 67 LCC Savings for Integrated Scenarios – 90% TSL

LCC Savings Summary - 90% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$236	$208	$267	$113	$106	$120	$588	$484	$710	$255	$176
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	-$109	-$105	-$114	-$154	-$148	-$159	$23	$18	$29	-$79	-$329
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	-$488	-$492	-$484	-$542	-$467	-$623	-$372	-$612	-$88	-$384	-$750
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	-$165	-$200	-$127	-$97	-$109	-$83	-$361	-$448	-$258	-$67	-$96
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	-$68	-$78	-$57	-$92	-$109	-$74	$12	$19	$3	-$42	-$70
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	-$215	-$159	-$278	-$266	-$184	-$355	-$68	-$93	-$39	-$212	-$555
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	-$725	-$605	-$861	-$804	-$590	-$1,038	-$556	-$711	-$372	-$650	-$1,050
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	-$271	-$136	-$422	-$178	-$145	-$213	-$547	-$100	-$1,074	-$194	-$218
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	-$128	-$100	-$160	-$171	-$145	-$198	$2	$34	-$35	-$99	-$140
Scenario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	-$263	-$260	-$267	-$336	-$332	-$341	-$58	-$67	-$47	-$272	-$623
Scenario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	-$277	-$276	-$277	-$344	-$340	-$349	-$81	-$95	-$64	-$284	-$630

Table 68 LCC Savings for Integrated Scenarios – 92% TSL

LCC Savings Summary - 92% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$305	$277	$336	$179	$172	$188	$659	$557	$779	$326	$247
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	-$75	-$77	-$74	-$117	-$124	-$109	$45	$52	$37	-$50	-$293
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	-$469	-$474	-$464	-$542	-$475	-$615	-$302	-$526	-$37	-$394	-$843
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	-$132	-$163	-$97	-$60	-$84	-$34	-$343	-$388	-$289	-$46	-$77
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	-$38	-$55	-$19	-$55	-$84	-$24	$19	$32	$3	-$9	-$37
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	-$181	-$131	-$237	-$233	-$161	-$310	-$36	-$55	-$14	-$183	-$533
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	-$727	-$614	-$854	-$764	-$554	-$993	-$687	-$858	-$486	-$502	-$1,053
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	-$243	-$113	-$388	-$142	-$120	-$167	-$541	-$84	-$1,081	-$168	-$186
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	-$97	-$75	-$123	-$135	-$120	-$151	$19	$60	-$29	-$72	-$109
Scenario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	-$200	-$185	-$216	-$263	-$245	-$283	-$27	-$29	-$24	-$205	-$558
Scenario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	-$223	-$213	-$233	-$278	-$263	-$293	-$62	-$69	-$53	-$224	-$569

Table 69 LCC Savings for Integrated Scenarios – 95% TSL

LCC Savings Summary - 95% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$388	$374	$404	$264	$259	$268	$730	$665	$807	$427	$330
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	-$40	-$56	-$22	-$80	-$106	-$51	$71	$70	$71	-$25	-$289
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	-$485	-$476	-$494	-$498	-$424	-$578	-$502	-$694	-$276	-$263	-$617
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	-$93	-$39	-$155	-$11	-$52	$33	-$333	$8	-$736	-$52	-$41
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	$2	-$24	$32	-$8	-$52	$40	$40	$60	$17	$23	-$1
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	-$445	-$520	-$361	-$443	-$458	-$427	-$430	-$687	-$126	-$302	-$804
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	-$955	-$1,008	-$896	-$873	-$841	-$908	-$1,233	-$1,537	-$874	-$628	-$1,200
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	-$266	-$307	-$221	-$287	-$307	-$265	-$191	-$300	-$63	-$179	-$182
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	-$251	-$306	-$189	-$287	-$307	-$265	-$128	-$293	$68	-$178	-$183
Scenario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	-$481	-$670	-$269	-$526	-$694	-$343	-$351	-$629	-$22	-$411	-$968
Scenario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	-$506	-$693	-$296	-$535	-$702	-$351	-$412	-$671	-$107	-$446	-$994

