Attachment E to the Comments of

AGA, APGA, NPGA, Spire, and ONE Gas

Docket Number EERE-2021-BT-STD-0027

August 1, 2022

Attachment E

Comments of Spire Inc.
January 6, 2016

Docket Number EERE-2014-BT-STD-0031

COMMENTS OF SPIRE INC.

BEFORE THE
OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY
UNITED STATES DEPARTMENT OF ENERGY
WASHINGTON, D.C.

Supplemental Notice of Proposed Rulemaking

Energy Conservation Program; Energy Conservation Standards for Residential Furnaces

81 Fed. Reg. 65720 (September 23, 2016)

Docket Number EERE-2014-BT-STD-0031/ RIN NO. 1904-AD20

Submitted via email to: ResFurnaces2014STD0031@ee.doe.gov

January 6, 2016

Spire Inc., ("Spire") is pleased to submit these Comments in response to the Supplemental Notice of Proposed Rulemaking ("SNOPR") of the Department of Energy, Office of Energy Efficiency and Renewable Energy ("DOE" or "Department") published at 81 Fed. Reg. 65720 (September 23, 2016). Spire, formerly the Laclede Group, Inc., is a holding company that owns and operates Laclede Gas Company, including its Missouri Gas Energy operating division, the two largest natural gas distribution companies in the state of Missouri, Alabama Gas Corporation, the largest natural gas distribution company in the state of Alabama, and Mobile Gas Service Corporation and Willmut Gas and Oil Company, which operate in Alabama and Mississippi, respectively. Spire's utility companies have been distributing gas in one form or another in their respective service areas for more than a century and a half. Today, they collectively provide natural gas distribution service to more than 1.7 million residential, commercial and industrial customers.

Spire supports energy conservation. Spire's utility businesses have supported energy efficiency education for homeowners and businesses alike for many years, and have invested significant resources in rebate programs promoting the sale of high-efficiency equipment and appliances. However, ill-conceived efficiency regulations can do considerable unnecessary harm, and Spire, its natural gas distribution companies, and the communities and customers those companies serve would be directly and adversely affected by the energy conservation standards proposed in the SNOPR. In particular, the proposed standards would eliminate non-condensing residential gas furnaces, forcing many consumers to switch from gas to electric appliances, a result that will leave consumers with higher energy costs and produce a loss of customers – and a direct loss of revenue – for natural gas distribution companies including those owned by Spire. Spire therefore has a keen interest in the subject of this rulemaking proceeding, as demonstrated by its comments in response to the previous Notice of Data Availability

(NODA)[1] and Notice of Proposed Rulemaking (NOPR)[2] issued in this rulemaking proceeding and DOE's earlier Direct Final Rule (DFR) concerning residential furnace standards,[3] (all of which comments are incorporated herein by reference).

Executive Summary

The regulatory analysis offered in support of the SNOPR seeks to justify heating efficiency standards that are not justifiable: heating efficiency standards for residential gas furnaces that can be achieved only through the use of condensing technology. The problems with these standards start with the fact that condensing gas furnaces are not merely costly; they are also subject to significant installation constraints that – among other things – make them incompatible with the existing vent systems found in the vast majority of American homes. As a result, there are many cases in which condensing gas furnaces cannot serve as direct substitutes for the non-condensing gas furnaces they would ostensibly replace, leaving consumers without any practical gas furnace option. In most other cases, it takes significant furnace operating hours to make an investment in a condensing gas furnace economically justifiable, and even then, there are cases in which the cost of installation issues imposed by condensing technology are such that condensing furnaces would not be an economical option. As a result, condensing gas furnaces often – but do not always – make economic sense in areas with long heating seasons, and most often do not make economic sense in the parts of the country with relatively short heating seasons.

Consumers generally consider economics when they are investing in a major appliance. As a result, consumers tend to purchase condensing gas furnaces when such furnaces are a practical option,

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[1] 80 Fed. Reg. 55038 (September 14, 2015).

[2] 80 Fed. Reg. 13120 (March 12, 2015).

[3] 76 Fed. Reg. 37408 (June 27, 37408).

they can afford the initial investment required, and efficiency benefits will pay back the cost of their investment within a reasonable period of time. The existence of this tendency is demonstrated beyond any reasonable doubt by the fact that condensing gas furnaces already dominate the market in areas where the economic justification for them tends to be strong, and have considerably smaller market shares in areas where the economic justification for them tends to be significantly weaker. This is important, because a condensing efficiency standard for gas furnaces (*i.e.*, a standard that can only be achieved through the use of condensing technology) would only serve to impose condensing gas furnaces on consumers who would not choose to purchase them on their own: primarily consumers for whom condensing gas furnaces present unacceptable installation challenges, provide inadequate economic returns, or require an unaffordable initial investment. It follows that a condensing standard for residential furnaces can be expected to have negative consequences for a variety of reasons.

Consumers facing serious installation problems – or for whom condensing gas furnaces simply are not a practical option – would generally have to consider alternatives to a gas furnace, and would frequently need to engage in "fuel switching" by substituting electric heating appliances for gas furnaces. In such cases, the presumed efficiency benefits of a condensing gas furnace would not be realized and – due to the inherent efficiency advantages of gas appliances over electric appliances – overall energy consumption and carbon emissions would, on average, increase. Consumers for whom condensing gas furnaces simply offer unacceptable economic returns might decide to take their lumps on an economically unjustified investment, but in many cases they would also consider – and sometimes select – electric alternatives that, on average, would consume more energy overall and result in more carbon emissions than a non-condensing gas furnace. Consumers who simply cannot afford to invest in a condensing gas furnace – particularly low-income consumers – would often be compelled to opt for a low-cost electric alternative, often electric resistance furnaces or space heaters that would – by far – be the worst choice from the standpoint of overall energy consumption, carbon emissions, and consumer economics. In other cases, such customers, driven by economic necessity, attempt to keep their furnaces operable, safely or otherwise. Worst of all, some will resort to patently unsafe ways to heat their homes; that can and do have tragic consequences.

If these do not sound like justifiable regulatory results, it is because they are not. Such results might appeal to those who stand to gain competitive advantage or are ruthlessly prepared to break as many eggs as it takes to end the residential use of natural gas as quickly as possible. However, the results for the consumers– particularly low-income consumers – would be egregious, which begs the question: how can DOE's regulatory analysis suggest that a condensing standard for residential gas furnaces would be economically justified? There are several answers, and none of them are good.

DOE's entire analysis is skewed by its reliance on unreasonable estimates and assumptions that systematically understate the costs of condensing gas furnaces while systematically overstating the benefits that a condensing standard for gas furnaces would provide. For example, DOE has grossly underestimated the installed cost of condensing gas furnaces, grossly overestimated the price of natural gas, and completely ignored the cost of additional maintenance condensing gas furnaces require. Similarly, it has overstated gas savings and understated the adverse impacts of fuel switching. As serious as these problems are – and they are serious – they are less troubling than more profound flaws built into the methodology of DOE's regulatory analysis.

In theory, DOE's regulatory analysis is based on a modeling approach in which it starts by constructing ten thousand "trial cases" to represent the full range of furnace installation scenarios that exist in the United States. It is then supposed to conduct simulations to determine how its proposed standards would change furnace installation outcomes in those ten thousand cases and to identify the trial cases in which furnace installation outcomes would be altered by the proposed standards. For those cases, DOE is then supposed to compare the economic consequences of the outcomes that would occur in the absence of the proposed standards (the "base case") with the economic consequences of the outcomes that would only occur if the proposed standards were adopted (the "standards case"). DOE is then supposed to compare the base case and standards case results to determine whether the costs of condensing gas furnaces would be justified by the efficiency benefits condensing gas furnaces would provide.

This, however, is not the kind of analysis DOE actually performed. Perhaps the most fundamental defect in DOE's analysis lies in the fact that its ten thousand trial cases are not reasonably designed to represent the real world in which consumers generally purchase condensing gas furnaces when it makes economic sense to do so and generally decline to purchase condensing gas furnaces where there would be installation problems, insufficient economic returns, or insufficient resources for the initial investment a condensing gas furnace would require. Instead, **DOE's trial cases represent an alternative universe in which consumers choose their gas furnaces with literally no consideration of economic factors at all.** DOE constructed this alternative universe by "assigning" condensing or non-condensing furnaces to the ten thousand trial cases used as the basis for analysis on a random basis, as though consumers who purchase condensing gas furnaces on their own are no more likely to make economically advantageous purchases – and no more likely to avoid economically disastrous purchases – than consumers who would only purchase a condensing gas furnaces if efficiency standards forced them to do so. This approach has significant impacts:

- It systematically eliminates many trial cases in which the proposed standards would impose significant net costs by arbitrarily "assigning" condensing gas furnaces to those cases as though consumers would choose those outcomes for themselves; and
- It manufactures regulatory benefits by *failing* to assign condensing gas furnaces to trial cases in which such furnaces would provide substantial economic benefits, as though those outcomes would occur only if they were forced upon consumers by the proposed standards.

In short, DOE's economic analysis does not actually address the consequences of the outcomes its proposed standards would impose; instead it addresses a substantially different set of outcomes; one that includes significantly more favorable outcomes, and significantly fewer net cost outcomes, than the proposed standards could be expected to produce in the real world. The result is a regulatory analysis that substantially overstates the frequency and magnitude of the beneficial outcomes the proposed standards would produce while understating the frequency and magnitude of the net cost outcomes the standards would impose.

Another remarkable feature of DOE's analysis is that it uses its fuel switching methodology to preferentially exclude high-cost/low-benefit condensing gas furnace outcomes from its economic analysis. To achieve this, DOE does not actually consider "the savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for, or maintenance expenses of, the covered products which are likely to result from the imposition of the standard" as required by law. 42 U.S.C. § 6295(o)(2)(B)(i)(II). In fact, the purported installed costs of condensing gas furnaces used in what DOE characterizes as a lifecycle cost ("LCC") analyses do not actually represent the installed costs **of condensing gas furnaces.** Instead, they are an installed-cost estimate in which DOE has preferentially removed the costs of high-cost/low benefit condensing gas furnace trial cases from its analysis and replaced them with the costs of lower-cost electrical appliances. Similarly, the purported operating cost savings used in DOE's analysis do not reflect **the operating cost savings provided by higher-efficiency condensing gas furnaces**. Instead they are an estimate of operating cost savings in which DOE has preferentially screened out the operating costs of high cost/low benefit condensing gas furnace trial cases and replaced them with the operating costs of substitute electric appliances. As a result, the "average LCC savings" shown at 81 Fed. Reg. at 65814, Table V.6, are not actually the average lifecycle cost savings **for condensing gas furnaces**; they are figures that suggest significantly greater average lifecycle cost savings than condensing gas furnaces would actually provide. Similarly, the "simple payback" figures shown at 81 Fed. Reg. 65814, Table V.5 are not actually the simple payback periods **for condensing gas furnaces**; they are figures suggesting significantly shorter payback periods than condensing gas furnaces would actually provide.

DOE's purported payback analysis presents an even more misleading picture, because it produces averages in which DOE has included the results of disproportionately high net-benefit condensing gas furnace purchases that would occur even in the absence of the proposed standards. The problem is not simply that DOE started with a seriously distorted base case, though it did; nor is it that DOE has underestimated the extent to which condensing gas furnaces can be expected to capture an increasing share of the gas furnace market in the absence of regulation, though it did that too. The problem is that DOE's payback analysis improperly accounts for the impacts of condensing gas furnace purchases **that DOE admits would occur even in the absence of the proposed standards.** As a result, the purported simple payback periods shown at 81 Fed. Reg. at 65814, Table V.5, do not reflect the actual impacts of the proposed standards; they reflect an average of the (disproportionately less favorable) outcomes that would occur as a result of the proposed standards and the (disproportionately more favorable) outcomes that would be expected to occur as a result of consumer choice in the absence of any new regulation. The result is a systematic understatement of the payback periods for purchases that would actually result from the proposed standards, and an overstatement of rule benefits. Perhaps the most striking impact of DOE's inclusion of base case results in its payback analysis is the fact that its stated percentages of consumers adversely affected by the proposed standards **are not the percentage of consumers affected by the rule that would be harmed**. Instead they are the percentages of purchases in all ten thousand trial cases (including those who would not be affected by the proposed standards at all) who would be harmed. In fact, the percentage of consumers affected by the proposed standards who would be harmed by them is –

even by DOE's wildly skewed analysis – roughly twice the percentages shown at 81 Fed. Reg. at 65814, Table V.6.

DOE's fuel switching methodology is also designed in a manner that produces significantly skewed results. Having started with the assumption that consumers **never** consider economics when they choose gas furnaces, DOE's analysis reduces the apparent impacts of fuel switching (*i.e.*, the substitution of electric appliances for gas appliances) by assuming that consumers **always** consider economics in deciding whether to switch from a gas appliance to an electric appliance. Specifically, DOE assumes:

- That consumers will switch to a lower-cost electric appliance if the initial savings in up-front costs would not be exceeded by increased operational costs in less than 3.5 years; and
- That when consumers do switch to an electric appliance, they (unlike purchasers of gas furnaces!) will always select "the most economically beneficial" electric alternative.

81 Fed. Reg. at 65792. This approach creates serious distortions in DOE's assessment of both the impacts fuel switching would have and upon whom the adverse economic impacts of fuel switching would fall.

The first problem with DOE's fuel switching methodology is that it disregards the fact that fuel switching caused by the proposed standards would occur primarily in cases in which the installation constraints associated with condensing gas furnaces pose serious problems or purchasers are particularly sensitive to (or simply unable to afford) high initial costs. Both of these cases tend to promote fuel switching to electric furnaces, which would typically be the low initial cost option by a wide margin and do not impose installation constraints similar to those of condensing gas furnaces (as heat pumps sometimes can). Under DOE's methodology, however, consumers switching to electric appliances are almost always assumed to invest in electric heat pumps, which are significantly more costly to purchase and install than electric resistance furnaces but are almost always considered "the most economically beneficial" electric alternative in the long haul. The result is that DOE's analysis almost completely screens out the worst fuel switching outcomes (particularly those in which consumers would switch to electric furnaces), thereby producing a significant understatement both of the adverse consumer impacts and the increases in overall energy consumption and carbon emissions the proposed standards can be expected to cause.

The second problem with DOE's fuel switching methodology is that its use of a single 3.5-year economic decision-making criterion for all consumers produces a dramatic understatement of the adverse impacts fuel switching would have on low-income consumers. In short, DOE took an average of data suggesting the obvious – that low-income consumers are highly sensitive to initial costs and relatively high-income consumers are not – and used that average to produce a single 3.5-year fuel-switching criterion that it applied to all consumers regardless of their income level. The result is a methodology that models an alternative universe in which low-income consumers are just as likely as millionaires to accept high initial costs in the pursuit of long-term efficiency returns and millionaires are just as likely as low-income consumers to make bad long-term investments in electric appliances in an effort to minimize their up-front costs. The result, obviously, is an analysis that fails to disclose the reality that bad fuel-switching outcomes would be disproportionately experienced by low-income consumers, who – not coincidentally – are the consumers least likely to make the substantial investment required to install a heat pump rather than an electric furnace.

This is not the only way in which the analysis offered in support of the SNOPR fails to identify and consider adverse impacts the proposed standards would have on low-income consumers. DOE has provided nothing but flawed economic analyses that studiously ignore the harsh realities low-income consumers face. In particular, it has sought to dismiss rather than to assess and consider obvious human impacts the proposed standards can be expected to have on low-income consumers, including disproportionate and adverse safety and human health impacts. DOE has an obligation to consider such impacts through an environmental justice review under Executive Order 12898, but has conspicuously failed to do so.

DOE has proposed a “small furnace” exemption from a national condensing standard for gas furnaces in an ostensible effort to moderate the adverse impacts of the proposed standards. However, its approach is flawed and the solutions offered are inadequate for several reasons. In short, the proposed “small furnace” exemption is based upon a serious misunderstanding of furnace sizing issues, would provide relief for only a small percentage of gas furnaces, and – apart from reducing the number of furnaces subject to condensing standards – would do little or nothing to address the fuel switching impacts or disproportionate adverse impacts to low-income consumers that a condensing standard for gas furnaces would cause.

Energy conservation standards effectively banning non-condensing gas furnaces would unquestionably eliminate the only gas furnaces that are compatible with the existing vent systems in most American homes and would leave many consumers without any practical gas furnace options. The proposed standards are impermissible under EPCA for that reason, are not economically justified, would cause counterproductive fuel switching, and would impose disproportionate adverse impacts on low-income consumers. The proposed small furnace exemptions would serve to reduce the number of furnaces subject to condensing standards, but are transparently inadequate to address any of the fundamental problems condensing standards would present. Accordingly, Spire respectfully submits that the proposed standards should be withdrawn.

Comments

A. The technical significance of the proposed ban on non-condensing gas furnaces

The proposed standards would impose heating efficiency standards for the overwhelming majority of residential gas furnaces that can only be achieved using condensing technology. While an exception may be provided for "small" non-weatherized residential gas furnaces with input capacities of 55,000 British Thermal Units per hour (Btu/hr) or less, such furnaces account for less than ten percent of total residential gas furnace shipments, only a fraction of which are non-condensing furnaces for which an exemption would be beneficial. The proposed efficiency standard for "small" furnaces would be 80% thermal efficiency on an "AFUE"[4] basis, which represents the maximum practical heating efficiency that can be achieved without condensing technology.

The distinction between condensing and non-condensing furnaces is significant: in short, condensing furnaces achieve higher thermal efficiencies by sacrificing the capability of the furnace to function with a natural draft vent system. That capability is an important feature that facilitates the use of gas furnaces in installations in which the use of a gas furnace would otherwise – for reasons unrelated to the cost of the furnace itself – be difficult or impractical. In the context of new home construction, the inability of condensing furnaces to function with natural draft vent systems imposes architectural design constraints with respect to furnace placement and venting that can sometimes make the use of gas furnaces awkward or even impractical. An illustration of the basic mechanical differences between condensing and non-condensing furnaces is provided as Attachment A to these Comments, and may be found at the following link:

https://www.aga.org/sites/default/files/aga_2995_furnace_standard_infographic_web_final.pdf

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[4] Annual fuel utilization efficiency, a measure of heating efficiency.

As DOE acknowledges, "the type of furnace that can be installed in a home is often dependent on structural and design decisions made when [a] building is constructed." 81 Fed. Reg. at 65790. Accordingly, the constraints imposed by non-condensing furnaces are considerably more difficult to work around when furnaces in existing homes must be replaced. The vast majority of existing homes were designed with vertical venting systems intended for use with appliances with exhaust gas temperatures that are high enough to minimize the potential for condensation to form before the exhaust gasses are vented through the roof of the structure. In other words, such existing homes are designed for natural draft (*i.e.*, *non-condensing*) gas furnaces. Condensing furnaces have lower exhaust gas temperatures because the normal products of natural gas combustion contain significant amounts of water vapor, and condensing technology achieves higher heating efficiency by condensing much (but not all) of that water vapor in order to recover heat that would otherwise be released with the exhaust gases. The exhaust gases from a condensing gas furnace still contain significant water vapor, but have a much lower temperature than the exhaust gases from non-condensing gas furnaces. As a result, excessive condensation would occur before the exhaust gases from a condensing furnace would exit a typical natural vent system, which in turn would cause corrosion and eventual vent failure of conventional venting materials. Accordingly, building safety codes require that condensing furnaces be installed with more exotic rust-proof vent systems that typically consist of relatively short horizontal intake and exhaust vents penetrating the exterior wall of the home. In addition, the liquid condensate resulting from condensing furnaces requires additional plumbing for condensate discharge, and condensate removal plumbing must be protected from freezing. For all of these reasons, existing non-condensing gas furnaces cannot simply be replaced with condensing furnaces: at a minimum, a new or modified vent system would be required, existing venting may need to be removed, and the facility to discharge condensate and protection from condensate freezing would need to be provided.

In some cases, existing furnaces may be located too far below grade – or too far from an exterior wall – to accommodate venting suitable for condensing equipment. In such cases, the installation of condensing equipment, if practical at all, may require that the furnace be relocated within the home. In these cases, construction and demolition work may be necessary, and – in addition to the basic venting and plumbing work required – modifications to the home heating duct system may also be required. In older homes, this may trigger expensive asbestos abatement requirements. Additionally, in many parts of the country, homes are constructed slab on grade with no basements. This often results in gas furnaces installed in unconditioned attics or crawl-spaces, which makes retrofit to condensing furnaces extremely expensive due in part to the need to prevent condensate from freezing.

An additional complication is that other natural draft gas appliances – typically gas water heaters – are commonly tied to the same vent system as a natural draft gas furnace. When the vent system is sized for multiple appliances – as is commonly the case – installation of a condensing gas furnace can result in venting problems for other appliances. In these situations, removal of a non-condensing gas furnace may leave other non-condensing gas appliances "stranded." In some cases, the stranded appliances may no longer be safely operated with the pre-existing venting system, and – by code – natural draft non-condensing appliances cannot share the venting system of a condensing gas appliance. In such cases, significant and costly venting modifications are necessary, and the lowest cost alternative may be to replace the gas water heater with an electric water heater. In other cases, "stranded" water heaters can be safely modified (at a more modest additional cost) to operate alone.

DOE has made no serious effort to account for the nature and extent of the issues posed by the common venting of non-condensing gas furnaces and non-condensing residential water heaters or the costs of modifying, upgrading, or abandoning natural draft vent systems as necessary to permit a non-condensing gas furnace to be replaced with a condensing gas furnace. Instead, DOE has inappropriately chosen to treat venting issues as simple installation cost adders to the covered product without making any reasonable attempt either to address the complex range of installation environments involved. Most significantly, DOE has grossly oversimplified the installation environment with respect to venting systems and how the replacement of non-condensing furnaces with condensing furnaces would actually have to be implemented. For example, DOE assumes that, for common-vented installations of non-condensing furnaces and water heaters, the venting systems will be essentially as shown below in Figure F.1(g), which is reproduced from the National Fuel Gas Code.[5]

Figure F.1(g).
Vent System Serving Two or More Appliances with Type B Double-Wall Vent and Single-Wall Metal Vent Connectors.

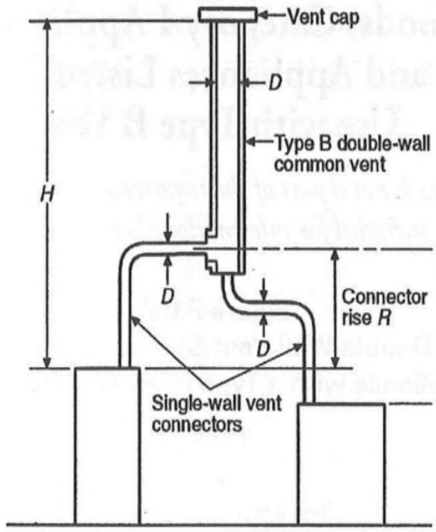

Table 13.2(b) is used when sizing single-wall vent connectors attached to a Type B double-wall common vent.

Note: Each appliance can be either Category I draft hood-equipped or fan-assisted type.

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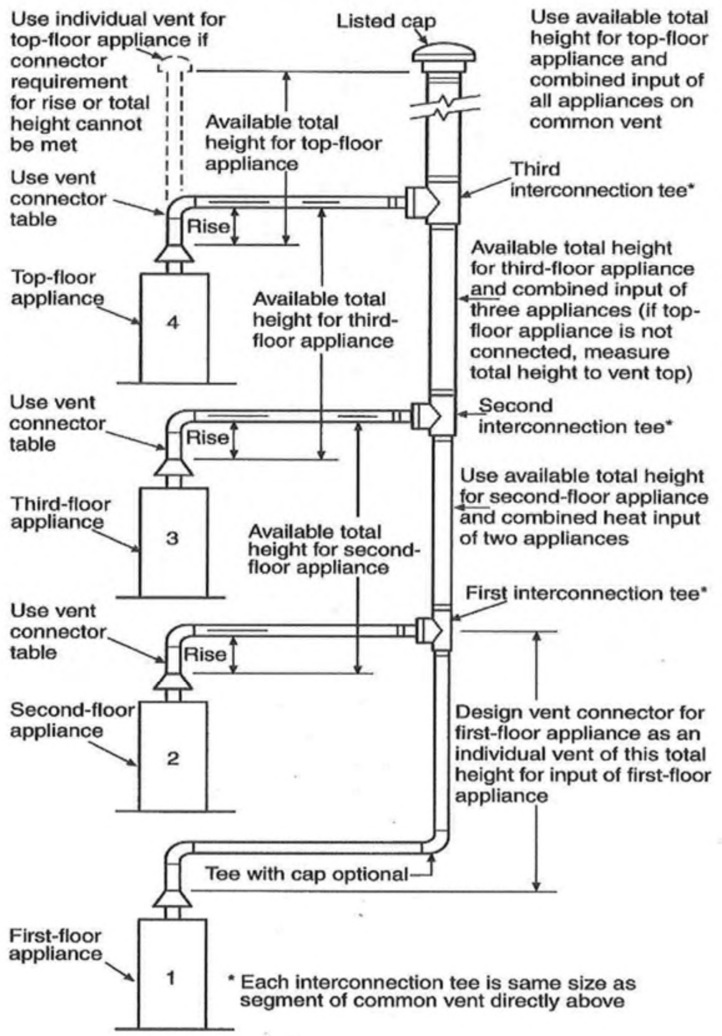
[5] National Fuel Gas Code, ANSI Z223.1/NFPA 54, 2015 Edition.

DOE then uses rudimentary assumptions to calculate costs of replacing non-condensing ("Category I") furnaces with condensing ("Category IV") furnaces and addressing the potential issues raised by common venting of the associated non-condensing residential storage water heater (such as venting size reductions) required to address the reduced venting system flows associated with the removal of a non-condensing gas furnace. However, venting systems are structural features that often serve multiple living units, as shown in Figure F1(n) below (also reproduced from the National Fuel Gas Code).

Figure F.1(n).
Principles of Design of Multistory Vents Using Vent Connector and Common Vent Design Tables.
[See 13.2.14 through 13.2.17.]



As a result, the problems posed are not a mere matter of installation cost adders for a single consumer's furnace system. In the scenario depicted, replacement of the "first floor appliance" (assuming it is a furnace) with a condensing furnace could leave the venting system oversized for proper venting of the other non-condensing appliances in the building. In that case, what would be the cost of modifying the venting system to accommodate the reduced venting flow for the remaining Category I appliances or of replacing all the other non-condensing appliances in the building and abandoning the entire existing venting system? At a minimum, such issues would need to be analyzed in detail using the vent sizing criteria of the National Fuel Gas Code. Yet DOE's technical and economic analysis does not appear to have addressed this kind of scenario at all; it simply treats venting issues as a matter of generic "installation cost" adders. More realistically, this kind of scenario generally would be one in which a condensing furnace simply would not be an option.

DOE cites comments suggesting that concerns about the installation issues associated with condensing gas furnaces are somehow overblown, and suggests that evidence from Canada – which has had condensing standards for gas furnaces in place for a number of years – indicates that the installation requirements for condensing gas furnaces may not be as severe as commenters with direct knowledge and experience have indicated. 81 Fed. Reg. at 65779. However, the "consultant research" DOE relied upon appears to have produced only a very brief note in the docket in which DOE's consultant candidly admits that he "could find no evidence to document the extent of consumer and/or contractors' difficulties during implementation of the [Canadian] standard."[6] The note further states that "a number of provincial jurisdictions, including Ontario, British Columbia and Manitoba" already had condensing standards in effect before the National standard was adopted, and that incentives were available at the time for

[6] 2016-02-23 SNOPR reference material (footnote 74, p. 65779): Technical Note, Impact of Canadian Condensing Gas Furnace Standard on Consumers

consumers seeking to install condensing gas furnaces. Nevertheless, the note suggests that very few stakeholders have contacted NRCan (the Canadian regulatory authority responsible for the standard) to "raise issues" about the standards, and leaps to the conclusion that potential problems with the installation of condensing furnaces must either have been "overstated" or that contractors had somehow found way to "resolve the issues." However, there is no particular reason why the relevant "issues" would have been raised with NRCan after the standard was already in place, particularly when substantially more than half of the Canadian population had already been subject to condensing standards imposed at the provincial level and the combination of incentives and the Canadian climate combine to make even relatively severe installation problems far more economically bearable.

In an effort to find more reliable information in the limited time available for comment, Spire conducted informal interviews with Canadian gas utilities. Those interviews generally confirmed that – despite significant mitigating factors including the availability of incentives, the Canadian climate, a gradual regulatory transition due to evolution of Provincial and National standards, and Canadian appliance leasing practices – the problems of the kind one would expect from condensing standards for gas furnaces have been experienced. In particular:

- The regulation was swift but uptake not as swift, because many homeowners kept repairing their older standard efficiency furnaces to avoid having to replace them with condensing gas furnaces;
- In new home construction, increased costs for two separate vents (one for a condensing gas furnace and another for a gas water heater) drove up the cost of gas water heaters to the extent that very substantial fuel switching – in the form of the substitution of electric water heaters for gas water heaters – has occurred;
- Stranded hot water tanks were a significant problem where water heaters are not leased (leasing is common in Canada, but not in the United States);
- Condensate disposal was a problem with many older homes;
- Side wall venting required for condensing gas furnaces has led to visual and noise complaints;
- Increased air flow from condensing furnaces often was not compatible with smaller ductwork; and

- Reliability and longevity issues were experienced with condensing gas furnaces.

Condensing gas furnaces plainly impose burdens on consumers that non-condensing gas furnaces do not. DOE's failure to acknowledge the true impacts of those burdens is a root cause of serious problems with the proposed standards.

B. The proposed standards would unreasonably lessen the utility and performance of residential furnaces and would unlawfully result in the unavailability in the United States of a product type (or class) of performance characteristics (including reliability), features, sizes, capacities, and volumes that are now generally available in the United States

As a preliminary matter, the primary impact of the proposed standards – effectively a ban on non-condensing gas furnaces – raises obvious statutory concerns. First, in determining whether proposed standards are economically justified, EPCA requires DOE to consider any lessening of the utility or the performance of products that is likely to result from the imposition of a proposed standard. 42 U.S.C. § 6295(o)(2)(B)(i)(IV). The utility of a product is obviously lessened to the extent that design choices are imposed that would significantly constrain the circumstances in which the product can reasonably be used. DOE has recognized this fact in a number of circumstances, including in its decision to maintain separate product classes for "space-constrained" heat pumps and air conditioners and other central heat pump and air conditioning products. 76 Fed. Reg. 37407, 37446 (June 27, 2011). The proposed rule would nevertheless eliminate all but a limited category of "small" natural draft gas furnaces.

As already indicated, non-condensing gas furnaces have an important and unique utility in that they are suitable for direct installation into existing homes that have natural draft venting systems. Such venting systems are not a part of any appliance DOE is authorized to regulate; they are structural features of the home itself, and are no different than other building features that constrain the installation and use of products. Gas furnaces that can be installed to replace an existing gas furnace without the need for substantial modification of the home itself plainly offer a utility that condensing gas furnaces do not.

DOE's attempt to dismiss such issues as a mere matter of installation cost is unreasonable. If the need to overcome constraints on the installation of a product can be dismissed as a matter of "installation" costs, there would never be a need to provide a separate product category for "space-constrained" appliances; there would simply be whatever "installation" costs are necessary to "un-constrain" space as necessary. In any event, there are plainly situations in which installation constraints eliminate condensing furnaces as a practical option. The suggestion that such issues can be characterized – and effectively dismissed – as an issue of "installation costs" is absurd.

Rather than consider the loss of product utility that a ban on natural draft gas furnaces would impose, DOE has unreasonably insisted that a feature that makes a gas furnace compatible with a home's existing mechanical infrastructure – and that can be the difference between a gas furnace that is a reasonable option for a given application and one that is not – does nothing for the utility of the product. Again, DOE's effort to dismiss the loss of that product utility – and the resulting practical impacts a condensing standard for gas furnaces would have – is a major defect in its regulatory analysis.

Second, EPCA makes it clear that DOE should avoid the adoption of any standard that is "likely to result in the unavailability in the United States of any product type (or class) of performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as those generally available in the United States" at the time a standard is under consideration. 42 U.S.C. § 6295(o)(4). As already discussed, the ability of a gas furnace to function with natural draft vent systems is an extremely important feature for consumers whose homes include such systems as part of the built environment. It is undisputed that the proposed standards would sacrifice that important feature by requiring condensing technology for all but a minor category of "small" gas furnaces, thereby eliminating every other category of natural vent gas furnaces. In response to comments pointing out that natural vent furnaces have an important feature and that the proposed standards would make products having that feature unavailable in the United States, DOE has simply denied the fact that the ability of a non-condensing furnace to function with a natural draft vent system is a "feature."[7] This seems like an odd assertion in view of DOE's recognition that the ability of non-condensing furnaces to function *without* a natural vent system requires "features" that non-condensing furnaces lack. 81 Fed. Reg. at 65755. In any case, DOE's denial does not change the fact that the ability of a furnace to function with a natural vent system is a feature that can be – and often is – the difference between a gas furnace that is a reasonable option for a particular application and one that is not.

For the foregoing reasons, Spire hereby requests, pursuant to 42 U.S.C. § 6295(o)(4), that DOE make and publish a finding that "interested persons have established by a preponderance of the evidence that [the proposed standards are] likely to result in the unavailability in the United States of [a] product type (or class) of performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as those generally available in the United States" at this time. With the publication of that finding, the proposed standards should be withdrawn.

C. <u>The proposed standards would likely cause sufficient fuel switching to eliminate the energy conservation and carbon emissions savings the proposed standards would otherwise be expected to provide</u>

Gas appliances generally have dramatic energy conservation and air emissions advantages over comparable electric products. There are two principal reasons for this:

- First, due to energy losses in the generation, transmission, and distribution of electricity, it takes a lot more energy to produce the power electric appliances require than the appliances themselves consume. In fact – on a National average – the energy required produce and transmit electricity to an electric appliance for use (referred to as "source energy" consumption) is more than three times the amount of energy the appliance consumes (referred to as "site energy" consumption).[8]

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[7] 81 Fed. Reg. at 65753.

[8] EPA has used a national average site-to-source ratio of 3.14:1 for purposes of its Energy Star program. See https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf

By contrast, the source energy consumption of gas appliances is only slightly exceeds the amount of energy that gas appliances consume.

- Second, approximately 70% of the electricity consumed in commercial and residential use in the United States today is generated through the combustion of fossil fuels, including both natural gas and coal.[9]

The combined result of these factors is that, on average, every unit of energy consumed by an electric appliance requires that three units of energy be consumed (so that one unit can actually reach the appliance), and about 2.1 of those units of energy will be produced through the combustion of fossil fuel (about half of which is coal). By contrast, an appliance consuming one unit of gas energy would consume roughly one third as much energy overall and less than half as much fossil fuel. As a result, gas appliances have inherent efficiency and carbon emissions advantages over electric appliances, particularly electric resistance appliances. While electric heat pumps have characteristics that decrease these disparities, they also contain supplemental electric resistance elements to provide heat when it is too cold for the heat pump to handle the full heating load.

Figures 1 and 2 present graphics from an EPA presentation that illustrate these impacts in the context of residential water heaters (which would also be highly impacted by the proposed standards). As these illustrations show, energy conservation standards that cause consumers to substitute electrical equipment for gas equipment have an obvious potential to do more harm than good from the standpoint of energy consumption, carbon emissions, and air quality impacts; in fact, the magnitude of the adverse impacts associated with fuel switching are such that even a relatively small amount of fuel switching could overwhelm the benefits an energy efficiency standard is intended to provide.

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[9] Based on data from the Energy Information Agency's Electric Power Annual at the following link: http://www.eia.gov/electricity/annual/html/epa_03_01_a.html

Figure 1

Example: Electric and Gas Water Heaters

Site vs. Source Energy Comparison

ENERGY STAR

Comparison of Site Energy, Source Energy, and CO_2 Emissions for Electric and Gas Water Heaters		
	Electric Water Heater	*Natural Gas Water Heater*
Energy factor (overall efficiency)	0.917*	0.594*
Output (Btu/day)	31,025	31,025
Annual **site** energy use in fuel-specific units	3,625 kWh	19,000 CF
Annual **site** energy use in kBtu	12,372	19,570
Annual **source** energy use in kBtu**	41,323	20,490
Annual **CO_2 emissions** (lbs) at national average emissions factors (0.399 lbs/kBtu electricity; 0.11638 lbs/kBtu natural gas)***	4,936	2,278
Annual **CO_2 emissions** (lbs) at the lowest US regional emissions factor for electricity (0.141 lbs/kBtu)	1,744	2,278
Annual **CO_2 emissions** (lbs) at the highest US regional emissions factor for electricity (0.597 lbs/kBtu)	7,386	2,278

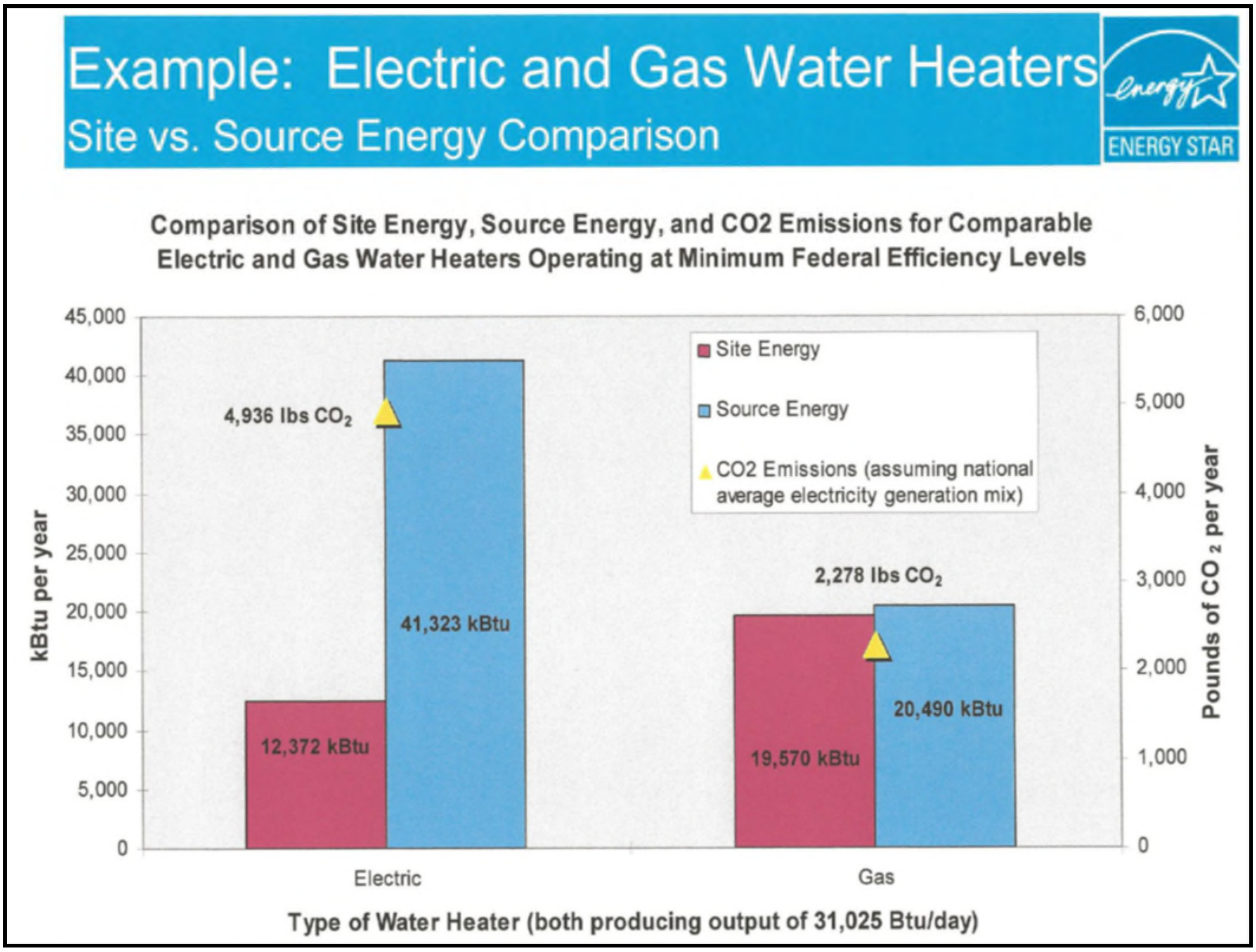
* Minimum federal efficiency for a new 40 gallon tank with given fuel source

** The following source-site ratios were applied (see: http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf)

Electricity: 1 unit site = 3.340 units source; Natural Gas: 1 unit site = 1.047 units source

*** See: http://www.energystar.gov/ia/business/evaluate_performance/Emissions_Supporting_Doc.pdf

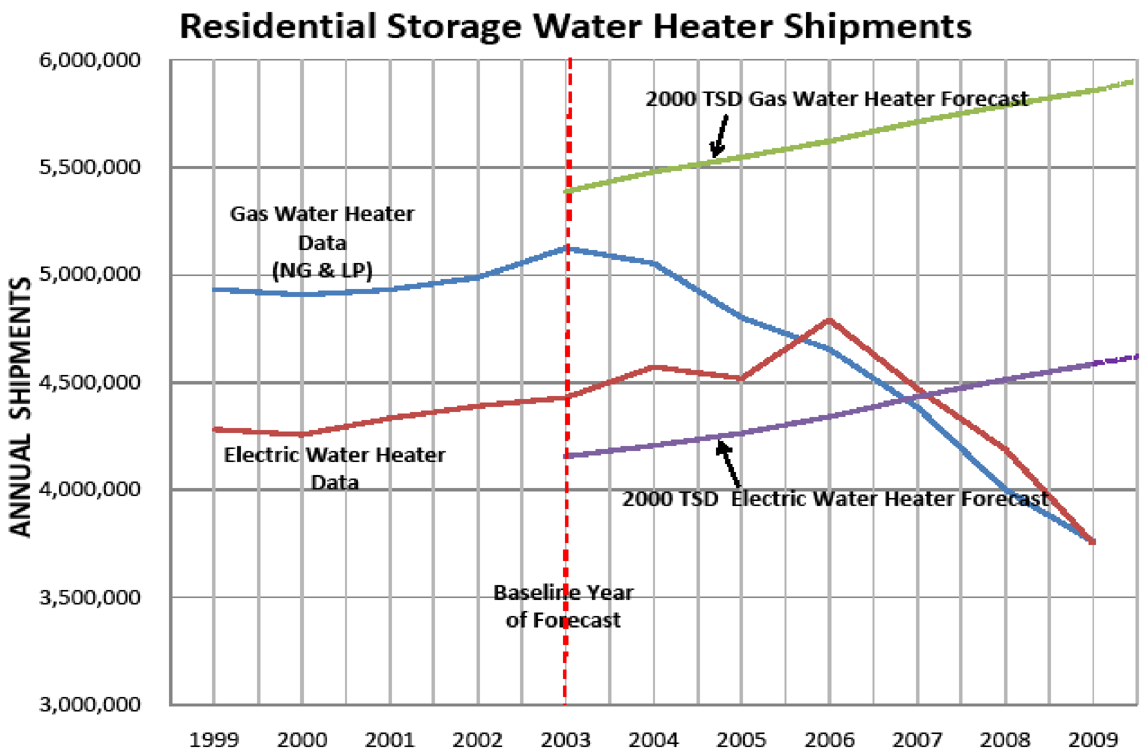
Figure 2



The SNOPR acknowledges that switching from natural gas furnaces to electrical appliances is already occurring, and that the proposed standards impose installation problems and costs that can be expected to cause significant increases in fuel switching. 81 Fed. Reg. at 65791. The SNOPR also acknowledges that, in addition to causing gas furnaces to be replaced by electric alternatives, the proposed standards for gas furnaces would cause some gas *water heaters* to be replaced with electric resistance water heaters as well. 81 Fed. Reg. at 65791. Unfortunately, the SNOPR significantly understates the extent to which fuel switching is likely to occur and – in part as a result of its systematic overstatement of the energy savings its standards would achieve – fails to recognize the net impacts fuel switching would have.

This is nothing new: DOE has routinely underestimated the potential for its standards to cause fuel-switching resulting in a net increase in overall energy consumption and carbon emissions. For example, DOE's assessment of the relative significance of fuel switching in the market for residential water heaters was grossly inaccurate, as Figure 3 shows.

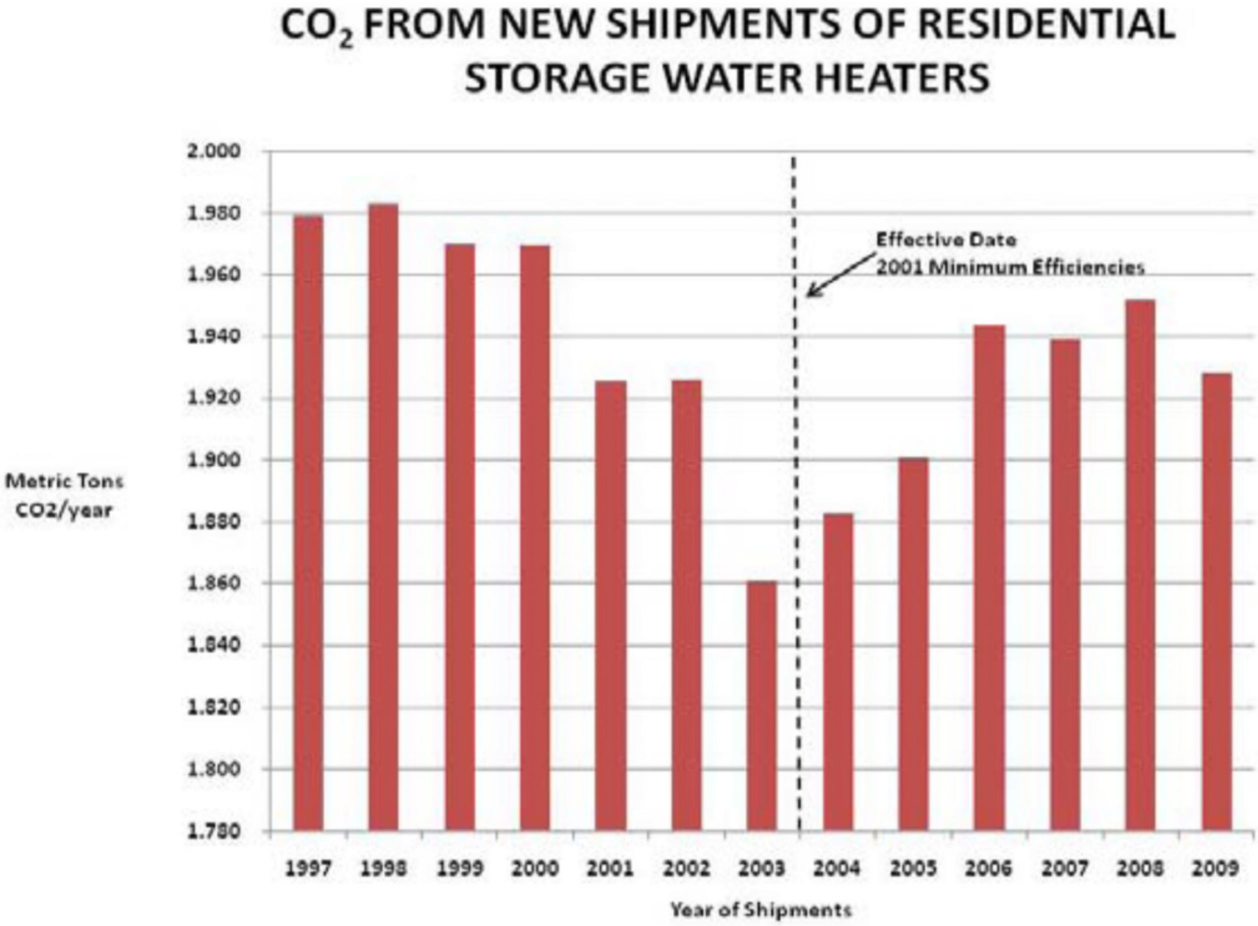
Figure 3



Source: American Gas Association comments to U. S. Department of Energy, "Reducing Regulatory Burden," Request for Information (RFI), <u>Federal Register</u> Vol. 76, No. 23, February 3, 2011, submitted April 15, 2011.

As a result of that erroneous assessment, the substitution of electric water heaters for gas water heaters became far more prevalent after the effective date of DOE's energy conservation standards for residential water heaters, with the result that energy consumption and carbon emissions actually increased after the effective date of the standards, as shown in Figure 4 (the figure addresses carbon dioxide emissions, but – as the EPA analysis presented in Figure 2 indicates – energy consumption and carbon emission impacts are closely related and exhibit similar trends).

Figure 4



Source: American Gas Association comments to U. S. Department of Energy, "Reducing Regulatory Burden," Request for Information (RFI), Federal Register Vol. 76, No. 23, February 3, 2011, submitted April 15, 2011.

The proposed standards clearly have a significant potential to cause net increases in overall energy consumption and carbon emissions, because – as illustrated by Figures 5 and 6[10] – the negative

[10] Figures 5 and 6 are derived from AGA energy calculations based on a 2,072 square-foot home with 4,811 heating degree days using 2009 IECC efficiency standards.

impacts associated with fuel switching can dramatically exceed the benefits that more stringent efficiency standards for gas appliances would otherwise be expected to provide. As a result, even relatively small increases in fuel switching have the potential to turn a rule designed to reduce energy consumption and carbon emissions into one that actually increases both.

In both Figures, the difference between the two left-hand bars reflects the benefit of replacing a standard efficiency (80% AFUE) gas furnace with a high-efficiency (92% AFUE) gas furnace. It should be noted that this is the only scenario in which the outcome of the proposed standards would produce energy conservation benefits.

Figure 5
Energy Consumption Impacts of Fuel Switching

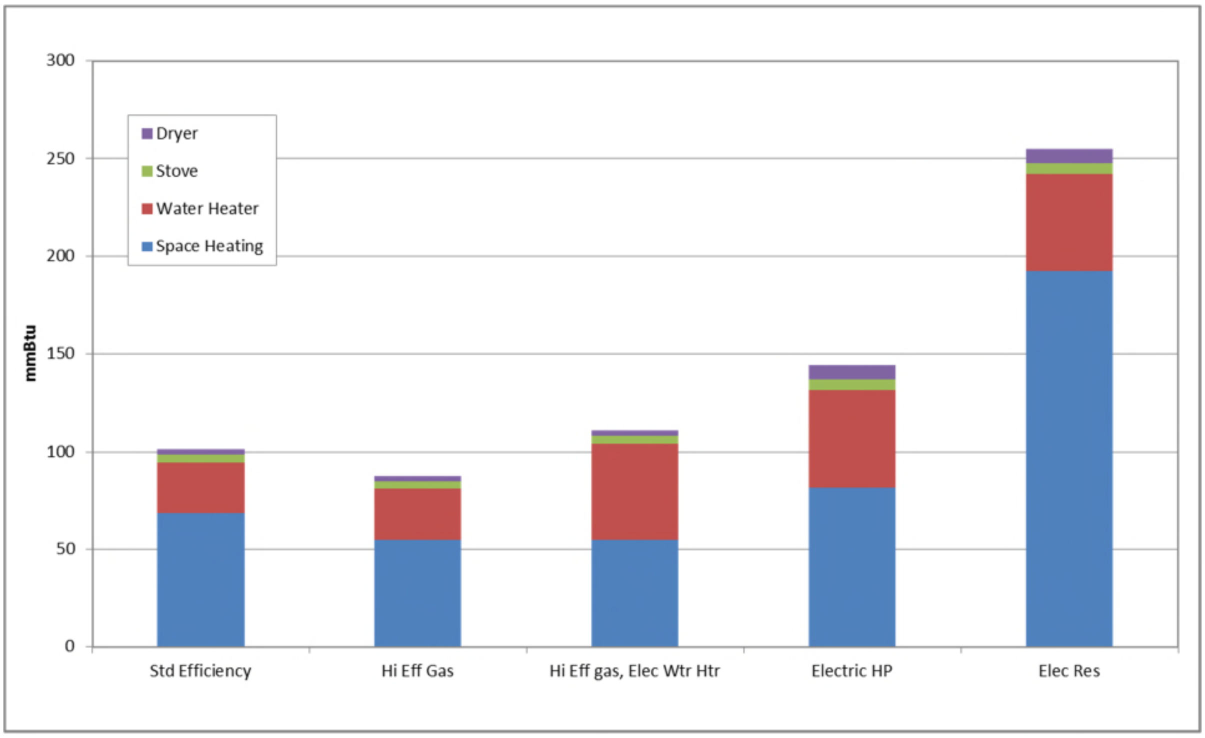
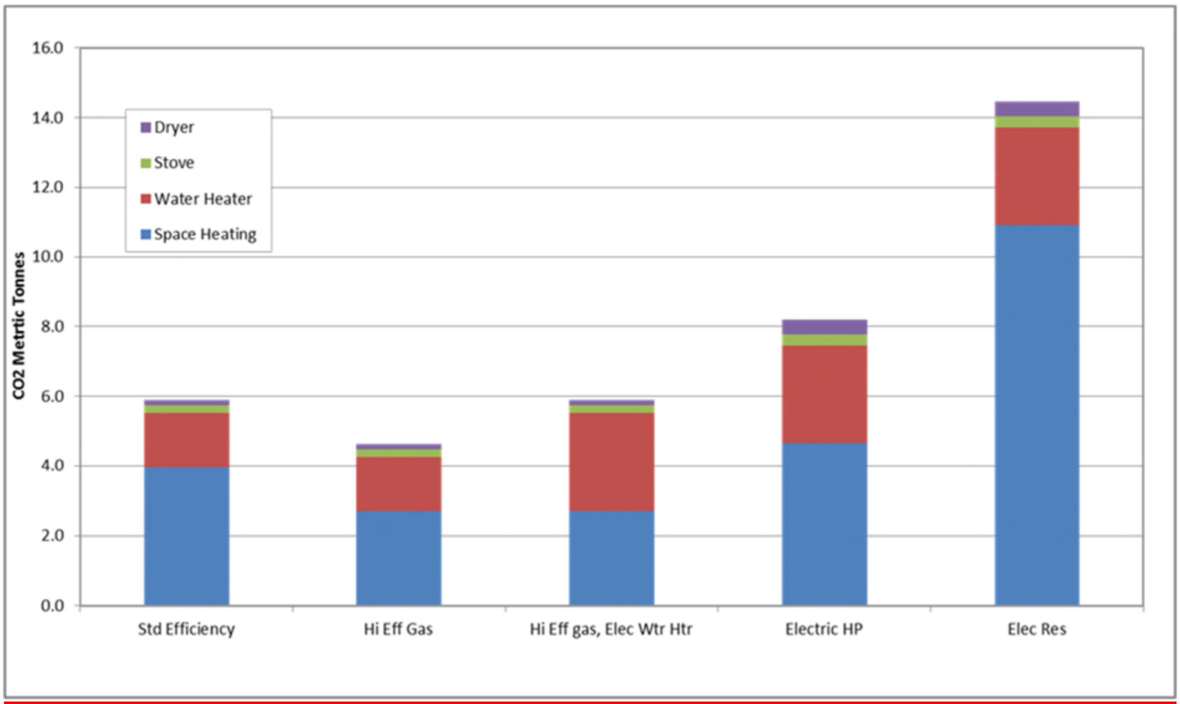


Figure 6
Carbon Emission Impacts of Fuel Switching



The center bar in Figures 5 and 6 represents the scenario in which the replacement of a standard efficiency gas furnace with a high efficiency gas furnace would also trigger the replacement of a gas water heater with an electric resistance water heater. DOE recognizes that this result will occur in the furnace replacement market due to the need to address stranded water heaters. However – as discussed below – this result is likely to occur to an even greater extent in the new home construction market. As a comparison between the first and third bars shows, this scenario results in an increase in overall energy consumption and essentially no reduction in carbon emissions.

The two right-hand bars in Figures 5 and 6 show the results in situations in which the cost or installation challenges associated with a high-efficiency gas furnace cause a switch from a standard-efficiency gas furnace to either an electric heat pump or an electric resistance heater (thus triggering a switch from a gas water heater to an electric water heater as well). As the difference between these two right-hand bars and the first bar on the left in each figure shows, these scenarios result in substantial increases in both energy consumption and carbon emissions; increases that are substantially greater than the reductions in energy conservation and carbon emissions the only "rule benefit" scenario would provide.

As figures 5 and 6 show, the net consequences of the proposed standards will depend entirely on the frequency with which the various rule outcomes occur. Notwithstanding this fact – and the obvious potential for the proposed standards to do as much or more to increase energy consumption and carbon emissions than to reduce them – the SNOPR relies upon an inadequate and systematically skewed analysis of the relevant issues that grossly overstates the prevalence and significance of "rule benefit" outcomes while understating the prevalence and significance of negative outcomes. Such an approach is unreasonable in view of the nature of the negative impacts fuel switching could have, a problem that is compounded by further bias introduced by DOE's fuel switching analysis. The principal flaws in that analysis are as follows.

1. <u>DOE did not adequately address fuel switching in new home construction</u>

Spire has already supplied evidence that the cost of condensing gas furnaces is so substantial that that home builders installing such furnaces often seek to reduce overall appliance costs by pairing them with electric water heaters rather than gas water heaters. To demonstrate that this is occurring, Spire has already provided evidence that Pulte Homes – the Nation's third largest homebuilder – offers a high-efficiency gas furnace and an electric water heater as standard equipment for all of its developments in the greater St. Louis area. The impetus for this choice is obvious: home builders are highly sensitive to appliance costs – as DOE has acknowledged[11] – and the combination of a condensing gas furnace and an

[11] 81 Fed. Reg. at 65791.

electric resistance water heater both reduces appliance costs and allows builders to avoid the substantial expense of installing a vertical natural draft vent system. Further, installing an electric resistance hot water heater (or two, given their inferior recovery performance), poses no penalty under conventional "green" building codes.

The impact of water heating fuel switching could easily turn the impact of the proposed standards negative for the entire new construction market. Just examining the St. Louis market, the majority of single-family detached home builders presently install both gas space and water heating. In 2015 the top ten builders accounted for 42% of all single family homes constructed in the region. Interviews with most of these builders have uncovered the fact that *any increase* in cost will prompt a review of the entire energy system in their homes, including water heaters. If even half of these builders switch to electric water heating, the impact on energy savings and carbon emissions will be substantial. Attachment B to these Comments, entitled Source Energy & Emissions Analysis Tool,[12] provides summary data from 44 different locations across the country that analyzed what to expect if homes install condensing furnaces but subsequently install electric resistance water heaters. Extrapolate these numbers to the entire nationwide market, and the magnitude of the shift from gas to electric water heating becomes apparent. According to the U.S. department of Housing and Urban Development, the seasonally adjusted building permits annual rate was 1,225,000. If 70% of these homes have gas furnaces and even 25% percent of those homes switch to electric resistance water heaters, this amounts to an increase of 214,375 electric water heaters per a year, each consuming substantially more energy and emitting considerably more carbon, on average, than a gas water heater would. Over five years, the increase in electric resistance water heaters would exceed one million.

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[12] http://www.cmictools.com/

Again, builders are incredibly sensitive to appliance price increases, and – in view of the pace at which housing costs continue to rise – they have good reason to be. According to the National Association of Home Builders (NAHB), each $1,000 increase in the cost of a new home price forces 206,000 prospective buyers out of the market for that home.[13] Another new NAHB study shows that, on average, government regulations account for 24.3% of the final price of a new single-family home.[14] Applying percentages from NAHB's studies to Census data on new home prices from 2011 to 2016 shows that regulatory costs for an average single-family home went from $65,224 to $84,671 – a 29.8% increase over that five-year period.[15] By comparison, disposable income per capita increased by only 14.4% over the same period. In other words, the cost of regulation in the price of a new home is rising more than twice as fast as the average American's ability to pay for it. With cost pressures like this, DOE should not take further appliance cost increases lightly, and must recognize the extent of the pressure the proposed standards would put on builders to switch to electric resistance water heaters to reduce overall appliance costs.

In view of the fact that the cost of condensing gas furnaces and the nature of their vent systems is already causing home builders to substitute electric resistance water heaters for gas water heaters, it is no surprise that major homebuilders have advised Spire that efficiency standards requiring them to install condensing gas furnaces would likely cause them to substitute electric resistance water hears for gas water heaters for the same reasons such fuel switching is already occurring. Canadian gas utilities have advised Spire that is precisely what occurred in Canada when condensing standards for residential furnaces were

[13] http://nahbnow.com/2014/08/new-nahb-study-how-fees-force-buyers-out-of-the-market/

[14] http://www.nahbclassic.org/generic.aspx?sectionID=734&genericContentID=250611&channelID=311

[15] http://nahbnow.com/2016/05/regulations-add-a-whopping-84671-to-new-home-prices/

imposed. Unfortunately, this is not the "rule benefit" scenario that would justify a requirement for condensing furnaces; instead – as Figures 5 shows – the result is fuel switching that would, on average, produce a net increase in energy consumption.

Despite Spire's previous comments on this issue, DOE's fuel switching analysis significantly understates the extent to which fuel switching of this kind can be expected, thus overstating the energy conservation and carbon emission benefits of the proposed standards.

2. DOE's fuel switching methodology is arbitrary

Despite DOE's assumption that consumers **never** consider lifecycle costs or payback economics when purchasing gas furnaces, DOE assumes – for purposes of its fuel switching analysis – that consumers **always** consider both initial cost and payback economics in deciding whether to switch from a gas furnace to an electric alternative. The latter premise is based upon proprietary consumer survey data and "RECS billing data" from which DOE claims to have "deduced" that consumers, on average, "would require a payback period of 3.5 years or less for a more-expensive but more-efficient product." 81 Fed. Reg. at 65792. DOE acknowledges that the proprietary survey data it relies on "do not directly address the consumer choice to switch heating fuels"[16] and that "different consumers are likely to use different criteria when considering fuel switching,"[17] but recites that "[c]ommenters did not provide additional data," that "DOE is not aware of" any more relevant data, and that – "in the absence of any data directly associated with fuel switching" – its analysis is good enough by default. 81 Fed. Reg. 65792-93.

DOE's analytical approach is not based upon substantial evidence. Indeed, it is difficult to see how evidence concerning consumer expectations with respect to paybacks on efficiency investments is

[16] 81 Fed. Reg. at 65793.

[17] 81 Fed. Reg. at 65792.

even relevant to what is essentially the opposite decision-making problem: the question of when up-front cost savings make long-term economic losses acceptable. In any event, DOE's methodology is unreasonable in several respects. First, it is obviously unreasonable for DOE to assume that consumers never engage in economic decision-making when choosing between gas furnaces (as it does for purposes of establishing the base case used in its analysis) while simultaneously assuming that consumers **always** engage in economic decision-making when choosing between a gas furnace and electric alternatives.[18] Second, as will be discussed in the context of impacts on low-income consumers, it is unreasonable for DOE to assume that all consumers have the same sensitivity to initial costs and will thus make decisions on the basis of exactly the same balancing of up-front costs against long-term economic consequences. Finally, the 3.5-year criterion used in DOE's fuel switching methodology serves to screen the worst fuel switching outcomes out of DOE's analysis, because – under DOE's approach – consumers will only engage in fuel switching if an electric alternative provides initial cost savings that would not be exceeded by increases in operating costs within less than 3.5 years. 81 Fed. Reg. at 65792. As a result, DOE's analysis does not even admit the possibility of fuel switching outcomes that would produce initial cost savings that would be eclipsed by increased operating costs more quickly. In addition, DOE's analysis assumes that fuel switching will result in the electrical alternative that would be "the most economically beneficial," presumably on the basis of lifecycle costs. 81 Fed. Reg. at 65792. Both of these assumptions skew DOE's fuel switching analysis heavily in favor of electric heat pumps, which explains DOE's conclusion that "only a small amount of switching to electric furnaces" would occur.[19] However, the

[18] In this context, it is important to distinguish between what DOE recognizes as fact and what it actually assumes for purposes of analysis. In particular, DOE recognizes that there is some economic decision-making in consumer appliance purchasing decisions, but its actual regulatory analysis assumes there is none. Similarly, DOE recognizes that fuel switching decisions are not based solely on an economic payback analysis, but its regulatory analysis assumes that they are. 81 Fed. Reg. 65792-93.

[19] 81 Fed. Reg. at 65792 and 65813, Tables V.3 and V.4.

assumptions that produce this result unreasonably ignore the fact that two of the primary concerns that drive fuel switching – high initial costs and installation constraints – strongly favor switching to electric furnaces, which typically have much lower initial costs than heat pumps and – unlike heat pumps – do not present installation challenges similar to those associated with condensing gas furnaces.[20] As Figures 5 and 6 show, the increases in energy consumption and carbon emissions associated with a switch to an electric furnace are significantly greater than the increases associated with a switch to electric heat pumps. As a result, DOE's methodology – which illogically limits switching to electric furnaces to a mere 1.1% of all non-weatherized gas furnace cases – results in a dramatic understatement of the adverse impacts fuel switching would have on overall energy consumption and carbon emissions. This gross distortion of reality – in addition to the distortions introduced by the unreasonable base case DOE imposed as the basis for analysis – likely explains how DOE manufactured rule outcomes in which fuel switching produces lifecycle cost savings relative to the "no standards" case. 81 Fed. Reg. at 65774.

3. Systematically overstated benefits and systematically understated costs can be expected to result in an understatement of fuel switching

As discussed at length in these Comments, DOE's regulatory analysis is systematically skewed to overstate the benefits of the proposed standards and understate their costs. In many cases, an analysis of this kind tends to produce rules that provide benefits that are insufficient to justify the regulatory burdens imposed. While such a result is not to be applauded, it can at least be said that the agency is achieving its regulatory purpose. That is not the case here, for two significant reasons. First, overstated benefits and understated costs provide input parameters for a fuel switching analysis in which installed appliance costs and operating costs are key factors. As a result, overstated benefits and understated costs do not merely

[20] When consumers have constrained space issues that that present problems for condensing furnaces (as can occur, for example, in cases involving row houses or multi-family homes) those issues may also pose problems for the installation of a heat pump.

tilt the scale toward economic justification of the proposed standards; they also produce a systematic understatement of the potential for fuel switching, thereby increasing the risk of a "regulatory failure" in which standards intended to reduce energy consumption and carbon emissions actually have the effect of increasing them.[21]

Second, as will be discussed in detail in these Comments, DOE's systematic overstatement of the benefits of the proposed standards consists in significant part of an overstatement of the frequency with which "rule benefit" results – an increase in furnace efficiency achieved without collateral adverse energy consumption impacts – would actually occur. The result of this overstatement is an analysis in which imaginary reductions in energy consumption from efficiency improvements are weighed against real increases in energy consumption caused by fuel switching, further exacerbating the risk that standards might actually do more harm than good even by the sole measure of energy consumption.

Reasonable decisions cannot be made on the basis of the systematically skewed and uncertainty-laden analysis presented in support of the proposed standards. It is therefore imperative that DOE conduct the thorough and *bias-free* analysis needed to ensure that DOE understands the energy conservation consequences of its proposed actions. The proposed standards plainly have the potential to cause fuel switching that would do as much or more to increase energy consumption as improved gas furnace efficiency could be expected to reduce it. Again, while such a result might please electric utilities and parties seeking to eliminate all residential use of natural gas, it is not a result that DOE can lawfully seek to achieve or reasonably fail to rule out.

[21] Attachment B, entitled "Source Energy & Emissions Analysis Tool," examines emissions increases for various gas-to-electric fuel switching across the U.S.

