the Energy to Lead

gti

GTI-11/0006

FINAL REPORT

GTI PROJECT NUMBERS 21225, 20705, and 02169

Technical Analysis of DOE Direct Final Rule on Minimum Efficiencies of Residential Furnaces

Reporting Period:
August 2011 through October 2011

Report Issued:
October 14, 2011

Prepared For:
American Gas Association and
American Public Gas Association

GTI Technical Contact:
Neil Leslie
R&D Director
End Use Solutions
847-768-0926
Fax: 847-768-0501
neil.leslie@gastechnology.org

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

Disclaimer

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

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

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

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Executive Summary

On January 15, 2010 a joint recommendation was submitted to the Department of Energy (DOE) to adopt a package of energy conservation standards for residential furnaces, central air conditioners, and heat pumps. Under provisions of the Energy Independence and Security Act of 2007, DOE used an expedited rulemaking process called a Direct Final Rule (DFR). The DFR was published in the Federal Register on June 27, 2011 and open for a 110 day public comment period. To substantiate the DFR determination, DOE released an extensive technical support document (TSD) that included a detailed review of the effects of the DFR as well as economic modeling to assess consumer-level cost impacts.

GTI analysts conducted a scenario analysis of the TSD to evaluate the impact of the regional minimum furnace efficiency requirements on consumers. The analysis considered the following:

- TSD analysis methodology and conclusions.
- Impact of updated energy price forecasts, marginal energy prices, and furnace expected lifetime on the economic justification of the regional minimum furnace efficiency requirements.
- Data on common vent installations and conversion costs.
- Estimates of consumer benefits and costs associated with the regional minimum furnace efficiency requirements.

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

- As illustrated in Table 1, several foreseeable scenarios, including a reasonable alternate to the DOE baseline scenario using the Annual Energy Outlook (AEO) 2011 reference case along with a 16 year furnace expected life, learning curve coefficient of 1.0, and conservative marginal gas prices, show negative composite average lifecycle cost savings for a 90% condensing furnace in the North Region compared to the 80% AFUE baseline furnace, indicating that the 90% furnace does not meet the DOE requirement for economic justification in the North Region.

Table 1 Integrated Scenario Analysis Results

Integrated Scenarios (16 Year Furnace Life, LC = 1.0 in All AEO 2011 Scenarios)	**North Composite**		**North Retrofit**		**North New Construction**	
	LCC Savings	**Payback Period Median/Avg**	**LCC Savings**	**Payback Period Median/Avg**	**LCC Savings**	**Payback Period Median/Avg**
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2011 Ref Case 13% Fixed Gas Costs	-$4	16.3 / 20.5	-$64	20.4 / 25.3	$172	4.1 / 7.1
AEO 2011 High Shale 13% Fixed Gas Costs	-$18	18.0 / 22.8	-$78	22.7 / 28.1	$157	4.3 / 7.9
AEO 2011 Ref Case Citygate Gas Price	-$39	21.7 / 28.7	-$98	27.0 / 35.4	$135	5.6 / 9.9
AEO 2011 High Shale Citygate Gas Price	-$48	23.9 / 31.3	-$107	29.7 / 38.8	$125	5.9 / 10.5

- Lifecycle costs for the North Region retrofit installations are worse than the composite costs. The payback period exceeds the average expected lifetime of the furnace under numerous foreseeable retrofit scenarios.
- New construction life cycle cost savings are positive in all scenarios based on DOE's installed cost assumptions. However, under DOE's assumed costs, the average installed cost of a 90% AFUE condensing furnace is lower than the installed cost of an 80% non-condensing furnace.
- The TSD analysis used average prices for natural gas, fuel oil, and LPG calculations, though not necessarily for all electricity calculations. Average impact analysis may be acceptable for inventory purposes, but it is inadequate and misleading for efficiency improvement impact calculations. The shift from an 80% AFUE furnace to a 90% AFUE furnace is a marginal change, and as such requires use of a marginal impact analysis, not an average impact analysis.
- The impact of updated energy price forecasts, marginal energy costs, and furnace expected lifetime on the economic justification of 90% furnaces is substantial, and can shift the result from a net positive average result to a net negative average result in the North Region.
- Based on analysis of empirical data developed by Laclede Gas Company, DOE's finding that the condensing furnace regional standard is economically justified is likely to be highly questionable or invalid in many of the 30 northern states currently affected, especially in the retrofit market. In the Laclede database example, nearly 60% of condensing furnaces either have no payback or have a payback that exceeds the expected life of the furnace.
- The overall impact of orphaned water heater fuel switching needs to be explicitly included in the analysis of consumer impacts and LCC savings. While this fuel switching may occur only in a fraction of installations, the impact per home is significant ($2,846 LCC per home in a typical example), and should be carefully considered by DOE before making a final determination.
- The DOE analytical tool and results were difficult to evaluate and use without additional assistance due to very limited user documentation and compatibility issues with the LCC spreadsheet and Crystal Ball software. More instructive user documentation and reasonable access to input variables necessary to run sensitivity analyses on critical parameters such as energy price, equipment costs, and installed costs would help other analysts navigate the tool, conduct parametric analyses, and correctly interpret results.

2.0 Background

The Energy Policy and Conservation Act of 1975 requires the Department of Energy (DOE) to establish energy conservation standards for select consumer products and equipment and to update the stringency of these standards when it is determined that in addition to yielding energy savings, the updated standards are technologically feasible and economically justified. A DOE Direct Final Rule (DFR) published in the Federal Register on June 27, 2011, proposes 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 (Table 2 and Figure 1). Under the DFR, these 90% AFUE standards would take full effect in 2013.

Table 2: DOE Direct Final Rule Proposed Standards for Residential Furnaces

Product Class	South Region Standards	North Region Standards
Non-weatherized gas	AFUE = 80%	AFUE = 90%
Mobile home gas	AFUE = 80%	AFUE = 90%
Weatherized gas	AFUE = 81%	AFUE = 81%
Non-weatherized oil-fired	AFUE = 83%	AFUE = 83%
Mobile home oil-fired	AFUE = 75%	AFUE = 75%
Weatherized oil-fired	AFUE = 78%	AFUE = 78%
Electric	AFUE = 78%	AFUE = 78%

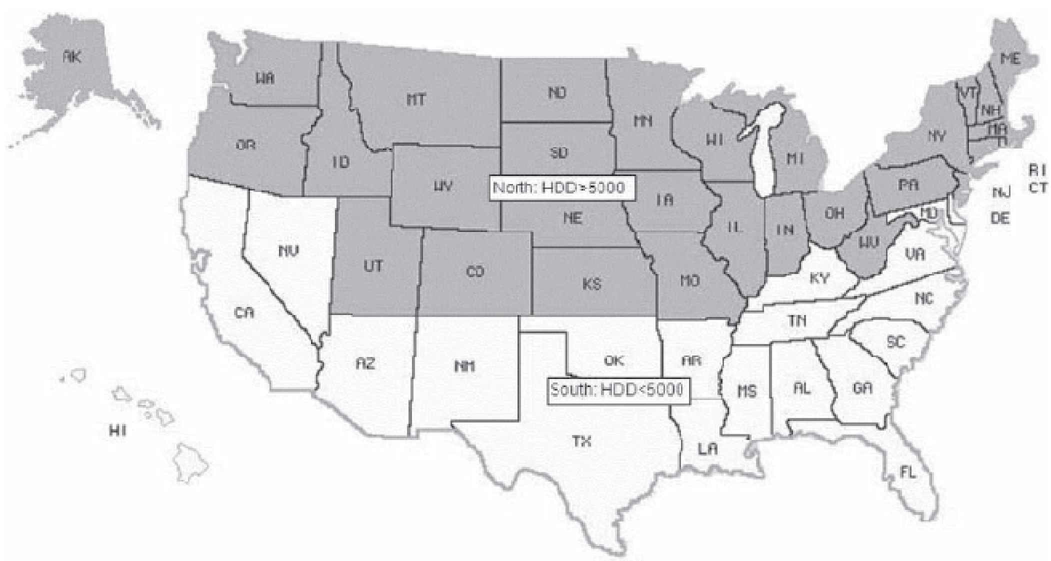


Figure 1: Map of Regions for the DFR Analysis of Furnace Standards

A technical support document (TSD) based on a sophisticated Excel/Crystal Ball spreadsheet tool prepared for DOE by 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. This spreadsheet tool was used by DOE to calculate the lifecycle cost and payback periods for the proposed efficiency increases under specific scenarios. Figure 2 shows a summary table of the results included in the DFR. Multiple variables strongly affect the results of lifecycle cost and payback period analyses, which jointly serve as the basis for DOE's determination that the proposed rule is economically justified. The assumptions and methodologies that are used within the LBNL spreadsheet tool to justify the 90% AFUE furnace standard for North Region states are the primary focus of this analytical report.

Efficiency Level	*AFUE*	Life-Cycle Cost *2009$*			Life-Cycle Cost Savings *2009$*				Median Payback Period *years*
		Installed Cost	Discounted Operating Cost	LCC	Average Savings *2009$*	% of Households with			
						Net Cost	No Impact	Net Benefit	
Nation									
0	80%	1,786	9,551	11,337	N/A	0	100	0	N/A
1	90%	2,357	8,621	10,978	87	25	52	22	15.8
2	92%	2,419	8,456	10,875	136	26	42	32	11.9
3	95%	2,564	8,220	10,785	205	36	17	47	11.7
4	98%	2,830	8,114	10,944	46	64	0	35	20.1
North									
0	80%	1,901	11,553	13,454	N/A	0	100	0	N/A
1	90%	2,474	10,409	12,883	155	10	71	19	10.1
2	92%	2,536	10,206	12,742	215	11	56	33	7.7
3	95%	2,685	9,916	12,601	323	23	23	54	9.4
4	98%	2,943	9,784	12,727	198	59	1	41	17.1
South (Rest of Country)									
0	80%	1,614	6,566	8,180	N/A	0	100	0	N/A
1	90%	2,182	5,955	8,137	(13)	48	24	28	24.1
2	92%	2,244	5,846	8,090	19	48	20	32	21.3
3	95%	2,384	5,692	8,076	28	56	8	36	20.5
4	98%	2,661	5,624	8,286	(181)	72	0	27	28.9

*Values in parentheses denote negative values.

Figure 2: DFR Lifecycle Cost and Payback Period Results for Non-Weatherized Gas Furnaces

Source: DOE Direct Final Rule, Technical Support Document Chapter 8[1]

3.0 Application of TSD Spreadsheet Analysis Methodology

GTI analysts planned to conduct a technical and economic analysis of the DFR to evaluate the impact of the regional minimum furnace efficiency requirements on consumers. The analysis was to consider the following:

- TSD analysis methodology and conclusions.
- Impact of updated energy price forecasts, marginal energy prices, and furnace expected lifetime on the economic justification of the regional minimum furnace efficiency requirements.
- Data on common vent installations and conversion costs.
- Estimates of consumer benefits and costs associated with the regional minimum furnace efficiency requirements.

The initial activity was to gain a working understanding of the DOE analysis outlined in the spreadsheet tool and the TSD. Once the results of the DOE analysis were reviewed, nearly 100 alternate analytical scenarios were identified that would enable a reasonable evaluation of the TSD and DFR analysis results by modifying and running DOE's analytical tool using alternate inputs.. However, challenges began to emerge as the work progressed. Some of these challenges were overcome, while others remained unsolved. Approximately 25% of the overall work effort was devoted to attempts to overcome these challenges. The following discussion provides some insights about the TSD analysis methodology and issues confronting GTI analysts during the course of this effort.

To make a determination regarding the economic merit of the DFR, LBNL used a set of Excel spreadsheets that invoked Oracle's Crystal Ball software to provide forecasts of costs and benefits of various options. Crystal Ball is a spreadsheet-based application suite used for simulation, forecasting, and modeling. The spreadsheet provided by DOE as part of the TSD utilized Crystal Ball version 7.3.2. However, the version of the software now available is Crystal Ball Fusion Edition release 11.1.2.1.0. Using Crystal Ball Fusion Edition, GTI analysts were not able to successfully run the LBNL version 7.3.2 spreadsheets to replicate the TSD results. This was the first step in the scenario analyses to ensure that there was exact agreement with the TSD results when GTI ran the tool. Otherwise, the effect of any changes could not be directly compared to the DOE values. To help determine the source of initial problems with running the LCC spreadsheet provided by DOE, GTI analysts worked directly with Oracle staff. After several extensive interactions, the vendor acknowledged that the spreadsheet was not compatible with the current version of Crystal Ball and provided archival version 7.3.2 (no longer available for sale) to be compatible with the DOE LCC_Payback_lcc_furnace_2011-06-06 spreadsheet. Oracle also provided a modified spreadsheet that ran successfully using Crystal Ball Fusion Edition.

The only user options for parametric analysis in the LCC_Payback_lcc_furnace_2011-06-06 spreadsheet are in limited drop down menus (marked by the red box in Figure 3). The four drop down menus include three AEO 2010 based forecasts of future energy prices, the year in which the standard would become effective, the number of trials evaluated by the Crystal Ball, and whether the results are limited to selected sub-groups (e.g., low income). This makes it difficult without detailed documentation and training for other analysts to examine the impact of alternate scenarios, including sensitivity analysis of parameters like alternative equipment useful life, installed costs, or future cost reductions.

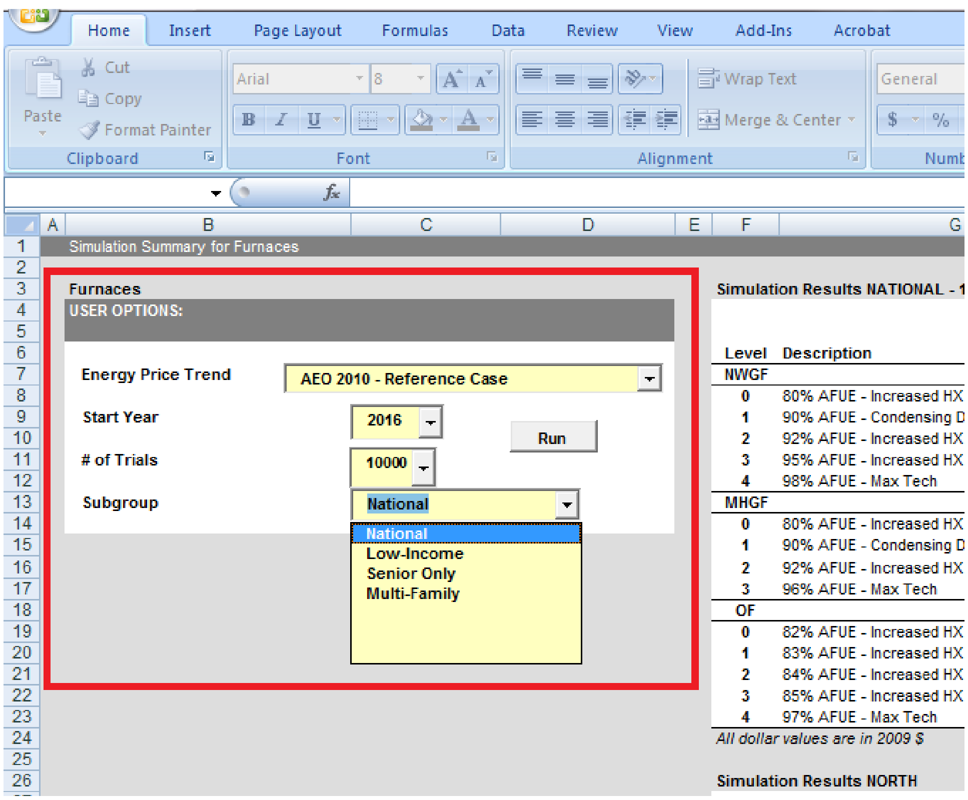


Figure 3: Drop Down Menu User Options in LCC Spreadsheet Analysis Tool

Based on extensive examination of the spreadsheet and TSD over a two month period, GTI analysts were ultimately able to use the tool to run most of the desired scenarios. Alternate energy price scenarios were conducted by modifying the energy price forecast tables within the spreadsheet to reflect updated forecasts and marginal prices. Equipment price was adjusted by changing the "LearningCurves_Coef" value in the "Equip Price" sheet from 0.902452574277439 to 1.0 to reflect a fully mature product price. Expected equipment life coefficients were modified to reduce the expected equipment life from the DOE value of 23.6 years to 16 years to reflect the value used by DOE in its multiyear plan.

However, attempts to evaluate impacts of equipment installation costs on LCC by modification of DOE default costs failed. For example, changing the value for relining costs to a higher amount based on gas industry survey data produced unexpectedly high resulting costs. These anomalous results could not be tracked or explained without examination of program inputs and results. This debugging was not possible within the time constraints of this effort. GTI analysts were not able to capture intermediate Crystal Ball simulation results called by the underlying spreadsheet, and were not able to reconcile key differences between TSD values, spreadsheet input values, and Crystal Ball output results. Given sufficient time, it is quite likely that successful runs could have been made, but the tool design was not sufficiently transparent to facilitate such a debugging effort.

The difficulties experienced in attempting to use this tool are not an inevitable result of its complexity. Other software modeling tools, such as the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model from Argonne National Laboratory are very complex as well. These tools make much more extensive use of dropdown menus with default values for a wide range of parameters that permit replicable scenario analyses by any analyst with a basic understanding of modeling. In the DOE spreadsheet tool, the lack of user interface necessary for such analyses means that even skilled analysts will have great difficulty in finding and using the full range of tool capabilities essential for parametric evaluations without assistance. Portions of the tool containing access to important input parameters were difficult to identify and had cell references that cross-referenced other named cells or ranges, making it nearly impossible to trace calculations and variables. Without a detailed Users Manual or other similar instructions to shed light on these issues, the tool could not be used by GTI analysts in the installed cost parametric analyses that relied on these inputs.

GTI analysts conducted LCC spreadsheet and Crystal Ball software parametric analyses using 15 alternate energy price projections, a 16 year expected furnace life, and a 1.0 learning curve coefficient, to compare the LCC and PBP results with the DOE AEO 2010 Reference Case, but did not conduct any of the desired venting installation cost scenario analyses. Table 3 shows the matrix of analytical scenarios that GTI initially planned to complete, delineating runs that were successfully completed from those that were not possible for reasons cited above.

Table 3: Planned and Completed Scenario Analyses

		SCENARIOS							
		Alternate Energy Price Projections	Alternate Equipment Price Learning Curve	Alternate Equipment Lifetime	Alternate Common Venting Split	Alternate Venting Modification Costs	Marginal Impact Analysis (Two Approaches)	Integrated Scenario - Citygate	Integrated Scenario - 13% Fixed Gas
EIA ENERGY PRICE PROJECTIONS	AEO 2010 Reference Case	Yes	Yes	Yes	No	No	N/A	N/A	N/A
	AEO 2010 High Economic Growth	Yes	N/A	Yes	No	No	N/A	N/A	N/A
	AEO 2010 Low Economic Growth	Yes	N/A	Yes	No	No	N/A	N/A	N/A
	AEO 2011 Reference Case	Yes	N/A	N/A	No	No	Yes	Yes	Yes
	AEO 2011 High Economic Growth	N/A	N/A	N/A	No	No	Yes	N/A	N/A
	AEO 2011 Low Economic Growth	N/A	N/A	N/A	No	No	Yes	N/A	N/A
	AEO 2011 High Shale Gas Use	Yes	N/A	N/A	No	No	Yes	Yes	Yes
	AEO 2011 Low Shale Gas Use	Yes	N/A	N/A	No	No	Yes	N/A	N/A

4.0 Energy Price Scenario Analysis

The purpose of the energy price projection scenario analysis was to evaluate the impact of lower or higher economic growth, updated baseline energy price projections, and high and low availability of shale gas on energy prices. GTI analysts conducted LCC spreadsheet and Crystal Ball software parametric analyses using 15 alternate energy price projections to compare the LCC and PBP results with the DOE AEO 2010 Reference Case.

4.1 Updated Energy Price Projections

As shown in Figure 4, there has been a large variability in the AEO projections of natural gas prices depending on the edition of the AEO. Of special interest for the furnace analysis is the significant impact of new projections of higher shale gas availability on future energy prices. Also of interest is the impact of shifting to marginal prices rather than average prices for calculating benefits.

The TSD provides multiple lifecycle cost inputs for economic modeling, including equipment costs (capital, installation, operating, maintenance, etc.), pricing (historical and projected), and annual energy use, among others. For energy price projections, DOE relied on the Energy Information Administration's AEO 2010 Reference Case for projections through 2035. Beyond 2035, the average annual rate of change in the price from 2020 to 2035 was calculated and applied to each year from 2035 to 2045. This methodology was used for natural gas, fuel oil, and LPG. It is not clear whether the same average price projection methodology was used for electricity. The TSD indicated that electricity rates included at least some marginal rate structures, but the application of those rate structures in the spreadsheet tool was not investigated.

AEO 2011 was released April 26, 2011, with revised data and projections. Although the DFR was released June 27, 2011, DOE selected AEO 2010 as the data source for energy price projections. To compare the relative effects of the revised energy price projections, GTI ran DOE's analytical tool using AEO 2011 Reference Case energy prices.