Table 70 LCC Savings for Integrated Scenarios – 98% TSL

LCC Savings Summary - 98% EL

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	$441	$467	$412	$319	$362	$273	$764	$704	$834	$542	$485
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	-$17	-$26	-$8	-$67	-$58	-$77	$102	$16	$202	$25	-$264
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	-$508	-$537	-$476	-$547	-$510	-$587	-$477	-$728	-$180	-$387	-$684
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	-$62	$26	-$160	$10	-$13	$35	-$291	$109	-$764	-$9	$34
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	$20	-$2	$44	-$5	-$48	$41	$99	$126	$66	$46	-$12
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	-$447	-$497	-$390	-$443	-$420	-$469	-$456	-$755	-$102	-$261	-$743
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	-$864	-$947	-$771	-$802	-$815	-$786	-$1,095	-$1,422	-$708	-$542	-$1,087
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	-$232	-$255	-$205	-$273	-$257	-$290	-$119	-$282	$73	-$139	-$98
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	-$251	-$291	-$206	-$290	-$289	-$292	-$130	-$304	$76	-$150	-$211
Scenario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	-$498	-$700	-$269	-$547	-$706	-$372	-$368	-$746	$79	-$352	-$1,008
Scenario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	-$555	-$777	-$306	-$589	-$767	-$394	-$447	-$825	-$2	-$421	-$1,144

Table 71 Fuel Switching for Integrated Scenarios – 90% TSL

Percent of Affected Buildings Swithcing - 90%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	18.0%	12.9%	20.5%	17.7%	11.6%	20.5%	20.0%	17.1%	21.7%	20.9%	14.2%
Scneario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	21.8%	19.6%	22.8%	22.2%	19.9%	23.0%	19.8%	19.4%	20.5%	24.8%	29.2%
Scneario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	35.8%	35.4%	36.0%	35.8%	33.9%	36.5%	40.1%	43.3%	34.1%	39.6%	44.6%
Scneario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	14.9%	16.0%	14.5%	11.4%	8.1%	12.5%	46.5%	41.5%	57.0%	14.7%	12.1%
Scneario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	11.5%	9.8%	12.2%	11.1%	8.1%	12.1%	18.6%	17.7%	22.0%	13.3%	11.3%
Scneario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	25.6%	20.8%	27.6%	25.6%	21.5%	27.0%	26.4%	19.7%	32.3%	33.5%	36.6%
Scneario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	41.8%	38.6%	43.1%	42.5%	39.1%	43.6%	41.7%	40.3%	42.9%	47.9%	49.7%
Scneario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	17.0%	12.0%	19.1%	10.6%	8.4%	11.4%	48.3%	21.6%	72.8%	18.2%	11.3%
Scneario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	12.0%	9.1%	13.2%	10.3%	8.4%	10.9%	22.7%	12.3%	33.0%	14.8%	8.6%
Scneario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	19.0%	12.1%	25.4%	18.4%	11.6%	24.6%	24.7%	15.8%	35.6%	21.6%	25.2%
Scneario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	19.1%	12.1%	25.7%	18.5%	11.6%	24.8%	27.0%	16.4%	40.1%	21.9%	25.5%

Table 72 Fuel Switching for Integrated Scenarios – 92% TSL

Percent of Affected Buildings Swithcing - 92%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	16.3%	10.5%	19.5%	16.2%	9.5%	19.6%	17.5%	13.5%	20.2%	19.3%	13.2%
Scneario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	19.2%	14.9%	21.5%	19.8%	15.8%	21.4%	15.8%	13.0%	22.9%	21.2%	26.8%
Scneario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	32.1%	27.2%	34.6%	33.1%	28.0%	35.1%	28.4%	27.2%	31.4%	35.9%	44.3%
Scneario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	13.6%	12.2%	14.3%	10.5%	6.7%	12.0%	35.7%	27.3%	58.5%	13.6%	12.0%
Scneario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	10.5%	7.7%	11.8%	10.2%	6.7%	11.6%	14.1%	12.2%	24.0%	11.6%	10.9%
Scneario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	22.4%	15.7%	25.9%	22.9%	17.0%	25.2%	21.3%	13.2%	31.1%	27.7%	33.1%
Scneario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	37.7%	30.5%	41.4%	38.3%	31.5%	41.0%	37.9%	30.5%	47.0%	39.1%	42.4%
Scneario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	15.1%	9.3%	18.1%	9.5%	6.5%	10.7%	39.9%	15.6%	70.3%	15.5%	10.5%
Scneario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	10.7%	7.0%	12.6%	9.2%	6.5%	10.3%	19.0%	8.8%	33.1%	12.6%	8.0%
Scneario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	18.7%	11.7%	24.9%	18.6%	11.7%	24.5%	20.0%	11.8%	30.6%	21.6%	25.7%
Scneario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	19.1%	11.9%	25.4%	18.7%	11.6%	24.7%	23.4%	13.2%	36.3%	21.9%	26.0%

