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Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies and Its Impact in Southern California

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Executive Summary

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

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

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

As a result of this detailed examination, GTI uncovered a serious technical flaw in the methodology DOE used to establish the homes that would be impacted by the proposed rule. GTI also uncovered a serious technical flaw in the methodology DOE used in its fuel switching analysis. Key input variables used in the DOE NOPR LCC model are also inaccurate. After uncovering these serious technical deficiencies, GTI developed an alternative approach to determine the baseline using a consumer economic decision (CED) framework based on criteria that more accurately depict how rational consumers choose one furnace option over another. GTI also identified a number of improvements to the input variables used in the DOE NOPR LCC model. GTI Integrated Scenario Int-5 includes several refinements to the DOE NOPR LCC model, including rational consumer economic decision making and improved input variables, and forms the primary basis for comparison to proposed furnace efficiency rulemaking; other scenarios are technically defensible as well based on different factors and are included for reference purposes. GTI Scenario Int-5 was selected based in three key factors:

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

Access to the 10,000 trial cases also permitted GTI analysts to identify cases in California and Southern California using weather station information available in the Crystal Ball output files. This granularity enabled GTI to use the same parametric scenarios as those used in GTI

Technical Report No. GTI-15/0002 to determine the impact of the DOE NOPR LCC model results on Southern California consumers.

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

- The DOE NOPR LCC model results show negative life cycle costs imposed on Southern California consumers. More Southern California consumers suffer a "Net Cost" than experience a "Net Benefit" under the DOE proposed rule. The 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the DOE requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life in Southern California.
- DOE's random baseline furnace assignment methodology is technically flawed. Replacing DOE's methodology with economic decision making criteria changes both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and significantly reduces the financial benefit of the rule, both nationally and regionally.
- DOE's predictive LCC model results combine random decisions and limited application of economic decisions that overstate LCC savings compared to a CED framework methodology.
- DOE's predictive LCC model results include an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the RECS survey that differ from gas company tariff data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data. Taken together, the DOE input information and forecasts associated with these parameters increase LCC savings compared to more current forecasts and available market data.
- GTI Integrated Scenario Int-5, based on improved consumer economic decision criteria and modifications to DOE's input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace in Southern California residences. The 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the DOE requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life in Southern California.

1 Background

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

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

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

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

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

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

DOE issued a notice of proposed rulemaking (NOPR), published in the Federal Register on March 12, 2015, that proposes a single national standard at a minimum efficiency level of 92% AFUE for non-weatherized gas furnaces and mobile home gas furnaces, as shown in Table 1. Under the DOE NOPR, these 92% AFUE standards would take effect in 2021.

Table 1: DOE Proposed Standards for Residential Furnaces

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

A technical support document (TSD) prepared for DOE by Lawrence Berkeley National Laboratory (LBNL) provides the technical rationale for DOE's determination that the proposed standard is technologically feasible, economically justified, and will save significant amounts of energy. The technical basis of the TSD is a complicated LCC spreadsheet tool developed by LBNL for DOE over a period of several years for use in several rulemakings, including this NOPR. The LCC model uses an Excel® spreadsheet that invokes the Oracle® Crystal Ball predictive modeling and forecasting software. DOE used this spreadsheet modeling tool to predict the LCC and payback periods (PBP) for the proposed efficiency increases. Figure 1 shows the flow chart for the DOE TSD analysis. Figure 2 and Figure 3 below show the summary tables of the results included in the NOPR for non-weatherized gas furnaces and mobile home gas furnaces.

The underlying methodology and multiple inter-related variables in the DOE predictive LCC model strongly affect the results of LCC and PBP analyses, which jointly serve as the technical basis for DOE's determination that the proposed rule is economically justified. The methodologies and input data used within the DOE predictive LCC spreadsheet tool to justify the 92% AFUE furnace standard for non-weatherized gas furnaces are the primary focus of the GTI report[1] and accompanying spreadsheets prepared for AGA and APGA under a separate research project. This report uses a subset of information available under that project to provide a similar analysis and results for the Southern California market.

1 Leslie, N.P. 2015. Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies, GTI-15/0002. Des Plaines, IL. Gas Technology Institute.