Unfortunately, DOE's entire analysis is comprehensively skewed so as to understate the nature, extent, and adverse impacts of the fuel switching the proposed standards can be expected to cause. Moreover, DOE even presents the results of its analysis in a way that systematically understates fuel switching impacts: rather than present the percentage of consumers impacted by proposed standards that would be driven to fuel switching, DOE presents its fuels switching results as a percentage of both the consumers who would be affected by the proposed standards and the large percentage of consumers that would be expected to purchase condensing gas furnaces even in the absence of new regulation. As a result, the percentage of consumers affected by the proposed standards that would be driven to fuel switching – instead of more efficient gas furnaces – would be on the order of twice the percentages stated at 81 Fed. Reg. 65813, Tables V.3 and V.4.

D. <u>The proposed standards would impose disproportionate and adverse impacts on low-income consumers</u>

Another major problem with the proposed standards is that they would impose disproportionate adverse economic, safety, and other human health impacts on low-income consumers. The regulatory analysis offered in support of the SNOPR purports to address adverse impacts, but instead effectively masks the economic impacts, obtusely ignores the existence of objectively obvious safety issues, and fails to identify or address the broader human health impacts the proposed standards can be expected to have on low-income consumers.

1. <u>Economic impacts</u>

The regulatory analysis offered in support of the proposed standards is based upon an economic analysis that – as will be discussed in detail in these comments – systematically understates the costs the proposed standards would impose and systematically overstates the benefits they would provide. DOE's analysis of rule impacts on low-income consumers is unreasonably skewed and invalid for this reason alone. In addition to these broader errors, however, there are significant additional errors that are specific to the impacts of the proposed standards on low-income consumers.

Most remarkably, the analysis offered in support of the SNOPR completely ignores the realities of low-income consumer economics and the impacts of economic decision-making. For example, DOE's fuel switching analysis assumes that consumers engage in economic decision-making, but applies the same 3.5 year average tolerable "payback" period for all consumers, regardless of their income level, to determine when fuel switching will occur. This 3.5 year criterion was reportedly based upon proprietary American Home Comfort Study (AHCS) survey information, but inspection of the available AHCS data confirms what any reasonable person would expect: the payback period consumers consider to be tolerable varies considerably on the basis of consumer income levels, with low-income consumers having very short tolerable payback periods.[22] As a result – just as one would expect – low-income consumers are far more likely than other consumers to pursue low first cost options even when higher product lifecycle costs would result. In other words, low-income consumers would be far more likely than the average consumer to respond to the proposed standards by resorting to low first-cost fuel switching options that will result in "net cost" outcomes over time. Conversely, relatively high-income consumers with far longer tolerable payback periods would be far *less likely* to focus on the desire to minimize first costs, and would thus be far more likely to make the investments required to enjoy "net benefit" outcomes. By using a 3.5-year

[22] Gas Technology Institute (GTI) *Technical Analysis of DOE Supplemental Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies* (November 21, 2016) ("GTI SNOPR Report") (copy provided as Attachment C to these Comments) at p.73. DOE suggests that "the survey data used by DOE does not provide sufficient information to drive a distribution of required payback periods that is transferable to DOE's methodology." 81 Fed. Reg. at 65792. There appears to be some careful phrasing involved in this statement, because the AHCS survey data did include sufficient information to demonstrate that a single 3.5-year criterion is unreasonable as applied to all consumers, and GTI's work demonstrates that it isn't hard to generate a distribution of payback periods that at least attempts to reflect material differences in consumer payback expectations.

average tolerable payback period for all consumers, DOE effectively screened these realities out of its regulatory analysis, thereby obscuring the fact that "net benefit" outcomes will be disproportionately enjoyed by high-income consumers while "net cost" outcomes will fall disproportionately on low-income consumers. The result is an analysis that significantly overstates the extent to which low-income consumers would enjoy net benefit outcomes while significantly understating the extent to which they would suffer net cost outcomes under the proposed standards. In addition – as already discussed – the 3.5-year criterion also serves to screen the worst fuel switching outcomes out of DOE's analysis, thereby understating the severity of such impacts as well as the frequency with which they would be experienced by low income consumers.

While DOE assumes that consumers engage in economic decision-making in evaluating fuel switching alternatives, it perversely assumes the opposite – that there is no economic decision-making involved – when consumers choose between gas furnaces. Interestingly, the resulting defect in DOE's analysis is the same: it unreasonably assumes that consumers behave in exactly the same way regardless of their income level, ignoring the intuitively obvious facts that high-income consumers can afford to have longer than average tolerable payback periods and that low-income consumers can only afford much lower than average tolerable payback periods. The practical result is also the same: the impacts of consumer income level on consumer decision-making are effectively screened out of DOE's analysis, thereby obscuring the fact that net benefit outcomes under the proposed standards would be disproportionately enjoyed by higher-income consumers while net cost outcomes would be disproportionately borne by low-income consumers. In short, DOE's analytical approach once again uses an unreasonable assumption to systematically overstate the extent to which low-income consumers would enjoy net benefit outcomes under the proposed standards while systematically understating the extent to which they would experience net cost outcomes. For these reasons, it is not surprising that DOE's economic analysis found results for low-income consumers that were "not substantially different" than the results for the average consumer. 81 Fed. Reg. at 65816. This is the inevitable result of a methodology that is systematically designed to model low-income consumers **as average consumers**.

Finally, DOE's abstract analysis fails to acknowledge the simple fact that the "low tolerable payback period" of low-income consumers is not simply a function of the relative *willingness* of low-income consumers to make investments for future reward; it is also a function of the frequent *inability* of low-income consumers to make such investments. In short, there is a point at which low-income consumers cannot afford higher housing costs. Incremental increases in appliance costs therefore incrementally reduce the housing options available to low-income consumers.[23] As a result, standards that effectively increase the cost of necessary home appliances have an adverse impact on low-income consumers.

Regulations that increase the cost of residential furnaces have an even more obvious impact in the appliance replacement market, because furnace replacements are often an emergency expense, and approximately 63% of "average" Americans do not have sufficient resources on hand to cover even a $500 emergency.[24] It is therefore logical to assume that low-income consumers would have considerably more difficulties finding the necessary funds. DOE nevertheless assumes that – despite a rule significantly increasing the cost of gas furnaces – consumers will always replace their furnaces as necessary. The reality is that many low-income consumers will not be able to find the resources to replace their non-condensing gas furnaces with condensing gas furnaces. Such consumers are likely to purchase substantially less expensive electric resistance furnaces – despite their adverse long-term economic

[23] http://nahbnow.com/2014/08/new-nahb-study-how-fees-force-buyers-out-of-the-market/

[24] http://www.forbes.com/sites/maggiemcgrath/2016/01/06/63-of-americans-dont-have-enough-savings-to-cover-a-500-emergency/#24512a156dde

consequences – or to resort to portable electric resistance space heaters or other uneconomical home heating expedients; that can often present safety issues (as will be discussed next). DOE's abstract economic analysis does more to obscure these realities than to account for them.

2. Safety impacts

Numerous commenters identified safety concerns raised by the proposed standards. In general, the concerns raised are intuitively obvious, and in many cases they undoubtedly reflect the engineering knowledge and practical experience of the particular commenters.

DOE's response to such comment is remarkable. In general, DOE characterized objectively obvious safety concerns as mere "speculation," glibly assumed that existing safety codes and practices are sufficient to reduce such concerns to insignificance, and suggested that the proposed standards wouldn't do anything to increase the frequency of safety problems related to inadequate or improper furnace repairs or consumer use of unsafe space heating expedients. 81 Fed. Reg. at 65745-46. In short, none of this is true. Even a quick internet search is sufficient to confirm that the safety concerns raised by commenters are legitimate and that the proposed standards can be expected to exacerbate specific existing safety problems that have been relentlessly contributing to the Nation's mortality statistics for years.

Readily available data confirm that – notwithstanding safety standards and practices – fires involving heating equipment occur, people die as a result, and factors such as improper furnace repairs and the use of home heating expedients are significant causal factors. NFPA statistics show that heating equipment was involved in an estimated 56,000 reported home fires from 2009 to 2013, causing 470 civilian deaths, 1,490 civilian injuries, and a billion dollars in direct property damage.[25] The NFPA data

[25] The NFPA data can be accessed at: http://www.nfpa.org/public-education/by-topic/top-causes-of-fire/heating

indicates that portable space heaters account for approximately 40% of these fires and over 80% of the resulting deaths. FEMA provides even more comprehensive data, showing an average of over 45,000 home heating fires per year from 2010 to 2012, with an average of 155 deaths, 625 injuries, and over $350,000,000 in property losses each year.[26] In addition, the Consumer Product Safety Commission is a ready source of information demonstrating that consumers die every year from non-fire carbon monoxide poisoning attributable to the misuse of portable space heaters and inadequately-maintained furnaces and vent systems, confirming that – safety standards and best practices notwithstanding – such fatalities often result from poor furnace maintenance by professionals or consumers, inadequate ventilation, and faulty exhaust pathways.[27]

In short, there is a clear factual basis for the safety concerns commenters have raised. Those concerns cannot reasonably be dismissed as mere speculation; nor can they be dismissed on the basis of the factually false suggestion that existing safety standards and practices are sufficient to reduce them to insignificance. Nor can these concerns be dismissed on the grounds that the proposed standards will do nothing to exacerbate the safety risks involved, despite DOE's strained suggestion that there is "no evidence" that they will. As already discussed, many low-income consumers lack the resources necessary to replace broken furnaces, and a rule materially increasing the cost of furnace replacements will leave more consumers in that position. Many such consumers will have little choice but to try to keep their existing furnaces running by any means necessary, to rely on portable electric resistance space heaters, or – worse – to resort to unsafe and inadequate improvised space heating measures. Desperate people can

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[26] FEMA data can be accessed at: https://www.usfa.fema.gov/prevention/outreach/heating.html and Heating Fires in Residential Buildings (2010-2012)

[27] CPSC information can be found at: https://www.cpsc.gov/Research--Statistics/Carbon-Monoxide and https://www.cpsc.gov/s3fs-public/pdfs/2012NonFireCODeaths.pdf

be expected to take desperate measures, and they obviously do, which is why many Americans – disproportionately low-income consumers – die in fires or of carbon monoxide poisoning every winter. As discussed below, it is a statistical fact that material increases in furnace replacement costs can be expected to exacerbate this problem.

DOE cannot play "see no evil, hear no evil" in order to avoid the need to speak about these evils. There is obviously a legitimate basis for concern about the adverse safety impacts of the proposed standards, and DOE has an obligation to investigate those concerns and ensure that they are adequately addressed in its regulatory analysis. It has plainly failed to discharge that responsibility.

3. Environmental Justice

Executive Order 12898 directs Federal agencies to identify and address any "disproportionately high and adverse human health or environmental effects" its actions may have on minority and low-income populations. The proposed standards can be expected to have disproportionate and adverse human health impacts on low-income populations, because – in addition to exacerbating known safety risks – the standards would effectively increase the cost and decrease the availability of heating for low-income consumers. Those results can be expected to translate directly into adverse health impacts, including increases in excess mortality in low-income communities. DOE has failed to fully identify or appropriately address these "disproportionately high and adverse" human health effects, and should do so as Executive Order 12898 and relevant implementing guidance requires.

For many families across our communities, cold winters bring the struggle to pay heating bills and stay warm. Often, the most affected neighbors are elderly, disabled or have children under the age of five. Spire is acutely conscious of this reality. For over thirty years, Spire and its predecessors have implemented and invested in programs to assist low-income consumers in paying their heating bills. Last year, Spire's DollarHelp program raised more than a million dollars to keep the heat on for nearly 3,000

Missouri families. Spire is proud to have introduced this important program in Alabama, and has not been alone among gas utilities in its efforts to assist low-income consumers.

Significant concern is warranted, because more is at stake than mere comfort. Minority and low-income populations in the United States are subject to well-documented patterns of disproportionate and adverse health effects, many of which can be linked directly to impacts of poverty at the community and individual level.[28] The impacts in question are dramatic; in fact, studies suggest that poverty may have an even stronger correlation with adverse health outcomes than tobacco use or obesity.[29] As a result, no complex modeling is required to conclude that additional costs imposed on low-income consumers would exacerbate economic conditions that are powerful drivers for significant adverse human health consequences.

Studies have confirmed that winter heating needs can impose harsh choices on individuals in low-income communities. A 2011 study of Low Income Home Energy Assistance Program (LIHEAP) recipients in Connecticut[30] found that – in order to afford home heating during the prior year – 23% of recipients reportedly kept their homes at a temperature they considered unsafe or unhealthy, 26% used a kitchen stove or oven for heat, 25% had gone without food for at least one day, 29% had gone without medical or dental care, and 31% had not taken their prescription medication. Not surprisingly, 15% of

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[28] Woolfe S., Braveman, P. Where Health Disparities Begin: The Role Of Social And Economic Determinants—And Why Current Policies May Make Matters Worse. Health Affairs (October 2011) available at: http://content.healthaffairs.org/content/30/10/1852.full

[29] *Id.*

[30] National Energy Assistance Directors' Association, 2011 National Energy Assistance Survey Connecticut Study, Final Report, November 20011, available at: http://www.appriseinc.org/reports/FINAL%20NEADA%20CT%202011%20Report.pdf

these consumers had reportedly become sick and needed to go to the doctor or hospital because their home was too cold. The need for adequate home heating is particularly acute for many low-income consumers, because such consumers disproportionately suffer from respiratory and circulatory conditions that are significantly exacerbated by exposure to cold temperatures. The bottom line should be obvious: like fuel switching, higher home heating costs attributable to fuel switching will disproportionately affect low-income populations, and they will do so in ways that have very real adverse human health consequences. The same can be said for "net cost" impacts resulting from excessive appliance and installation costs, because "net cost" impacts are not merely *economic* impacts for low-income consumers; they are impacts with significant adverse human health consequences that DOE must consider in assessing the impacts of its proposed standards.

Unfortunately, DOE's abstract economic assessment does not even address some of the critical human costs its proposed standards would have. Every winter, there are low-income consumers who are forced to go without heat because they lack the resources to repair – let alone replace – a broken furnace. DOE's suggestion that such consumers would suffer the same fate whether or not the proposed standards are adopted ignores the fact that standards that increase the cost of furnace replacement will make an existing problem worse. Again, this is an issue with which Spire is familiar, because Spire services its customers' furnaces and manages a "Red Tag Equipment Repair" program to help low-income customers maintain or restore gas heating to their home. The facts are straight-forward: this program – which provides up to $450 per customer per year toward the total cost of qualifying repairs as long as funds are available – will keep the heat on in fewer homes if the proposed standards are adopted. The consequence is as simple as it is certain: the proposed standards will cause more low-income consumers to go without adequate home heating. The issue will not be inadequate payback on an investment in a more efficient appliance: it will be human suffering, illness, and excess mortality.

E. **The proposed "small furnace" exemption is completely inadequate and would likely have adverse impacts on consumer welfare and energy conservation**

DOE has seriously understated the extent to which any national condensing standard has the potential to impose serious adverse consequences in the form of fuel switching and disproportionate adverse impacts on low-income consumers. It has nevertheless recognized that such a standard would impose adverse consequences, and has proposed a "small furnace" exemption (actually several alternative variations of a "small furnace" exemption) as a means to moderate the adverse impacts a national condensing standard would have. Under DOE's proposed approach, a national condensing standard in the range of 92-98% AFUE would be imposed for furnaces with input capacities above a specified cut-off point, and a non-condensing standard (80% AFUE, the maximum practical efficiency for non-condensing furnaces) would apply to gas furnaces with lower input capacities. Unfortunately, there are serious problems with DOE's proposed solution to the problems posed by a condensing standard for gas furnaces.

The problems start with the fact that DOE's entire understanding of furnace size and furnace sizing criteria is based on erroneous assumptions. However, there is an even more basic problem with DOE's proposed "small furnace" exemptions: they are not directed at the problems they are ostensibly designed to address. In short, condensing standards for gas furnaces are problematic for two primary reasons: because the cost of condensing gas furnaces is such that they generally make economic sense for consumers with relatively high furnace use but not for consumers with relatively low furnace use, and because condensing furnaces impose home design and installation constraints that can make them an impractical or economically unreasonable choice for some consumers regardless of the level of furnace use involved. These are the problems that would cause fuel switching, net negative impacts for far too many consumers, and disproportionate adverse impacts on low-income consumers, and they are a function of the *characteristics of condensing gas furnaces*, not of *furnace size*. DOE's proposed furnace size criteria would incrementally reduce the number of gas furnaces subject to condensing standards and would – to that extent – incrementally reduce the adverse impacts of the proposed standards. However, they are not logically designed to address the problems inherent in a condensing standard for gas furnaces.

DOE's premise is that the cost and installation issues associated with condensing gas furnaces are disproportionately prevalent with respect to small furnaces, with the result that an exemption for such furnaces would go a long way toward solving the problems inherent in a national condensing standard for gas furnaces. However, there is no credible evidence that this premise is correct. In fact, DOE's analysis is based entirely on erroneous assumptions and an inadequate understanding of the relevant facts and issues. The result is proposed solutions that have a significant potential to cause adverse impacts that DOE has failed to identify or consider.

1. A "small furnace" exemption would have very limited impact, would impose losses in consumer utility, and would have adverse impacts on energy conservation

One of the basic problems is that DOE's "small furnace" exemptions simply wouldn't cover enough furnaces to make a dent in the problems caused by a condensing standard for gas furnaces. Indeed, available shipment data indicates that less than 10% of gas furnaces would be small enough to qualify for DOE's proposed 55,000 kBtu/hr. "cut off," and only a fraction of those are non-condensing furnaces for which a "small furnace" exemption would even be relevant.

DOE's theory is that a "small furnace" exemption would have a more significant impact than the percentage of "small" furnaces currently in the market would suggest, because the cost and installation issues associated with condensing gas furnaces would force many consumers to "down-size" to a "small" furnace to avoid the burdens a condensing standard would otherwise impose. DOE suggests that such "down-sizing" would be a good thing, because many consumers with "over-sized" furnaces would save energy by moving to a smaller input furnace. However, DOE's understanding of issue with respect to furnace size is seriously defective, and DOE has completely failed to consider negative impacts that furnace down-sizing can be expected to have on furnace utility and energy conservation.

It is important to recognize that the term “over-sized” is extremely misleading with respect to gas furnaces. In fact, a furnace that is **not** “over-sized” is actually inadequate to satisfy a consumer’s heating needs. The reason for this is that the baseline for furnace sizing starts with the level of steady-state performance necessary to satisfy normal heating needs. By definition, this baseline capacity is not sufficient to satisfy peak heating demands required to heat up a house reasonably quickly when the furnace has not been in operation or to maintain desired heat during the coldest days of the heating season. As a result, a larger-capacity furnace is needed to satisfy the full range of actual heating needs, and it is merely a quirk of terminology that describes such a right-sized furnace as “over-sized.” DOE optimistically assumes that an “over-sizing” factor of 1.35 will be sufficient to ensure that a furnace satisfies actual consumer heating needs, and then assumes that this factor will actually be applied in furnace “down-sizing” decisions driven by the economic and installation penalties imposed by condensing gas furnaces. The reality is that issues of furnace-sizing are not as tidy as DOE seems to suppose and, in view of the price penalty and installation problems a condensing standard would impose, the market distortion created by DOE’s proposed “small furnace” exemption would unquestionably lead to furnace-sizing brinksmanship that would leave many consumers – disproportionately low-income consumers desperate to minimize initial costs – with furnaces that are inadequate to meet their peak heating needs. Indeed, it has been suggested that a small furnace exemption would be an effective means to “encourage” consumers to invest in insulation improvements,[31] which inadequate heat would certainly do, though at human and economic costs DOE has not accounted for. DOE has done nothing to consider the impact the loss of

[31] 81 Fed. Reg. at 65752.

consumer utility furnace down-sizing would impose; it has simply provided a regulatory analysis that – due to the criteria employed to determine when down-sizing would occur – conveniently (and indefensibly) assumes that harmful furnace under-sizing will never result.

In addition to the loss of consumer utility furnace down-sizing can be expected to cause, DOE has failed to consider the adverse impact that furnace down-sizing can be expected to have on energy conservation. Consumers commonly secure significant energy conservation benefits by setting their thermostats back during overnight periods or during the day when a home is not occupied. The problem is that the significant energy conservation benefits that can be achieved by furnace set-back strategies can only be achieved if there is sufficient furnace capacity to ensure that a home can be warmed up relatively quickly when the thermostat is turned back up. If a furnace lacks sufficient capacity to provide a relatively short "set-back recovery" period, consumers will be less able to conserve energy by setting back their thermostats and – in many cases – are likely to give up the attempt entirely. These are important energy conservation issues that DOE has not considered at all. DOE has simply assumed that "good" furnace down-sizing will occur and that harmful furnace under-sizing will never result.[32]

In fact, it appears that negative impacts from furnace down-sizing – both loss in heating utility and energy conservation penalties resulting from reduced use of thermostat set-back strategies to reduce energy consumption – are likely to be the rule rather than the exception. GTI has conducted a study concerning furnace sizing indicating that a 55,000 Btu/hr furnace would be sufficient to satisfy the steady-

[32] Another likely result of a rule that would create a powerful incentive for furnace under-sizing is yet another form of fuel switching: after trying to scrape by with an undersized furnace, consumers will find that supplemental heating is required and invest in one or more electric resistance space heaters, an expedient that would have low initial costs but would be no bargain from an energy conservation, carbon emissions, or a consumer economics standpoint.

state heating needs for only a small minority of single-family homes in the United States.[33] Even in the cases in which steady-state heating needs would be satisfied, consumers would likely see a meaningful loss in heating function amounting to extended hours in which heating capacity would be insufficient to maintain desired home temperatures.[34] In all cases, a 55,000 Btu/hour furnace would likely compromise setback recovery performance, and homeowners would likely be inclined to limit the extent, or stop employing, thermostat setback as an energy conservation measure.[35]

2. The impacts of a "small furnace" exemption would be misdirected

Again, the basic premise of the proposed "small furnace" exemption is that the adverse impacts of a condensing standard for gas furnaces fall disproportionately on consumers that have (or ought to have) "small" furnaces: low-income consumers (because DOE assumes that low-income consumers disproportionately have small homes), and consumers in the south, for whom condensing gas furnaces would generally not be economically justified. 81 Fed. Reg. at 65752 and 65795. However, DOE is wrong on the facts.

For purposes of its analysis, DOE determined furnace size on the basis of home size and climate. 81 Fed. Reg. 65770. In addition to home size and climate, however, heating needs (and thus furnace size) depend on the extent to which a home retains or loses heat; in effect, how thermally "tight" a home is. Yet DOE's analysis neglected the latter consideration entirely. This is a critical omission, because neither low-income consumers nor consumers in the South tend to live in very well insulated homes.

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[33] Gas Technology Institute (GTI) *Empirical Analysis of Natural Gas Furnace Sizing and Operation* (November 10, 2016) (Copy provided as Attachment D to these Comments) at p. 32.

[34] *Id.*

[35] *Id.*

GTI conducted a study based on extensive real-world data spanning several states in the North and South, and found a very strong correlation between furnace size and "UA" value (a value that combines the impacts of home size, climate, and the thermal tightness of the home itself); by contrast, correlation between home size and furnace size was surprisingly weak.[36] GTI also found that furnace sizing requirements actually increased for homes located Southern, cooling-dominated regions in Arkansas and Oklahoma, with smaller furnaces being found in Minnesota.[37] In short, there is no basis for the premise that a "small furnace" exemption would disproportionately favor low-income consumers and consumers for whom condensing gas furnaces tend not to be economically justified; as a result, such an exemption would do little or nothing to address the core problems a condensing standard for gas furnaces would impose.

3. **DOE's entire analysis of furnace sizing issues is based upon unreasonable assumptions.**

DOE's methodology in analyzing input-related furnace sizing threshold proposals for condensing and non-condensing furnace minimum efficiency standards is flawed in several ways. As already indicated, DOE's basic assumptions with regard to furnace sizing are baseless and inconsistent with available information. Its understanding of furnace sizing criteria – and the manner in which furnace sizing decisions are made – is equally flawed.

First, the Air Conditioning Contractors of America (ACCA) Manual J and Manual S criteria for furnace sizing cited as the basis for evaluating DOE's "small furnace" exemptions do not apply to decision-making for furnace replacements, and furnace replacements reportedly represent 75% to 80% of

[36] *Id*. at pp. 31.

[37] *Id*. at pp. 31-32.

total furnace shipments. In fact, HVAC contractors do not use Manual J or Manual S criteria for furnace sizing as a standard practice when replacing furnaces, except perhaps in statistically-rare instances involving deep rehabilitations of residential properties. DOE's assumption that these criteria are applicable to the entire furnace market is baseless and undermines its entire analysis of the potential for – and likely impacts of – furnace "down-sizing."

Pilot field survey data, collected in November 2016, tends to confirm that installers do not use the ACCA documents in replacing furnaces and provides insights as to why that is the case. The pilot survey involved five furnace installers in the Arlington, VA area, and all five installers indicated that they do not utilize ACCA Manual J or Manual S criteria as the basis for quoting furnace replacements. Instead, all five installers reported that they address the sizing of replacement furnaces by:

- Asking their customers whether or not occupants have experienced comfort-related issues when operating their existing furnaces (three installers explicitly explained that this question is designed to address any potential under-sizing of existing furnaces); and

- Estimating the existing furnace heat output on the basis of furnace input and either the quoted AFUE efficiency of the existing furnace or the estimated efficiency of the existing furnace based on its age so that they can recommend a replacement furnace that delivers the same heat output.

When asked why they did not apply Manual J and Manual S criteria in the context of replacement furnaces, the pilot survey installers indicated that the calculations required would take time and impose costs that would be very difficult to justify; one respondent added that costs more than $1,000 just to have a Manual J calculation done. DOE has not accounted for any costs for such calculations in its regulatory analysis.

Additionally, claims of energy gains made by energy efficiency organizations and DOE from downsizing furnaces are not technically justified within reasonable furnace oversize ranges. Proponents of the use of Manual J and Manual S criteria for furnace sizing must surely understand this, since as stated in Manual S, oversizing by as much as 100% will not lead to significant decreases in energy efficiency in terms of increased operating cost.[38] This was recognized when the furnace test procedure was designed, assuming a 70% oversizing factor. In contrast, energy efficiency advocates at the August 2016 public meeting on the SNOPR cited that field-observed oversizing leads to decreased energy efficiency, but the specific example cited was for a case of 200% oversizing (characterized in the public meeting discussion as "gross oversizing"). It does not follow that replacement of such furnaces would be done according the ACCA guidance, further confounding the assumption that Manual J and Manual S criteria would apply even in these installations.

In view of the foregoing, DOE's assumption that Manual J and Manual S sizing criteria have any direct relevance in the context of furnace replacements – and particularly its unstated assumption that such criteria could be employed in the furnace replacement context without imposing substantial additional costs on consumers – is unjustified and unreasonable. Spire recommends that DOE revise its assumptions with respect to furnace sizing and the decision-making involved in furnace-sizing decisions and, in particular, that it abandon its reliance on furnace sizing criteria based on the ACCA documents.

F. DOE unreasonably dismissed the alternative of a separate product class for non-condensing furnaces

As already discussed, non-condensing furnaces have an important feature that condensing furnaces do not have: the ability of function with a natural draft vent system, as necessary (among other things) to make such furnaces compatible with the existing vent systems in the vast majority of existing homes in the United States. The fact that condensing standards for gas furnaces would eliminate this important feature is the root cause of serious problems raised by condensing standards for gas furnaces, including significant cost and installation-related challenges that would induce counterproductive fuel switching and

[38] "Residential Equipment Selection: Manual S," Air Conditioning Contractors of America (ACCA). Page 2-1 and Appendix 4.

impose disproportionate adverse impacts on low-income consumers. "Small furnace" exemptions are inadequate to address these problems because they are non-responsive to the problems themselves and provide purported "solutions" that amount to little more than an exercise in horse-trading as to how many bad outcomes must be avoided to make a bad standard bearable.

The obvious alternative would be a solution that would actually address the problem: a separate product class for non-condensing furnaces. Standards appropriate for condensing gas furnaces – if economically justified – could then be imposed on condensing gas furnaces, including the "small" condensing furnaces that make up a substantial percentage of whatever "small" furnace category one might choose to define. The problems caused by the elimination of the features natural draft furnaces provide would be eliminated, along with the bulk of the fuel switching problems and adverse impacts on low-income consumers the proposed standards would otherwise impose.

DOE's suggestion that it "has no statutory basis for defining a separate product class based on venting and drainage characteristics"[39] is both frivolous and contrary to its own prior interpretation of its EPCA authority. In fact, EPCA provides express authority for DOE to establish a separate product class for products that have a "capacity or other performance-related feature which other products within such type (or class) do not have and such feature justifies a higher or lower standard from that which applies (or will apply) to other products within such type (or class)."[40] DOE's suggestion that non-condensing gas furnaces do not "provide unique utility to consumers beyond the basic function of providing heat, which all furnaces perform"[41] is both false and irrelevant. It is false because non-condensing gas furnaces

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[39] 81 Fed. Reg. at 65753.

[40] 42 U.S.C. § 6295(q)(1)(b).

[41] 81 Fed. Reg. at 65753.

can serve the function of providing heat in homes in which condensing gas furnaces would provide no heat because they cannot reasonably be installed. It is irrelevant, because – if it were not – there could never be any such thing as a "capacity or other performance-related feature which other products within such type (or class) do not have," and DOE will have impermissibly interpreted 42 U.S.C. § 6295(q)(1)(b) to be a nullity.[42] The fact that all gas furnaces are forced-air heating appliances simply goes to show that they are a "group of covered products which have the same function or intended use" under 42 U.S.C. § 6295(q)(1), which establishes that the provisions of 42 U.S.C. § 6295(q)(1)(b) *can* apply, not that they *cannot*.

DOE's rejection of a separate product class for furnaces that are compatible with the existing vent systems in most existing buildings is also flatly inconsistent with extensive precedent confirming that separate product classes are warranted as a means to address differences in installation requirements. For electric residential clothes dryers, for example, DOE has recognized five different product classes including:

- Vented electric, standard capacity (4.4 cubic feet or greater);
- Vented electric, compact capacity (less than 4.4 cubic feet) and operating on 120 volts;
- Vented electric, compact capacity (less than 4.4 cubic feet) and operating on 240 volts;
- Ventless electric, compact capacity (less than 4.4 cubic feet) and operating on 240 volts; and
- Ventless electric combination washer/dryers.[43]

In these examples, "standard" and "compact" criteria for differentiating the products are associated with the building elements of constrained installation space, the "120 volt" and "240 volt" differentiation

[42] NRDC v. EPA, 489 F.3d 1364, 1373 (D.C. Cir. 2007).

[43] 10 C.F.R. § 430.32(h)(3).

addresses differences in building system electrical supply, and the vented/ventless distinction addresses installation constraints based on venting requirements.

Similarly, product classes for residential direct heating equipment are based on variations in their manner of installation, including:

- Gas wall fan type (wall furnaces);
- Gas wall gravity type (wall furnaces);
- Gas floor (floor furnaces); and
- Gas room (room heaters).[44]

These product class distinctions address variations in building characteristics affecting the relative ease or feasibility of different types of product installations (i.e., wall, floor, or room installations), as well as the availability of electrical supply (fan-driven wall furnaces require electrical power, whereas gravity wall furnaces may not).

Similarly, the following separate product classes exist for residential heat pumps and air conditioners:

- Split systems;
- Single-package (unitary) systems;
- Small-duct, high-velocity systems; and
- Space-constrained systems.[45]

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[44] 10 C.F.R. § 430.32(i).

[45] 10 C.F.R. § 430.32(c).

Again, all of these separate product classes exist to address installation constraints imposed by variations in the installation environment, including differences in wall area, building volume available for duct work, and available space in the structure for the installation of indoor units.

It is irrational to suggest that building features that constrain the installation and use of consumer products warrant separate product classes in all of the examples identified above but not in the case of the non-condensing gas furnaces. Again, non-condensing gas furnaces are the only type of gas furnace that is compatible with the vent systems present in the vast majority of American homes. By refusing to establish separate product classes for condensing and non-condensing gas furnaces, DOE is effectively regulating the building environment instead of the product to be installed, imposing the need for building modifications characterized as mere "installation costs," and forcing fuel switching in cases in which it would impractical or impossible to shoehorn condensing furnace into buildings that were not designed to accommodate them.

In fact, DOE would have a statutory obligation to provide a separate product category for non-condensing furnaces if it were to adopt a condensing standard for gas furnaces, because 42 U.S.C. § 6295(q)(1) states that DOE "shall specify" a separate efficiency standard (*i.e*., a separate product class) for products such as non-condensing gas furnaces that have "a capacity or other performance-related feature which other products within such type (or class) [*i.e.*, condensing gas furnaces] do not have and such feature justifies a . . . lower standard from that which applies (or will apply) to other products within such type (or class)." DOE laments that such an approach would allow continued sales of non-condensing furnaces, 81 Fed. Reg. 65753, but that is exactly the result that 42 U.S.C. § 6295(q)(1) was designed to achieve, and is consistent the clearly-expressed legislative intent that efficiency standards must not result in the unavailability of products having the same range of features that are currently available in the United States. 42 U.S.C. § 6295(o)(4).

DOE's claim that a separate product class for non-condensing gas furnaces would "[undercut] any possible energy savings that might be achieved by improving the efficiency standard for the condensing product class" is similarly without merit. Non-condensing furnaces are needed when the features they offer make them a practical necessity, or when furnace use is insufficient to make the incremental efficiency benefits of a condensing gas furnace worth the incremental costs. Where condensing furnaces are a reasonable option, however, there is no reason to suggest that an economically justified improvement in condensing furnace efficiency would drive consumers back to significantly less efficient non-condensing furnaces. To the contrary, the different features of condensing and non-condensing furnaces cut both ways, and – in the increasingly substantial share of the market in which homes have been designed for condensing gas furnaces or a condensing gas furnace has already been installed, the differences in installation requirements would run in reverse, making it more costly – if not impractical – to switch from a condensing gas furnace back to a non-condensing gas furnace.

G. DOE's determinations that the proposed standards would result in significant conservation of energy and are economically justified are arbitrary and unsupported by substantial evidence

DOE may only impose energy conservation standards if it determines **– on the basis of substantial evidence –** that such standards would result in significant conservation of energy and are technologically feasible and economically justified. 42 U.S.C. §§ 6295(o)(2)(A) and (o)(3)(B), 42 U.S.C. § 6306(b)(2). DOE's proposed determinations that the proposed standards would result in significant conservation of energy and are economically justified are arbitrary in numerous respects, and are not based on substantial evidence.

In lieu of substantial evidence, the proposed standards are supported by substantial bulk: a lengthy SNOPR accompanied in the record by a Technical Support Document of nearly 1200 pages and over 6000 pages of spreadsheets. This bulk is symptomatic of an excessively complex and unreasonably opaque methodology in which DOE systematically substitutes elaborate analysis based on inadequate data and unreasonable assumptions for credible analysis of credible data. The methodologies employed do not serve to provide an intelligible demonstration that proposed efficiency standards are economically justified as EPCA requires; instead they produce a skewed analysis that systematically overstates regulatory benefits while understating regulatory burdens, and that does so in a manner that is so convoluted and opaque that it is extraordinarily difficult to understand or contest on the merits.

DOE's economic analysis involves modeling in which it constructs ten thousand trial cases to represent the full range of furnace installation scenarios that would be expected to be encountered in the United States. In theory, DOE is supposed to conduct simulations to compare the economic outcomes that would occur in those ten thousand cases in the absence of any new regulation (the base case) with those that would occur if new standards were imposed (the standards case). DOE is then supposed to compare the two results to determine whether the proposed standards would result in significant energy conservation, and whether the costs of required efficiency improvements would be justified by the benefits of the efficiency improvements required. However, every step of the analysis provided in support of the SNOPR – from the construction of the base case for analysis through the parameter inputs used and the nature of the analysis performed – is systematically skewed to produce an overstatement of regulatory benefits and an understatement of regulatory burdens.

Independent expert analysis – conducted at considerable expense – confirms that "DOE's findings are skewed in favor of the rule based on flawed methodologies and inferior data," and that correction of even a subset of the major defects in DOE's analysis demonstrates that **none of the standards proposed in the SNOPR are economically justified**.[46]

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[46] GTI SNOPR Report at pp. viii and 75.

1. **DOE's arbitrary trial case furnace assignments invalidates its entire economic analysis**

As already indicated, DOE's regulatory analysis involves modeling in which it selects ten thousand trial cases as its basis for analysis. To determine the impact of proposed standards, DOE then simulates and compares two potential futures: one in which no new standards are adopted, and one in which its proposed standards are adopted. Perhaps the single most fundamental defect in DOE's regulatory analysis lies in the fact that its ten thousand trial cases are not designed to reflect the market they are supposed to represent. Instead they are constructed in a way that creates a "total disconnect from market conditions" and creates a "high bias toward rule benefit." GTI SNOPR Report at 62.

For purposes of regulatory analysis, it is necessary to account for the fact that some consumers will have condensing gas furnaces even in the absence of the proposed standards. Because these outcomes are not attributable to the proposed standards, their economic consequences must be excluded from consideration in any assessment of the economic impacts of the proposed standards. In short, it is essential to distinguish the purchases that would occur in the absence of regulation from those that would occur as a result of the proposed standards. This, in turn, requires consideration of how purchasing decisions can be expected to be made in the absence of regulation.

In the real world, purchasers of residential furnaces commonly engage in economic decision-making, with the result that they disproportionately choose condensing gas furnaces when it makes economic sense for them to do so and disproportionately choose not to invest in condensing gas furnaces when it would be economically unreasonable to do so. There is overwhelming evidence that this is the case: for example, evidence confirms that purchasers of gas furnaces disproportionately choose condensing gas furnaces in the northern United States – where the economic justification for them tends to be strongest – but not in the South, where investment in condensing gas furnaces generally makes little if any economic sense. By DOE's own analysis, condensing gas furnaces are already headed toward a 95% share of the gas furnace market in all of New England as well as in states such as Wisconsin, Iowa, Minnesota, and the Dakotas. By contrast, DOE projects that non-condensing gas furnaces will retain a substantial share of the market in states such as Florida, Louisiana, Texas and Arizona. TSD Tables 8I4.1 and 8I4.2. DOE cites further evidence that consumers engage in economic decision-making in its fuel switching analysis,[47] assumes that economic decision-making always occurs in that context, and more broadly "acknowledges that furnace efficiency choice is affected by economic factors."[48] It follows that – to reasonably reflect the realities of the market realities – the ten thousand trial cases used as the basis for regulatory analysis should be designed to reflect the fact that the most economically advantageous purchases of condensing gas furnaces are those consumers are most likely to make in the absence of regulation, and the most economically disadvantageous purchases are those consumers are least likely to make on their own. In short, while there may be room for debate as to the details:

- Trial cases in which condensing gas furnaces would be present in the absence of regulation should disproportionately include cases in which condensing furnaces provide significant economic benefits (particularly cases in which economic benefits would be most substantial); and

- Trial cases in which condensing gas furnaces would be absent should disproportionately include cases in which condensing furnaces would impose significant net costs (particularly cases in which net costs would be most substantial).

DOE did not construct its ten thousand trial cases in this way. Instead, DOE has insisted that – for purposes of constructing its ten thousand trial cases – it can reasonably assume that consumers **never consider economics when selecting a gas furnace.** 81 Fed. Reg. at 68789-90. DOE therefore "assigned" condensing or non-condensing furnaces to its ten thousand trial cases on a random basis (*i.e.*, regardless

[47] 81 Fed. Reg. at 65792.

[48] 81 Fed. Reg. at 65789.

of the economic consequences involved), as though consumers who purchase condensing gas furnaces in the absence of regulation are literally no more likely to make economically advantageous purchases – and no more likely to avoid economically disastrous purchases – than consumers who would only purchase condensing gas furnaces if forced to do so by the proposed standards. In short, DOE's analysis assigned furnaces to the ten thousand trial cases in a way that reflects a massive market failure instead of the well-functioning market that actually exists.

In its efforts to justify its decision to assign furnaces to trial cases as though consumers do not consider economics in their purchasing decisions at all, DOE suggests that the resulting distribution of condensing and non-condensing gas furnaces "is not entirely random," because it assumes that the percentage of condensing gas furnaces in different geographic regions will be consistent with the historical market share in each region. 81 Fed. Reg. at 65789. However, the problem with DOE's approach cannot be addressed simply by randomly "assigning" the right percentage of condensing and non-condensing furnaces to each region, because – by assuming that consumers do not consider economics in their selection of gas furnaces – DOE is still breaking the link between consumer decision-making and purchasing outcomes. The result is significant, because – by fixing the distribution of condensing and non-condensing furnaces but assuming that purchases are made on a random basis, DOE models an alternative universe in which purchases that consumers would make in the absence of regulation are no more likely to be economically favorable than purchases that are forced upon consumers by regulation, and purchases forced by regulation would be no more likely to be economically unfavorable than purchases consumers would choose to make on their own. The result is that DOE's analytical approach moves economically favorable purchases of condensing furnaces from the "base case" to the "standards case" while moving economically unfavorable purchases from the "standards case" to the "base case." This produces startlingly unrealistic results. For example, there are multiple instances in which DOE's furnace assignments enabled it to claim regulatory benefits for cases in which the proposed standards are assumed to be necessary to force consumers to save money by buying significantly less expensive furnaces that will give them significant energy savings to boot. Similarly, there are multiple cases in which DOE effectively sheds responsibility for purchases by assuming that – in the absence of regulation – consumers choose to pay more than $1,500 extra for furnaces that wouldn't provide sufficient energy savings to pay back the investment in less than a century.[49] The problem, however, is not confined to a few outrageous examples, and its cumulative impacts are massive. Indeed, GTI found that **55% of total economic benefits claimed in SNOR** come from purchases in which DOE effectively assumes that the proposed standards are necessary **to prevent consumers from paying extra for less efficient furnaces.[50]** The result, obviously, is a systematic overstatement of the number and magnitude of "net benefit" outcomes the proposed standards would produce and a systematic understatement of the number and magnitude of the "net cost" outcomes the proposed standards would impose.

DOE's other attempted justification amounts to the assertion that the assumption that consumers don't consider economics at all might be no worse than an assumption that all consumer decisions are made solely on the basis of economics. 81 Fed Reg. at 65789. This justification fails for the simple reason that there is no binary choice involved. To the contrary, consumer behavior can be modeled in a way that reflects a degree of economic decision-making that would be reasonably consistent with observed consumer behavior: that's exactly the kind of issue distribution functions in Crystal Ball modeling are designed to address, and GTI was able to develop an appropriate consumer choice methodology within the limited time available for comment on the SNOPR. DOE's consultants simply did not try to do so,

[49] GTI SNOPR Report at p. 22, Tables 15 and 16.

[50] GTI SNOPR Report at p. 23.

and it is easy to see why: modeling that reasonably reflects observed consumer behavior confirms that the general tendency of consumers to make decisions that are in their own economic interest is such that the proposed standards would disproportionately serve to impose purchasing decisions that consumers would be right to reject.

2. DOE's consideration of life-cycle costs and payback periods is unreasonable and does not satisfy EPCA requirements

In determining whether energy conservation standards are economically justified, EPCA expressly directs DOE to consider "the savings in operating costs throughout the estimated average life **of the covered product** in the type (or class) **compared to any increase in the price of**, or in the initial charges for, or maintenance expenses of, **the covered products** which are likely to result from the imposition of the standard." 42 U.S.C. § 6295(o)(2)(B)(i)(II). Similarly, DOE is directed to consider a payback analysis based on a comparison of "the additional cost to the consumer of purchasing **a product complying with an energy conservation standard level**" and "the value of the energy . . . savings during the first year that the consumer will receive **as a result of the standard**." 42 U.S.C. § 6295(o)(2)(B)(iii). Both requirements expressly require comparison between the cost of furnaces that meet the proposed standards and the value of the savings that improved furnace efficiency would provide as a result of the standard. DOE has provided no such analyses and has thus failed to show that the proposed standards are economically justified as EPCA requires.

a. DOE's purported lifecycle cost analysis

DOE clearly knows how a lifecycle cost analysis is supposed to be conducted. 81 Fed. Reg. at 65773. Rather than provide a lifecycle cost estimate for condensing gas furnaces, however, DOE has provided a purported lifecycle cost analysis in which it uses its fuel switching methodology to preferentially eliminate high-cost/low benefit condensing gas furnace trial cases from its lifecycle cost analysis. 81 Fed. Reg. at 65812. As a result, DOE has not considered "the savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for, or maintenance expenses of, the covered products which are likely to result from the imposition of the standard" as EPCA expressly requires. 42 U.S.C. § 6295(o)(2)(B)(i)(II). In particular, rather than estimating the installed costs **of condensing gas furnaces**, DOE provides an installed cost estimate in which it has preferentially excluded the costs from high-cost/low benefit condensing gas furnace trial cases from its analysis and replaced them with installed costs for low cost electric appliances. Similarly, rather than estimating "the savings in operating costs throughout the estimated average life of" **higher-efficiency condensing gas furnaces**, it provides an estimate of operating costs from which it has preferentially screened out operating costs from high cost/low benefit condensing gas furnace trial cases and replaced them with operating costs for substitute electric appliances. As a result, the "average LCC savings" shown at 81 Fed. Reg. at 65814, Table V.6, are not actually LCC savings for the more the efficient gas furnaces the proposed standards would require.

There are multiple problems with this analysis, the most obvious of which is that it is not the analysis that is expressly required by statute. DOE's curious suggestion that the statute is not clear on the nature of the analysis required[51] is belied by the express language of the statute itself. Moreover, DOE's analysis makes no sense, because it actually serves to conceal the economics of the efficiency improvements the various alternative standards would require. There is an obvious reason why the relevant statutory language reads as it does: to consider the economic impacts of increased efficiency under a proposed standard, it is necessary to compare the additional cost of the more efficient appliance with the benefits the required efficiency improvements would provide. By preferentially screening out

[51] 81 Fed. Reg. at 65791.

cases in which more efficient gas furnaces would leave consumers with high costs and low benefits (and that is exactly what the analysis provided in support of the SNOPR does), DOE has effectively misrepresented the economics of the standards themselves. In effect, DOE's analysis combines the benefits of higher efficiency with purported benefits attributable – not to required efficiency improvements – but to fuel switching resulting from cost increases that would incrementally price gas furnaces out of the market. While fuel switching impacts must obviously be considered in DOE's national impacts analysis to ensure that they will not cancel out the purported benefits of required efficiency improvements, efficiency standards can only be justified economically on the basis of the value of the efficiency improvements they require. Otherwise efficiency standards could be "economically justified" on the basis of the impact of the costs they impose rather than the value of the efficiency improvements they require, which obviously isn't what Congress intended.

b. DOE's purported payback analysis

DOE's purported payback analysis suffers from the same defect as its purported LCC analysis. 81 Fed. Reg. at 65813. In addition, it inexplicably includes the impacts of disproportionately high net-benefit purchases that would be expected to occur even in the absence of the proposed standards. The problem is not simply that DOE has underestimated the extent to which economically advantageous purchases of high-efficiency gas furnaces would occur in the absence of new regulation, thought it has certainly done that. The problem is that DOE's payback analysis improperly accounts for the impacts of condensing gas furnace purchases **that even DOE admits would occur in the absence of the proposed standards.** As a result, the purported simple payback periods shown at 81 Fed. Reg. at 65814, Table V.5, do not actually provide an assessment of how long it will take before "the additional cost to the consumer of purchasing a product complying with an energy conservation standard" will be paid back by savings "**that the consumer will receive as a result of the standard.**" 42 U.S.C. § 6295(o)(2)(B)(iii). Instead it provides purported payback periods that average the results of purchases that occur "as a result of the standard" (i.e., the disproportionately higher cost/lower benefit purchases that would not occur in the absence of the proposed standards) with the disproportionately lower cost/higher benefit purchases that consumers could be expected to make on their own in the absence of new standards. The results significantly overstate the benefits of the proposed standards by systematically understating the payback periods for purchases that would occur as a result of their adoption. For example, the "simple payback" of 6.4 years reported at 81 Fed. Reg. 65814 is less than half the actual payback period for consumers actually affected by the rule. GTI SNOPR Report at 68-69. DOE uses a similarly misleading approach in that its stated percentages of consumers adversely affected by the proposed standards are not based on the consumers that would actually be affected by the proposed standards. Instead they are the percentages of all gas furnace trial cases, including purchasers who would purchase condensing gas furnaces even in the absence of the proposed standards. As a result, the percentages of consumers affected by the proposed standards who would be harmed by them is – even by DOE's wildly skewed analysis – approximately twice the percentages shown at 81 Fed. Reg. at 65814, Table V.6.

c. <u>Erroneous Calculations</u>

There is another related (and even more disarming) error in DOE's analysis that has caused it to claim customer benefits that include energy savings from sales of condensing gas furnaces that – even by DOE's own analysis – would occur whether or not the proposed standards were adopted. For example, DOE assumes that only 47.93% of non-weatherized gas furnaces being sold in 2022 would have efficiencies of 92% AFUE or above in the absence of the proposed standards, with the result that a 92% efficiency standard would produce energy savings resulting from required efficiency improvements in the remaining 52.47% of gas furnaces. However, DOE calculates equipment, operating costs, and life cycle costs, reported at 81 Fed. Reg. 65814, Table V.5, assuming efficiency improvements for 100% of gas furnaces, not the 52.47% that it claims would be affected by the proposed standard. As a result, of this error, Table V.5 claims consumer cost benefits for a 92% standard for non-weatherized gas furnaces that are much higher than those for affected consumers, resulting in stated payback periods that are about half of what they should be. The same basic problem affects DOE's consumer energy cost savings claims for each of the proposed standards, with the extent of the error increasing for each higher efficiency standard proposed.

3. <u>DOE's analytical approach is too opaque and prone to error to provide credible justification for the proposed standards</u>

The justification provided in support of the proposed standards is the product of an analytical approach that has become notoriously opaque and lacking in credibility. In short, the NOPR and SNOPR rely upon excessively complicated and opaque "black box" analyses in which key assumptions and parameter inputs – or the basis for such assumptions and inputs – may not be disclosed on the record. These models include the National Energy Modeling system (NEMS),[52] which DOE admits can only be run by a handful of independent entities outside of DOE.[53] This is due to the sheer complexity of NEMS.

Remarkably, some critical parameter inputs are provided by DOE contractors without their basis even being known to DOE. In particular, DOE relies on critical analytical inputs that are provided to DOE by contractors on the basis of product "tear-down" analysis and manufacturer interviews of which DOE reportedly has no knowledge whatsoever beyond conclusory numbers it receives on a spread sheet. Indeed, it appears that DOE does not prepare – and often does not even understand – the regulatory

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[52] https://www.eia.gov/forecasts/aeo/info_nems_archive.cfm

[53] Email communication between EIA's Paul Kondis and Mark Krebs on Wednesday, November 16, 2016 8:39 AM.

analysis offered in support of its proposed rules, with the result that "DOE's analysis" is in fact the analysis of third-party DOE contractors.[54]

DOE's reliance upon a proprietary "Crystal Ball" model to generate many of its most critical conclusions is particularly opaque and has been nearly impossible to reproduce independently. Indeed, previous efforts to penetrate the veil of DOE's regulatory analysis have required the use of outside technical experts at considerable expense, and still have left commenters unable to understand exactly how DOE had produced its results.[55] Spire – along with other industry representatives – has again had to retain technical consultants to have any hope of understanding DOE's regulatory analysis and ferreting out the sometimes truly surprising defects it contains.

The lack of transparency in DOE's analytical approach is particularly troubling in view of DOE's apparent ability to generate almost any results it chooses without commenters being able to understand the data inputs, assumptions, and analysis involved. For example, DOE employed this same analytical approach in estimating life cycle costs for residential furnaces in 2011 and 2015 as it did in the 2016 SNOPR. Yet – as shown in Table 1 – DOE's 2015 analysis produced estimated LCC savings for high-efficiency furnaces that were considerably more than double, and – depending on the region and type of installation – as much as 4,177 percent higher than the LCC savings DOE had estimated for essentially the same products only three years previously. There were no material changes of fact to explain the dramatic differences in the outputs from DOE's analysis, and – while DOE obviously used different

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[54] With this understanding – and for the sake of economy of expression – Spire nevertheless refers to the regulatory analysis and conclusions underlying the SNOPR and supporting TSD as "DOE's."

[55] "Gas Technology Institute (GTI) *Technical Analysis of DOE Direct Final Rule on Minimum Efficiencies of Residential Furnaces* (GTI Project Numbers 21225, 20705, and 02169; October 14, 2011), available at: http://www.gastechnology.org/reports_software/Documents/21853-Furnace-NODA-Analysis-Task-Report-10-14-2015.pdf

assumptions or data inputs somewhere in the course of its analysis – the nature of those differences and the reasons for them have never been cogently explained. Now – as also shown in Table 1 – DOE's numbers have once again changed dramatically.

Table 1

	AFUE	2011 Average LCC savings	2015 Average LCC savings	Delta from 2011	% Change	2016 Average LCC Savings	Delta from 2011	% Change from 2011
National - All Installations	90%	$87	$236	$149	170.9%	$582	$495	569.0%
	92%	$136	$305	$169	124.1%	$617	$481	353.7%
	95%	$205	$388	$183	89.1%	$561	$356	173.7%
	98%	$46	$441	$395	859.1%	$506	$460	1000.0%
North - All Installations	90%	$155	$208	$53	34.0%	$701	$546	352.3%
	92%	$215	$277	$62	29.0%	$711	$496	230.7%
	95%	$323	$374	$51	15.7%	$597	$274	84.8%
	98%	$198	$467	$269	135.9%	$487	$289	146.0%
South/Rest of Country - All Installations	90%	-$13	$267	$280	2156.3%	$530	$543	4176.9%
	92%	$19	$336	$317	1667.2%	$569	$550	2894.7%
	95%	$28	$404	$376	1341.4%	$537	$509	1817.9%
	98%	-$181	$412	$593	327.7%	$528	$709	391.7%

Notes:
2011 data from EERE-2011-BT-STD-0011-0010 LCC spreadsheet, summary tab, cells K9:K58, L9:L58 & AI9:AI58.
2014 data from EERE-2014-BT-STD-0031-0021 LCC spreadsheet, summary tab, cells O8:O41, AE8:AE41 & AT:AT41.
2016 SNOPR data from LCC Results spreadsheet for cases without a kBtu/h threshold for condensing/non-condensing.

In addition to the opacity of DOE's analysis and the inexplicable variations in the results DOE's analysis can produce, there are at least several objectively obvious reasons to question the overall credibility of DOE's analytical methods and results. First, although the critical results of DOE's analysis are generated using the "Crystal Ball" model, DOE has not validated that model as specified by guidance supplied by the model developer. Validation of a model is a basic procedure that is necessary to ensure that the model as applied produces results within a reasonable range of accuracy consistent with the model's intended application. As a result, DOE's failure to validate the model is sufficient reason by itself to question the credibility of the results obtained. Second, a model is only as good as the relevance of the scenarios simulated and the quality of the data used as input for modeling, and DOE – lacking much of the critical data and information the model requires – has based its analysis largely on scenarios and parameter values generated on the basis of inadequate information and arbitrary assumptions. Finally, DOE's analysis is notoriously error-prone and often produces demonstrably erroneous results.

a. Model Validation

Oracle, the developer of the Crystal Ball model, prescribes six steps in developing a Crystal Ball model in its "Essentials" Training, one of which is to validate the model.[56] Oracle recommends four means for validating Crystal Ball simulation models:

- "Compare simulated results to actual process data.
- "Ask subject matter experts (SMEs) to compare their experiences with simulated results. If a distinction can be made, use SME feedback to refine the model.
- Test extreme conditions.
- Compare your model to any similar models."

From the documentation provided in the Technical Support Document and accompanying Excel spreadsheets, it is clear that DOE has not validated its Crystal Ball model. Spire focuses upon this problem as it relates to the LCC calculation spreadsheet and its results; in particular, the average installed costs. Of utmost importance, DOE has not engaged SMEs in development of its equipment costs and pricing through the total installed cost of covered products other than its contractors' alleged contacts with manufacturers concerning manufactured cost teardowns and other preliminary steps in its attempt to build up product costs to their ultimate selling prices. Otherwise, DOE only provides the end results of its analysis to SMEs and – as in a number of notable other rulemaking analyses – those results systematically underestimate equipment costs and prices for products meeting proposed efficiency standards. DOE has

[56] Crystal Ball 11.1.2 Essentials, Student Guide," Lesson 1, Edition 1.0, November 2010, Oracle Corporation (copyrighted).

appeared to be oblivious to this contradictory information in prior rulemakings and has totally discarded virtually all critical SME feedback.

For example, in the recent residential boiler minimum efficiency rulemaking (Docket No. EERE-2012-BT-STD-0047) a broad survey of boiler installers conducted by AHRI, the Air Conditioning Contractors of America (ACCA), and the Plumbing Heating Cooling Contractors National Association (PHCC), demonstrated that DOE's simulated installed costs of new residential boiler systems were on the order of 40% the cost of surveyed installed costs. DOE, having received comments incorporating this data-supported SME input, might have used that information invalidating its Crystal Ball analysis to review its analytical procedure, but it did not.

In 2010, DOE received comments on its direct final rule (DFR) and NOPR covering minimum efficiency standards for residential gas furnaces (Docket No. EERE-2011-BT-STD-0011) in which it received comments from the American Gas Association (AGA) referencing an American Public Gas Association (APGA) survey showing that installation cost adders were underestimated by the DOE estimates used in its Crystal Ball analysis by approximately 40%. Again, DOE did not use this information as called for by the Crystal Ball model validation guidance.

As discussed later in these Comments, real world data once again reveals that DOE's modeling has systematically understated the installed cost of equipment meeting the proposed standards, thereby biasing its entire economic analysis in favor of the adoption of new standards.

b. <u>Unreasonable generation of parameter inputs</u>

Although there are many data quality problems in the analysis provided in support of the proposed standards, one particularly obvious problem is DOE's tendency to respond to a lack of critical data or information by using arbitrary assumptions to "fill in the blanks" in its analysis. For example, DOE has no data with regard to the distribution of gas furnace efficiencies. This was freely admitted during the October 17, 2016 public meeting, in which a DOE consultant stated:

> MR. FRANCO: The shipment data is the only real data that we actually have about what actually people are installing. The other data is just our analysis of what might happen after the standard.[57]

The shipment data referred to does not provide information concerning furnace efficiencies, beyond a break-down between non-condensing and condensing furnace market share. Needing much more detailed information for its analysis, DOE simply piled assumption upon assumption to generate the numbers it needed. 81 Fed. Reg. at 65788. DOE did not make its various assumptions because it had any reasonable basis to do so; it made them because it needed numbers, lacked the data needed to provide credible numbers, and therefore had to come up with something to fill in the blanks so that it could proceed with its analysis. DOE's entire analysis of standards imposing different condensing standards is compromised by this basic lack of information as to what the distribution of efficiencies actually is. Yet DOE proceeds as though it needs no evidence, and is entitled to proceed on the basis of arbitrary assumptions instead.

Another systemic problem with DOE's analysis is its reliance on data inputs developed through abstract analysis rather than the collection of relevant data. For example, the price consumers pay to purchase equipment and have it installed are critical data inputs required for any economic justification of the proposed standards. In most cases (and all cases involved in this proceeding), the equipment at issue is already available in the market and actual data on equipment cost and installation exists and could be collected. However – rather than attempt to collect such data – DOE engages in an elaborate theoretical

[57] Transcript of October 17, 2016 Public Meeting: U.S. Department of Energy Supplemental Notice of Proposed Rulemaking for Residential Furnaces Energy Conservation Standards, at p. 155.

exercise in which it attempts to "build up" cost estimates by determining what it costs manufacturers to produce the equipment, what mark-ups manufacturers would use, what distribution channels equipment would pass through, what mark-ups would be imposed along the way, and what – on the basis of all of that – consumers would actually pay for the equipment in question. DOE then engages in an equally abstract assessment of installation costs to ultimately generate estimates of the installed costs purchasers would pay. The inherent problems with this approach are obvious: rather than needing data on only one parameter – the installed costs of gas furnaces actually paid by purchasers – DOE needs data and information on literally dozens of parameter values to construct the one parameter value it needs. Specifically, DOE "builds up" the product selling price by generating a "manufacturer product cost" on the basis of twenty-two separate sets of parameter inputs, including raw material and manufacturing costs, the cost of purchased parts, and generic assumptions addressing eighteen different "factory parameters." It then develops estimated "non-production" manufacturer costs based on eleven additional categories of parameter inputs, including inputs addressing such things as selling and R&D costs. It then calculates a manufacturer selling price by combining its estimated manufacturer product cost with its estimated non-production costs, adjusting for manufacturer markup, and factoring in shipping costs. The result is a single product cost parameter that is derived from thirty-five different sets of parameter inputs, most of which are supplied on the basis of little if any credible data. DOE suggests that many of the parameter values supplied for purposes of this analysis are based on information its consultants obtained through product tear-downs and manufacturer interviews, but there are no reports of product tear-down analysis or manufacturer interviews available for review and comment, so there is no way for commenters to understand what information DOE's consultants had, what information they chose to credit or ignore, precisely how that information was interpreted to produce parameter value inputs, what errors crept into the analysis along the way. In this respect, DOE appears to be no better off than commenters, because

DOE's consultants reportedly supplied parameter values to DOE as numbers on a spreadsheet, without any supporting data or evidence. However, the analysis does not stop there, because DOE (or its consultants) must then embark on a similarly elaborate analysis – with many more parameters for which values are supplied on dubious grounds – to generate the one parameter value that really matters: the installed cost that consumers can actually be expected to pay.

Oddly, DOE is happy to look up the cost of purchased parts to fill one of the dozens of sets of parameter inputs required to synthesize an installed cost parameter value, but is unwilling to consider data on the ultimate issue of what consumers actually pay to have furnaces installed. On one level, it is easy to see why: DOE's synthetic installed cost numbers are always dramatically lower than direct evidence of installed costs would suggest.[58] Worse, actual data concerning the costs actually paid by consumers reflects installations that are already occurring in the absence of regulation, and can thus be expected to be significantly lower on average than the cost of installations under the proposed standards (which would disproportionately include relatively expensive installations that generally would not occur in the absence of regulation). Yet DOE persists in ignoring real world evidence of installed product costs, despite the obvious fact that real world data on a single parameter value is inherently more reliable than an indirect estimate based on dozens of different parameter values (particularly when credible evidence for those parameter values is generally lacking).

As illustrated in Figure 7, DOE's use of unreasonable parameter inputs consistently skew its analysis toward rule benefit, and they collectively skew its analysis to an extent that manufactures claimed benefits for proposed standards that more balanced analysis suggests would have net negative impacts.

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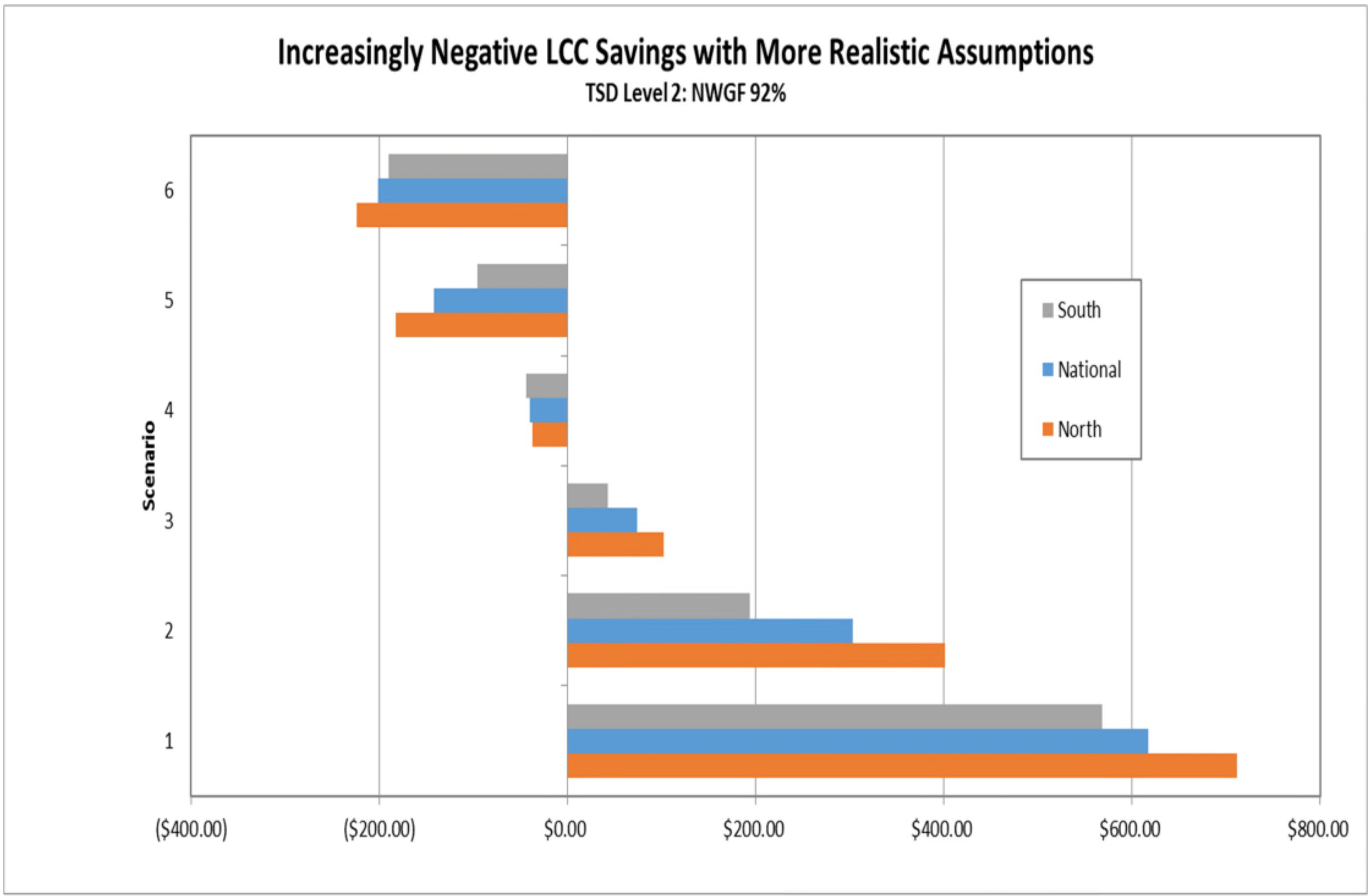
[58] *See, e.g.*, Comments of Laclede Gas Company, July 30, 2015 (Docket No. EERE-2014-BT-STD-0031), Air Conditioning Contractors of America, July 1, 2015 (Docket No. EERE-2012-BT-STD-0047-0002), Air Conditioning, Heating and Refrigeration Institute, August 6, 2015 (Docket No. EERE-2012-BT-STD-0047-0002).