Table 73 Fuel Switching for Integrated Scenarios – 95% TSL

Percent of Affected Buildings Swithcing - 95%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.2%	8.3%	20.0%	15.8%	7.8%	20.7%	14.4%	9.7%	18.9%	16.1%	13.5%
Scneario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	16.9%	9.8%	22.0%	17.3%	10.3%	21.1%	15.9%	8.9%	32.0%	17.2%	24.0%
Scneario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	26.0%	16.9%	32.5%	26.6%	16.9%	31.8%	25.5%	18.0%	42.7%	22.4%	27.9%
Scneario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	12.4%	6.0%	16.9%	9.3%	4.0%	12.2%	28.2%	10.8%	68.4%	10.7%	11.4%
Scneario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	10.0%	5.1%	13.2%	9.2%	4.0%	12.0%	17.9%	10.5%	34.9%	9.5%	10.6%
Scneario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	28.2%	16.3%	35.9%	30.2%	17.9%	36.8%	23.2%	13.3%	32.8%	27.4%	35.8%
Scneario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	35.1%	22.9%	43.0%	36.6%	24.1%	43.3%	32.1%	21.3%	42.6%	30.8%	38.5%
Scneario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	13.4%	4.3%	19.4%	13.2%	4.8%	17.7%	14.6%	3.7%	25.2%	14.3%	11.7%
Scneario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	13.2%	4.4%	19.1%	13.2%	4.8%	17.7%	13.7%	3.8%	24.5%	14.2%	11.9%
Scneario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	31.6%	20.3%	42.4%	32.2%	19.4%	44.0%	30.1%	22.7%	37.2%	31.2%	36.1%
Scneario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	32.3%	20.9%	43.1%	32.3%	19.5%	44.3%	32.2%	25.2%	39.0%	31.7%	36.3%

Table 74 Fuel Switching for Integrated Scenarios – 98% TSL

Percent of Affected Buildings Swithcing - 98%

	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
DOE NOPR (GTI Scenario 0)	15.5%	6.1%	26.0%	15.7%	5.0%	27.3%	15.7%	9.4%	23.2%	15.1%	14.6%
Scneario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	16.1%	6.3%	27.6%	16.1%	5.6%	27.7%	16.8%	9.6%	27.9%	15.2%	20.9%
Scneario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	22.2%	10.9%	35.6%	22.0%	9.4%	36.0%	25.4%	18.4%	36.1%	19.1%	23.7%
Scneario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	11.1%	3.0%	20.8%	8.3%	2.0%	15.3%	26.8%	7.5%	58.8%	9.5%	9.6%
Scneario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	9.5%	2.7%	17.4%	8.6%	2.1%	15.5%	17.3%	6.4%	38.3%	9.1%	8.7%
Scneario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	23.4%	9.9%	38.5%	23.3%	9.0%	38.8%	24.1%	12.4%	37.8%	20.6%	26.9%
Scneario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	27.7%	13.0%	44.3%	27.1%	11.8%	43.7%	30.4%	16.5%	46.7%	22.6%	28.4%
Scneario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	10.3%	2.5%	19.0%	9.6%	2.3%	17.6%	12.8%	3.1%	24.0%	9.9%	8.1%
Scneario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	10.7%	2.6%	19.6%	9.8%	2.4%	17.8%	14.2%	3.5%	26.0%	10.4%	8.3%
Scneario Int-9 (Scenarios 26 & I-16) (D2, D8, D11, I2, I6, I8, I13)	32.7%	19.3%	47.6%	33.1%	18.4%	49.1%	32.3%	22.2%	43.6%	30.4%	36.7%
Scneario Int-10 (Scenarios 27 & I-16) (D2, D8, D12, I2, I6, I8, I13)	33.6%	20.0%	48.4%	33.5%	18.8%	49.5%	34.8%	24.6%	45.6%	31.1%	38.0%

Table 75 Energy Use and Greenhouse Gas Emissions for Integrated Scenarios – 90% TSL