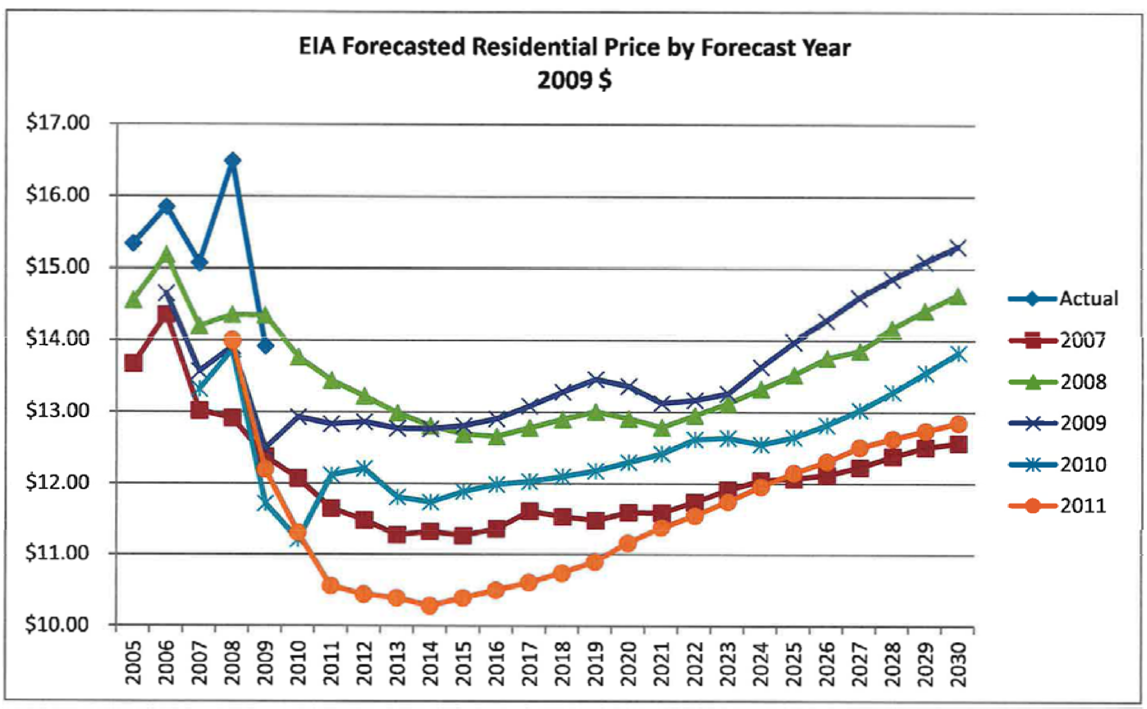


Figure 4 AEO 2007 through AEO 2011 Natural Gas Price Projections

AEO 2011 accounts for important changes in the U.S. energy economy, including a significant increase in projected shale gas resources (more than doubling the volume assumed in AEO 2010), among others. Since energy price projections are a vital central piece of the economic analysis, the most up-to-date values should be used. Table 4 shows the meaningful impact of changes in average residential natural gas prices in 2015 and 2020 between AEO 2010 and AEO 2011 projections. This level of change led to significant changes in payback. The scenario analyses show, for example, the North Region retrofit payback period increased from 12.9 years (using the AEO 2010 price data) to 17.6 years (using the AEO 2011 price data) as shown in Table 5. When looking at marginal natural gas pricing—a suitable method of evaluating incremental changes in consumer natural gas use—the payback periods for a Northern Region retrofit payback increases to 26.3 years (median value) and 34.6 years (average value) using the 2011 AEO Reference Case outlook price data as shown in Table 6.

Table 4 AEO Reference Case Natural Gas Price and Residential Retrofit Payback Comparisons

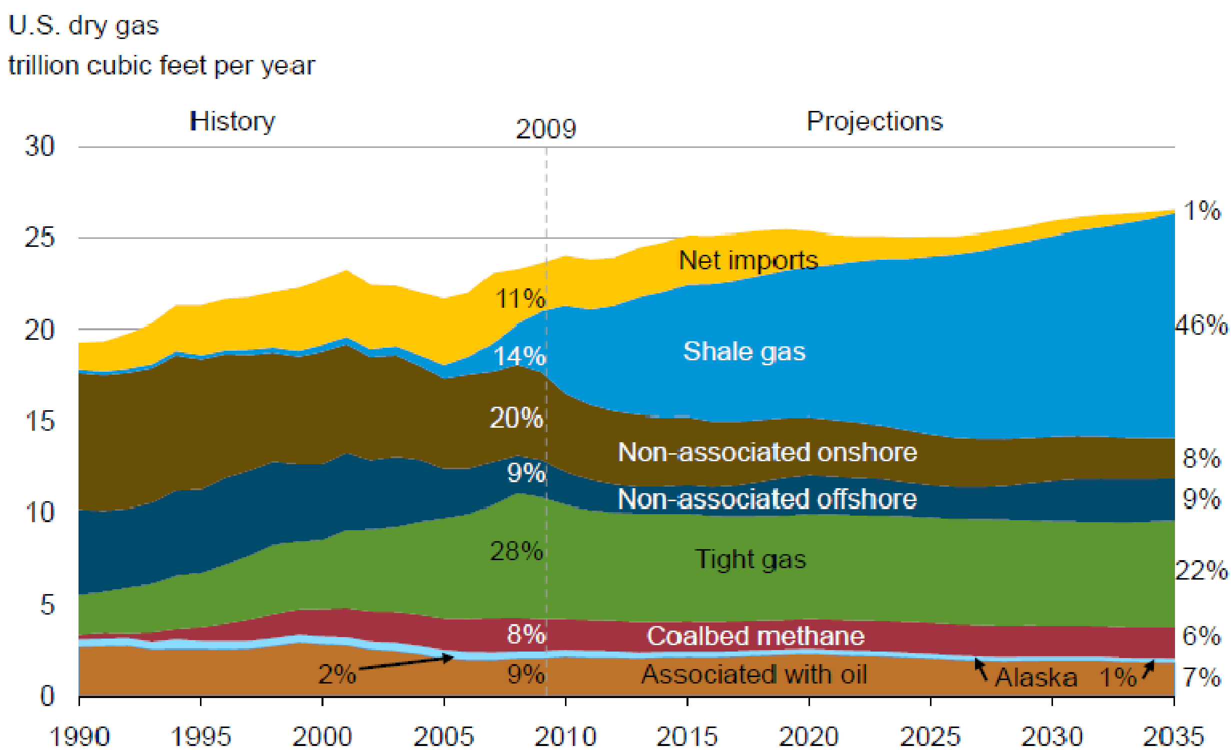
	2015 Price $/MMBtu	2020 Price $/MMBtu	North Region Retrofit Payback (Years)
AEO 2010 Residential Natural Gas Price	$11.73	$12.13	12.9 Years
AEO 2011 Residential Natural Gas Price	$10.12	$10.86	17.6 years
% Change from AEO 2010	-13.7%	-10.5%	+36%

The analytical spreadsheets that accompany the TSD also include energy price projections under EIA's High Economic Growth and Low Economic Growth scenarios. However, the alternate price projections under the High and Low Economic Growth scenarios were not considered in the final results of the economic analysis. GTI used energy price projections for both the AEO 2010 High and Low Economic Growth scenarios to re-run an LCC analysis to determine the impact of economic growth projections on the economic performance of the proposed DFR efficiency levels.

With the unprecedented growth in domestic shale gas production and projected resources in recent years, shale gas is expected to play a significant and growing role in the U.S. energy market for at least the next several decades (Figure 5). Therefore, a scenario that considers the impact of this expanded resource base on future natural gas prices is important.

A sizable increase in the shale gas resource base will also have secondary effects on the residential price of electricity. According to EIA data, of the total electric generation capacity additions planned between 2009 and 2035 about 60 percent will be fueled by natural gas (Figure 6).[2] The reduced cost of natural gas in response to expanded shale gas extraction is therefore likely to reduce electricity prices. This new expectation is reflected in AEO 2011.

Figure 7 shows residential electricity prices under four EIA price projections – the projected prices in the Reference Cases for AEO 2010 and AEO 2011 and two alternate scenarios included in AEO 2011, one with higher levels of shale gas use and one with lower levels of shale gas use. A similar graph showing the various projected residential natural gas prices is shown in Figure 8. Since the focus of this analysis is the North Region, the electricity prices shown are average residential electric prices weighted by the number of electric customers within the North Region to be consistent with the methodology used in the TSD.



Source: *EIA, Annual Energy Outlook 2011*

Figure 5: AEO 2011 U.S. Natural Gas Supply Estimates through 2035 by Source

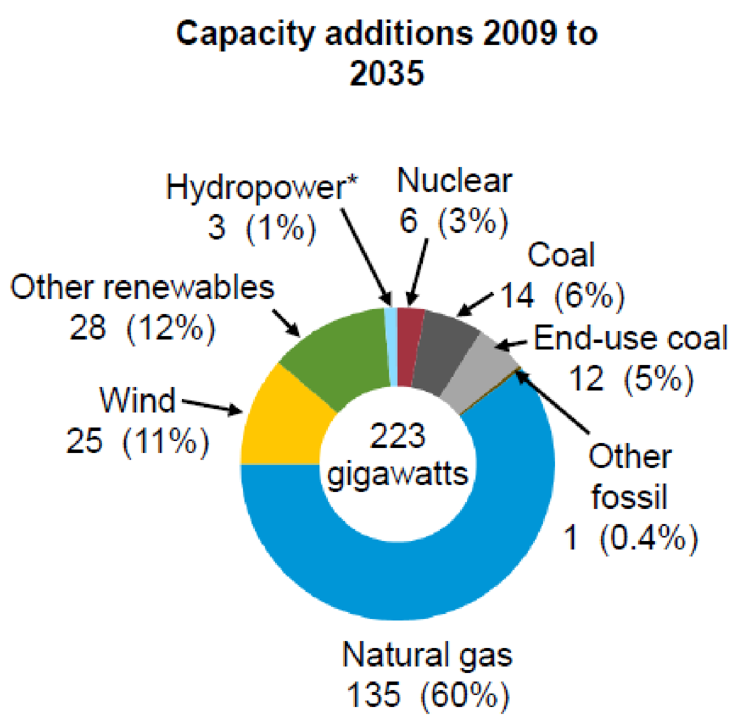


Figure 6: AEO 2011 Expected Electric Capacity Additions 2009-2035

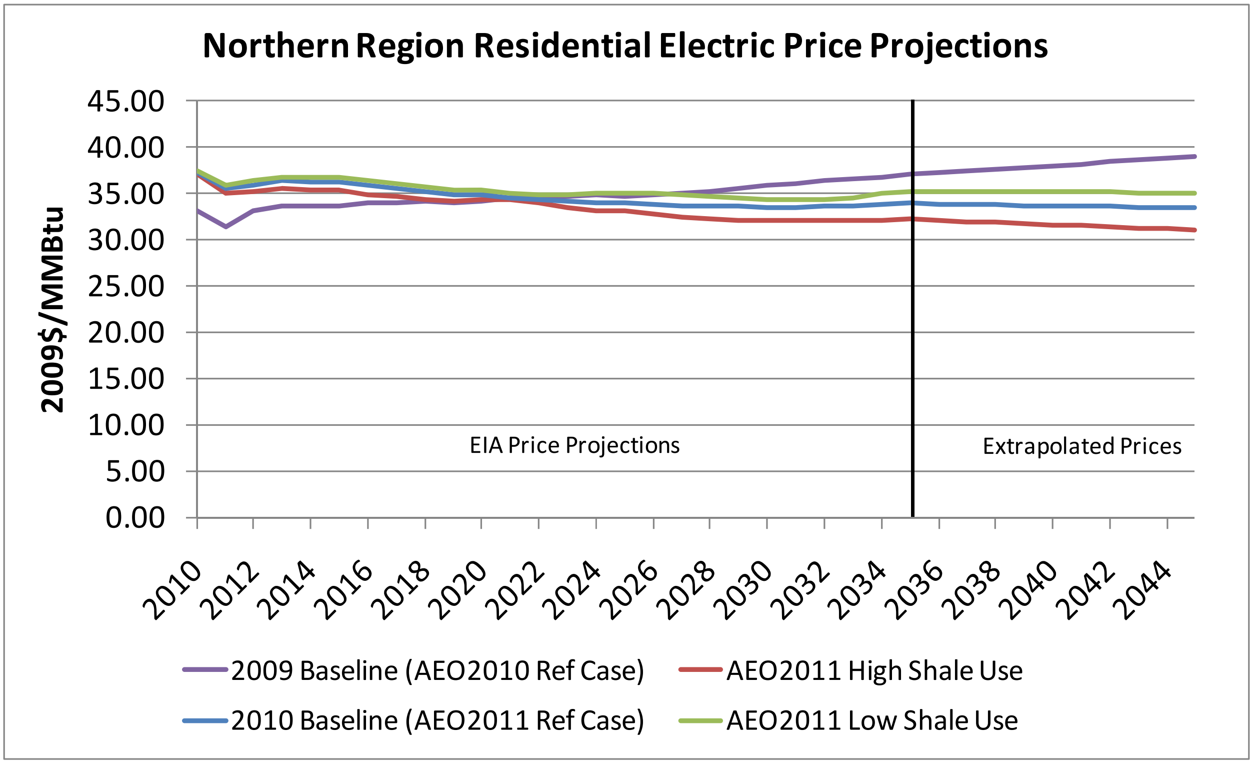


Figure 7: AEO Residential Electric Price Projections for the North Region

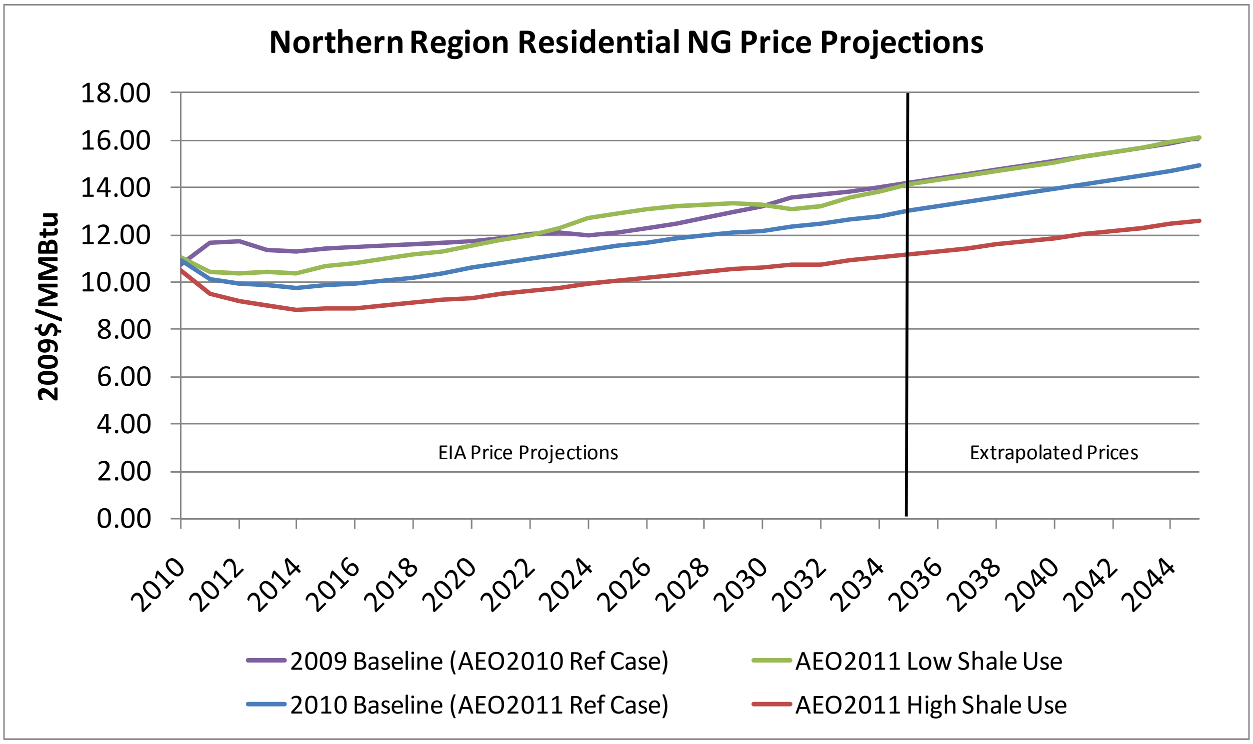


Figure 8: AEO Residential Natural Gas Prices Projections for the North Region

To gauge the impact of changes in the level of shale gas use on LCC results, EIA's energy price projections under high and low shale gas availability scenarios were modeled. The high shale gas availability data were taken from the AEO 2011 "High Shale EUR" scenario, which assumes that the estimated ultimate recovery is 50% higher than the reference case. The low shale gas availability data were taken from AEO 2011 "Low Shale Recovery" scenario, which assumes that 50% less gas is recovered from each shale gas play than the reference case.

To examine the impact of alternate economic growth forecasts on the lifecycle costs of the proposed furnace efficiency upgrades, GTI analysts also ran scenarios utilizing AEO 2010 energy price projection data for High Economic Growth and Low Economic Growth.

The results presented below are generated from Oracle's Crystal Ball software version 7.3.2. This spreadsheet-based tool was the analytical foundation for DOE's economic analysis and was therefore determined to be the most appropriate tool to analyze the alternate scenarios outlined within this report. The results of Crystal Ball analysis include a large range of tables and information. However, only key summary tables are included to enable high-level comparisons across the scenarios. These high-level tables are the same summary tables that were included in the DFR and used as the basis for the economic justification. The scenarios focus solely on the North Region.

For ease of comparison across these multiple scenarios, a summary table that includes the estimated lifecycle cost savings and the median and average payback periods for retrofit installations in the north region is included (Table 5 and Figure 9). Additionally, the original results of DOE's Crystal Ball economic analysis that are included in the current DFR are shown in Figure 10 through Figure 12. Figure 13 through Figure 27 provide tabular results from Crystal Ball runs for alternative price scenarios.

As shown in these tables and figures, the effect of alternate energy price projections is significant, increasing the expected average payback period beyond 20 years in the North Retrofit market. With expanded shale gas use, the LCC savings of the proposed rule approach zero for retrofit/replacement installations, and the average payback period exceeds the DFR expected furnace life of 23.6 years. The analysis shows attractive economics for new construction installations under all price scenarios.

There are also concerns with DOE's conclusions from the AOE2010 baseline analysis. DOE concluded that the standards in this rule represent the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in the significant conservation of energy. However, it selected the new minimum for northern climates to be 90% AFUE even though the TSD analysis indicates that the 95% AFUE furnace saves more money and is deemed to be cost-effective in northern climates, with better LCC benefits and shorter payback period than the 90% AFUE furnace. The 95% furnace also has a much higher fraction of consumers with net benefits (54% vs 19%) than the 90% furnace. This analytical result is inconsistent with DOE's stated conclusion.

Also of interest is the DFR estimate that the average 90% furnace installed cost is less than the average installed cost of an 80% furnace in new construction. This result is counterintuitive and shifts the results in favor of the condensing furnace. A good explanation may exist, but it is worth reviewing to see if it is a robust assumption.

DOE notes in its DFR that the projected economic impacts of the standards in this rule on individual consumers are generally positive, but only 19% of homes in the north region accrue a net benefit with the 90% furnace according to the TSD analysis. The TSD analysis indicates that 72% of consumers in the north are not impacted by the rule for a 90% furnace retrofit, while 23% are not impacted for a 95% furnace retrofit. An a priori expectation is that few if any consumers would not be impacted unless the "no impact" definition is fairly broad. Note that the 98% furnace retrofit case shows only 1% of consumers with no impact, which is more aligned with the a priori expected result. GTI analysts were not able to determine the reason for the different "no impact" fractions.