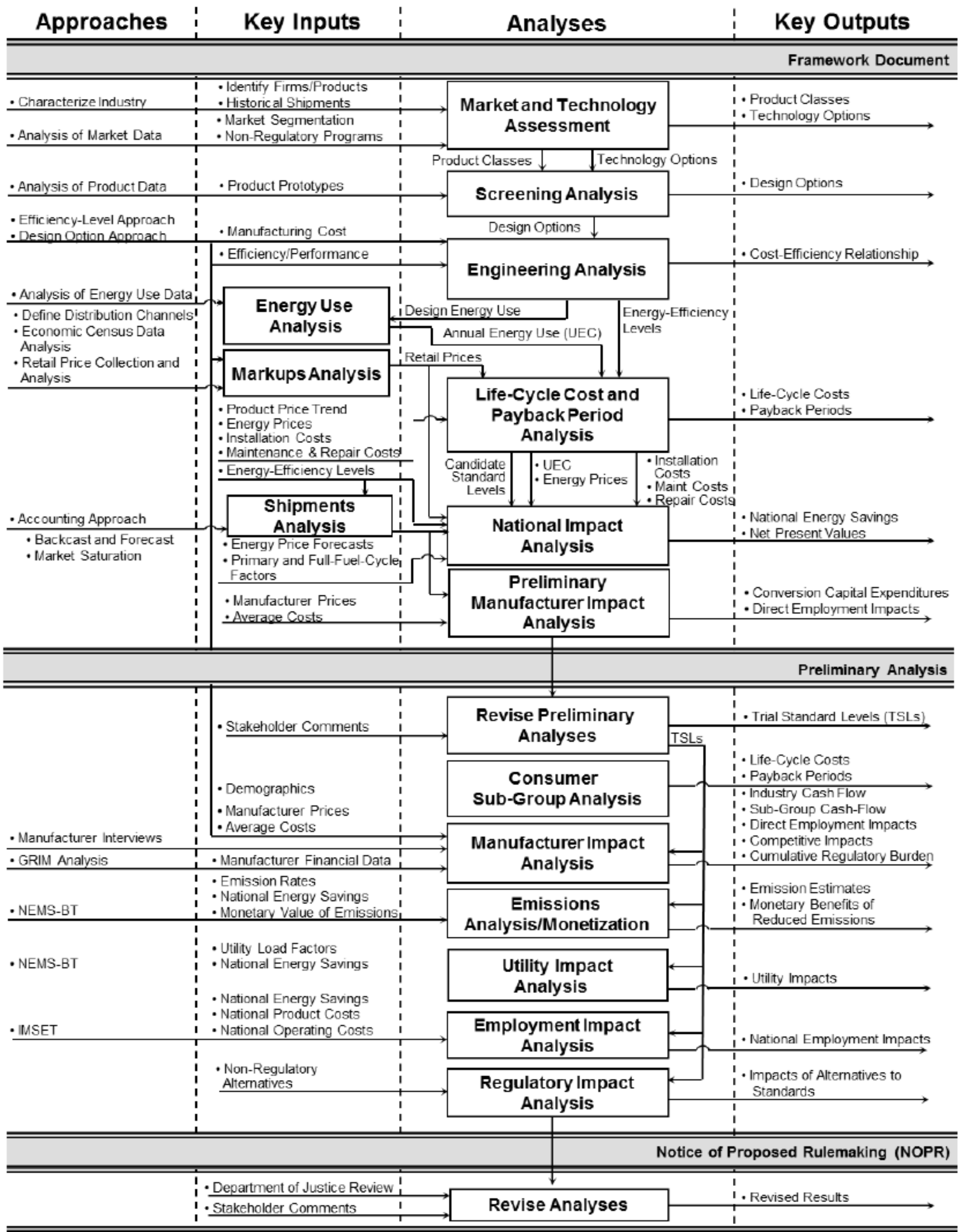

Figure 1: NOPR Technical Support Document Analysis Methodology

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

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

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

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

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

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

Figure 3 Lifecycle Cost and Payback Period Results for Mobile Home Gas Furnaces

Source: DOE Notice of Proposed Rulemaking, Technical Support Document Chapter 8[4]

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

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

2 LCC Analysis Methodology for Southern California

2.1 Overview

GTI Technical Report No. GTI-15/0002 describes in detail the methodology for the evaluation of the DOE NOPR LCC model and results. The following paragraphs provide an overview of the methodology and its application in the Southern California market impact analysis.

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

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

To account for these and other variables, the DOE LCC analysis spreadsheet model methodology uses complex algorithms that include interactive impacts among a large number of input parameters. Some algorithms, such as manufacturer component costs and consumer decision making logic, use proprietary or confidential technical and cost information. DOE's methodology includes a combination of fixed values, partial or full distributions, and random assignments to conduct its forecasting analysis. After incorporating all these various distributions and random assignments, the DOE LCC analysis model provides a single answer for key parameters rather than a probability distribution of possible results with error bars or other indicator of accuracy, precision, and confidence level.