Energy Use Summary - 90% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.2	28.8	312	1,045	-22.4%	234.6%	-1.2	-158.5
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	29.9	21.6	270	1,099	-27.8%	306.8%	-0.2	-14.8
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	29.9	17.0	270	2,169	-43.2%	702.5%	6.3	862.9
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	29.8	22.1	270	1,005	-25.9%	273.0%	-0.5	-62.2
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	29.3	23.4	267	653	-20.0%	144.8%	-2.2	-297.0
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	29.2	20.4	266	1,256	-30.1%	371.5%	1.0	145.4
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	29.2	15.0	266	2,574	-48.6%	866.0%	9.2	1,267.0
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	29.1	21.3	266	1,120	-26.9%	321.7%	0.6	93.7
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	28.7	22.9	263	667	-20.1%	153.1%	-2.0	-263.8
Scenario Int-9 (Scenarios 26 &I-16) (D2 ,D8 ,D11, I2, I6, I8, I13)	37.1	28.6	303	1,118	-23.1%	269.2%	-0.6	-74.0
Scenario Int-10 (Scenarios 27 &I-16) (D2 ,D8 ,D12, I2, I6, I8, I13)	36.6	28.1	300	1,112	-23.2%	271.2%	-0.6	-68.7

Table 76 Energy Use and Greenhouse Gas Emissions for Integrated Scenarios – 92% TSL

Energy Use Summary - 92% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.4	29.3	314	961	-21.8%	205.9%	-2.0	-258.2
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	30.6	22.9	276	999	-25.4%	262.7%	-0.7	-91.3
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	30.6	18.9	276	1,953	-38.3%	608.7%	5.1	711.3
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	30.5	23.2	274	930	-23.9%	238.9%	-0.9	-116.0
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	29.9	24.1	271	620	-19.1%	128.8%	-2.5	-330.2
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	30.1	21.9	272	1,139	-27.3%	318.4%	0.3	51.8
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	30.1	17.0	272	2,332	-43.4%	757.0%	7.8	1,073.2
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	29.9	22.4	271	1,045	-25.0%	285.8%	0.1	27.1
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	29.4	23.8	268	634	-19.2%	136.1%	-2.3	-300.8
Scenario Int-9 (Scenarios 26 &I-16) (D2 ,D8 ,D11, I2, I6, I8, I13)	36.9	28.1	303	1,093	-23.9%	260.7%	-1.2	-148.3
Scenario Int-10 (Scenarios 27 &I-16) (D2 ,D8 ,D12, I2, I6, I8, I13)	35.9	27.2	297	1,086	-24.3%	265.4%	-1.1	-137.4

Table 77 Energy Use and Greenhouse Gas Emissions for Integrated Scenarios – 95% TSL

Energy Use Summary - 95% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	37.9	29.9	317	912	-20.9%	187.2%	-2.3	-301.7
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	33.3	26.2	293	896	-21.1%	206.3%	-1.2	-156.3
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	33.3	23.4	293	1,603	-29.8%	447.7%	3.2	446.8
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	33.1	26.6	292	834	-19.7%	186.0%	-1.3	-168.1
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	32.1	26.6	286	594	-17.1%	108.0%	-2.7	-357.6
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	32.4	22.9	289	1,340	-29.3%	364.3%	0.9	130.3
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	32.4	20.5	289	1,949	-36.7%	575.3%	4.8	664.5
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	32.4	26.4	288	700	-18.6%	142.6%	-2.2	-287.8
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	32.1	26.1	286	668	-18.5%	133.2%	-2.4	-320.5
Scenario Int-9 (Scenarios 26 &I-16) (D2 ,D8 ,D11, I2, I6, I8, I13)	39.1	25.6	317	1,718	-34.6%	442.1%	0.3	50.8
Scenario Int-10 (Scenarios 27 &I-16) (D2 ,D8 ,D12, I2, I6, I8, I13)	38.2	24.6	311	1,724	-35.7%	454.1%	0.3	51.5

Table 78 Energy Use and Greenhouse Gas Emissions for Integrated Scenarios – 98% TSL