Table 5: 90% AFUE Furnace LCC and PBP Results for Alternate Average Price Scenarios

	North Composite		North Retrofit		North New Construction	
	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2010 High Economic Growth	$170	10.0 / 12.6	$106	12.7 / 15.6	$360	2.5 / 4.2
AEO 2010 Low Economic Growth	$136	10.5 / 13.2	$73	13.4 / 16.3	$323	2.6 / 4.4
AEO 2011 Reference Case	$90	13.8 / 17.6	$27	17.6 / 21.9	$276	3.2 / 5.9
AEO 2011 High Shale Gas Use	$66	15.4 / 19.8	$3	19.5 / 24.5	$251	3.5 / 6.6
AEO 2011 Low Shale Gas Use	$107	12.9 / 16.3	$43	16.4 / 20.3	$293	3.0 / 5.4

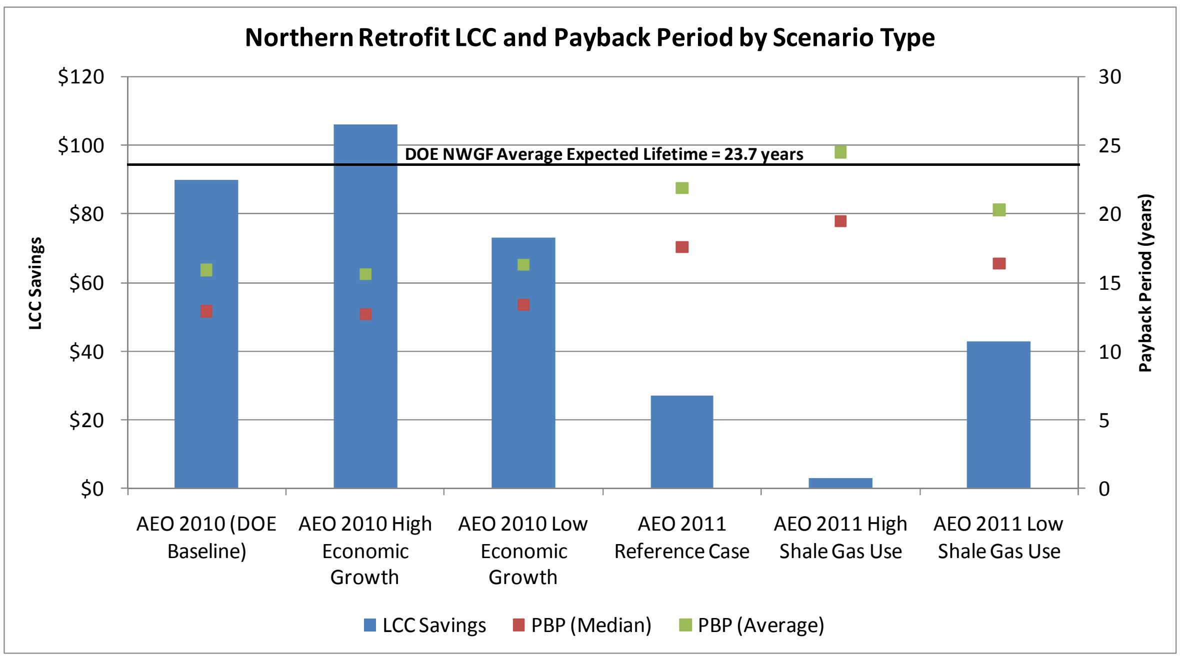


Figure 9: 90% AFUE Furnace North Retrofit LCC and PBP by Energy Price Scenario

4.1.1 DFR AEO 2010 Reference Case Economic Analysis

Simulation Results NORTH										AEO 2010 - Reference Case
		Average LCC Results							Payback Results	
		Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF	5,986									
0	80% AFUE - Increased HX Area	$1,901	$11,553	$13,454						
1	90% AFUE - Condensing Design	$2,474	$10,409	$12,883	$155	10%	71%	19%	10.1	12.8
2	92% AFUE - Increased HX Area	$2,536	$10,206	$12,742	$215	11%	56%	33%	7.7	10.1
3	95% AFUE - Increased HX Area	$2,685	$9,916	$12,601	$323	23%	23%	54%	9.4	11.3
4	98% AFUE - Max Tech	$2,943	$9,784	$12,727	$198	59%	1%	41%	17.1	28.2
All dollar values are in 2009 $		* discounted and summed over lifetime of equipment								

Figure 10: DFR Economic Analysis Results – North Composite

Simulation Results NORTH - Replacements										AEO 2010 - Reference Case
		Average LCC Results							Payback Results	
		Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF	4,465									
0	80% AFUE - Increased HX Area	$1,713	$11,464	$13,177						
1	90% AFUE - Condensing Design	$2,483	$10,328	$12,811	$90	13%	72%	16%	12.9	15.9
2	92% AFUE - Increased HX Area	$2,543	$10,126	$12,669	$151	13%	57%	30%	9.0	11.7
3	95% AFUE - Increased HX Area	$2,687	$9,838	$12,524	$262	25%	23%	52%	9.7	11.9
4	98% AFUE - Max Tech	$2,925	$9,704	$12,629	$158	60%	1%	39%	16.9	26.5
All dollar values are in 2009 $		* discounted and summed over lifetime of equipment								

Figure 11: DFR Economic Analysis Results – North Retrofit

Simulation Results NORTH - New Construction										AEO 2010 - Reference Case
		Average LCC Results							Payback Results	
		Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF	1,521									
0	80% AFUE - Increased HX Area	$2,452	$11,815	$14,268						
1	90% AFUE - Condensing Design	$2,447	$10,647	$13,094	$343	2%	70%	27%	2.5	4.3
2	92% AFUE - Increased HX Area	$2,516	$10,440	$12,956	$404	4%	55%	41%	5.1	5.5
3	95% AFUE - Increased HX Area	$2,680	$10,145	$12,825	$502	16%	23%	61%	8.8	9.8
4	98% AFUE - Max Tech	$2,996	$10,017	$13,012	$315	55%	1%	44%	17.9	33.3
All dollar values are in 2009 $		* discounted and summed over lifetime of equipment								

Figure 12: DFR Economic Analysis Results – North New Construction

4.1.2 AEO 2010 High Economic Growth Energy Price Projections

Simulation Results NORTH Composite											AEO 2010 High Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$12,090	$13,991						
1	90% AFUE - Condensing Design		$2,474	$10,890	$13,364	$170	10%	71%	19%	10.0	12.6
2	92% AFUE - Increased HX Area		$2,536	$10,676	$13,213	$235	10%	56%	33%	7.5	9.9
3	95% AFUE - Increased HX Area		$2,685	$10,373	$13,058	$354	21%	23%	56%	9.3	11.1
4	98% AFUE - Max Tech		$2,943	$10,234	$13,177	$236	57%	1%	43%	16.8	28.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 13: AEO 2010 High Economic Growth Results – North Composite

Simulation Results NORTH Replacement											AEO 2010 High Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$11,995	$13,708						
1	90% AFUE - Condensing Design		$2,483	$10,804	$13,287	$106	12%	72%	16%	12.7	15.6
2	92% AFUE - Increased HX Area		$2,543	$10,592	$13,135	$171	13%	57%	30%	8.8	11.5
3	95% AFUE - Increased HX Area		$2,687	$10,290	$12,976	$293	24%	23%	54%	9.4	11.6
4	98% AFUE - Max Tech		$2,925	$10,150	$13,075	$195	58%	1%	42%	16.5	26.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 14: AEO 2010 High Economic Growth Results – North Retrofit

Simulation Results NORTH New Construction											AEO 2010 High Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$12,369	$14,821						
1	90% AFUE - Condensing Design		$2,447	$11,143	$13,590	$360	2%	70%	28%	2.5	4.2
2	92% AFUE - Increased HX Area		$2,516	$10,925	$13,441	$426	4%	55%	41%	4.9	5.4
3	95% AFUE - Increased HX Area		$2,680	$10,616	$13,295	$535	15%	23%	62%	8.6	9.6
4	98% AFUE - Max Tech		$2,996	$10,481	$13,476	$355	53%	1%	46%	17.5	33.1
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 15: AEO 2010 High Economic Growth Results – North New Construction

4.1.3 AEO 2010 Low Economic Growth Energy Price Projections

Simulation Results NORTH Composite											AEO 2010 Low Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$10,935	$12,836						
1	90% AFUE - Condensing Design		$2,474	$9,856	$12,330	$136	10%	71%	18%	10.5	13.2
2	92% AFUE - Increased HX Area		$2,536	$9,664	$12,200	$192	12%	56%	32%	8.0	10.4
3	95% AFUE - Increased HX Area		$2,685	$9,391	$12,075	$287	24%	23%	53%	9.8	11.7
4	98% AFUE - Max Tech		$2,943	$9,267	$12,210	$154	61%	1%	39%	17.6	29.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 16: AEO 2010 Low Economic Growth Results – North Composite

Simulation Results NORTH Replacement											AEO 2010 Low Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$10,852	$12,565						
1	90% AFUE - Condensing Design		$2,483	$9,780	$12,263	$73	13%	72%	15%	13.4	16.3
2	92% AFUE - Increased HX Area		$2,543	$9,589	$12,132	$128	14%	57%	29%	9.3	12.1
3	95% AFUE - Increased HX Area		$2,687	$9,317	$12,004	$227	27%	23%	51%	10.0	12.2
4	98% AFUE - Max Tech		$2,925	$9,192	$12,117	$115	62%	1%	37%	17.3	27.6
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 17: AEO 2010 Low Economic Growth Results – North Retrofit

Simulation Results NORTH New Construction											AEO 2010 Low Growth
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$11,181	$13,633						
1	90% AFUE - Condensing Design		$2,447	$10,079	$12,526	$323	2%	70%	27%	2.6	4.4
2	92% AFUE - Increased HX Area		$2,516	$9,884	$12,400	$378	4%	55%	41%	5.2	5.6
3	95% AFUE - Increased HX Area		$2,680	$9,606	$12,286	$464	17%	23%	60%	9.0	10.0
4	98% AFUE - Max Tech		$2,996	$9,485	$12,481	$269	56%	1%	43%	18.4	34.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 18: AEO 2010 Low Economic Growth Results – North New Construction

4.1.4 AEO 2011 Reference Case Energy Price Projections

Simulation Results NORTH Composite											AEO 2011 Forecast
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$9,413	$11,314						
1	90% AFUE - Condensing Design		$2,474	$8,500	$10,974	$90	12%	71%	16%	13.8	17.6
2	92% AFUE - Increased HX Area		$2,536	$8,336	$10,873	$133	15%	56%	29%	10.2	13.7
3	95% AFUE - Increased HX Area		$2,685	$8,104	$10,789	$197	32%	23%	45%	12.8	15.2
4	98% AFUE - Max Tech		$2,943	$8,033	$10,976	$11	71%	1%	29%	23.4	37.8
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 19: AEO 2011 Reference Case Results – North Composite

Simulation Results NORTH Replacement											AEO 2011 Forecast
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$9,324	$11,037						
1	90% AFUE - Condensing Design		$2,483	$8,420	$10,903	$27	16%	72%	13%	17.6	21.9
2	92% AFUE - Increased HX Area		$2,543	$8,257	$10,800	$70	18%	57%	25%	12.2	15.9
3	95% AFUE - Increased HX Area		$2,687	$8,027	$10,713	$137	34%	23%	43%	13.3	16.0
4	98% AFUE - Max Tech		$2,925	$7,955	$10,880	-$29	73%	1%	27%	23.2	36.9
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 20: AEO 2011 Reference Case Results – North Retrofit

Simulation Results NORTH New Construction											AEO 2011 Forecast
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$9,674	$12,126						
1	90% AFUE - Condensing Design		$2,447	$8,736	$11,183	$276	3%	70%	27%	3.2	5.9
2	92% AFUE - Increased HX Area		$2,516	$8,569	$11,085	$319	6%	55%	39%	6.8	7.5
3	95% AFUE - Increased HX Area		$2,680	$8,331	$11,011	$373	24%	23%	53%	11.7	13.1
4	98% AFUE - Max Tech		$2,996	$8,262	$11,258	$127	65%	1%	34%	24.0	40.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 21: AEO 2011 Reference Case Results – North New Construction

4.1.5 AEO 2011 High Shale Gas Energy Price Projections

Simulation Results NORTH Composite											AEO 2011 High Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$8,653	$10,554						
1	90% AFUE - Condensing Design		$2,474	$7,821	$10,295	$66	14%	71%	15%	15.4	19.8
2	92% AFUE - Increased HX Area		$2,536	$7,671	$10,208	$103	17%	56%	27%	11.7	15.2
3	95% AFUE - Increased HX Area		$2,685	$7,459	$10,144	$151	36%	23%	41%	14.4	16.9
4	98% AFUE - Max Tech		$2,943	$7,406	$10,349	-$52	75%	1%	25%	26.4	42.9
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 22: AEO 2011 High Shale Gas Results – North Composite

Simulation Results NORTH Replacement											AEO 2011 High Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$8,567	$10,280						
1	90% AFUE - Condensing Design		$2,483	$7,743	$10,226	$3	17%	72%	11%	19.5	24.5
2	92% AFUE - Increased HX Area		$2,543	$7,595	$10,138	$40	20%	57%	23%	13.6	17.7
3	95% AFUE - Increased HX Area		$2,687	$7,384	$10,071	$92	39%	23%	39%	14.6	17.7
4	98% AFUE - Max Tech		$2,925	$7,330	$10,255	-$91	77%	1%	23%	26.2	41.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 23: AEO 2011 High Shale Gas Results – North Retrofit

Simulation Results NORTH New Construction											AEO 2011 High Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$8,905	$11,357						
1	90% AFUE - Condensing Design		$2,447	$8,049	$10,496	$251	4%	70%	25%	3.5	6.6
2	92% AFUE - Increased HX Area		$2,516	$7,896	$10,412	$287	8%	55%	37%	7.5	8.3
3	95% AFUE - Increased HX Area		$2,680	$7,679	$10,359	$326	28%	23%	49%	13.1	14.6
4	98% AFUE - Max Tech		$2,996	$7,628	$10,624	$62	68%	1%	31%	26.6	47.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 24: AEO 2011 High Shale Gas Results – North New Construction

4.1.6 AEO 2011 Low Shale Gas Energy Price Projections

Simulation Results NORTH Composite											AEO 2011 Low Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$9,957	$11,858						
1	90% AFUE - Condensing Design		$2,474	$8,987	$11,460	$107	12%	71%	17%	12.9	16.3
2	92% AFUE - Increased HX Area		$2,536	$8,813	$11,349	$154	14%	56%	30%	9.6	12.7
3	95% AFUE - Increased HX Area		$2,685	$8,566	$11,251	$229	29%	23%	48%	12.0	14.2
4	98% AFUE - Max Tech		$2,943	$8,482	$11,425	$56	67%	1%	32%	21.6	36.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 25: AEO 2011 Low Shale Gas Results – North Composite

Simulation Results NORTH Replacement											AEO 2011 Low Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$9,868	$11,581						
1	90% AFUE - Condensing Design		$2,483	$8,905	$11,388	$43	15%	72%	13%	16.4	20.3
2	92% AFUE - Increased HX Area		$2,543	$8,733	$11,276	$91	17%	57%	26%	11.5	14.7
3	95% AFUE - Increased HX Area		$2,687	$8,488	$11,174	$169	32%	23%	46%	12.2	14.9
4	98% AFUE - Max Tech		$2,925	$8,404	$11,328	$16	69%	1%	31%	21.6	35.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 26: AEO 2011 Low Shale Gas Results – North Retrofit

Simulation Results NORTH New Construction											AEO 2011 Low Shale Gas
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Cour	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$10,221	$12,673						
1	90% AFUE - Condensing Design		$2,447	$9,225	$11,672	$293	3%	70%	27%	3.0	5.4
2	92% AFUE - Increased HX Area		$2,516	$9,047	$11,563	$341	5%	55%	40%	6.3	6.9
3	95% AFUE - Increased HX Area		$2,680	$8,795	$11,475	$407	21%	23%	55%	10.9	12.2
4	98% AFUE - Max Tech		$2,996	$8,713	$11,709	$173	62%	1%	37%	22.1	39.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 27: AEO 2011 Low Shale Gas Results – North New Construction

4.2 Marginal Energy Price Scenarios

The TSD analysis used average prices for natural gas, fuel oil, and LPG calculations, though not necessarily for all electricity calculations. Average impact analysis may be acceptable for inventory purposes, but it is inadequate and misleading for efficiency improvement impact calculations. The shift from an 80% AFUE furnace to a 90% AFUE furnace is a marginal change, and as such requires use of a marginal impact analysis, not an average impact analysis. This is especially true for regional standards, because the marginal impact is relevant both for energy prices and for weather-related loads.

In addition to the alternate average energy price projection scenarios, GTI analysts conducted a parametric analysis using marginal energy prices. Natural gas prices consist of variable and fixed costs, with fixed costs primarily comprising a customer charge (also sometimes referred to as a facilities charge). This monthly fixed charge is paid by every customer regardless of the volume of gas used. It accounts for the cost of such services as meter reading, billing, and customer support. By removing the fixed costs from the energy price it is possible to assess the marginal impact of the proposed increase in efficiency. The marginal price analysis captures the change in the overall lifecycle cost at the margin as the amount of gas used by the furnace decreases.

Fixed costs vary by utility and region, which makes it difficult to develop a thorough methodology using the average prices contained in the TSD and EIA databases. GTI analysts developed two simplified scenarios to estimate marginal gas price impacts based on available EIA databases:

1. Citygate natural gas prices (available using EIA databases), providing the lower bound of marginal gas prices
2. An algorithm that removes a fixed value of 13% of the January average costs from average price projections throughout the year as the estimate of the fixed customer charge, providing the upper bound of marginal gas prices

To show how a marginal approach would work in concert with other price projection scenarios, both of these approaches were analyzed under six of the AEO 2011 scenarios: the reference case, high shale gas use, low shale gas use, high economic growth, and low economic growth.

4.3 Citygate Natural Gas Price Analysis

The citygate is the point or measuring station along the gas transmission system where a local distribution company (LDC) takes ownership of gas from a pipeline company. As such, the price of gas at this point in the supply chain does not include the fixed costs paid by the end customer. The citygate price does not show the same seasonality as the average price paid by residential customers (Figure 28). In addition to the fixed customer charge, the citygate price does not include local and state taxes, utility mark-ups, or programmatic costs (such as fees for energy efficiency programs, etc.). Although the true marginal cost of gas would include additional variable factors such as taxes, the citygate price provides a good estimate of the lower boundary of marginal gas prices.

Citygate monthly price data was gathered from EIA for each state from 1990 to 2010. The same methodology used by DOE in the TSD was used to develop both average annual prices and monthly energy factors for the nine census divisions and four large states (New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific, New York, Florida, Texas, and California). These values were used as inputs to the spreadsheet tool and run using Crystal Ball to determine lifecycle cost and payback period results. Electricity prices were held constant because there was no “citygate” equivalent for electricity pricing.

The results of the citygate price analysis are presented in Table 6 and Figure 29 through Figure 44 below for comparison with the DFR estimates from Figure 10 through Figure 12. For ease of comparison, both a summary table and a graph of results for the retrofit scenarios are shown.

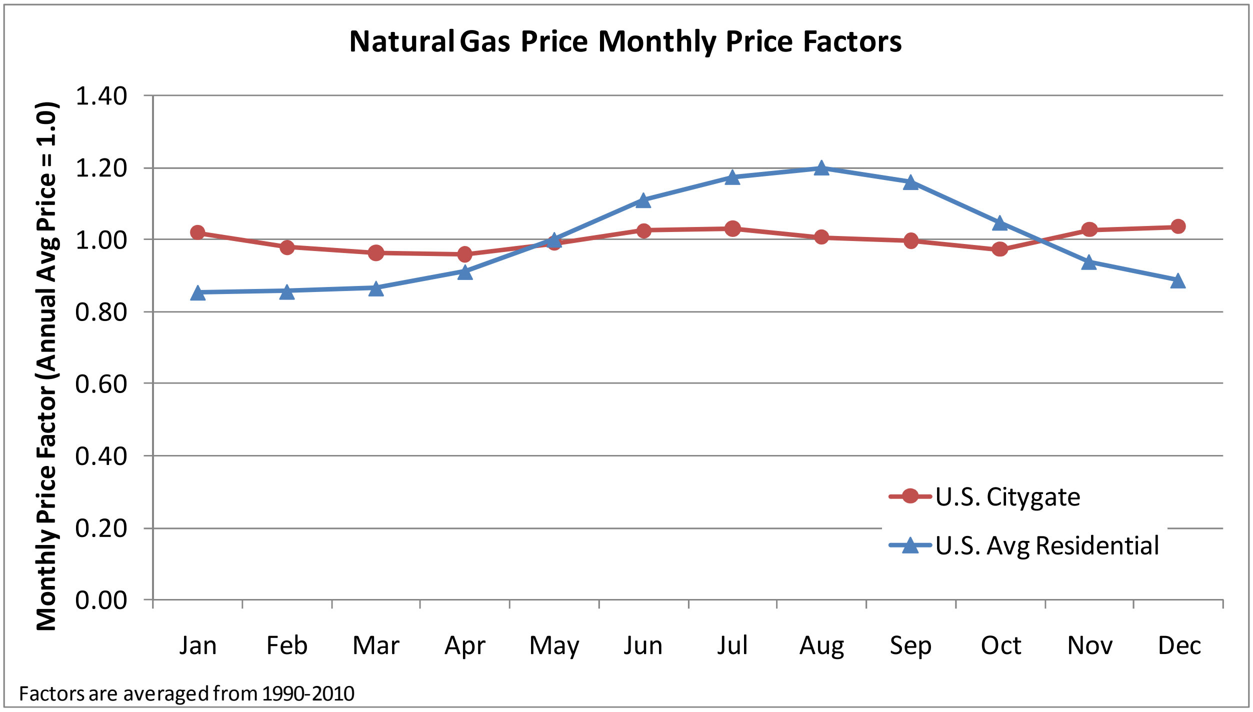


Figure 28: Citygate and Average Monthly Residential Natural Gas Price Factors

Table 6: 90% AFUE Furnace Summary Results – AEO 2011 Citygate Natural Gas Prices

	North Composite		North Retrofit		North New Construction	
	LCC Savings	**Payback Period Median/Avg**	**LCC Savings**	**Payback Period Median/Avg**	**LCC Savings**	**Payback Period Median/Avg**
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2011 Reference Case	$18	20.9 / 27.9	-$43	26.3 / 34.6	$198	5.0 / 9.2
AEO 2011 High Economic Growth	$25	20.2 / 27.2	-$36	25.6 / 33.7	$206	4.9 / 9.0
AEO 2011 Low Economic Growth	$11	20.8 / 28.1	-$53	26.9 / 35.4	$194	5.6 / 9.6
AEO 2011 High Shale Gas Use	-$1	23.7 / 31.4	-$60	28.9 / 38.4	$182	4.6 / 9.8
AEO 2011 Low Shale Gas Use	$27	19.4 / 25.8	-$34	24.5 / 32.1	$208	4.7 / 8.3