Figure 7



Scenario Descriptions

1. DOE's published LCC savings as published in SNOPR and TSD
2 Natural gas marginal (tail block) price factor (per MMbtu) based on 5 year average of EIA reported city-gate prices + 1$ additional overhead charge to customers
3 Scenario 2 + Average difference in installation costs between condensing and non-condensing furnace of $550 vs. $253 DOE estimates (based on ACCA 2015 "Survey of Furnace Installation Contractors")
4 Scenario 3 + Furnace average lifetime 18.1 years per Laclede study
5 Scenario 4 + Natural gas price escalation forecast set to equal electric price escalation forecasts per AEO 2016
6 Scenario 5 + 10% Discount rate with normal distribution mean of 10% and standard deviation of 5%

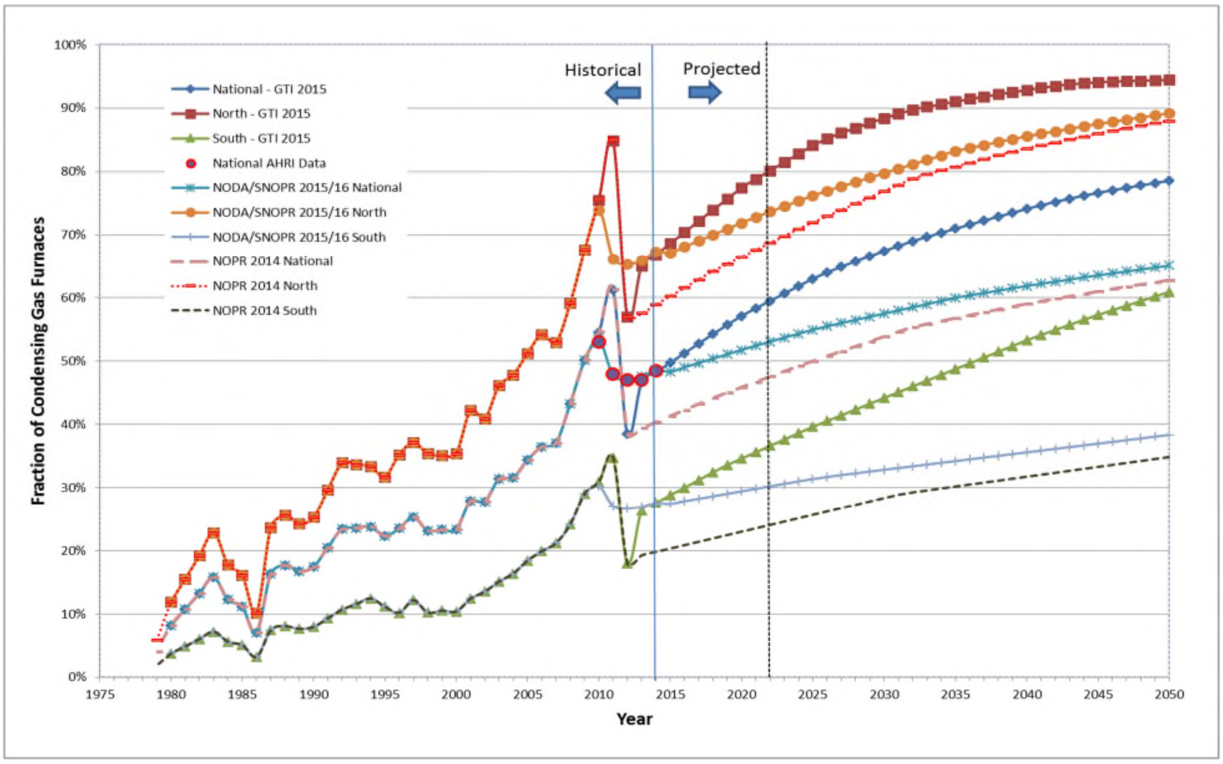
In view of the lack of transparency of DOE's regulatory approach, its reliance on information that is undisclosed and thus unavailable for review and potential refutation, its reliance on the use of an non-validated model, and its use of key parameter values generated on the basis of objectively questionable and demonstrably error-prone analysis, the results of DOE's regulatory analysis lack the credibility to support a reasonable determination – based on substantial evidence – that the proposed standards would result in significant conservation of energy and are economically justified.

4. DOE has significantly overstated the benefits of the proposed standards

a. Unreasonable assumptions as to product shipments and market trends result in an erroneous regulatory baseline and thus a significant overstatement of the benefits of the proposed standards

AHRI has provided updated shipment data to DOE showing that condensing gas furnaces have been gaining an increasingly large share of the gas furnace market for a number of years. DOE manipulated this data to project the share of the market that condensing gas furnaces can be expected to occupy going forward in the absence of new regulation. The historical trend and DOE's projections for the years following 2014 are shown in Figure 8 below.

Figure 8



The single most obvious problem with DOE's projections is that they appear to be based on an unexplained and arbitrary assumption that condensing gas furnaces will never capture more than 95% of the gas furnace market in the absence of regulation. TSD at 8I-11. With this arbitrary assumption holding down one end of the trend line, DOE holds down the other end by attributing the rapid historical increase in the market share of condensing gas furnaces to Federal tax credits that were available between 2005 and 2011, and draws its trend line only on the basis of data for the years 2012-2014. 81 Fed. Reg. at 65788. This approach is unreasonable for several reasons. First, any suggestion that the rapid increase in market share for condensing gas furnaces can be attributed to the availability of Federal tax credits is belied by the fact that that rapid increase started several years before the tax credit became available in 2005. Second, DOE's approach ignores the economic elephant in the room: the Great Recession, which resulted in virtual collapse in new home construction (and hence the market for appliances in new home construction) in 2008 and produced a sharp decline in the real household income of American consumers, from an average of $57,423 in 2007 to $52,666 in 2012, with a slow and uneven recovery from 2012 to 2014.[59] In view of the existence of a strong market trend before 2005 and impacts of the Great Recession, it is more reasonable to suggest that Federal tax credits – rather than being wholly responsible for market trend line from 2005-2011 – served in large part to moderate the impact of the Great Recession on that trend line. This conclusion is consistent with more of the available data, including the pre-existing market trend line and relative flattening of the trend line followed by a sharp up-turn coming out of the Great Recession during 2012-2014. By unreasonably skewing the trend line going forward, DOE has further skewed the regulatory baseline used for purposes of DOE's analysis and overstated the benefits of the proposed standards.

[59] https://fred.stlouisfed.org/series/MEHOINUSA672N

An even more disturbing consideration is the fact that DOE appears to have data suggesting that condensing gas furnaces may already have a significantly greater share of the gas furnace market than its analysis in this proceeding suggests. This information was only revealed outside the record of this rulemaking proceeding, when David Cohen of DOE spoke at the International Energy Conservation Code (IECC) Public Comment Hearing in Kansas City, MO on October, 19, 2016. Mr. Cohen stated that, based on regional survey data, the percentage of homes with furnaces of 90% AFUE efficiency or better (i.e., condensing gas furnaces) is as follows:

- New England – 70%
- Mid-Atlantic – 81%
- East North Central – 80%
- West North Central – 88%
- East South Central – 78%
- West South Central – 29%
- Mountain – 78%
- Pacific – 79%
- South Atlantic – 48%
- National – 67.4%.[60]

Taken literally, the percentages quoted would apply to the installed furnace population, but it is possible that the data only addresses new construction. Regardless, the cited percentages are significantly higher than DOE's SNOPR analysis suggests. In fact – as Figure 8 shows – the cited data shows a national

[60] Mr. Cohen's remarks were transcribed from a streamed video of the IECC Hearing.

percentage for condensing furnaces that is even higher than the national percentage the SNOPR analysis projects for the year 2050. At a minimum, the data shows – as Mr. Cohen suggested in the discussion in which it was cited – that condensing gas furnaces enjoy an increasingly dominant position in the gas furnace market.

It is remarkable that DOE – having apparently paid to have this data compiled – failed even to disclose its existence in this rulemaking proceeding, particularly in view of its own consultant's statement that "the only real data" DOE had as to what furnaces are actually being installed was AHRI shipment data.[61] In light of this additional data – which may or may not include further critical information Mr. Cohen did not refer to – DOE clearly needs to revise its otherwise inadequate analysis of current market shares and trends. DOE's current estimates and projections plainly understate both the current market share for condensing gas furnaces and the extent to which that market share can be expected to increase over time in the absence of the proposed standards.

b. DOE unreasonably overstates the benefits of the proposed standards by claiming regulatory benefits associated with sales of condensing gas furnaces that can reasonably be expected to occur in the absence of the proposed standards

As already discussed, there is compelling evidence that purchasers of residential furnaces commonly engage in economic decision-making and disproportionately choose condensing gas furnaces when the investment in a condensing gas furnaces makes economic sense. Accordingly, there is no basis to suggest that a significant percentage of economically beneficial purchases of condensing gas furnaces would only occur as a result of the proposed standards. To the contrary, the more economically beneficial a purchase of a high-efficiency gas furnace would be, the more likely it is that the purchase would occur

[61] Transcript of October 17, 2016 Public Meeting: U.S. Department of Energy Supplemental Notice of Proposed Rulemaking for Residential Furnaces Energy Conservation Standards, at p. 155.

even in the absence of the proposed standards. It follows that the energy conservation benefits resulting from such purchases cannot be treated as benefits of the proposed standards and used to justify their adoption. However, the regulatory analysis in support of the SNOPR indicates that a substantial percentage of purchasers will enjoy net benefits as a result of the proposed standards, and – as already indicated – DOE's methodology allows it to claim credit for absurdly favorable purchasing decisions that a regulation would never be needed to induce. By improperly treating such purchases as consequences of the proposed standards, DOE has significantly overstated the benefits those standards would provide.

The unreasonable attribution of high-net benefit outcomes to the proposed standards significantly skews DOE's LCC and payback analyses, which appear to be particularly sensitive to the percentage of consumers that would enjoy significant net benefits as a result of the proposed standards (indeed, DOE's economic justification for the proposed standards turns in part on the assertion that consumers enjoying net benefits as a result of the proposed standards would gain more than the consumers suffering net costs would lose). 81 Fed. Reg. 65740. DOE cannot reasonably ignore the fact that the consumers who would benefit the most from purchases of high-efficiency gas furnaces are those most likely to make such purchases on their own, yet that is precisely what it has done.

c. <u>Unreasonable claims of regulatory benefits from purchases of high-efficiency equipment that should not be expected to occur on a timely basis if at all</u>

A corollary of the fact that consumers can generally be expected to make purchasing decisions that are in their own economic interest is the fact that principal impact of the proposed standards would be to impose purchasing decisions that do not make economic sense due to some combination of factors such as:

- Impracticality of installation or unusually high installation and installation-related demolition and construction costs;
- Unusually low efficiency benefits due to limited furnace use; and

- Inability to afford the up-front cost necessary to transition to a condensing gas furnace.

As already discussed, most existing homes are designed for *non-condensing* gas furnaces, with the result that the replacement of a non-condensing gas furnace with a condensing furnace can become difficult or even impractical. In many cases, a condensing standard would result in unreasonable costs, and – even in cases in which the costs involved would not be prohibitive – the disruption and the extent of time required to address installation challenges may be unacceptable to consumers who suddenly find themselves without heat in the dead of winter (as is often the case).

Inadequate efficiency benefits can also make condensing technology economically disadvantageous. This can occur in any situation in which heating demand is limited. These situations include location in mild climates, significant reliance on zone heating to reduce furnace usage, and/or intermittent or seasonal patterns of occupation (as commonly occurs in the case of second homes and particularly vacation homes). In any of these circumstances, furnace use may be too limited to justify investment in high-efficiency gas furnaces.

Finally – as already discussed – there are cases in which consumers simply cannot afford the up-front investment required to replace a non-condensing gas furnace with a condensing gas furnace. Yet DOE assumes that – despite a rule significantly increasing the cost of gas furnaces – consumers will dutifully replace gas furnaces as necessary without resorting to repairs in an effort to extend furnace life. 81 Fed. Reg. at 65795. This assumption is unreasonable. As already discussed, many low-income consumers will have no choice but to keep old furnaces patched together by any means necessary. Many others will resort to the use of portable electric resistance space heaters or other expedient but unsafe space heating options, or will be left with no home heating at all. The only certain thing is that these consumers will not do what they cannot: promptly invest in new condensing gas furnaces. As a result, furnace replacements may be deferred or might not occur at all, reducing or eliminating energy conservation benefits DOE has claimed to justify the proposed standards.

DOE's own analysis recognizes that the proposed standards would impose net costs on a substantial percentage of purchasers, but nevertheless assumes that such purchases will occur, thereby providing energy conservation benefits. This assumption is invalid for all the reasons just stated: many consumers can be expected to find the costs, complications, and lack of compensating economic benefits that come with condensing gas furnaces to be unacceptable, in which case the replacement of non-condensing gas furnaces with condensing gas furnaces cannot reasonably be expected to occur and regulatory benefits associated with such purchases will not be realized. By unreasonably assuming that its proposed standards can force consumers to make purchasing decision that they may be unwilling or unable to make, DOE has significantly overstated the benefits of the proposed standards.

d. Unreasonable marginal energy price forecasts

As Spire has routinely explained in previous comments and public meetings, DOE's estimates of benefits from gas appliance efficiency standards are significantly overstated as the result of serious errors in its assumptions with respect to utility marginal pricing and pricing forecasts. In fact, what DOE calls marginal prices are actually average prices multiplied by an arbitrary and inaccurate adjustment factor that result in a systematic overstatement of gas prices. These average prices appear to be derived from data submitted by utilities via Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers." DOE continues to use biased data to achieve the answer they are trying to justify.

i. DOE used average costs instead of true marginal costs

Clearly, what is reported on EIA-857 is average costs including average "fixed charges." Fixed charges generally do not vary with changes in monthly consumption, and are therefore irrelevant in valuing the benefits of gas savings resulting from efficiency standards. Along with lower consumption in warmer months, that is why DOE's prices are shown to be higher in the summer and lower in the winter. Nevertheless, rather than considering actual marginal costs – the prices actually paid by energy consumers – DOE continues to rely on average costs as adjusted by an inadequately disclosed shortcut "factor," an approach that consistently results in inaccurate and significantly overstated gas prices.

To analyze this issue correctly, DOE needs to consider how changes in energy consumption are actually reflected in consumer energy bills based upon actual tariffs. Based upon a DOE publication of a July 1999 "draft" report on the subject titled: Marginal Energy Prices Report, DOE should already understand how to do this correctly.[62] Accordingly DOE's unexplained reliance on an analysis that systematically overstates gas pricing (and therefore the benefits of efficiency standards for gas equipment and appliances) is particularly troubling.

DOE responded to Spire NOPR comments that tariff data is not available. This is categorically false. Almost every utility in the nation posts their tariff rates on line. In most states, they are also available on the utility regulatory body's website. Spire agrees that marginal tariff rates are complicated and would take time to compile, but they are critical – not merely relevant – to every rulemaking involving gas appliances. Under the circumstances, DOE's continued reliance on plainly unreliable gas pricing methods is simply inexcusable.

Spire analyzed the residential tariff rates of the top seven natural gas utilities within Missouri as summarized in Table 2. These companies cover 98% of the residential customers in Missouri.

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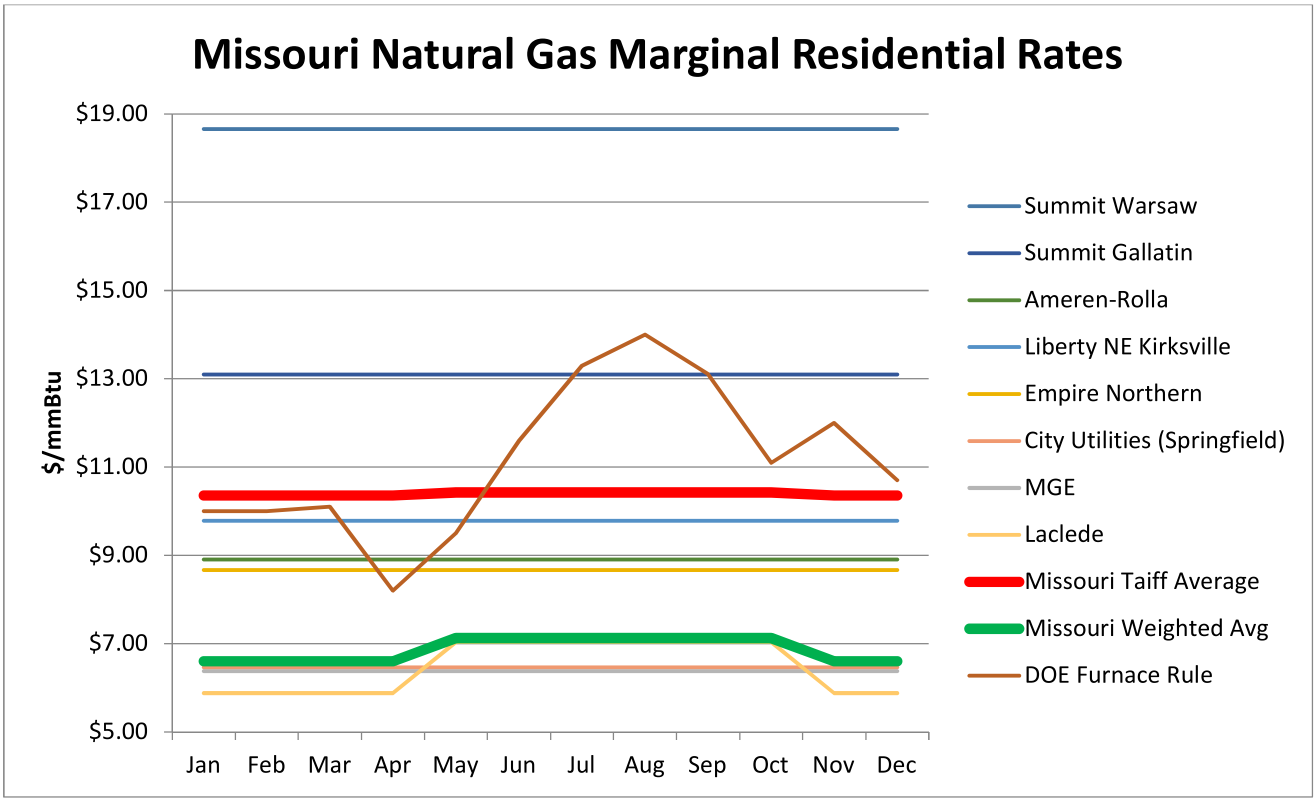
[62] http://energy.gov/sites/prod/files/2013/12/f5/marg_eprice_0799.pdf

Table 2

Company Name	Residential Natural Gas Customers (actual) 2013 Y	Residential Natural Gas Customers (actual) 2012 Y	Cumulative Customers	Cumulative %
Laclede Gas Company	602,459	597,355	602,459	44.4%
Missouri Gas Energy	440,401	430,639	1,042,860	76.8%
Union Electric Company	114,019	112,517	1,156,879	85.2%
City Utilities of Springfield	74,907	74,632	1,231,786	90.7%
Liberty Utilities (Midstates Natural Gas) Corp	47,682	48,514	1,279,468	94.2%
Empire District Gas Company	37,777	37,897	1,317,245	97.0%
Summit Natural Gas of Missouri, Inc.	12,702	11,337	1,329,947	98.0%
Total Missouri Residential Natural Gas Customers			1,357,740	

Figure 9 shows true marginal prices based upon tail-block rates in comparison to what the NOPR cites as "marginal prices" for Missouri.

Figure 9



As Figure 9 shows, on average over the year, DOE's calculated "marginal cost" is dramatically higher than true marginal costs based upon tail-block rates. In addition, DOE's methodology improperly includes fixed costs in their calculation, which drives summer prices almost 3 times higher than actual marginal rates. Natural gas prices paid by residential customers are normally higher in the winter than summer rates, not the opposite as DOE's faulty analysis suggests.

ii. DOE averaged tariff rates in the states

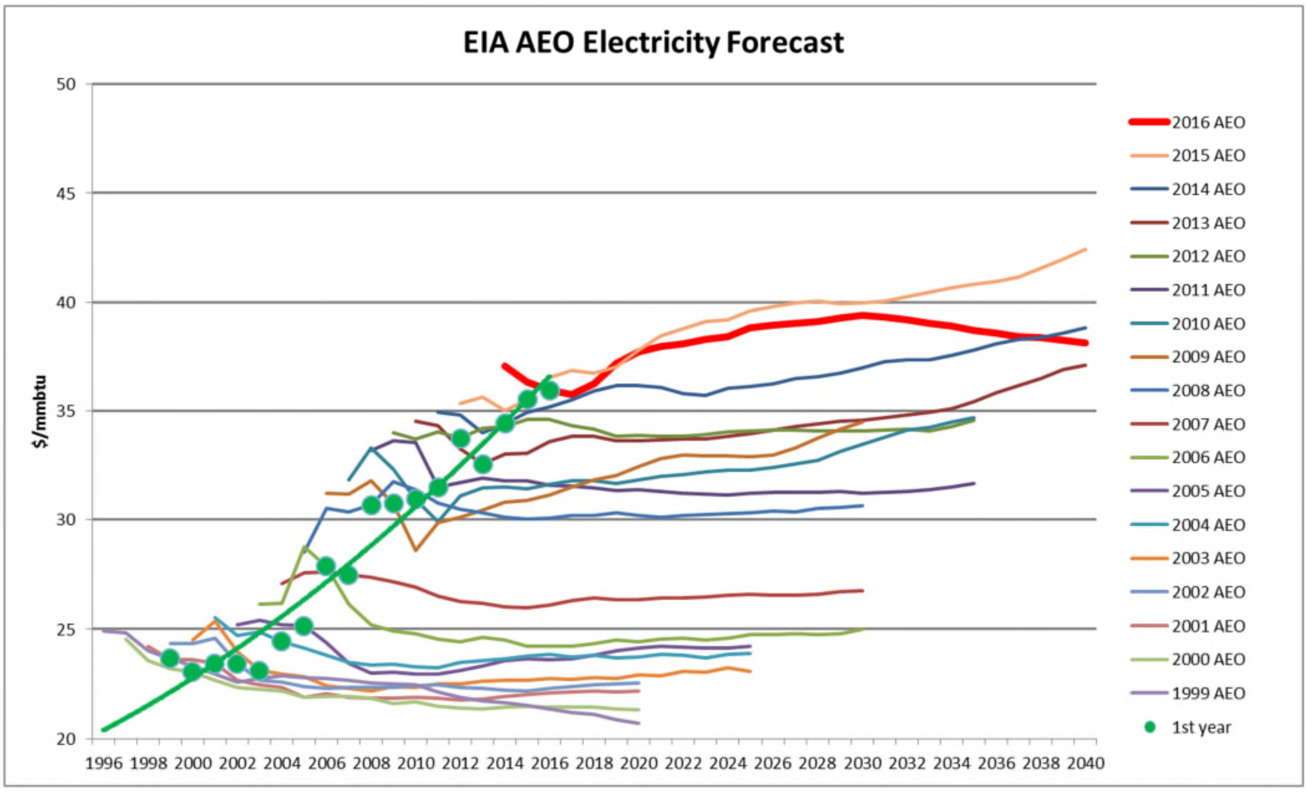
The DOE "marginal price" methodology compounds the over-pricing problem by averaging rates across the entire state. DOE states that this is appropriate because randomly selecting customers in the state takes into account all the customers in the state. What it actually does is over-emphasize high cost rural rates and under-emphasize low cost urban rates. A proper methodology would be a weighted average of customer rates based on the actual tail block marginal rates. The marginal rates at urban utilities are in many cases less than half that of rural utilities. The vast majority of customers in the State of Missouri are served by the four largest utilities with very low marginal rates. Less than 10% of the customers are on the high cost rural systems. But DOE equally weights the tariff data without accounting for the relative numbers of consumers served. This unreasonably drives the marginal prices to levels much higher than those the vast majority of customers actually pay.

iii. DOE used chronically biased forecasts

DOE admits that AEO (Annual Energy Outlook) has consistently overestimated natural gas prices for the past seven years (AEO2006-AEO2012). AEO forecasts have also underestimated electricity prices for the past 20 years. Spire maintains that there has been a fundamental change in natural gas prices in the past 10 years due to the shale gas revolution. When a model is wrong seven years in a row, it is time to change the model.

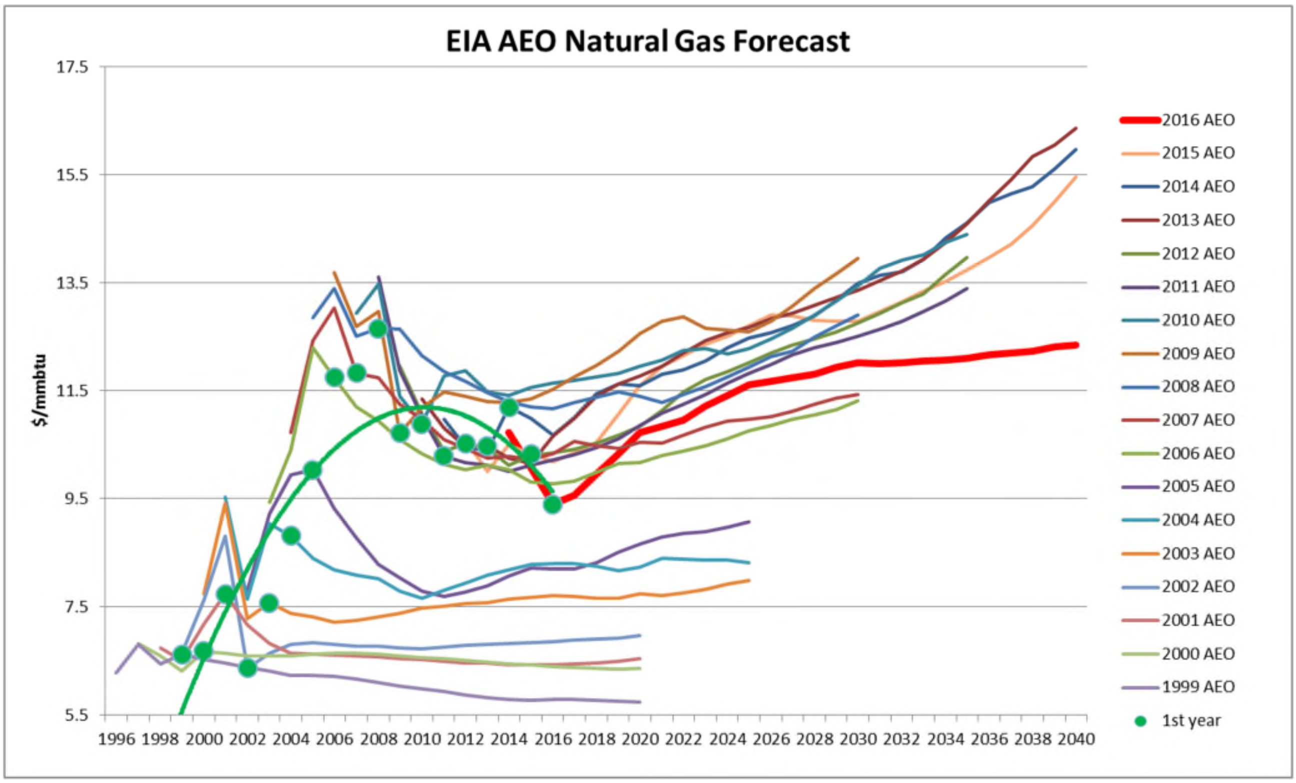
The AEO keeps forecasting that electricity prices are going to be flat to declining, but every year they raise their forecast because electric rates have risen 50% in the past 10 years, as shown in Figure 10.

Figure 10



Similarly, as shown in Figure 11, the AEO keeps forecasting that natural gas prices are going to go up and then have to revise their forecast down as rates have continued to fall over the past decade

Figure 11



Neither the flattening in the price of electricity nor the increases in the price of natural gas have occurred per AEO predictions, yet DOE continues to rely on these demonstrably skewed and inaccurate forecasts. The result is a serious overstatement of the benefits of efficiency standards for gas appliances and a serious understatement of the adverse impacts of fuel switching from gas to electric appliances. There is no excuse for this systematic bias in DOE's analysis, particularly in view of the fact that natural gas has become the marginal electrical generation source across most of the country. With natural gas at the margin for electricity generation, natural gas and electricity prices have become increasingly correlated and can be expected to escalate at very similar rates. Assumptions to the contrary are unreasonable and serve only to again skew DOE's analysis in the direction of rule benefit.

Since DOE has decided that actual tail block marginal rates are too cumbersome to use in practice, Spire recommends using a simple methodology to determine marginal rates–city gate pricing. Historical city gate prices are available on EIA's website for every state. A simple methodology to arrive at a much more reasonable marginal price is to use the latest city gate prices available: just adjust for seasonal gas pricing and add a $1/MMBtu for delivery costs. Spire utilized this methodology and derived prices that are very close to actual marginal tariff rates in Missouri. Rerunning the LCC model with the city gate pricing methodology results in drastically lower LCC savings. Spire's runs show LCC savings drop over 50% and payback increases over 100%.

In addition, Spire recommends using natural gas and electricity price increases that rise at the same rate. Rerunning the LCC model with natural gas prices escalating at the same rate as electricity also lowers the LCC savings. Spire reran the model using this methodology and it reduced the LCC savings by 30%. When combined with the city gate pricing methodology, LCC savings decline dramatically and lead a reasonable person to question why DOE is advocating higher efficiency furnaces that will lead to extensive fuel switching and much higher heating costs for most Americans.

e. Unreasonable projection of regulatory benefits far into the future

DOE's justification for the proposed standards relies upon a quantification of benefits accumulating over a period of more than fifty years following the projected effective date of the proposed standards. Specifically, the SNOPR takes credit for energy savings from the projected effective date of the standards to the end of the useful life of all products sold within the following thirty years. 81 Fed. Reg. at 65725 and 65729. In doing so, DOE has unreasonably assumed that – in the absence of the proposed standards – there would be no material improvement in the efficiency of commercial water heaters for the next 35 years (*i.e.*, within 30 years after the effective date of the proposed standards). As already discussed, that assumption is both preposterous and contradicted by available data. DOE is also assuming the proposed standards – once adopted – will remain unaltered for at least 35 years after the date of their adoption, a proposition that is also preposterous in view of the nature of the products involved and DOE's statutory obligation to reviews its standards six years after they are adopted – and every three years thereafter – to determine whether any more stringent standards would be technically feasible and economically justified. 42 U.S.C. § 6295(m)(1) and (m)(3)(B). As energy prices rise and technology improves over time, efficiency levels that are not economically justified today will become economically justified, the standards will be amended again, and the bulk of the benefits claimed to justify the proposed standards will never be realized. Instead, the bulk of those benefits will be subsumed in benefits claimed to justify a new standard, and will actually be realized – not as benefits of the proposed standards – but as benefits of a new standard (and likely of further generations of standards imposed over the following decades).

Besides these baseless and objectively unreasonable assumptions, considerable additional speculation is required to project energy conservation benefits more than fifty-five years into the future. There are, after all, many moving parts in a world in which enormous change – technological and otherwise – has been the norm given the time scales involved. Even thirty years ago, business correspondence was routinely produced on typewriters and dispatched for physical transport and delivery by the U.S. Postal Service. Yet the SNOPR purports to project any number of things – from energy prices to how many of what products will be sold – without even attempting to consider the material changes that are likely to occur over a time as vast as fifty-five years. In this regard, it is particularly telling that the predictions offered in the SNOPR conflict directly with those of Secretary Moniz, who has stated that "full decarbonization" – *i.e.*, the end of all natural gas use – can be expected to occur within just the next few decades.[63] That development would completely eliminate many years of the benefits – amounting to a substantial proportion of the total benefits – the SNOPR claims to justify the proposed standards. The SNOPR not only failed to consider the possibility of this development; it failed to consider the possibility that there might be any developments that would have material impacts on its projections.

DOE obviously cannot resort to unwarranted assumptions or speculation to justify standards that may only be justified based on substantial evidence. 42 U.S.C. § 6306(b)(2). Nor may it ignore potentially material considerations because efforts to address them would require baseless speculation, because the *failure to address* such considerations amounts to a baseless assumption that they are not material. If DOE needs to dismiss potentially material factors or resort to undue speculation to drum up benefits for its analysis, it is trying to drum up the wrong numbers. That is the case here: the SNOPR seeks to project benefits much farther into the future than credible analysis permits.

Time and time again, DOE has justified energy conservation standards based on grossly speculative benefits extending decades into the future, only to prove its approach to be unjustified by coming back within a much shorter span of years to adopt new standards that effectively eliminate the bulk of the benefits claimed to justify the previous standard. In recognition of this fact, DOE should not focus not on an arbitrary 30-year time horizon (plus the projected life of the products at issue). Instead, it should focus on the projected life of any standards it seeks to impose. DOE's decision to project benefits far out into the future is arbitrary, too speculative to provide substantial evidence that proposed standards are justified, and serves only to provide absurdly inflated estimates of the energy savings and related benefits its efficiency standards would provide.

[63] http://www.energylivenews.com/2016/08/18/us-to-decarbonise-by-2050-with-energy-storage/

5. DOE has significantly under-stated the costs its proposed standards would impose

As already discussed, there are fundamental problems with DOE's estimates of the costs the proposed standards would impose. Both the frequency of high-cost installations and DOE's statement of average costs are significantly understated as a result of DOE's unreasonable misallocation of bad regulatory outcomes to the base case in its regulatory analysis. Similarly, both the frequency of high-cost installations and average cost figures are significantly understated as a result of an unreasonable fuel switching analysis under which the costs associated with gas furnaces that are effectively priced out of the market are replaced by the costs representing lower-cost electric alternatives. In addition – through an unprecedented change in its published analysis – DOE has omitted separate analytical results for two categories of consumers whose different circumstances are critical for understanding the potential impacts of the proposed furnace standards: consumers who are replacing their existing gas furnaces and consumers purchasing new homes with gas furnaces. Furnace replacements and furnaces in new construction involve fundamentally-different installation cost issues, which is why DOE has provided separate cost information for each in previous rulemakings. By combining them into one set of calculations – particularly for purposes of life cycle cost analysis – DOE has effectively "averaged away" the fundamental differences between these two categories of consumers and presented average cost information that is not actually representative for either category. This "averaging away" effect is especially problematic in replacement installations in which costs vary significantly due to case-specific issues such as those raised by the common venting of non-condensing furnaces and water heaters in a single home or more complex common venting scenarios in multifamily housing.

Compounding all of these problems is the fact that the basic data inputs for DOE's cost analysis are estimates that are derived by arbitrary means and that demonstrably understate the costs the proposed standards would actually impose.

a. Unreasonable equipment and installation costs

As already discussed, DOE does not even attempt to collect data on the actual costs consumers pay to purchase and install gas furnaces. Instead it relies upon a Rube Goldberg analysis in which dozens of questionable parameter inputs – many of which are supplied by DOE consultants on the basis of information reportedly unknown even to DOE – are used to produce installed cost estimates that are grossly inconsistent with considerable available evidence as to the costs consumers actually pay in the real world (including price guide data, extensive survey data, and actual price quotes). DOE has no reasonable basis to reject actual data providing direct evidence of the installed appliance costs consumers actually pay in favor of indirect estimates derived on the basis of facially less reliable information concerning dozens of other parameters.

Spire maintains that it would have been relatively easy for DOE to collect "real world" cost data if only it had tried. After all, DOE admits that it surveyed utilities about their rebate programs; so, it would have taken very little incremental effort to find out what customer installations received rebates and what the total installed costs were. In fact, Spire collected such data and offered it to DOE, but still DOE has declined to consider it even in an effort to validate the results of its indirect cost "build up" methodology. Not surprisingly, Spire's real-world data suggests that DOE's dubious indirect estimates are once again low by a wide margin. This is confirmed by data from an installed cost survey conducted by the Air Conditioning Contractors of America (ACCA) and the Plumbing, Heating, and Cooling Contractors Association (PHCC) that was attached as Appendix A to AHRI's comments filed in response to DOE's NOPR in the present docket.[64] The upshot of that survey data is that DOE's dubious indirect installed cost estimates were roughly half of what real world evidence suggests. Moreover, real world

[64] 2015-07-10 Comment response to published notice of proposed rulemaking (NOPR) and announcement of public meeting

cost data is representative of installations consumers are choosing to make in the absence of regulation: a range of installations that disproportionately includes cost-effective installations. As a result, such data should considerably under-state the cost of the disproportionately cost-ineffective installations that would occur only under the compulsion of the proposed standards.

DOE suggests that its numbers should be considered to have some credibility because the consultants that generated them claim to have based them on manufacturer interviews and follow-up back-and-forth with product manufacturers. 81 Fed. Reg. at 65764. However, there is nothing in the record to show what input DOE's consultants actually sought or obtained, and the only manufacturers' input that is available on the record is comment demonstrating that manufactures consider DOE's installed cost numbers to be gross underestimates of actual installed costs.

DOE also suggests that "the sales prices currently seen in the market place . . . are not necessarily indicative of what the sales prices of those furnaces would be following the implementation of a more stringent energy conservation standard" due to the potential price impacts of increases in manufacturing volume and economies of scale, possible changes in mark-ups, and so forth. 81 Fed. Reg. at 65763-64. There is no basis for any of this. Condensing gas furnaces are nothing new, are already being produced in considerable volume, make up a substantial percentage of the total gas furnace market, and actually dominate the market in some regions. There is simply no legitimate reason to assume that the proposed standards would result in any material decrease in furnace pricing, let alone an impact sufficient to explain away the differences between DOE's indirect estimates and observed product pricing.

DOE's unreasonable rejection of actual evidence of installation costs in favor of the product of its inherently less reliable indirect estimates is particularly unreasonable. 81 Fed. Reg. at 65776-83. No matter how elaborate a theoretical exercise may be, a material disconnect between the indirect cost estimates produced and direct evidence of real world costs is reason to question the reliability of the theoretical exercise, not the real world data. This is particularly true with respect to installation costs, because – as already discussed – one of the principal impacts of the proposed standards would be to force consumers to install condensing gas furnaces in circumstances in which installation issues impose costs that consumers would not willingly accept in the absence of the proposed standards. As a result, observed installation costs – which disproportionately represent installations consumers considered economically advantageous – should be expected to be significantly lower than the installation costs the proposed standards would impose. Yet DOE's theoretical estimates substantially underestimate even the costs suggested by current real-world evidence.

Remarkably, DOE has suggested that its unreasonably low cost estimates for condensing gas furnaces do not have a material impact on its analysis, because only the incremental differences between installed costs matter, and the incremental differences between its installed cost numbers are similar to the incremental differences between installed costs commenters have suggested. 81 Fed. Reg. at 65781-82. However, the claimed resemblance between incremental installed costs is questionable, and there is no basis to suggest that the incremental differences between two wildly inaccurate DOE cost estimates are likely to be any more representative of reality than the wildly inaccurate cost estimates themselves. To the contrary, if DOE's cost estimates are systematically low by about half (as is typically the case across a wide spectrum of products), the differential between them – rather than being on target – would also be low by about half. In any event, the comparison between DOE's estimates and market-based data is an apples-to oranges comparison. Again, market-based installed cost data would disproportionately represent low-cost condensing gas furnace installations, whereas installed costs for installations forced upon consumers by the proposed standards would disproportionately include high-cost condensing gas furnace installations that are unlikely to occur by consumer choice. Thus, market-based data would significantly understate the installed cost of condensing gas furnaces actually installed as a result of the proposed standards that reduce consumer choice. However, the same logic does not apply with respect to market-based data concerning the installed cost of **non-condensing** gas furnaces. As a result, market-based data should be expected to understate both the installed cost of condensing gas furnaces sold because of the proposed standards and the incremental difference between those costs and the installed costs for non-condensing furnaces. There is therefore no basis to suggest that the incremental differences between DOE's installed cost estimates are even accidentally consistent with market data. They are not.

b. <u>Unreasonable product lifetime and maintenance cost assumptions</u>

DOE's analysis relied upon an opaque black-box analysis to assume a remarkably long product life for gas furnaces of 21.5 years. Commenters responded to this product life assumption with information indicating that DOE's estimate was at odds with reality and would produce a significant overstatement of the benefits of the proposed standards. 81 Fed. Reg. at 65786-87. Interestingly, DOE also assumed that condensing gas furnaces have the same long product life as non-condensing gas furnaces. This is illogical, as Spire has previously commented:

> *Moving to an all condensing furnace market will decrease furnace life. Condensing furnaces are more complicated, have more electronics and the new furnace fan rules will shorten furnace life. [Spire] used a Weibull distribution for furnace life with a mean of 18.1 years to more realistically describe furnace life.*

DOE responded to adverse comment as follows:

> *DOE acknowledges that the data it used to derive furnace lifetimes primarily refer to non-condensing furnaces. However, the one source it found on lifetime of condensing furnaces[106] shows the same lifetime (18 years) as other sources provide for noncondensing furnaces. In addition, DOE reviewed warranty information primarily related to heat exchangers and did not find any significant differences between condensing and non-condensing furnaces. If manufacturers expect condensing furnaces to have a shorter lifetime than non-condensing furnaces, it seems likely that the warranty periods would be different. Based on the information reviewed, DOE maintained the same lifetime for condensing and non-condensing furnaces in the SNOPR.*

81 Fed. Reg. at 65787. There are several obvious problems with DOE's logic. First, DOE has not even attempted to contest the fact that – for technical reasons – the reasonable engineering expectation is that

condensing gas furnaces would have a shorter product life than non-condensing furnaces. Second, it is irrational to defend a 21.5-year product lifetime for condensing gas furnaces on the basis of data suggesting that they have an 18-year product lifetime.

DOE cites its own data[65] suggesting a 21.5-year lifetime for **non-condensing** furnaces, and there are obvious engineering reasons to expect that condensing gas furnaces would have a shorter lifetime than non-condensing gas furnaces. In view of that data and information, there are several ways to explain data suggesting an 18-year lifetime for both condensing and non-condensing furnaces. The data could reasonably be dismissed as unreliable on the grounds that it is inconsistent both with DOE's data suggesting a 21.5-year lifetime for non-condensing furnaces and with the engineering expectation that condensing gas furnaces should generally have a shorter lifetime than non-condensing furnaces. Alternatively, the data suggesting an 18-year product lifetime might be considered unreliable for non-condensing furnaces (as DOE's other data suggests) but reliable for condensing furnaces (which would be consistent both with engineering expectations and the results of Spire's analysis). If the data were sufficiently robust, it might even be suggested that it is accurate for both types of furnaces, despite other data suggesting a longer lifetime for non-condensing furnaces and the engineering expectation that condensing furnaces would have shorter lives. However, that interpretation would support an 18-year product life for condensing gas furnaces rather than the 21.5-year product life DOE has assumed. DOE's interpretation is more remarkable: it takes the position that the data suggesting an 18-year lifetime is unreliable for both condensing and non-condensing furnaces, but is nevertheless accurate to show that – contrary to engineering expectations – condensing gas furnaces have the same lifetime as non-condensing

[65] https://publications.lbl.gov/islandora/object/ir%3A157288/datastream/PDF/download/citation.pdf

gas furnaces. The only thing to commend this interpretation is that it enables DOE to characterize data that does not support its 21.5-year product lifetime assumption as data that does.

DOE's reference to warranty information is no better. Product warranties are obviously based on complex market forces, as is the competitive, economic, and business calculus behind them. Furnace warranties often include provisions that extend longer than consumers typically stay in the same home, which can – depending on the specific warranty terms – inflate the apparent value of the warranty, provide a useful means to tie future home-owners to the manufacturer's brand, or both. As a result, there is no basis for DOE's casual assumption that "if manufacturers expect condensing furnaces to have a shorter lifetime than non-condensing furnaces, it seems likely that the warranty periods would be different." It can as easily be said that "if manufacturers want consumers to upgrade to a considerably more expensive type of furnace, the warranty periods better not be shorter."

A related problem in DOE's analysis is that it has understated the additional maintenance and repair costs condensing furnaces require. In Docket Number EE-2010-BT-STD-0011, titled Energy Conservation Standards Notice of Proposed Rulemaking for Residential Furnace Fans, Laclede's comments[66] went into considerable depth in an effort to explain and provide examples of how one small electronic component failure can devastate DOE's life-cycle savings estimates. Some excerpts from those comments are included below:

> *The Department has not properly considered the increased costs of replacing furnace/motor control boards. Such repair bills typically range between $500 and $1,000. As such, these types of electronics failures can easily decimate expected consumer average savings that the Department indicates.*
>
> *The picture on the last page shows a failed capacitor on a furnace fan control board. The failure of that one inexpensive capacitor meant a $736 bill to this particular consumer.*

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[66] https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0089

> *Electronic components like this obviously can fail; and frequently do. Power surges, lightning strikes and ambient environments can be linked to such failures. If surge protection is needed to protect sensitive electronic components, then the cost of such protection devices should also be factored into the cost/benefit analyses.*

Spire services its customers' furnaces, and manages a "Red Tag Equipment Repair" program to help provide low-income residential customers with secure service work on gas heating systems in order to maintain or restore gas heating to their home. Given the nature of this program, most of the furnaces being repaired are older, non-condensing types, but not all. We have reviewed our records to specifically examine repair costs for condensing furnaces. These costs averaged $309 per repair. The most common repairs included replacement of motherboards and inducer motors. Higher maintenance and repair costs for condensing gas furnaces is confirmed by other reported industry experience:

> Condensing furnaces offer higher efficiencies and better comfort, but they also require more care than standard 80 percent AFUE furnaces. As John Poyle, owner, Hagerstown Heating and Cooling LLC, Hagerstown, Maryland, noted: "With noncondensing furnaces, you mainly just have to check for cracks in the heat exchanger and do a combustion safety test. With condensing furnaces, there's a lot more stuff that can fail, so more maintenance is required."
>
> That's because condensing furnaces have condensate drains and secondary heat exchangers, which can become plugged, as well as additional safety devices, pressure switches, and other controls that need to be tuned up and/or adjusted annually, said Eric Knaak, vice president of service, Isaac Heating and Air Conditioning, Rochester, New York. "Lack of regular maintenance can lead to system lockout, decreased efficiency, and premature failure of the components."[67]

DOE nevertheless persists in the unreasonable assumption that there is no difference in the maintenance and repair costs of condensing and non-condensing gas furnaces. 81 Fed. Reg. 65796, Table IV.19. By ignoring evidence to the contrary, DOE has understated the costs the proposed standards would impose.

[67] http://tsihvac.blogspot.com/2014/12/condensing-furnaces-require-special-care.html

c. Unreasonable discount rates

Spire has repeatedly submitted comments urging DOE to use more realistic discount rates for purposes of its analysis. In response, DOE notes that Spire has suggested the use of implicit discount rates, and claims that

> implicit discount rates are not appropriate in the framework of the LCC analysis. The implicit discount rate is inferred from consumer purchase data and generally incorporates many influences on consumer decision-making (e.g., rates of return, uncertainty, and transaction costs).

81 Fed. Reg. at 65788. Spire has consulted with several University and financial experts, and its research regarding LCC theory does not validate DOE's claims. Rather, the use of implicit discount rates is not only appropriate in lifecycle cost analysis; as the following papers show, the use of implicit discount rates in lifecycle cost analysis is actually superior:

- One Discount Rate Fits All? The Regressive Effects of DOE's Energy Efficiency Rule[68]
- Making the implicit explicit: A look inside the implicit discount rate[69]
- Implicit Discount Rates and the Purchase of Untried, Energy-Saving Durable Goods[70]

DOE's explanation of its use of discount rates in its LCC analysis illustrates the basic flaw in its approach:

> DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. The stream of savings is discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE notes that the LCC does not analyze the appliance purchase decision, so the implicit discount rate is not relevant in this model.

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[68] https://regulatorystudies.columbian.gwu.edu/sites/regulatorystudies.columbian.gwu.edu/files/downloads/policy-perspectives_One-Discount-Rate-Fits-All.pdf

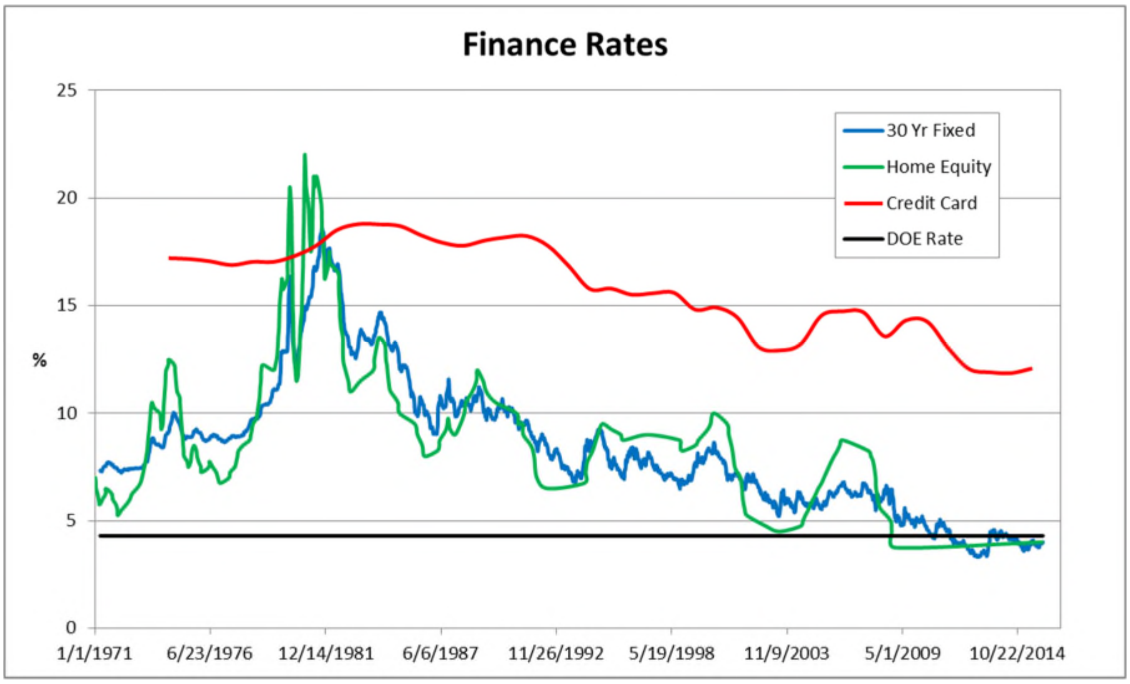
[69] http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-4040318.pdf

[70] https://kuscholarworks.ku.edu/bitstream/handle/1808/10092/Implicit%20Discount%20Rates%20and%20the%20Purchase%20of%20Untried%20Energy-Saving%20Durable%20Goods.pdf?sequence=1

TSD at Section 8.2.2.6. The problem is obvious: the proposed standards will put many consumers in a position in which it will be necessary to finance a furnace replacement through a high-interest loan. Such a purchase is not simply an investment that will yield a steam of cost savings over time; it is at least equally an expense that will yield a stream of costs over time. If the loan is eventually refinanced or paid off, the effects will be very different than those addressed in an average discount rate, because the high interest rate impacts the early years, the low interest rate impacts the later years. Discounting future cash flows at a low rebalanced interest rate will have a much smaller impact on LCC and high upfront interest rates will have a much higher impact on the LCC. DOE's use of low average discount rates effectively disregards the high initial cost of debt many consumers – particularly low-income consumers – will be required to bear, systematically understating the lifecycle costs of the appliance.

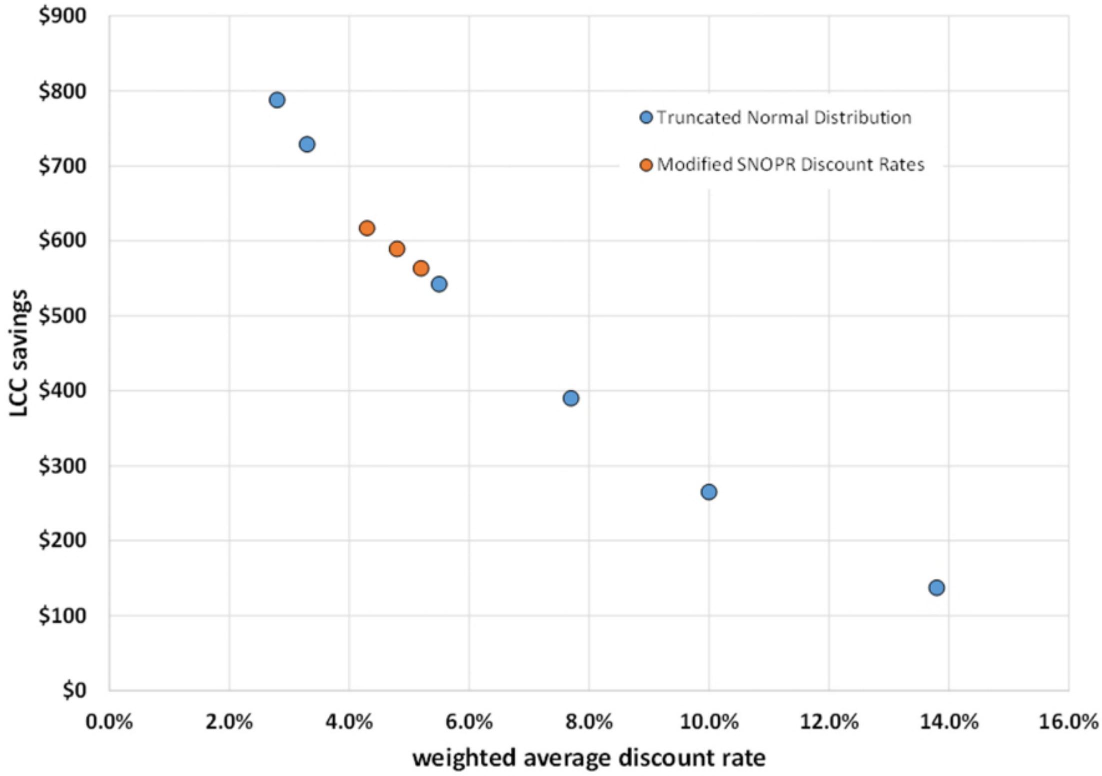
Historically, rates have been much higher than DOE's rates. As shown in Figure 12, DOE has cherry picked the lowest rates seen in over 50 years to do their analysis. There is very little expectation that rates will remain at fifty year lows for the next several decades. Rates have been kept very low due to the Federal Reserve's quantitative easing policy and inflation at very low levels. The Federal Reserve has signaled they will continue to raise rates for the foreseeable future and these increased rates are being priced into all financial instruments.

Figure 12



The weighted average rate in DOE's analysis is 4.3%. Spire ran a more believable truncated normal distribution with a mean of 10%, and a standard deviation of 5%, and the LCC savings were substantially lower. Once again, reasonable input assumptions have a large negative impact on LCC savings. The GTI report also looked at discount rates and ran several alternative scenarios with dramatic reductions in LCC savings solely attributable to more realistic discount rates as shown in Figure 13.

Figure 13



H. The Proposed Standards Will Lessen Competition.

APGA and AGA sent comments to the Department of Justice (DOJ), dated November 8, 2016, that fully described the lessening of competition that should be expected if this SNOPR is finalized. Spire is in full agreement with the APGA/AGA joint letter. Spire's letter to the DOJ for the commercial water heater NOPR were referenced in their letter, and Spire has sent a similar letter to DOJ in response to this SNOPR, a copy of which is provided as Attachment E to these Comments.

In the simplest terms, DOE is lessening competition by banning cost-effective gas products while basically moving the market to electricity and leaving much less efficient electric resistance appliances "off the hook." Simultaneously, DOE is waging war against non-condensing appliance venting systems under the guise of energy efficiency.

I. **<u>DOE failed to consider non-regulatory alternatives</u>**

Executive Order 12866 states an express presumption against the need for regulation, and states that "Federal agencies should promulgate only such regulations as are required by law . . . or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American People."[71] To ensure that agencies act in a manner consistent with this philosophy, the Order directs agencies to identify the problem they seek to address through regulation, to "assess the significance of that problem," and to identify "the failures of private markets or public institutions that warrant new agency action."[72]

Assuming there is actually a "problem" to be addressed, proper regulatory analysis requires that DOE consider the extent to which non-regulatory alternatives may provide an effective means to address them.[73] DOE plainly failed to engage in any such analysis. In fact, the regulatory analysis offered in support of the SNOPR amounts to nothing more than a summary dismissal of non-regulatory alternatives on the grounds that such alternatives would not *completely eliminate* lower-efficiency appliances as a mandatory regulation would. 81 Fed. Reg. at 65746. The analysis of these alternatives was perfunctory, because the outcome of the analysis was predetermined by the question DOE addressed. In short, DOE simply asked whether there are non-regulatory alternatives that would provide *one hundred percent* of the

[71] Executive Order 12866 of September 30, 1993 at Section 1(a).

[72] Executive Order 12866 at Section 1(b)(1).

[73] *See* Executive Order 12866 at Section 1(b)(3); Office of Management and Budget, Circular A-4 (September 17, 2003).

energy conservation benefits a mandatory standard would provide, and naturally assumed that none would. If that were the appropriate question to ask, consideration of non-regulatory alternatives would always be the completely empty exercise that DOE would have it be.

In the consideration of non-regulatory alternatives, the question is not whether there are non-regulatory benefits that would provide one hundred percent of the benefits that a regulation would achieve; it is whether such alternatives would address the identified regulatory "problem" to an extent that would effectively eliminate the need for regulatory intervention. In this context, the appropriate question is whether there is a non-regulatory alternative that would be sufficiently effective that the incremental additional benefits of regulation would be insufficient to justify the burdens a regulatory intervention would impose.

DOE has given this issue no consideration at all. Instead it has suggested that it "has no discretion under the statute to substitute energy conservation standards that are economically justified with other policies." 81 Fed. Reg. at 65746. However, DOE misstates the issue. To the extent a non-regulatory alternative would achieve a substantial portion of the benefits an energy conservation standard would achieve – and the incremental additional benefits of the standard would be insufficient to justify the costs the standard would impose – the standard would not be economically justified within the meaning of 42 U.S.C. § 6295(o). The statute certainly does not unambiguously foreclose such an interpretation, because 42 U.S.C. § 6295(o)(2)(B)(i)(VII) gives DOE considerable discretion with respect to the factors it may consider in determining whether a proposed standard is economically justified, and it is difficult to see how – particularly in view of policies articulated in Executive Order 12866 and the principles of sound regulatory analysis set forth in OMB Circular C-4 – DOE could reasonably ignore the potential of non-regulatory alternatives to make a standard economically unjustifiable. DOE's decision to interpret EPCA in a way that ties its own hands is not required by statute and has no basis in sound regulatory policy.

It is particularly disappointing that DOE effectively ignored alternatives to mandated energy efficiency levels that have been proven to work. In particular, DOE noted that federal energy efficiency tax credits were highly effective in incentivizing condensing furnace installations even through the impacts of the Great Recession. Such incentives are particularly effective in helping consumers overcome high initial costs, and could thus be particularly effective in reducing both the potential for fuel switching and adverse impacts on low-income consumers. As a result, a well-designed incentives program could do what mandatory standards would not: promote energy conservation through the sale of higher efficiency gas furnaces in situations in which mandatory efficiency standards would result in counter-productive fuel switching. It is no answer for DOE to wave off such alternatives on the grounds that they would require funding, because part of DOE's job is to point out the potential utility of such alternatives so that governmental officials in a position to provide such funding may understand the value of doing so.

J. The SNOPR is too deeply flawed to support the issuance of any final rule

The SNOPR proposes energy conservation standards that can only be justified on the basis of affirmative technical and economic determinations for which substantial information collection and analysis is required, and those determinations must be based on substantial evidence. As discussed at length in these comments, the SNOPR was issued on the basis of inadequate information and a profoundly flawed analysis. As a result, the gaps in information and analysis necessary to support the issuance of a final rule are too great to be filled without further notice and opportunity for comment. The reason for this is straight-forward: interested parties have a right to notice and opportunity for comment on proposed energy conservation standards and, in particular, on the technical and economic justification offered in support of such standards. 42 U.S.C. § 6295(p)(2). For notice and opportunity for comment to be legally sufficient, interested parties must have notice of – and an opportunity to comment on – *all* of the critical information and analysis relied upon to justify the standards imposed.[74] It follows that an agency cannot issue a proposed rule on the basis of opaque analysis or placeholder assertions or assumptions that are destined to be discarded and replaced in response to adverse comment; otherwise the result would be a final rule issued on the basis of information and analysis that has never been made available for review and "exposed to refutation" during the rulemaking process as required by law.[75]

Because the SNOPR was issued without remotely sufficient information and analysis to justify the adoption of any final rule, it is inadequate as a basis to satisfy notice and comment requirements and should therefore be withdrawn.

Conclusion

Spire respectfully submits that the proposed standards are based upon a comprehensively flawed analysis that is insufficient even to demonstrate that the proposed standards are likely to do more good than harm even from the narrow perspective of energy consumption. Independent analyses correcting just some of the major flaws in DOE's regulatory analysis indicates that all of the proposed standards would have net negative impacts for consumers and are not economically justified. Spire believes that even this independent suggestion is overly-optimistic, and that the proposed standards would likely result in increased overall energy consumption and carbon emissions and serious disproportionate and adverse impacts for low-income consumers. Because there is plainly no substantial evidence providing a basis to conclude otherwise, the proposed standards should be withdrawn.

[74] Chamber of Commerce v. SEC, 443 F.3d 890,900-02 (D.C. Cir. 2006); Ass'n of Data Processing Service Orgs. V. Bd. of Governors, 745 F.2d 677, 684 (D.C. Cir. 1984).

[75] Owner-Operator Indep. Drivers Ass'n v. FMCSA, 494 F.3d 188, 209 (D.C. Cir. 2007) (quoting Ass'n of Data Processing Service Orgs. v. Bd. of Governors, 745 F.2d 677, 684 (D.C. Cir. 1984).

Communications

Any communications regarding this submittal should be addressed to:

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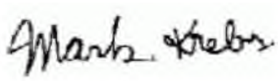
Respectfully submitted,

SPIRE INC.

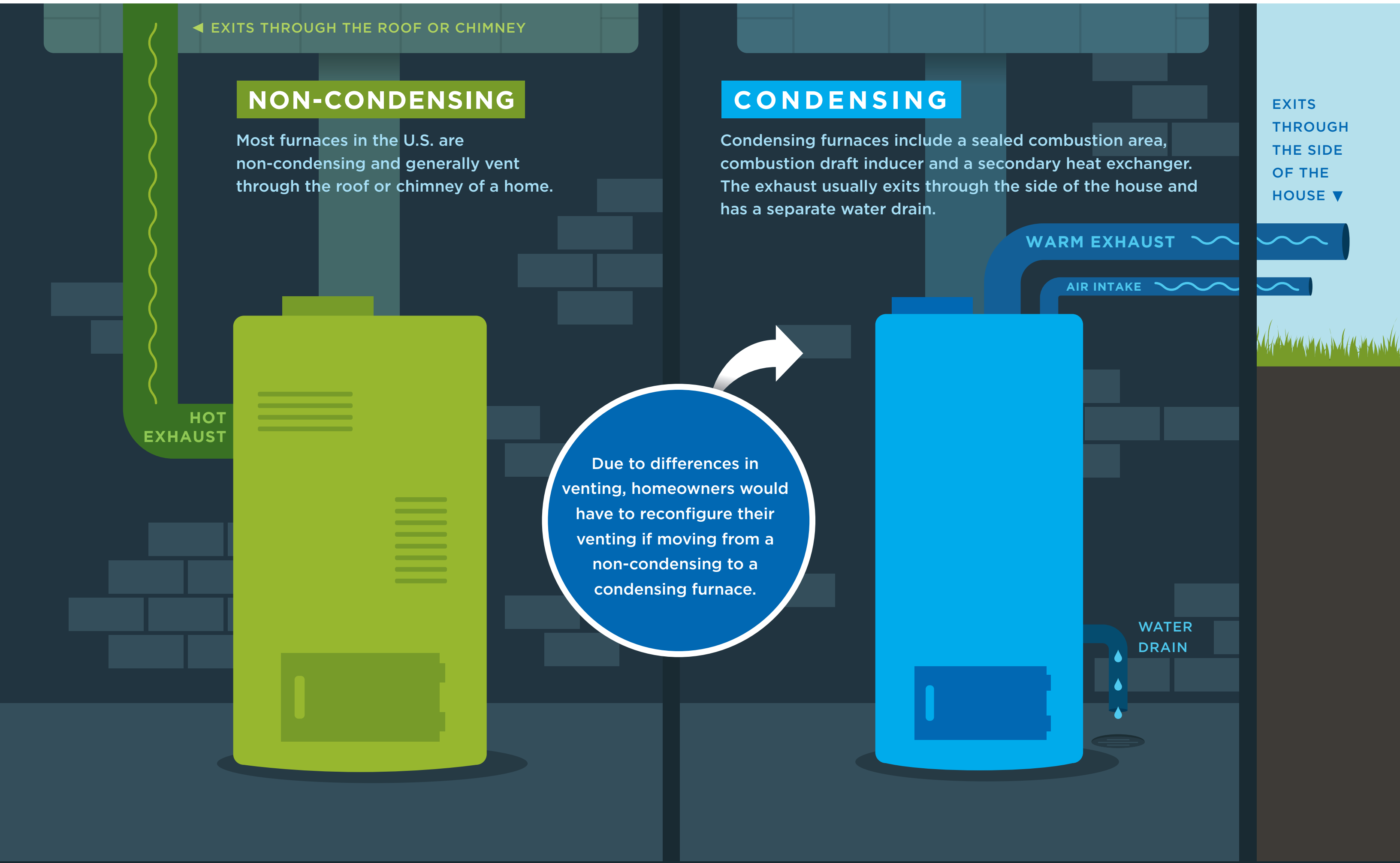


Mark Krebs

Energy Policies and Standards Specialist

NATURAL GAS: SAFE AND RELIABLE

177 million Americans use abundant natural gas to heat their homes and water and cook their food. But new standards by the U.S. Department of Energy could lead to switching away from natural gas to other fuels that could negatively impact consumer costs and the environment.



These changes could impose significant costs, driving homeowners away from natural gas to alternative fuel heating systems that could be ultimately less efficient and less cost effective.

New standards could eliminate non-condensing furnaces, forcing homeowners and builders to use a condensing natural gas furnace, or because of cost and logistics select an alternative heating system.

New standards from the U.S. Department of Energy could eliminate non-condensing furnaces.

HOW WOULD THESE STANDARDS IMPACT HOMEOWNERS?

These changes could require homeowners to make structural modifications to their home.

Structural Modifications

New condensing furnaces cannot be connected to the existing venting in a home, and require a new venting system and possible relocation of the equipment. This increases the installation cost of the more energy efficient natural gas heating system options.

Challenges

There are situations where a homeowner or builder wouldn't be able to install a condensing furnace, forcing them to switch to another fuel for heating. Challenges include if a homeowner could not access an external wall, like in apartments or condominiums, if outside venting is restricted by a homeowners' association, or if a homeowner could not meet venting requirements related to nearby windows, doors, or other air intakes.

Increased Emissions

Increased Operating Costs

Increased Energy Usage

Unintended Consequences

Homeowners and builders would be incentivized to move away from natural gas because of the associated costs and changes that would need to be made to the home, causing operating costs, energy usage and emissions to go up.