To explore the impact of various parameters on LCC results, GTI analysts added Excel Visual Basic for Applications (VBA) code to the DOE LCC spreadsheet. The VBA code captured outputs of interest and enabled a detailed analysis of the Crystal Ball trial cases in the DOE LCC spreadsheet as well as GTI's parametric scenarios. To increase the size of the California and Southern California building sample, the number of trials was increased to 100,000 from the DOE default of 10,000 trials. This produced a sample of more than 10,000 California buildings. The VBA code stepped the Crystal Ball simulation through each of the

Life-Cycle Cost and Payback Period Analysis. http://www.regulations.gov/#!documentDetail;D=EERE-2014-BT-STD-0031-0027

100,000 trial cases, capturing desired output information related to each trial case. It did not affect any calculations in the DOE NOPR LCC model (referred to as Scenario 0 in this report) or any of the GTI parametric runs that examined the decision making methodology, input variable modifications, and integrated scenarios.

Access to the 100,000 trial cases also permitted GTI analysts to identify cases in California and Southern California using weather station information available in the Crystal Ball output files. This granularity enabled GTI to use the same parametric scenarios as those used in GTI Technical Report No. GTI-15/0002 to determine the impact of the DOE NOPR LCC model results on Southern California consumers.

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

- Decision Making Algorithms
- Input Data Modifications
- Integrated Scenarios

This report describes and summarizes results of GTI Scenario Int-5, one of several GTI scenarios that integrate several reasonable and technically defensible parameters into a single scenario for comparison with the DOE LCC model results. GTI Scenario Int-5 was selected for comparisons in this report based in three key factors:

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

2.2 Consumer Economic Decision Analysis Framework

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

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

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

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

Table 2 Consumer Economic Decision Making Framework

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

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

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

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

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

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

2.3 Base Case Furnace Assignment Methodology

The DOE NOPR LCC model includes economic criteria and a distribution of allowable cost recovery times in its trial standard level (TSL) furnace analysis and fuel switching decision algorithm. However, DOE's Base Case furnace assignment algorithm ignores economic decision making parameters. Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly to each of the 10,000 trial cases in the DOE LCC model (or 100,000 trials for purposes of this analysis). The economics of a particular efficiency level selection compared to other levels (e.g., 80% AFUE vs. 92% AFUE) are not considered in DOE's baseline furnace decision for any of the trial cases.

DOE's decision to use a random assignment methodology to assign base case furnace efficiency to each of the trial cases in the Crystal Ball simulation is a significant technical flaw with meaningful impact on the DOE NOPR LCC results. A random assignment methodology misallocates a random fraction of consumers that use economic criteria for their decisions and results in higher LCC savings compared to rational economic decision making criteria.

The overstated savings in the DOE NOPR LCC model occur for two different reasons:

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

DOE's Base Case furnaces in the trial case buildings are intended to be representative of the RECS survey furnace distribution across various locations and categories. Random assignment of the Base Case furnace does not achieve this key objective and is not a technically defensible proxy for rational residential decision making processes. GTI's Base Case furnace assignment algorithm incorporates a CED framework into the trial case assignments to provide a reasonable, technically defensible Base Case furnace assignment algorithm for the LCC analysis.

2.4 DOE Fuel Switching Decision Making Methodology

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

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

2.5 American Home Comfort Study Application

The DOE fuel switching decision algorithm chooses the option with the longest switching payback if more than one option's switching payback period is over 3.5 years. DOE selected the 3.5 year switching payback period as the decision point based on analysis of four versions (2006, 2008, 2010, and 2013) of the American Home Comfort Study (AHCS) published by Decision Analyst.[5] The derivation of the 3.5 year switching payback period criterion used by DOE is described in section 8J.2.2 of the TSD. It comes from the amount consumers responding to the AHCS reported being willing to pay for a 25 percent improvement in the efficiency of their HVAC system and the space conditioning costs determined from the 2001, 2005, and 2009 RECS information. The average amount consumers were willing to pay from the AHCS was divided by 25% of the energy costs for space conditioning derived from the RECS information to arrive at 3.5 years.

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

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

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

2.6 GTI Decision Making Analysis Methodology

To examine the impact of DOE's random baseline decision making and fuel switching algorithms on modeling results, GTI analysts developed several parametric scenarios that investigate the impact of economic decision making criteria on LCC model results. The scenarios GTI analysts developed and evaluated include various combinations of data, surveys, studies, and engineering principles to incorporate consumer economic and non-economic decision making processes into the LCC analysis. The CED framework, coupled with the availability of detailed information from the AHCS, permitted consideration of a wide range of decision making scenarios under different allowable payback period and "switching payback period" parametrics.