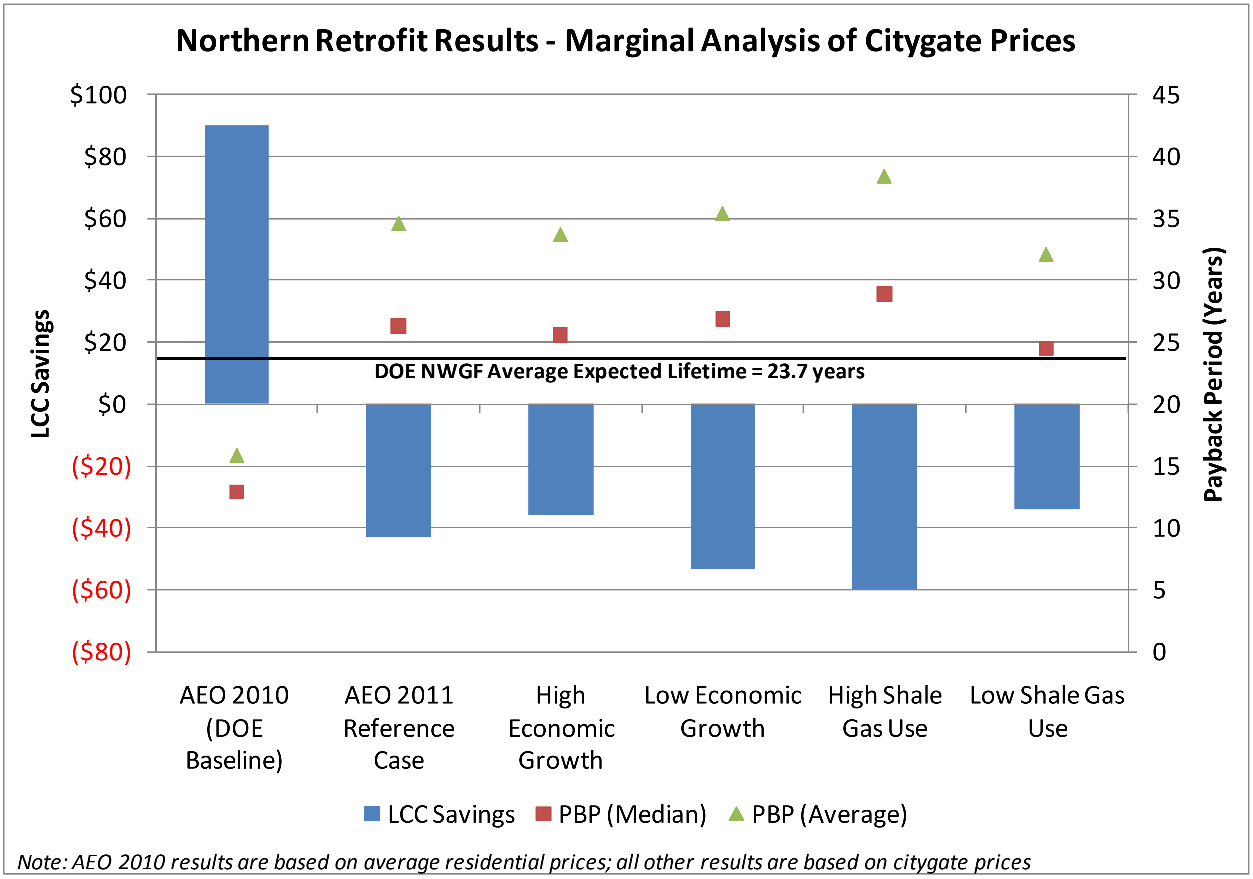


Figure 29: AEO 2011 Citygate Natural Gas Prices LCC and PBP Results – North Region Retrofit

4.3.1 AEO 2011 Reference Case Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast -Citygate Gas Prices								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$7,194	$9,094						
1	90% AFUE - Condensing Design		$2,474	$6,525	$8,998	$18	17%	71%	12%	20.9	27.9
2	92% AFUE - Increased HX Area		$2,536	$6,403	$8,939	$42	22%	56%	22%	15.4	20.8
3	95% AFUE - Increased HX Area		$2,685	$6,230	$8,915	$60	45%	23%	32%	18.9	22.3
4	98% AFUE - Max Tech		$2,943	$6,247	$9,190	-$213	82%	1%	17%	36.4	64.8
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 30: AEO 2011 Citygate Gas Prices Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Citygate Gas Prices								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$7,118	$8,831						
1	90% AFUE - Condensing Design		$2,483	$6,456	$8,939	-$43	20%	72%	8%	26.3	34.6
2	92% AFUE - Increased HX Area		$2,543	$6,336	$8,879	-$18	25%	57%	18%	18.1	24.2
3	95% AFUE - Increased HX Area		$2,687	$6,164	$8,851	$3	48%	23%	29%	19.1	23.4
4	98% AFUE - Max Tech		$2,925	$6,179	$9,104	-$249	85%	1%	15%	36.6	64.9
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 31: AEO 2011 Citygate Gas Prices Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Citygate Gas Prices								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$7,415	$9,867						
1	90% AFUE - Condensing Design		$2,447	$6,725	$9,172	$198	7%	70%	23%	5.0	9.2
2	92% AFUE - Increased HX Area		$2,516	$6,600	$9,116	$221	12%	55%	33%	10.3	11.2
3	95% AFUE - Increased HX Area		$2,680	$6,423	$9,103	$228	36%	23%	40%	17.4	19.2
4	98% AFUE - Max Tech		$2,996	$6,446	$9,441	-$108	76%	1%	24%	35.7	64.6
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 32: AEO 2011 Citygate Gas Prices Results – North New Construction

4.3.2 AEO 2011 High Shale Gas Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast -Citygate Gas Prices - High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,894	$6,869	$8,762						
1	90% AFUE - Condensing Design		$2,484	$6,237	$8,721	-$1	18%	72%	11%	23.7	31.4
2	92% AFUE - Increased HX Area		$2,546	$6,122	$8,668	$20	23%	57%	20%	16.9	24.3
3	95% AFUE - Increased HX Area		$2,695	$5,958	$8,652	$33	49%	23%	28%	20.9	24.5
4	98% AFUE - Max Tech		$2,952	$5,998	$8,950	-$263	84%	1%	15%	38.4	71.8
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 33: AEO 2011 High Shale Gas Citygate Gas Prices Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Citygate Gas Prices - High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$6,853	$8,566						
1	90% AFUE - Condensing Design		$2,492	$6,224	$8,716	-$60	21%	72%	7%	28.9	38.4
2	92% AFUE - Increased HX Area		$2,552	$6,108	$8,660	-$38	27%	57%	16%	19.8	28.3
3	95% AFUE - Increased HX Area		$2,696	$5,944	$8,640	-$20	52%	23%	25%	21.3	25.6
4	98% AFUE - Max Tech		$2,935	$5,980	$8,915	-$293	86%	1%	13%	38.4	71.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 34: AEO 2011 High Shale Gas Citygate Gas Prices Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Citygate Gas Prices - High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$6,915	$9,367						
1	90% AFUE - Condensing Design		$2,457	$6,280	$8,737	$182	7%	71%	22%	4.6	9.8
2	92% AFUE - Increased HX Area		$2,526	$6,165	$8,691	$200	13%	57%	31%	10.6	12.1
3	95% AFUE - Increased HX Area		$2,690	$6,001	$8,691	$198	39%	25%	36%	19.2	20.8
4	98% AFUE - Max Tech		$3,005	$6,056	$9,061	-$169	78%	1%	21%	38.1	74.1
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 35: AEO 2011 High Shale Gas Citygate Gas Prices Results – North New Construction

4.3.3 AEO 2011 Low Shale Gas Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast -Citygate Gas Prices - Low Shale Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$7,476	$9,376						
1	90% AFUE - Condensing Design		$2,474	$6,773	$9,247	$27	16%	71%	12%	19.4	25.8
2	92% AFUE - Increased HX Area		$2,536	$6,646	$9,182	$54	21%	56%	23%	14.8	19.2
3	95% AFUE - Increased HX Area		$2,685	$6,466	$9,150	$78	43%	23%	34%	17.7	20.9
4	98% AFUE - Max Tech		$2,943	$6,460	$9,403	-$173	81%	1%	19%	33.6	56.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 36: AEO 2011 Low Shale Gas Citygate Gas Prices Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Citygate Gas Prices - Low Shale Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$7,401	$9,114						
1	90% AFUE - Condensing Design		$2,483	$6,706	$9,189	-$34	20%	72%	9%	24.5	32.1
2	92% AFUE - Increased HX Area		$2,543	$6,580	$9,123	-$7	24%	57%	19%	16.7	22.4
3	95% AFUE - Increased HX Area		$2,687	$6,400	$9,087	$20	46%	23%	31%	18.2	21.9
4	98% AFUE - Max Tech		$2,925	$6,393	$9,318	-$209	83%	1%	16%	33.6	55.7
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 37: AEO 2011 Low Shale Gas Citygate Gas Prices Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Citygate Gas Prices - Low Shale Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$7,694	$10,147						
1	90% AFUE - Condensing Design		$2,447	$6,971	$9,418	$208	6%	70%	24%	4.7	8.3
2	92% AFUE - Increased HX Area		$2,516	$6,841	$9,357	$233	11%	55%	34%	9.2	10.3
3	95% AFUE - Increased HX Area		$2,680	$6,657	$9,336	$246	34%	23%	43%	16.2	18.0
4	98% AFUE - Max Tech		$2,996	$6,656	$9,652	-$67	74%	1%	25%	33.4	57.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 38: AEO 2011 Low Shale Gas Citygate Gas Prices Results – North New Construction

4.3.4 AEO 2011 High Economic Growth Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast -Citygate Gas Prices High Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$7,457	$9,358						
1	90% AFUE - Condensing Design		$2,474	$6,762	$9,235	$25	16%	71%	12%	20.2	27.2
2	92% AFUE - Increased HX Area		$2,536	$6,635	$9,171	$52	21%	56%	22%	15.0	20.2
3	95% AFUE - Increased HX Area		$2,685	$6,455	$9,140	$75	44%	23%	33%	18.6	21.8
4	98% AFUE - Max Tech		$2,943	$6,475	$9,418	-$202	82%	1%	18%	35.4	63.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 39: AEO 2011 High Growth Citygate Gas Prices Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Citygate Gas Prices High Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$7,379	$9,092						
1	90% AFUE - Condensing Design		$2,483	$6,691	$9,174	-$36	20%	72%	8%	25.6	33.7
2	92% AFUE - Increased HX Area		$2,543	$6,566	$9,109	-$9	24%	57%	19%	17.6	23.5
3	95% AFUE - Increased HX Area		$2,687	$6,387	$9,074	$17	47%	23%	30%	18.9	22.8
4	98% AFUE - Max Tech		$2,925	$6,405	$9,330	-$237	84%	1%	15%	35.5	63.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 40: AEO 2011 High Growth Citygate Gas Prices Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Citygate Gas Prices High Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$7,686	$10,138						
1	90% AFUE - Condensing Design		$2,447	$6,968	$9,415	$206	6%	70%	24%	4.9	9.0
2	92% AFUE - Increased HX Area		$2,516	$6,839	$9,354	$231	12%	55%	33%	9.8	10.9
3	95% AFUE - Increased HX Area		$2,680	$6,655	$9,334	$244	35%	23%	42%	16.9	18.7
4	98% AFUE - Max Tech		$2,996	$6,680	$9,676	-$96	75%	1%	24%	34.7	64.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 41: AEO 2011 High Growth Citygate Gas Prices Results – North New Construction

4.3.5 AEO 2011 Low Economic Growth Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast -Citygate Gas Prices Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,907	$6,939	$8,846						
1	90% AFUE - Condensing Design		$2,474	$6,295	$8,769	$11	17%	72%	11%	20.8	28.1
2	92% AFUE - Increased HX Area		$2,536	$6,178	$8,715	$33	23%	56%	21%	15.4	20.8
3	95% AFUE - Increased HX Area		$2,685	$6,013	$8,698	$45	47%	23%	30%	19.2	22.5
4	98% AFUE - Max Tech		$2,943	$6,028	$8,971	-$227	83%	1%	16%	37.1	65.9
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 42: AEO 2011 Low Growth Citygate Gas Prices Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Citygate Gas Prices Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,717	$6,814	$8,531						
1	90% AFUE - Condensing Design		$2,482	$6,183	$8,665	-$53	20%	72%	7%	26.9	35.4
2	92% AFUE - Increased HX Area		$2,542	$6,068	$8,610	-$31	26%	57%	17%	18.4	24.3
3	95% AFUE - Increased HX Area		$2,686	$5,905	$8,590	-$16	50%	23%	27%	19.7	23.7
4	98% AFUE - Max Tech		$2,924	$5,919	$8,843	-$267	86%	1%	14%	38.0	66.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 43: AEO 2011 Low Growth Citygate Gas Prices Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Citygate Gas Prices Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,450	$7,295	$9,746						
1	90% AFUE - Condensing Design		$2,450	$6,617	$9,067	$194	7%	69%	23%	5.6	9.6
2	92% AFUE - Increased HX Area		$2,519	$6,494	$9,013	$215	14%	54%	32%	10.3	11.7
3	95% AFUE - Increased HX Area		$2,683	$6,321	$9,004	$217	38%	23%	39%	17.7	19.3
4	98% AFUE - Max Tech		$2,999	$6,338	$9,337	-$115	75%	1%	24%	34.3	65.6
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 44: AEO 2011 Low Growth Citygate Gas Prices Results – North New Construction

4.4 Mid-Winter 13% Fixed Cost Marginal Gas Prices

A second approach for assessing the marginal impact of the proposed efficiency increase provided an estimate of the upper boundary of marginal gas price. For the second approach, the fixed cost component of the gas price associated with a typical meter charge was removed from the total average price using a simple algorithm. Based on the residential tariff and actual consumption data from the local Chicago gas company, it was estimated that in January fixed costs would represent approximately 13 percent of the total gas price. In reality, the fixed cost fraction of the average price would increase in the summer when gas usage is significantly lower; however, the 13 percent estimate provides a conservative approach and represents a reasonable upper boundary of the marginal price over the course of the year. A monetary value was calculated for each of the nine census divisions and four states that accounted for 13 percent of the cost of gas in the month of January. This amount was considered to be roughly representative of the fixed cost component of the total price. This fixed amount was then subtracted from the gas prices for each of the remaining months for each of the thirteen geographic regions. These revised energy prices were then used to develop marginal price factors to be inserted in the spreadsheet and used by Crystal Ball to generate results.

The results of the mid-winter 13% fixed cost analysis are presented in Table 7 and Figure 45 through Figure 61 below for comparison with the DFR estimates from Figure 10 through Figure 12. For ease of comparison, both a summary table and a graph of results for the retrofit scenarios are shown.

Table 7: 90% AFUE Furnace Summary Results – 13% Fixed Cost Natural Gas Prices

	North Composite		North Retrofit		North New Construction	
	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2011 Reference Case	$65	15.7 / 19.9	$2	19.8 / 24.7	$250	3.6 / 6.6
AEO 2011 High Economic Growth	$77	15.3 / 18.9	$16	19.1 / 23.5	$253	4.0 / 6.8
AEO 2011 Low Economic Growth	$56	15.9 / 20.1	-$5	20.2 / 25.0	$233	3.6 / 6.8
AEO 2011 High Shale Gas Use	$46	17.3 / 22.1	-$17	21.9 / 27.4	$229	3.9 / 7.4
AEO 2011 Low Shale Gas Use	$77	14.6 / 18.4	$14	18.3 / 22.9	$263	3.6 / 6.2

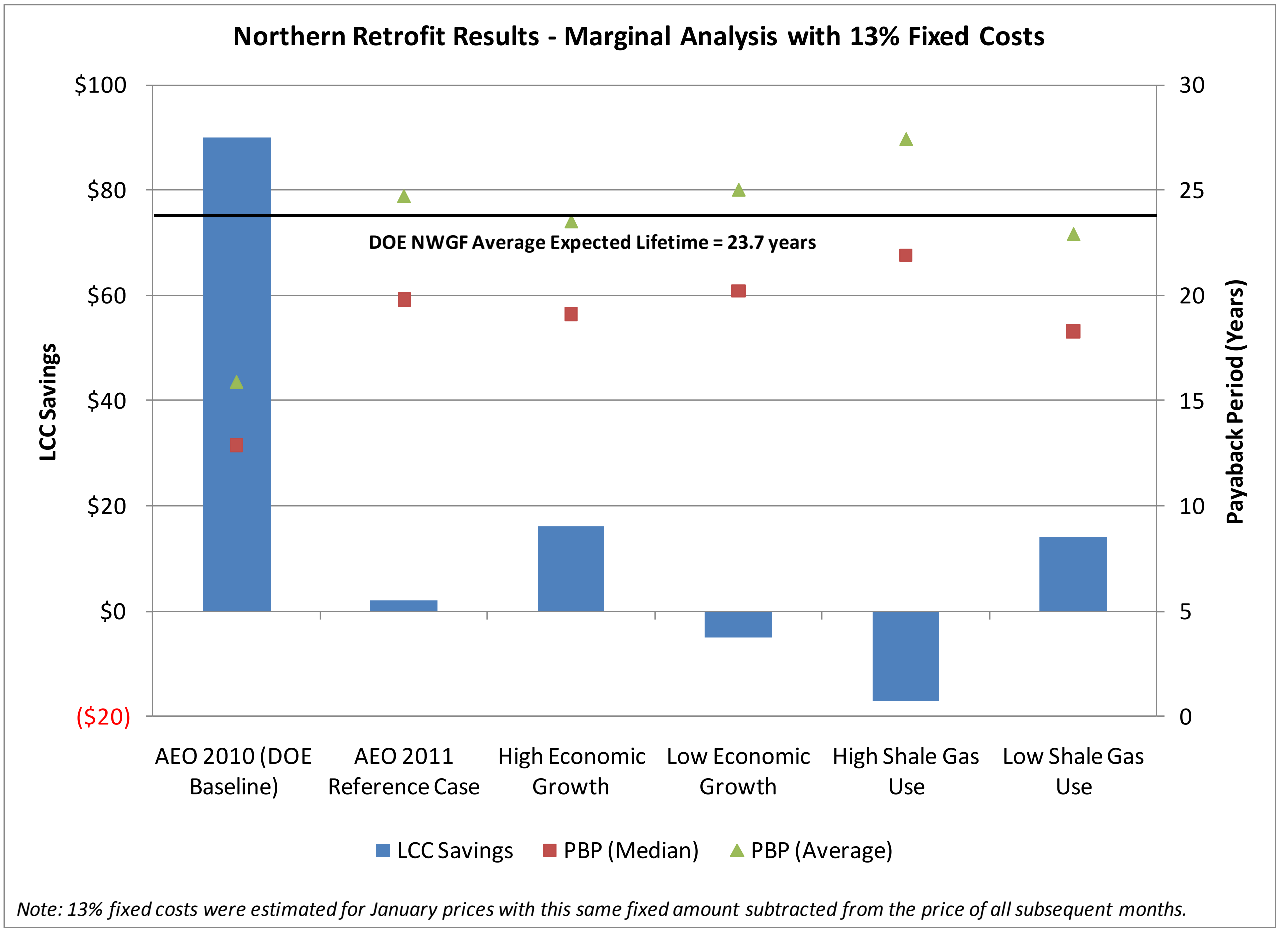


Figure 45: AEO 2011 13% Fixed Costs LCC and PBP Results – North Region Retrofit

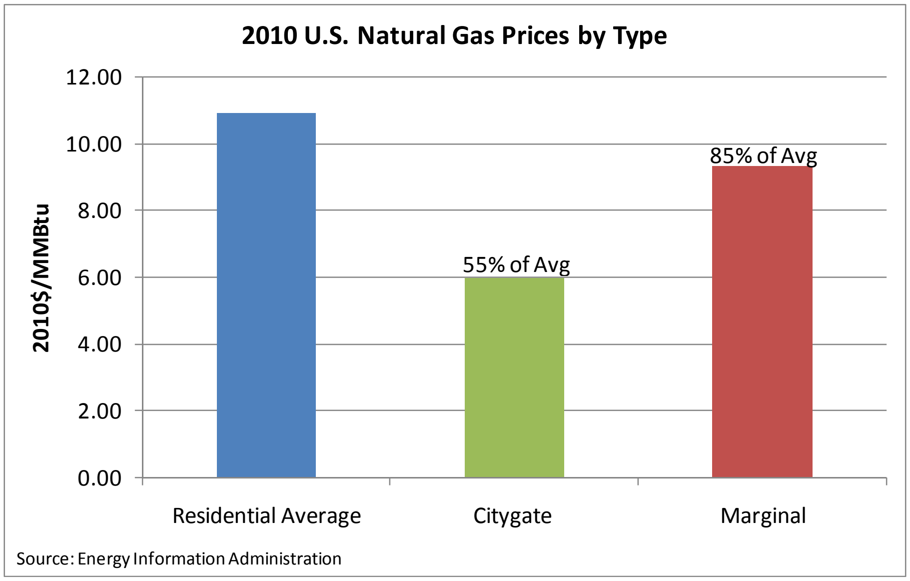


Figure 46: Comparison of Average, Citygate, and 13% Fixed Cost Prices

4.4.1 AEO 2011 Reference Case 13% Fixed Cost Marginal Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast - Gas 13% Fixed Cost Component Reference Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$8,649	$10,550						
1	90% AFUE - Condensing Design		$2,474	$7,821	$10,295	$65	14%	71%	15%	15.7	19.9
2	92% AFUE - Increased HX Area		$2,536	$7,672	$10,208	$102	17%	56%	27%	11.9	15.5
3	95% AFUE - Increased HX Area		$2,685	$7,460	$10,145	$150	36%	23%	41%	14.6	17.2
4	98% AFUE - Max Tech		$2,943	$7,428	$10,370	-$74	75%	1%	24%	26.8	43.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 47: AEO 2011 Reference Case 13% Fixed Costs Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast - Gas 13% Fixed Cost Component Reference Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$8,562	$10,275						
1	90% AFUE - Condensing Design		$2,483	$7,743	$10,226	$2	17%	72%	11%	19.8	24.7
2	92% AFUE - Increased HX Area		$2,543	$7,595	$10,138	$40	20%	57%	23%	13.9	18.1
3	95% AFUE - Increased HX Area		$2,687	$7,385	$10,071	$91	39%	23%	39%	14.9	18.0
4	98% AFUE - Max Tech		$2,925	$7,351	$10,275	-$112	77%	1%	22%	26.8	42.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 48: AEO 2011 Reference Case 13% Fixed Costs Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast - Gas 13% Fixed Cost Component Reference Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$8,904	$11,356						
1	90% AFUE - Condensing Design		$2,447	$8,052	$10,499	$250	4%	70%	25%	3.6	6.6
2	92% AFUE - Increased HX Area		$2,516	$7,899	$10,415	$286	8%	55%	37%	7.7	8.4
3	95% AFUE - Increased HX Area		$2,680	$7,682	$10,362	$324	27%	23%	49%	13.1	14.8
4	98% AFUE - Max Tech		$2,996	$7,653	$10,649	$38	69%	1%	30%	27.4	47.7
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 49: AEO 2011 Reference Case 13% Fixed Costs Results – North New Construction