AGA American Gas Association

aga.org

truebluenaturalgas.org

twitter.com/AGA_naturalgas

facebook.com/naturalgas

Attachment B
Source Energy & Emissions Analysis Tool

Summary Data from 44 Analyses

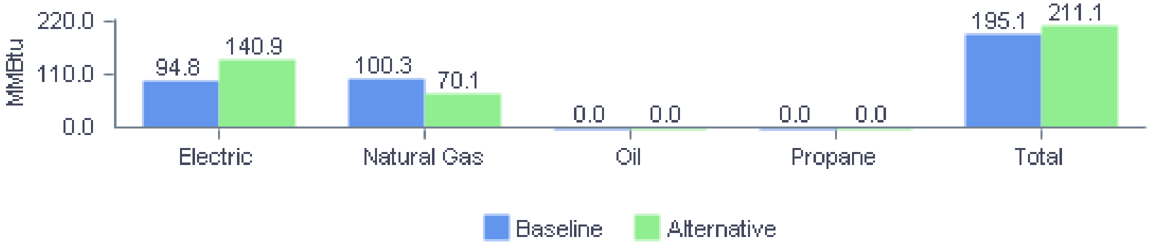
Description

- Appendix B used GTI's Source Energy & Emissions Analysis Tool (SEEAT) to analyze the impact of homes moving to condensing furnaces and electric resistance water heaters. This combination represents what is occurring in new construction as builders move away from non-condensing gas appliances. This situation is a form of fuel switching; the results of which generally increase emissions under most scenarios evaluated around the United States. The SEEAT tool is internet-based and freely available to the public.

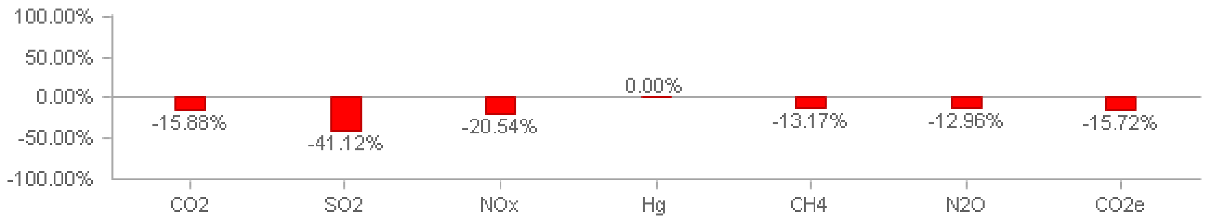
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RMPA (e.g., Denver CO)

Annual Source Energy Consumption by Fuel Type



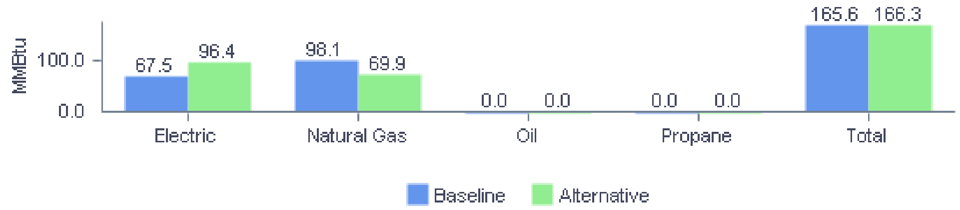
Annual Emission Percent Reduction vs. Baseline



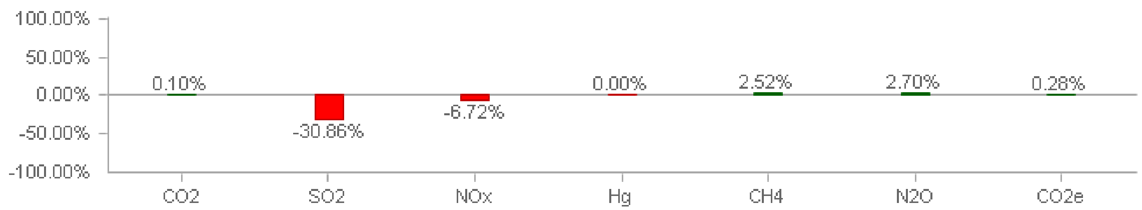
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NWPP (e.g., Salt Lake City UT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

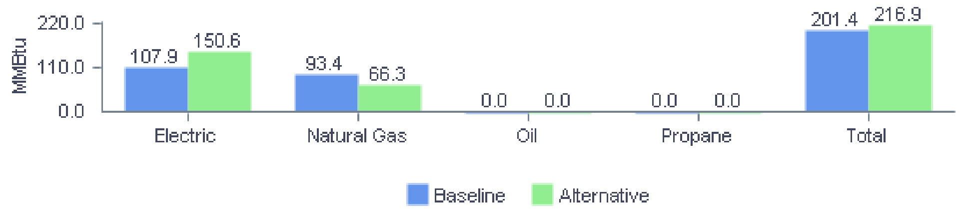


Scenario 1

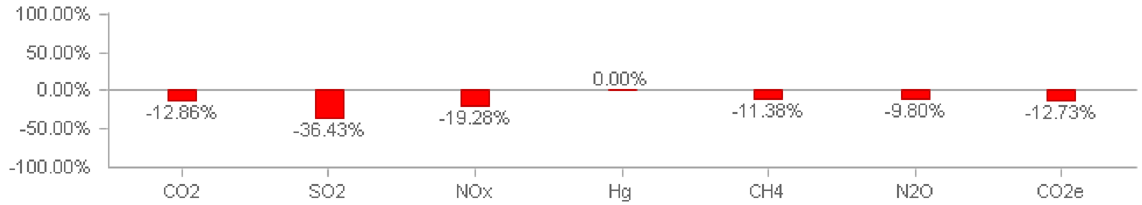
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SPNO (e.g., Kansas City MO)

Annual Source Energy Consumption by Fuel Type



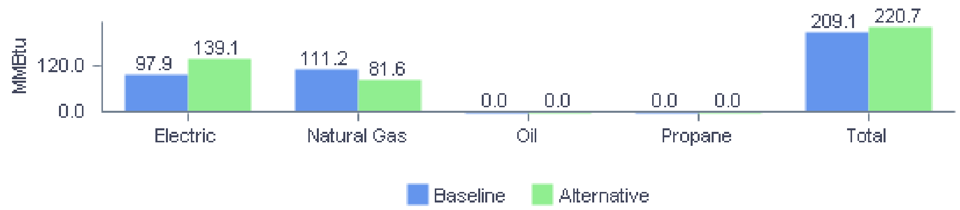
Annual Emission Percent Reduction vs. Baseline



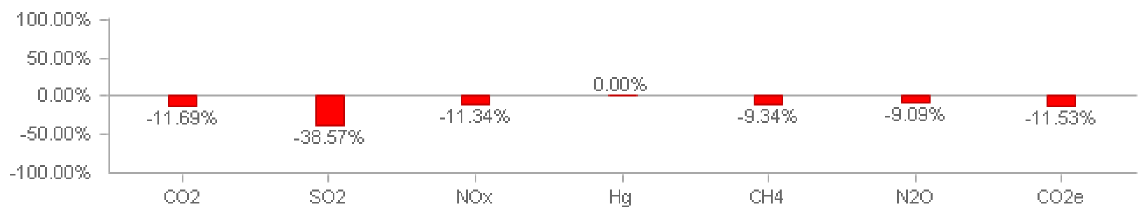
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SRMW (e.g., St. Louis MO)

Annual Source Energy Consumption by Fuel Type



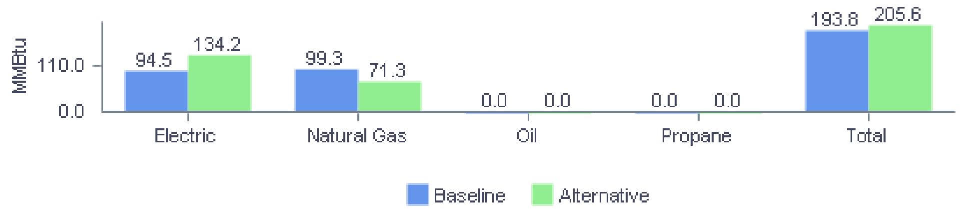
Annual Emission Percent Reduction vs. Baseline



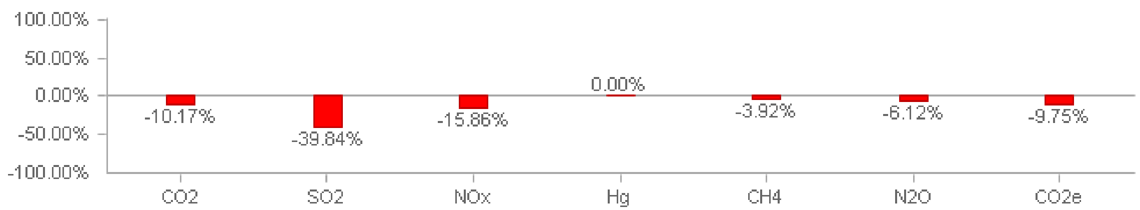
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCW (e.g., Columbus OH)

Annual Source Energy Consumption by Fuel Type



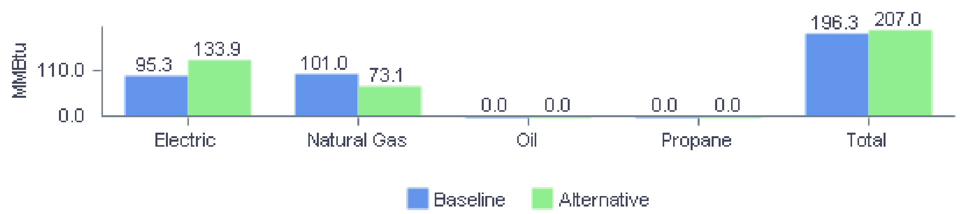
Annual Emission Percent Reduction vs. Baseline



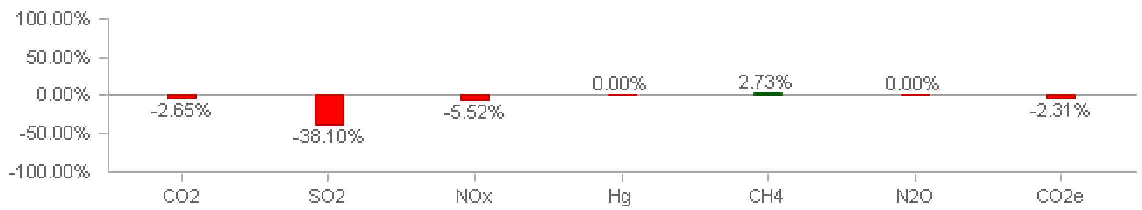
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCE (e.g., Philadelphia PA)

Annual Source Energy Consumption by Fuel Type



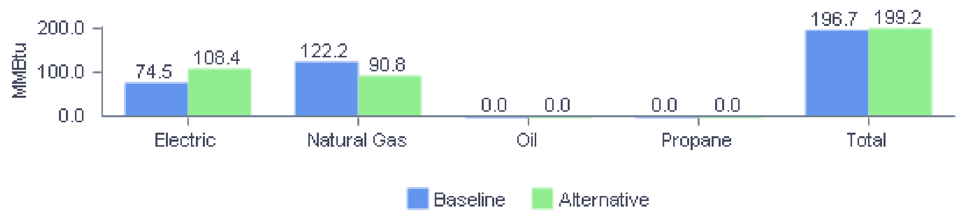
Annual Emission Percent Reduction vs. Baseline



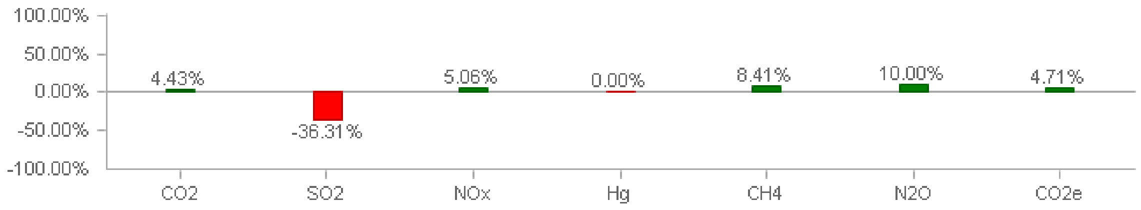
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NYUP (e.g., Albany NY)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

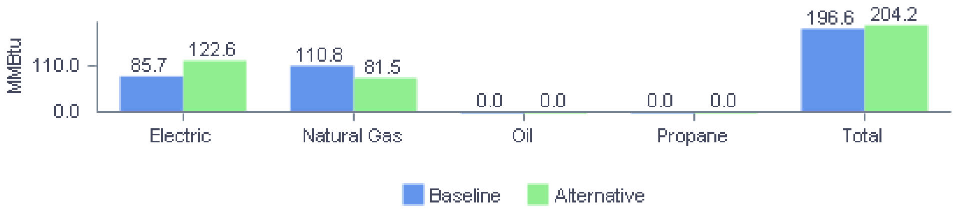


Scenario 1

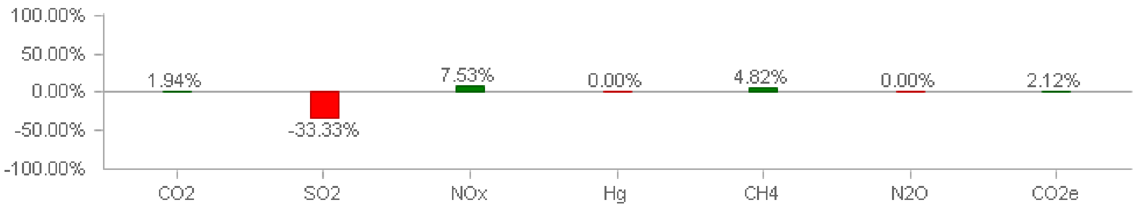
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NEWE (e.g., Bridgeport CT)

Annual Source Energy Consumption by Fuel Type



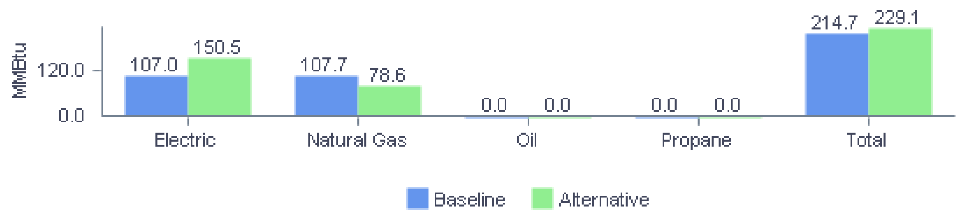
Annual Emission Percent Reduction vs. Baseline



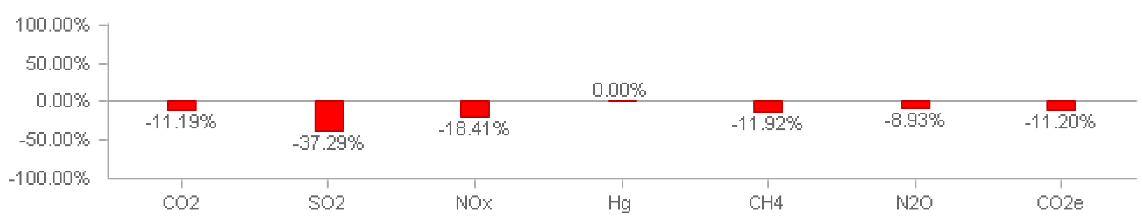
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROW (e.g., Omaha NE)

Annual Source Energy Consumption by Fuel Type



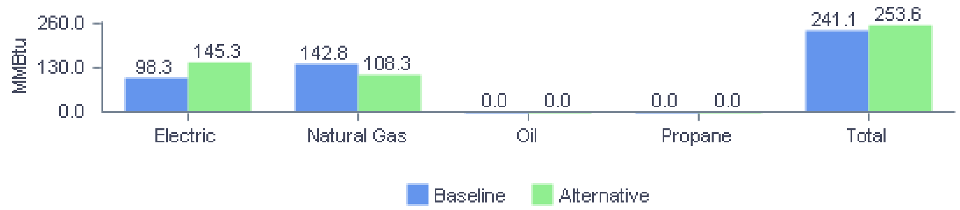
Annual Emission Percent Reduction vs. Baseline



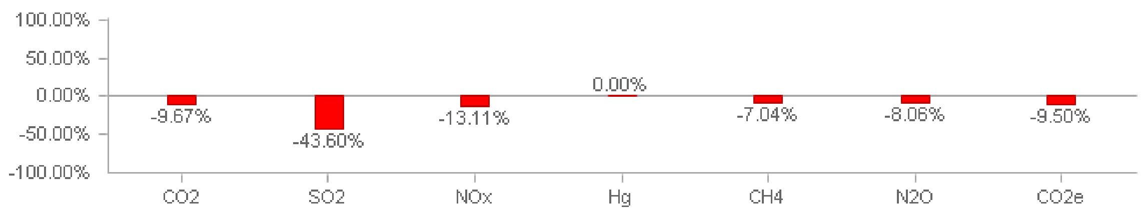
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROE (e.g., Green Bay WI)

Annual Source Energy Consumption by Fuel Type



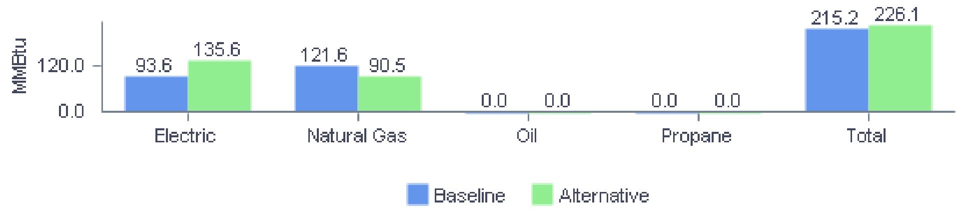
Annual Emission Percent Reduction vs. Baseline



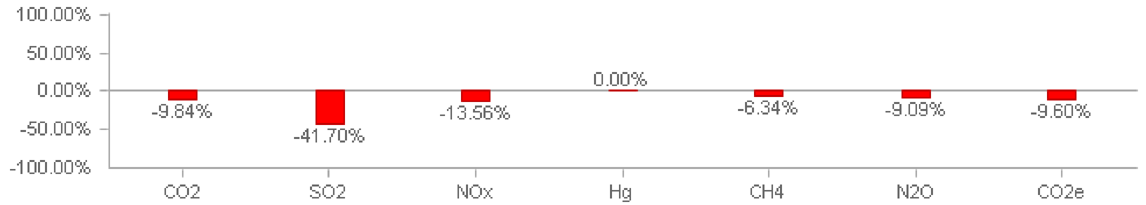
Scenario 1
90% Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCM (e.g., Detroit MI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

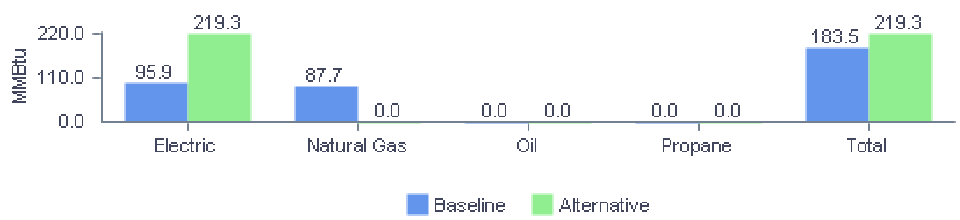


Scenario 2

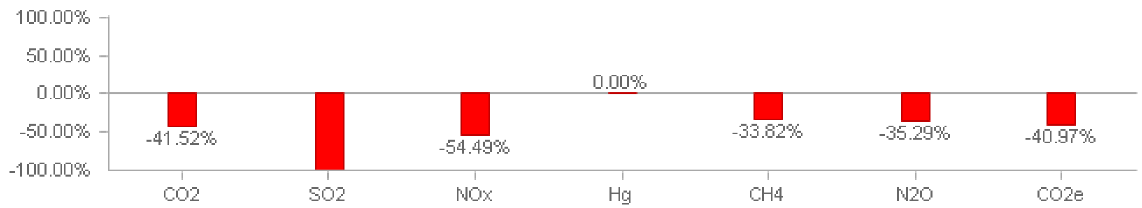
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RMPA (e.g., Denver CO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

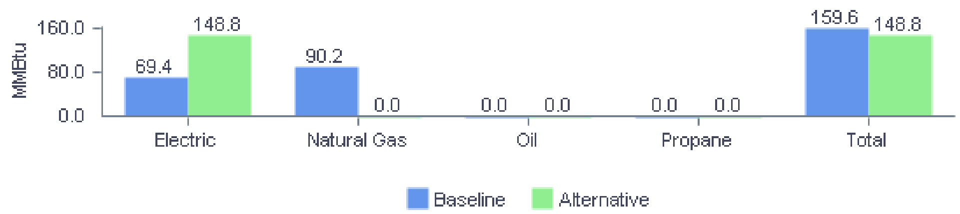


Scenario 2

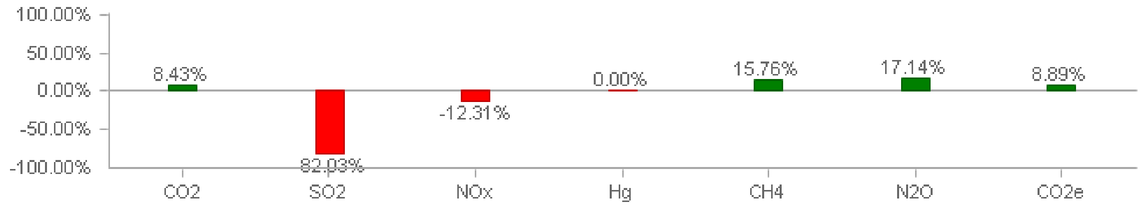
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NWPP (e.g., Salt Lake City UT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

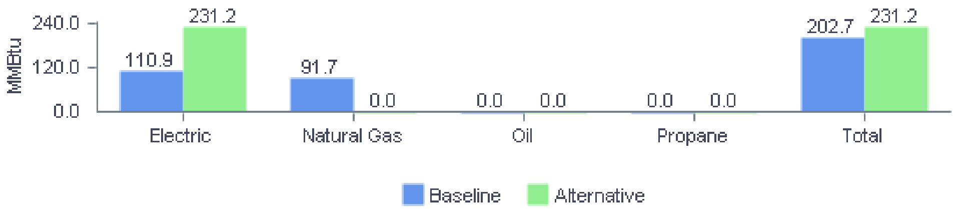


Scenario 2

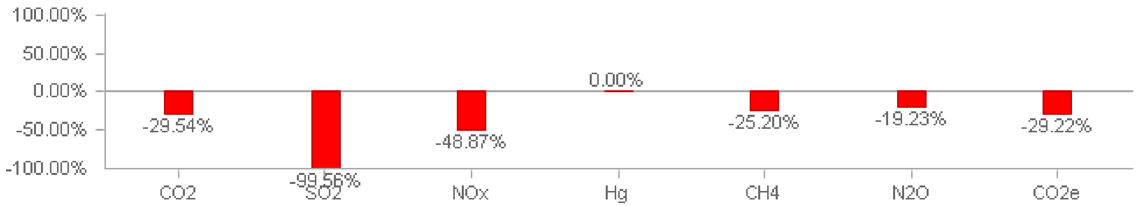
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SPNO (e.g., Kansas City MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

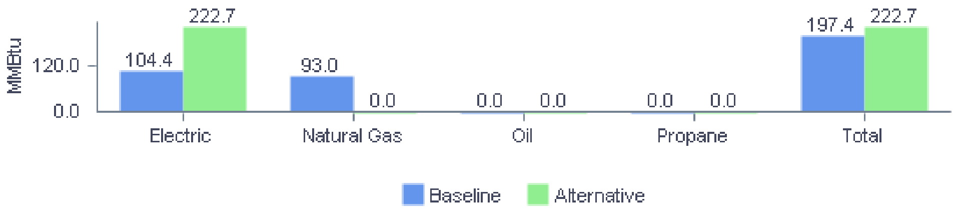


Scenario 2

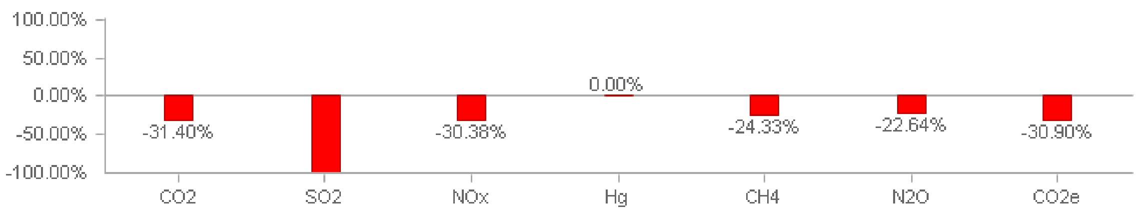
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SRMW (e.g., St. Louis MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

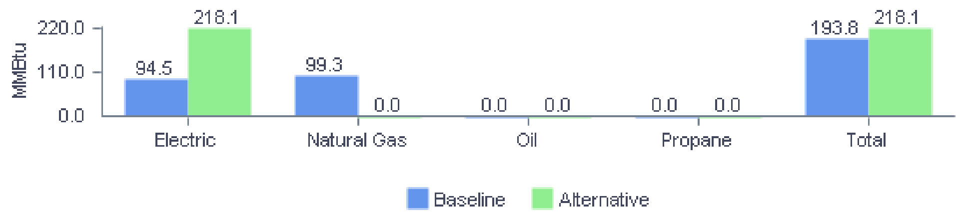


Scenario 2

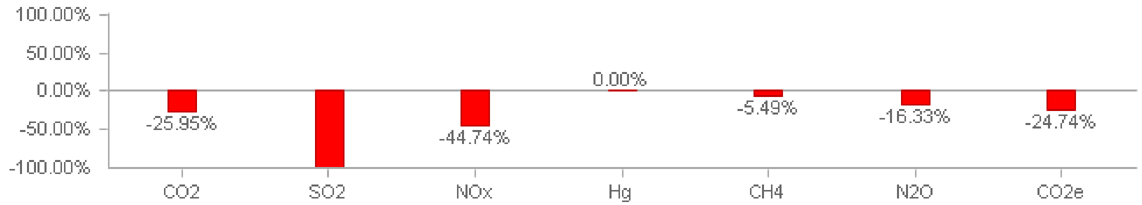
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCW (e.g., Columbus OH)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

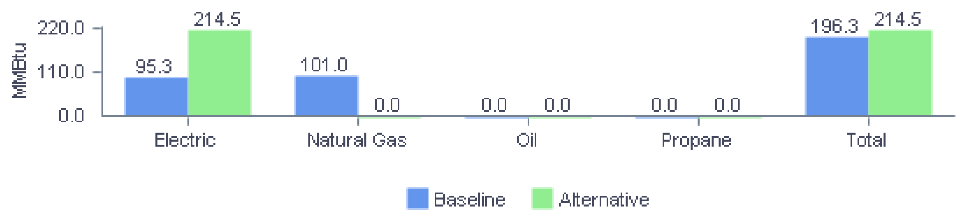


Scenario 2

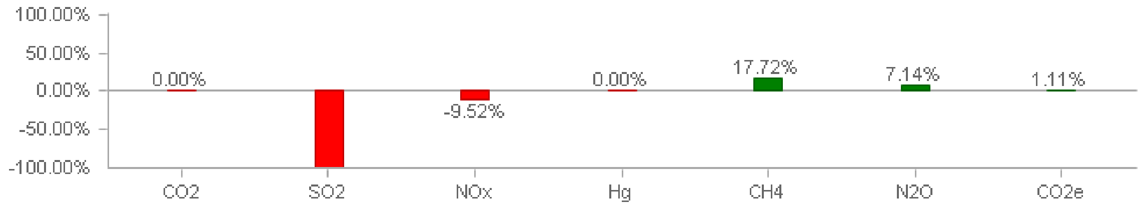
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCE (e.g., Philadelphia PA)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

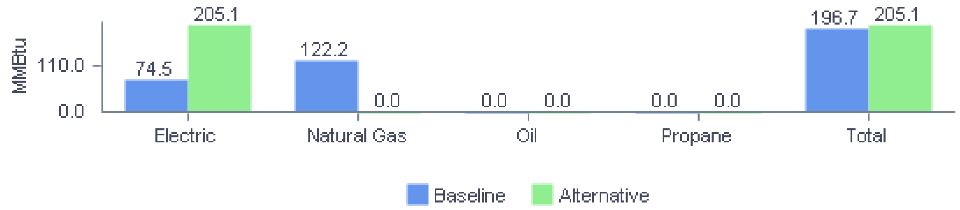


Scenario 2

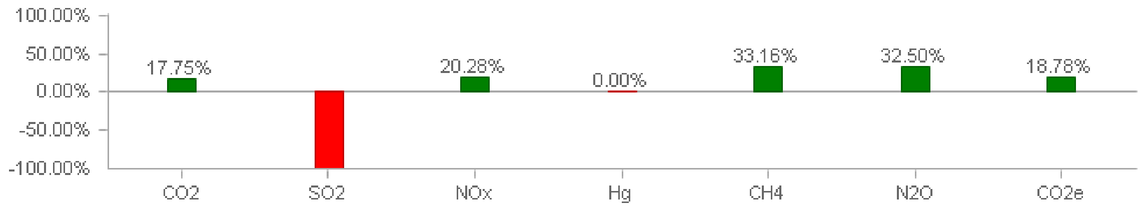
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NYUP (e.g., Albany NY)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

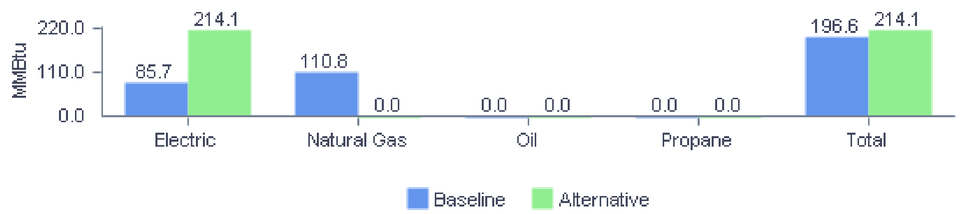


Scenario 2

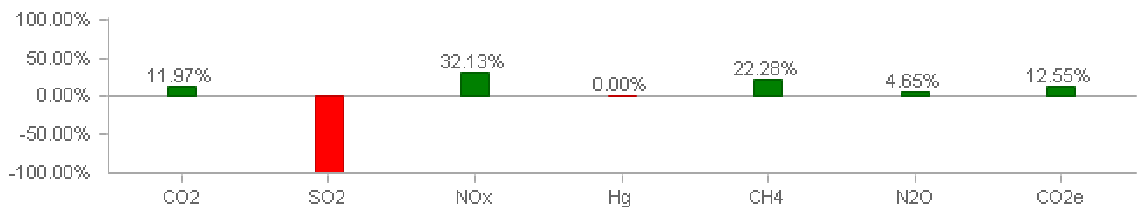
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NEWE (e.g., Bridgeport CT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

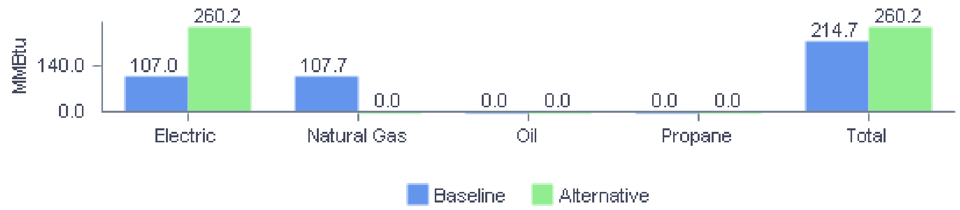


Scenario 2

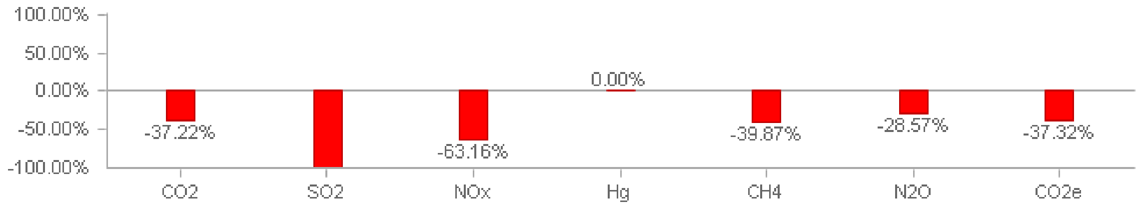
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROW (e.g., Omaha NE)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

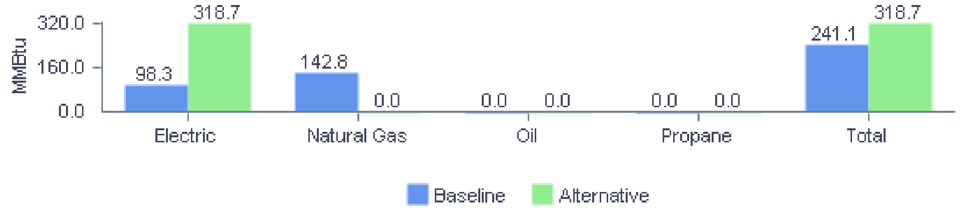


Scenario 2

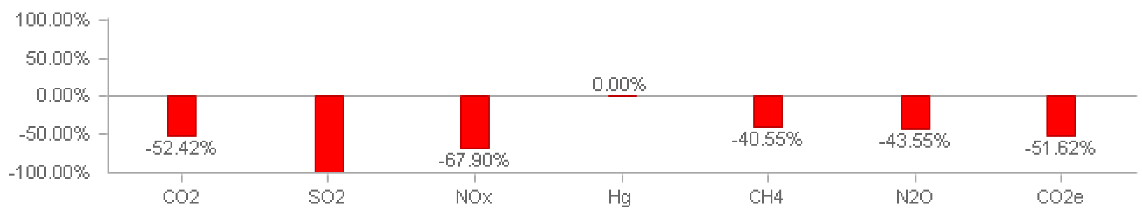
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROE (e.g., Green Bay WI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

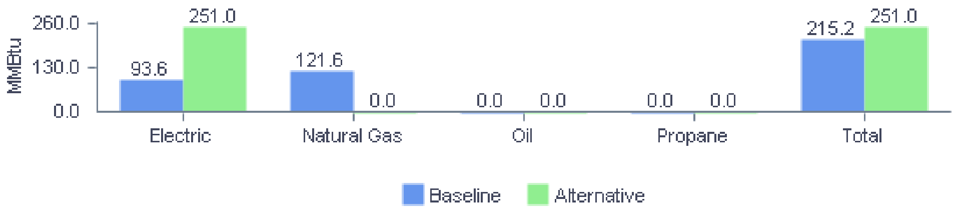


Scenario 2

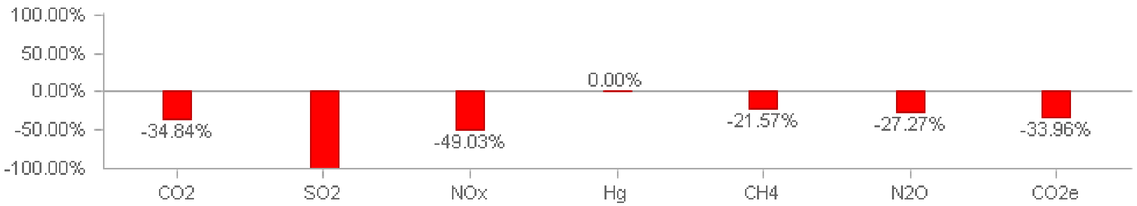
SEER 14/HSPF 8.2 Heat Pump & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCM (e.g., Detroit MI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

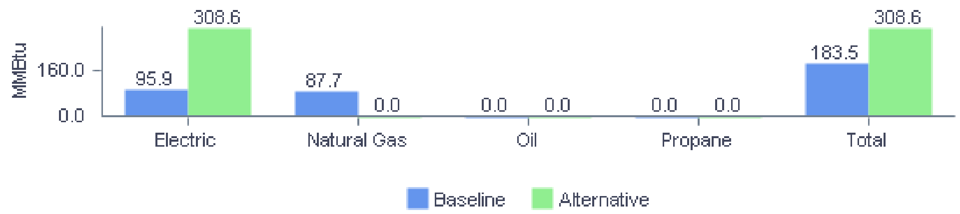


Scenario 3

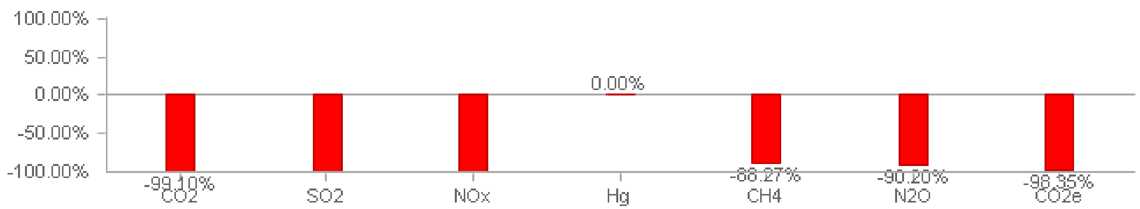
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RMPA (e.g., Denver CO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

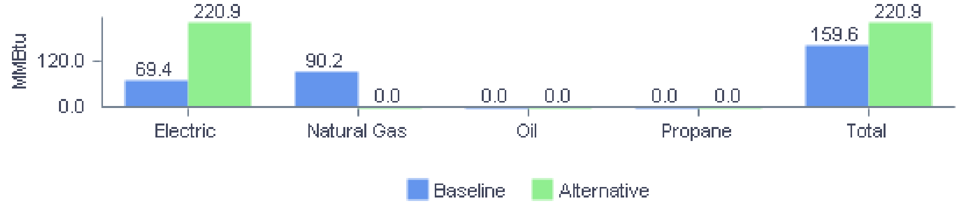


Scenario 3

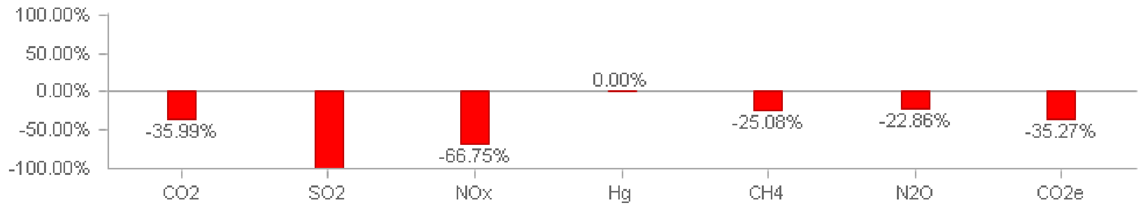
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NWPP (e.g., Salt Lake City UT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

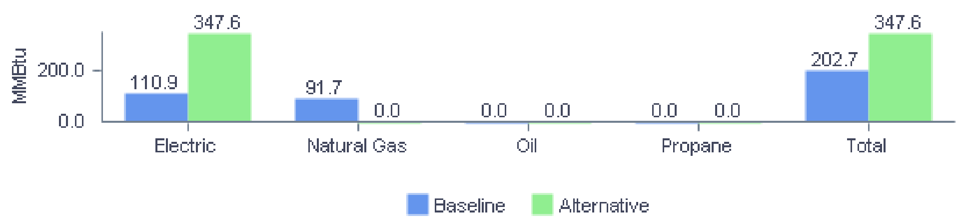


Scenario 3

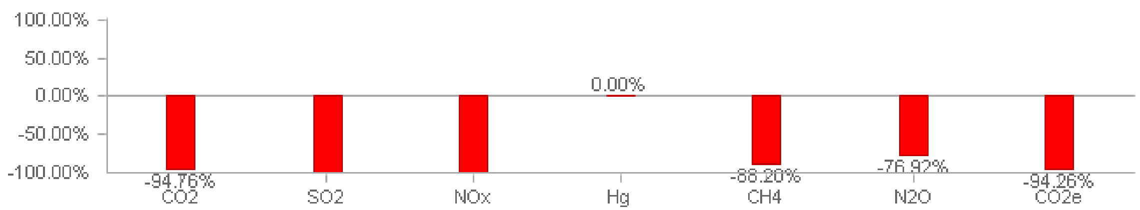
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SPNO (e.g., Kansas City MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

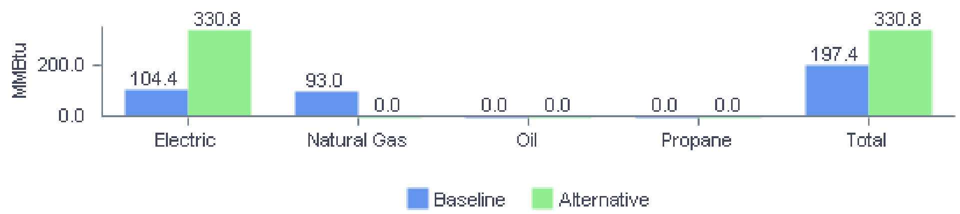


Scenario 3

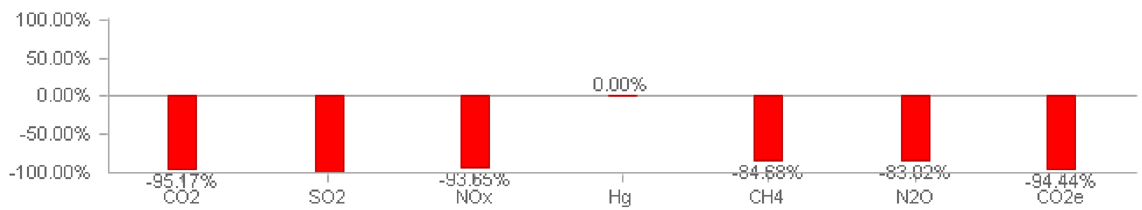
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion SRMW (e.g., St. Louis MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

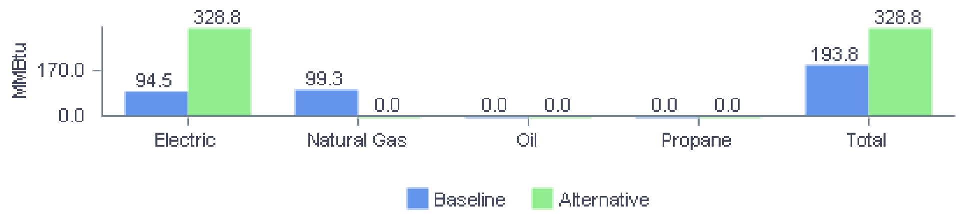


Scenario 3

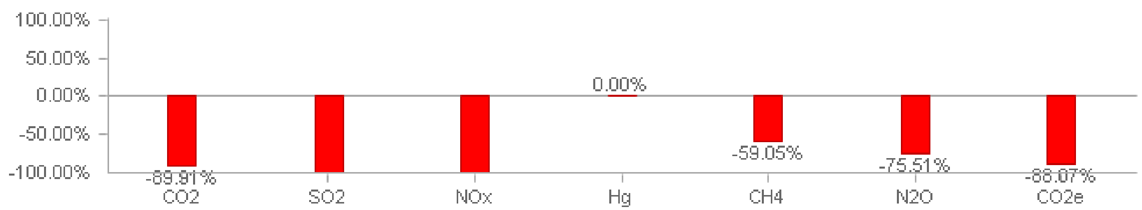
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCW (e.g., Columbus OH)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

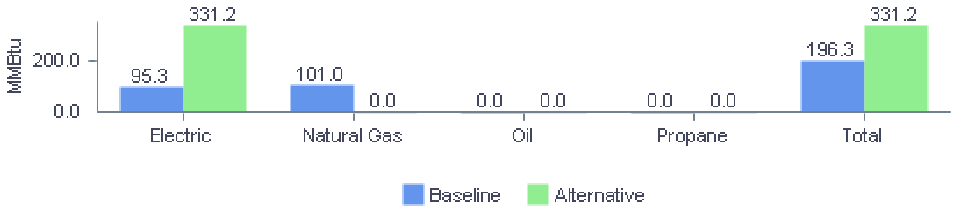


Scenario 3

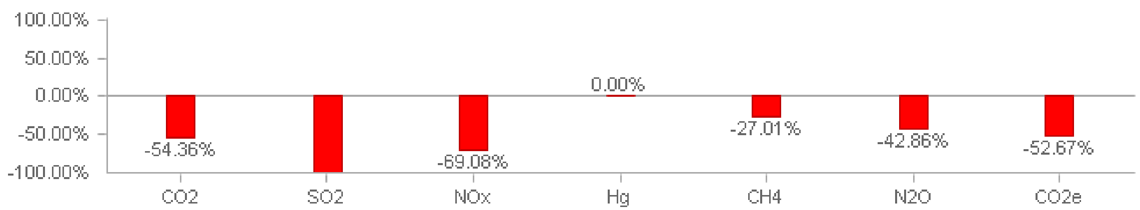
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCE (e.g., Philadelphia PA)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

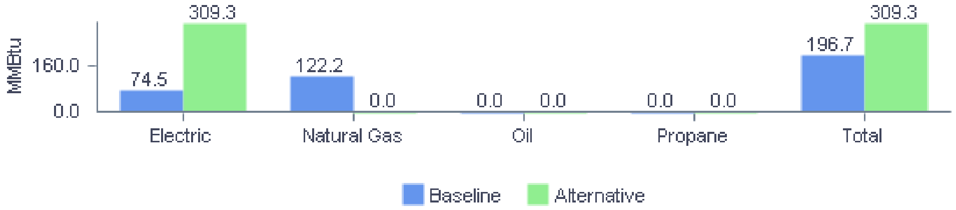


Scenario 3

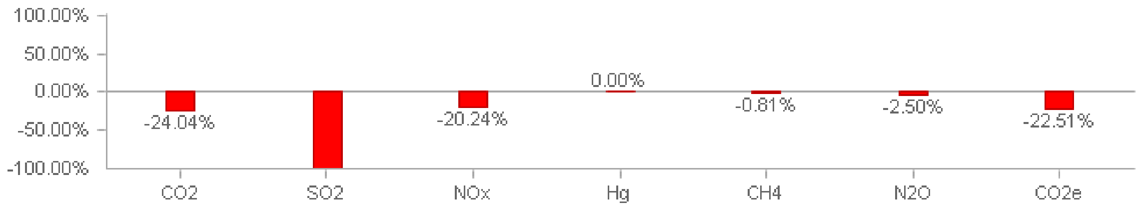
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NYUP (e.g., Albany NY)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

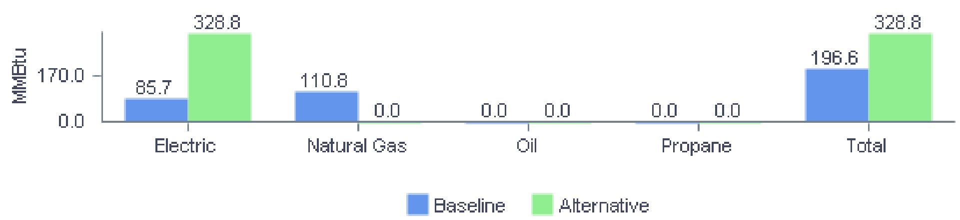


Scenario 3

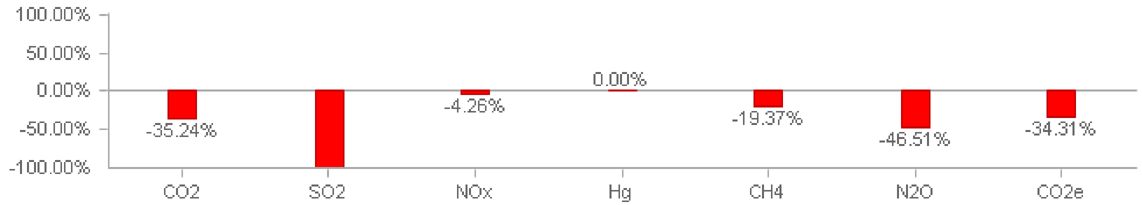
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion NEWE (e.g., Bridgeport CT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

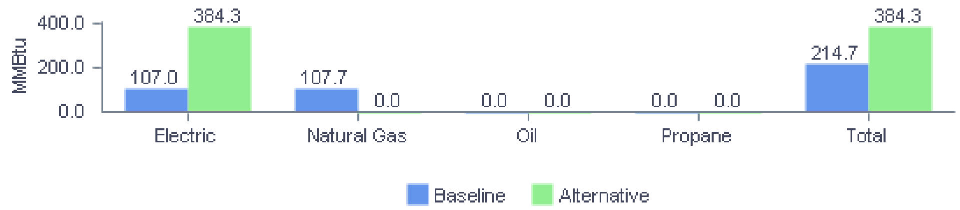


Scenario 3

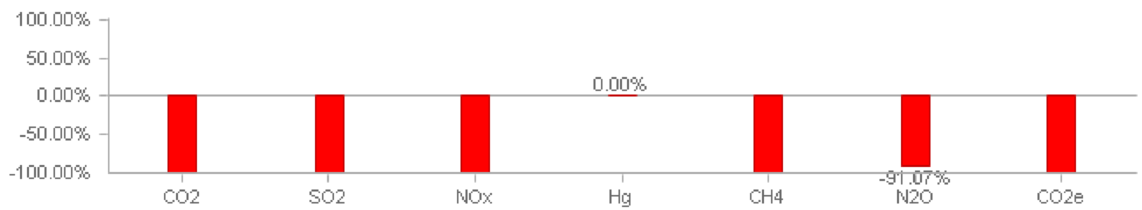
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROW (e.g., Omaha NE)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

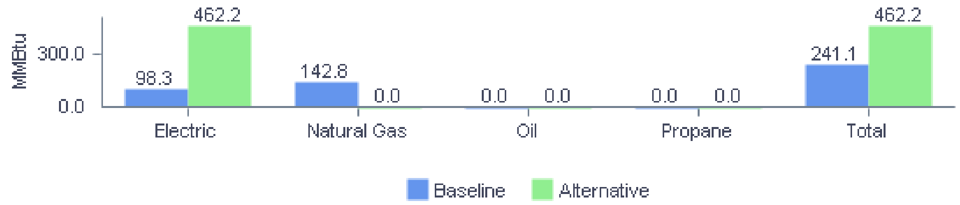


Scenario 3

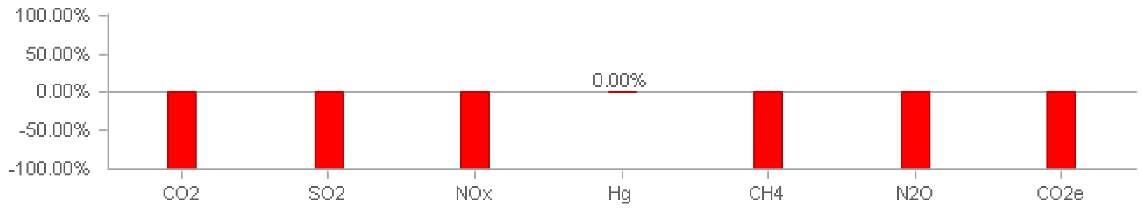
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion MROE (e.g., Green Bay WI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

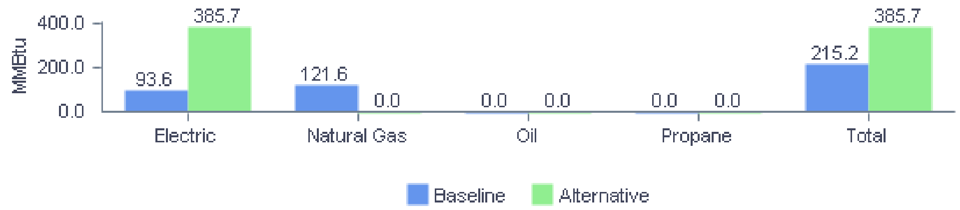


Scenario 3

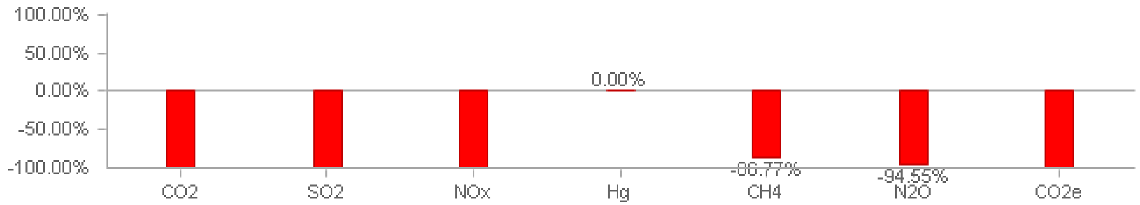
Electric Resistance Furnace & 0.9 EF Electric Resistance Water Heater

for eGrid Subregion RFCM (e.g., Detroit MI)

Annual Source Energy Consumption by Fuel Type



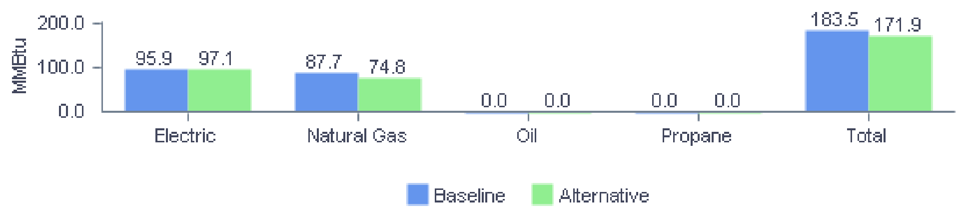
Annual Emission Percent Reduction vs. Baseline



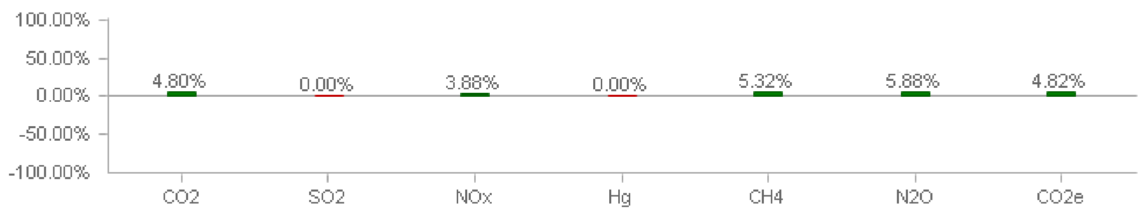
Scenario 4
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion RMPA (e.g., Denver CO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

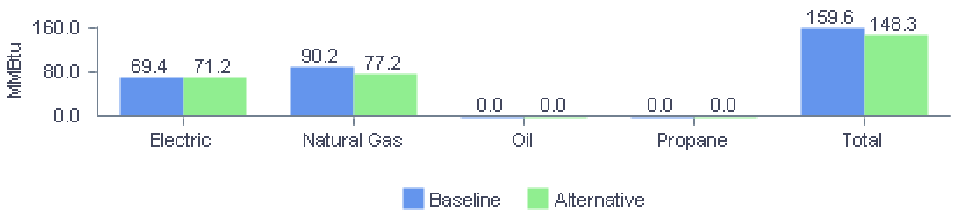


Scenario 4

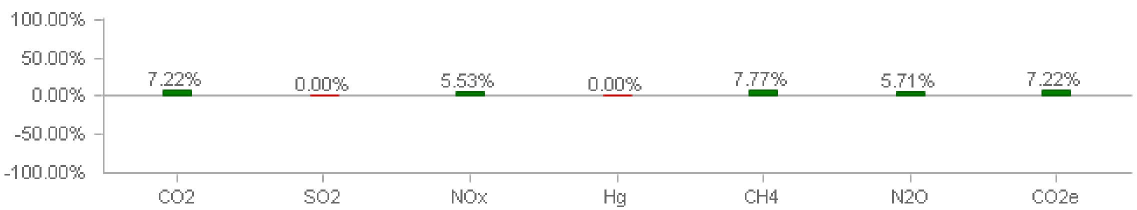
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion NWPP (e.g., Salt Lake City UT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

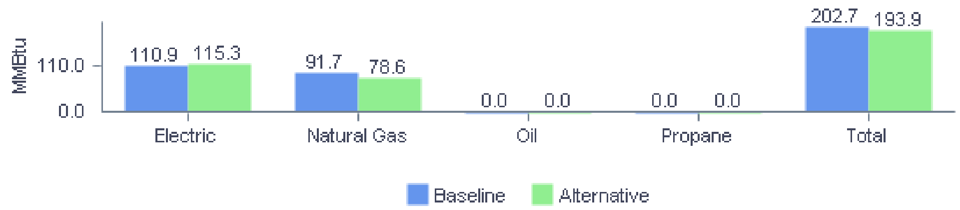


Scenario 4

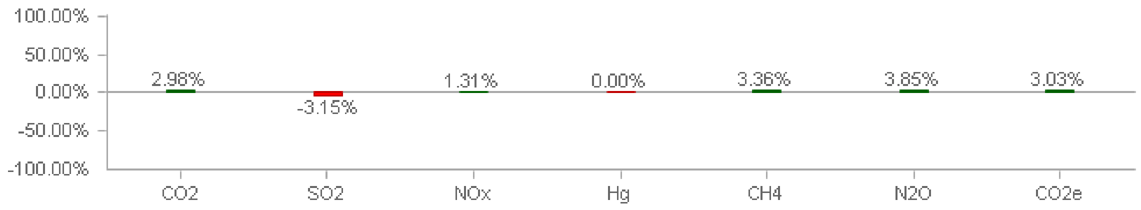
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion SPNO (e.g., Kansas City MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

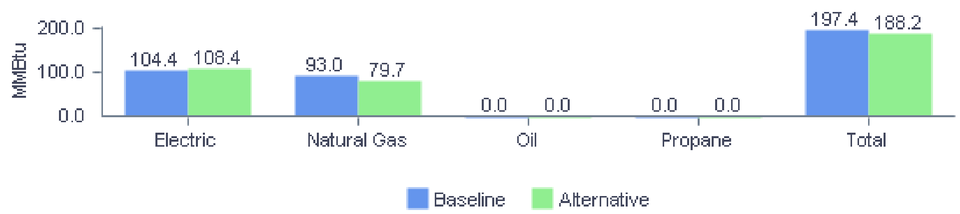


Scenario 4

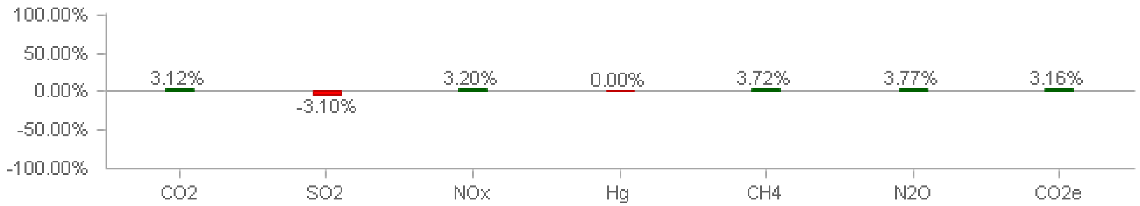
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion SRMW (e.g., St. Louis MO)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

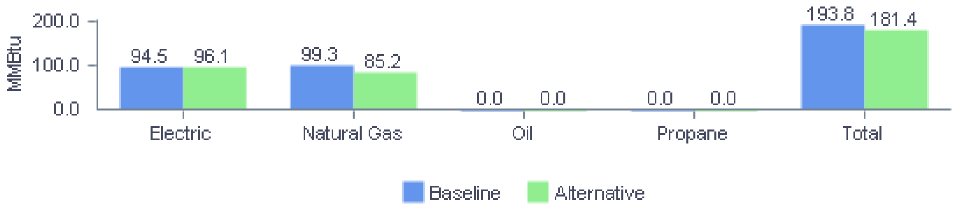


Scenario 4

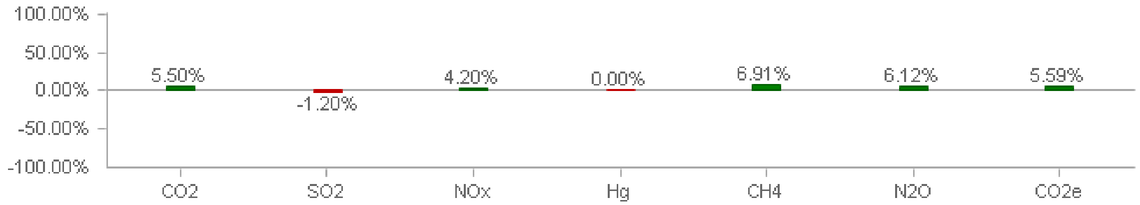
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion RFCW (e.g., Columbus OH)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

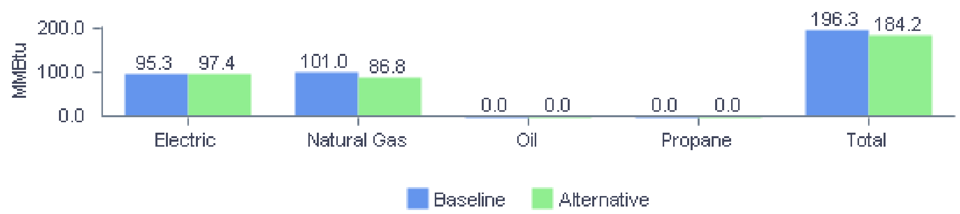


Scenario 4

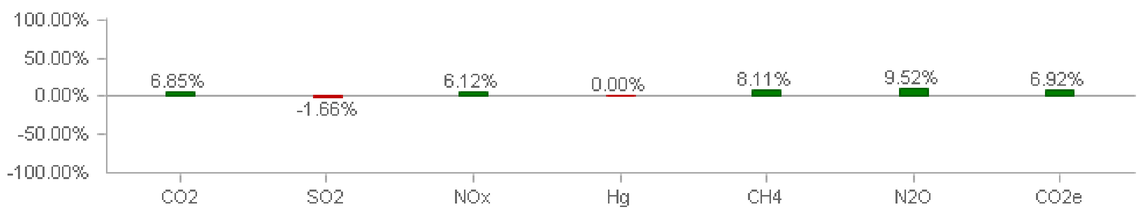
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion RFCE (e.g., Philadelphia PA)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

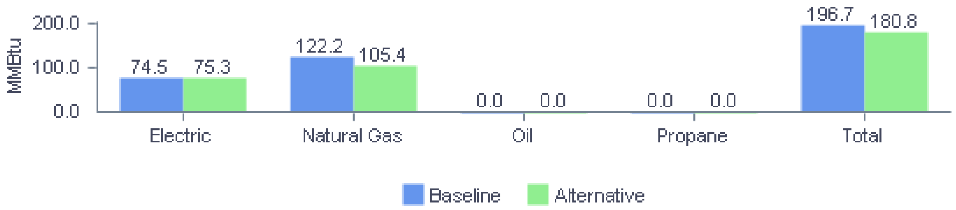


Scenario 4

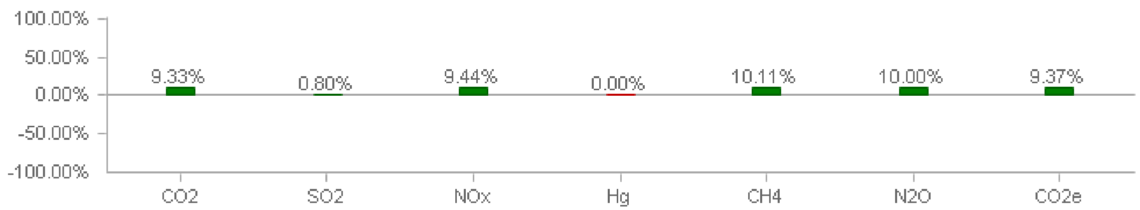
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion NYUP (e.g., Albany NY)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

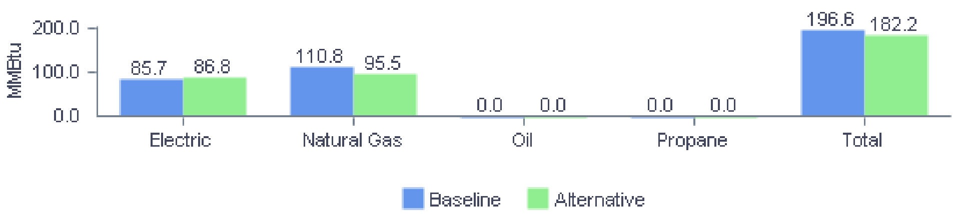


Scenario 4

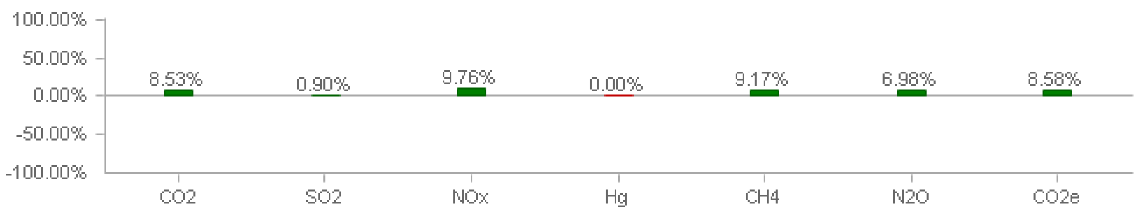
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion NEWE (e.g., Bridgeport CT)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

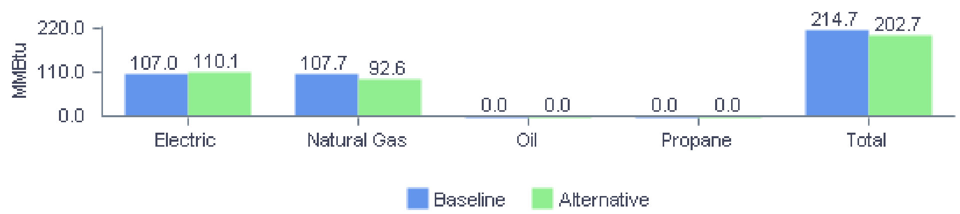


Scenario 4

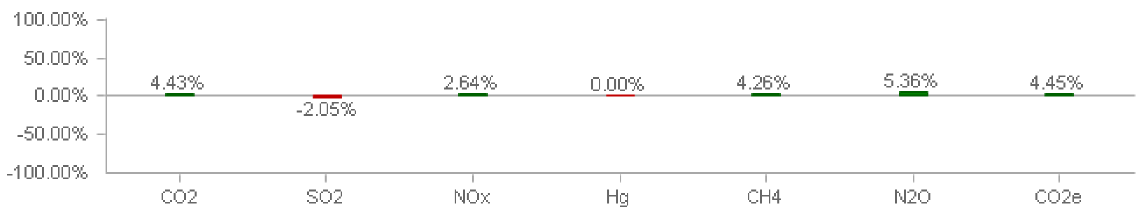
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion MROW (e.g., Omaha NE)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

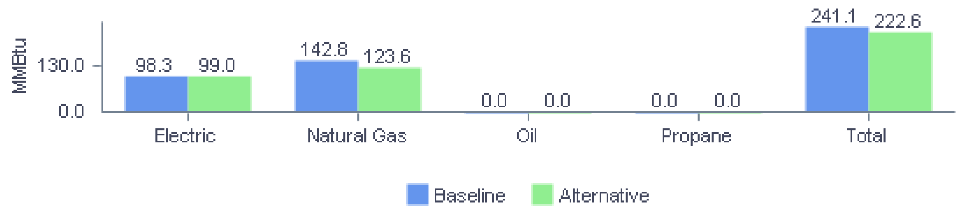


Scenario 4

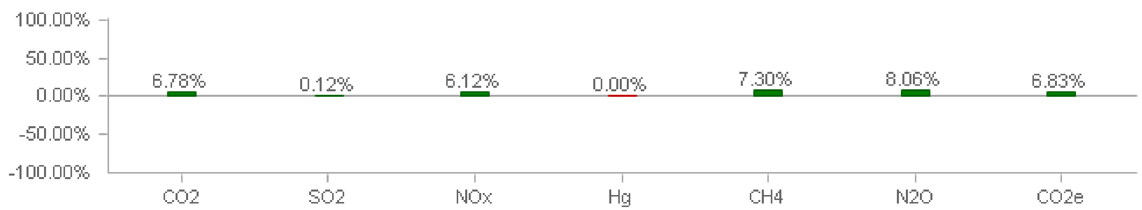
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion MROE (e.g., Green Bay WI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline

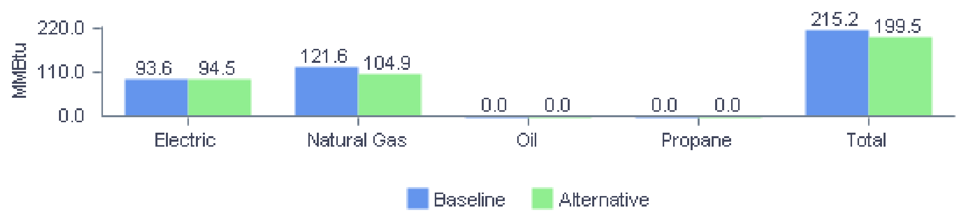


Scenario 4

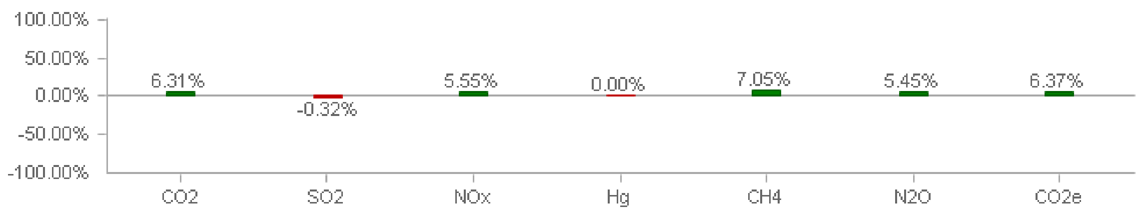
90% Furnace & 0.85 EF Condensing Gas Water Heater

for eGrid Subregion RFCM (e.g., Detroit MI)

Annual Source Energy Consumption by Fuel Type



Annual Emission Percent Reduction vs. Baseline



GTI-16/0002

FINAL REPORT

GTI PROJECT NUMBERS 22063 and 22080

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

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Executive Summary

On September 23, 2016, The U.S. Department of Energy (DOE) issued a supplemental notice of proposed rulemaking (SNOPR) that proposes a single national standard at a minimum efficiency level of 92% annual fuel utilization efficiency (AFUE) for all mobile home gas furnaces (MHGFs) and for non-weatherized gas furnaces (NWGFs) above 55 thousand Btu/hr (kBtu/h) input capacity. GTI conducted a scenario analysis of the DOE furnace SNOPR to evaluate the impact of the proposed rule requirements and other Trial Standard Levels (TSLs) on consumers. DOE's findings are skewed in favor of the rule based on flawed methodologies and inferior data. GTI SNOPR Integrated Scenarios Int-14.55 and Int-14 combine corrected methodologies and improved data for comparison with the flawed DOE SNOPR proposed rule as follows:

- Replace DOE's technically flawed random Base Case furnace assignment methodology with an improved methodology that uses a Consumer Economic Decision (CED) framework and aligns with AHRI condensing furnace fractions;
- Monetize the impact of imperfect market and non-economic consumer decision making factors within the GTI CED framework with a time-horizon-based distribution function;
- Apply American Home Comfort Study income distributions for fuel switching decisions;
- Replace DOE's engineering estimates and other inferior data with improved data for furnace prices, condensing furnace fractions, and marginal gas prices;
- Incorporate AEO 2016 Clean Power Plan Scenario forecast information; and
- Replace DOE's flawed furnace sizing algorithm based on home size with an improved algorithm based on RECS annual heating consumption.