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

It is important to identify and justify the alternative scenario or scenarios that produce credible and technically defensible results for comparisons with the DOE LCC model results. Integrated scenarios that include combinations of scenarios that address economic decision making and substitution of improved input variables for those used by DOE are most suited to that purpose. As noted in Section 2.1, GTI analysts selected Integrated Scenario Int-5 for that purpose. Since Scenario 24 is included in Scenario Int-5 (along with Input Data Scenario I-16), the methodology description below focuses on Scenario 24, comprising decision making parametrics D2, D4, D5, and D8, which are summarized in Report No. GTI-15/0002.

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

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

2.7 GTI Input Data Analysis Methodology

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

Similar to the GTI decision making scenarios, the input data scenarios evaluated by GTI analysts incorporate individual and combined parametrics that modify, in the manner specified for each parameter, the DOE LCC model input data parameters. Similar to the approach taken in the GTI decision making scenarios, GTI analysts evaluated alternative input parameters with the potential to produce credible and technically defensible results for comparisons with the DOE LCC model results. Input Data Scenario I-16 is included in Scenario Int-5, comprising input variable parametrics I2, I6, I8, and I13, which are summarized in Report No. GTI-15/0002.

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

2.8 GTI Integrated Scenario Analysis Methodology

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

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

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

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

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

3 LCC Analysis Results for Southern California

Table 3 shows LCC savings for each TSL compared to the DOE NOPR LCC analysis results for California and Southern California. Table 4 shows fuel switching percentages in homes impacted by the rule for each TSL compared to the DOE NOPR LCC analysis results for California and Southern California.

Table 5 summarizes the DOE NOPR LCC analysis results for Southern California. Table 6 summarizes GTI Scenario Int-5 LCC analysis results for Southern California.

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

- The DOE NOPR LCC model results show negative life cycle costs imposed on Southern California consumers. More Southern California consumers suffer a "Net Cost" than experience a "Net Benefit" under the DOE proposed rule. The 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the DOE requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life in Southern California.
- DOE's random baseline furnace assignment methodology is technically flawed. Replacing DOE's methodology with economic decision making criteria changes both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and significantly reduces the financial benefit of the rule, both nationally and regionally.
- DOE's predictive LCC model results combine random decisions and limited application of economic decisions that overstate LCC savings compared to a CED framework methodology.
- DOE's predictive LCC model results include an older version of the Annual Energy Outlook forecasts; engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the RECS survey that differ from gas company tariff data; and condensing furnace shipment forecasts based on assumed current market conditions that differ from AHRI condensing furnace shipment data. Taken together, the DOE input information and forecasts associated with these parameters increase LCC savings compared to more current forecasts and available market data.
- GTI Integrated Scenario Int-5, based on improved consumer economic decision criteria and modifications to DOE's input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace in Southern California residences. The 92% furnace proposed in the DOE NOPR as well as any other condensing furnace efficiency levels do not meet the DOE requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life in Southern California.

Table 3 LCC Savings – DOE NOPR vs. GTI Scenario Int-5 for Southern California

Scenario	California	Southern California	Residential Replacement	Residential Replacement - Southern California	Residential New	Residential New - Southern California	Senior Only	Senior Only - Southern California	Low Income	Low Income - Southern California
	LCC Savings Summary - 90% TSL									
DOE NOPR (GTI Scenario 0)	$122	-$137	-$50	-$269	$857	$405	$250	-$92	-$113	-$506
GTI Scenario Int-5	-$526	-$635	-$605	-$694	-$176	-$392	-$469	-$623	-$842	-$1,046
	LCC Savings Summary - 92% TSL									
DOE NOPR (GTI Scenario 0)	$186	-$98	-$241	-$228	$903	$435	$328	-$33	-$60	-$474
GTI Scenario Int-5	-$492	-$609	-$241	-$667	-$145	-$375	-$432	-$586	-$807	-$1,032
	LCC Savings Summary - 95% TSL									
DOE NOPR (GTI Scenario 0)	$221	-$115	-$228	-$243	$893	$392	$393	-$35	-$78	-$584
GTI Scenario Int-5	-$719	-$850	-$228	-$934	-$364	-$520	-$638	-$781	-$1,017	-$1,278
	LCC Savings Summary - 98% TSL									
DOE NOPR (GTI Scenario 0)	$156	-$259	-$296	-$398	$815	$231	$331	-$158	-$125	-$651
GTI Scenario Int-5	-$847	-$1,026	-$296	-$1,132	-$476	-$680	-$749	-$971	-$1,089	-$1,433