4.4.2 AEO 2011 High Shale Gas 13% Fixed Cost Marginal Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast - 13% Gas Fixed Cost High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$8,054	$9,955						
1	90% AFUE - Condensing Design		$2,474	$7,294	$9,768	$46	15%	71%	14%	17.3	22.1
2	92% AFUE - Increased HX Area		$2,536	$7,156	$9,692	$77	19%	56%	25%	12.7	17.2
3	95% AFUE - Increased HX Area		$2,685	$6,960	$9,645	$113	40%	23%	38%	16.1	18.9
4	98% AFUE - Max Tech		$2,943	$6,960	$9,903	-$143	79%	1%	20%	30.5	51.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 50: AEO 2011 High Shale Gas 13% Fixed Cost Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast - 13% Gas Fixed Cost High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$7,969	$9,682						
1	90% AFUE - Condensing Design		$2,483	$7,217	$9,700	-$17	18%	72%	10%	21.9	27.4
2	92% AFUE - Increased HX Area		$2,543	$7,080	$9,623	$15	22%	57%	21%	15.3	20.0
3	95% AFUE - Increased HX Area		$2,687	$6,886	$9,573	$54	43%	23%	35%	16.5	19.8
4	98% AFUE - Max Tech		$2,925	$6,884	$9,809	-$180	81%	1%	18%	30.5	50.6
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 51: AEO 2011 High Shale Gas 13% Fixed Cost Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast - 13% Gas Fixed Cost High Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$8,305	$10,758						
1	90% AFUE - Condensing Design		$2,447	$7,520	$9,967	$229	5%	70%	25%	3.9	7.4
2	92% AFUE - Increased HX Area		$2,516	$7,379	$9,895	$260	10%	55%	35%	8.5	9.3
3	95% AFUE - Increased HX Area		$2,680	$7,179	$9,858	$286	31%	23%	46%	14.7	16.4
4	98% AFUE - Max Tech		$2,996	$7,183	$10,179	-$33	72%	1%	27%	30.5	53.7
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 52: AEO 2011 High Shale Gas 13% Fixed Cost Results – North New Construction

4.4.3 AEO 2011 Low Shale Gas 13% Fixed Cost Marginal Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast - 13% Gas Fixed Cost Low Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$9,059	$10,960						
1	90% AFUE - Condensing Design		$2,474	$8,184	$10,658	$77	13%	71%	16%	14.6	18.4
2	92% AFUE - Increased HX Area		$2,536	$8,027	$10,563	$118	16%	56%	28%	10.8	14.4
3	95% AFUE - Increased HX Area		$2,685	$7,804	$10,489	$174	33%	23%	44%	13.5	16.0
4	98% AFUE - Max Tech		$2,943	$7,744	$10,687	-$23	72%	1%	27%	24.5	39.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 53: AEO 2011 Low Shale Gas 13% Fixed Cost Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast - 13% Gas Fixed Cost Low Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$9,000	$10,713						
1	90% AFUE - Condensing Design		$2,484	$8,130	$10,614	$14	16%	71%	12%	18.3	22.9
2	92% AFUE - Increased HX Area		$2,544	$7,974	$10,518	$54	19%	57%	24%	12.9	16.7
3	95% AFUE - Increased HX Area		$2,687	$7,752	$10,439	$114	36%	23%	41%	13.7	16.8
4	98% AFUE - Max Tech		$2,925	$7,690	$10,615	-$61	74%	1%	25%	24.4	37.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 54: AEO 2011 Low Shale Gas 13% Fixed Cost Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast - 13% Gas Fixed Cost Low Shale Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,450	$9,232	$11,683						
1	90% AFUE - Condensing Design		$2,445	$8,343	$10,788	$263	4%	70%	26%	3.6	6.2
2	92% AFUE - Increased HX Area		$2,514	$8,184	$10,698	$303	7%	55%	39%	7.2	7.9
3	95% AFUE - Increased HX Area		$2,678	$7,958	$10,636	$349	25%	23%	52%	12.4	13.8
4	98% AFUE - Max Tech		$2,995	$7,902	$10,897	$89	66%	1%	33%	25.3	43.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 55: AEO 2011 Low Shale Gas 13% Fixed Cost Results – North New Construction

4.4.4 AEO 2011 High Economic Growth13% Fixed Cost Marginal Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast - Gas 13% Fixed Cost Component High Growth Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,904	$8,955	$10,858						
1	90% AFUE - Condensing Design		$2,474	$8,095	$10,569	$77	13%	71%	15%	15.3	18.9
2	92% AFUE - Increased HX Area		$2,536	$7,940	$10,476	$116	16%	56%	28%	11.4	14.7
3	95% AFUE - Increased HX Area		$2,685	$7,720	$10,405	$171	34%	23%	43%	14.1	16.7
4	98% AFUE - Max Tech		$2,943	$7,688	$10,631	-$54	74%	1%	25%	26.2	41.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 56: AEO 2011 High Growth 13% Fixed Costs Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast - Gas 13% Fixed Cost Component High Growth Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,718	$8,913	$10,631						
1	90% AFUE - Condensing Design		$2,485	$8,057	$10,542	$16	16%	72%	12%	19.1	23.5
2	92% AFUE - Increased HX Area		$2,545	$7,903	$10,448	$56	19%	57%	24%	13.3	17.1
3	95% AFUE - Increased HX Area		$2,688	$7,683	$10,372	$115	37%	23%	40%	14.5	17.5
4	98% AFUE - Max Tech		$2,926	$7,649	$10,575	-$87	77%	0%	23%	26.1	40.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 57: AEO 2011 High Growth 13% Fixed Costs Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast - Gas 13% Fixed Cost Component High Growth Scenario								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,443	$9,076	$11,519						
1	90% AFUE - Condensing Design		$2,441	$8,205	$10,647	$253	4%	69%	26%	4.0	6.8
2	92% AFUE - Increased HX Area		$2,510	$8,049	$10,559	$290	7%	54%	39%	7.9	8.5
3	95% AFUE - Increased HX Area		$2,673	$7,828	$10,502	$333	27%	23%	50%	13.1	14.3
4	98% AFUE - Max Tech		$2,992	$7,801	$10,792	$44	67%	1%	31%	26.6	44.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 58: AEO 2011 High Growth 13% Fixed Costs Results – North New Construction

4.4.5 AEO 2011 Low Economic Growth13% Fixed Cost Marginal Gas Prices

Simulation Results NORTH Composite			AEO 2011 Forecast - 13% Gas Fixed Cost Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,903	$8,291	$10,195						
1	90% AFUE - Condensing Design		$2,473	$7,500	$9,972	$56	14%	72%	14%	15.9	20.1
2	92% AFUE - Increased HX Area		$2,535	$7,357	$9,892	$90	17%	57%	26%	11.9	15.7
3	95% AFUE - Increased HX Area		$2,684	$7,155	$9,838	$130	37%	23%	40%	14.8	17.3
4	98% AFUE - Max Tech		$2,941	$7,121	$10,063	-$93	77%	1%	23%	27.4	43.9
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 59: AEO 2011 Low Growth 13% Fixed Costs Results – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast - 13% Gas Fixed Cost Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$8,236	$9,950						
1	90% AFUE - Condensing Design		$2,481	$7,450	$9,931	-$5	17%	72%	11%	20.2	25.0
2	92% AFUE - Increased HX Area		$2,541	$7,308	$9,849	$29	20%	57%	22%	14.4	18.3
3	95% AFUE - Increased HX Area		$2,685	$7,106	$9,791	$74	40%	23%	37%	15.1	18.1
4	98% AFUE - Max Tech		$2,922	$7,071	$9,993	-$128	79%	1%	21%	27.4	42.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 60: AEO 2011 Low Growth 13% Fixed Costs Results – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast - 13% Gas Fixed Cost Low Growth Scenario								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,454	$8,450	$10,904						
1	90% AFUE - Condensing Design		$2,448	$7,645	$10,093	$233	5%	70%	25%	3.6	6.8
2	92% AFUE - Increased HX Area		$2,517	$7,501	$10,018	$265	8%	55%	37%	7.8	8.5
3	95% AFUE - Increased HX Area		$2,681	$7,296	$9,977	$294	29%	23%	48%	13.5	15.1
4	98% AFUE - Max Tech		$2,996	$7,267	$10,264	$9	70%	1%	29%	27.5	48.1
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 61: AEO 2011 Low Growth 13% Fixed Costs Results – North New Construction

5.0 Equipment Cost and Expected Life Analysis

5.1 Equipment Price Trends

The TSD includes data on equipment pricing and trends over time. A key assumption for the LCC analysis is that as the cumulative number of furnace shipments rises, the relative price will fall (Figure 62). This is also referred to as the learning rate or experience curve and attempts to estimate the rate at which commodity prices will fall as the manufacturing industry expands production of a specific product. The experience curve varies significantly across products and industries. For instance, the DFR uses different curves for furnaces than for air conditioners.

The development of the curve is based on data such as historical prices and production rates. Once these data are collected a learning rate can be calculated. The learning rate represents the percentage reduction in cost in a product price with each doubling of the cumulative production. Since the learning rate is calculated by using historical cost and shipment data over a given timeframe, any change in the timeframe can result in a change in the learning rate. By simply selecting a different timeframe, research has shown that the learning rates can vary by as much as 50 percent for identical technologies.[3] The DFR used a calculated learning rate of 30.6 percent for furnaces for the 1990-2010 timeframe in its analysis.

As can be seen by the experience curve included in the DFR, residential warm air furnaces have shown a significant decline in relative price as cumulative shipments have increased (Figure 62). If this learning rate were assumed to continue unchanged, then the expected prices of furnaces by 2045 could be significantly lower than current prices (Figure 63). However, the last 10 million shipments (marked between about 130 million and 140 million on the graph and corresponding roughly to the years 2006 through 2009) show stabilized prices, indicating that product maturity is very near or has already been reached. The DFR noted that for the 2000-2010 timeframe the learning rate was determined to be 19.2 percent. Given the significant increase in the market penetration of condensing furnaces since the early 1990s and the high market penetration (especially in the North Region), it may be too optimistic to assume that price decreases will continue into the future. Condensing furnaces have effectively moved from a niche market to a mature, cost-competitive product, comprising 50% of national furnace shipments in 2009 and 68% of furnace shipments to the North Region (Figure 64).

It is also worth noting that the experience curve is not a universal paradigm. There are industries in which costs have not declined with production experience, such the U.S. nuclear power industry, or industries where cost declines have occurred but not continued, such as the airplane manufacturing industry.[4] Similarly the assumption that cost reductions are a function of cumulative production alone may fail to capture the importance of other variables such as R&D spending or volatility of input prices.[5]

According to the TSD, DOE analysts used the 30.6% experience curve to determine the estimated price reduction by 2016. The resulting factor is a fixed equipment price factor of 0.902452574277439 that is applied to all furnaces. The inference is that the furnace prices are considered fixed for the 30 year duration of the analysis, and the experience curve was used only to determine the price reduction opportunity at the beginning of the analysis period, in this case 2016.

To examine the impact of fully mature market pricing, GTI analysts conducted a scenario analysis in which the price reduction factor was increased to 1.0, reflecting no further real price reduction opportunities after 2009, as part of the integrated scenario analysis in Section 6.

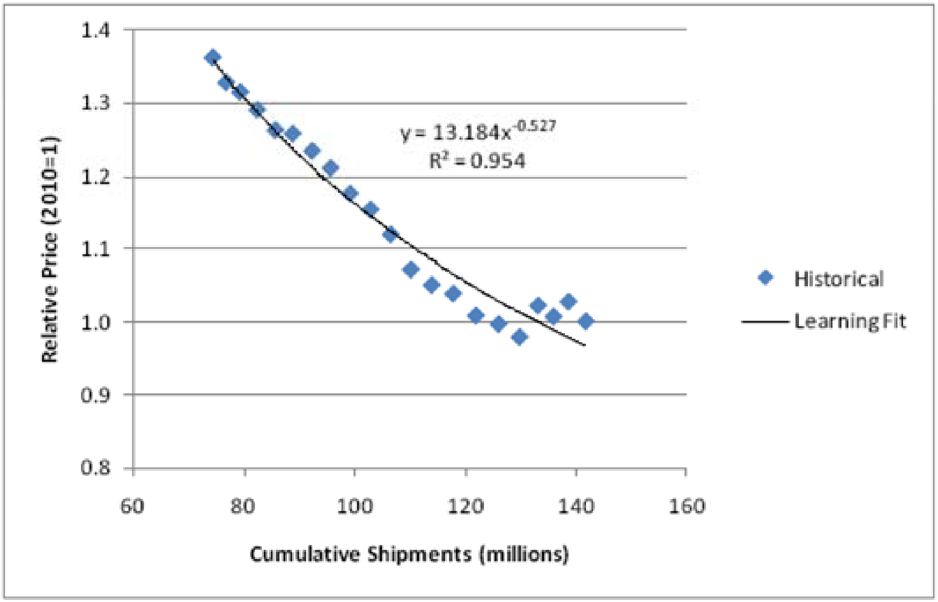


Figure 62: DOE Projection of Furnace Cost as a Function of Cumulative Historic Shipments

Source: DOE Direct Final Rule, Technical Support Document Appendix 8-J6

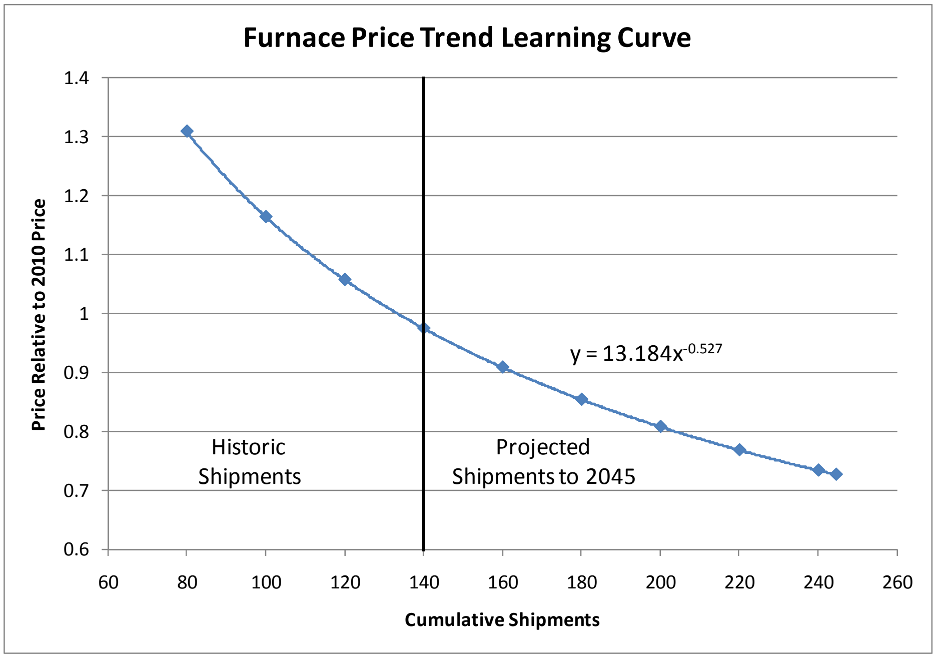


Figure 63: Extension of DOE Learning Rate to Projected Furnace Prices through 2045

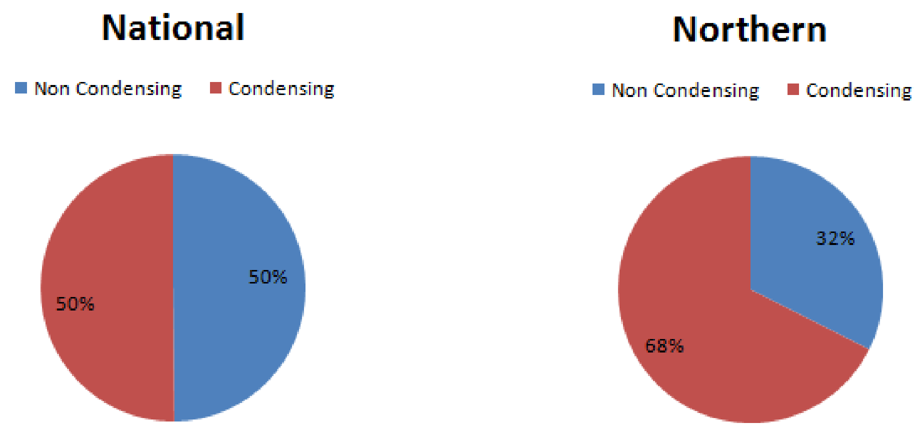


Figure 64: 2009 Furnace Shipments of Condensing and Non-Condensing Furnaces

Source: Stanonik, F.A. representing AHRI, Letter to Mohammed Khan, DOE. July 20, 2010.

5.2 Equipment Expected Lifetime

Estimated equipment lifetime is a function of fuel type, location, and patterns of use, among other factors. Within the DFR, the stated average equipment lifetimes were 23.6 years for non-weatherized gas furnaces, 18.8 years for manufactured home furnaces, and 26.6 years for oil-fired furnaces. DOE combined national survey data from the Energy Information Administration's Residential Energy Consumption Survey (RECS) as well as the U.S. Census's American Housing Survey (AHS) to estimate the lifetime of various furnace types. The AHS has a larger sample size than the RECS database and the data were combined to reduce sampling error. DOE combined this information with appliance shipment data from manufacturer trade associations to estimate the fraction of appliances of a given age that are still in use within the residential sector. According to DOE, this information can then be used to create a survival curve, which estimates the portion of units that are still in service at any given point in their lifetime. Such a curve was not included in the TSD for furnaces, although it was included for heat pumps and air conditioners. However, GTI analysts were able to utilize the furnace data to construct a Weibull survivor curve (Figure 65).

The non-weatherized furnace expected life in the DFR is in conflict with other industry sources as well as the DOE Multi-Year Program Plan. DOE's estimate of furnace expected life in its Multi-Year Plan is 16 years[7]. Manufacturer information based on engineering assessments also indicates that the average expected lifetime of residential furnaces may be considerably lower than the DFR estimate. The average life expectancy of residential gas furnaces estimated by Appliance Magazine is 15 years (with a low estimate of 12 years and a high estimate of 17 years)[8] based on of manufacturer surveys and estimates by industry professionals. Additionally, AEO 2011 assumes that central forced-air furnaces for residential use have a minimum life of 10 years and a maximum life of 25 years, which would suggest an average life expectancy of 17.5 years.[9] This estimate is consistent with other DOE and manufacturer estimates and is also less than the expected life used in the DFR.

Reports provided by Crystal Ball Version 7.3.2 were not sufficiently detailed to aid GTI analysts in determining the input parameters for the expected life scenario analysis. However, as part of their effort to update the spreadsheet to be compatible with the current version of Crystal Ball, Oracle staff generated a modified LCC spreadsheet that provided the same results as the original DOE LCC spreadsheet. Using this spreadsheet and the current version of Oracle that provides more extensive reporting than version 7.3.2, GTI analysts were able to identify the necessary expected life input parameters and conduct the analysis.