Table 1 summarizes the difference in consumer impacts when comparing the DOE SNOPR LCC model results with GTI Scenario Int-14.55 for the proposed rule (SNOPR TSL 6) and with GTI Scenario Int-14 for a national 92% AFUE standard (SNOPR TSL 5). DOE and GTI NOPR analysis results (comparable to DOE SNOPR TSL 5) are included for reference. Table 2 and Table 3 provide a more detailed comparison of the DOE SNOPR LCC model results with the comparable GTI Integrated Scenario Int-14.55 and Int-14 results. Key findings include:

- GTI Integrated Scenario Int-14.55, based on CED and non-economic decision criteria coupled with an improved furnace sizing algorithm along with refinements to DOE's input data, shows negative composite average lifecycle cost (LCC) savings for all four NWGF TSLs (90%, 92%, 95%, and 98% AFUE) above 55 kBtu/h input capacity.
- Based on GTI's scenario analyses, there is no economic justification for the proposed rule of a 92% AFUE for NWGFs above 55 kBtu/h input capacity (DOE SNOPR TSL 6), a single product class 92% AFUE national furnace efficiency level (DOE SNOPR TSL 5), or any other condensing furnace efficiency levels with or without the 55 kBtu/h input capacity limit for 80% AFUE furnaces.
- GTI Integrated Scenario Int-14 cases with 80% AFUE furnace input capacity limits ranging from 40 kBtu/h to 160 kBtu/h show negative composite average LCC savings for a separate product class below 90 kBtu/h input capacity when using DOE's furnace downsizing methodology. This finding aligns with the empirical data analysis summarized in GTI Topical Report GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation."
- No furnace input capacity limit provides a net benefit to the low income market segment.

Table 1: SNOPR and NOPR Lifecycle Cost and Market Impact Comparisons

LCC Model Scenario	Average Furnace Life-Cycle Cost (LCC) Savings per Impacted Case	Fraction of Furnace Population (%)		
		Net Cost	No Impact	Net Benefit
DOE SNOPR TSL 6 (92%/55 kBtu/h)	$692	11%	60%	29%
GTI Integrated Scenario Int-14.55	-$118	15%	73%	12%
DOE SNOPR TSL 5 (92% all capacities)	$617	17%	48%	35%
GTI Integrated Scenario Int-14	-$149	22%	64%	15%
DOE NOPR (92% all capacities)	$520	20%	41%	39%
GTI NOPR Scenario Int-5	-$417	27%	57%	17%

Table 2 LCC Savings – DOE SNOPR TSL 6 vs. GTI Scenario Int-14.55

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE SNOPR (Scenario 0.55)	$667	$755	$615	$445	$479	$426	$1,242	$1,369	$1,158	$885	$592
SNOPR Scenario Int-14.55	-$196	-$470	-$23	-$232	-$678	-$47	$309	$203	$494	-$176	-$475
	LCC Savings Summary - 92% TSL										
DOE SNOPR (Scenario 0.55)	$692	$749	$654	$502	$532	$483	$1,148	$1,176	$1,125	$890	$611
SNOPR Scenario Int-14.55	-$118	-$286	$17	-$182	-$493	-$23	$239	$153	$404	-$81	-$455
	LCC Savings Summary - 95% TSL										
DOE SNOPR (Scenario 0.55)	$609	$617	$601	$499	$511	$489	$840	$783	$900	$770	$592
SNOPR Scenario Int-14.55	-$69	-$206	$53	-$139	-$342	-$18	$171	$13	$466	-$35	-$371
	LCC Savings Summary - 98% TSL										
DOE SNOPR (Scenario 0.55)	$543	$502	$600	$447	$419	$488	$777	$677	$913	$724	$674
SNOPR Scenario Int-14.55	-$74	-$123	-$2	-$121	-$149	-$85	$121	-$82	$395	-$10	-$276

Table 3 LCC Savings – DOE SNOPR TSL 5 vs. GTI Scenario Int-14

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE SNOPR (GTI Scenario 0)	$582	$701	$530	$361	$430	$334	$1,263	$1,360	$1,210	$755	$440
GTI Scenario Int-14	-$203	-$487	-$88	-$258	-$698	-$113	$294	$166	$489	-$166	-$562
	LCC Savings Summary - 92% TSL										
DOE SNOPR (GTI Scenario 0)	$617	$711	$569	$420	$496	$386	$1,177	$1,172	$1,180	$775	$476
GTI Scenario Int-14	-$149	-$309	-$65	-$222	-$519	-$100	$220	$136	$347	-$88	-$506
	LCC Savings Summary - 95% TSL										
DOE SNOPR (GTI Scenario 0)	$561	$597	$537	$437	$492	$405	$865	$773	$949	$692	$482
GTI Scenario Int-14	-$104	-$223	-$26	-$185	-$361	-$97	$178	$6	$453	-$57	-$426
	LCC Savings Summary - 98% TSL										
DOE SNOPR (GTI Scenario 0)	$506	$487	$528	$399	$405	$394	$801	$668	$956	$662	$554
GTI Scenario Int-14	-$104	-$136	-$69	-$166	-$163	-$169	$139	-$88	$396	-$40	-$344

1 Background

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

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

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

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

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

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

DOE issued a NOPR, published in the Federal Register on March 12, 2015, that proposed 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 4. Under the DOE NOPR, these 92% AFUE standards would take effect in 2021.

Table 4: DOE NOPR 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

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

DOE subsequently issued a supplemental notice of proposed rulemaking (SNOPR) that proposes a single national standard at a minimum efficiency level of 92% AFUE for all mobile home gas furnaces and for NWGFs above 55 kBtu/h input capacity as shown in Table 5. Under the DOE SNOPR, these standards would take effect in 2022.

Table 5: DOE SNOPR Proposed Standards for Residential Furnaces

Product Class	Certified Input Capacity	National Standard
Non-weatherized gas	≤55 kBtu/h >55 kBtu/h	80% AFUE 92% AFUE 8.5 W Standby/Off Mode
Mobile home gas	All	92% AFUE 8.5 W Standby/Off Mode

The SNOPR was published in the Federal Register on September 23, 2016 and open for a 60-day public comment period through November 22, 2016. The SNOPR supersedes the DOE NOPR published March 12, 2015, and updates information provided in the DOE NODA. On September 2, 2016, DOE released a pre-publication SNOPR along with an extensive, 1,198 page, technical support document (TSD) prepared for DOE by staff members of Navigant Consulting, Inc., and Lawrence Berkeley National Laboratory (LBNL). The TSD includes a detailed review of the effects of the SNOPR as well as economic modeling and associated methodologies to assess consumer-level cost impacts, manufacturer impacts, and national impacts.

DOE's LCC analyses summarized in the DFR, NOPR, NODA, and SNOPR all yielded different results for a single product class 92% minimum AFUE national standard. Table 6 and Table 7 compare the LCC savings results adjusted to 2015$ and associated consumer impacts among those versions of the DOE LCC analysis. The LCC savings and fraction of consumers benefiting from a 92% AFUE national minimum efficiency standard increased significantly in southern markets in the SNOPR compared to the DOE DFR LCC analysis. The SNOPR LCC savings increased significantly in all market segments compared to the NODA LCC savings, while the fraction of consumers benefiting from the proposed rule were similar, except for the senior citizen market segment.

Table 6: DOE LCC Savings (2015$) for DFR, NOPR, NODA, & SNOPR (92% AFUE)

National

TSL (% AFUE)	Per Impacted Furnace				Per all 10,000 Trial Case Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	$202	$449	$348	$582	$96	$240	$164	$271
92	$259	$529	$426	$617	$151	$310	$226	$324
95	$273	$515	$420	$561	$226	$394	$311	$413
98	$51	$451	$344	$506	$51	$449	$342	$501

North

TSL (% AFUE)	Per Impacted Furnace				Per All North Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	$596	$622	$470	$701	$171	$211	$132	$189
92	$547	$698	$555	$711	$238	$282	$191	$240
95	$463	$624	$513	$597	$357	$380	$290	$335
98	$220	$471	$366	$487	$219	$475	$363	$480

Rest of Country

TSL (% AFUE)	Per Impacted Furnace				Per All Rest of Country Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	-$20	$359	$292	$530	-$15	$272	$201	$363
92	$26	$428	$357	$569	$21	$341	$246	$419
95	$34	$431	$357	$537	$31	$410	$247	$502
98	-$200	$420	$319	$528	-$200	$419	$220	$526

Low Income

TSL (% AFUE)	Per Impacted Furnace				Per All Low Income Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	NA	$314	$210	$306	$176	$179	$102	$144
92	NA	$402	$302	$353	$244	$251	$162	$186
95	NA	$442	$364	$403	$371	$336	$267	$288
98	NA	$497	$357	$518	$192	$493	$354	$511

Senior Citizen

TSL (% AFUE)	Per Impacted Furnace				Per All Senior Citizen Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	NA	$520	$447	$540	$196	$259	$194	$235
92	NA	$608	$522	$582	$266	$332	$256	$283
95	NA	$597	$520	$574	$399	$434	$366	$389
98	NA	$554	$479	$586	$255	$551	$476	$578

Residential - Replacements

TSL (% AFUE)	Per Impacted Furnace				Per All Replacment Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	-$25	$212	$167	$361	-$12	$115	$79	$169
92	$74	$310	$275	$420	$43	$182	$144	$218
95	$148	$364	$318	$437	$123	$268	$225	$307
98	-$29	$326	$236	$399	-$29	$325	$235	$395

Residential - New

TSL (% AFUE)	Per Impacted Furnace				Per All New Construction Furnaces			
	DFR	NOPR	NODA	SNOPR	DFR	NOPR	NODA	SNOPR
90	$906	$1,171	$991	$1,263	$423	$598	$463	$580
92	$824	$1,147	$945	$1,177	$474	$670	$517	$639
95	$651	$874	$723	$865	$538	$743	$605	$723
98	$294	$780	$631	$801	$292	$777	$629	$797

Table 7: DOE Consumer Impacts for DFR, NOPR, NODA, & SNOPR (92% AFUE)

National

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	25%	52%	22%	22%	47%	32%	20%	53%	28%	18%	53%	28%
92	26%	42%	32%	20%	41%	39%	18%	47%	35%	17%	48%	35%
95	36%	17%	47%	24%	23%	53%	22%	26%	53%	22%	26%	51%
98	64%	0%	35%	40%	0%	60%	41%	0%	58%	34%	1%	65%

North

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	10%	71%	19%	11%	67%	22%	10%	72%	18%	10%	73%	17%
92	11%	56%	33%	10%	60%	30%	9%	66%	26%	9%	66%	25%
95	23%	23%	54%	14%	40%	46%	12%	43%	45%	13%	44%	43%
98	59%	1%	41%	37%	1%	62%	39%	1%	60%	30%	1%	69%

South

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	48%	24%	28%	33%	24%	42%	31%	31%	38%	28%	31%	41%
92	48%	20%	32%	31%	20%	49%	28%	26%	46%	26%	26%	47%
95	56%	8%	36%	35%	5%	60%	33%	6%	61%	33%	6%	61%
98	72%	0%	27%	43%	0%	57%	44%	0%	56%	39%	0%	61%

Low-Income

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	NA	NA	NA	40%	12%	47%	22%	52%	26%	22%	52%	26%
92	NA	NA	NA	34%	9%	57%	20%	46%	34%	20%	47%	33%
95	NA	NA	NA	33%	3%	64%	24%	27%	50%	28%	27%	45%
98	NA	NA	NA	43%	0%	57%	44%	1%	55%	43%	1%	55%

Senior Citizen

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	NA	NA	NA	21%	50%	29%	6%	86%	8%	17%	57%	25%
92	NA	NA	NA	19%	45%	36%	6%	83%	11%	17%	51%	32%
95	NA	NA	NA	23%	27%	50%	9%	69%	22%	22%	30%	48%
98	NA	NA	NA	39%	1%	60%	39%	3%	58%	34%	1%	64%

Residential - Replacements

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	31%	52%	17%	28%	46%	26%	25%	52%	22%	24%	53%	23%
92	32%	42%	27%	25%	41%	34%	23%	47%	30%	22%	48%	30%
95	41%	17%	42%	27%	26%	46%	25%	29%	45%	26%	30%	44%
98	67%	0%	32%	44%	0%	56%	46%	0%	54%	39%	1%	59%

Residential - New

TSL (% AFUE)	DFR			NOPR			NODA			SNOPR		
	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit	Net Cost	No Impact	Net Benefit
90	7%	53%	40%	4%	49%	47%	3%	53%	43%	3%	54%	43%
92	9%	42%	49%	4%	42%	55%	3%	45%	51%	3%	46%	51%
95	21%	17%	62%	13%	15%	72%	10%	16%	74%	11%	16%	73%
98	55%	1%	44%	27%	0%	72%	26%	0%	73%	19%	0%	81%

This report is a follow-up to technical reports GTI-15/0002, "Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies" http://www.gastechnology.org/reports_software/Documents/21693-Furnace-NOPR-Analysis-FinalReport_2015-07-15.pdf, and GTI-15/0003, "Technical Analysis of Furnace Sizing for the DOE Notice of Data Availability on Residential Furnace Minimum Efficiencies" http://www.gastechnology.org/reports_software/Documents/21853-Furnace-NODA-Analysis-Task-Report-10-14-2015.pdf. GTI-15/0002 included a comprehensive technical and economic analysis of the DOE NOPR calling for a minimum national furnace efficiency of 92% AFUE and pointed to significant deficiencies in the DOE NOPR LCC analysis, including:

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

Addressing these deficiencies and shortcomings, GTI's scenario analyses showed the proposed standard in the NOPR, instead of yielding positive national benefits, would instead result in: 1) negative average lifecycle cost savings and 2) increased primary energy consumption and greenhouse gas emissions (from fuel switching from natural gas to electric options that are less efficient on a primary energy basis). GTI's NODA analysis confirmed these findings for a minimum national furnace efficiency of 92% AFUE and highlighted flaws in the DOE furnace sizing methodology for a separate product class based on furnace input capacity.

Table 8 and Table 9 provide a recap of the comparison of the NOPR, NODA, and GTI scenario analysis findings, underscoring the average negative costs, higher proportion of consumers faced with a net cost (27% of the population), and reduced level of consumers who would experience a net benefit (only 17% of the population) in the NOPR. GTI's analysis of the NOPR and NODA shows negative average savings for all single standard TSLs (compared to DOE's findings of positive savings). The single standard results in the NODA did not appreciably alter the overall negative average savings findings in the GTI analysis of the NOPR. For the first time in the NODA, DOE used a new segmentation grouping of "impacted furnaces" in place of "all furnaces" in the LCC savings calculations. The "impacted furnaces" approach to summarizing information was also used in the DOE SNOPR for LCC savings, but not for fuel switching fractions.

A 1,198 page technical support document (TSD) prepared for DOE by staff members of LBNL and Navigant Consulting, Inc. provides the technical rationale for DOE's determination that the proposed standard in the SNOPR is technologically feasible, economically justified, and will save significant amounts of energy. The technical basis of the life cycle cost and payback period analysis described in detail in Chapter 8 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 SNOPR. The DOE 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 show the summary tables of the results included in the SNOPR for non-weatherized gas furnaces and mobile home gas furnaces.

Table 8: Lifecycle Cost and Rulemaking Market Impact

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

Table 9: National Average LCC Savings for DOE NOPR and NODA LCC Models

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

It appears that DOE corrected an error in the NOPR in its updated SNOPR LCC model analysis that may have impacted LCC savings calculations in the SNOPR. DOE appears to have changed one of their nested, indexed, if then statements when assigning the AFUE of the existing furnace for each residential trial case. In the SNOPR, DOE revised the "Region ID" for AFUE existing assignment for residential cases as follows:

NOPR: =IF(INDEX(_Div,D3)<8,INDEX(_Div,D3),IF(INDEX(_Div,D3)=10, 9, 8))

SNOPR: =IF(INDEX(_ResCom, D3) = 1, INDEX(BldgRegions, D3), IF(INDEX (BldgRegions,D3) <8,INDEX(BldgRegions,D3),IF(INDEX(BldgRegions,D3)=10, 9, 8)))

The "Region ID" used to select the "AFUE existing" was always based on the census division in the NOPR for both residential and commercial cases, rather than pulling census division only when commercial, and using RECS regions for residential. The NOPR error biased the selection to cold regions because census divisions 1-9 by chance are cold RECS regions. That would tend to make the NOPR "AFUE existing" relatively higher efficiency on average because cold regions have historically higher adoption rates of higher efficiency furnaces. The DOE NOPR cold climate bias error led to relatively lower building heating loads because DOE estimated building heating load by taking fuel consumption and dividing by the "AFUE existing" efficiency, resulting in erroneously lower potential for gas savings in the NOPR. The SNOPR equation appears to have corrected this error, though no explanation was found in the TSD.

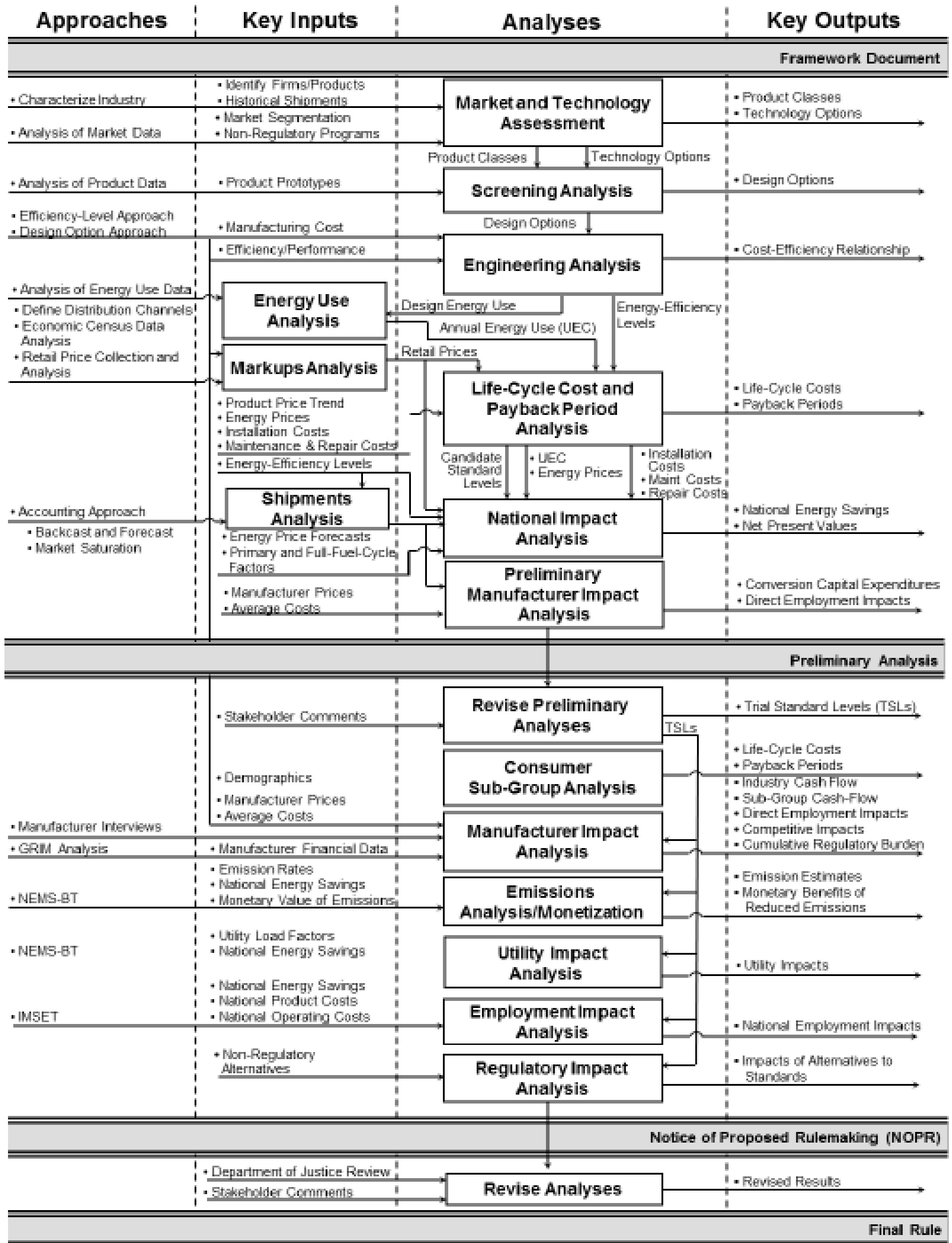

Figure 1: DOE SNOPR Technical Support Document Analysis Methodology

Source: DOE SNOPR TSD Chapter 2[1]

1 U.S. Department of Energy Docket website. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Chapter 2. Analytical Framework. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

Table 8.6.1 Average LCC and PBP Results by AFUE Standard Efficiency Level for Non-Weatherized Gas Furnaces

EL	AFUE	Average Costs 2015$				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
National							
0	80%	2,175	684	11,020	13,194	N/A	21.5
1	90%	2,597	623	10,026	12,623	6.8	21.5
2	92%	2,635	612	9,859	12,493	6.4	21.5
3	95%	2,742	597	9,608	12,350	6.5	21.5
4	98%	2,858	586	9,403	12,261	6.9	21.5
North							
0	80%	2,370	870	13,868	16,238	N/A	21.5
1	90%	2,919	792	12,675	15,595	7.1	21.5
2	92%	2,962	778	12,460	15,422	6.5	21.5
3	95%	3,083	758	12,149	15,231	6.4	21.5
4	98%	3,217	742	11,867	15,083	6.6	21.5
Rest of Country							
0	80%	1,955	476	7,809	9,763	N/A	21.5
1	90%	2,234	431	7,040	9,274	6.3	21.5
2	92%	2,266	425	6,926	9,192	6.1	21.5
3	95%	2,358	415	6,745	9,103	6.6	21.5
4	98%	2,453	410	6,626	9,079	7.5	21.5

Note: The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8.6.9 Average LCC and PBP Results by Efficiency Level for AFUE Standards for Large Non-Weatherized Gas Furnaces with an Input Capacity >55 kBtu/h

EL	AFUE	Average Costs 2015$				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
National							
0	80%	2,175	684	11,020	13,194	N/A	21.5
1	90%	2,542	628	10,127	12,668	6.5	21.5
2	92%	2,576	618	9,971	12,547	6.1	21.5
3	95%	2,672	604	9,737	12,410	6.2	21.5
4	98%	2,775	593	9,540	12,315	6.6	21.5
North							
0	80%	2,370	870	13,868	16,238	N/A	21.5
1	90%	2,893	795	12,718	15,610	7.0	21.5
2	92%	2,933	782	12,510	15,444	6.4	21.5
3	95%	3,048	763	12,209	15,257	6.3	21.5
4	98%	3,176	746	11,932	15,108	6.5	21.5
Rest of Country							
0	80%	1,955	476	7,809	9,763	N/A	21.5
1	90%	2,146	440	7,206	9,352	5.3	21.5
2	92%	2,173	434	7,109	9,282	5.2	21.5
3	95%	2,248	425	6,951	9,199	5.8	21.5
4	98%	2,324	420	6,844	9,167	6.6	21.5

Note: The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

Figure 2 DOE LCC and PBP Results for Non-Weatherized Gas Furnaces

Source: DOE SNOPR TSD Chapter 8[2]

2 U.S. Department of Energy Docket website. "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." Chapter 8. Life-Cycle Cost and Payback Period Analysis. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

Table 8.6.29 Average LCC and PBP Results by AFUE Standards Efficiency Level for Mobile Home Gas Furnaces

EL	AFUE	Average Costs 2015				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
National							
0	80%	1,515	785	12,216	13,731	0.0	21.5
1	92%	1,667	698	10,924	12,591	1.7	21.5
2	95%	1,800	679	10,643	12,443	2.7	21.5
3	96%	1,846	677	10,599	12,445	3.1	21.5
North							
0	80%	1,558	919	14,208	15,766	0.0	21.5
1	92%	1,711	816	12,678	14,389	1.5	21.5
2	95%	1,843	793	12,336	14,179	2.3	21.5
3	96%	1,890	789	12,275	14,165	2.6	21.5
Rest of Country							
0	80%	1,445	569	9,011	10,456	0.0	21.5
1	92%	1,596	508	8,102	9,698	2.5	21.5
2	95%	1,730	496	7,919	9,649	3.9	21.5
3	96%	1,776	495	7,902	9,678	4.5	21.5

Note: The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.

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

Source: DOE SNOPR TSD Chapter 8[3]

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 used to justify the 92% AFUE furnace standard with or without a separate product class for non-condensing furnaces based on capacity for non-weatherized gas furnaces are the primary focus of this report and accompanying spreadsheets.

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. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217

2 LCC Analysis Methodology

2.1 Overview

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

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

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

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

- Baseline furnace design
- Higher efficiency furnace designs
- Fuel switching options
- Energy prices
- Furnace capacities
- 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 (deterministic) values, partial or full distributions, and random assignments to conduct its forecasting analysis. After incorporating all these various deterministic values, 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.

Building on previous work described in GTI-15/0002 and GTI-15/0003, GTI analysts conducted parametric scenario analyses to evaluate the impact of changes to the DOE SNOPR LCC model in five topical areas:

- Base Case Decision Making Algorithms Incorporating Non-Economic Factors
- Technology and Fuel Switching Decision Making Algorithms
- Furnace Sizing Algorithms
- Input Data Modifications
- Integrated Scenarios

Parametric analyses conducted by GTI analysts in response to the DOE NOPR, NODA, and SNOPR incorporate a higher degree of granularity than was provided in the corresponding DOE LCC spreadsheet model output files and published results. Additional detail was required to conduct the desired analyses on individual trial cases, Base Case assignment decisions, fuel switching decisions, furnace sizing decisions, and subcategory impacts (e.g., state-level, low income, senior citizen, or housing type subcategories).

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

Table 10 shows the matrix of parametric scenarios associated with the 2015 DOE NOPR that GTI explored in detail in GTI-15/0002. Appendix A, Sections A.2 through A.10, of GTI-15/0002 provide descriptions of these parametric runs and associated results.

Table 11 shows the matrix of incremental and updated parametric scenarios that GTI explored under the SNOPR for this project. The main body of this report describes and summarizes results of GTI Scenario Int-14 cases and constituent Parametrics. GTI Scenario Int-14, an updated and modified version of GTI NOPR Scenario Int-5, was selected for comparison with the 92% AFUE single product class TSL 5 in the SNOPR (GTI Scenario 0) to address the following issues:

- Base Case furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria,
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions when using a CED framework for Base Case furnace assignment and fuel switching decisions,
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices,
- Incorporation of AEO 2016 Clean Power Plan* Scenario forecast information for comparisons with anticipated DOE final rule benefits calculations, and

*Note: The U.S. Supreme Court has temporarily blocked the EPA Clean Power Plan implementation.

- Application of a time-horizon-based distribution function based on the DOE LCC model payback period for each of the 10,000 trial cases for consumer economic decision making that monetizes the impact of imperfect market and non-economic consumer decision making factors into the LCC analysis for comparisons within the GTI CED framework.

GTI Scenario Int-14.55, the SNOPR proposed rule case under GTI Scenario Int-14, was selected to examine the impact of a 55 kBtu/h furnace capacity limit for non-condensing furnaces on rule benefits for direct comparisons with the DOE SNOPR proposed rule TSL 6 (GTI Scenario 0.55). GTI Scenario Int-14.55 includes a furnace capacity algorithm for each trial case based on annual heating consumption rather than home size and uses the DOE furnace "downsizing" methodology.

The following Excel spreadsheets accompanying this report provide tabular results of the GTI parametric analysis of the DOE SNOPR:

- 22063 Short LCC tables - all EL 2016-11-21.xlsx,
- 22063 Short Switching Tables 2016-11-21.xlsx, and
- 22063 Energy Use Tables 2016-11-21.xlsx.

These spreadsheets provide detailed results tables and supporting information for each of the scenarios evaluated in this report, along with the shorter summary tables included in this report. These documents are available to the public at:

http://www.gastechnology.org/reports_software/Documents/Technical-Analysis-of-DOE-Supplemental-Notice-of-Proposed-Rulemaking-on-Residential-Furnace-Minimum-Efficiencies.pdf

http://www.gastechnology.org/reports_software/Documents/22063-Short-LCC-tables-all-EL-2016-11-21.zip

http://www.gastechnology.org/reports_software/Documents/22063-Short-Switching-Tables-2016-11-21.zip

http://www.gastechnology.org/reports_software/Documents/22063-Energy-Use-Tables-2016-11-21.zip

2.2 Consumer Economic Decision Analysis Framework

To demonstrate economic justification for a condensing furnace efficiency rule, the DOE SNOPR LCC analysis methodology needs to show overall financial benefit to those consumers that would otherwise not have selected a 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 the proposed new rulemaking on consumers. The DOE SNOPR LCC model Base Case furnace assignment methodology fails to use a rational consumer economic decision framework, which results in nonsensical furnace selections and unwarranted claimed rule benefits.

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

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

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

Table 10: GTI Parametric Analysis Scenarios for DOE NOPR

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

Table 11: GTI Parametric Analysis Scenarios for DOE SNOPR

	DOE SNOPR	D2	D4	D5	D8	D11	D12	D13	D14	I2	I6	I13	I17	F1	92% EL only
Scenario 0	x														
Scenario 2		x													x
Scenario 7					x										x
Scenario 24		x	x	x	x									x	x
Scenario 28		x			x	x									x
Scenario 29		x			x		x								x
Scenario 30						x									x
Scenario 31							x								x
Scenario 32								x							x
Scenario 33					x			x							x
Scenario 36		x			x				x					x	x
Scenario 39									x					x	x
Scenario F1														x	x
Scenario I2, I6										x	x				x
Scenario I2,I6, I13										x	x	x			x
Scenario I17													x		x
Scenario Int-11		x	x	x	x					x	x	x		x	
Scenario Int-12		x	x	x	x					x	x	x	x	x	
Scenario Int-13		x			x				x	x	x	x		x	
Scenario Int-14		x			x				x	x	x	x	x	x	

Note: Several Scenarios were run with and without Parametric F1

It is possible that 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 SNOPR are significant. The unregulated market and market transformation shortcomings that the DOE rule addresses 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.

Table 12 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.

Objective and credible market data, such as AHRI shipment data, furnace prices, furnace sizes, installation costs, marginal natural gas and electricity prices, and heating energy consumption are top priorities to ensure a credible LCC analysis. It is critical for economic parameter calculations such as equipment and installation costs, baseline conditions, required furnace sizing, and energy prices. Where such market data and statistics are not available, topical consumer and industry surveys such as the proprietary 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, such as “spot checking” the reasonableness of estimates.

Consumers make purchase decisions based primarily on economics, but consider factors other than economics as well, including product performance or reliability, manufacturer reputation, intangible societal benefits, and perceived risks and rewards associated with the decision. Table 13 characterizes consumer decision making related to condensing furnaces, including economic and non-economic factors, based on unregulated market factors, market transformations, and regulatory interventions. This is a more complete decision making analytical framework because it acknowledges the value consumers attach to differentiating attributes such as delivered air temperature or risk-based decisions due to unique financial circumstances. It is possible to monetize such consumer behavioral decisions, but DOE chose not to address non-economic factors in the DOE SNOPR LCC Base Case furnace assignment methodology. In response to a request for suggested options by DOE in the SNOPR, GTI was able to add a set of parametrics in this report that estimate the relative impact of economic and non-economic factors in consumer purchase decisions within the LCC analysis CED framework.

2.3 Base Case Furnace Assignment Methodology

The DOE SNOPR 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 for an individual trial case. 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 SNOPR LCC model. The economics of a particular efficiency level selection compared to other levels (e.g., 80% AFUE vs. 92% AFUE) are not considered in DOE's baseline furnace decision for any of the 10,000 Crystal Ball trial cases. Figure 4 illustrates the DOE random Base Case furnace assignment algorithm. Appendix A, Section A.2.1 provides further details on the DOE random Base Case furnace assignment methodology.

DOE's decision to use a random assignment methodology to assign Base Case furnace efficiency to each of the trial cases in the Crystal Ball simulation is a significant technical flaw with meaningful impact on the DOE SNOPR LCC results. A random assignment methodology misallocates a random fraction of consumers that use economic criteria for their decisions and results in higher LCC savings compared to rational economic decision making criteria. DOE's Base Case furnaces in the 10,000 Crystal Ball trial case homes are intended to be representative of the RECS survey furnace distribution across various locations and categories. Random assignment of the Base Case furnace does not achieve this key objective and is not a technically defensible proxy for rational residential decision making processes. Figure 5 shows GTI's Base Case furnace assignment algorithm that incorporates a CED framework into the trial case assignments to provide a reasonable, technically defensible Base Case furnace assignment algorithm for the LCC analysis.

Table 14 and Table 15 provide illustrative examples of Crystal Ball trial case homes that result in overstated savings due to the DOE random Base Case furnace assignment methodology compared to economic decision making criteria. The overstated savings in the DOE SNOPR LCC model occur because DOE's random assignment puts non-condensing furnaces in buildings that would purchase condensing furnaces based on limited economic decisions (Table 14); and puts condensing furnaces in buildings that would not purchase condensing furnaces based on limited economic decisions (Table 15) and categorizes these as no impact. These technical flaws inappropriately skew the DOE SNOPR analysis results significantly in favor of rule benefit.

Table 13 Consumer Economic and Non-Economic Decision Making Framework

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

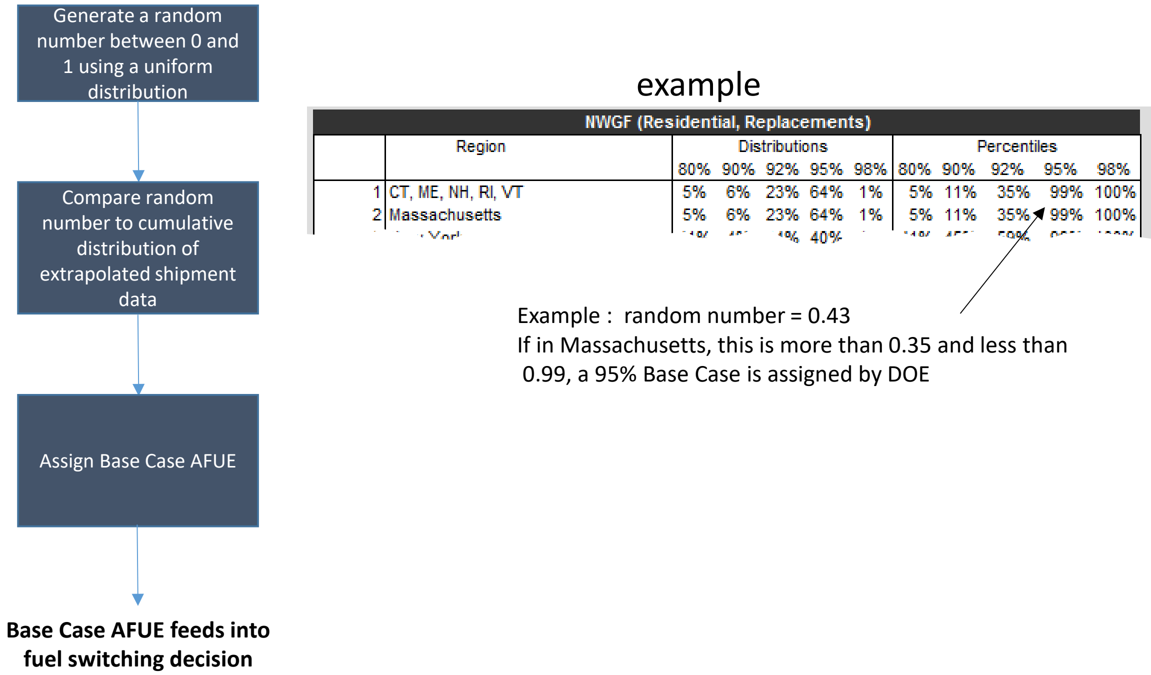

Figure 4 GTI Illustration of DOE Random Base Case Furnace Assignment Algorithm

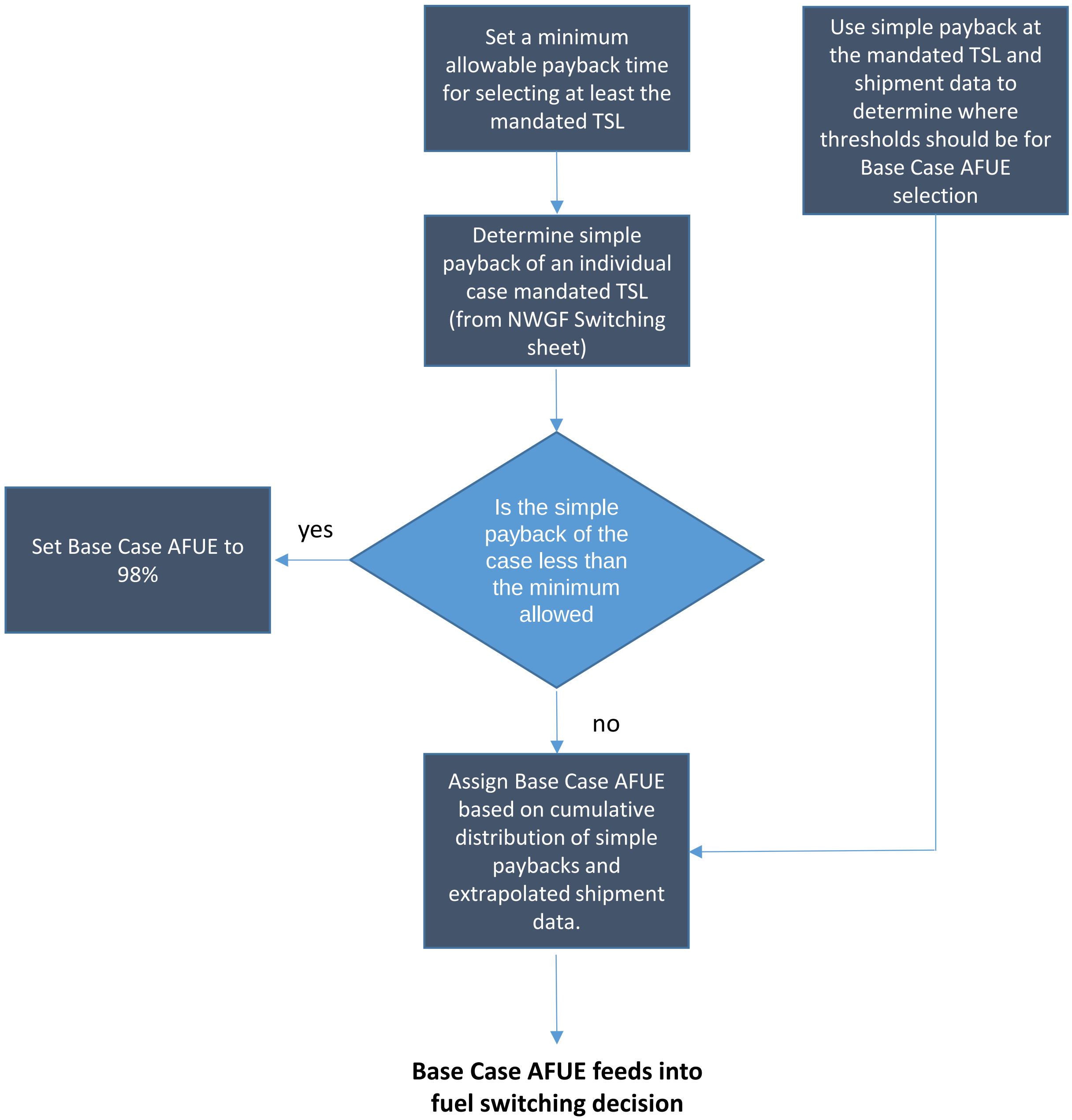

Figure 5 GTI Economic Decision Base Case Furnace Assignment Flow Chart

Table 14 illustrates a subset of TSL 5 trial cases classified by DOE as benefitted by the rule ("Net Benefit") that would almost certainly have condensing furnaces and therefore would not be impacted by the rule. These cases would be excluded from the LCC analysis as "No Impact" under rational economic and non-economic criteria. Table 15 shows a subset of TSL 5 trial cases excluded from DOE's LCC analysis as "No Impact" because they were inappropriately assigned a condensing furnace and excluded from the analysis. These cases would likely be negatively impacted by the rule as "Net Cost" and included in the LCC analysis if decisions were based on economic and non-economic criteria rather than assigned by a random number.

Table 14 Cases Included as "Net Benefit" in the DOE SNOPR TSL 5 LCC Model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
366	-$1,759	$61	$3,052	No Impact	South / California	Residential Replacement	-29
9122	-$1,620	$151	$4,502	No Impact	North/ New York	Residential New	-11
3682	-$1,592	$43	$2,320	No Impact	South / Carolina	Residential Replacement	-37
2312	-$1,266	$176	$4,120	No Impact	North/ New Jersey	Residential New	-7
6651	-$1,242	$177	$6,371	No Impact	North/ OR, WA	Residential New	-7
8835	-$1,192	$168	$5,621	No Impact	North/ Illinois	Residential New	-7

Table 15 Cases Considered "No Impact" in the DOE SNOPR TSL 5 LCC Model

Crystal Ball Trial Case	92% vs. 80%		LCC Savings		Region/ Location	Type	Payback (Years)
	Cost Penalty	Annual Savings	DOE	GTI Scenarios			
1758	$4,890	$51	No Impact	-$4,183	North/ New York	Residential Replacement	95
7406	$3,937	$113	No Impact	-$3,484	North/ Michigan	Residential Replacement	35
8377	$3,409	$26	No Impact	-$6,299	South/ Carolina	Residential Replacement	132
7010	$1,805	$17	No Impact	-$1,575	South/ California	Residential Replacement	109
9467	$1,548	$1	No Impact	-$1,621	North/ OR, WA	Residential Replacement	1338
5439	$1,192	$17	No Impact	-$1,173	North/ IA, MN, ND, SD	Residential Replacement	71

Table 16 provides comparative results of the Base Case furnace assignments using DOE's random assignment methodology versus a limited rational economic decision framework that accounts for non-economic factors. Of all new installation trial cases in the DOE SNOPR LCC model, 69% (1732/2476) have a negative payback period (i.e., negative first cost premium divided by positive annual energy savings). Of the 1,732 cases with negative payback period, 62% (1000 cases) are assigned an 80% efficient furnace by DOE's random Base Case furnace assignment methodology and therefore are misallocated as "Net Benefit" cases instead of "No Impact" cases. These misallocated cases represent 42% of the total LCC savings projected by DOE under its proposed rule. Under the limited rational economic decision framework used in GTI Scenario Int-14, these cases would be considered "No Impact" because the market would choose a condensing furnace without the DOE rule. The similarly misallocated 284 replacement cases with negative payback account for another 13% of total LCC savings projected by DOE under its proposed rule. A total of 13% (1284/9717) of residential cases and 55% of DOE's claimed rule benefit comes from a combination of builders and consumers that DOE inexplicably claims would otherwise be willing to pay extra for lower efficiency furnaces. This results in excessive claims of benefits and avoided net cost that do not reflect a connection to reasonable and expected consumer behavior and rational decision making by builders or consumers.

Table 16 DOE Random Base Case Assignment Compared to GTI Scenario Int-14

Characteristics of Crystal Ball Trial Cases at 92% TSL	DOE LCC Model		GTI Scenarios	
	Number of Cases	Percent of Total	Number of Cases	Percent of Total
Number of Residential Cases	9717	100%	9717	100%
Replacements	7241	75%	7241	75%
- Payback Period ≤ 0 years	510	5%	412	4%
- Impacted by Rule	284	3%	0	0%
- Payback Period >15 years	3138	32%	3775	39%
- No Impact	1258	13%	1398	14%
New Installations	2476	25%	2476	25%
- Payback Period ≤ 0 years	1732	18%	1472	15%
- Impacted by Rule	1000	10%	0	0%
- Payback Period >15 years	0	0%	0	0%
- No Impact	0	0%	0	0%
Total Residential Trial Cases	9717	100%	9717	100%
- Payback Period ≤ 0 years	2242	23%	1884	19%
- Impacted by Rule	1284	13%	0	0%
- Payback Period >15 years	3138	32%	3775	39%
- No Impact	1258	13%	1398	14%

For long payback period cases, GTI's scenarios have similar numbers of "No Impact" cases as DOE. The difference between the two analyses is that in DOE's random methodology a consumer who has a short payback period is as likely as one who has a long payback period to choose a high efficiency furnace. GTI's scenarios assume that consumers are more likely, but not guaranteed, to choose a high efficiency furnace when the payback period is short. This rational consumer economic decision methodology is supported by DOE's own data that shows the reasonable correlation between payback time and shipment data. Figure 6 shows a clear relationship between condensing furnace market share and payback periods, with high market share being achieved when payback periods reach approximately 10 years.

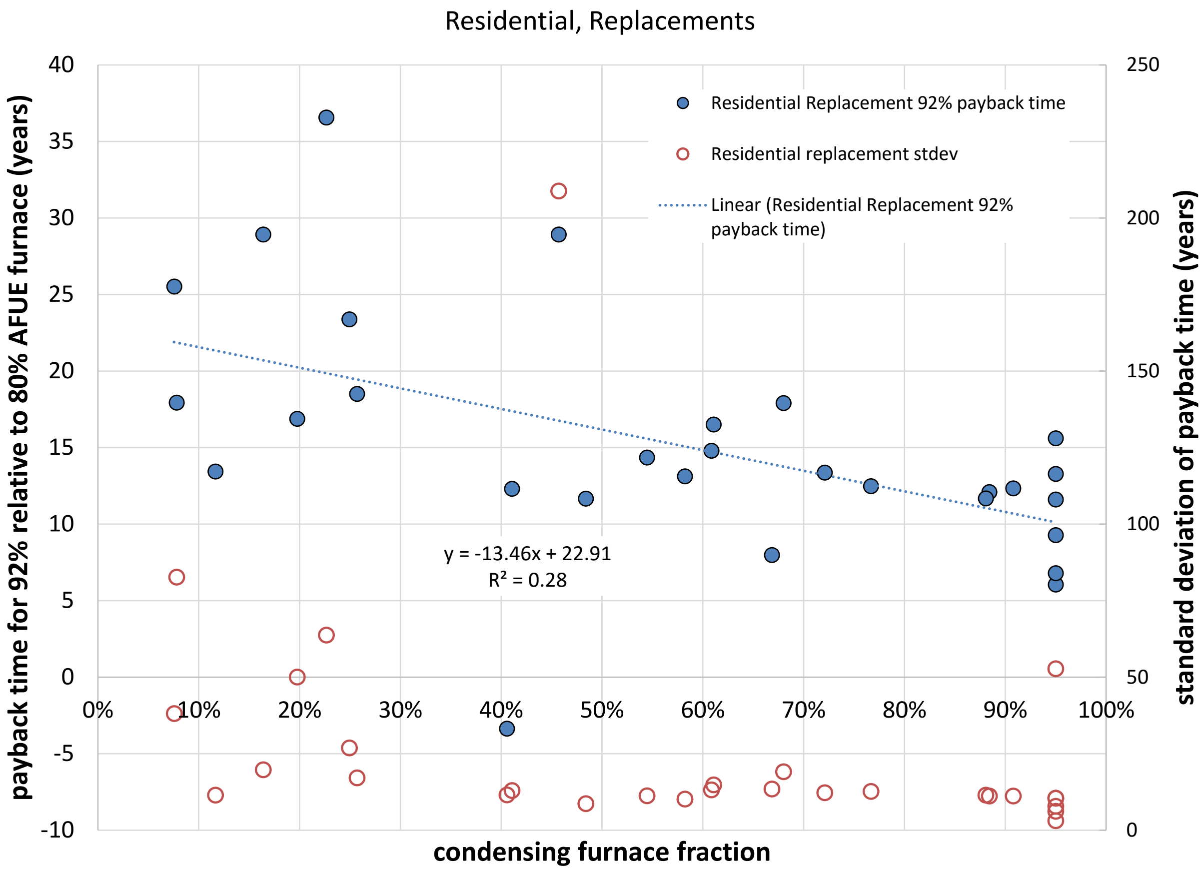

Figure 6: DOE LCC Model Condensing Furnace Market Share vs. Payback Period

2.4 DOE Fuel Switching Decision Making Methodology

Unlike the random allocations in the Base Case AFUE assignment, decisions on whether or not a consumer will choose a fuel switching option are based on consumer economics in the baseline DOE LCC model. Figure 7 illustrates GTI's understanding of the DOE LCC fuel switching decision-making process flow chart.

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.

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

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

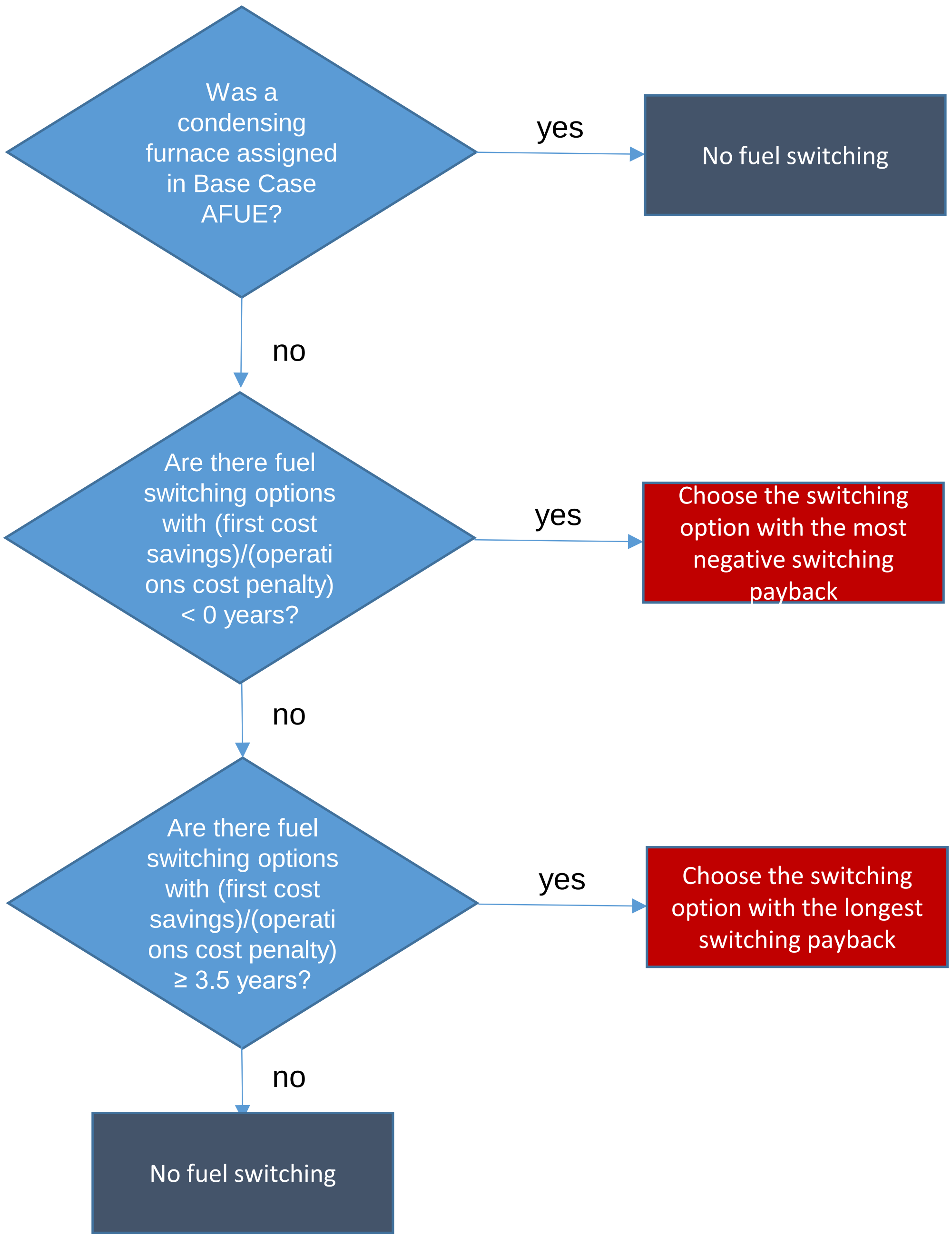

Figure 7 GTI Illustration of DOE Fuel Switching Logic Flow Chart

The distribution of LCC savings for individual trial cases is a non-linear function of switching payback period in the DOE LCC model. LCC savings drop significantly as the switching payback period falls below 4 years, but rise only slightly, with flat LCC savings for longer switching payback periods. Since DOE uses a single 3.5 year switching payback period in its fuel switching decision methodology, savings associated with fuel switching are overstated in the DOE LCC model compared to consideration of the full distribution of fuel switching payback periods. Parametrics D2 and D8 incorporate the distribution of fuel switching payback periods in the fuel switching analysis. Figure 8 shows GTI's fuel switching decision logic algorithm used in Scenarios 24 and 36 that incorporate a CED framework into the LCC analysis. Appendix A, Section A.2.2, provides further details on the DOE fuel switching decision methodology.

2.5 American Home Comfort Study Application

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

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

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

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

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

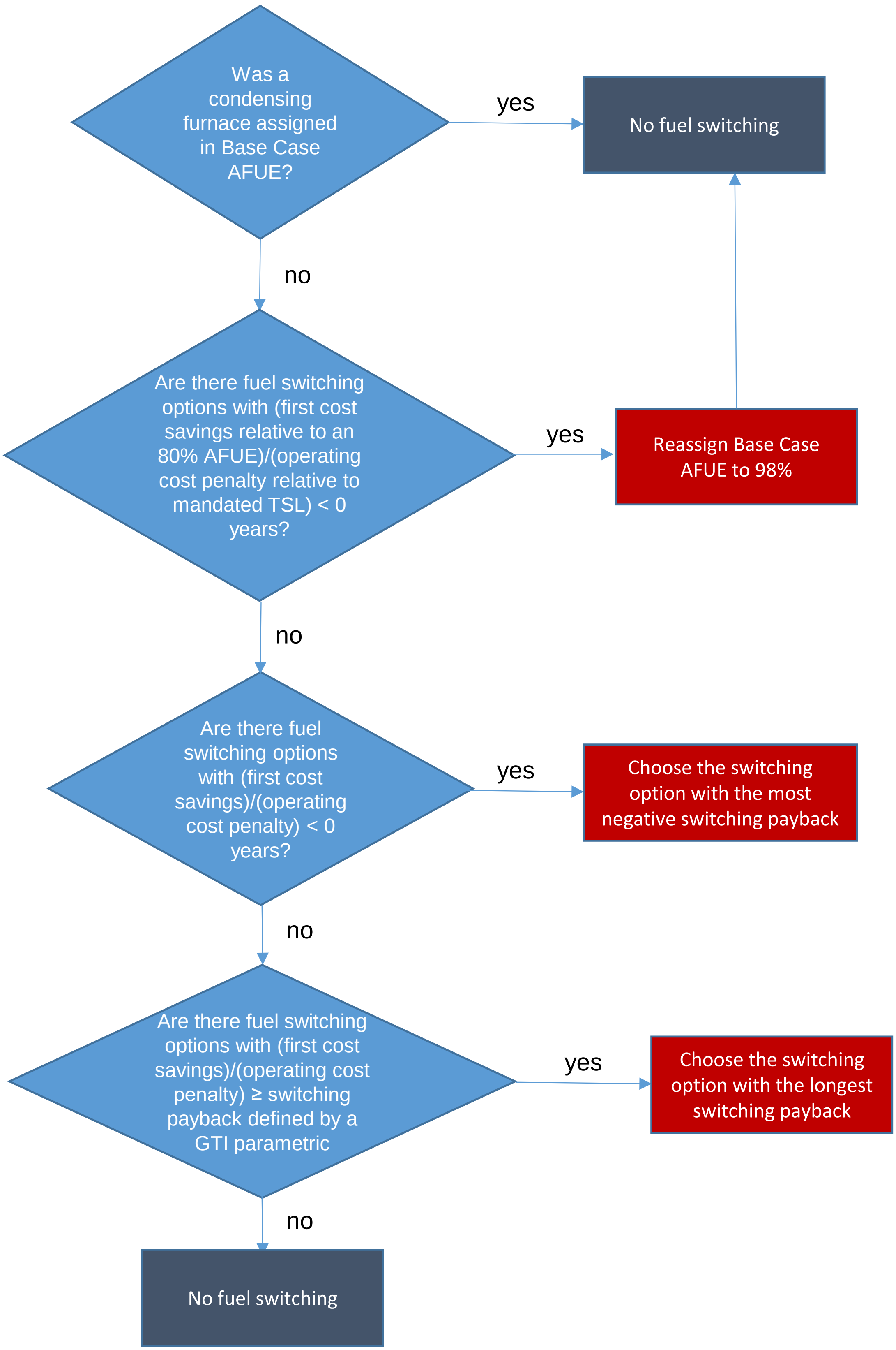

Figure 8 GTI Scenario 24 Fuel Switching Logic Flow Chart

2.6 GTI Decision Making Analysis Methodology

To examine the impact of DOE's random baseline decision making and fuel switching algorithms on modeling results, GTI analysts developed several parametric scenarios for the 2015 DOE NOPR analysis that investigated 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 decision making processes into the NOPR 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 in the GTI analysis of the 2015 DOE NOPR. GTI-15/0002 includes detailed information on rationale and impacts of the decision making Parametrics and Scenarios considered for the 2015 DOE NOPR analysis as diagrammed in Table 10. These Parametric and Scenario options were also considered as potentially relevant for the current SNOPR analysis, but only Scenario 24, selected as part of GTI Integrated Scenario Int-5 in the NOPR analysis, was selected for continued evaluation in the GTI SNOPR analysis.

It is important to identify and justify the alternative scenario or scenarios that produce credible and technically defensible results for comparisons with DOE LCC model results. For the GTI analysis of the 2015 DOE NOPR diagrammed in Table 10, integrated scenarios included combinations of scenarios that address economic decision making (GTI Decision Making Scenarios 1 through 18 and 23 through 27) and substitution of improved input data for those used by DOE (GTI Input Variable Scenarios I-1 through I-16 were used for that purpose in the GTI NOPR analysis). As noted in Section 2.1, GTI analysts selected Integrated Scenario Int-5, including Scenario 24, as the most credible and technically defensible integrated scenario in the NOPR analysis. Scenario 24 is also included in GTI's Integrated Scenarios for the SNOPR analysis diagrammed in Table 11. The description below focuses on Scenario 24, comprising decision making parametrics D2, D4, D5, and D8, and Scenario 36, that comprises parametrics D2, D8, and D14.

Scenario 24 is a reasonable and technically defensible decision making scenario for use in the CED framework based on overall analytical constraints and assumptions. It corrects the technically flawed DOE SNOPR LCC analysis random Base Case AFUE assignment by substituting rational consumer economic decision making, thereby avoiding extremely unlikely consumer behavior caused by the DOE random assignment. 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.

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

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

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

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

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

In response to DOE assertions about non-economic and imperfect market decision making factors in the SNOPR, GTI analysts developed an LCC model approach to address these factors. The rational economic decision making criteria used in Scenario 24 permitted GTI analysts to monetize the impact of additional non-economic factors within the CED framework. The additional CED methodology developed for the GTI SNOPR analysis incorporates economic and non-economic criteria to characterize the overall consumer decision making process when choosing one furnace option over another. The additional CED methodology uses DOE's LCC model payback period distribution coupled with furnace shipment data to assign Base Case furnaces as well as the manner in which consumers make fuel switching decisions. Parametric D14 replaces the deterministic value for the DOE LCC model payback period in Parametrics D4 and D5 with a distribution function to adjust the payback period for each of the 10,000 trial cases. This approach comports with the "reasonable person" standard of imperfect decision making rather than a random, haphazard approach that yields numerous nonsensical results.

Parametric D14 accommodates a range of non-economic factors in the LCC analysis by monetizing these factors and incorporating the resultant distribution of paybacks into the GTI CED framework. The distribution function in Parametric D14 acknowledges the increasing uncertainty associated with longer payback periods, as well as the range of consumer knowledge, biases, market imperfections, and behaviors that shift the consumer's effective payback period for the furnace decision away from the DOE LCC model deterministic energy cost payback period under the CED framework in Parametrics D4 and D5. Parametric D14 uses a distribution function whose payback period standard deviation is 50% of the DOE LCC model payback period. Crystal Ball applies that distribution function in place of the deterministic value used in Parametric D4 for Scenario 24 to determine the modeled payback period for each of the 10,000 trial cases in Scenario 36. Parametric D14 is also used in Scenario 39 to isolate the impact of the CED framework coupled with the DOE fuel switching methodology.

Using a distribution function instead of a deterministic value for an individual home's payback period, decisions influenced by non-economic factors such as environmental stewardship, split incentives, imperfect information, and other non-monetary factors can be incorporated into the LCC model and improve its connection to actual market behavior in which the homeowner or their agent (e.g., builder or contractor) makes an imperfect, but not random, economic decision when purchasing a furnace.

2.7 GTI Input Data Analysis Methodology

To examine the impact of DOE's input data assumptions on SNOPR LCC modeling results, GTI analysts developed parametric scenarios using alternative input data with the potential for significant impact on the DOE LCC model results. The GTI SNOPR Input Data scenarios supplemented the parametric scenarios developed for the NOPR analysis as described in GTI-15/0002. In priority order, the GTI Input Data scenarios were based on publicly available market data, targeted surveys, construction and engineering principles, and persuasive anecdotal information. Appendix A, Section A.5, provides additional information on these scenarios.

Similar to the GTI decision making scenarios, the input data scenarios evaluated by GTI analysts incorporate individual and combined parametrics that modify, in the manner specified for each parameter, the DOE LCC model input data parameters. Similar to the approach taken in the GTI decision making scenarios, GTI analysts evaluated alternative input parameters with the potential to produce credible and technically defensible results for comparisons with the DOE LCC model results. GTI SNOPR Scenario I-17, an updated version of GTI NOPR Scenario I-16, replaces Input Data parametric I8 with Input Data parametric I17. The methodology description below focuses on Scenario I-17, comprising Input Data parametrics I2, I6, I13, and I17, which are also summarized. Input Data parametric I8 (AEO 2015 Update) was also included in Scenario I-16, but is no longer relevant since the SNOPR used the AEO 2015 forecasts.

The objective of Scenario I-17 was to incorporate furnace pricing data from the 2013 Furnace Price Guide (Parametric I2); substitute marginal gas prices derived from AGA tariff analysis for the DOE marginal gas prices (Parametric I6); incorporate updated AEO 2016 Clean Power Plan forecasts (Parametric I17), and use a more complete historical trend line of condensing furnace market penetration data from AHRI to revise the DOE forecasted trend line of condensing furnace market share (Parametric I13). These substitutions used superior data and forecasts compared to the information used in the DOE SNOPR LCC model.

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

Parametric I6 replaced the DOE NOPR LCC model marginal gas price factors with the marginal price factors developed by AGA using gas companies' tariff data. Similar to DOE, AGA relied on EIA residential natural gas sales and revenues by state (EIA 2014 NG Navigator). However, in contrast to the DOE methodology described in the SNOPR TSD, AGA developed a fixed cost component of natural gas rates for each state and applied it to the EIA data to develop state level residential marginal price factors. These state level data were then weighted according to furnace shipments using the same approach as DOE to generate marginal rates for each region.

Parametric I13 uses NWGF condensing and non-condensing furnace shipment data trends provided to DOE by AHRI in 2015 to revise the DOE 2022 forecast of Base Case condensing furnace shipment fraction. For the SNOPR analysis, GTI analysts developed a trend line that aligned with AHRI 2014 data and historical shipment data from 1998 through 2005. The GTI trend line did not consider 2006 through 2013 shipment data to avoid concerns with observed perturbations caused by federal energy credits phased out in 2011 that may have influenced shipment numbers between 2006 and 2013. DOE chose to use just 3 years (2012 to 2014) of shipment data in forecasting for years 2015 to 2050 in the SNOPR. To create a 2022 forecast trend line that matched actual 2014 shipment data, GTI used 1998 to 2005 trending years. This combined approach resulted in a 2014 condensing furnace shipment fraction of 48%, which is slightly lower than the actual fraction of 48.5% reported by AHRI. Based on this trend line, Parametric I13 uses condensing furnace shipment fractions of 62.5% (National), 84.1% (North), and 38.6% (Rest of Country) for the 2022 baseline instead of DOE's 2022 furnaces shipment fractions of 53.1% (National), 73.7% (North), and 30.2% (Rest of Country).