Energy Use Summary - 98% EL

	Gas Use Before (MMBtu)	Gas Use After (MMBtu)	Electric Use Before (kWh)	Electric Use After (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
DOE NOPR (GTI Scenario 0)	39.4	31.1	323	952	-21.1%	195.1%	-2.3	-308.4
Scenario Int-1 (Scenarios 24 & I-15) (D2, D4, D5, D8, I6, I8, I13)	39.1	31.9	322	889	-18.3%	176.1%	-1.7	-225.4
Scenario Int-2 (Scenarios 23 & I-15) (D1, D4, D5, D8, I6, I8, I13)	39.1	29.8	322	1,415	-23.7%	339.2%	1.6	228.8
Scenario Int-3 (Scenarios 18 & I-15) (D8, D10, I6, I8, I13)	38.8	32.4	320	772	-16.3%	141.3%	-2.1	-272.7
Scenario Int-4 (Scenarios 17 & I-15) (D8, D9, I6, I8, I13)	36.7	31.2	308	601	-15.1%	95.1%	-2.9	-389.9
Scenario Int-5 (Scenarios 24 & I-16) (D2, D4, D5, D8 D9, I2, I6, I8, I13)	38.4	29.9	319	1,179	-22.3%	269.5%	-0.1	-9.1
Scenario Int-6 (Scenarios 23 & I-16) (D1, D4, D5, D8 D9, I2, I6, I8, I13)	38.4	28.5	319	1,539	-25.9%	382.3%	2.2	309.7
Scenario Int-7 (Scenarios 18 & I-16) (D8, D10, I2, I6, I8, I13)	38.4	32.8	319	626	-14.6%	96.4%	-2.8	-378.0
Scenario Int-8 (Scenarios 17 & I-16) (D8, D9, I2, I6, I8, I13)	37.2	31.6	312	630	-15.1%	102.0%	-2.7	-366.0
Scenario Int-9 (Scenarios 26 &I-16) (D2 ,D8 ,D11, I2, I6, I8, I13)	41.0	26.7	328	1,763	-34.8%	438.1%	-0.2	-12.0
Scenario Int-10 (Scenarios 27 &I-16) (D2 ,D8 ,D12, I2, I6, I8, I13)	39.6	25.4	319	1,779	-36.0%	456.9%	0.1	22.5

A.9 Regional LCC Savings in the North vs. Rest of Country

In the DOE NOPR LCC Model results, the reported LCC savings in the North region are lower than in the Rest of Country region. This result may seem counterintuitive when one considers the generally higher heating loads in the North relative to the Rest of Country. The DOE NOPR LCC model calculates LCC savings summarized in the results tables using the average of all buildings, including “Net Cost,” “Net Benefit,” and “No Impact” cases in each region, rather than just including impacted buildings. To allow direct comparisons, the GTI scenarios also use the same calculation in the results summary tables. DOE’s calculation approach creates a statistical anomaly when attempting to analyze and compare regional results.

The apparent inversion in LCC savings between North and Rest of Country in the DOE NOPR LCC Model is reversed when “No Impact” cases are excluded from the calculation of LCC savings, as shown in Table 79. Average LCC savings in the Rest of Country become larger than in North when all buildings are considered because shipment data used by DOE in its analysis indicates that a larger fraction of trial cases in the North will be “No Impact” cases that are excluded from the benefits calculations, but not the DOE averaging calculation. This causes a larger number of zeros to be averaged into the North region calculation, reducing the “average” LCC savings in the North region compared to the Rest of Country region.

GTI Input Data Scenario I-16 shows similar results because it does not change decision making algorithms in the DOE model. However, AHRI shipment data included in Scenario I-16 changes the fraction of trial cases in the North that will be “No Impact” cases compared to the DOE NOPR LCC model. This combined effect reduces the “average” LCC savings in the North, but changes the savings relative to the Rest of Country compared to the shipment data used by DOE. Table 80 shows that when “No Impact” cases are removed, average LCC savings are larger in the North than in the Rest of Country. When “No Impact” cases are included in the averages, it also shows larger LCC savings in the North for replacements, but smaller LCC savings in the North for new construction.