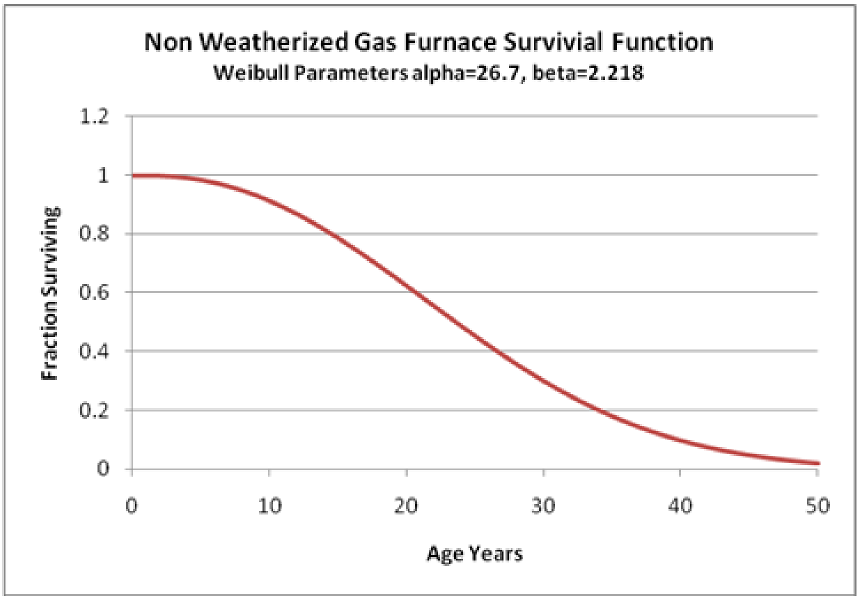


Figure 65: Weibull Distribution for Non-weatherized Gas Furnaces

Source: GTI analysis of data from TSD Chapter 8[10]

The results of the 16 year furnace lifetime analysis using AEO 2010 prices are presented in Table 8 and Figure 66 through Figure 72 below for comparison with the DFR estimates from Figure 10 through Figure 12. For ease of comparison of the results from multiple scenarios, a summary table and graph are shown below, which include the lifecycle savings and median and average payback periods under the 16 year expected furnace lifetime scenario.

Table 8: 90% AFUE Furnace Summary Results – 16 Year Furnace Life

	North Composite		North Retrofit		North New Construction	
	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2010 Reference Case	$67	10.1 / 12.8	$6	12.9 / 15.9	$247	2.5 / 4.3
AEO 2010 Low Economic Growth	$57	10.5 / 13.2	-$4	13.4 / 16.3	$235	2.6 / 4.4
AEO 2010 High Economic Growth	$77	10.0 / 12.6	$16	12.7 / 15.6	$257	2.5 / 4.2

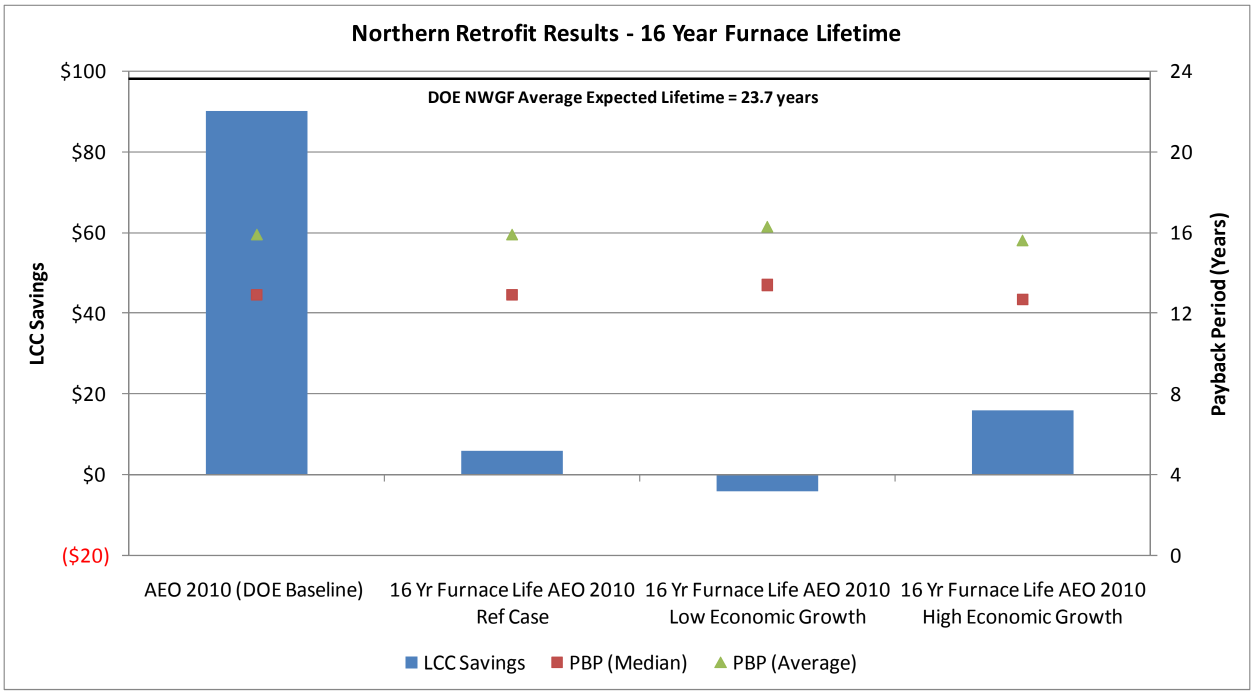


Figure 66: AEO 2010 16 Year Furnace Life LCC and PBP Results – North Region Retrofit

5.2.1 AEO 2010 Reference Case 16 Year Furnace Life

Simulation Results NORTH Composite			AEO 2010 Forecast - Reference Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$8,442	$10,342						
1	90% AFUE - Condensing Design		$2,474	$7,607	$10,081	$67	13%	71%	16%	10.1	12.8
2	92% AFUE - Increased HX Area		$2,536	$7,459	$9,995	$104	15%	56%	28%	7.7	10.1
3	95% AFUE - Increased HX Area		$2,685	$7,247	$9,932	$152	32%	23%	45%	9.4	11.3
4	98% AFUE - Max Tech		$2,943	$7,155	$10,098	-$13	70%	1%	29%	17.1	28.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 67: AEO 2010 Reference Case 16 Year Furnace Life – North Composite

Simulation Results NORTH Replacement			AEO 2010 Forecast - Reference Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$8,411	$10,124						
1	90% AFUE - Condensing Design		$2,483	$7,579	$10,062	$6	16%	72%	12%	12.9	15.9
2	92% AFUE - Increased HX Area		$2,543	$7,431	$9,974	$44	18%	57%	25%	9.0	11.7
3	95% AFUE - Increased HX Area		$2,687	$7,220	$9,907	$96	34%	23%	43%	9.7	11.9
4	98% AFUE - Max Tech		$2,925	$7,127	$10,051	-$48	72%	1%	28%	16.9	26.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 68: AEO 2010 Reference Case 16 Year Furnace Life – North Retrofit

Simulation Results NORTH New Construction			AEO 2010 Forecast - Reference Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$8,531	$10,983						
1	90% AFUE - Condensing Design		$2,447	$7,689	$10,136	$247	4%	70%	26%	2.5	4.3
2	92% AFUE - Increased HX Area		$2,516	$7,539	$10,055	$282	7%	55%	38%	5.1	5.5
3	95% AFUE - Increased HX Area		$2,680	$7,327	$10,007	$318	26%	23%	51%	8.8	9.8
4	98% AFUE - Max Tech		$2,996	$7,239	$10,235	$91	66%	1%	33%	17.9	33.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 69: AEO 2010 Reference Case 16 Year Furnace Life – North New Construction

5.2.2 AEO 2010 High Economic Growth 16 Year Furnace Life

Simulation Results NORTH Composite			AEO 2010 High Growth Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,901	$8,778	$10,678						
1	90% AFUE - Condensing Design		$2,474	$7,908	$10,382	$77	13%	71%	16%	10.0	12.6
2	92% AFUE - Increased HX Area		$2,536	$7,753	$10,290	$117	15%	56%	29%	7.5	9.9
3	95% AFUE - Increased HX Area		$2,685	$7,533	$10,218	$172	31%	23%	46%	9.3	11.1
4	98% AFUE - Max Tech		$2,943	$7,438	$10,381	$10	69%	1%	30%	16.8	28.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 70: AEO 2010 High Growth 16 Year Furnace Life – North Composite

Simulation Results NORTH Replacement			AEO 2010 High Growth Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,713	$8,745	$10,458						
1	90% AFUE - Condensing Design		$2,483	$7,879	$10,362	$16	16%	72%	13%	12.7	15.6
2	92% AFUE - Increased HX Area		$2,543	$7,724	$10,267	$56	17%	57%	26%	8.8	11.5
3	95% AFUE - Increased HX Area		$2,687	$7,504	$10,191	$115	33%	23%	44%	9.4	11.6
4	98% AFUE - Max Tech		$2,925	$7,407	$10,332	-$25	71%	1%	29%	16.5	26.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 71: AEO 2010 High Growth 16 Year Furnace Life – North Retrofit

Simulation Results NORTH New Construction			AEO 2010 High Growth Scenario (16 years furnace life)								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,452	$8,874	$11,326						
1	90% AFUE - Condensing Design		$2,447	$7,996	$10,443	$257	4%	70%	26%	2.5	4.2
2	92% AFUE - Increased HX Area		$2,516	$7,840	$10,356	$295	6%	55%	39%	4.9	5.4
3	95% AFUE - Increased HX Area		$2,680	$7,618	$10,298	$338	25%	23%	52%	8.6	9.6
4	98% AFUE - Max Tech		$2,996	$7,527	$10,523	$114	65%	1%	35%	17.5	33.1
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 72: AEO 2010 High Growth 16 Year Furnace Life – North New Construction

5.2.3 AEO 2010 Low Economic Growth 16 Year Furnace Life

Simulation Results NORTH Composite							AEO 2010 Low Growth Scenario (16 years furnace life)					
			Average LCC Results								Payback Results	
			Installed	Lifetime		LCC	Net	No	Net			
Level	Description	Count	Price	Oper. Cost	LCC	Savings	Cost	Impact	Benefit		Median	Average
NWGF		5,986										
0	80% AFUE - Increased HX Area		$1,901	$8,076	$9,977							
1	90% AFUE - Condensing Design		$2,474	$7,280	$9,754	$57	14%	71%	15%		10.5	13.2
2	92% AFUE - Increased HX Area		$2,536	$7,138	$9,674	$91	16%	56%	27%		8.0	10.4
3	95% AFUE - Increased HX Area		$2,685	$6,936	$9,621	$131	34%	23%	43%		9.8	11.7
4	98% AFUE - Max Tech		$2,943	$6,849	$9,792	-$38	72%	1%	27%		17.6	29.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*									

Figure 73: AEO 2010 Low Economic Growth 16 Year Furnace Life – North Composite

Simulation Results NORTH Replacement							AEO 2010 Low Growth Scenario (16 years furnace life)					
			Average LCC Results								Payback Results	
			Installed	Lifetime		LCC	Net	No	Net			
Level	Description	Count	Price	Oper. Cost	LCC	Savings	Cost	Impact	Benefit		Median	Average
NWGF		4,465										
0	80% AFUE - Increased HX Area		$1,713	$8,048	$9,760							
1	90% AFUE - Condensing Design		$2,483	$7,254	$9,737	-$4	17%	72%	12%		13.4	16.3
2	92% AFUE - Increased HX Area		$2,543	$7,112	$9,655	$31	19%	57%	24%		9.3	12.1
3	95% AFUE - Increased HX Area		$2,687	$6,911	$9,597	$75	36%	23%	41%		10.0	12.2
4	98% AFUE - Max Tech		$2,925	$6,822	$9,747	-$73	74%	1%	25%		17.3	27.6
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*									

Figure 74: AEO 2010 Low Economic Growth 16 Year Furnace Life – North Retrofit

Simulation Results NORTH New Construction							AEO 2010 Low Growth Scenario (16 years furnace life)					
			Average LCC Results								Payback Results	
			Installed	Lifetime		LCC	Net	No	Net			
Level	Description	Count	Price	Oper. Cost	LCC	Savings	Cost	Impact	Benefit		Median	Average
NWGF		1,521										
0	80% AFUE - Increased HX Area		$2,452	$8,161	$10,613							
1	90% AFUE - Condensing Design		$2,447	$7,357	$9,804	$235	4%	70%	25%		2.6	4.4
2	92% AFUE - Increased HX Area		$2,516	$7,215	$9,730	$267	7%	55%	38%		5.2	5.6
3	95% AFUE - Increased HX Area		$2,680	$7,012	$9,692	$295	27%	23%	50%		9.0	10.0
4	98% AFUE - Max Tech		$2,996	$6,928	$9,924	$64	68%	1%	31%		18.4	34.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*									

Figure 75: AEO 2010 Low Economic Growth 16 Year Furnace Life – North New Construction

5.3 Venting Modifications

The LCC and payback period analyses rely on numerous assumptions to calculate the different frequency and costs of vent resizing, relining of masonry chimneys, and venting modifications for orphaned water heaters both in retrofit and new construction scenarios. Each of these modifications will increase the cost of the efficiency upgrade and will accordingly be reflected within the LCC. In order to determine the cumulative effect these modifications would have on the overall economic analysis for the DFR, DOE had to estimate what portion of the furnace population would require each of these modifications. This required the combined use of historical data and multiple assumptions. These modifications were only considered within the retrofit/replacement portion of the market and not within new construction. Additionally, these modifications were only necessary when a common vent was shared by the furnace and another appliance within the household, such as a water heater (Table 9). To determine the characteristics of the existing product stock, DOE used data from the EER and GRI reports included or referenced in the TSD. The 2007 Final Rule for residential furnaces referenced the 1994 GRI Furnace Survey to determine the percentage of common vents as well as fraction of existing masonry chimney installations. It also provided the distribution of vent types based on the 1994 GRI report[11]. However, the DFR changed datasets for the percentage of common vents, instead referencing the 1991 GRI Water Heater Survey that included regional breakouts as the primary data source. It is not clear if the DFR is using the same vent distribution as the TSD for the 2007 Final Rule or another distribution.

Table 9: Fraction of Common Vented Furnace and Water Heater Installations

Common Venting	Northeast	Midwest	South	West
Common	78%	68%	22%	65%
Isolated	22%	32%	78%	35%

Source: 1991 GRI Water Heater Survey[12]

For chimney relining, DOE assumed that all interior chimneys would need to be relined if they were built before 1995 or if the existing furnace was a natural draft non-condensing unit. Utilizing EIA's Residential Energy Consumption Survey results from 2005, DOE calculated that approximately 26 percent of households have an unlined chimney, half of which were assumed to be relined already due to furnace replacement in the period of 2005 to 2016. Based on the fraction and age of existing chimney installations, DOE determined that 13 percent of the stock would require chimney relining when the proposed rulemaking came into effect in 2016. This value appears to be a national average rather than a regional split. If so, it would be understating the fraction of stock in the north needing relining and overstating the fraction in the south since over 70% of masonry chimneys are in the north.

Table 10: Fraction of Existing Masonry Chimney Installations

Venting Type	North	South
Masonry	71.8%	16.4%
Metal Vent	28.2%	83.6%

Source: 1994 GRI Furnace Survey[13]

For installations that need to reduce vent sizes to meet NFGC requirements, DOE states that there are two options: to resize the vent connector or to resize the whole vent. The analysis assumes that vent resizing only occurs when a non-condensing fan-assisted furnace (80% AFUE or greater) replaces a natural draft non-condensing furnace (75% AFUE or lower). Based on a report by EER Consulting LLC, DOE assumed that the vent connector was resized for about 4 percent of the total stock and the whole vent was resized for about 1 percent of the total stock.[14]

There is a third type of modification that may need to occur when replacing a commonly vented furnace with a condensing furnace. After upgrading to a condensing furnace, the common vent may now be too large for the remaining “orphaned” water heater. In order for the orphaned water heater venting to meet safety codes a combination of modifications may be required, including resizing of the vent connectors or the whole vent. The DFR technical support document assumes that 100 percent of venting systems with an existing natural draft furnace would need new vent connectors but only 40 percent would need to have the whole vent resized (representing 2 percent and 1 percent of the total stock, respectively). The analysis further assumes that 100 percent of orphaned water heater chimneys would need to be relined if built before 1990 and if the existing furnace is a natural draft furnace (representing 7 percent of the total stock). Finally, the analysis assumes that 20 percent of the venting systems with existing fan-assisted non-condensing furnaces would need to have the whole vent for the water heater resized (representing 8 percent of the total stock).

These venting modification fractions may or may not accurately capture the required venting modifications. However, it was not possible to isolate these assumptions with the analytical tool; therefore, it was not possible to evaluate alternate venting modification fractions.

A parametric analysis of venting modifications costs was attempted, though it ultimately did not produce realistic results. Alteration of the program input data defining material and labor installation costs for replacement equipment, which would include different venting modification costs, was possible but yielded unpredictable and inconsistent results.

As an example, DOE default input data for the labor and material cost for chimney relining in common vent installations (Table Installation Cost Components for NWGF -Chimney Relining in LCC Installation Costs spreadsheet) are low (~$370) but generate a Crystal Ball cost distribution with a reasonable mean composite cost estimate of $698 (based on a 10,000 sample run output report). However, increasing the program input value costs to reflect higher values that are closer to the American Gas Association’s average costs estimate for chimney relining of $800 (a desired parametric run), Crystal Ball estimated mean cost of this operation rises rapidly to $1,167 - well above a reasonable average cost for relining. GTI analysts attempted to perform a parametric analysis by shifting a single cost element within the tool, but the resulting Crystal Ball output deviated significantly from the expected result.

In an attempt to resolve this area of concern, GTI analysts reviewed the available Crystal Ball charts and reports. However it was difficult to determine the cause of these unexpected results from the analytical tool, though it appears that the probabilities of occurrence for various venting modifications (as outlined in previous paragraphs) may be affecting the final installation cost results. Additionally, the Crystal Ball sensitivity analysis reports show that 25 assumptions/variables affect the estimate of the “real possible costs” of chimney relining for each analyzed case (Figure 76). Some of these assumptions are clearly labeled and many are simply labeled with letters and numbers that appear to be cell addresses without further reference. Attempts by GTI analysts to identify assumptions names encoded with combination of letters and numbers were not successful. Without the ability to trace the way values are manipulated within the analytical tool, it was not possible to determine if the results would be valid or not. Therefore, it was not be possible to rely on modeling results using alternate inputs for venting costs or use them to determine the validity of the results obtained using DOE default input costs.

Use of the tool is further complicated by lack of clear distinction between tables and values listed in the spreadsheet as reference vs. that of working inputs. Frequently the user must rely on trial and error to determine specific cell contents bearing on the analytical output. An example of challenges GTI faced trying to follow cell references and input data calculations is presented below for a single variable “NWGF” used in defining Common Venting installations for the Northeast Census Region.

NWGF [CY5] = IF(OR(AND(Y5=3,Z5=1,R5>1, AA5=0, T5>0, T5<>9999999), AND(Y5=3,Z5=2,R5>1, AA5=0, U5>0, U5<>9999999), AND(AD5=1, AE5=1,R5>1, AA5=0, T5>0, T5<>9999999), AND(AD5=1, AE5=2,R5>1, AA5=0, U5>0, U5<>9999999)),K5,0) * IF(AND(CV5>1,OR(AN5=1,AN5=3)),0.8,1) * CHOOSE(CV5,0.96,1.05,1.03) * IF(CW5=1, 2, 1)
Where
CV5=IF(OR(CU5=6,CU5=7,CU5=12,CU5=13, CU5=5),3,IF(OR(CU5=8.1,CU5=11),2,1))
And
CW5=IF(AND(AD5=1,AE5<=3), IF(Y5=3, IF(Z5=AE5, 1, 2), 2), IF(OR(AND(Y5=3, Z5=1, AI5=1), AND(Y5=3, Z5=2, AJ5=1), AND(Y5=3, Z5=3, AK5=1)), 3, IF(AND(Y5=3, Z5<=3, OR(R5=2, R5=3), OR(CM5>4000, AND(CG5>1, CG5<9, BS5>10, BS5<99))), 1,0)))

This is a single cell that contains conditional statements and cross-references to other cells that also have other cell references. In the absence of documentation or user support, this aspect of the tool made tracing and debugging nearly impossible in any meaningful timeframe.