Figure 9 compares the DOE SNOPR and GTI Parametric I13 condensing furnace shipment forecast trend line. The GTI trend line shows a much higher market penetration of condensing furnaces without the DOE rule than the DOE LCC model. The GTI forecast trend line indicates a more robust free market for condensing furnaces without the rule in the future than the forecasts in the DOE LCC model.

Parametric I17 replaced the 2015 EIA AEO forecasts and utility prices used in the DOE SNOPR LCC model with the current 2016 EIA AEO forecasts for energy price trends and updated gas and electric utility prices. Since DOE noted that it plans to use the AEO 2016 forecasts for the Clean Power Plan (AEO 2016 CPP) scenario in its final rule, Parametric I17 uses the same AEO 2016 CPP scenario.

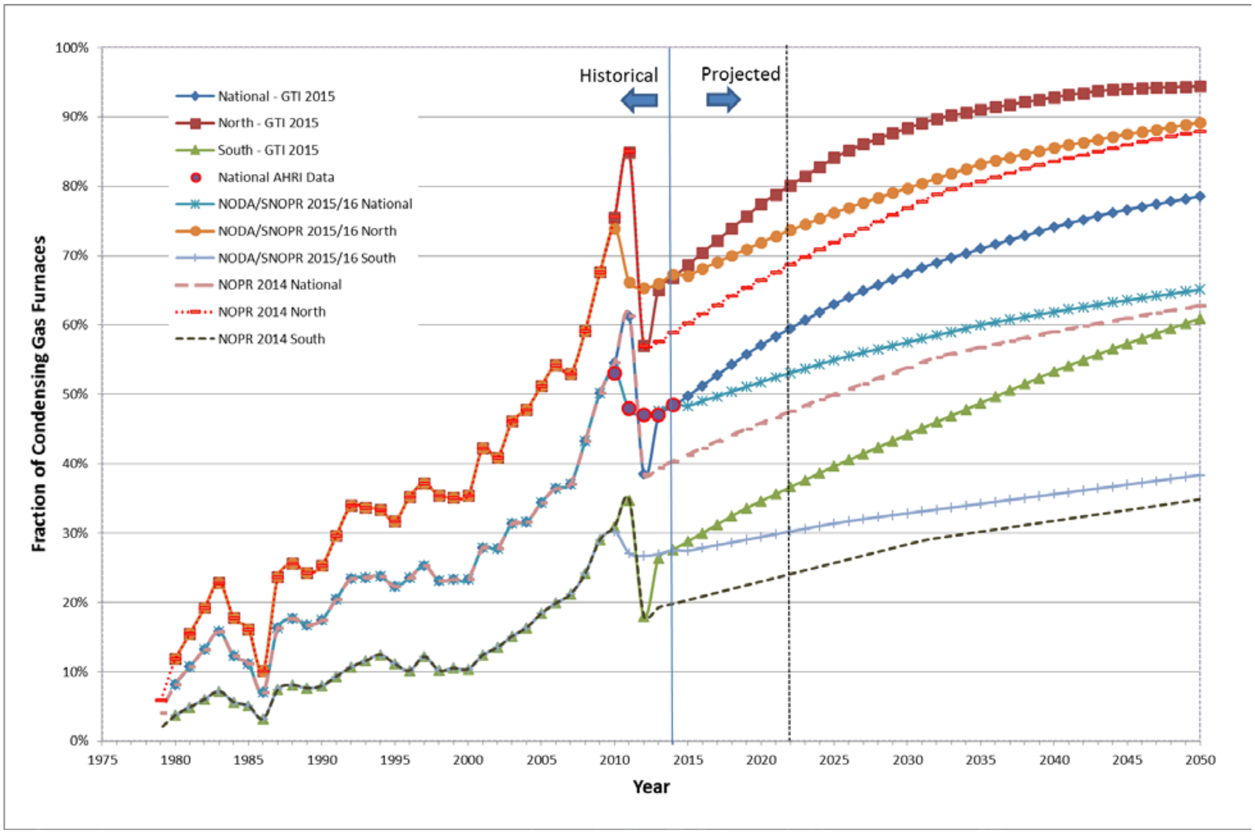

Figure 9 Condensing Furnace Trends – DOE SNOPR Model vs. GTI Parametric I13

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 SNOPR LCC spreadsheet fuel switching fractions to identify scenario combinations that were both technically defensible and consistent with other technical information and data sources. Appendix A, Section A7, provides a detailed description of the integrated scenarios developed for the SNOPR analysis.

As described in GTI-15/0002, GTI developed a set of integrated scenarios for the DOE NOPR LCC model analysis that were also considered for use in the SNOPR analysis. GTI Integrated Scenario Int-5 included several refinements to the DOE NOPR LCC model, including rational consumer economic decision making and improved input data, and formed the primary basis for comparison to DOE's analysis of its proposed furnace efficiency standards in the NOPR. Other technically defensible scenarios based on different assumptions and factors were included in GTI-15/0002 for reference purposes and were not used or updated in the GTI SNOPR analysis.

The GTI SNOPR analysis includes several integrated scenarios that incorporate updated decision making, input data, and furnace sizing parametrics and provide technical information related to issues on which DOE seeks comments in the DOE SNOPR. In response to DOE assertions in the SNOPR about non-economic and imperfect market decision making factors, GTI analysts developed an LCC model approach to address those factors. Based on concerns with the DOE furnace sizing methodology, GTI analysts also developed an alternative furnace sizing methodology for use in the separate product class analysis.

The GTI SNOPR integrated scenarios updated the GTI NOPR CED framework to incorporate non-economic decision making criteria, and substituted a heating consumption furnace sizing methodology for the DOE home size furnace sizing methodology. Building on the GTI NOPR CED framework, GTI SNOPR analysis scenarios include distribution functions that accommodate additional non-economic factors in the CED framework; and furnace sizing algorithms linked to the RECS database that examine the impact of different furnace capacity limits for 80% AFUE furnaces on rule benefits, including national, regional, new construction, replacement, senior, and low income segment impacts. GTI Integrated Scenarios Int-11 through Int-14 and Int-11.55 through Int-14.55 address these two major issues.

GTI SNOPR Scenario Int-14, an updated version of GTI NOPR Scenario Int-5, was selected for comparison with the 92% AFUE single product class TSL 5 in the SNOPR (GTI Scenario 0) to address the following issues:

- Base Case furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria,
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions when using a CED framework for Base Case furnace assignment and fuel switching decisions,
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices,
- Incorporation of AEO 2016 Clean Power Plan Scenario forecast information for comparisons with anticipated DOE final rule benefits calculations, and

- Application of a time-horizon-based distribution function based on the DOE LCC model payback period for each of the 10,000 trial cases for consumer economic decision making that monetizes the impact of imperfect market and non-economic consumer decision making factors into the LCC analysis for comparisons within the GTI CED framework, and gives consumers a limited ability to make economic decisions.

GTI Scenario Int-14.55, one of the cases under Scenario Int-14, was selected to examine the impact of a 55 kBtu/h furnace capacity limit for non-condensing furnaces on rule benefits for direct comparisons with the DOE SNOPR proposed rule TSL 6 (GTI Scenario 0.55). GTI Scenario Int-14.55 includes a furnace capacity algorithm for each trial case based on annual heating consumption rather than home size and uses the DOE furnace "downsizing" methodology.

2.9 DOE SNOPR Furnace Sizing Methodology

DOE describes its methodology for furnace sizing beginning on page 7B-17 of the SNOPR TSD. The steps DOE took to assign furnace size in the SNOPR LCC model are the same as in the NOPR LCC model in the NOPR TSD. The DOE SNOPR furnace sizing methodology includes the following steps as noted in the TSD:

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

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

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

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

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

In the procedure for furnace sizing described in the SNOPR TSD, the distribution of furnace input capacity used in Step 2 was used to split the 10 kBtu/hr size bins based on AHRI shipment numbers for the year 2000 in each size bin. As indicated in the SNOPR (81 Fed. Reg. 65770), furnaces were binned into 5 kBtu/hr size bins using the reduced models dataset from the September 2015 NODA analysis.

Correct furnace fan sizing is important to ensure that the furnace/AC system will provide adequate space conditioning during summer cooling periods in conventional forced air systems with an evaporator coil located adjacent to the furnace. This issue is especially important in warmer climates dominated by cooling demand. Furnace capacity in those cases will not be based solely on the peak heating load, but on the furnace fan capacity linked to the AC system capacity. As a result, the furnace capacity will often be oversized for the heating load to maintain adequate delivered air temperature in heating mode based on the fan output. The amount of oversizing varies, but can limit the minimum furnace capacity in those cases to a higher capacity than calculated based on peak heating load. ACCA Manual S acknowledges this application and permits additional oversizing in those cases. However, DOE chose not to consider the size of an air conditioning (AC) system when determining furnace size. As noted by DOE in the SNOPR, (81 Fed. Reg. 65770):

> *…the furnace fan standards that will take effect in July 2019 require fan motor designs that can modulate the amount of air depending on both heating and cooling requirements. Thus, the size of the furnace fan (and the furnace capacity) will be able to better match the heating requirements of the house.*

As a result, DOE determined the lower limit of furnace input capacity in the DOE LCC model based on the historical shipment information and number of models in AHRI Directory irrespective of the size of the air conditioning system in the 10,000 trial cases.

2.10 DOE Furnace Sizing Model Poor Correlation with Annual Heating Load

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

Figure 10 shows annual heating load vs. furnace size along with a best fit line for all furnaces, whether impacted by the rule or not, using the DOE SNOPR furnace sizing methodology. The correlation between heating load and furnace size using the DOE methodology is extremely weak (R^2=0.11). This is an expected result because the DOE furnace sizing algorithm is based on home size modified by a small random term. Further, as shown by the “continuous operation” curves in Figure 10, the DOE furnace sizing algorithm results in furnace sizes in some instances that cannot meet the average heating load (cases to the right of the “continuous operation” curves). The lack of a strong relationship between heating load and furnace size helps explain the lack of a consistent trend in LCC savings with furnace size in the SNOPR.

As noted above in Section 2.9, the DOE sizing methodology does not consider AC requirements when sizing furnaces. Thus, the lack of correlation between heating load and furnace size is not driven to any meaningful extent by AC size and associated fan requirements. In addition, empirical data gathered by GTI indicates that peak space heating loads in southern climate zones may be relatively higher compared to equivalent size homes in colder northern climate zones due to regional building codes and construction practices that may have lower levels of weatherization. This means that a smaller furnace may not be able to meet the needs of many southern homes as well, especially in the middle of the country with relatively cold design heating temperatures as far south as Texas.

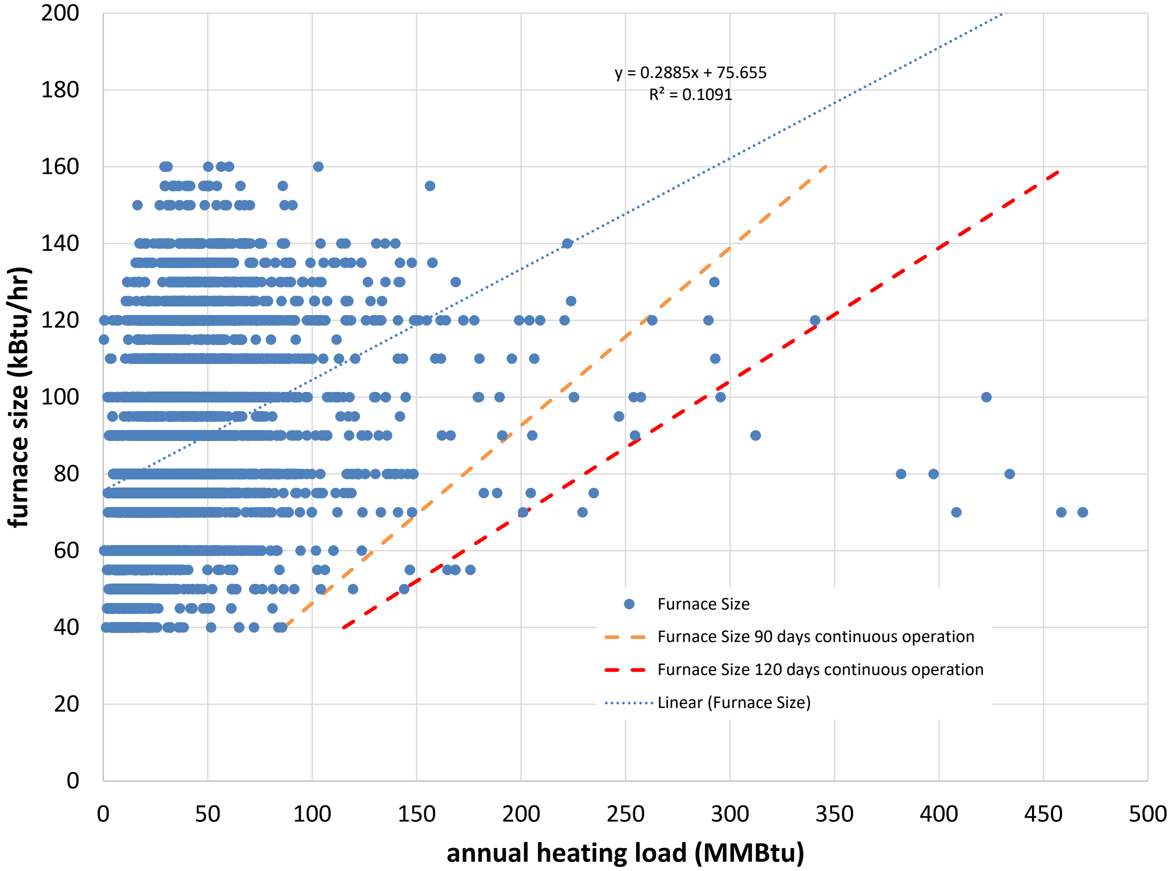

Figure 10: Furnace Size vs. Annual Heating Load Using DOE SNOPR Methodology

2.11 RECS Database Limitations

In both the NOPR and SNOPR, DOE derived annual heating load, existing furnace efficiency level, and existing furnace capacity from limited information in the RECS 2009 database. DOE chose to randomly assign existing furnace AFUE to individual trial cases and derived the annual heating load from the randomly assigned existing AFUE based on annual gas consumption. Available RECS database information includes location, physical size, and annual gas consumption. However, the RECS database does not include critical information on furnace size, monthly heating consumption, or monthly or annual heating load. The lack of this critical information in the RECS database makes it inadequate for use in the furnace capacity and annual heating load assignments used in the SNOPR, both for the single standard level and for separate standard levels for large and small furnaces evaluated in the SNOPR. Additional market information and analytical methodologies are needed for this purpose.

In an effort to address the RECS database shortcomings for use in determining a reasonable furnace size for LCC model calculations, GTI analysts examined detailed empirical data on house characteristics and gas consumption from natural gas company databases and GTI energy efficiency field data acquisition projects. Empirical data included house size, age, monthly heating degree days, outdoor design temperature, and hourly and monthly gas consumption. The empirical data enabled development of a steady-state and setback recovery furnace capacity algorithm based on house characteristics. GTI Topical Report GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation" (http://www.gastechnology.org/reports_software/Documents/Empirical-Analysis-of-Natural-Gas-Furnace-Sizing-and-Operation.pdf) summarizes the results of this investigation. As shown in Figure 11 through Figure 14, detailed empirical data analysis described in GTI-16/0003 shows the expected strong correlation between annual heating consumption and house "UA" (a combination of thermal efficiency and envelope area), a strong correlation between required furnace capacity and house "UA", but a very weak correlation between annual heating consumption or UA and home size. Unfortunately, the lack of monthly gas consumption data and poor correlation between gas consumption, annual HDD, design outdoor air temperature, and peak heating load in the RECS database used by DOE in the SNOPR LCC spreadsheet model for each of the 10,000 trial cases precluded the use of the GTI empirical model with RECS database information.

2.12 GTI RECS Annual Heating Consumption Furnace Sizing Model

To examine an easily implemented alternative to the DOE furnace sizing methodology, GTI analysts developed a furnace capacity algorithm for each of the 10,000 trial cases based on the RECS database annual heating consumption rather than home size (Scenario F1 in Table 11). Figure 15 shows heating load vs. furnace size along with a best fit line for all furnaces, whether impacted by the rule or not, using the RECS annual heating consumption model furnace sizing methodology. The correlation between annual heating load and furnace size (R^2=0.69) is substantially better with the RECS annual heating consumption model than the correlation using the DOE furnace sizing methodology (R^2=0.11). This is an a priori expectation because annual heating consumption should have a fair to strong correlation with peak heating load, whereas home size has been demonstrated to have poor correlation with peak heating load for a variety of reasons. The RECS annual heating consumption model is also compatible with the furnace "downsizing" methodology used by DOE in the SNOPR proposed rule (TSL 6). It also provided the desired sensitivity to market conditions compared to the DOE methodology. The data in Figure 12 is net delivered energy (before efficiency losses) – not gross furnace input capacity.

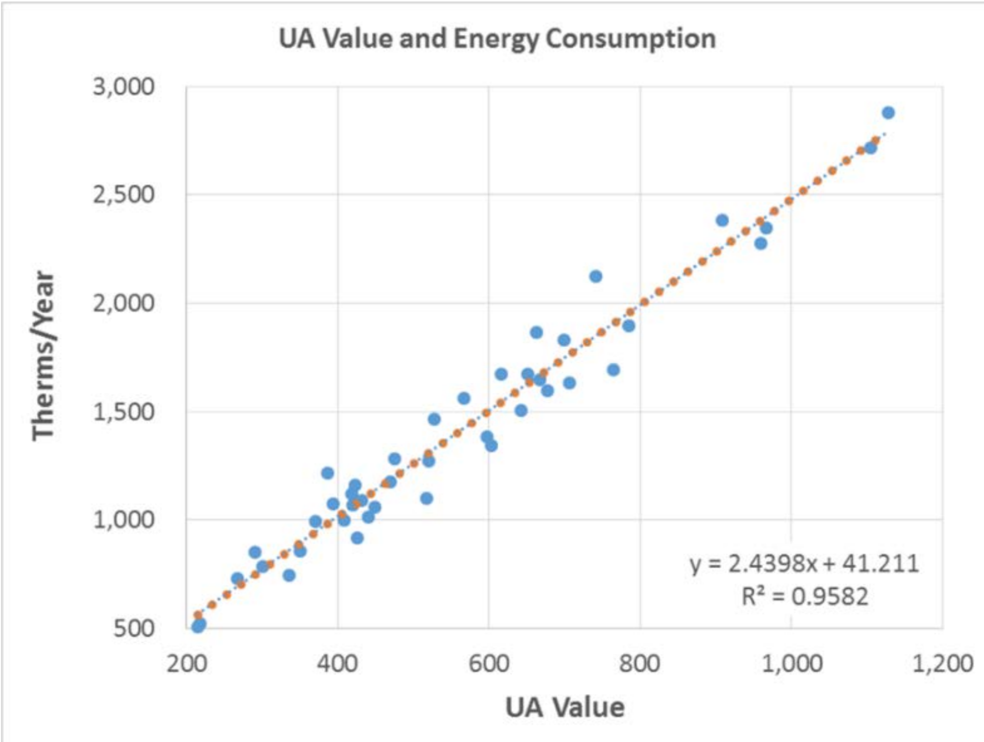

Figure 11: Strong Correlation Between Furnace Natural Gas Use and UA Value

Source: GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation"

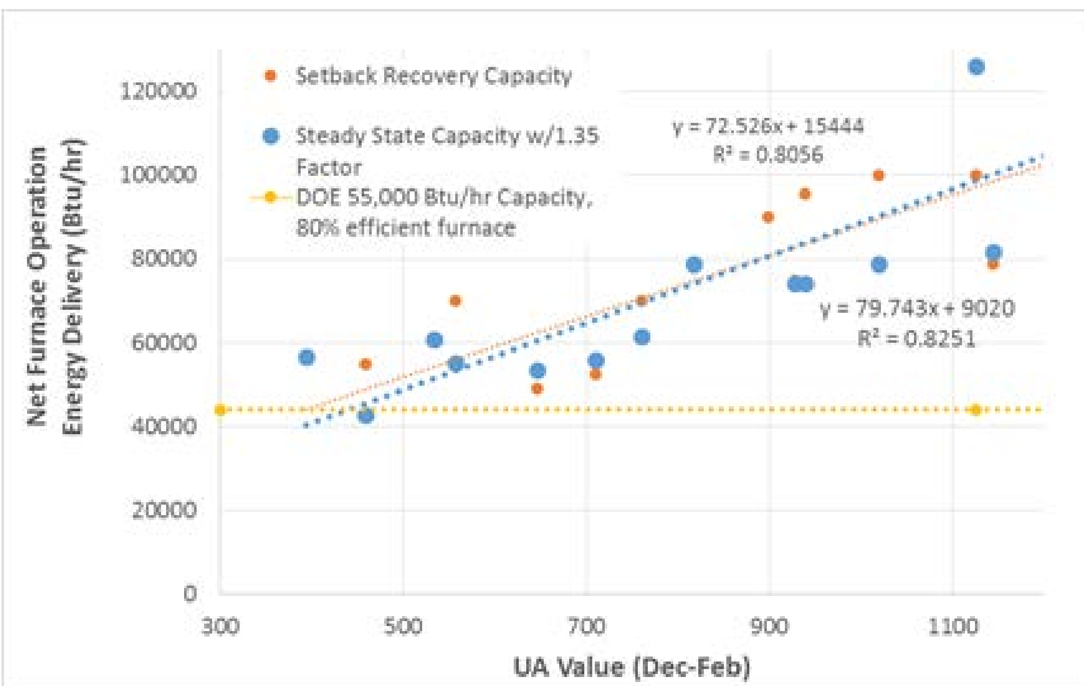

Figure 12: Strong Correlation Between Furnace Energy Delivery and UA Value

Source: GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation"

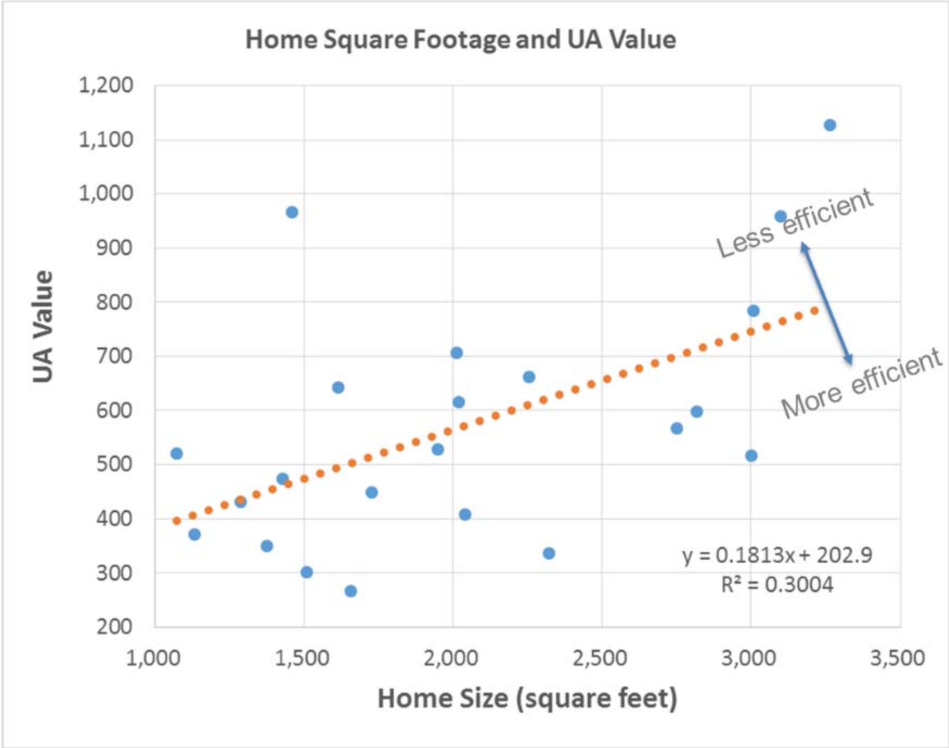

Figure 13: Weak Correlation Between Home Size and UA Value

Source: GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation"

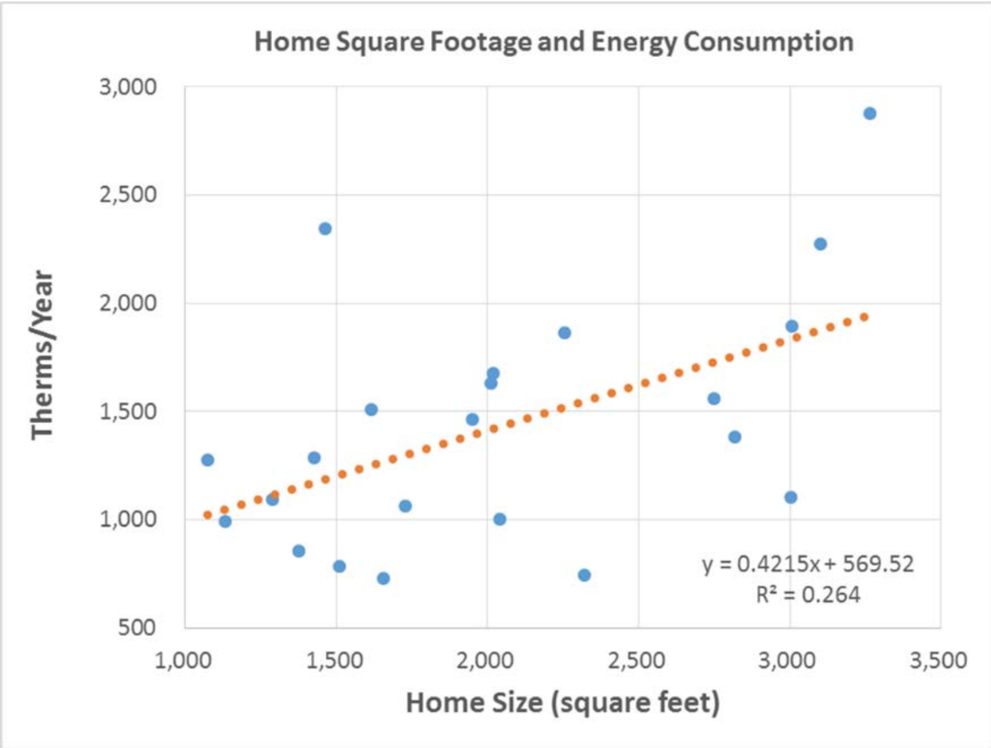

Figure 14: Weak Correlation Between Home Size and Furnace Natural Gas Use

Source: GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation"

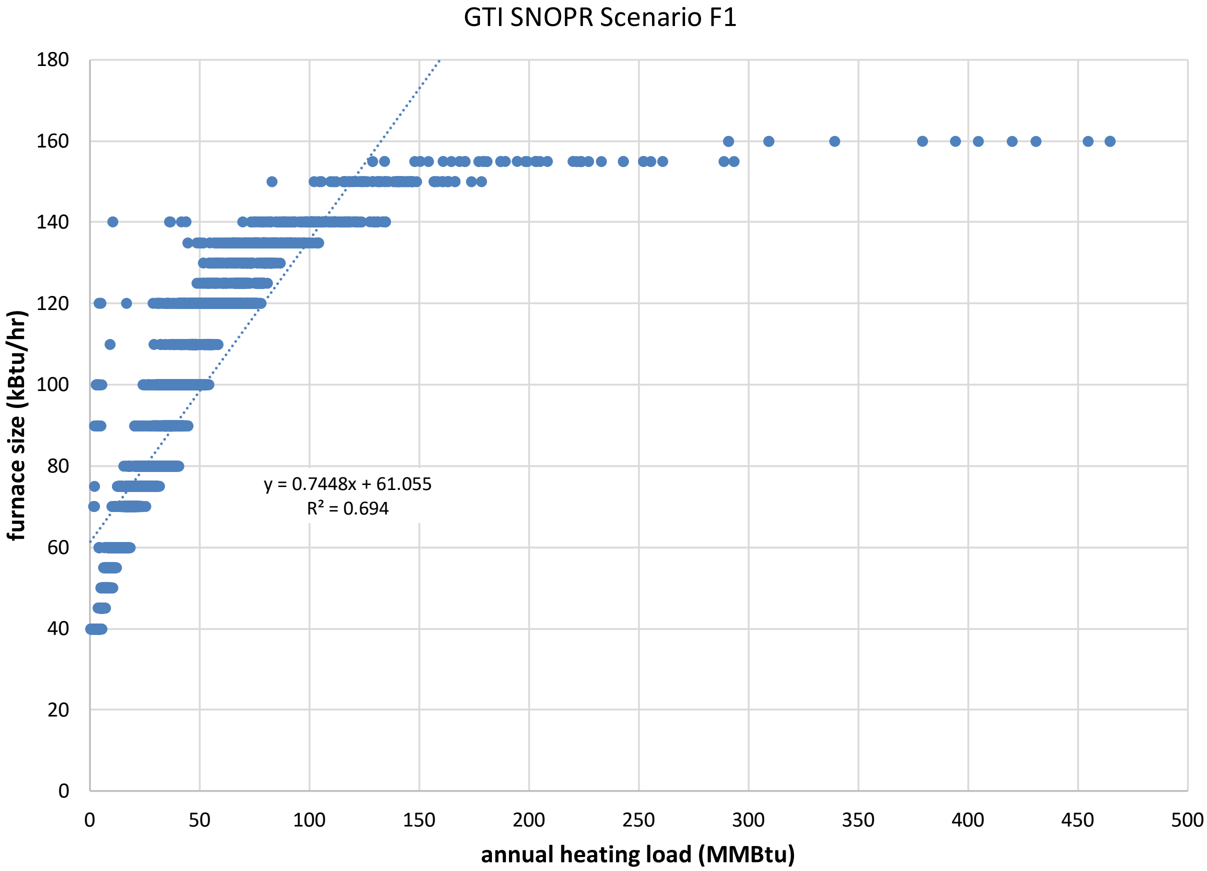

Figure 15: Furnace Size vs. Annual Heating Load with RECS Heating Consumption Model

An examination of DOE's approach to configuring 10,000 trial cases from the buildings in the RECS database further illustrates the impact of DOE's flawed random Base Case assignment methodology, DOE's flawed furnace sizing methodology, and the inherent limitations in the RECS database for LCC analysis purposes. Starting with RECS database Building No. 8113 (RECS Region 27, OR/WA), DOE configured five different residential replacement trial cases (3848, 8785, 8906, 9052, and 9467) by changing selected parameters related to installed costs and other factors. RECS Building 8113 is a 3-story, 3,613 ft^2 home, with a design heating temperature of 9°F and 6,385 HDD_{65}. DOE randomly assigned Base Case efficiencies to each trial case. Using its size-based algorithm, DOE selected a 120 kBtu/h furnace for LCC model analysis. For unknown reasons, the annual furnace gas consumption in the RECS database for that home is 0.97 MMBtu, which indicates virtually no gas consumption for heating compared to the average of 49.6 MMBtu for the buildings used by DOE in RECS Region 27.

Table 17 compares the DOE SNOPR TSL 6 LCC model results (GTI Scenario 0.55) with GTI Scenario Int-14.55 results for the five trial cases that use RECS Building No. 8113. Note that trial case 9467 changes from "Net Cost," as shown previously in Table 15, to "No Impact" using the GTI CED framework coupled with the GTI furnace sizing algorithm based on annual heating consumption. With such a low annual consumption, the GTI methodology assigned the smallest available furnace capacity of 40 kBtu/h to that trial case. DOE's house size methodology assigned a large furnace capacity of 120 kBtu/h to the 3,613 ft^2 home. Both DOE and GTI consider that trial case as No Impact in TSL 6, but for different reasons. DOE randomly assigned a 92% furnace to that trial case, so it considered it never impacted, either in TSL 5 or TSL 6. In Contrast, GTI's 80% AFUE Base Case assignment using the GTI CED framework with non-economic factors considered it impacted in TSL 5 based on the 1,337-year payback of the condensing furnace; but with a 55 kBtu/h limit, the 80% AFUE furnace was not impacted by the rule, which was the understood intent of the capacity limit approach in TSL 6. DOE assigned trial case 9052 a 120 kBtu/h 80% AFUE furnace, so it was impacted under TSL 5, as it was using the GTI methodology, but it remained impacted under TSL 6 because of the flawed DOE furnace sizing methodology, in this case reducing the TSL 6 rule benefit erroneously.

Table 17: DOE and GTI Methodologies Applied to RECS Building No. 8113

RECS Bldg. No. 8113 Crystal Ball Trial Case No.	DOE Base Case AFUE	DOE Furnace Capacity (Kbtu/h)	GTI Base Case AFUE	GTI Furnace Capacity (Kbtu/h)	92% AFUE vs. 80% AFUE		LCC Savings		Region/ Location	Type	Payback (Years)
					Cost Penalty	Annual Savings	DOE	GTI			
3848	80%	120	80%	40	$812	-$1	-$212	No Impact	North/ OR, WA	Residential Replacement	Never
8785	92%	120	92%	40	-$622	-$1	No Impact	No Impact	North/ OR, WA	Residential Replacement	995
8906	95%	120	80%	40	$876	$1	No Impact	No Impact	North/ OR, WA	Residential Replacement	675
9052	80%	120	80%	40	$1,385	$1	-$1,449	No Impact	North/ OR, WA	Residential Replacement	1933
9467	92%	120	80%	40	$1,548	$1	No Impact	No Impact	North/ OR, WA	Residential Replacement	1337

Note: Payback period for Case 8785 is for the higher cost non-condensing furnace.

2.13 DOE SNOPR Furnace Downsizing Methodology

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

The equation for the DOE downsizing algorithm is as follows:

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

Figure 16 shows the flowchart for the SNOPR furnace downsizing methodology. The SNOPR downsizing methodology assumes a rational consumer response to a market constraint to protect their economic interests. It appropriately employs rational consumer behavior methodology, and it is inconsistent with the random furnace sizing and baseline furnace efficiency assignment methodology used by DOE elsewhere in the SNOPR. The downsizing methodology, however, fails to account for the selection of furnace size based on AC size and associated fan requirements, or differences in regional construction practices that affect furnace sizing requirements in the north and south differently. Nonetheless, as shown in Figure 12, the 1.35 oversizing factor used by DOE in this rational consumer methodology aligns with the empirical dataset in GTI-16/0003 for required furnace output capacity in the Chicago area sample set, and is close to the 1.4 oversizing factor used by ACCA in Manual S calculations for heating-dominated climates.

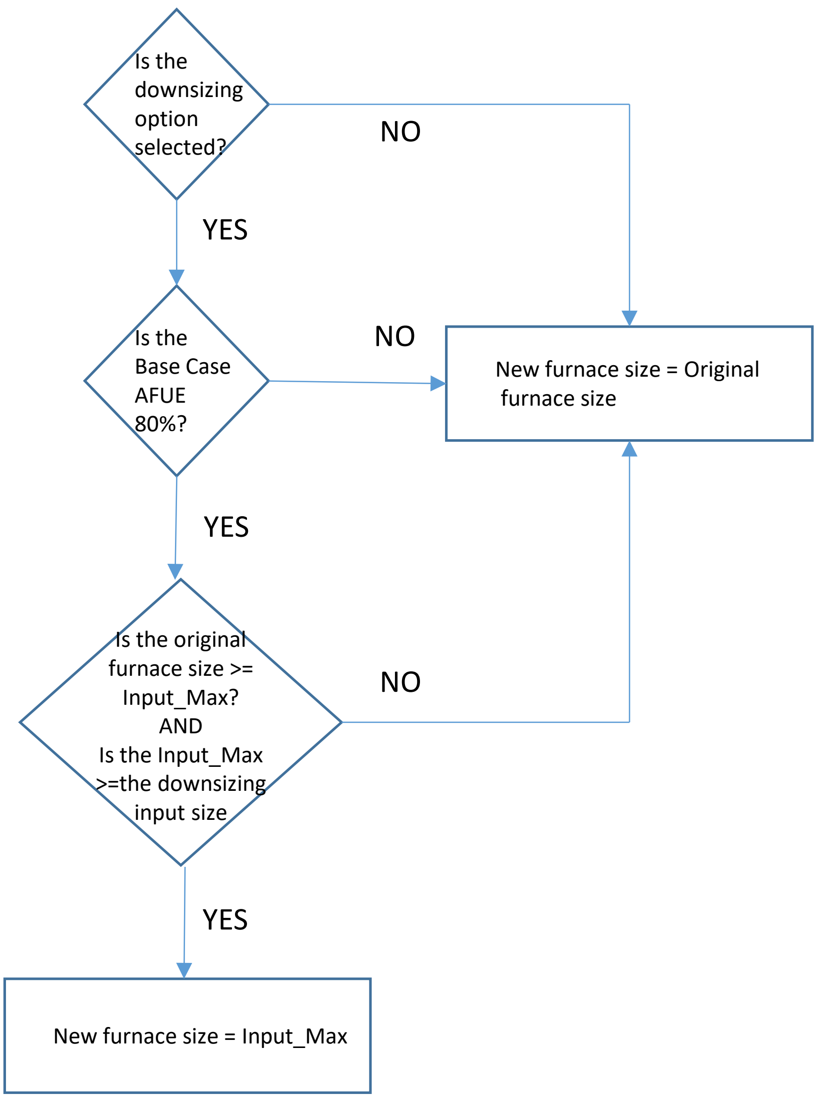

Figure 16 DOE SNOPR Furnace Down-Sizing Methodology

3 LCC Parametric Scenario Analysis Results

3.1 GTI Incremental Scenario Summary Results

Table 19 compares LCC savings for incremental GTI SNOPR analysis Parametrics and Scenarios used to build the GTI integrated scenarios with the DOE SNOPR LCC analysis results for a single national 92% AFUE standard (SNOPR TSL 5, GTI Scenario 0) and the SNOPR proposed rule (SNOPR TSL 6, GTI Scenario 0.55).

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

- Incremental improvements to the flawed methodologies DOE used in its SNOPR highlight the value of an integrated approach to analyzing the SNOPR in totality, as well as prioritizing which improvements have the most impact.
- DOE's technically flawed random baseline furnace assignment methodology has the most significant impact on rule benefits and costs. Replacing DOE's methodology with limited economic decision making criteria that monetizes non-economic factors more closely aligns with real-world consumer choices and significantly reduces the LCC savings of the SNOPR.
- Addition of non-economic factors into the GTI SNOPR analysis (GTI Integrated Scenario Int-14) did not materially change the LCC savings results compared to the rational CED framework used in GTI NOPR Integrated Scenario Int-5 and GTI SNOPR Integrated Scenario Int-12.
- Incorporation of the set of improved Decision Parametrics on their own, without improved input data, result in negative rule LCC savings under a CED framework, and virtually no savings when adding non-economic decision making factors to the CED framework.
- Incorporation of an improved furnace sizing methodology (GTI Parametric F1) provided the desired sensitivity to market conditions compared to the DOE methodology.
- Incorporation of improved input data had a modest, but meaningful negative impact on LCC savings compared to the DOE input information.

Table 18 LCC Savings – DOE SNOPR vs. GTI Decision Scenarios

Increment	GTI Decision Parametrics Compared to DOE SNOPR TSL 5 (92% AFUE Minimum) TSL 6 (80% AFUE ≤55 kBtu/h, 1.35 Oversizing)	LCC Savings (TSL 5)	LCC savings (TSL 6)	LCC Savings (TSL 5 with F1)	LCC savings (TSL 6 with F1)
0	DOE SNOPR	$617	$692	$635	$684
1	Add to Increment 0 income-based fuel switching decision payback period. (D2)	$600	$679	$608	$658
2	Remove from Increment 0 cases where fuel switching was cheaper than an 80% furnace and saved annual cost. (D8)	$504	$599	$495	$580
3	Add to Increment 0 income-based fuel switching decision payback period.; Remove from Increment 0 cases where fuel switching was cheaper than an 80% furnace and saved annual cost. (Combined Parametrics D2, D8)	$486	$585	$467	$553
4	Remove from Increment 0 cases with negative payback period in Base Case AFUE assignment. (D5)	$360	$446	$354	$422
5	Change Increment 0 to give consumers limited ability to make decisions based on economics, aligned with projected shipment fractions; replace payback period for Base Case AFUE assignment with a normal distribution with mean equal to the calculated payback period and standard deviation 50% of calculated payback period. (D14 w/SD 50%)	$99	$155	$102	$125
6	Add to Increment 5 income-based fuel switching decision payback period (Combined Parametrics D2, D14 w/SD 50%)	$41	$103	$43	$65
7	Remove from Increment 5 cases where fuel switching was cheaper than an 80% furnace and saved annual cost. (Combined Parametrics D8, D14 w/SD 50%)	$36	$78	$57	$79
8	Change Increment 0 to give consumers reasonable ability to make decisions based on economics, aligned with projected shipment fractions. (D4, D5)	$32	$57	$45	$61
9	Add to Increment 7 income-based fuel switching decision payback period. (GTI Scenario 36 including D2, D8, D14 w/SD 50%)	-$24	$25	-$2	$19
10	Combine Increments 2 and 8 (GTI Scenario 24 including D2, D4, D5, D8)	-$65	-$37	-$53	-$37

Note: GTI selected Increment 9 for inclusion in GTI Integrated Scenario Int-14.

Table 19 LCC Savings – DOE SNOPR vs. GTI Decision, Input, and Integrated Scenarios

Increment	GTI Decision and Input Parametrics and Scenario Changes Compared to DOE SNOPR TSL 5 (92% AFUE Minimum) and TSL 6 (80% AFUE ≤55 kBtu/h, 1.35 Oversizing)	LCC Savings (TSL 5)	LCC savings (TSL 6)
0	DOE SNOPR	$617	$692
1	Change Increment 0 using annual fuel consumption based furnace sizing. (F1)	$635	$684
2	Change Increment 1 using AEO 2016 with CPP, AHRI shipment data, real world furnace cost, and AGA derived marginal gas prices. (I2, I6, I13, I17, F1)	$456	$517
3	Add to Increment 2 income based fuel switching decision payback period to Increment 2. (D2, I2, I6, I13, I17, F1)	$420	$483
4	Remove cases from Increment 2 where fuel switching was cheaper than an 80% furnace and saved annual cost. (D2, D8, I2, I6, I13, I17, F1)	$297	$386
5	Remove cases from Increment 3 with negative payback period in Base Case AFUE assignment. (D2, D5, D8, I2, I6, I13, I17, F1)	$107	$175
6	Change Increment 0 to give consumers very poor ability to make decisions based on economics, aligned with projected shipment fractions; replace payback period for Base Case AFUE assignment with a normal distribution with mean equal to the calculated payback period and standard deviation 1000% of calculated payback period. (D2, D8, D14 w/SD 1000%, I2, I6, I13, I17, F1)	$81	$136
7	Change Increment 0 to give consumers very limited ability to make decisions based on economics, aligned with projected shipment fractions; replace payback period for Base Case AFUE assignment with a normal distribution with mean equal to the calculated payback period and standard deviation 100% of calculated payback period. (D2, D8, D14 w/SD 100%, I2, I6, I13, I17, F1)	-$114	-$85
8	Change Increment 0 to give Change Increment 0 to give consumers limited ability to make decisions based on economics, aligned with projected shipment fractions; replace payback period for Base Case AFUE assignment with a normal distribution with mean equal to the calculated payback period and standard deviation 50% of calculated payback period. (GTI Scenario Int-14 including D2, D8, D14 w/SD 50%, I2, I6, I13, I17, F1)	-$149	-$118
9	Change Increment 0 to give consumers reasonable ability to make decisions based on economics, aligned with projected shipment fractions. (GTI Scenario Int-12 including D2, D4, D5, D8, I2, I6, I13, I17, F1)	-$179	-$157

Note: GTI selected Increment 8 (Scenarios Int-14 and Int-14.55) for comparison with DOE SNOPR LCC model results.

3.2 GTI Integrated Scenario Int-14.55 and Int-14 Results

Table 20 summarizes the difference in consumer impacts when comparing the DOE SNOPR LCC model results with GTI Scenario Int-14.55 for the proposed rule (SNOPR TSL 6, GTI Scenario 0.55) and with GTI Scenario Int-14 for a single national 92% AFUE standard (SNOPR TSL 5, GTI Scenario 0). Comparable results for the NOPR analysis (updated by DOE as SNOPR TSL 5) are also included for reference. Table 21 through Table 30 provide a more detailed comparison of the DOE SNOPR LCC model results with the comparable GTI Integrated Scenario Int-14.55 and Int-14 results. The main differences, as noted, stem from the removal of the technically flawed DOE random assignment methodology for baseline furnace efficiency that results in (1) overstated Net Benefit cases (29% versus 12%) and (2) understated Net Cost cases (11% versus 15%) for DOE SNOPR TSL 6.

Table 20: SNOPR and NOPR Lifecycle Cost and Market Impact Comparisons

LCC Model Scenario	Average Furnace Life-Cycle Cost (LCC) Savings per Impacted Case	Fraction of Furnace Population (%)		
		Net Cost	No Impact	Net Benefit
DOE SNOPR TSL 6 (92%/55 kBtu/h)	$692	11%	60%	29%
GTI Integrated Scenario Int-14.55	-$118	15%	73%	12%
DOE SNOPR TSL 5 (92% all capacities)	$617	17%	48%	35%
GTI Integrated Scenario Int-14	-$149	22%	64%	15%
DOE NOPR (92% all capacities)	$520	20%	41%	39%
GTI NOPR Scenario Int-5	-$417	27%	57%	17%

Table 21 LCC Savings – DOE SNOPR TSL 6 vs. GTI Scenario Int-14.55

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE SNOPR (Scenario 0.55)	$667	$755	$615	$445	$479	$426	$1,242	$1,369	$1,158	$885	$592
SNOPR Scenario Int-14.55	-$196	-$470	-$23	-$232	-$678	-$47	$309	$203	$494	-$176	-$475
	LCC Savings Summary - 92% TSL										
DOE SNOPR (Scenario 0.55)	$692	$749	$654	$502	$532	$483	$1,148	$1,176	$1,125	$890	$611
SNOPR Scenario Int-14.55	-$118	-$286	$17	-$182	-$493	-$23	$239	$153	$404	-$81	-$455
	LCC Savings Summary - 95% TSL										
DOE SNOPR (Scenario 0.55)	$609	$617	$601	$499	$511	$489	$840	$783	$900	$770	$592
SNOPR Scenario Int-14.55	-$69	-$206	$53	-$139	-$342	-$18	$171	$13	$466	-$35	-$371
	LCC Savings Summary - 98% TSL										
DOE SNOPR (Scenario 0.55)	$543	$502	$600	$447	$419	$488	$777	$677	$913	$724	$674
SNOPR Scenario Int-14.55	-$74	-$123	-$2	-$121	-$149	-$85	$121	-$82	$395	-$10	-$276

Table 22 Fuel Switching – DOE SNOPR TSL 6 vs. GTI Scenario Int-14.55

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	Percent of Impacted Buildings Switching - 90% TSL										
DOE SNOPR (GTI Scenario 0.55)	18.3%	12.3%	21.9%	20.8%	11.0%	26.2%	14.3%	16.9%	12.6%	19.2%	15.6%
Scenario Int-14.55	10.1%	8.8%	10.8%	10.0%	7.2%	11.2%	13.4%	15.1%	10.3%	11.6%	13.0%
	Percent of Impacted Buildings Switching - 92% TSL										
DOE SNOPR (GTI Scenario 0.55)	17.2%	10.1%	22.1%	20.0%	9.1%	26.9%	12.6%	13.4%	12.1%	18.3%	13.9%
Scenario Int-14.55	11.9%	7.7%	14.7%	12.4%	6.9%	15.3%	11.5%	10.2%	13.8%	13.2%	12.5%
	Percent of Impacted Buildings Switching - 95% TSL										
DOE SNOPR (GTI Scenario 0.55)	18.3%	6.6%	20.8%	20.8%	6.1%	25.6%	14.3%	8.2%	10.7%	14.5%	12.3%
Scenario Int-14.55	11.8%	5.7%	16.5%	13.2%	6.1%	17.4%	8.6%	5.6%	14.2%	11.9%	13.3%
	Percent of Impacted Buildings Switching - 98% TSL										
DOE SNOPR (GTI Scenario 0.55)	12.4%	4.2%	24.2%	13.7%	3.3%	28.8%	10.3%	7.0%	14.9%	11.2%	10.9%
Scenario Int-14.55	10.6%	3.7%	19.6%	10.6%	3.2%	20.2%	12.3%	6.6%	20.0%	9.2%	12.6%

Table 23 Energy and GHG Emissions – DOE SNOPR TSL 6 vs. GTI Scenario Int-14.55

Scenario	Gas Use w/o Rule (MMBtu)	Gas Use w/ Rule (MMBtu)	Electric Use w/o Rule (kWh)	Electric Use w/ Rule (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
	Impacted Buildings - 90% TSL							
DOE SNOPR (GTI Scenario 0.55)	39.7	30.2	926.1	1,166.1	-24%	26%	-8.0	-1,080.7
Scenario Int-14.55	34.9	28.1	289.7	780.1	-20%	169%	-2.4	-331.4
	Impacted Buildings - 92% TSL							
DOE SNOPR (GTI Scenario 0.55)	40.6	31.3	329.5	1,097.8	-23%	233%	-2.2	-313.6
Scenario Int-14.55	35.2	27.9	292.9	847.2	-21%	189%	-2.3	-319.0
	Impacted Buildings - 95% TSL							
DOE SNOPR (GTI Scenario 0.55)	40.5	32.7	330.1	915.0	-19%	177%	-2.6	-357.7
Scenario Int-14.55	37.3	30.5	304.7	803.7	-18%	164%	-2.2	-312.0
	Impacted Buildings - 98% TSL							
DOE SNOPR (GTI Scenario 0.55)	42.3	34.7	334.4	856.6	-18%	156%	-2.8	-389.9
Scenario Int-14.55	42.5	36.0	319.0	779.6	-15%	144%	-2.3	-315.1

Table 24 LCC Savings – DOE SNOPR TSL 5 vs. GTI Scenario Int-14

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	LCC Savings Summary - 90% TSL										
DOE SNOPR (GTI Scenario 0)	$582	$701	$530	$361	$430	$334	$1,263	$1,360	$1,210	$755	$440
GTI Scenario Int-14	-$203	-$487	-$88	-$258	-$698	-$113	$294	$166	$489	-$166	-$562
	LCC Savings Summary - 92% TSL										
DOE SNOPR (GTI Scenario 0)	$617	$711	$569	$420	$496	$386	$1,177	$1,172	$1,180	$775	$476
GTI Scenario Int-14	-$149	-$309	-$65	-$222	-$519	-$100	$220	$136	$347	-$88	-$506
	LCC Savings Summary - 95% TSL										
DOE SNOPR (GTI Scenario 0)	$561	$597	$537	$437	$492	$405	$865	$773	$949	$692	$482
GTI Scenario Int-14	-$104	-$223	-$26	-$185	-$361	-$97	$178	$6	$453	-$57	-$426
	LCC Savings Summary - 98% TSL										
DOE SNOPR (GTI Scenario 0)	$506	$487	$528	$399	$405	$394	$801	$668	$956	$662	$554
GTI Scenario Int-14	-$104	-$136	-$69	-$166	-$163	-$169	$139	-$88	$396	-$40	-$344

Table 25 Fuel Switching – DOE SNOPR TSL 5 vs. GTI Scenario Int-14

Scenario	National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
	Percent of Impacted Buildings Switching - 90% TSL										
DOE NOPR (GTI Scenario 0)	23.2%	12.5%	28.0%	24.0%	11.0%	29.2%	23.5%	18.0%	26.5%	25.3%	20.8%
GTI Scenario Int-14	21.3%	11.2%	25.3%	22.2%	9.7%	26.4%	19.0%	18.1%	20.3%	24.9%	27.5%
	Percent of Impacted Buildings Switching - 92% TSL										
DOE NOPR (GTI Scenario 0)	22.1%	10.4%	28.2%	23.3%	9.2%	29.8%	21.0%	14.3%	25.6%	24.4%	20.0%
GTI Scenario Int-14	22.9%	9.7%	29.9%	24.2%	9.1%	30.4%	20.3%	12.2%	32.4%	25.9%	26.9%
	Percent of Impacted Buildings Switching - 95% TSL										
DOE NOPR (GTI Scenario 0)	18.5%	6.9%	26.3%	20.5%	6.4%	28.7%	15.5%	8.8%	21.6%	19.1%	17.3%
GTI Scenario Int-14	20.7%	7.1%	29.6%	22.7%	7.8%	30.1%	16.2%	6.4%	31.7%	20.8%	23.2%
	Percent of Impacted Buildings Switching - 98% TSL										
DOE NOPR (GTI Scenario 0)	16.2%	4.4%	29.2%	17.1%	3.6%	31.6%	15.3%	7.4%	24.6%	15.2%	15.3%
GTI Scenario Int-14	17.5%	4.5%	31.8%	17.4%	4.0%	32.0%	20.4%	7.3%	35.1%	15.4%	20.1%

Table 26 Energy and GHG Emissions – DOE SNOPR TSL 5 vs. GTI Scenario Int-14

Scenario	Gas Use w/o Rule (MMBtu)	Gas Use w/ Rule (MMBtu)	Electric Use w/o Rule (kWh)	Electric Use w/ Rule (kWh)	change gas use %	change electric use %	change source energy (MMBtu)	change emissions (lbs $CO2_e$)
	Impacted Buildings - 90% TSL							
DOE SNOPR (GTI Scenario 0)	35.3	26.1	300.4	1,118.8	-26%	272%	-1.6	-234.2
GTI Scenario Int-14	30.6	23.1	267.9	865.0	-25%	223%	-2.0	-283.5
	Impacted Buildings - 92% TSL							
DOE NOPR (GTI Scenario 0)	36.3	27.2	305.9	1,071.8	-25%	250%	-2.0	-288.1
GTI Scenario Int-14	31.2	23.1	272.2	933.9	-26%	243%	-1.9	-269.9
	Impacted Buildings - 95% TSL							
DOE NOPR (GTI Scenario 0)	37.1	29.1	311.4	926.2	-22%	197%	-2.4	-334.3
GTI Scenario Int-14	33.8	26.5	287.4	876.7	-22%	205%	-1.9	-273.9
	Impacted Buildings - 98% TSL							
DOE NOPR (GTI Scenario 0)	39.4	31.7	320.0	882.2	-20%	176%	-2.6	-367.1
GTI Scenario Int-14	39.4	32.4	304.7	839.0	-18%	175%	-2.0	-285.3

Table 27 DOE SNOPR TSL 6 (GTI Scenario 0.55) LCC Analysis Summary Results

DOE SNOPR (GTI Scenario 0.55)		National				Replacement				New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$667	12%	65%	23%	$313	15%	67%	18%	$1,053	2%	61%	37%
2	NWGF 92%	$692	11%	60%	29%	$364	14%	62%	24%	$993	2%	53%	45%
3	NWGF 95%	$609	15%	40%	44%	$385	17%	46%	37%	$749	9%	25%	65%
4	NWGF 98%	$543	26%	16%	58%	$369	29%	18%	52%	$703	16%	10%	74%

DOE SNOPR (GTI Scenario 0.55)		North - Replacement				Rest of Country- Replacement			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$418	11%	78%	12%	$271	21%	55%	24%
2	NWGF 92%	$474	10%	72%	18%	$313	19%	52%	30%
3	NWGF 95%	$468	12%	55%	33%	$336	23%	36%	41%
4	NWGF 98%	$394	31%	7%	62%	$342	27%	30%	42%

DOE SNOPR (GTI Scenario 0.55)		North - New				Rest of Country- New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$1,301	2%	71%	27%	$916	1%	49%	50%
2	NWGF 92%	$1,126	2%	62%	36%	$903	2%	43%	55%
3	NWGF 95%	$755	8%	29%	63%	$743	11%	21%	68%
4	NWGF 98%	$656	17%	4%	79%	$758	16%	17%	67%

DOE SNOPR (GTI Scenario 0.55)		Senior				Low-Income			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$610	10%	71%	19%	$360	11%	71%	18%
2	NWGF 92%	$636	9%	65%	25%	$389	11%	66%	23%
3	NWGF 95%	$585	13%	47%	40%	$406	16%	50%	34%
4	NWGF 98%	$585	24%	20%	55%	$509	29%	25%	46%

Table 28 GTI Scenario Int-14.55 LCC Analysis Summary Results

Scenario Int-14.55		National				Replacement				New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$196	13%	79%	8%	-$232	17%	76%	7%	$309	1%	89%	10%
2	NWGF 92%	-$118	15%	73%	12%	-$182	19%	72%	10%	$239	4%	79%	17%
3	NWGF 95%	-$69	28%	53%	19%	-$139	32%	53%	16%	$171	15%	55%	30%
4	NWGF 98%	-$74	46%	24%	30%	-$121	52%	20%	28%	$121	24%	42%	34%

Scenario Int-14.55		North - Replacement				Rest of Country- Replacement			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$678	14%	84%	2%	-$47	21%	67%	12%
2	NWGF 92%	-$493	15%	79%	6%	-$23	22%	63%	14%
3	NWGF 95%	-$342	26%	63%	11%	-$18	38%	41%	21%
4	NWGF 98%	-$149	59%	8%	33%	-$85	45%	32%	23%

Scenario Int-14.55		North - New				Rest of Country- New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$203	2%	86%	12%	$494	0%	91%	8%
2	NWGF 92%	$153	5%	73%	22%	$404	2%	86%	12%
3	NWGF 95%	$13	22%	44%	34%	$466	7%	68%	25%
4	NWGF 98%	-$82	29%	37%	34%	$395	19%	49%	33%

Scenario Int-14.55		Senior				Low-Income			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$176	13%	81%	6%	-$475	15%	78%	7%
2	NWGF 92%	-$81	15%	76%	9%	-$455	18%	73%	9%
3	NWGF 95%	-$35	26%	57%	17%	-$371	31%	54%	15%
4	NWGF 98%	-$10	47%	23%	30%	-$276	53%	23%	24%

Table 29 DOE SNOPR TSL 5 (GTI Scenario 0) LCC Analysis Summary Results

DOE SNOPR (GTI Scenario 0)		National				Replacement				New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$582	18%	53%	28%	$361	24%	53%	23%	$1,263	3%	54%	43%
2	NWGF 92%	$617	17%	48%	35%	$620	22%	48%	30%	$620	3%	46%	51%
3	NWGF 95%	$561	22%	26%	51%	$561	26%	30%	44%	$561	11%	16%	73%
4	NWGF 98%	$506	34%	1%	65%	$417	26%	30%	44%	$417	11%	16%	73%

DOE SNOPR (GTI Scenario 0)		North - Replacement				Rest of Country- Replacement			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$430	12%	74%	13%	$334	36%	30%	34%
2	NWGF 92%	$496	11%	69%	20%	$386	33%	25%	41%
3	NWGF 95%	$492	14%	50%	36%	$405	39%	7%	54%
4	NWGF 98%	$248	14%	50%	36%	$378	39%	7%	54%

DOE SNOPR (GTI Scenario 0)		North - New				Rest of Country- New			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$1,360	2%	70%	28%	$1,210	3%	36%	62%
2	NWGF 92%	$1,172	3%	60%	38%	$1,180	4%	29%	67%
3	NWGF 95%	$773	9%	26%	65%	$949	14%	5%	82%
4	NWGF 98%	$573	9%	26%	65%	$907	14%	5%	82%

DOE SNOPR (GTI Scenario 0)		Senior				Low-Income			
TSL		LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$755	17%	57%	25%	$440	22%	52%	26%
2	NWGF 92%	$775	17%	51%	32%	$476	20%	47%	33%
3	NWGF 95%	$692	22%	30%	48%	$482	28%	27%	45%
4	NWGF 98%	$490	22%	30%	48%	$354	28%	27%	45%

Table 30 GTI Scenario Int-14 LCC Analysis Summary Results

Scenario Int-14		National				Replacement				New			
	TSL	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$203	20%	70%	10%	-$258	26%	65%	10%	$294	1%	87%	11%
2	NWGF 92%	-$149	22%	64%	15%	-$222	27%	59%	13%	$220	5%	75%	20%
3	NWGF 95%	-$104	35%	42%	23%	-$185	41%	39%	20%	$178	17%	50%	34%
4	NWGF 98%	-$104	54%	12%	34%	-$166	63%	5%	32%	$139	28%	34%	39%

Scenario Int-14		North - Replacement				Rest of Country- Replacement			
	TSL	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$698	15%	83%	2%	-$113	38%	44%	18%
2	NWGF 92%	-$519	17%	78%	6%	-$100	39%	40%	21%
3	NWGF 95%	-$361	28%	61%	11%	-$97	56%	15%	29%
4	NWGF 98%	-$163	61%	5%	33%	-$169	64%	5%	31%

Scenario Int-14		North - New				Rest of Country- New			
	TSL	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	$166	2%	86%	12%	$489	1%	89%	10%
2	NWGF 92%	$136	6%	73%	22%	$347	4%	79%	18%
3	NWGF 95%	$6	23%	43%	34%	$453	10%	58%	33%
4	NWGF 98%	-$88	30%	35%	35%	$396	25%	32%	43%

Scenario Int-14		Senior				Low-Income			
	TSL	LCC Savings	Net Cost	No Impact	Net Benefit	LCC Savings	Net Cost	No Impact	Net Benefit
1	NWGF 90%	-$166	19%	72%	8%	-$562	23%	67%	10%
2	NWGF 92%	-$88	21%	67%	12%	-$506	26%	62%	12%
3	NWGF 95%	-$57	33%	46%	20%	-$426	40%	41%	19%
4	NWGF 98%	-$40	55%	11%	34%	-$344	63%	8%	28%

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

- DOE's random baseline furnace assignment methodology remains technically flawed, with significant impact in terms of overstated rule benefits and understated rule costs. Replacing DOE's methodology with economic decision making criteria that monetizes non-economic factors changes both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and significantly reduces the financial benefit of the rule nationally, regionally, and by subgroup.
- A total of 13% of all residential trial cases and 55% of DOE's claimed rule benefit comes from a combination of builders and consumers that DOE inexplicably claims are willing to pay extra for lower efficiency furnaces – an irrational outcome that stems from DOE's technically flawed baseline furnace efficiency assignment.
- DOE's predictive LCC model results combine random decisions and selective application of economic decisions that overstate LCC savings compared to a CED framework methodology that monetizes non-economic factors.
- Key input data used in the DOE SNOPR LCC model are also inconsistent with market-based information. DOE's predictive LCC model results include engineering estimates of furnace prices that differ from available market data; marginal gas prices derived from the EIA 2014 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data; and condensing furnace shipment forecasts that are lower than the long term historical trend from AHRI shipment data. Taken together, the DOE input information and forecasts associated with using these variables overstate LCC savings compared to credible market data.
- GTI Integrated Scenario Int-14, based on rational consumer economic and non-economic decision criteria and modifications to DOE's input data, shows negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE) compared to the 80% AFUE baseline furnace, indicating that the 92% furnace proposed in the DOE SNOPR for a single product class as well as any other condensing furnace efficiency levels do not meet the EPCA requirement for economic justification of positive LCC savings and a payback period that is shorter than the equipment expected life.
- The GTI furnace sizing methodology based on annual heating consumption (GTI Sizing Scenario F1) provides the expected trend of increased LCC savings and reduced number of impacted homes as the non-condensing furnace capacity limit increases, whereas the DOE SNOPR methodology, based on building size, is insensitive to incremental changes in capacity limits due to the poor correlation between home size and required furnace capacity to meet the home heating load.
- GTI Integrated Scenario Int-14.55 (Including Scenario F1) combines limited ability to make economic decisions with a more market-sensitive furnace sizing methodology has significant implications for fuel switching compared to the flawed DOE methodologies. As shown by comparing fuel switching results in Table 22 and Table 25, the GTI methodologies predict a much more significant reduction in fuel switching with the second product class than the DOE methodologies. Under the DOE SNOPR, national average fuel switching per impacted building drops from 22.1% to 17.2%, a reduction of 4.9% - roughly a 22% change in fuel switching behavior. Under the GTI Int-14 and Int-

14.55 methodologies, national average fuel switching drops from 22.9% to 11.9%, a reduction of 11% - nearly a 50% change in fuel switching behavior.

- The significant reduction in fuel switching under GTI Scenario Int-14.55 compared to the DOE SNOPR also affects the national impact analysis. While consumer economics are still poor, the mitigation of fuel switching through a separate product class improves the national impact compared to a single product class rule.
- DOE's furnace market penetration methodology is insensitive to distinctions in condensing furnace market adoption in new construction compared to replacements. Since DOE's underlying framework is insensitive to market penetration, the impact of this flaw is not distinguishable in the DOE SNOPR results. Unfortunately, GTI SNOPR analysis scenarios could not address this flaw because no market data was available from AHRI or other sources. However, the impact of this flaw on the GTI market-sensitive methodology is to misallocate market segment benefits between new construction and replacements. Since new construction market share is likely to be higher than replacement market share without the rule, the market segment results in the GTI analysis may be slightly overstating new construction market segment LCC savings and slightly understating replacement market segment LCC savings.

3.3 Separate Product Class Based on Furnace Capacity Results

Table 31 shows LCC savings for the 92% AFUE TSL under GTI Scenario Int-14 compared to the DOE SNOPR LCC analysis results for a separate product class based on furnace input capacity, with and without the DOE downsizing methodology. Figure 17 through Figure 19 compare the incremental and cumulative savings for different furnace capacity limits ranging from 40 kBtu/h through 140 kBtu/h using the DOE SNOPR furnace sizing methodology and the annual heating consumption methodology (GTI Parametric F1). Figure 20 provides results for different market segments.

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

- GTI Integrated Scenario Int-14 cases show negative composite average lifecycle cost savings for a separate product class below 115 kBtu/h input capacity, and negative composite average lifecycle cost savings for a separate product class below 90 kBtu/h input capacity when adding DOE's furnace downsizing methodology. These findings align well with the empirical data analysis findings summarized in GTI Topical Report GTI-16/0003.
- LCC savings using the DOE SNOPR furnace sizing methodology show no trend with furnace size. This is consistent with the poor correlation between annual heating load and the DOE SNOPR random Base Case furnace assignment and sizing methodology.
- LCC savings using the GTI Integrated Scenario Int-14 furnace sizing methodology show a flat to negative trend with furnace size up to 110 kBtu/h without downsizing, and a strong upward trend for furnaces above 110 kBtu/h. This is consistent with the CED framework and the strong correlation between annual heating load and the furnace size.
- LCC savings using GTI Integrated Scenario Int-14 show a flat to negative trend with furnace size up to 90 kBtu/h when adding DOE's downsizing methodology, and a strong upward trend for furnaces above 90 kBtu/h. However, results using the DOE downsizing methodology are being confounded by the aggregating approach to cumulative LCC

savings used by DOE. The use of cumulative savings vs. incremental savings at each furnace capacity is misleading due to the significant rule benefits above 120 kBtu/h compared to smaller furnace capacity limit benefits. Incremental savings are masked when using the average savings approach because of the significant contribution to average savings at larger furnace capacity levels.

- There is no capacity limit that provides a net benefit to the low income market segment, under either a current market furnace sizing methodology or when adding the DOE furnace downsizing methodology.