This trend does not continue when CED decision making is considered, as in GTI Scenarios 24 and Int-5, shown in Table 81 and Table 82. In both scenarios, LCC savings in both calculations (including or excluding “No Impact” cases) are larger in the Rest of Country compared to the North. This result is also tied back to shipment data. In both of these scenarios, consumers make decisions based on economics using simple payback periods. The threshold for determining whether or not a consumer chooses a particular furnace is set by either a minimum threshold, or by shipment data, whichever is larger. These payback decision thresholds are generally much larger in the North than in the Rest of Country, so there is less opportunity in the North for a rule to force LCC benefits. Under CED scenarios, consumers in the North region are already deciding to take advantage of LCC benefits of condensing furnaces without the rule, shifting the relative rule benefit to the “Rest of Country” region.

Table 79 ***DOE NOPR LCC Model Regional Average LCC Savings Comparison***

Scenario 0 (DOE NOPR LCC Model)

Type	Region	LCC Savings for Impacted Homes	LCC Savings Including Not Impacted Homes
Replacement	North	**$449**	$172
	Rest of Country	$231	**$188**
New	North	**$1,273**	$557
	Rest of Country	$1,028	**$779**

Table 80 ***GTI Scenario I-16 Regional Average LCC Savings Comparison***

Scenario I-16 (I2, I6, I8, I13)

Type	Region	LCC Savings for Impacted Homes	LCC Savings Including Not Impacted Homes
Replacement	North	**$210**	**$55**
	Rest of Country	-$51	-$36
New	North	**$837**	$298
	Rest of Country	$649	**$437**

Table 81 ***GTI Scenario 24 Regional Average LCC Savings Comparison***

Scenario 24 (D2, D4, D5, D8)

Type	Region	LCC Savings for Impacted Homes	LCC Savings Including Not Impacted Homes
Replacement	North	-$333	-$121
	Rest of Country	**-$5**	**-$4**
New	North	$270	**$85**
	Rest of Country	**$485**	$63

Table 82 ***GTI Scenario Int-5 Regional Average LCC Savings Comparison***

Scenario Int-5 (Scenario 24 & I-16) (D2, D4, D5, D8, I2, I6, I8, I13)

Type	Region	LCC Savings for Impacted Homes	LCC Savings Including Not Impacted Homes
Replacement	North	-$632	**-$161**
	Rest of Country	**-$439**	-$310
New	North	-$165	-$55
	Rest of Country	**-$42**	**-$14**

A.10 Mobile Home Gas Furnaces

The TSD states, on a footnote on page 8J-1, that "DOE did not analyze switching for mobile home gas furnaces (MHGFs) because the installation cost differential is small between condensing and non-condensing products, so the incentive for switching is insignificant." The LCC analysis under the DOE baseline LCC model shows an 11, 20, and 28% average cost increase for 92, 95, and 97% AFUE MHGFs on average as shown in Table 83. This installed cost difference is high enough that simple payback periods for 92% AFUE MHGFs is less than 3.5 years less than 20% of the time, as shown in Figure 38. This is the same as the payback period DOE defined for fuel switching decisions. Furthermore, mobile home owners typically have lower incomes than other single family home owners and so, are even more likely to have lower payback period tolerance and are therefore at least as likely as the NWGF group to fuel switch. Out of the 10,000 trials there are 815 low-income households in the NWGF sample and 1867 low-income households in the MHGF sample. This strongly suggests that the assertion that fuel switching for mobile homes can be safely ignored is unlikely to be correct. However, because the DOE LCC Model was not constructed to allow mobile home fuel switching and would have required a substantial rewrite of the model to include, the analysis presented here also does not consider fuel switching for mobile homes.

Table 83 DOE LCC Analysis Results for Mobile Home Gas Furnaces

Simulation Results NATIONAL - 10000 samples				MHGF Scenario 0						
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
MHGF										
0	MHGF 80%	$1,551	$10,887	$12,438						
1	MHGF 92%	$1,721	$9,694	$11,415	$691	7%	26%	67%	5.9	1.7
2	MHGF 95%	$1,864	$9,440	$11,304	$778	13%	14%	73%	8.8	4.4
3	MHGF 97%	$1,979	$9,319	$11,298	$784	25%	0%	75%	13.1	6.5