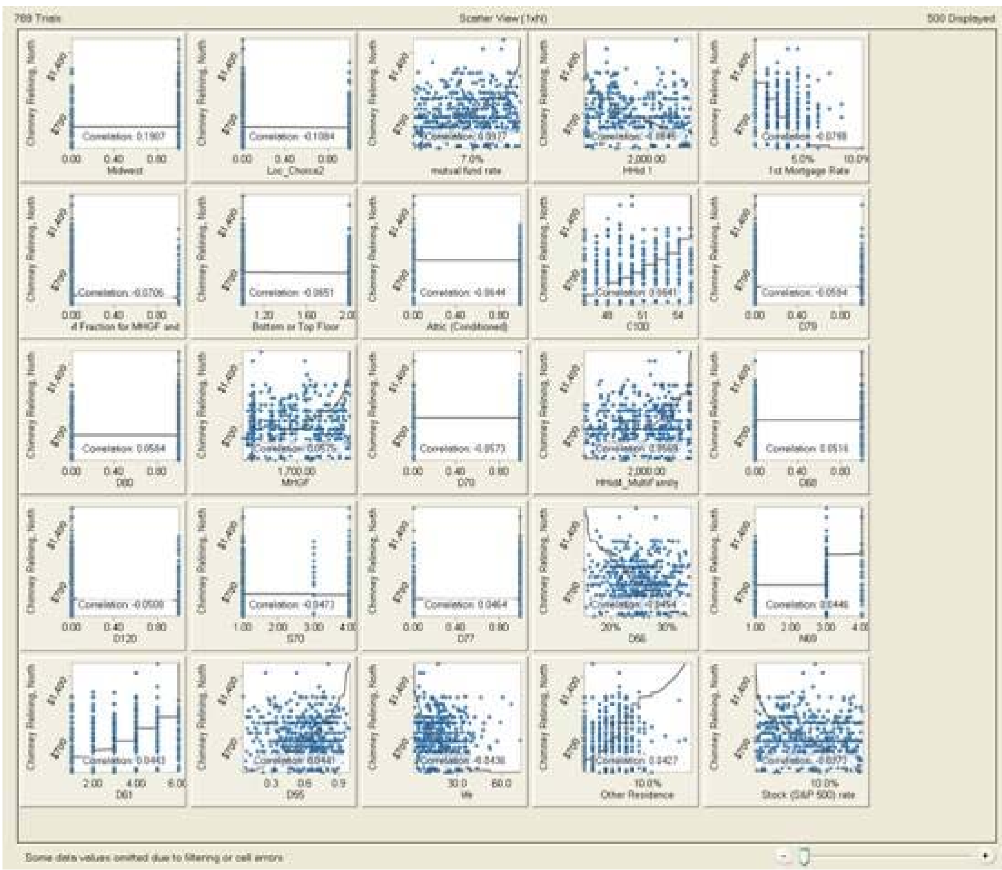


Figure 76: Weighting Factors used in the Crystal Ball Analysis

5.4 Water Heater Fuel Switching

For the DFR, DOE did not explicitly quantify the potential for fuel switching from gas furnaces to electric heating equipment. In its reasoning, DOE stated that because the operating costs of electric space heating systems are relatively high due to the price of electricity, using an electric system in a cold climate is significantly more expensive than using a gas furnace. Based on the this logic, DOE inferred that consumers with high heating loads would be unlikely to switch to electric space heating systems as a result of amended standards. This assertion is questionable, especially in states such as Missouri, Kansas, and West Virginia that have warmer climates but are still included in the north region. Even if one accepts the questionable DOE hypothesis, there is another appliance impacted by the DFR that, according to the TSD, is highly likely to experience perverse fuel switching as a result of the amended standard. According to the TSD, in 5% to 10% of instances in which the mandated shift to a condensing furnace results in an orphaned water heater, the consumer will install a new electric water heater to replace the gas unit, because this is a less expensive alternative to a separately vented water heater.[15]

This fuel switching has both energy cost and environmental consequences. The operating costs of an electric water heater are typically more than twice as high as a comparable gas storage water heater, and the greenhouse gas emissions associated with the electric water heater are also typically over twice the emissions of a comparable gas water heater. Table shows the results of a cost comparison based on an annual water heating load of 12.8 MMbtu using AEO2011 2010 energy prices in the north region of $1.095/therm for gas and $0.127/kWh for electricity.

Table 11 Comparison of Water Heating Options for a Typical North Region Home

	Storage Capacity (Gallons)	Efficiency (EF)	Installed Cost (1)	Gas Usage (Therms)	Electric Usage (kWh)	Annual Energy Cost	Simple Payback (Years)	13-Year LCC (2)
Conventional Electric Storage	50	0.91	$750	0	3,965	$504	NA	$6,110
Conventional Gas Storage	40	0.62	$850	207	0	$227	0.4	$3,264

Notes:
1 http://www.aceee.org/consumer/water-heating
2 LCC discount rate = 3%
3 Maintenance costs not included

The results show that from an energy cost perspective, switching to an electric resistance water heater from a gas water heater in the north region is not in the consumer's best interest based on typical current and projected energy prices and typical installed costs. However, for reasons cited by EER in the TSD, a certain fraction of consumers will make this choice anyway, to their own detriment and with negative impact on the nation's energy consumption and global greenhouse gas emissions.

The overall impact of this irrational fuel switching needs to be included in the analysis of consumer impacts and LCC savings. While this fuel switching may occur only in a fraction of overall installations, the impact per home is significant ($2,846 LCC per home in this example), and should be carefully considered by DOE before making its determination.

6.0 Missouri Consumer Impact Analysis

The DFR 90% AFUE furnace minimum standard for the North Region applies to states and cities with heating degree days (HDD) that are near or below 5,000 HDD. The lower local heating requirements reduce the consumer energy cost savings in those states and cities relative to the regional average savings. A good example of this negative consumer impact is typical condensing furnace retrofits in the state of Missouri, with focus on the St. Louis metropolitan area.

GTI analysts worked with Laclede Gas Company staff to evaluate empirical data obtained by Laclede on pre-and post-retrofit energy costs collected from their energy efficiency rebate database and their meter data management company. This empirical data permitted a marginal gas price analysis as well as an average gas price analysis that show the range of energy savings and unintended consequences of condensing furnace retrofits (predominantly 95% AFUE) that replaced non-condensing furnaces (77% to 83% AFUE). The analysis methodology applied to this database resulted in key information on energy cost savings and estimated payback assuming a typical incremental installed cost of $1,500 for a 95% condensing furnace.

Figure 77 through Figure 79 show the results of the payback analysis for condensing furnace retrofits in the Laclede service territory. Key findings from this analysis include the following:

- Shifting from an average price analysis methodology to a marginal price methodology has significant impact on estimated payback periods for a 95% furnace retrofit. Using an average price methodology, 59% of retrofits have a payback period less than or equal to 20 years. Using a marginal price methodology, that number is reduced to 43% of retrofits. Nearly 60% of condensing furnaces either have no payback or have a payback that exceeds the expected life of the furnace.
- Over 20% of 95% furnace retrofits have no payback at all under either the marginal price or average price methodology. In these cases, the heating energy cost actually increased after the 95% furnace retrofit. Laclede staff did not expect this result and went to great lengths to attempt to explain this data, including an investigation of coincident installation of thermostats, potential weather normalization effects, change of ownership, and empirical data anomalies. Based on this review, the data appear robust. While continuing to seek an explanation for this finding, Laclede remains confident that the increased annual energy costs after a condensing furnace retrofit represent a real, unintended consequence of their energy efficiency rebate program.

The implications of the Laclede empirical database for the DFR findings are significant. Based on this empirical data, DOE’s finding that the condensing furnace regional standard is economically justified is likely to be highly questionable or invalid in many of the 30 northern states currently affected, especially in the retrofit market. DOE’s use of an average price methodology rather than a marginal price methodology skews the DOE analysis against the non-condensing furnace. The lower heating loads in these warmer North Region states further reduces the benefit of shifting to a condensing furnace compared to the benefit in colder states and also compared to the regional average benefit. As shown in this analysis, the combination of these two factors can result in increased life cycle costs that exceed the energy benefit for the majority of retrofit consumers.

An additional factor for DOE to consider is the unexpected and unintended consequence of the condensing furnace retrofit on energy use. It appears that a significant fraction of consumers (in this case over 20%) may be altering some aspect of their behavior when they install higher efficiency equipment that ultimately results in higher energy consumption rather than the expected lower energy consumption. Until this issue is further explored and understood, it is premature for DOE to require all consumers in the North Region to install these systems.

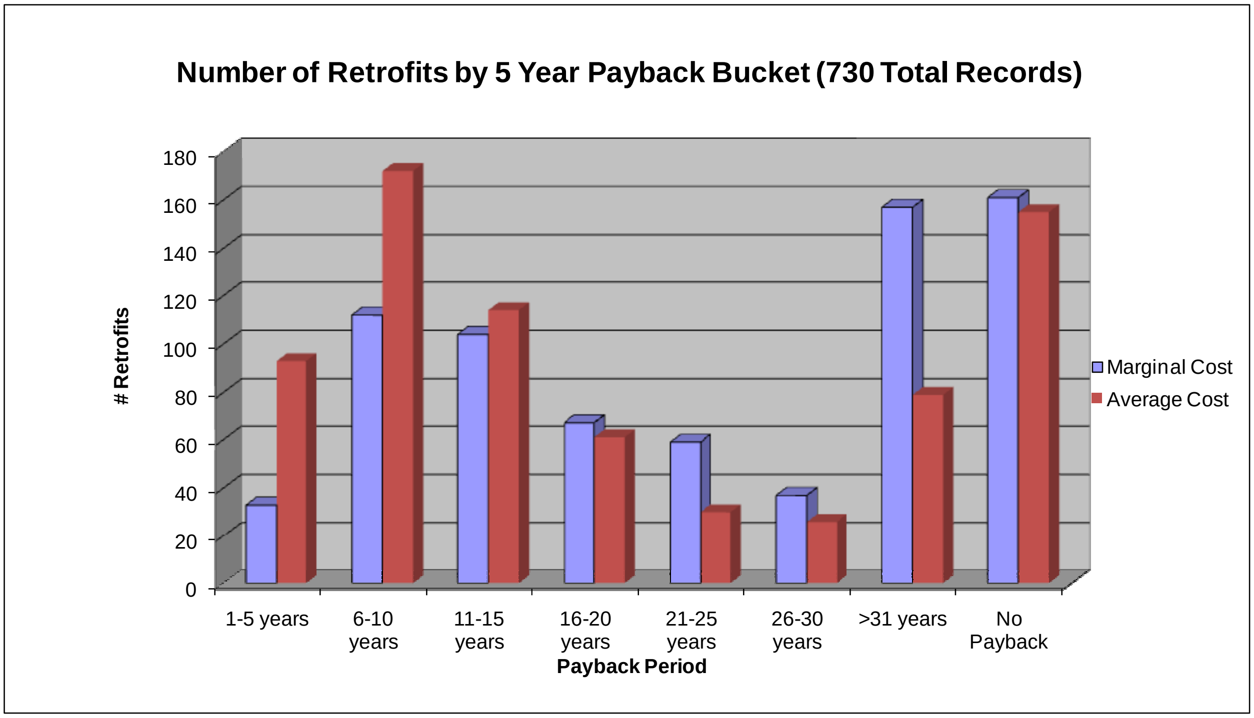


Figure 77 95% Furnace Retrofit Marginal and Average Gas Price Payback Period Comparison

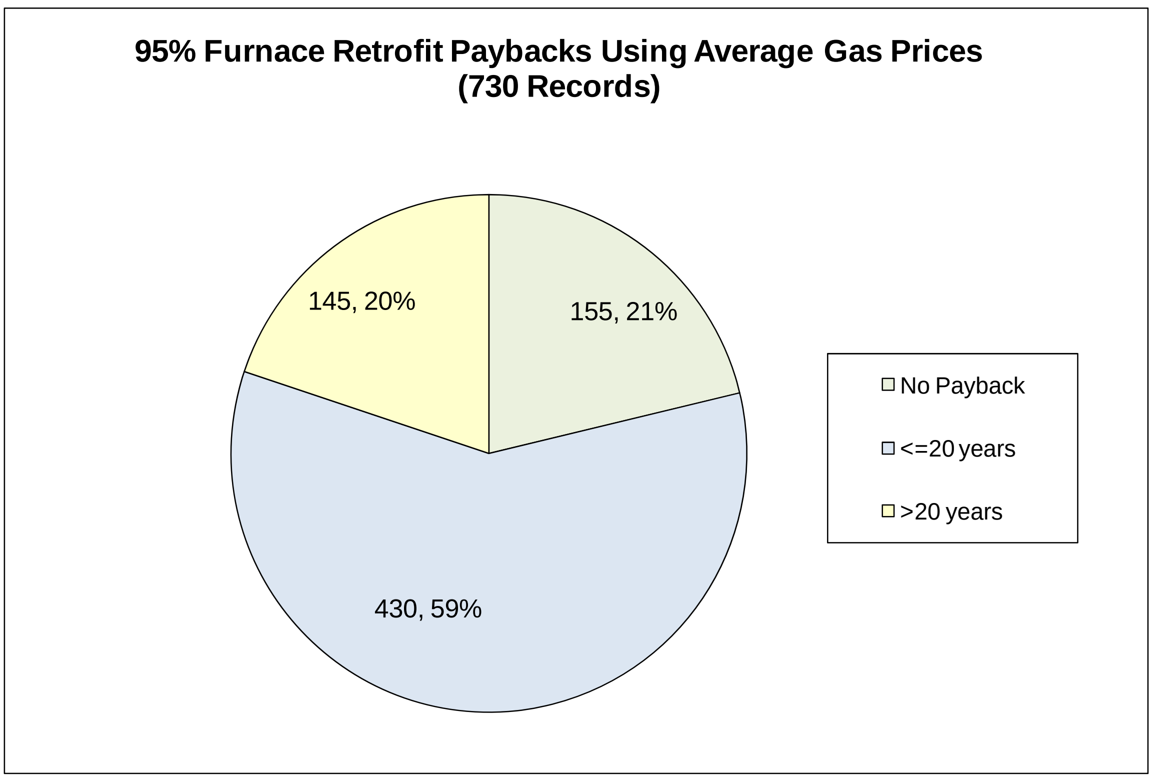


Figure 78 95% Furnace Payback Period Profile Based on Average Gas Prices

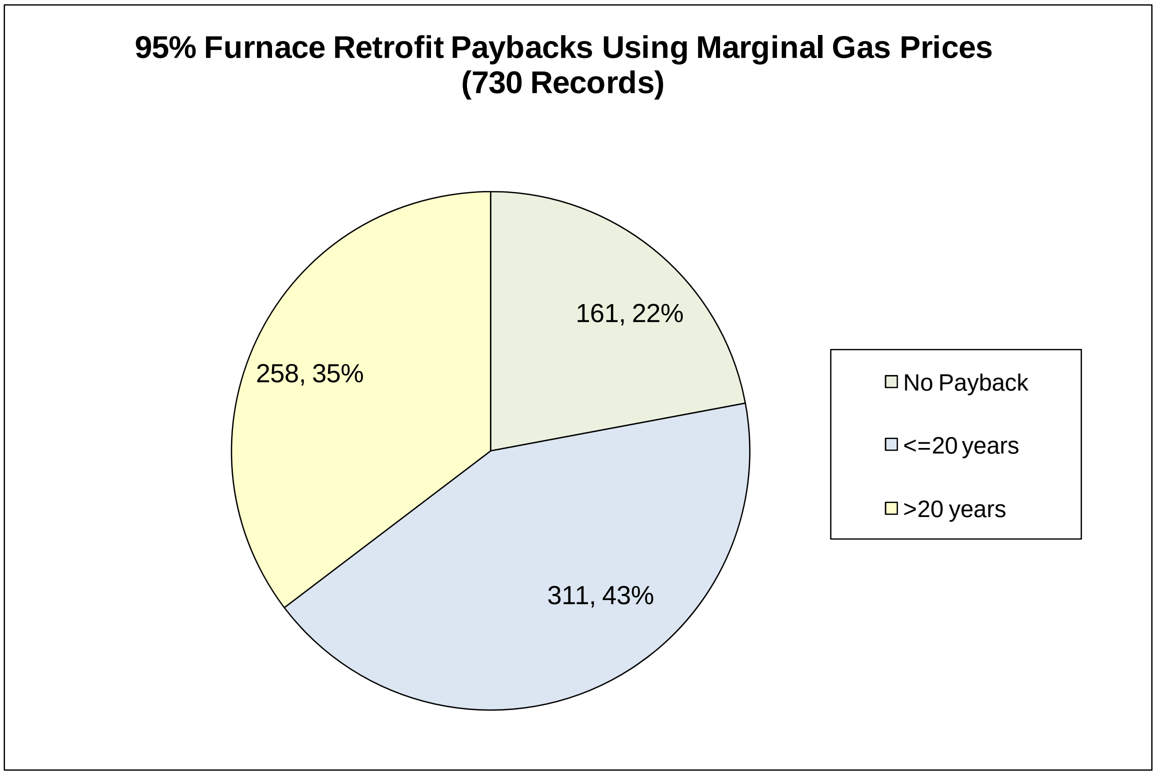


Figure 79 95% Furnace Payback Period Profile Based on Marginal Gas Prices

7.0 Integrated Scenario Analysis

The availability of useable information on updated energy prices, marginal energy prices, furnace expected lifetime, and mature market equipment pricing permitted GTI analysts to conduct an integrated scenario analysis. The goal of the integrated scenario analysis was to use selected combinations of the targeted input parameters to determine the cumulative impact on overall life cycle costs. The parameters selected for the integrated analysis provide alternates that may be more aligned with current and projected conditions than the DFR baseline assumptions. Unfortunately, neither the venting cost modifications nor the fuel switching component could be included in the integrated scenario analysis. Nonetheless, the results of this analysis show the significant impact combining these parameters has on the overall result. Table 12 and Figure 80 through Figure 92 summarize the results of this scenario analysis below for comparison with the DFR estimates from Figure 10 through Figure 12. For ease of comparison of the results from multiple scenarios, a summary table and graph are shown below, which include the lifecycle savings and median and average payback periods under the integrated scenarios.

Table 12: 90% AFUE Furnace Summary Results – Integrated Scenario Analysis

Integrated Scenarios (16 Year Furnace Life, LC = 1.0 in All AEO 2011 Scenarios)	North Composite		North Retrofit		North New Construction	
	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg	LCC Savings	Payback Period Median/Avg
AEO 2010 (DOE Baseline)	$155	10.1 / 12.8	$90	12.9 / 15.9	$343	2.5 / 4.3
AEO 2011 Ref Case 13% Fixed Gas Costs	-$4	16.3 / 20.5	-$64	20.4 / 25.3	$172	4.1 / 7.1
AEO 2011 High Shale 13% Fixed Gas Costs	-$18	18.0 / 22.8	-$78	22.7 / 28.1	$157	4.3 / 7.9
AEO 2011 Ref Case Citygate Gas Price	-$39	21.7 / 28.7	-$98	27.0 / 35.4	$135	5.6 / 9.9
AEO 2011 High Shale Citygate Gas Price	-$48	23.9 / 31.3	-$107	29.7 / 38.8	$125	5.9 / 10.5

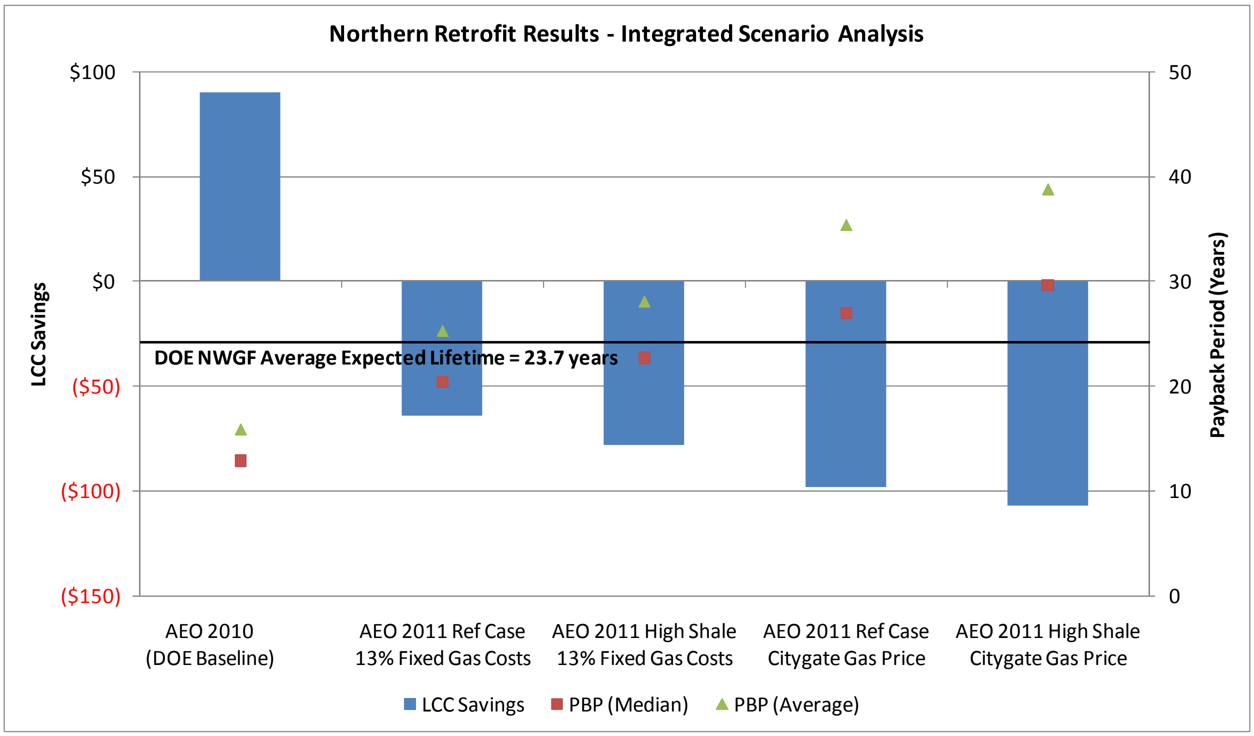


Figure 80: AEO 2011 Integrated Scenarios LCC and PBP Results – North Region Retrofit