Table 4 Fuel Switching – DOE NOPR vs. GTI Scenario Int-5 for Southern California

Percent of Impacted Buildings Switching

	Scenario 0 (DOE Baseline LCC Model)										
	TSL	California	Southern California	Residential Replacement	Replacement - Southern California	Residential New	Residential New - Southern California	Senior Only	Senior Only - Southern California	Low Income	Low Income - Southern California
1	NWGF 90%	24.0%	28.7%	20.3%	24.0%	39.7%	47.2%	24.0%	21.2%	31.3%	43.5%
2	NWGF 92%	23.5%	27.8%	19.9%	23.4%	38.5%	45.4%	23.4%	20.5%	30.5%	43.1%
3	NWGF 95%	24.0%	27.5%	20.7%	23.6%	37.7%	42.8%	23.0%	21.1%	28.5%	40.5%
4	NWGF 98%	28.1%	30.4%	25.0%	27.2%	40.8%	43.0%	26.4%	24.0%	31.3%	43.7%

	Scenario Int-5 (Scenarios 24 & I-16)										
	TSL	California	California	Replacement	Replacement -	New	New - Southern	Senior Only	- Southern	Income	Southern
1	NWGF 90%	25.2%	28.1%	24.6%	24.6%	39.0%	42.9%	27.4%	24.7%	43.0%	56.0%
2	NWGF 92%	24.1%	27.4%	24.0%	24.0%	39.0%	43.1%	25.3%	23.2%	40.6%	54.9%
3	NWGF 95%	28.6%	32.3%	28.9%	28.9%	40.9%	47.4%	24.8%	22.2%	41.8%	55.7%
4	NWGF 98%	32.0%	36.5%	33.7%	33.7%	44.1%	48.4%	28.6%	27.9%	45.9%	61.9%

Table 5 DOE NOPR LCC Analysis Summary Results for Southern California

Southern California Only		Scenario 0 (DOE NOPR LCC Model)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	-$137	3,290	2,802	52%	15%	33%
2	NWGF 92%	-$98	3,290	2,894	50%	12%	38%
3	NWGF 95%	-$115	3,290	3,181	56%	3%	40%
4	NWGF 98%	-$115	3,290	3,289	56%	0%	40%

Residential - Replacement Southern California Only		Scenario 0 (DOE NOPR LCC Model)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	-$269	2,640	2,256	62%	15%	24%
2	NWGF 92%	-$228	2,640	2,323	59%	12%	29%
3	NWGF 95%	-$243	2,640	2,544	64%	4%	32%
4	NWGF 98%	-$243	2,640	2,639	64%	0%	32%

Residential - New Southern California Only		Scenario 0 (DOE NOPR LCC Model)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	$405	600	508	13%	15%	72%
2	NWGF 92%	$435	600	531	13%	12%	76%
3	NWGF 95%	$392	600	591	23%	2%	76%
4	NWGF 98%	$392	600	600	23%	0%	76%

Table 6 GTI Scenario Int-5 LCC Analysis Summary Results for Southern California

Southern California Only		Scenario Int-5 (Scenarios 24 & I-16)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	-$635	3,290	2,499	65%	24%	11%
2	NWGF 92%	-$609	3,290	2,589	64%	21%	14%
3	NWGF 95%	-$850	3,290	3,001	81%	9%	11%
4	NWGF 98%	-$1,026	3,290	3,127	84%	5%	11%

Residential - Replacement Southern California Only		Scenario Int-5 (Scenarios 24 & I-16)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	-$694	2,640	2,081	74%	21%	4%
2	NWGF 92%	-$667	2,640	2,167	74%	18%	8%
3	NWGF 95%	-$934	2,640	2,498	87%	5%	8%
4	NWGF 98%	-$1,132	2,640	2,561	89%	3%	8%

Residential - New Southern California Only		Scenario Int-5 (Scenarios 24 & I-16)					
Level	Description	LCC Savings	Total Buildings	Affected Buildings	Net Cost	No Impact	Net Benefit
NWGF							
0	NWGF 80%						
1	NWGF 90%	-$392	600	387	25%	36%	40%
2	NWGF 92%	-$375	600	390	24%	35%	42%
3	NWGF 95%	-$520	600	466	54%	22%	24%
4	NWGF 98%	-$680	600	521	64%	13%	23%