Key findings of the scenario analyses conducted by GTI analysts to examine the impact of different furnace capacity limits for 80% AFUE furnaces on rule benefits using the DOE LCC spreadsheet and Crystal Ball predictive modeling software include:

- The DOE SNOPR furnace size assignment methodology based on home size and design outdoor air temperature derived from the RECS 2009 database is technically flawed and poorly correlated with heating consumption and furnace capacity required to meet peak heating and setback recovery loads.
- The lack of data in the RECS database on the key values of furnace AFUE and capacity makes it an inadequate source of information for use in the furnace capacity and annual heating load assignments used in the SNOPR, both for the single standard level and for separate standard levels based on furnace input capacity evaluated in the SNOPR. Additional market information is needed for this purpose.
- Detailed empirical data analysis described in GTI Topical Report GTI-16/0003 shows the expected high correlation between annual heating consumption and house “UA” (a combination of thermal efficiency and envelope area), a strong correlation between required furnace capacity and home “UA”, but a very poor correlation between annual heating consumption and home size (or UA and home size). Unfortunately, the lack of monthly gas consumption data and poor correlation between gas consumption, annual HDD, design outdoor air temperature, and peak heating load in the RECS database used by DOE in the SNOPR LCC spreadsheet model for each of the 10,000 trial cases precluded the use of the GTI empirical model with RECS database information.
- DOE’s furnace sizing methodology is not adequate for determining the benefits of different furnace capacity limits on LCC savings, providing inconsistent and misleading results due to the poor correlation between home size and required furnace capacity.
- A furnace capacity algorithm (GTI Parametric F1) developed by GTI analysts based on the RECS database annual heating consumption rather than home size has a relatively strong correlation between annual heating load and associated furnace size (R^2=0.69). The correlation between annual heating load and furnace size (R^2=0.69) is substantially better with the RECS annual heating consumption model than the correlation using the DOE furnace sizing methodology (R^2=0.11). This is an a priori expectation because annual heating consumption should have a fair to strong correlation with peak heating load, whereas home size has been demonstrated to have poor correlation with peak heating load for a variety of reasons. The RECS annual heating consumption model is also compatible with the furnace “downsizing” methodology used by DOE in the SNOPR proposed rule (TSL 6). It also provided the desired sensitivity to market conditions compared to the DOE methodology.

- The incremental cost of going to a higher efficiency furnace does not increase strictly proportionally to furnace size. For example, if an installer needs to put in venting to the outside it is not twice as expensive to vent a 100 kBtu/h furnace compared to a 50 kBtu/h furnace. Similarly, the cost of the furnace is not strictly proportional to size. The cost per Btu/h of a 100 kBtu/h furnace will be lower than the cost per Btu/h of a 50 kBtu/h furnace. However, LCC savings are strictly proportional to the heating load. So, if furnace sizing is responsive to load, a 100 kBtu/h furnace will cost less than twice what a 50 kBtu/h furnace costs, but it will save about twice as much energy. So LCC savings benefits increase as furnace size increases. In DOE's furnace sizing algorithm there is almost no connection between heating load and furnace size, so DOE's methodology is insensitive to that trend.
- Under an economic decision making framework with a low income distribution for fuel switching decisions, for the fewer and fewer remaining impacted cases, the rule benefits per home go up as a function of load. So at some point, rule benefits are net positive due to less irrational fuel switching at larger furnace sizes caused by the rule, coupled with proportionally higher LCC savings at larger furnace sizes.

Table 31: LCC Savings (92% AFUE TSL) with Furnace Capacity Product Class Options

Furnace Size (kBtu/h)	SNOPR, LCC savings at each size	SNOPR, cumulative average LCC savings	SNOPR, cumulative average LCC savings, with downsizing	Scenario F1, LCC savings at each size	Scenario F1, cumulative average LCC savings	Scenario F1, cumulative average LCC savings, with downsizing	Scenario Int-14, LCC savings at each size	Scenario Int-14, cumulative average LCC savings	Scenario Int-14, cumulative average LCC savings, with downsizing	Scenario Int-14, north, cumulative	Scenario Int-14, south, cumulative	Scenario Int-14, low-income, cumulative
40	$266	$617	$666	$440	$635	$644	-$460	-$149	-$138	-$309	-$65	-$506
45	$166	$624	$671	$547	$638	$643	-$197	-$144	-$138	-$310	-$56	-$502
50	$135	$636	$691	$499	$639	$683	-$224	-$143	-$118	-$307	-$54	-$502
55	$527	$669	$692	$664	$646	$684	-$133	-$138	-$149	-$313	-$37	-$473
60	$500	$674	$741	$413	$646	$748	-$221	-$138	-$83	-$312	-$32	-$469
65	#N/A	$699	$712	#N/A	$689	$765	#N/A	-$120	-$134	-$289	$18	-$537
70	$563	$699	$730	$575	$689	$780	-$155	-$120	-$140	-$289	$18	-$537
75	$559	$727	$727	$486	$713	$846	-$167	-$110	-$155	-$283	$78	-$657
80	$762	$770	$676	$622	$779	$881	$62	-$91	-$35	-$262	$154	-$814
85	#N/A	$773	$676	#N/A	$848	$881	#N/A	-$164	-$35	-$295	$74	-$891
90	$753	$773	$671	$567	$848	$947	-$96	-$164	$52	-$295	$74	-$891
95	$1,286	$780	$695	#N/A	$923	$947	#N/A	-$183	$52	-$307	$91	-$1,046
100	$652	$728	$452	$788	$923	$1,348	-$327	-$183	$224	-$307	$91	-$1,046
105	#N/A	$773		#N/A	$1,003		#N/A	-$61		-$139	$131	-$302
110	$817	$773		$636	$1,003		-$364	-$61		-$139	$131	-$302
115	$443	$763		#N/A	$1,088		#N/A	$48		-$29	$242	-$167
120	$876	$796		$623	$1,088		-$57	$48		-$29	$242	-$167
125	$686	$649		$1,233	$1,836		$78	$357		$323	$478	-$745
130	$561	$635		$1,354	$1,956		$178	$436		$419	$478	-$1,188
135	$202	$685		$1,504	$2,067		$299	$507		$507	$509	-$1,493
140	$522	$1,494		$1,568	$2,623		$457	$912		$1,321	$161	$0
145	#N/A	$6,031		#N/A	$3,723		#N/A	$1,561		$2,528	$271	$0
150	-$18	$6,031		$2,285	$3,723		$864	$1,561		$2,528	$271	$0
155	$12,079	$12,079		$2,635	$4,699		$825	$2,084		$2,625	$460	$0
160	#N/A	#N/A		$12,269	$12,269		$5,860	$5,860		$5,860	$0	$0

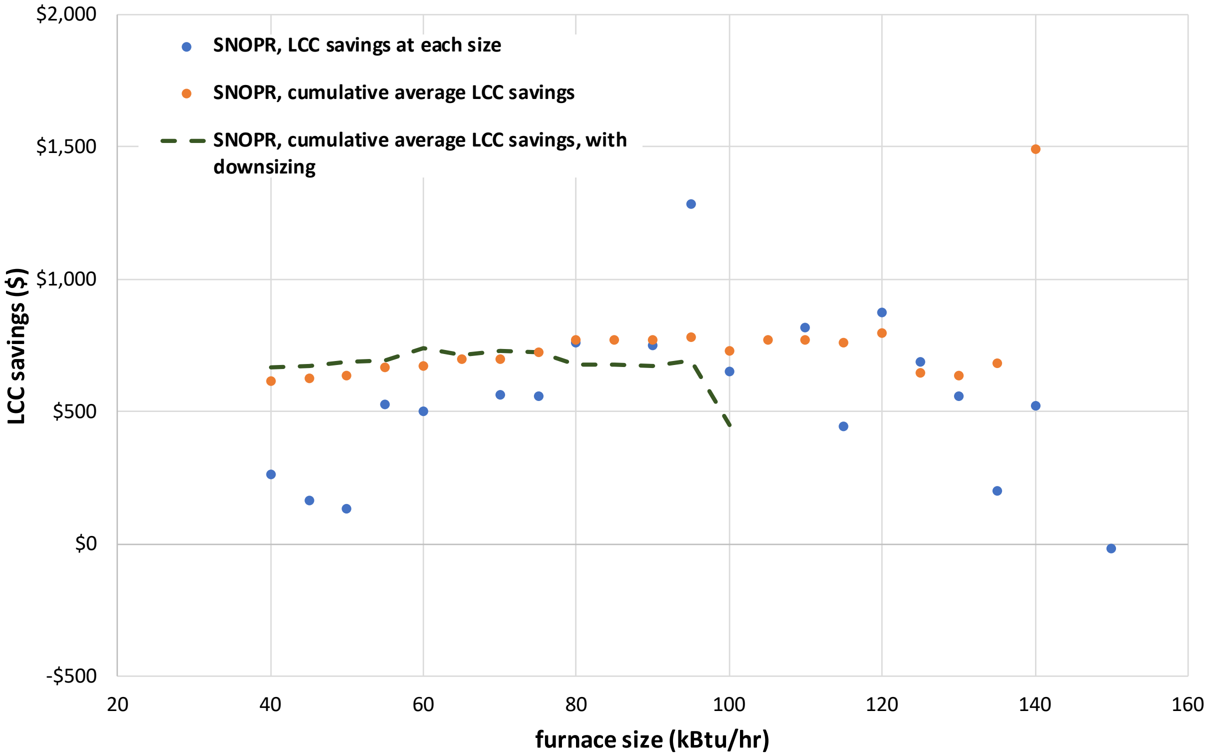

Figure 17: DOE SNOPR LCC Savings with Different Furnace Capacity Limits

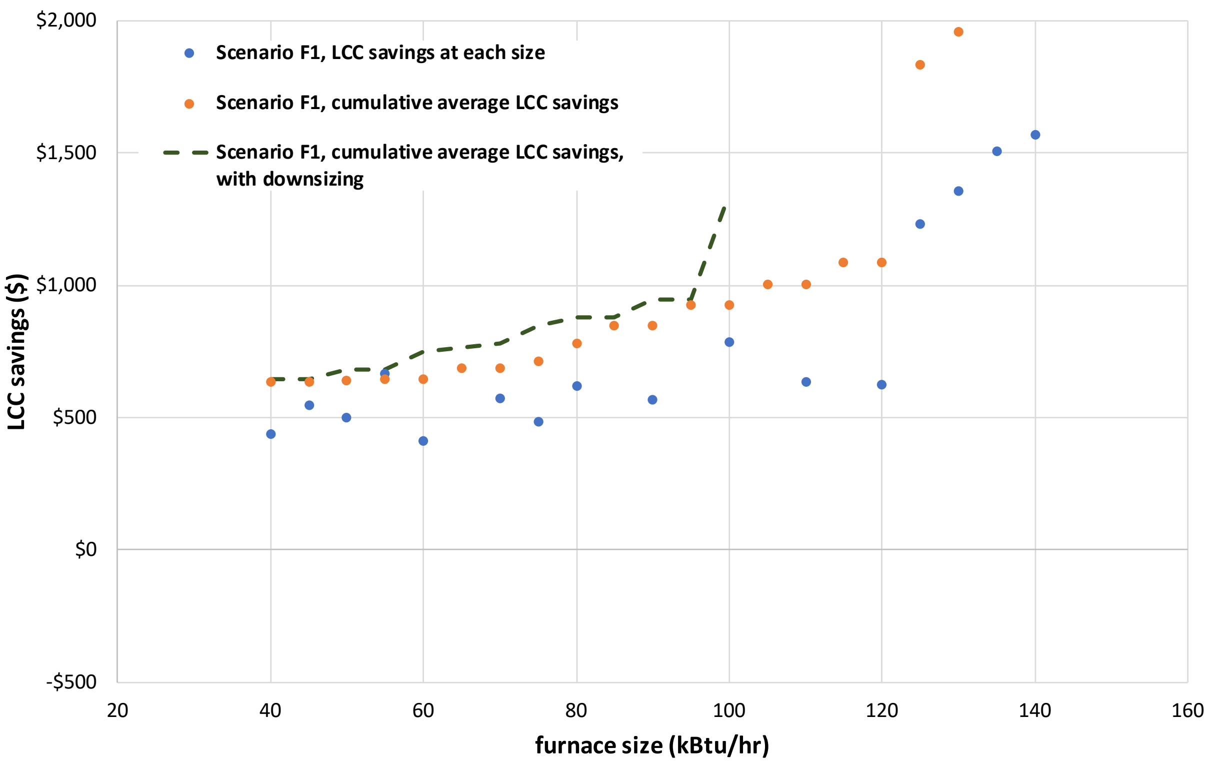

Figure 18: GTI Scenario F1 LCC Savings with Different Furnace Capacity Limits

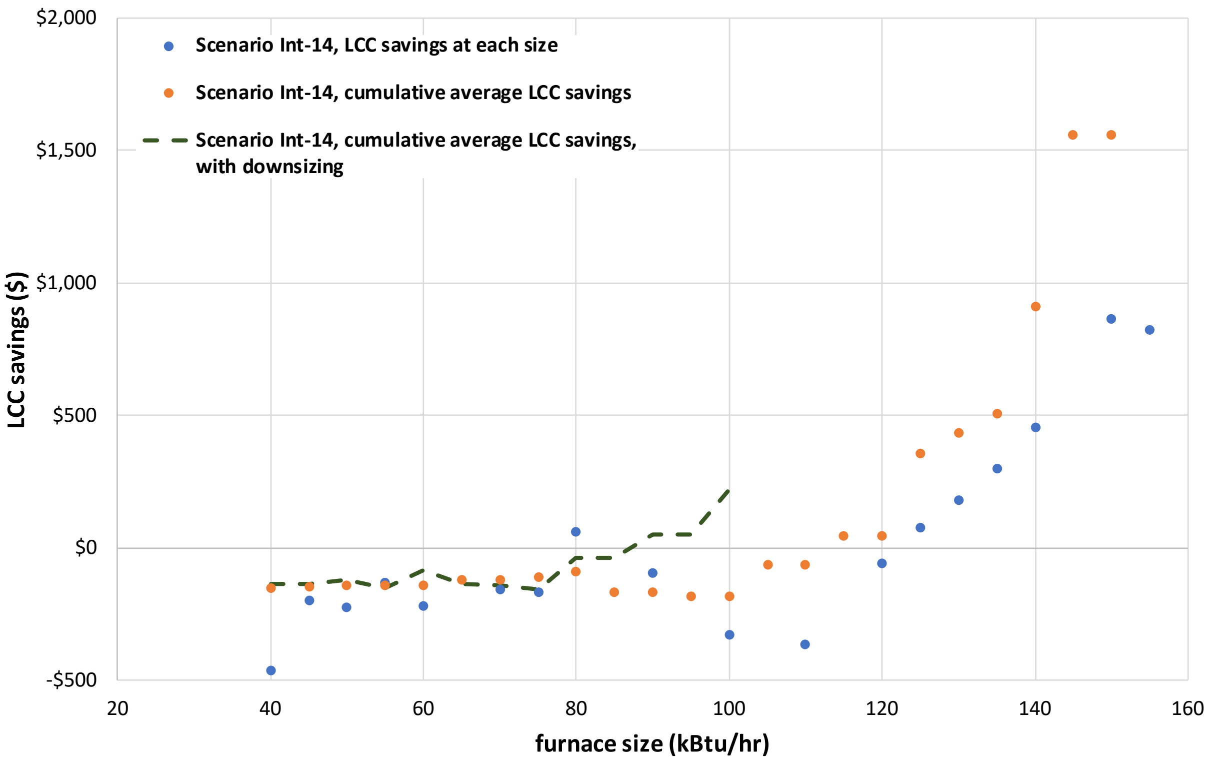

Figure 19: GTI Scenario Int-14 LCC Savings vs. Furnace Capacity Limits

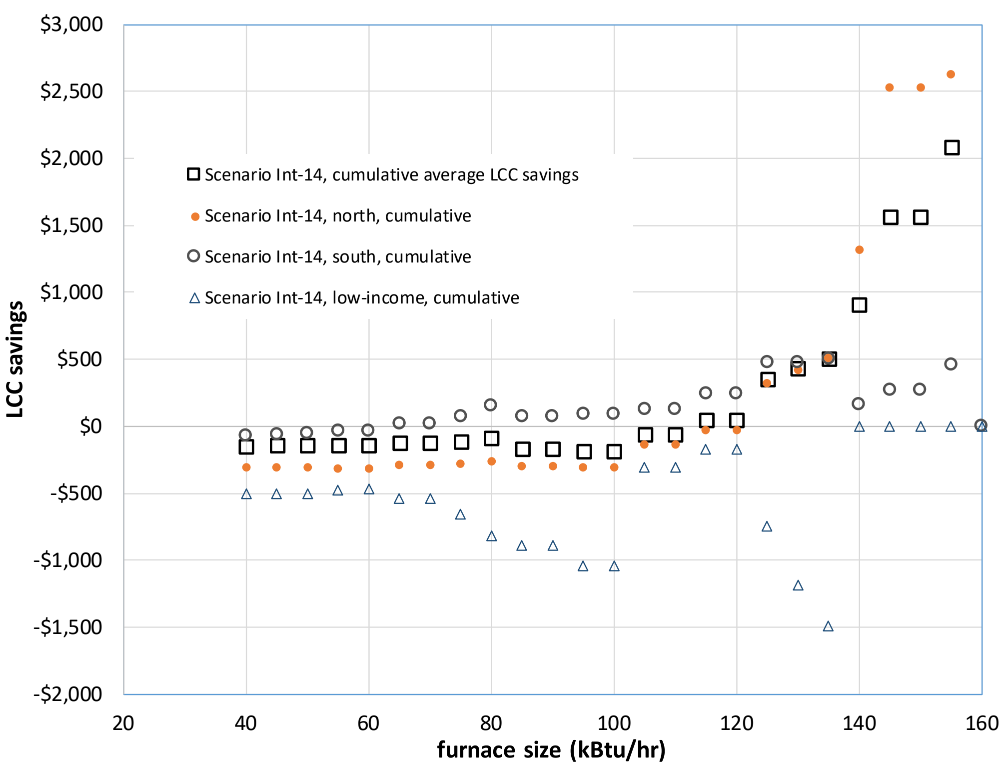

Figure 20: Regional and Low Income LCC Savings vs. Int-14 Furnace Capacity Limits

4 Implications of DOE SNOPR Methodology Technical Flaws

4.1 Random Base Case Furnace Assignment

In the SNOPR (Federal Register Vo. 81 No. 185, p 65789), DOE asserts that "*the assignment of furnace efficiency in the no-new-standards case is not entirely random.*" DOE further asserts that "*the method of assignment, which is in part random, may simulate actual behavior as well as assigning furnace efficiency based solely on imputed cost-effectiveness.*"

DOE's assertion that the Base Case furnace assignment is not entirely random is misleading and does not address the critical technical flaw in the DOE assignment methodology. In addition, the way DOE's LCC model results are calculated and displayed in the SNOPR masks this key technical flaw and meaningful disconnect with current and projected market behavior caused by the DOE random Base Case furnace assignment methodology.

When determining rule benefit per impacted building compared to the "no-new-standards" case, <u>the DOE Base Case furnace assignment methodology is entirely random</u>. The DOE SNOPR LCC model uses a random distribution function to assign the "Base Case AFUE" to each of the 10,000 trial cases, with the probability based on a specific region and building category, as illustrated in Figure 21.

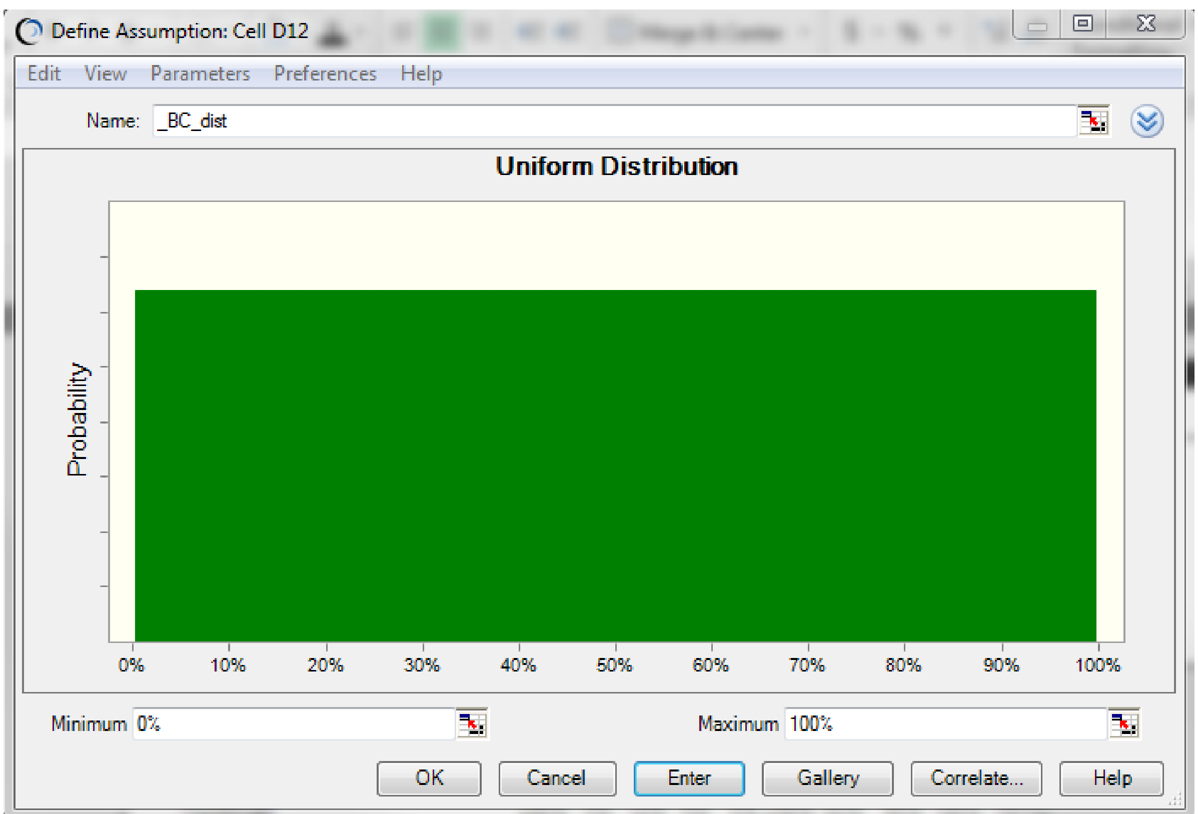

Figure 21: Random Assignment of Each Trial Case Base Case Furnace

In sheet "Base Case AFUE" cell D12, a uniform random number is generated by Crystal Ball. This random number is then used to determine the base case furnace efficiency using a lookup table based on DOE's regional estimates of condensing furnace shipment fractions applied to homes of a given major category in that region. This quasi-deterministic "not entirely random" approach changes the number of homes of a given type and region that are impacted by the rule, but it does not affect the projected savings or costs caused by the rule for an individual trial case building within that region.

The entirely random DOE Base Case furnace selection for an individual building does not consider any individual building's characteristics that significantly influence rule benefit and cost for that building, including size, age, annual heating load, heating energy consumption, rational economic decisions by builders for new construction, cost to replace existing furnaces, or other potentially important parameters when using this random number assignment approach. Any building of a given type in a given region has the same probability of being assigned a non-condensing furnace as any other building of that type in that region. As a result, any individual building is as likely as any other to be considered impacted by the rule in any given region and major building type.

The DOE random assignment approach results in a quasi-deterministic number of buildings of a given type within each of the 30 RECS or 9 CBECS regions that are considered not impacted by the rule because of the furnace shipment fractions in that region. But whether a specific trial case building will be one of those not impacted cases is strictly and totally random, dramatically biasing the model results "per impacted building" toward rule benefit.

DOE does not consider economics for decision making associated with Base Case AFUE assignment. The shipment data projections affect the number of impacted buildings only on a per region and type basis, not the LCC savings per impacted home, within a certain region and type, caused by a rule. For a given region and type the LCC savings per impacted building will be the same regardless of the condensing furnace shipment numbers. (new/replacement, residential/commercial).

DOE's assertion that *"the method of assignment, which is in part random, may simulate actual behavior as well as assigning furnace efficiency based solely on imputed cost-effectiveness"* is demonstrably false and disconnected from market behavior. The inherent result of the DOE SNOPR LCC model random assignment methodology is a finding of LCC savings in any region where LCC savings are present on average whether or not the shipment data projects a very high or very low rate of condensing furnace market share in the "no-new-standards" Base Case. For example, if market penetration of condensing furnaces is projected at 90% for a given region and type of home, and LCC savings associated with condensing furnaces is <u>on average</u> positive for the region, a net LCC savings due to rule would be determined by the model without consideration of the economics associated with the 10% of consumers impacted by the rule separate from the non-impacted group. This is a critical technical flaw in the model, as shown in Figure 22. The only way LCC savings on a national basis are affected by DOE's approach is by changing the number of impacted buildings based on region and type.

This has the effect of causing the DOE model to "find" LCC savings nationally as long as consumers on average benefit from condensing furnaces nationally. The model is a priori precluded from finding that, on average, the consumers that tend to benefit are the consumers that tend to purchase condensing furnaces.

To illustrate this effect and its significant impact on results, GTI analysts developed a simplified market penetration sensitivity scenario for different assumed initial condensing furnace market penetrations within the overall DOE analytical framework. For this analysis, it was necessary to remove the numerous confounding factors that mask the total market disconnect in DOE's results summaries that were caused by deterministic regional differences in market penetration of condensing furnaces. To isolate the known lack of market sensitivity of the DOE random methodology and compare it with the market-sensitive approach used in GTI Scenarios, only 80% and 92+% AFUE furnaces were considered in this analysis, and all regions were assigned the same market penetration.

Figure 22 highlights this key technical flaw when using the DOE random methodology. The graph compares results using the DOE methodology with results using the market-sensitive methodology in GTI Scenario Int-14 that incorporates a combination of rational economic and non-economic decisions in the Base Case furnace assignment methodology. This example illustrates the total disconnect from market conditions, with high bias toward rule benefit, when using the DOE random assignment methodology. This market disconnect and bias are necessarily the case when using the DOE random assignment methodology for this purpose. The DOE model is guaranteed to show LCC savings regardless of the modeled market's functional behavior. This critical flaw fundamentally undermines the DOE LCC model results.

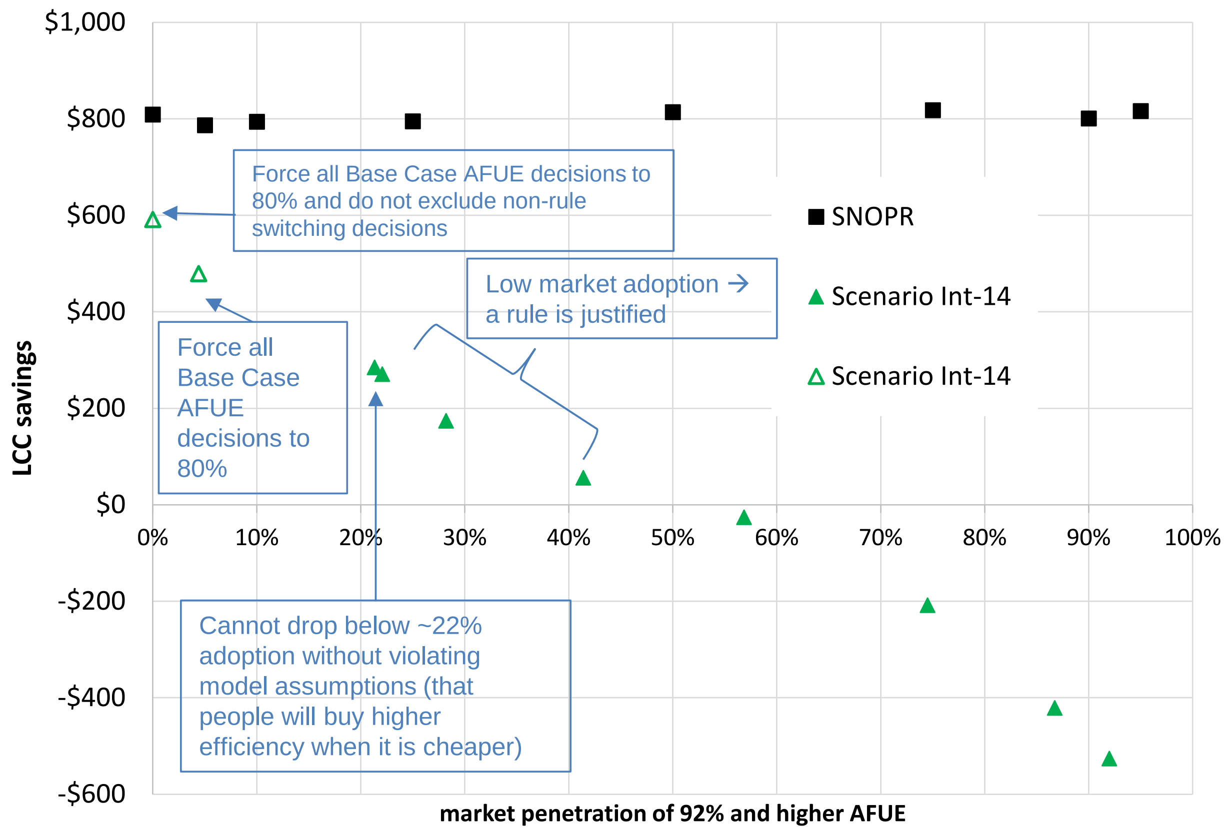

Figure 22: DOE LCC Model Market Disconnect Addressed by GTI Scenario Int-14

Figure 23 further illustrates the irrational disconnect from the marketplace when using the DOE random assignment methodology. As shown by the cumulative distribution function (CDF), with DOE's random Base Case furnace assignment of 80% AFUE furnaces in the new construction market in its LCC model, builders would willingly pay higher first cost for lower efficiency 75% of the time without the rule. Builders clearly do not have a split incentive, but – according to DOE – make obviously bad decisions for themselves most of the time according to the DOE methodology. This is a nonsensical, irrational result caused by the DOE random assignment methodology. Builders will not, in any significant number, hurt themselves directly by paying extra for a lower efficiency furnace that does not help them sell homes.

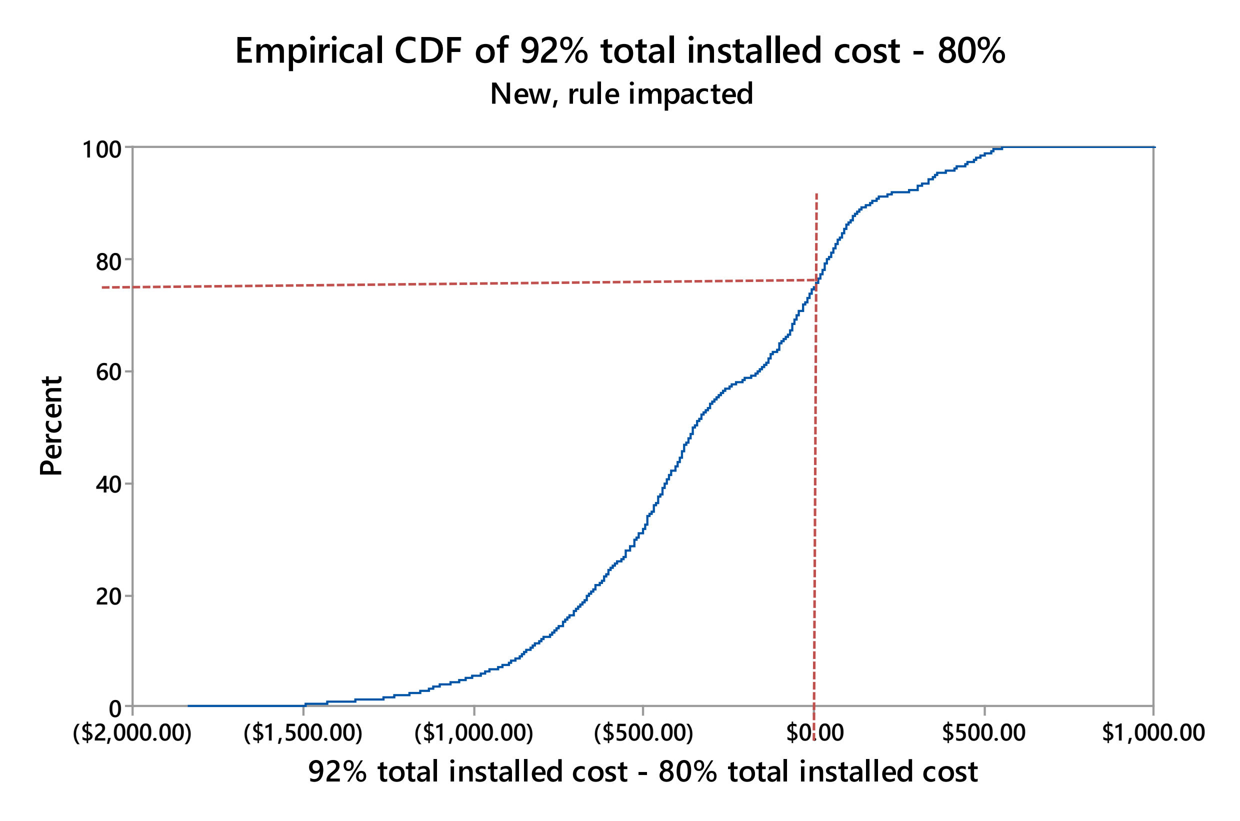

Figure 23: DOE Random Assignment Irrational Impact on New Construction

In contrast, GTI Scenario Int-14, including rational economic and non-economic factors in its decision algorithm, is sensitive to initial market conditions. This was also an a priori expectation using economic rather than random Base Case furnace assignment. The higher the initial condensing furnace market penetration for the LCC analysis, the less likely the rule will have remaining benefits for those consumers with more challenging economics such as difficult installation requirements (northern installations), long payback periods (southern installations), or residual new construction challenges (a very small fraction of new construction). DOE's assertion that these two fundamentally incompatible Base Case furnace assignment methodologies are equivalent from a market behavior perspective is demonstrably false.

4.2 AHCS Allowable Payback Period Distribution Based on Income

In the SNOPR, DOE asserts that the proprietary AHCS survey it used to develop a deterministic 3.5 year switching payback period did not provide sufficient information to develop a distribution function of fuel switching payback periods based on income or other factors that was transferable to its analytical framework. It further asserted that commenters did not provide such information or data. From Federal Register Vo. 81 No. 185, p 65792,

> *"DOE acknowledges that different consumers are likely to use different criteria when considering fuel switching, but the survey used by DOE does not provide sufficient information to derive a distribution of required payback periods that is transferable to DOE's methodology. Commenters did not provide any additional data on this point, nor did they suggest a more suitable source. As DOE is not aware of any better data source, it maintained its existing approach for this SNOPR."*

The necessary information was constructively available to DOE during its NOPR, NODA, and SNOPR development period, requiring only a brief supplemental interaction between LBNL and the study's author, Decision Analysts, after LBNL purchased the proprietary AHCS. As noted on Page 21 of GTI-15/0002:

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

Further evidence of the constructive availability of this information to DOE during the NOPR is from Page A-9 of GTI-15/0002:

> *"DOE used the AHCS to determine its switching payback period by converting the average amount consumers were willing to pay for an efficiency improvement combined with the average HVAC energy costs to arrive at a single switching payback period. However, the AHCS contains significantly more detailed information than simple averages. According to Decision Analyst, the AHCS is the largest knowledge base of homeowner behavior, perceptions, and attitudes related to energy efficiency, home comfort, and HVAC. Topics covered in the AHCS include:*
>
> - *The level of consumers' interest in energy efficiency*
> - *How consumers balance rising energy costs with home comfort*
> - *Consumers' willingness to spend money on home improvements to achieve energy efficiency*
> - *Home comfort differences by region and demographics*
>
> *It contains between 2,849 and 3,803 respondents in each of the years 2006, 2008, 2010, and 2013. It includes enough data to produce distributions of switching payback periods as a function of income groups to produce a more granular evaluation of fuel switching behavior than DOE incorporated into their analysis using the single point average switching payback period."*

Regarding the assertion that DOE was not able to transfer this information to DOE's analytical framework, GTI-15/0002 for the NOPR, specifically Section A.3.2 - Parametrics D1, D2, and D3, includes sufficient explanatory text to easily enable a shift from a deterministic value for switching payback period to a distribution function based on income group if DOE wanted to develop such a distribution.

As noted in that description, the distribution function based on income is important because the distribution is highly skewed, with long switching payback periods for higher income consumers skewing the average result. This makes the single 3.5 year average switching payback period used by DOE insensitive to market conditions and biased toward rule benefit. GTI SNOPR Scenario 36, including Parametric D2, addresses this skewed distribution in a conservative manner by averaging the allowable switching payback period distribution available from the four AHCS surveys in 2006, 2008, 2010, and 2013.

In the NOPR analysis described in GTI-15/0002, the minimum payback period that was allowed (smallest bin of payback periods) was 0.5 years. The analysis has been expanded in this report to use the amount consumers were willing to pay for efficiency improvements from the AHCS as well as how much consumers spent on space conditioning from the RECS database, both as a function of income. This controls both switching and Base Case AFUE decisions. Parametric D13 also included payback times down to 0 years which came from AHCS respondents that indicated they were willing to pay nothing for improved efficiency.

Table 32 shows the dramatic impact of using the full distribution of AHCS allowable payback periods on LCC analysis results. Incorporation of the full distribution of payback periods available within the AHCS data set drives poor economic decision making with respect to fuel switching which makes LCC savings negative across all groups. The data needed to incorporate the full distribution is included in data sets DOE already used for this analysis (AHCS and RECS).

Because the full AHCS distribution function did not align well with projected fuel-switching fractions associated with the DOE rule shown in the SNOPR, these scenarios were not selected for comparison with the DOE SNOPR overall results, but are shown here to illustrate the significant effect of including a distribution function rather than a single value for payback periods as a function of income.

Table 32: LCC Analysis Results Using Full AHCS Payback Period Distribution

Scenario		National	North	Rest of Country	Residential Replacement	Residential Replacement - North	Residential Replacement - Rest of Country	Residential New	Residential New - North	Residential New - Rest of Country	Senior Only	Low-Income
		LCC Savings Summary - 92% TSL										
DOE SNOPR	**LCC**	**$617.38**	**$711.32**	**$568.83**	**$420.49**	**$495.74**	**$386.11**	**$1,176.53**	**$1,171.96**	**$1,179.59**	**$775.23**	**$476.48**
	Number Affected	5247	1788	3459	3760	1179	2581	1345	539	806	706	431
GTI Scenario 2 (D2)	**LCC**	**$599.87**	**$690.32**	**$553.12**	**$408.57**	**$492.05**	**$370.43**	**$1,141.56**	**$1,110.40**	**$1,162.40**	**$745.51**	**$346.12**
	Number Affected	5247	1788	3459	3760	1179	2581	1345	539	806	706	431
GTI Scenario 32 (D13)	**LCC**	**-$1,928.77**	**-$3,282.13**	**-$1,035.96**	**-$1,592.35**	**-$2,597.29**	**-$1,066.43**	**-$4,751.53**	**-$6,011.94**	**-$907.29**	**-$1,506.69**	**-$2,353.64**
	Number Affected	4687	1863	2824	4014	1379	2635	567	427	140	640	407
GTI Scenario 33 (D8,D13)	**LCC**	**-$2,022.88**	**-$3,473.42**	**-$1,080.96**	**-$1,617.65**	**-$2,640.53**	**-$1,084.20**	**-$5,742.84**	**-$7,019.60**	**-$1,555.46**	**-$1,569.48**	**-$2,370.33**
	Number Affected	4605	1813	2792	3994	1369	2625	505	387	118	631	405
GTI Scenario 33&I16	**LCC**	**-$2,458.68**	**-$4,140.12**	**-$1,358.57**	**-$2,029.31**	**-$3,315.97**	**-$1,346.69**	**-$6,881.97**	**-$8,074.78**	**-$2,475.86**	**-$2,228.43**	**-$3,225.02**
	Number Affected	4579	1811	2768	4010	1390	2620	460	362	98	639	404

4.3 Uncertainty and Confidence Limits Applied to LCC Savings Results

DOE intends to make a rule based on LCC savings that are ~0.5% of life cycle costs using technically flawed methodologies and selective application of uncertainty principles. Because DOE will be interfering with the free market and regulated incentive programs that may already be working adequately without further intervention, it is critical for DOE to clearly demonstrate analytically that its rule is statistically distinguishable from the null hypothesis that the rule has no benefits. DOE has chosen to selectively use random or market-sensitive methodologies; deterministic, distribution, or random methodologies; and market data or engineering estimates coupled with highly uncertain future forecasts as the basis of its assertion that the DOE SNOPR LCC model savings are positive and meaningful. With the extensive number of variables and associated uncertainties, the DOE results may be statistically indistinguishable from the null hypothesis of no rule benefit.

In such cases, uncertainty in LCC savings requires methodologies that are sensitive to distributions of effects wherever known market behaviors include such distributions. This sets a high bar for what must be taken into account to make a positive finding of rule benefits when analytical benefits are so close to zero. DOE selectively uses a Monte Carlo analysis to acknowledge the complexity of the problem and uncertainty compared to a much simpler payback period analysis approach. But the DOE LCC model chooses to ignore known market uncertainties associated with several key parameters, including:

- Energy prices
- Furnace manufacturing costs
- Condensing furnace market penetration
- Consumer discount rates
- Labor costs

The AEO retrospective acknowledges the limited precision and accuracy of its own predictions of energy prices over time. But, DOE assumes these values are fixed and does not incorporate uncertainty into the Monte Carlo analysis. Similarly, DOE assumes that their estimates of manufacturing costs, condensing furnace market penetration forecasts, consumer discount rates, and labor costs contain no uncertainty. These factors are major drivers of the LCC savings. By selectively ignoring these sources of uncertainty, the DOE LCC model fails to arrive at a best estimate of overall uncertainty in LCC savings, further diminishing confidence in the DOE LCC model results.

4.4 Application of Non-Economic Factors in the CED Framework

In the SNOPR (Federal Register Vo. 81 No. 185, p 65790), "*DOE recognizes that its approach to allocating the efficiency level of a new gas furnace across RECS households within States may not fully reflect actual consumer behavior. However, it is far from clear that allocating the efficiency of furnaces based solely on estimated cost-effectiveness is likely to be any more accurate than the method currently used by DOE. An attempt to more explicitly model consumer choices across furnace efficiency would have to take into account the non-monetary preferences and market failures outlined above, in addition to the economic tradeoffs. At the present time, DOE does not have a method to include site specific economics as well as noneconomic decision making criteria in the Monte Carlo simulation, as suggested by ACEEE. However, this is an issue that DOE intends to investigate, and it welcomes suggestions as to how it might incorporate economic and other relevant factors in its assignment of furnace efficiency in its analyses.*"

DOE's assertion that a random approach to Base Case assignment is as accurate as a methodology based solely on estimated cost-effectiveness is inconsistent with DOE's findings elsewhere in the DOE SNOPR LCC model that incorporate rational economic decisions by various stakeholders, including consumers. For example, DOE chose to monetize the non-economic "comfort" value of the rebound effect when switching to a lower operating cost option such as a condensing furnace. To avoid use of a distribution function or other means of incorporating this effect, DOE simply assumed its monetary value to the consumer was exactly the same amount as the annual savings without consideration of the rebound effect. This selective use of monetizing consumer behavior increased rule benefits compared to the known reduction in energy savings due to the rebound effect in consideration of improved comfort.

DOE's approach to determining fuel switching decisions also used an economics-derived point at which consumers will make decisions about fuel switching. Under DOE's fuel switching decision methodology, consumers can and do think about economics when switching from gas to electric options. In contrast, the DOE random Base Case furnace assignment methodology asserts that these same consumers are somehow unable to consider economics when decided between two gas appliances.

DOE's citations used to support the contention that ignoring consumer decision making is as accurate as considering economic decision making do not support DOE's claims. Arguments in those citations align much more closely with the GTI CED framework, and make the point that many consumers aren't good at making decisions based on economics, especially long range economics or large purchases. Those citations refute rather than support DOE's contention that consumers do not think about economics at all when making decisions on large appliances, and therefore random assignment should be used instead of a CED framework.

In its furnace downsizing methodology, DOE assumes furnaces are improperly oversized in today's marketplace. Because of this perceived market failure, DOE concludes that a downsized furnace is still likely to meet consumer comfort needs and other utility functions provided by the furnace, such as offsetting incremental ventilation loads, reasonable setback recovery period, and accommodation of variations in building construction characteristics. DOE applies the analytical equivalent of consumer economic decision making by assuming a consumer runs a steady state peak load calculation and picks the furnace only on that criterion. DOE's "rational" downsizing decision approach ignores other utility functions of a furnace and the range of consumer risk tolerances regarding known variability in design calculations and accommodation of their own behavior (e.g., opening a window when it is -10°F outside for desired ventilation). It then connects this methodology to current furnace sizing practices that may already be accounting for such "oversizing" factors by using a simple adjustment factor. Regulation of installation practices such as furnace sizing in this rulemaking is being done using an analytical framework and underlying RECS database that were not intended for that purpose, and are demonstrably inadequate for use in regulations based on furnace size.

4.5 DOE SNOPR LCC Modeling Results Reporting Issues

Except for LCC Savings and Average and Median Simple-First Year Payback, other DOE SNOPR LCC reported results are based on the average of 10,000 trial cases, including the significant fraction of homes not impacted by the rule (e.g., 48% of trial cases are not impacted under TSL 5), rather than average of impacted trial cases only (e.g., 52% of trial cases under TSL 5). DOE's reporting choice is potentially important in operating cost, life cycle cost, and fuel switching fractions reporting, but it is highly misleading in favor of rule benefits when reporting payback period.

As shown in Table 33 and Table 34, the simple payback period for NWGFs is reported in SNOPR Table V.5 as 6.4 years for TSL 5, and 6.1 years for TSL 6 (the proposed rule). In contrast, the first year average payback period in the LCC spreadsheet analysis summary sheet, based only on impacted trial cases, shows a payback period of 13.9 years for TSL 5, a much longer, less misleading statistic.

Table 33: DOE SNOPR Table V.5 Results Based on Average of 10,000 Trial Cases

TABLE V.5—AVERAGE LCC AND PBP RESULTS FOR NON-WEATHERIZED GAS FURNACE AFUE STANDARDS

TSL	AFUE (%)	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
1	92/80*	2,375	652	10,512	12,887	6.1	21.5
2	92/80*	2,469	635	10,244	12,714	6.0	21.5
3	95/80**	2,552	625	10,108	12,661	6.4	21.5
4	92/80*	2,512	628	10,126	12,638	5.9	21.5
5	92†	2,635	612	9,859	12,493	6.4	21.5
6	92/80*	2,576	618	9,971	12,547	6.1	21.5
7	95†	2,742	597	9,608	12,350	6.5	21.5
8	95/80*	2,672	604	9,737	12,410	6.2	21.5
9	98 (Max-Tech)†	2,858	586	9,403	12,261	6.9	21.5

*The first number refers to the standard for large NWGFs; the second refers to the standard for small NWGFs. The input capacity threshold definitions for small NWGFs are as follows: TSL 1: 80 kBtu/h; TSL 2: 70 kBtu/h; TSL 4: 60 kBtu/h; TSL 6: 55 kBtu/h; TSL 8: 55 kBtu/h.
**The first number refers to the efficiency level for the North; the second number refers to the efficiency level for the Rest of Country.
†Refers to national standards.
Note: The results for each TSL are calculated assuming that all consumers use products at that efficiency level. The PBP is measured relative to the baseline product.

Table 34: DOE SNOPR LCC Analysis Summary Results for TSL 5

		Average LCC Results									Payback Results		
Level	Description	Installed Price	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	LCC Savings	Simple LCC Savings	Net Cost	No Impact	Net Benefit	Simple PBP	First Year Average	First Year Median
0	NWGF 80%	$2,175	$684	$11,020	$13,194	NA	NA	NA	100%	NA			
1	NWGF 90%	$2,597	$623	$10,026	$12,623	$582	$571	18.3%	53.5%	28.2%	6.8	17.7	8.9
2	NWGF 92%	$2,635	$612	$9,859	$12,493	$617	$701	17%	48%	35%	6.4	13.9	6.8
3	NWGF 95%	$2,742	$597	$9,608	$12,350	$561	$844	22%	26%	51%	6.5	12.2	7.8
4	NWGF 98%	$2,858	$586	$9,403	$12,261	$506	$934	34%	1%	65%	6.9	14.3	10.0

The DOE misleading payback period reported in the SNOPR is of concern for the NWGF analysis, but it may be even more significant for the MHGF analysis. DOE reports in its MHGF LCC analysis results (SNOPR Table V.7) that the simple payback period is 1.7 years, which would appear to satisfy the EPCA rebuttable presumption that the standard is economically justified if the additional cost to the consumer is less than three times the value of the energy savings during the first year. However, if the first year average payback considering only impacted cases is more than three years, the rebuttable presumption would no longer hold for the MHGFs.

The DOE SNOPR also contains a reporting error in cases in which it evaluated a separate product class based on furnace input capacity (SNOPR TSLs1, 2, 4, 6, and 8). When a trial case qualifies for NWGF downsizing, the equipment and installation costs calculated for the downsized 80% AFUE furnace are also being assigned to condensing furnace alternatives and consequently included in their average Installed Price, First Year Operating Cost, Life Time Operating Cost, LCC, and Simple PB reported in LCC spreadsheet Summary and Federal Register. This error does not impact LCC savings or first year average payback results because homes that qualify for 80% AFUE furnace downsizing exemption are excluded from the impacted population and therefore not included in calculation of averages for these two parameters.

In addition, downsized non-condensing furnace cases excluded from the analysis based on input capacity have their furnace price and installation cost calculated before downsizing. So a 60 kBtu/h furnace downsized to 55 kBtu/h is still priced as a 60 kBtu/h furnace. That inconsistency impacts average results for those parameters (e.g., Installed Price) reported by DOE as averages for all 10,000 trial cases.

DOE’s fuels switching reporting choice is also misleading. Fuel switching fractions reported in DOE SNOPR Table V.3 are 11.5% of all consumers under TSL5, and drop to 6.9% of all consumers under TSL 6 (the proposed rule). These reported fractions mask the true impact of the rule because they include all consumers rather than just impacted consumers, thereby reducing the apparent fuel switching fractions. In contrast, as shown in Table 22 of this report, the fuel switching fraction is 17.2% of remaining impacted consumers. While both statistics are valid, the DOE choice is insensitive to different scenarios and remaining relevant fuel switching caused by the rule.

5 National Primary Energy and Emissions Impact Assessment

The DOE SNOPR LCC model results provide input information to the DOE SNOPR National Impact Analysis (NIA) that is summarized in the DOE NIA spreadsheet. The underlying model used to estimate national impacts of the proposed rule is the National Energy Modeling System (NEMS) model, an economic and energy model of U.S. energy markets created and maintained by EIA (https://www.eia.gov/forecasts/aeo/nems/overview/pdf/0581(2009).pdf). NEMS projects the production, consumption, conversion, import, and pricing of energy. The model relies on assumptions for economic variables, including world energy market interactions, resource availability (which influences costs), technological choice and characteristics, and demographics. DOE's NIA spreadsheet summarizes the results of the NEMS model, but provides no opportunity to adjust impacts based on different LCC model results.

Few private sector organizations outside of EIA are staffed and equipped to run parametric analyses by modifying the NEMS model. GTI analysts do not have the resources necessary to manipulate and modify the NEMS model for a parametric analysis of national impacts in the DOE NIA model. Although GTI was not able to adjust the DOE NIA model inputs to determine the national impact of the DOE SNOPR LCC model technical flaws, the LCC analysis provided enough annual energy consumption information to estimate the national impact of the proposed rule, similar to the analysis that was conducted by GTI in response to the NOPR in 2015. GTI analysts had planned on conducting a 30 year analysis of the projected national impact of the proposed furnace rulemaking based on the DOE SNOPR LCC model results and the GTI Integrated Scenario Int-14.55 analysis results. However, due to the limited comment period and extensive effort to address LCC savings scenarios and issues, this analysis was not conducted.

Based on the annual energy and GHG emissions savings results, the a priori expectation is that the national impacts of the proposed rule would have been similar under GTI Integrated Scenario Int-14.55 compared to the DOE SNOPR NIA results.

6 Summary and Conclusions

DOE issued a SNOPR that proposes a single national standard at a minimum efficiency level of 92% AFUE for all MHGFs and for NWGFs above 55 kBtu/h input capacity. The SNOPR was published in the Federal Register on September 23, 2016 and open for a 60-day public comment period through November 22, 2016. The SNOPR supersedes the DOE NOPR published March 12, 2015, and updates information provided by DOE in a NODA published on September 14, 2015, containing a provisional analysis of the potential economic impacts and energy savings that could result from promulgating amended energy conservation standards for residential NWGFs that include two product classes defined by input capacity. Accompanying DOE's 134-page SNOPR was a 1,198 page technical support document (TSD) prepared for DOE by staff members of Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory (LBNL). The TSD includes a detailed review of the effects of the SNOPR as well as economic modeling and associated methodologies to assess consumer-level cost impacts, manufacturer impacts, and national impacts.

GTI conducted a technical and economic analysis of the DOE furnace SNOPR to evaluate the impact of the 92% AFUE minimum furnace efficiency requirements along with other TSLs on consumers, as well as the impact of a potential product class for small NWGFs. The GTI SNOPR analysis updates previous analyses conducted in response to the DOE NOPR and NODA. The GTI SNOPR analysis included:

- Comparison of DOE NOPR, NODA, and SNOPR results, along with updated versions of selected GTI analyses conducted in response to the NOPR and NODA;
- DOE SNOPR TSD modeling approach, assumptions, and results;
- DOE SNOPR LCC analysis spreadsheet and Crystal Ball model;
- An updated CED framework and related methodologies developed by GTI analysts to incorporate non-economic factors;
- Surveys (e.g., American Home Comfort Study) and data on input variables judged to have potential impact on LCC analysis results;
- Estimates of consumer benefits and costs associated with a national 92% furnace standard as well as other trial standard levels of furnace efficiency;
- Estimates of consumer benefits and costs associated with a national 92% furnace standard as well as other trial standard levels of furnace efficiency coupled with a national 80% furnace standard for a separate product class for non-weatherized gas furnaces based on input capacity; and
- Impact of AEO 2016 Clean Power Plan Scenario parameters on results.

Table 35 summarizes the difference in consumer impacts when comparing the DOE SNOPR LCC model results with GTI Scenario Int-14.55 for the proposed rule (SNOPR TSL 6, GTI Scenario 0.55) and with GTI Scenario Int-14 for a single national 92% AFUE standard (SNOPR TSL 5, GTI Scenario 0). Comparable results for the NOPR analysis (updated by DOE as SNOPR TSL 5) are also included for reference.

Table 35: SNOPR and NOPR Lifecycle Cost and Market Impact Comparisons

LCC Model Scenario	Average Furnace Life-Cycle Cost (LCC) Savings per Impacted Case	Fraction of Furnace Population (%)		
		Net Cost	No Impact	Net Benefit
DOE SNOPR TSL 6 (92%/55 kBtu/h)	$692	11%	60%	29%
GTI Integrated Scenario Int-14.55	-$118	15%	73%	12%
DOE SNOPR TSL 5 (92% all capacities)	$617	17%	48%	35%
GTI Integrated Scenario Int-14	-$149	22%	64%	15%
DOE NOPR (92% all capacities)	$520	20%	41%	39%
GTI NOPR Scenario Int-5	-$417	27%	57%	17%

The following Excel spreadsheets accompanying this report provide tabular results of the GTI parametric analysis of the DOE SNOPR:

- 22063 Short LCC tables - all EL 2016-11-21.xlsx,
- 22063 Short Switching Tables 2016-11-21.xlsx, and
- 22063 Energy Use Tables 2016-11-21.xlsx.

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

The GTI NOPR analysis, conducted in 2015 and described in detail in GTI-15/0002, "Technical Analysis of DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies" http://www.gastechnology.org/reports_software/Documents/21693-Furnace-NOPR-Analysis-FinalReport_2015-07-15.pdf, uncovered a serious technical flaw in the methodology DOE used to establish the homes that would be impacted by the proposed rule. Specifically, the Base Case furnace assignment algorithm used by DOE ignores any form of economic decision making by individual consumers or their representatives (e.g., builders or installing contractors). Instead, the Base Case AFUE, which is the efficiency of the furnace that is chosen by an individual consumer without the influence of DOE's rule, is assigned randomly in the DOE SNOPR LCC model. DOE's baseline furnaces in the 10,000 Crystal Ball trial case homes are intended to be representative of the 2009 Residential Energy Consumption Survey (RECS) furnace distribution across various locations and categories throughout the country projected out to 2022 (the first year the rule would be enforced). Random assignment of the baseline furnace does not achieve this objective. The economics of a particular efficiency level selection compared to other levels (e.g., 80% AFUE vs. 92% AFUE) are not considered in DOE's baseline furnace decision making methodology. DOE's methodology assumes that individual consumers or their representatives do not consider economics when choosing a furnace. This serious technical flaw resulted in significantly overstated LCC savings in the NOPR. Despite this finding, DOE chose to continue to use this technically flawed random methodology in the SNOPR, with similarly overstated LCC savings for each of the TSLs included in the SNOPR.

Examples of irrational results when using the DOE random Base Case furnace assignment include:

- Homes that would have selected a condensing furnace without the rule were randomly assigned 80% AFUE furnaces. This irrational assignment primarily affected new construction cases where the condensing furnace installed cost was less than the installed cost of an 80% AFUE furnace, and should therefore have been eliminated as “No Impact” cases. This has the effect of inflating the benefits of the proposed rule by taking credit for unwarranted LCC savings.
- Homes that would have selected an 80% AFUE non-condensing furnace without the rule were randomly assigned condensing furnaces. This irrational assignment primarily affected replacements having extremely long payback periods for condensing furnaces, and should therefore have been “Net Cost” cases. This inflates the benefits of the proposed rule by not including appropriate LCC costs.

The GTI NOPR analysis conducted in 2015 also uncovered a serious technical flaw in the methodology DOE used in its fuel switching analysis in the NOPR. DOE used a single switching payback value of 3.5 years for fuel switching decisions in its algorithm based on an average tolerable payback period for more efficient appliance purchases derived from proprietary American Home Comfort Study (AHCS) survey information. However, more detailed inspection of the available granular AHCS information showed that tolerable switching payback periods are a strong function of income and are dominated by large numbers of very low payback periods, with small numbers of much larger payback periods. This skewed distribution by income level reduces the benefit of the proposed rule compared to DOE’s single average switching payback period approach whenever the rule induces low income consumers with low tolerable payback periods to fuel switch to low first cost options despite negative LCC impacts. In addition, the DOE fuel switching analysis includes as a rule benefit cases in which rational fuel switching would accrue significant incremental benefits to the consumer compared to the TSL furnace. These cases would likely cause fuel switching without the rule in an unregulated market, and would be considered “No Impact” cases when using economic criteria for incremental technology and fuel switching decisions. Despite this finding, DOE chose to continue to use this technically flawed single switching payback period methodology in the SNOPR, with similarly overstated LCC savings for each of the TSLs included in the SNOPR.

Key input data used in the DOE SNOPR LCC model are also inconsistent with market-based information. DOE used engineering estimates of furnace prices that differ from available market data. DOE’s marginal gas prices derived from the EIA 2014 NG Navigator state level reporting of natural gas sales and revenues differ from gas companies’ tariff data to supplement EIA data; and condensing furnace shipment forecasts that are lower than the long term historical trend from AHRI shipment data. Taken together, the DOE input information and forecasts associated with using these variables overstate LCC savings compared to credible market data.

As described in GTI-15/0002, GTI developed a set of integrated scenarios for the DOE NOPR LCC model analysis that remain relevant for the SNOPR analysis. GTI Integrated Scenario Int-5 included several refinements to the DOE NOPR LCC model, including rational consumer economic decision making and improved input data, and formed the primary basis for comparison to DOE's analysis of its proposed furnace efficiency standards in the NOPR. Other technically defensible scenarios based on different assumptions and factors were included in GTI-15/0002 for reference purposes and were not updated in the GTI SNOPR analysis.

The GTI SNOPR analysis incorporated several integrated scenarios that incorporate updated decision making, input data, and furnace sizing parametrics and provide technical information related to issues on which DOE seeks comments in the DOE SNOPR. In response to DOE assertions in the SNOPR about non-economic and imperfect market decision making factors, GTI analysts developed an LCC model approach to address these factors. Scenarios of interest addressed in the GTI SNOPR analysis focused on updating the GTI NOPR CED framework to incorporate non-economic decision making criteria, and development and application of alternative furnace sizing methodologies. Building on the GTI NOPR analysis, GTI SNOPR analysis scenarios include distribution functions that accommodate additional non-economic factors in the CED framework; and a furnace sizing algorithm linked to the RECS database annual heating consumption that examines the impact of different furnace capacity limits for 80% AFUE furnaces on rule benefits, including national, regional, new construction, replacement, senior, and low income segment impacts. GTI Integrated Scenarios Int-11 through Int-14 and Int-11.55 through Int-14.55 address these issues.

GTI SNOPR Scenario Int-14, an updated version of GTI NOPR Scenario Int-5, was selected for comparison with the 92% AFUE single product class TSL 5 in the SNOPR (GTI Scenario 0) to address the following issues:

- Base Case furnace assignment that aligns with AHRI condensing furnace fractions and economic decision making criteria,
- Application of American Home Comfort Study information for fuel switching decisions that results in reasonable alignment with DOE fuel switching fractions when using a CED framework for Base Case furnace assignment and fuel switching decisions,
- Improved data for furnace prices, condensing furnace fractions, and marginal gas prices,
- Incorporation of AEO 2016 Clean Power Plan Scenario forecast information for comparisons with anticipated DOE final rule benefits calculations, and
- Application of a time-horizon-based distribution function based on the DOE LCC model payback period for each of the 10,000 trial cases for consumer economic decision making that monetizes the impact of imperfect market and non-economic consumer decision making factors into the LCC analysis for comparisons within the GTI CED framework.

GTI Scenario Int-14.55, one of the cases under Scenario Int-14, was selected to examine the impact of a 55 kBtu/h furnace capacity limit for 80% AFUE furnaces on rule benefits for direct comparisons with the DOE SNOPR proposed rule TSL 6 (GTI Scenario 0.55). GTI Scenario Int-14.55 includes a furnace capacity algorithm based on RECS annual heating consumption rather than home size and uses the DOE furnace "downsizing" methodology.

Key findings of the GTI SNOPR scenario analyses include:

- GTI Integrated Scenarios Int-14.55 and Int-14, based on consumer economic and non-economic decision criteria coupled with refinements to DOE's inferior input data and an improved furnace sizing algorithm, each show negative composite average lifecycle cost savings for all four condensing furnace trial standard levels (90%, 92%, 95%, and 98% AFUE). Based on these findings, there is no economic justification for the proposed rule of a 92% AFUE for NWGFs above 55 kBtu/h input capacity (DOE SNOPR TSL 6), a single product class 92% AFUE national furnace efficiency level (DOE SNOPR TSL 5), or any other condensing furnace efficiency levels with or without the 55 kBtu/h input capacity limit.
- GTI Integrated Scenario Int-14 cases run with different 80% AFUE furnace input capacity limits ranging from 40 kBtu/h to 160 kBtu/h show negative composite average lifecycle cost savings for a separate product class below 115 kBtu/h input capacity, and negative composite average lifecycle cost savings for a separate product class below 90 kBtu/h input capacity when adding DOE's furnace downsizing methodology. These findings align with the empirical data analysis summarized in Topical Report GTI-16/0003, "Empirical Analysis of Natural Gas Furnace Sizing and Operation."
- There is no capacity limit that provides a net benefit to the low income market segment, under either a current market furnace sizing methodology or when adding the DOE furnace downsizing methodology.
- The overall market relevance of the proposed rule is reduced in Scenario Int-14.55 and Int-14, with more furnaces in the "No Impact" category than the comparable DOE scenarios. Through application of rational economic decision making criteria that also incorporates non-economic factors, coupled with other analytical refinements incorporated into GTI Integrated Scenario Int-14.55 and Int-14, the number of consumers with a "Net Benefit" is reduced and the portion of consumers who experience an increase in "Net Cost" rises. Together, these impacts result in negative Life-cycle Cost Savings under Scenarios Int-14.55 and Int-14.
- DOE's random Base Case furnace AFUE assignment methodology remains technically flawed and is meaningfully disconnected from market factors, resulting in overstated LCC savings in the SNOPR compared to market-sensitive consumer economics methodologies. A total of 13% of all residential trial cases and 55% of DOE's claimed rule benefit comes from a combination of builders and consumers that DOE inexplicably claims are willing to pay extra for lower efficiency furnaces.
- Replacing DOE's technically flawed methodology with rational economic decision making criteria that incorporates non-economic factors in the GTI CED framework as applied in GTI Integrated Scenario Int-14 cases substantially shifts both the characteristics and fractions of "Net Benefit" and "No Impact" consumers and appreciably lowers the LCC savings of the proposed rule.
- DOE's random Base Case furnace AFUE assignment methodology is insensitive to assumed initial year market penetration of condensing gas furnaces, providing the same level of benefit irrespective of variations in assumed market penetration of condensing furnaces in the initial year of the analysis. The GTI methodology is demonstrably sensitive to market penetration of condensing furnaces in the initial year of the analysis, indicating a close connection to market factors compared to the DOE random assignment approach that is insensitive to the key market factor of interest for this rulemaking.

- The DOE SNOPR LCC model results overstate LCC savings compared to the updated CED framework included in the GTI LCC analysis. This occurred because DOE used a combination of random decisions and limited application of economic decisions in the fuel switching algorithm. The DOE fuel switching decision algorithms do not consider low income economics, while the GTI CED framework methodology using a full distribution of economics across incomes provides a reasonable and conservative fuel switching decision making algorithm for low income consumers.
- The DOE SNOPR LCC model results include inferior input data than the input data selected for inclusion in GTI Integrated Scenario Int-14 cases. The DOE SNOPR LCC model includes engineering estimates of furnace prices that differ from available furnace price market data. Marginal gas prices derived from the EIA 2014 NG Navigator state level reporting of natural gas sales and revenues that differ from using gas companies' tariff data to supplement EIA data. DOE's condensing furnace shipment forecasts are based on three years of statistics (2012-2014) from the AHRI shipment data that were impacted by residual effects of the removal of incentives in 2011, and are substantially lower than the long term historical trend from AHRI shipment data. Based on this trend line, GTI Scenario Int-14 uses condensing furnace shipment fractions of 62.5% (National), 84.1% (North), and 38.6% (Rest of Country) for the 2022 baseline instead of DOE's 2022 furnaces shipment fractions of 53.1% (National), 73.7% (North), and 30.2% (Rest of Country). Taken together, the DOE input information associated with these parameters overstates DOE SNOPR LCC savings compared to credible market data.
- The lack of data in the RECS database on the key values of furnace AFUE and capacity makes it an inadequate source of information for use in the furnace capacity and annual heating load assignments used in the SNOPR, both for the single national standard level and for separate standard levels based on furnace input capacity evaluated in the SNOPR. Additional market information is needed for this purpose.
- The DOE SNOPR furnace size assignment methodology based on home size and design outdoor air temperature derived from the RECS database is technically flawed and poorly correlated with home heating consumption and furnace capacity required to meet peak heating and thermostat setback recovery loads.
- DOE's furnace sizing methodology is not adequate for determining the benefits of different furnace capacity limits on LCC savings, providing inconsistent and misleading results due to the poor correlation between home size and required furnace capacity.
- LCC savings using the DOE SNOPR furnace sizing methodology show no trend with furnace size. This is consistent with the poor correlation between annual heating load and the DOE SNOPR random Base Case furnace assignment and sizing methodology.
- A furnace capacity algorithm (GTI Parametric F1) developed by GTI analysts based on the RECS database annual heating consumption rather than home size has a relatively strong correlation between annual heating load and associated furnace size (R^2=0.69). The correlation between annual heating load and furnace size (R^2=0.69) is substantially better with the RECS annual heating consumption model than the correlation using the DOE furnace sizing methodology (R^2=0.11). This is an a priori expectation because annual heating consumption should have a fair to strong correlation with peak heating load, whereas home size has been demonstrated to have poor correlation with peak heating load for a variety of reasons. The RECS annual heating consumption model is also compatible with the furnace "downsizing" methodology used by DOE in the SNOPR

proposed rule (TSL 6). It also provided the desired sensitivity to market conditions compared to the DOE methodology.