7.1 AEO 2011 Reference Case, 16 Year Furnace Life, LC = 1.0, 13% Fixed Gas Costs

Simulation Results NORTH Composite			AEO 2011 Ref Case - Gas Marginal Prices, 16 years furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,996	$6,311	$8,307						
1	90% AFUE - Condensing Design		$2,591	$5,709	$8,300	-$4	18%	71%	11%	16.3	20.5
2	92% AFUE - Increased HX Area		$2,660	$5,600	$8,260	$12	23%	56%	20%	12.8	16.3
3	95% AFUE - Increased HX Area		$2,825	$5,446	$8,270	$4	50%	23%	27%	15.9	18.7
4	98% AFUE - Max Tech		$3,109	$5,427	$8,536	-$260	85%	1%	14%	29.3	47.4
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 81: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, 13% Fixed Costs – North Composite

Simulation Results NORTH Replacement			AEO 2011 Ref Case - Gas Marginal Prices, 16 years furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,803	$6,274	$8,077						
1	90% AFUE - Condensing Design		$2,595	$5,675	$8,270	-$64	21%	72%	7%	20.4	25.3
2	92% AFUE - Increased HX Area		$2,661	$5,567	$8,228	-$47	27%	57%	16%	14.5	18.9
3	95% AFUE - Increased HX Area		$2,820	$5,413	$8,234	-$51	53%	23%	24%	16.2	19.4
4	98% AFUE - Max Tech		$3,083	$5,393	$8,476	-$292	87%	1%	12%	29.2	45.7
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 82: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, 13% Fixed Costs – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Ref Case - Gas Marginal Prices, 16 years furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,560	$6,420	$8,981						
1	90% AFUE - Condensing Design		$2,579	$5,807	$8,387	$172	7%	70%	23%	4.1	7.1
2	92% AFUE - Increased HX Area		$2,656	$5,697	$8,353	$186	14%	55%	31%	8.6	9.2
3	95% AFUE - Increased HX Area		$2,837	$5,541	$8,378	$164	41%	23%	35%	14.6	16.4
4	98% AFUE - Max Tech		$3,185	$5,525	$8,710	-$165	79%	1%	21%	29.9	52.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 83: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, 13% Fixed Costs – North New Construction

7.2 AEO 2011 High Shale Gas, 16 Year Furnace Life, LC = 1.0, 13% Fixed Gas Costs

Simulation Results NORTH Composite			AEO 2011 Forecast -Gas Marginal Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,996	$5,890	$7,885						
1	90% AFUE - Condensing Design		$2,591	$5,335	$7,926	-$18	18%	71%	10%	18.0	22.8
2	92% AFUE - Increased HX Area		$2,660	$5,234	$7,894	-$5	25%	56%	18%	13.6	18.1
3	95% AFUE - Increased HX Area		$2,825	$5,091	$7,916	-$22	54%	23%	23%	17.6	20.5
4	98% AFUE - Max Tech		$3,109	$5,094	$8,203	-$308	87%	1%	13%	33.1	56.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 84: AEO 2011 High Shale, 16 Yr Life, LC=1.0, 13% Fixed Costs – North Composite

Simulation Results NORTH Replacement			AEO 2011 Forecast -Gas Marginal Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,803	$5,852	$7,655						
1	90% AFUE - Condensing Design		$2,595	$5,301	$7,896	-$78	22%	72%	6%	22.7	28.1
2	92% AFUE - Increased HX Area		$2,661	$5,201	$7,862	-$64	28%	57%	15%	16.5	20.9
3	95% AFUE - Increased HX Area		$2,820	$5,058	$7,879	-$77	57%	23%	21%	18.0	21.4
4	98% AFUE - Max Tech		$3,083	$5,060	$8,143	-$340	89%	1%	10%	33.1	55.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 85: AEO 2011 High Shale, 16 Yr Life, LC=1.0, 13% Fixed Costs – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Forecast -Gas Marginal Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
			Installed	Lifetime		LCC	Net	No	Net		
Level	Description	Count	Price	Oper. Cost*	LCC	Savings	Cost	Impact	Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,560	$6,001	$8,562						
1	90% AFUE - Condensing Design		$2,579	$5,435	$8,015	$157	8%	70%	22%	4.3	7.9
2	92% AFUE - Increased HX Area		$2,656	$5,333	$7,989	$167	16%	55%	29%	9.3	10.2
3	95% AFUE - Increased HX Area		$2,837	$5,188	$8,026	$137	45%	23%	32%	16.3	18.1
4	98% AFUE - Max Tech		$3,185	$5,195	$8,380	-$215	80%	1%	19%	33.5	59.0
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 86: AEO 2011 High Shale, 16 Yr Life, LC=1.0, 13% Fixed Costs – North New Construction

7.3 AEO 2011 Reference Case, 16 Year Furnace Life, LC = 1.0, Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 Ref Case -Citygate Gas Prices, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,996	$5,257	$7,253						
1	90% AFUE - Condensing Design		$2,591	$4,769	$7,360	-$39	20%	71%	9%	21.7	28.7
2	92% AFUE - Increased HX Area		$2,660	$4,681	$7,341	-$31	27%	56%	16%	16.5	21.8
3	95% AFUE - Increased HX Area		$2,825	$4,554	$7,379	-$61	58%	23%	19%	20.9	24.2
4	98% AFUE - Max Tech		$3,109	$4,571	$7,680	-$361	89%	1%	11%	39.5	70.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 87: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, Citygate Prices – North Composite

Simulation Results NORTH Replacement			AEO 2011 Ref Case -Citygate Gas Prices, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,803	$5,223	$7,027						
1	90% AFUE - Condensing Design		$2,595	$4,739	$7,334	-$98	23%	72%	5%	27.0	35.4
2	92% AFUE - Increased HX Area		$2,661	$4,651	$7,312	-$89	31%	57%	12%	19.0	25.3
3	95% AFUE - Increased HX Area		$2,820	$4,525	$7,345	-$115	61%	23%	16%	20.9	25.2
4	98% AFUE - Max Tech		$3,083	$4,540	$7,624	-$391	91%	1%	9%	39.5	70.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 88: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, Citygate Prices – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 Ref Case -Citygate Gas Prices, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,560	$5,356	$7,916						
1	90% AFUE - Condensing Design		$2,579	$4,858	$7,438	$135	9%	70%	21%	5.6	9.9
2	92% AFUE - Increased HX Area		$2,656	$4,768	$7,424	$139	18%	55%	27%	11.4	12.2
3	95% AFUE - Increased HX Area		$2,837	$4,641	$7,478	$96	49%	23%	28%	19.4	21.1
4	98% AFUE - Max Tech		$3,185	$4,662	$7,846	-$270	83%	1%	16%	39.6	71.2
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 89: AEO 2011 Ref. Case, 16 Yr Life, LC=1.0, Citygate Prices – North New Construction

7.4 AEO 2011 High Shale Gas, 16 Year Furnace Life, LC = 1.0, Citygate Gas Prices

Simulation Results NORTH Composite			AEO 2011 - Citygate Gas Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		5,986									
0	80% AFUE - Increased HX Area		$1,996	$4,965	$6,960						
1	90% AFUE - Condensing Design		$2,591	$4,511	$7,102	-$48	20%	71%	9%	23.9	31.3
2	92% AFUE - Increased HX Area		$2,660	$4,427	$7,087	-$43	29%	56%	14%	17.9	24.6
3	95% AFUE - Increased HX Area		$2,825	$4,309	$7,134	-$80	60%	23%	17%	23.0	26.6
4	98% AFUE - Max Tech		$3,109	$4,344	$7,453	-$397	89%	1%	10%	42.2	80.3
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 90: AEO 2011 High Shale, 16 Yr Life, LC=1.0, Citygate Prices – North Composite

Simulation Results NORTH Replacement			AEO 2011 - Citygate Gas Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		4,465									
0	80% AFUE - Increased HX Area		$1,803	$4,930	$6,733						
1	90% AFUE - Condensing Design		$2,595	$4,479	$7,074	-$107	24%	72%	5%	29.7	38.8
2	92% AFUE - Increased HX Area		$2,661	$4,396	$7,058	-$101	32%	57%	11%	21.6	28.6
3	95% AFUE - Increased HX Area		$2,820	$4,279	$7,099	-$133	63%	23%	14%	23.4	27.7
4	98% AFUE - Max Tech		$3,083	$4,312	$7,395	-$427	91%	1%	8%	42.2	79.1
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 91: AEO 2011 High Shale, 16 Yr Life, LC=1.0, Citygate Prices – North Retrofit

Simulation Results NORTH New Construction			AEO 2011 - Citygate Gas Prices, High Shale Use, 16 yr furnace life, Learning Curve 1								
			Average LCC Results							Payback Results	
Level	Description	Count	Installed Price	Lifetime Oper. Cost*	LCC	LCC Savings	Net Cost	No Impact	Net Benefit	Median	Average
NWGF		1,521									
0	80% AFUE - Increased HX Area		$2,560	$5,067	$7,628						
1	90% AFUE - Condensing Design		$2,579	$4,602	$7,182	$125	10%	70%	20%	5.9	10.5
2	92% AFUE - Increased HX Area		$2,656	$4,518	$7,174	$127	20%	55%	25%	12.0	13.4
3	95% AFUE - Increased HX Area		$2,837	$4,398	$7,236	$77	51%	23%	26%	21.3	23.3
4	98% AFUE - Max Tech		$3,185	$4,438	$7,622	-$307	84%	1%	15%	42.4	83.5
All dollar values are in 2009 $			** discounted and summed over lifetime of equipment*								

Figure 92: AEO 2011 High Shale, 16 Yr Life, LC=1.0, Citygate Prices – North New Construction

8.0 Conclusions

On January 15, 2010 a joint recommendation was submitted to the Department of Energy (DOE) to adopt a package of energy conservation standards for residential furnaces, central air conditioners, and heat pumps. Under provisions of the Energy Independence and Security Act of 2007, DOE used an expedited rulemaking process called a Direct Final Rule (DFR). The DFR was published in the Federal Register on June 27, 2011 and open for a 110 day public comment period. DOE released an extensive technical support document (TSD) to substantiate the DFR, which included a detailed review of the effects of the DFR as well as economic modeling to assess consumer-level cost impacts.

GTI conducted a technical and economic analysis of the DFR to evaluate the impact of the regional minimum furnace efficiency requirements on consumers. The analysis considered the following:

- DOE technical support document analysis and conclusions.
- Impact of updated, lower natural gas price projections due to new shale gas supplies.
- Data on common vent installations and conversion costs.
- Estimates of consumer benefits and costs associated with the 90% furnace standard.

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

- Several foreseeable scenarios, including a reasonable AEO 2011 alternate to the DOE baseline scenario, show negative composite average lifecycle cost savings for a 90% condensing furnace in the North Region compared to the 80% AFUE baseline furnace, indicating that the 90% furnace does not meet the DOE requirement for economic justification in the North Region of positive LCC savings and a payback period that is shorter than the equipment expected life.

- Lifecycle costs for the North Region retrofit installations are worse than the composite costs. The payback period exceeds the average expected lifetime of the furnace under numerous foreseeable retrofit scenarios. New construction life cycle cost savings are positive in all scenarios based on DOE's installed cost assumptions. However, under DOE's assumed costs, the average installed cost of a 90% condensing furnace is lower than the installed cost of a non-condensing furnace($2,447 vs. $2,552 average installed cost).

- The impact of updated energy price forecasts, marginal energy costs, and furnace expected lifetime on the economic justification of 90% furnaces is substantial, and can shift the result from a net positive average result to a net negative average result in North Regions.

- Negative life cycle cost findings for the retrofit market would likely be further reinforced if a parametric analysis of the DFR venting installed costs that were based on empirical and engineering data from the 1990's could be performed. However, attempted scenario analyses yielded unreasonable preliminary results. Challenges with debugging the inputs prevented these scenarios from being executed within the desired timeframe.

- The overall impact of orphaned water heater fuel switching needs to be included in the analysis of consumer impacts and LCC savings. While this fuel switching may occur only in a fraction of overall installations, the impact per home is significant ($2,846 LCC per home in this example), and should be carefully considered by DOE before making its determination.

- The DOE analytical tool and results were difficult to evaluate and use without additional assistance due to very limited user documentation and compatibility issues with the LCC spreadsheet and Crystal Ball software. More instructive user documentation and reasonable access to input variables necessary to run sensitivity analyses on critical parameters such as energy price, equipment costs, and installed costs would help other analysts navigate the tool, conduct parametric analyses, and correctly interpret results.

9.0 Appendix A: DFR User Instructions for Furnaces LCCA Spreadsheet

APPENDIX 8-A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET FOR FURNACES

TABLE OF CONTENTS

APPENDIX 8-A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET FOR FURNACES

8-A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on the Department of Energy's (DOE's) central air conditioner and furnace rulemaking website:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_nopr_analysis.html. From that page, follow the links to the notice of proposed rulemaking (NOPR) phase and then to Analytical Tools.

8-A.2 STARTUP

DOE's spreadsheet enables users to perform life-cycle cost (LCC) and payback period (PBP) analyses for each product class. One spreadsheet exists for all three furnace product classes.

To examine the spreadsheets, DOE assumes that the user has access to a personal computer with a hardware configuration capable of running Windows XP or later. All LCC spreadsheets require Microsoft Excel 2003 or later installed under the Windows operating system. Because certain variables inside the spreadsheets are defined as distributions, a copy of Crystal Ball (a commercially available add-on program) is required to view them.

8-A.3 DESCRIPTION OF LIFE-CYCLE COST WORKSHEETS

For all of the furnace product classes, DOE created a single spreadsheet containing a collection of worksheets. Each worksheet represents a conceptual component within the LCC calculation. To facilitate navigability and identify how worksheets are related, each worksheet contains an area on the extreme left showing variables imported to and exported from the current worksheet. The LCC spreadsheet contains the following worksheets:

Summary The *Summary* worksheet contains a user interface to manipulate energy price trend and start year inputs and to run the Crystal Ball simulation. LCC and PBP simulation results for each efficiency level are also displayed here.

LCC&PB Calcs The *LCC&PB Calcs* worksheet shows LCC calculation results for different efficiency levels for a single Residential Energy Consumption Survey (RECS) household.[1] During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household.

Rebuttable Payback The *Rebuttable Payback* worksheet contains the total and incremental manufacturer costs, retail prices, the installation costs, the repair and maintenance costs, energy use calculations, and the simple PBP calculations for each efficiency level. DOE's furnace test procedure is used to calculate

8-A-1

parameters used in energy use calculations.

Equip Price	The *Equip Price* worksheet calculates retail price values used as inputs in the LCC calculations in the *Summary* worksheet. DOE applied baseline and incremental markups to calculate final retail prices. DOE calculated the markups differently for replacement units and new units.
Installation Cost	The *Installation Cost* worksheet provides the weighted average installation cost for each design option. These results are used to calculate the total installed prices of the design options.
Maintenance and Repair Cost	The *Maintenance and Repair Cost* worksheet provides the maintenance and repair costs for each design option. These results are used to determine operating costs for the design options.
RECS Sample	The *RECS* worksheet contains the RECS 2005 household data for each product class. During a Crystal Ball simulation, DOE uses these household characteristics to determine the analysis parameters.
Base Case AFUE	The *Base Case AFUE* worksheet determines the annual fuel utilization efficiency (AFUE) of the base case units in 2016.
AFUE (Existing)	The *Existing AFUE* worksheet includes the furnace efficiency for all years during the period 1966-2005.
Energy Use	The *Energy Use* worksheet calculates annual energy use by fuel type, depending on product class. The annual energy use calculations for each design option are inputs to the *LCC&PB Calcs* worksheet to calculate the annual operating cost of the LCC.
Energy Price	The *Energy Price* worksheet shows the estimated monthly natural gas, electricity, and oil prices.
Energy Price Trends	The *Energy Price Trends* worksheet shows the future price trends of the different heating fuels. DOE used energy price data and forecasts from the Energy Information Administration's (EIA's) Annual Energy Outlook 2010 for the period until 2035 and extrapolated beyond 2035.[2]
Discount Rate	The *Discount Rate* worksheet contains the distributions of discount rates for replacement and new units.
Lifetime	The *Lifetime* worksheet contains the distribution of lifetimes for equipment of that product class.

8-A-2

Labor Costs The *Labor Costs* worksheet contains the labor cost factors by region.

Census Population Data The *Census Population Data* worksheet contains the Census estimated housing units by State.

Models Data The *Models Data* worksheet includes characteristics of the furnace products used in the analysis.

Energy Use Adjustment Factors The *Energy Use Adjustment Factors* worksheet contains the energy use adjustment factors by region according to heating and cooling degree day data.

Weather Data The *Weather Data* worksheet contains heating degree days, cooling degree days, heating and cooling outdoor design temperature, and annual mean temperature by weather station.

Shipments The *Shipments* worksheet contains historical furnace shipments by State by product class.

NIA Inputs The *NIA Inputs* worksheet contains intermediate inputs used for other DOE analyses.

8-A.4 BASIC INSTRUCTIONS FOR OPERATING THE LIFE-CYCLE COST SPREADSHEETS

Basic instructions for operating the LCC spreadsheet are as follows:

1. Once the LCC spreadsheet has been downloaded, open the file using Excel. Click "Enable Macro" when prompted and then click on the tab for the *Summary* worksheet.

2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to fit your monitor.

3. The user can change the parameters listed under USER OPTIONS on the *Summary* worksheet. There are three drop-down boxes and one command button. The default parameters are:

    a. Energy Price Trend: Defaults to "AEO 2010 - Reference Case." To change the input, use the drop-down menu and select the desired trend (Reference, Low, or High).

    b. Start Year: Defaults to "2016." To change the value, use the drop-down menu and select the desired year.

8-A-3

c. # of Trials: Defaults to "10,000." To change the value, use the drop-down menu and select the desired number of trials (1,000, 2,000, 3,000, 5,000, or 10,000).

d. Subgroup: Defaults to "National." To change the sample used for LCC and PBP calculations, use the drop-down menu and select the desired subgroup from the available samples (National, Low-Income, Senior-Only, Multi-Family).

4. To run the Crystal Ball simulation, click the "run" button (you must re-run after changing any parameters). The spreadsheet will then be minimized. You can monitor the progress of the simulation by watching the count of iterations at the left bottom corner. When the simulation is finished, the worksheet named *Summary* will reappear with the results.

REFERENCES

1. U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2005 Public Use Data Files,* 2005. <http://www.eia.doe.gov/emeu/recs/recspubuse05/pubuse05.html>

2. Energy Information Administration, *Annual Energy Outlook 2010 with Projections to 2035*, 2010. Washington, DC. Report No. DOE/EIA-0383(2010). <http://www.eia.doe.gov/oiaf/aeo/>

[1] U.S. Department of Energy website. "Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document." Chapter 8. Life-Cycle Cost and Payback Period Analyses. Accessed October 4, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

[2] U.S. Department of Energy, Energy Information Administration presentation. June 21, 2011. "Shale Gas and the Outlook for U.S. Natural Gas Markets and Global Gas Resources". Organization for Economic Cooperation and Development (OECD) conference. Paris, France.

[3] Bass, F. 1980. The Relationship between Diffusion Rates, Experience Curves, and Demand Elasticities for Consumer Durable Technological Innovations. Journal of Business. Vol. 53, Issue 3, pp. 51-67.

[4] Weiss, M., Junginger, M., Patel, M., Blok, K. 2010. A Review of Experience Curve Analyses for Energy Demand Technologies. Technological Forecasting and Social Change. Vol. 77, pp. 411-428.

[5] Weiss, M., Junginger, M., Patel, M., Blok, K. 2010. A Review of Experience Curve Analyses for Energy Demand Technologies. Technological Forecasting and Social Change. Vol. 77, pp. 411-428.

[6] U.S. Department of Energy website. "Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document." Appendix 8-J. Forecast of Equipment Price Trends for Central Air Conditioners, Heat Pumps and Furnaces. Accessed October 4, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

[7] Multi-Year Program Plan - Building Regulatory Programs - U. S. Department of Energy - Energy Efficiency and Renewable Energy - Building Technologies Program, Page 33, October 2010.

[8] Appliance magazine. June 2011. U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture. UBM Canon Data Products. Los Angeles, CA.

[9] U.S. Department of Energy, Energy Information Administration. Assumptions to the Annual Energy Outlook 2011. Accessed September 23, 2011.

[10] U.S. Department of Energy website. "Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document." Chapter 8. Life-Cycle Cost and Payback Period Analyses. Accessed October 4, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

[11] U.S. Department of Energy, Furnace and Boiler Final Rule Technical Support Document, Appendix C. Installation Model, Page C-29, November 2007.

[12] Paul, D. Sheppard, W., Whitacre, G., Fischer, R. Rutz, A., Locklin, D., Crisafulli, J., Stickford, G., Murray, J., Landstrom, D., Talbert, S., Buhr, A. 1991. Assessment of Technology for Improving the Efficiency of Residential Gas Water Heaters. Gas Research Institute. Chicago, IL. GRI-91/0298.

[13] Jakob, F., Crisafulli, J., Menkedick, J., Fischer, R., Philips, D., Osbone, R., Cross, J., Whitacre, G., Murray, J., Sheppard, W., DeWirth, D., Thrasher, W. 1994. Assessment of Technology for Improving Efficiency of Residential Gas Furnaces and Boilers, Volume I and II – Appendices. Gas Research Institute. Chicago, IL. GRI-94/0175

[14] U.S. Department of Energy website. "Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document." Appendix 8-B Installation Cost Determination for Furnaces. Accessed October 4, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html.

[15] Department of Energy, Residential Furnaces and Central Air Conditioners and Heat Pumps Direct Final Rule Technical Support Document, Appendix 8-B. Installation Cost Determination for Furnaces, Page 8-B-35, July 2011.