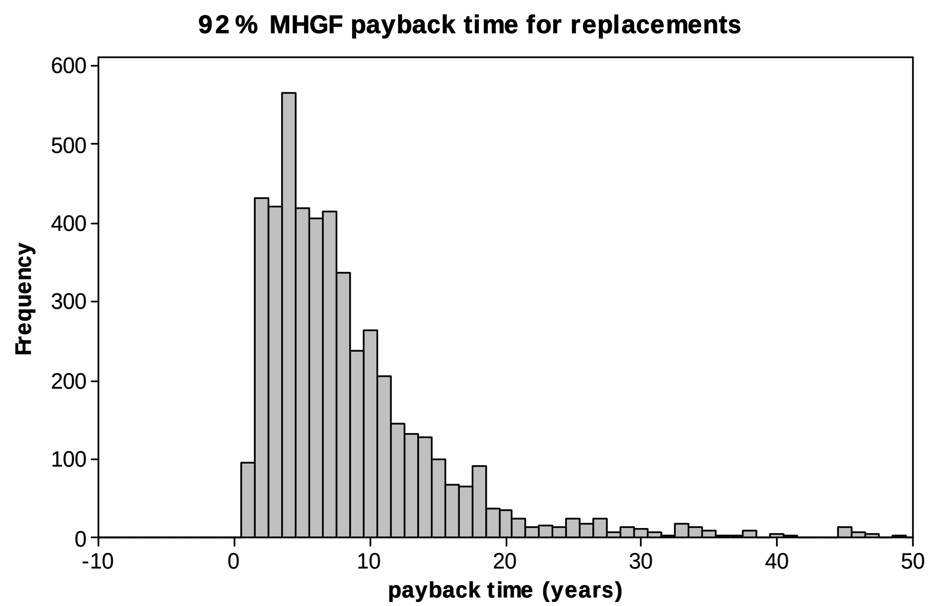


Figure 38 MHGF Payback Distribution – 92% AFUE

Several scenarios for decision making that do not involve fuel switching were run for mobile homes. The focused on the Base Case AFUE assignment and employed parametric D4 in combination with D5, D6, or D7. The results of these scenarios at a national level are shown in Table 84. When CED is used for Base Case AFUE assignment LCC Savings are substantially reduced at all TSLs. The percentage of No Impact cases also increases significantly, particularly at low TSLs. It is very likely that the inclusion of fuel switching, with the full AHCS distribution (D1) or the simpler income dependent AHCS linear fits (D2), would show negative LCC savings as occurred in the NWGF case.

Table 84 Mobile Home LCC Savings Results Using CED for Base Case AFUE Assignments

Simulation Results NATIONAL - 10000 samples					MHGF Scenario 0					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
MHGF										
0	MHGF 80%	$1,551	$10,887	$12,438						
1	MHGF 92%	$1,721	$9,694	$11,415	$691	7%	26%	67%	5.9	1.7
2	MHGF 95%	$1,864	$9,440	$11,304	$778	13%	14%	73%	8.8	4.4
3	MHGF 97%	$1,979	$9,319	$11,298	$784	25%	0%	75%	13.1	6.5

Simulation Results NATIONAL - 10000 samples					MHGF Scenario 4 (D4, D5)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
MHGF										
0	MHGF 80%	$1,551	$10,935	$12,486						
1	MHGF 92%	$1,721	$9,733	$11,453	$241	9%	55%	36%	11.0	7.3
2	MHGF 95%	$1,864	$9,504	$11,368	$627	13%	16%	71%	8.7	5.3
3	MHGF 97%	$1,979	$9,388	$11,366	$796	20%	0%	80%	11.4	6.2

Simulation Results NATIONAL - 10000 samples					MHGF Scenario 5 (D4, D6)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
MHGF										
0	MHGF 80%	$1,551	$10,926	$12,477						
1	MHGF 92%	$1,721	$9,724	$11,444	$114	9%	66%	25%	13.9	8.9
2	MHGF 95%	$1,864	$9,481	$11,345	$160	12%	54%	34%	13.5	8.9
3	MHGF 97%	$1,979	$9,375	$11,354	$259	18%	33%	49%	15.0	8.7

Simulation Results NATIONAL - 10000 samples					MHGF Scenario 6 (D4, D7)					
		Average LCC Results							Payback Results	
Level	Description	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Average	Median
MHGF										
0	MHGF 80%	$1,551	$10,927	$12,478						
1	MHGF 92%	$1,721	$9,725	$11,446	$143	9%	64%	28%	13.0	8.3
2	MHGF 95%	$1,864	$9,494	$11,357	$330	12%	38%	50%	10.5	7.1
3	MHGF 97%	$1,979	$9,381	$11,360	$532	18%	19%	63%	12.9	7.1