- Detailed empirical data analysis described in Topical Report GTI-16/0003 shows the expected high correlation between annual heating consumption and house “UA” (a combination of thermal efficiency and envelope area), a strong correlation between required furnace capacity and house “UA”, but a very poor correlation between annual heating consumption and home size (or UA and home size). Unfortunately, the lack of monthly gas consumption data and poor correlation between gas consumption, annual HDD, design outdoor air temperature, and peak heating load in the RECS database used by DOE in the SNOPR LCC spreadsheet model for each of the 10,000 trial cases precluded the use of the house UA empirical data with RECS database information.
- GTI SNOPR Integrated Scenario Int-14.55 and Int-14 results differ from the GTI NOPR Scenario Int-5 results that showed increased annual primary energy consumption and greenhouse gas emissions for SNOPR TSL 5 compared to the “no rule” baseline. In the SNOPR analysis, both GTI Integrated Scenario Int-14.55 and Int-14 results and the DOE SNOPR LCC model results show decreased annual source energy consumption and greenhouse gas (GHG) emissions, though the GTI scenarios show smaller reductions than the DOE scenarios. Due to time constraints, the reason for the different result between the NOPR and SNOPR was not investigated in detail, but may be related to the DOE heating load calculation error in the NOPR that reduced the rule benefits compared to the SNOPR.
- GTI analysts had planned on conducting a 30 year analysis of the projected national impact of the proposed furnace rulemaking based on the DOE SNOPR LCC model results and the GTI Integrated Scenario Int-14.55 analysis results. However, due to the limited comment period and extensive effort to address LCC savings scenarios and issues, this analysis was not conducted.Based on the annual energy and GHG emissions savings results, the a priori expectation is that the national impacts of the proposed rule would have been similar under GTI Integrated Scenario Int-14.55 compared to the DOE SNOPR NIA results.

Appendix A Supplemental Information

A.1 VBA Code for Detailed Parametric and Scenario Analysis

This report contains a higher degree of granularity than exists in the DOE LCC spreadsheet model and published results. Many of the desired outputs of DOE's model were not provided in sufficient detail to conduct analysis on individual case and subcategory results. The addition of Visual Basic for Application (VBA) code that exported outputs of interest to a new spreadsheet enabled this level of detailed analysis. The VBA code used for this purpose stepped the baseline model through each of the 10,000 individual trials while the Crystal Ball simulation was running and enabled capture of key information related to individual trial cases. The VBA code to capture data output did not affect the calculation of any parameters for the DOE SNOPR LCC Model (referred to as Scenario 0 and Scenario 0.55 in this report and accompanying spreadsheets). Nor did it affect the calculations in any of the GTI parametric runs that examined the decision making methodology, input data assumptions, and integrated scenarios. However, additional VBA code was added as necessary to apply GTI parametric decision making methodology algorithms described in this Appendix.

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

A.2.1 DOE Base Case Furnace Efficiency Levels

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

DOE includes two conflicting assumptions in its SNOPR LCC model that combine to overstate the number and type of impacted trial cases. DOE assumes that it is reasonable to linearly extrapolate condensing furnace shipments into the future, while simultaneously assuming that condensing furnace installed costs will drop relative to 80% AFUE furnaces. The combination of these two assumptions causes more cases to be considered "Net Benefit" than would experience first cost increases when selecting a condensing furnace. Using DOE's combined assumptions, some Base Cases choose lower efficiency furnaces even when higher efficiency ones are less expensive. This is especially true in new construction.

Similarly, cases where the payback for the 92% AFUE furnace was very poor, DOE's random assignment algorithm selected these cases as "No Impact," i.e., not affected by the DOE rule. According to DOE's random assignment methodology, the consumer would have freely chosen a 92% or higher efficiency furnace even though the simple payback period exceeds 100 years, causing that consumer to incur a financial loss. Under an economic decision making algorithm, such as Scenario 24, most consumers with long payback periods would have been considered "Net Cost," i.e., negatively affected by the DOE rule, and would have been included in the LCC calculations, reducing the overall benefit of the rule. Another flaw in the random assignment methodology is the rational fuel switching that would be expected to occur if the fuel switch to a low cost (compared to an 80% AFUE furnace), efficient electric technology is a superior choice to the 92% furnace, as is the case in Crystal Ball trial case 8785. In that case, rational fuel switching is considered unregulated market behavior and is excluded from the economic decision making scenarios as "No Impact" as well, but for economic reasons, not by random assignment.

A.2.2 DOE Fuel Switching Decision Making Methodology

Unlike the random decisions in the Base Case AFUE assignment, decisions on whether or not a consumer will choose a fuel switching option are based on consumer economics in the baseline DOE LCC model. Figure 7 in the main report describes GTI's understanding of the DOE LCC fuel switching decision-making process flow chart. The flow chart aligns with the process that is coded into the LCC spreadsheet rather than the limited description in the TSD. Cases that have selected a furnace with efficiency higher than 80% in the Base Case AFUE sheet are excluded from fuel switching in the LCC&PB Calcs sheet in a large range of cells in columns P through DG using statements like "=IF(AND(optSwitch=1, Index(iBase,1=0),…" which has the effect of verifying that fuel switching in the DOE model is turned on and that the selected furnace is an 80% AFUE furnace. Cells D63 through D66 in the DOE NWGF switching sheet look for cases that have negative payback and cases that have payback periods above the 3.5 year "switching payback period" (a term explained below) set in cells D48 and D49 in the same sheet. They are coded by DOE such that negative payback options will be selected first, followed by those with the largest switching payback period over the 3.5 year payback period threshold.

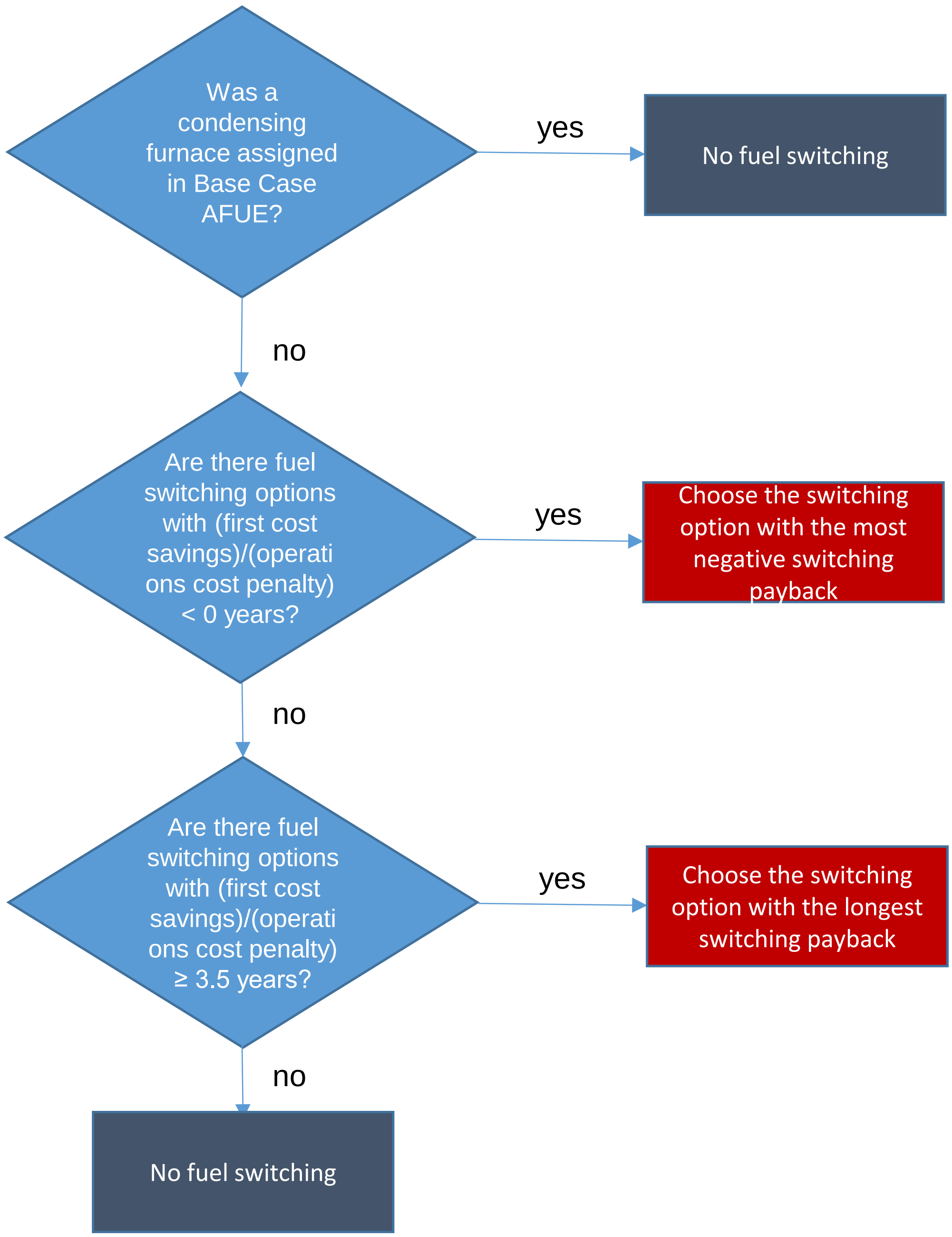

Figure 24 GTI Illustration of DOE Fuel Switching Logic Flow Chart

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

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

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

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

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

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

A.3 GTI Decision Making Parametrics

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

A.3.1 Parametrics D1, D2, and D3

Figure 25 shows the effect of the switching payback period on LCC savings in the DOE model. This was generated simply by changing the values of cells D48 and D49 in the NWGF Switching sheet. The distribution of LCC savings is non-linear. Because of the shape of the response, any distribution of switching payback periods with an average of 3.5 years will have lower LCC savings than the use of a single 3.5 year switching payback period. The data available in the AHCS contains a wide distribution of payback periods that are a function of household income. These factors motivated the development of parametric modifications to the baseline model which represent more thoroughly the detailed distribution of consumer preferences in the AHCS.

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

- The level of consumers' interest in energy efficiency

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

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

Figure 26 shows the full distribution of switching payback periods from the AHCS for each income group, calculated following the DOE methodology described in the TSD but for the whole distribution of data from the AHCS instead of an average. The distribution of responses reported by Decision Analyst was used to simulate 5,000 data points for each income group in each of the four years (2006, 2008, 2010, and 2013) of the AHCS. Data from all four years were combined to yield the distributions shown.

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

Histograms shown in Figure 27 for the highest and lowest income groups from the 2010 AHCS data further illustrate the skewed allowable switching payback distribution. As shown in Figure 25, switching payback periods much shorter than 3.5 years have a significant negative effect on LCC savings while switching payback periods much greater than 3.5 years have little positive incremental effect on LCC savings. Application of a single average value to this skewed distribution as DOE continued to do in its SNOPR LCC model overstates LCC savings compared to using the full distribution of switching payback periods as was done in the GTI scenarios.

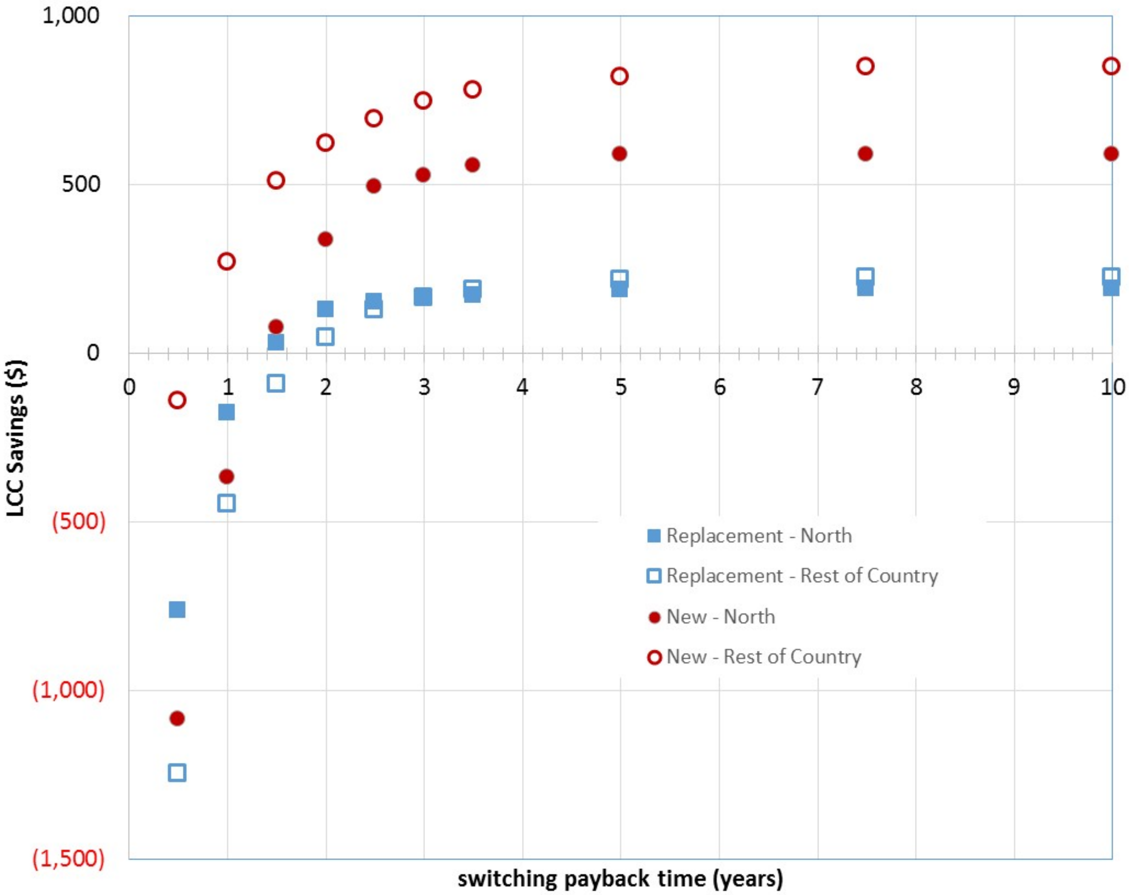

Figure 25 Non-linear LCC Savings Distribution vs. Switching Payback Period

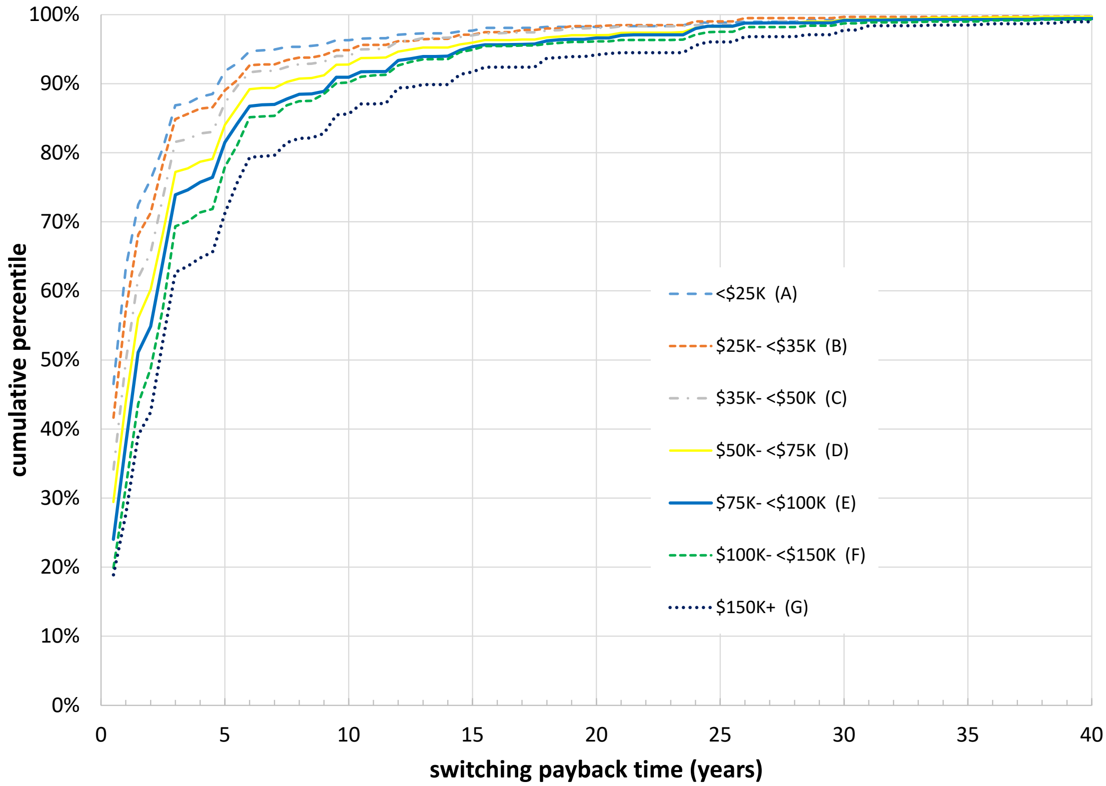

Figure 26 Switching Payback Distribution for Different Income Levels

Source: American Home Comfort Study[5]

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

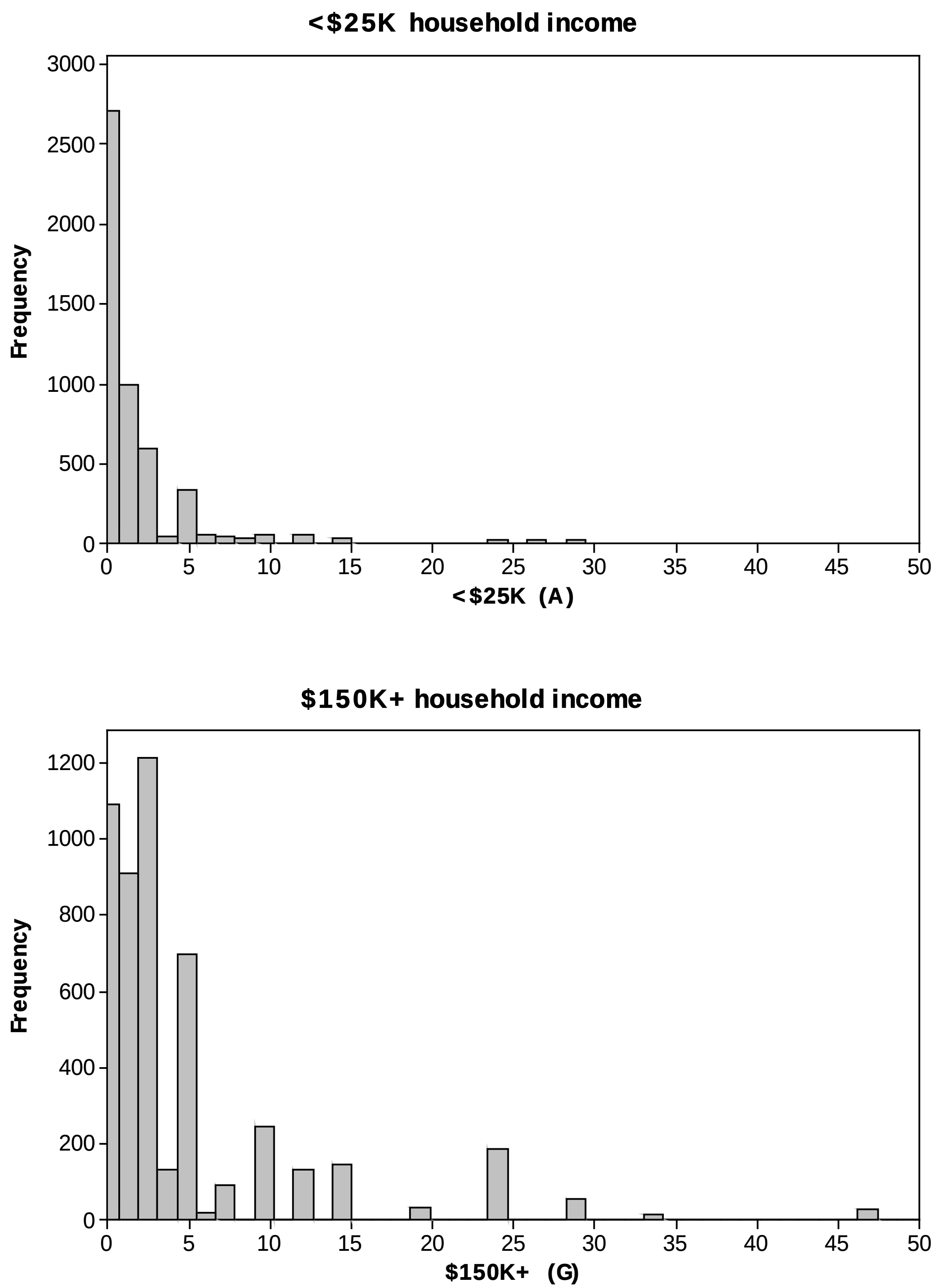

Figure 27 Allowable Switching Payback Distribution by Income Group

Source: American Home Comfort Study[6]

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

Decision making parametric D1 uses the cumulative distributions shown in Figure 27 combined with income data from the RECS 2009 data available in the DOE LCC model and a random number generator to replace the 3.5 year single switching payback period given in the baseline LCC model.

Two other parametrics were based on a less complete use of the AHCS data than parametric D1, but still more complete than the DOE analysis. As shown in Figure 28, there is a consistent trend in all years of the AHCS between tolerable payback periods for consumers and household income. Decision making scenario D2 assigns payback periods according to household income using the average payback period calculated for all 4 years of the AHCS data (2006, 2008, 2010, and 2013). Tolerable payback periods in the 2013 AHCS were somewhat lower than in previous years. Decision making scenario D3 uses a linear fit to the 2013 AHCS data only.

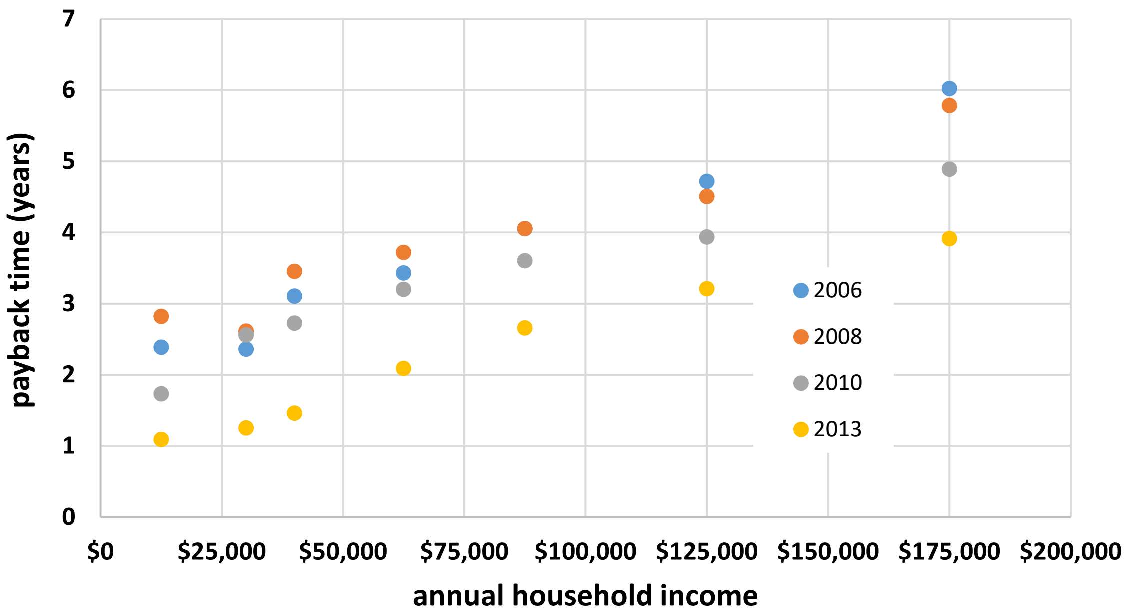
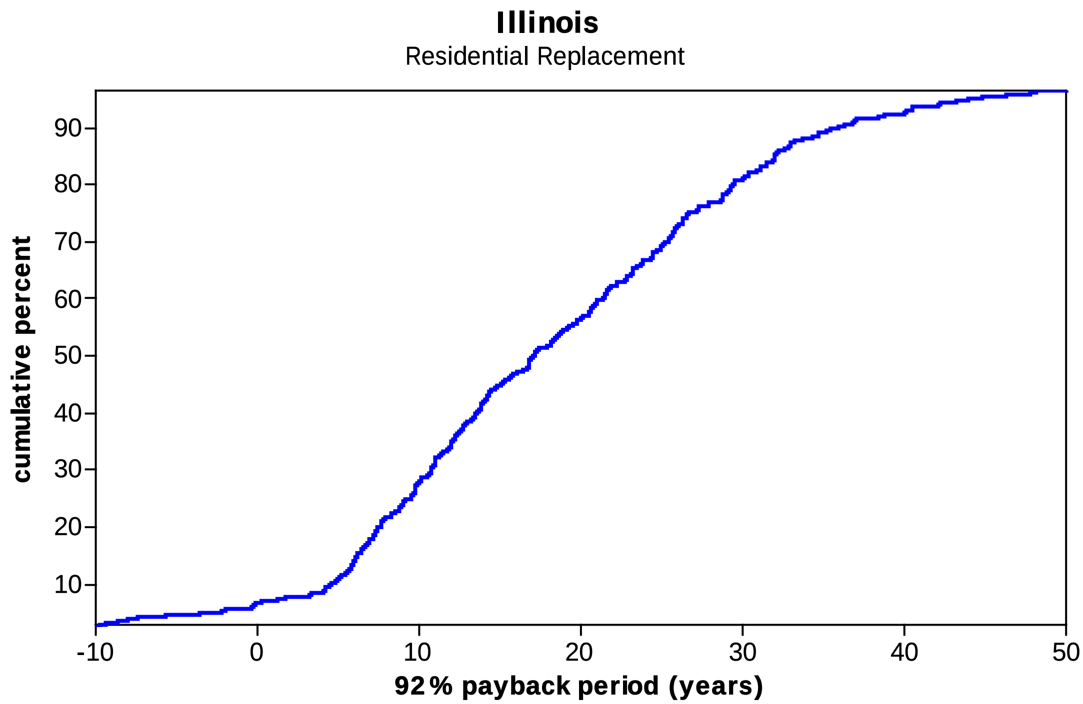


Figure 28 Tolerable Switching Payback Periods for Lower and Higher Income Households

A.3.2 Parametric D4

This parametric replaces DOE's random Base Case AFUE assignment with economic decision making, giving consumers a reasonable ability to make economic decisions. Base Case AFUE assignment by this parametric is based on the payback period for the TSL furnace relative to an 80% AFUE furnace. This payback period is already calculated and available in the LCC model in the NWGF Switching sheet in column AI (specifically in cell AI13 in the case of a 92% AFUE TSL). The DOE LCC model calculates in for every case whether the case is affected by the rule or not. GTI analysts ran the baseline model and collected data on all payback periods so that cumulative distributions could be produced for each region, installation type (new or replacement), and building type (residential or commercial). Figure 29 shows two example cumulative distributions of payback periods for Illinois and Georgia. Parametric D4 combines these cumulative distributions with the extrapolated shipment data provided by DOE to assign payback periods for furnaces at different efficiencies. The method of assigning payback periods is illustrated for Illinois residential replacements and Georgia residential new construction in GTI-15/0002, along with implications for the rulemaking that apply to the SNOPR as well.



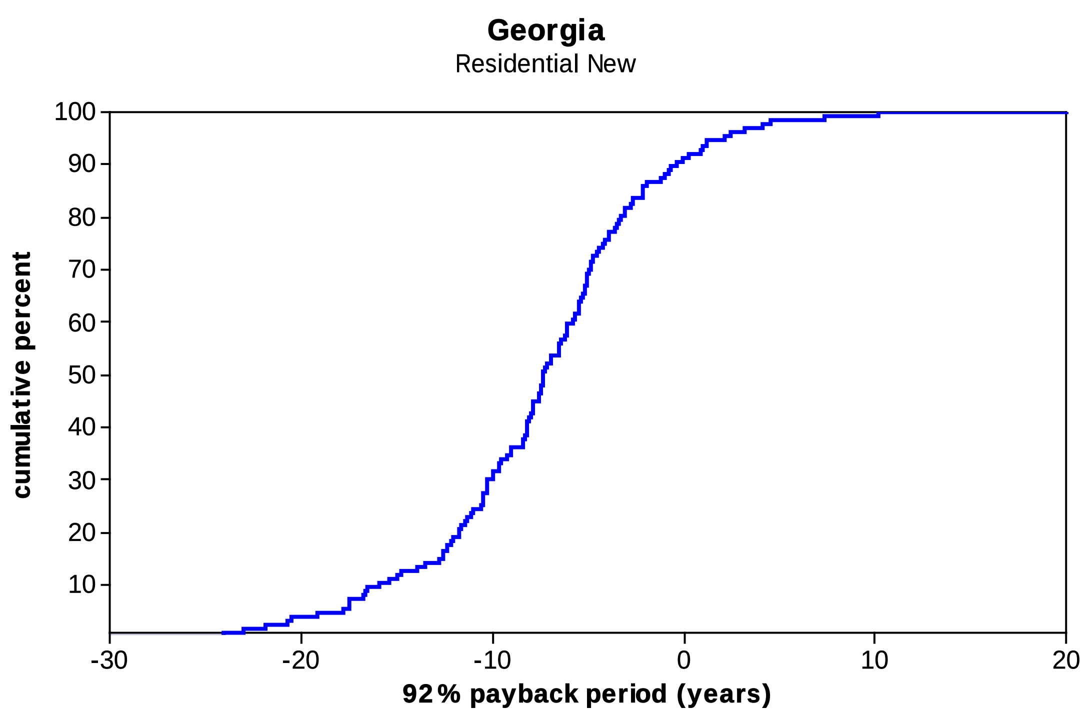


Figure 29 Cumulative Distribution of Payback Periods in DOE Model

Because of the prevalence of negative payback periods within the DOE model caused by DOE's projections that condensing furnace total installed costs will drop relative to 80% AFUE furnaces, even applying CED will result in substantial numbers of consumers being considered Impacted when they would experience first cost savings by choosing a furnace at the mandated TSL. Therefore, Parametric D4 was never run alone. It was always combined with another scenario such as D5 to remove these highly improbable negative and extremely low payback period cases from the "Net Benefit" category.

A.3.3 Parametric D5

Parametric D5 sets the minimum allowed payback period for Base Case furnace assignment to 0 years from the AHCS. The 0 year minimum payback period in D5 results in more consumers being considered impacted by the rule than a 3.5 year allowable payback period for decisions or a full distribution function aligned with the full AHCS survey information. To avoid negative and very short payback periods from being incorrectly assigned to the "Net Benefit" group, parametric D5 is combined with parametric D4. The full flow chart for Base Case AFUE assignment, including parametrics D4 and D5 is shown in Figure 5.

A.3.4 Parametric D8

This parametric removes cases where a fuel switching option has a lower first cost than an 80% furnace and operating costs savings relative to a TSL furnace. Those switching occurrences should occur in the absence of a rule. Cases are removed from the affected group by assigning a Base Case AFUE high enough that the case becomes considered not affected by the rule. The addition of parametric D8 to the fuel switching decision making is illustrated in Figure 8.

A.3.5 Parametric D11 and D12

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

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

A.3.6 Parametric D13 and D14

Parametric D13 uses a more complete implementation of the AHCS, sets payback periods for furnace selection and for fuel switching, and adjusts percentages to align with AHRI shipment percentages. This parametric uses the full distribution of amounts consumers would pay in each income range to determine a payback time using a random number generator and a lookup table for each income range. This is used for both switching and furnace AFUE selection, AFUE selections are adjusted to match the AHRI shipment numbers as closely as possible.

Parametric D14 acknowledges that consumers are better at making decisions for items with short payback periods than they are for items with longer payback periods. It provides a reasonable way to monetize a variety of non-economic factors within the CED framework. D14 modifies the combined parametrics D4 and D5 that use deterministic DOE LCC model payback periods for each trial case by adding a normal distribution function whose payback period standard deviation is 50% of the DOE LCC model calculated payback period. This gives consumers a more limited ability to consider economics in decision making than combined parametrics D4 and D5. The thresholds for decision making are still based on projected shipment fractions, so regions with higher market penetration generally will tolerate longer payback periods than those with lower market penetrations. D14 also prevents trial cases with negative payback periods from being impacted by the proposed rule using the same logic as D5.

A.4 GTI Decision Making Scenarios

As described in the preceding section, scenarios represent the outputs of the LCC model when one or more parametric modifications are included in the LCC model. For the GTI SNOPR analysis, decision making parametrics were incorporated into scenarios according to the matrix in Table 11. Some of these scenarios were run only to illustrate the impact of the selected parametrics, whether or not they are technically defensible on their own. This section describes the rationale for inclusion of each scenario in the GTI SNOPR analysis. Summaries of LCC savings, fuel switching for impacted buildings, and energy use for impacted buildings can be found in the spreadsheets accompanying this report.

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

A.4.1 Scenario 2

Scenario 2 illustrates the impact of changing the fuel switching payback periods using a more comprehensive analysis of the AHCS than DOE chose to use in the SNOPR. Scenario 2 does not address any other decision making in the LCC model. Scenario 2 fuel switching percentages are similar to the DOE SNOPR LCC model and the GTI fuel switching survey results. While future market behavior in response to the DOE SNOPR cannot be known in advance, the GTI fuel switching survey that informed the DOE SNOPR LCC model is the most recent market information available, and may be useful as a metric for comparing the scenario results.

Scenario 2 shows reduced LCC savings relative to the DOE NOPR LCC Model. Low income households show a particularly large reduction in LCC savings compared to other categories. This result is expected because parametrics D1, D2, and D3 all produce shorter switching payback periods, especially for low income trial cases, compared to the DOE NOPR LCC Model.

A.4.2 Scenario 7

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

A.4.3 Scenario 24

Scenario 24 combines CED in the Base Case AFUE assignment with a minimum threshold of zero years, removal of fuel switching cases that are unrelated to the rule, and modification to the fuel switching payback periods. Scenario 24, including parametrics D2, D4, D5, and D8, and shows very significant decreases in LCC savings relative to the DOE SNOPR LCC Model. Scenario 24 yields fuel switching levels that are similar to the DOE SNOPR LCC Model and the 2014 GTI fuel switching survey.

A.4.4 Scenario 36

Scenario 36 combines CED with monetized non-economic factors in the Base Case AFUE assignment with a minimum threshold of zero years, removal of fuel switching cases that are unrelated to the rule, and modification to the fuel switching payback periods. Scenario 36, including parametrics D2, D8, and D14, and shows very significant decreases in LCC savings relative to the DOE SNOPR LCC Model. Scenario 36 yields fuel switching levels that are reasonably close to the DOE SNOPR LCC Model and the 2014 GTI fuel switching survey.

A.5GTI Input Data Parametrics

In addition to improving decision making over the Baseline AFUE assignment in DOE LCC Model, input parameters were also changed to more technically defensible ones when such information was available.

A.5.1 Parametric I2

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

There was not sufficient data for 90% AFUE furnaces in the 2013 Furnace Price Guide for a reasonable curve fit, and there were no 98% AFUE furnaces in the 2013 Furnace Price Guide.

To estimate prices for 90% and 98% AFUE furnaces, differential prices between 92% and 90% as well as 95% and 98% from the DOE 2014 LCC spreadsheet were applied to 92% and 95% AFUE groups from 2013 Furnace Price Guide as inputs to the model.

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

Figure 30, Figure 31, and Figure 32 illustrate the 2013 Furnace Price Guide curve fitted data for 80%, 92% and 95% AFUE NWGF.

As illustrated in Figure 33, the curve fitted 2013 Price Guide price trends show a $326 differential between the 92% and 80% AFUE 80,000 Btu/h furnace, and a $452 differential for 120,000 Btu/h furnace. The DOE SNOPR 92% AFUE retail prices were similar, but DOE's 80% AFUE furnace price is higher than the 2013 Price Guide furnace price. Also, the 2013 Price Guide 95% AFUE furnace retail price is much higher than DOE's price.

To make the 2013 Price Guide compatible with 2022 fan motor assumptions, the 2013 Price Guide numbers were adjusted by adding the upgrade cost from a PSC motor to a BPM motor based on percentages of PSC motors being installed in each AFUE efficiency group in equipment currently available per the X16_RF_SNOPR_AnalysisInputs_2016-08-30.xlsm sheet "Furnace Fan Motor Types."

Current Fractions of PSC and BPM Motors are shown in Table 36 and 2022 motor type fractions used in the DOE SNOPR LCC model are shown in Table 37. The cost of the motor upgrade is based on DOE numbers listed on page 5-23 of the TSD, shown in Table 38.

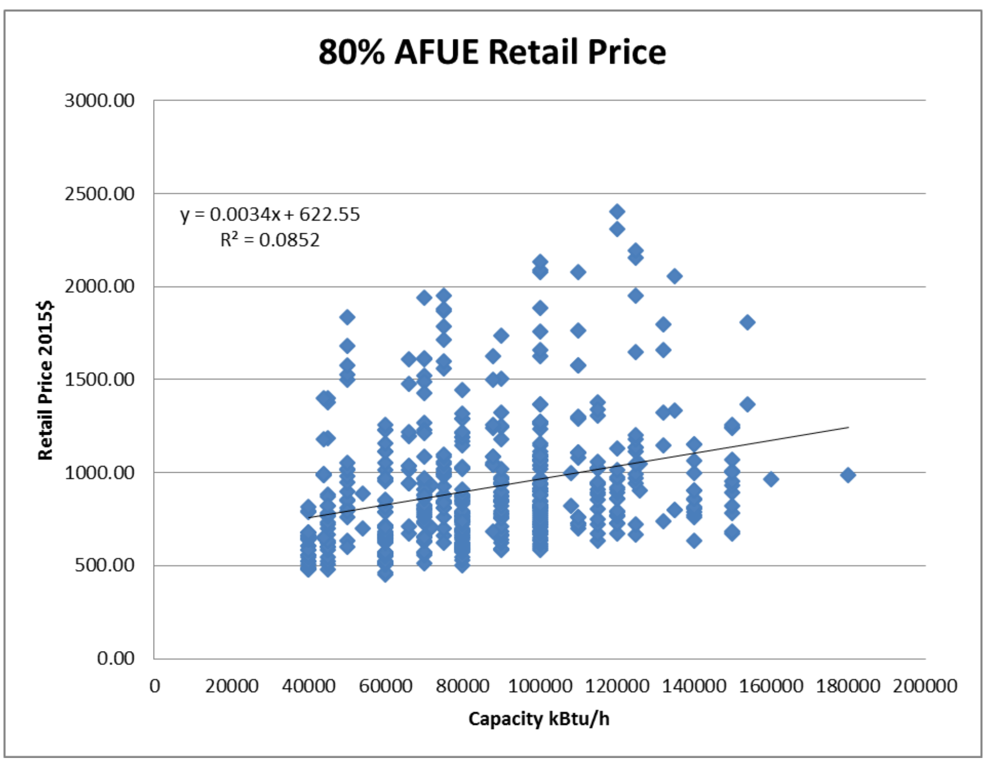


Figure 30 Retail Price vs. Capacity at 80% AFUE

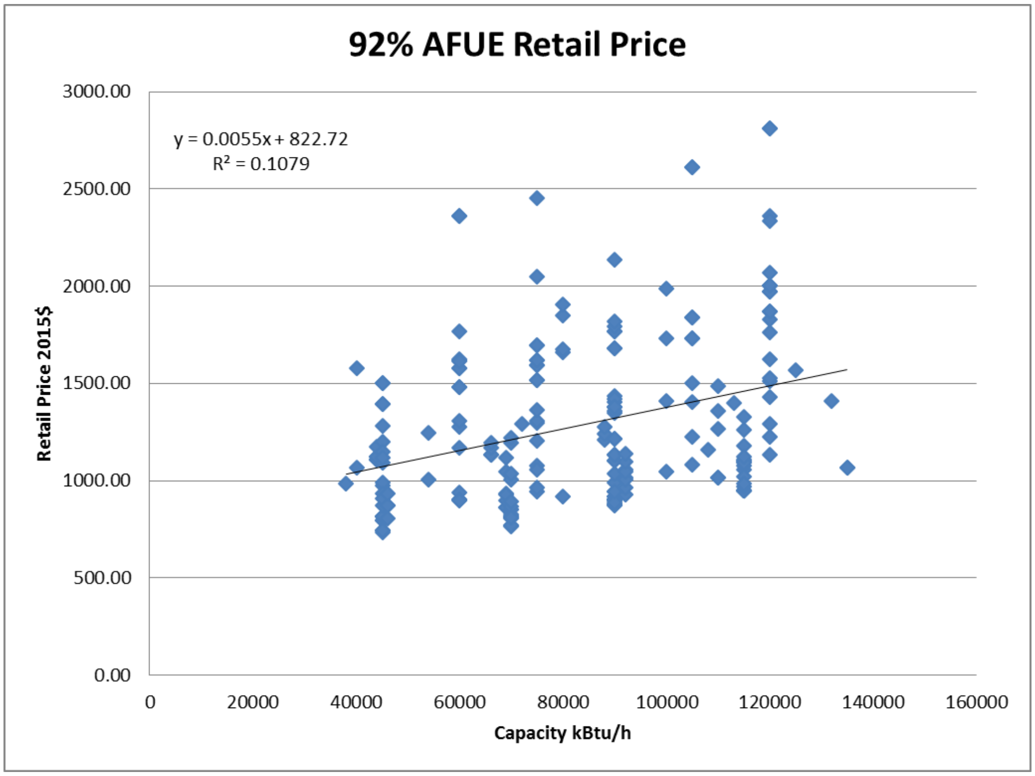


Figure 31 Retail Price vs. Capacity at 92% AFUE

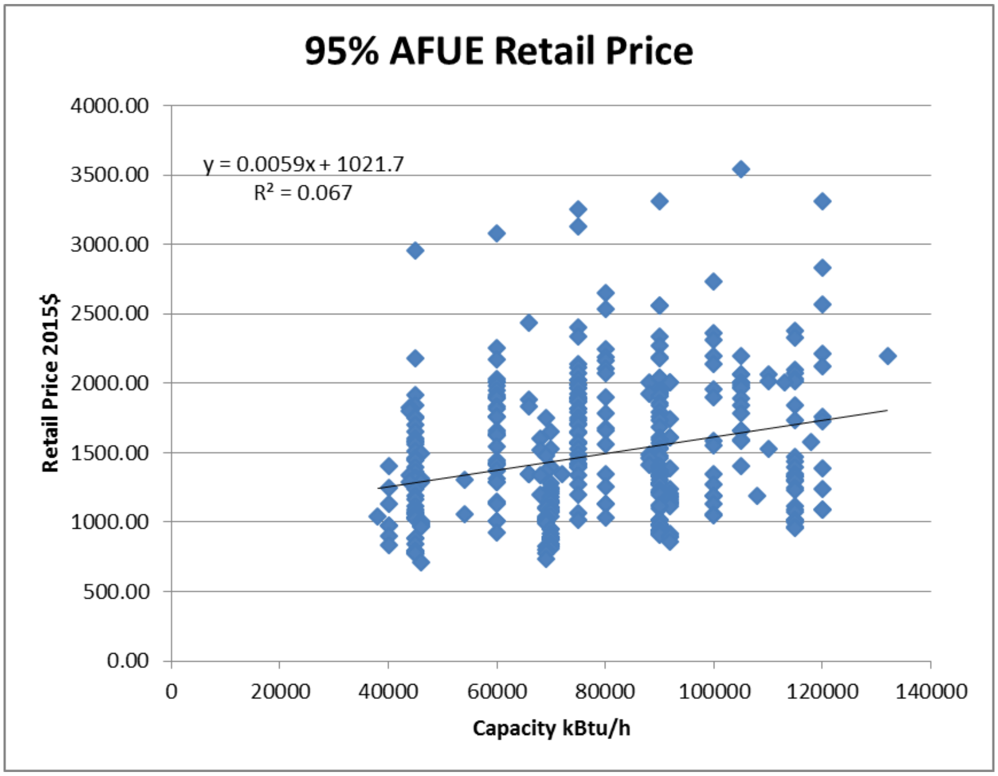


Figure 32 Retail Price vs. Capacity at 95% AFUE

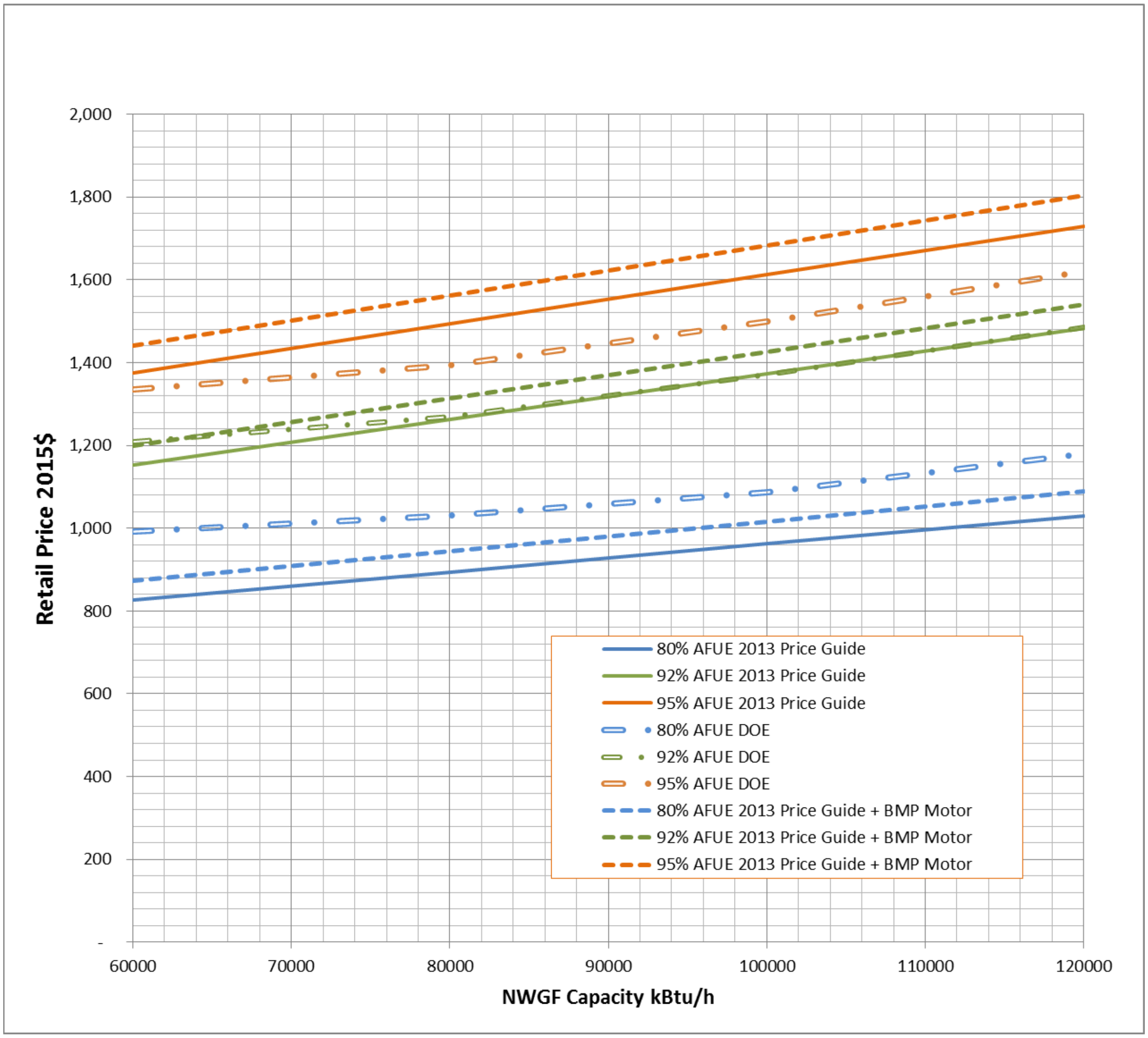


Figure 33 Retail Price Comparison –DOE LCC Model vs. 2013 Price Guide

Table 36 Current Fractions of PSC and BPM Motors

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

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

Table 37 2022 Motor Type Fractions

Crystal Ball Assumptions

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

Table 38 Additional Cost for Motor Upgrades

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

Product Class	Input Capacity (kBtu/h)	Incremental Cost Increase for Improved PSC ($)	Incremental Cost Increase for Constant-torque BPM ($)	Incremental Cost Increase for Constant-airflow BPM ($)
Non-weatherized Gas	60	-	38.43	92.35
	80	-	42.56	94.41
	100	-	46.68	96.47
	120	-	50.80	98.53
Mobile Home Gas	80*	6.30	42.56	94.41

A.5.2 Parametric I6

Parametric I6 replaces the DOE SNOPR LCC model marginal gas price factors with the marginal price factors developed by AGA. The DOE methodology used EIA residential natural gas sales and revenues by state (EIA 2014 NG Navigator) to estimate the marginal price factors within each RECS geographical area as described below:

> *"EIA provides historical monthly electricity and natural gas consumption and expenditures by state. This data was used to determine 10-year average marginal prices for the RECS 2009 geographical areas, which are then used to convert average monthly energy prices into marginal monthly energy prices. Because a furnace operates during both the heating and cooling seasons, DOE determined summer and winter marginal price factors."* (SNOPR TSD Section 8E.3.3)

AGA also used EIA 2014 NG Navigator data. However, in contrast to the DOE methodology that used average RECS database prices, AGA developed a fixed cost component of natural gas rates for each state based on tariffs and monthly consumption and applied it to the EIA data to develop state level residential marginal price factors. These state level data were then weighted according to furnace shipments in the same manner that DOE used to generate marginal rates on a regional basis.

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

This approach is conservative in estimating the marginal cost. Use of the customer charge by itself ignores other changes in gas rates as the volume changes. For example, at least 20 large utilities use declining block rates, which, if incorporated into the analysis, could reduce the marginal cost factor even more. Table 39 shows residential natural gas marginal price factors developed by AGA and percentage change from factors used by DOE.

The marginal rates section in TSD Appendix 8E does not describe how DOE actually calculated marginal rate factors for use in the DOE SNOPR LCC model. DOE is using EIA state level monthly NG consumption and corresponding revenue. The year is divided into two seasons with summer months (April to October) and winter months (Jan to March and Nov. to Dec.) For each season, DOE calculates the average slope of change in NG revenue as a function of consumption. It also calculates average revenue per 1000 cf sold. The ratio of these two calculated values is assumed to be the marginal rate factor for the season considered. Marginal rate factor calculations are averaged for years 2005 to 2014 for each state. Next the state numbers are converted to RECS regional numbers where multiple states are aggregated using a weighting factor related to furnace shipments to each state. DOE assumes that shipments are good approximation of NG gas use by furnace in each state.

Table 39 AGA Marginal Gas Price Factors

Region	AGA NG Residential			DOE SNOPR			AGA Factors vs. DOE	
	Div. & Lrg. State	Non-Winter	Winter	Div. & Lrg. State	Non-Winter	Winter	Non-Winter	Winter
CT, ME, NH, RI, VT	1	0.58	0.87	1	0.82	0.91	71.1%	95.1%
Massachusetts	2	0.88	0.97	2	0.90	1.03	97.8%	93.4%
New York	3	0.51	0.82	3	0.73	0.92	69.9%	90.1%
New Jersey	4	0.80	0.94	4	0.81	1.01	98.9%	93.2%
Pennsylvania	5	0.68	0.91	5	0.70	0.94	97.8%	96.5%
Illinois	6	0.66	0.88	6	0.68	0.98	97.4%	89.1%
Indiana, Ohio	7	0.47	0.82	7	0.64	0.92	72.7%	89.4%
Michigan	8	0.70	0.91	8	0.78	0.94	90.1%	96.6%
Wisconsin	9	0.59	0.88	9	0.80	0.99	74.1%	89.0%
IA, MN, ND, SD	10	0.66	0.90	10	0.72	1.00	92.8%	89.4%
Kansas, Nebraska	11	0.59	0.86	11	0.66	0.91	89.7%	94.8%
Missouri	12	0.42	0.80	12	0.55	0.77	76.0%	104.6%
Virginia	13	0.64	0.89	13	0.65	0.92	98.4%	96.9%
DE, DC, MD	14	0.66	0.90	14	0.68	0.93	97.4%	97.0%
Georgia	15	0.98	0.99	15	0.56	0.86	176.3%	115.6%
NC, SC	16	0.59	0.90	16	0.62	0.93	95.8%	96.8%
Florida	17	0.72	0.82	17	0.64	0.84	112.8%	98.2%
AL, KY, MS	18	0.73	0.92	18	0.70	0.87	104.0%	104.7%
Tennessee	19	0.62	0.90	19	0.71	0.93	86.8%	96.8%
AR, LA, OK	20	0.60	0.85	20	0.63	0.85	95.6%	99.7%
Texas	21	0.49	0.78	21	0.56	0.83	87.8%	93.5%
Colorado	22	0.62	0.85	22	0.66	0.90	93.6%	94.7%
ID, MT, UT, WY	23	0.72	0.93	23	0.85	0.93	85.1%	99.2%
Arizona	24	0.55	0.83	24	0.63	0.82	87.7%	101.3%
NV, NM	25	0.54	0.83	25	0.69	0.86	77.4%	95.6%
California	26	0.89	0.95	26	0.86	1.05	103.1%	90.3%
OR, WA	27	0.76	0.92	27	0.84	0.96	90.3%	95.7%
Alaska	28	0.79	0.91	28	0.85	0.97	92.8%	94.4%
Haw aii	29	0.89	0.90	29	0.94	1.02	95.1%	88.6%
West Virginia	30	0.68	0.91	30	0.77	0.95	88.1%	96.1%
U.S. Avg	US	0.67	0.89	US	0.72	0.94	92.7%	94.6%

A.5.3 Parametric I13

Parametric I13 uses NWGF condensing and non-condensing furnace shipment data provided to DOE by AHRI to revise the DOE 2022 forecast of Base Case condensing furnace shipment fraction. AHRI provided updated information in May 2015 regarding NWGF shipment data for the years 2010 through 2014. However, GTI analysts used only AHRI 2014 data to avoid concerns with possible perturbations caused by federal energy credits phased out in 2013 that may have influenced shipment numbers between 2010 and 2013. To create a 2022 forecast trend line that matched actual 2014 shipment data, GTI used 1998 to 2005 trending years. This combined approach resulted in a 2014 condensing furnace shipment fraction of 48%, which is slightly lower than the actual fraction of 48.5% reported by AHRI. Based on this trend line, Parametric I13 uses condensing furnace shipment fractions of 62.5% (National), 84.1% (North), and 38.6% (Rest of Country) for the 2022 baseline instead of DOE's 2022 furnaces shipment fractions of 53.1% (National), 73.7% (North), and 30.2% (Rest of Country).

DOE chose to use just 3 years (2012 to 2014) of shipment data in forecasting for years 2015 to 2050 in the SNOPR to avoid the market distortion associated with the 2005 tax credit, implemented in 2006 (http://energy.gov/savings/residential-energy-efficiency-tax-credit), that expired in 2011. This approach resulted in a flatter slope of annual change in forecasted condensing market share without the rule in DOE's LCC model compared to taking advantage of the entire available AHRI historical shipment data. GTI started the data trending using 1998 data to exclude the earlier time period when condensing furnace technology was less mature. Extrapolating the 1998 through 2005 trend line matches the 2014 AHRI data quite well. Each of these choices helped align the GTI 2022 forecasting trend line closely with the actual 2014 AHRI condensing furnace fractions and long term observed market dynamics. Figure 36 and Figure 37 compare the DOE SNOPR and GTI condensing furnace shipment forecast trend line. The GTI trend line shows a much higher market penetration of condensing furnaces without the DOE rule than the DOE LCC model. The GTI forecast trend line indicates a more robust free market for condensing furnaces without the rule in the future than the forecasts in the DOE LCC model.

A.5.4 Parametric I17

Parametric I17 replaced the 2015 EIA AEO forecasts and utility prices used in the DOE SNOPR LCC model with the current 2016 EIA AEO forecasts for energy price trends and updated gas and electric utility prices. Since DOE noted that it plans to use the AEO 2016 forecasts for the Clean Power Plan (AEO 2016 CPP) scenario in its final rule, Parametric I17 uses the same AEO 2016 CPP scenario.

A.5.5 Discount Rate Parametric Analysis (GTI NOPR Parametric I5)

This parametric updates the GTI NOPR Parametric I5 analysis to examine the effects of consumer discount rate on LCC savings. Discount rate is expected to have a significant effect on the LCC calculation of long lifetime equipment such as residential furnaces. In its analysis, DOE used the Federal Reserve Board's Survey of Consumer Finances (SCF) to estimate consumer opportunity cost of funds (TSD pg. 8-26). DOE used information in the SCF to determine equity and debt percentages of income groups which were then used to determine distributions of discount rates for each income group. (for a full description, see TSD pg. 8-30). DOE used distributions of discount rates based on income group. The weighted average of discount rates used in the DOE SNOPR LCC model is 4.3%.

DOE used all asset and debt classes to determine discount rates. In the NOPR, AHRI commented that debt was the only available instrument for the majority of consumers when purchasing a new furnace with a cost of $3,000 - $4,000, and DOE should be using a marginal rate rather than an average rate. In the SNOPR, DOE refuted the AHRI argument, saying that consumers have an ability to "re-balance their debt and asset holdings over the entire time period modeled in the LCC analysis." In this assertion, DOE selectively assigns consumers a sophisticated ability to manage their finances. This methodology is in contrast with their random Base Case AFUE assignment which implies that consumers have no ability to make any decision related to economics. DOE's methodology to assign discount rates based on long term rational portfolio re-balancing is an example of DOE's selective use of consumer economic decision making, and overstates the resulting LCC savings in the DOE SNOPR LCC model compared to higher discount rates without re-balancing.

DOE's assertion that consumers can re-balance debt and equity over long periods of time ignores critical short term consumer decisions. HVAC contractors expect to be paid at the time of installation. In cases with high debt load, especially for low income consumers but also higher income consumers with high debt, the furnace purchase will incur additional debt at a much higher interest rate than the DOE SNOPR LCC model discount rate. In addition, the inclusion of the mortgage interest debt type may not be reasonable in all cases. Mortgages may be a reasonable debt type to consider when a furnace is included in the price of a new home, but it may not be reasonable to include it when considering replacements. Credit card debt, especially for emergency replacements, is likely to be a more reasonable debt type for consumers already experiencing significant personal debt that cannot be easily re-balanced.

Table 40 shows the types of debt or equity by percentage for each income group. Mortgages represent a very significant portion of consumer debt – more than 24% for the top five income groups defined in Table 41. Mortgage debt is also a very low interest debt type. It becomes especially low interest when DOE considers the tax deductibility of mortage and home equity loan interest and inflation (TSD pg 8-28). DOE does not appear to account for the observation that the mortgage interest tax deduction is only available to taxpayers with more than the standard deduction for tax payers that itemize deductions. Many taxpayers in the lower income groups may not qualify for the itemized mortgage interest deduction if they have no other significant itemized deductions. In that regard, in testimony before the Committee on Ways and Means, Eric J. Toder submitted that 24% of tax units (married couples or singles) will benefit from the deduction, while 47% of those tax units pay home secured debt interest. (Eric J. Toder, Testimony before the Committee on Ways and Means April 25, 2013 http://www.taxpolicycenter.org/UploadedPDF/1001677-Toder-Ways-and-Means-MID.pdf). Toder's testimony indicates that 49% of mortgage holders do not qualify for the tax deduction. DOE's tax deductibility assumption reduces the effective discount rate, particularly for lower income households, and overstates the resulting LCC savings in the DOE SNOPR LCC model.

Table 40 DOE SNOPR Types of Household Debt and Equity

Table 8.2.26 Types of Household Debt and Equity by Percentage Shares (%)

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

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013.

Table 41 DOE SNOPR Definition of Income Groups

Table 8.2.25 Definitions of Income Groups

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

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013.

Table 42 DOE SNOPR Effective Interest Rates by Income Group

Table 8.2.28 Average Real Effective Interest Rates for Household Debt

Type of Debt	Income Group					
	1	2	3	4	5	6
Mortgage	6.6%	6.2%	6.1%	5.2%	5.0%	4.0%
Home equity loan	7.0%	6.9%	6.7%	5.9%	5.7%	4.3%
Credit card	15.2%	15.0%	14.5%	14.2%	14.0%	14.5%
Other installment loan	10.8%	10.3%	9.9%	9.4%	8.7%	8.6%
Other residential loan	9.8%	10.2%	8.9%	8.2%	7.7%	7.4%
Other line of credit	9.1%	10.9%	9.6%	8.8%	7.4%	6.1%

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, and 2013.

As shown in Figure 34, the DOE SNOPR LCC model analysis used exceptionally low rates, currently at 50 year lows. Historically, rates have been much higher than the DOE SNOPR LCC model. Rates have been historically low due to recent Federal Reserve choices for quantitative easing policy coupled with very low inflation levels. There is very little expectation that rates will remain at 50 year lows for next several decades. The DOE SNOPR LCC model overstates resulting LCC savings compared to higher discount rates likely to prevail in the future.

DOE has not provided tabular data or spreadsheets containing each of their full distributions of consumer discount rates for each debt and asset class and for each income group. Without this information, discount rate parametric analysis such as removal of mortgages from consideration on replacement furnaces would require repeating the entire DOE discount rate analysis. Even if repeating the DOE discount rate analysis were feasible, the fundamental rationale for the DOE methodology is arguably flawed. Aggregating debt and equity together to determine a discount rate based on opportunity cost appears to ignore that the purchase of a furnace, particularly in the replacement market, is not likely well represented by an aggregate of all debt and equity for a particular consumer. A marginal rate that is specific to the financial instrument used to purchase the furnace would be a more defensible value. For example, a homeowner with a mortgage of $100,000 and savings of $1,000 that needs to purchase a new furnace which costs $3,000 will not experience the weighted average rate of 99% mortgage interest rate and 1% savings interest rate. They will more likely experience a rate represented by 1/3 savings and 2/3 credit card, yielding a rate closer to 12% than to 3%.

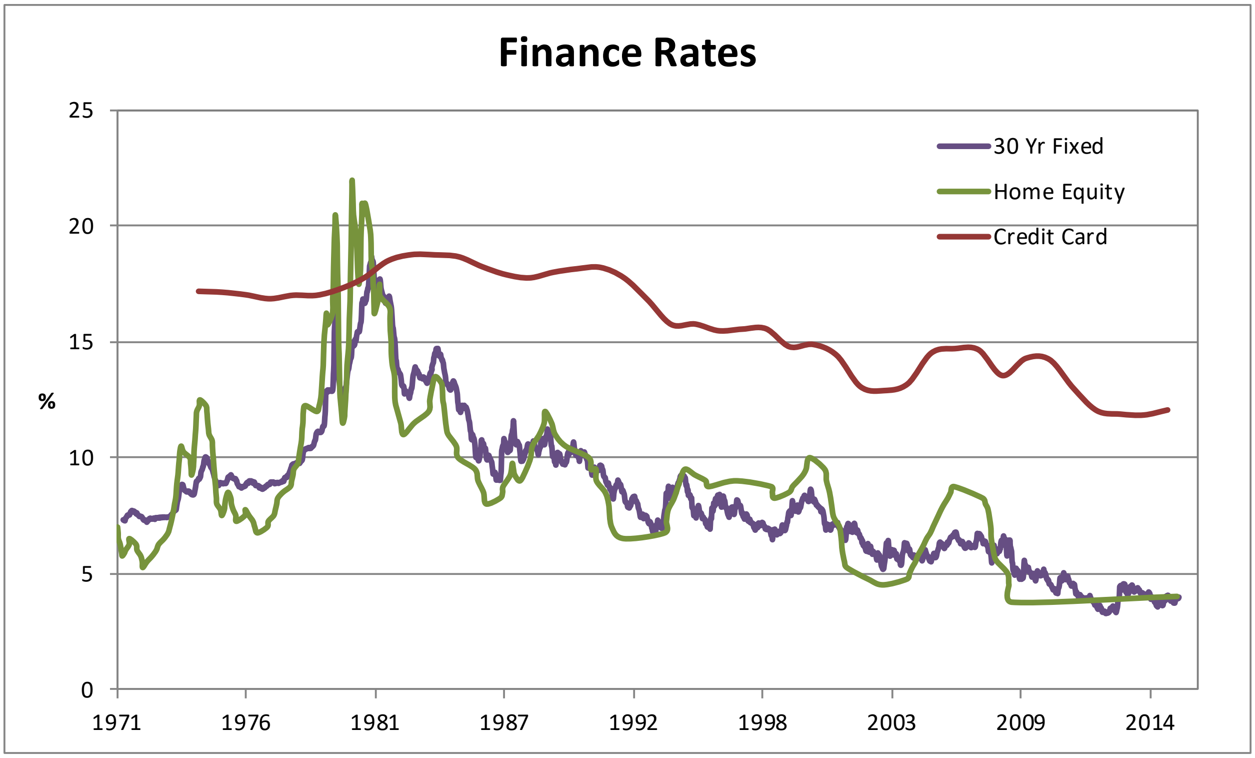


Figure 34: Finance Rate Trends – 1971 through 2015

Source: Freddie Mac, Federal Reserve

Sufficient time was not available within the 60-day comment period to modify the DOE model to account for much higher rates for each future replacement furnace. Instead, GTI analysts ran parametric analyses with varying discount rates using the same distributions as DOE but increased discount rates by 0.5% and 1% (i.e., a 5% rate is increased to 5.5% and 6%). A truncated normal distribution was also included with varying mean and a standard deviation of 5%. The normal distribution was truncated such that all of the distribution above 23% or below 0.5% were assigned a discount rate of 23% or 0.5% respectively. As shown in Figure 35, a truncated full normal distribution impacted the LCC savings significantly more than the DOE SNOPR LCC model limited distribution of discount rates. LCC savings decrease roughly linearly with increasing discount rate and drive LCC savings to zero at a discount rate below 18%, less than the rate charged by many credit cards.

Modified discount rates were also incorporated in GTI Scenarios Int-14 and Int-14.55 using a truncated normal distribution with means of 5 and 10% and a standard deviation of 5%. As shown in Table 43, either parametric substantially reduces the LCC savings under each scenario. When combined with other reasonable assumptions, the GTI parametric analysis of discount rates shows that the proposed rule will result in negative LCC savings.

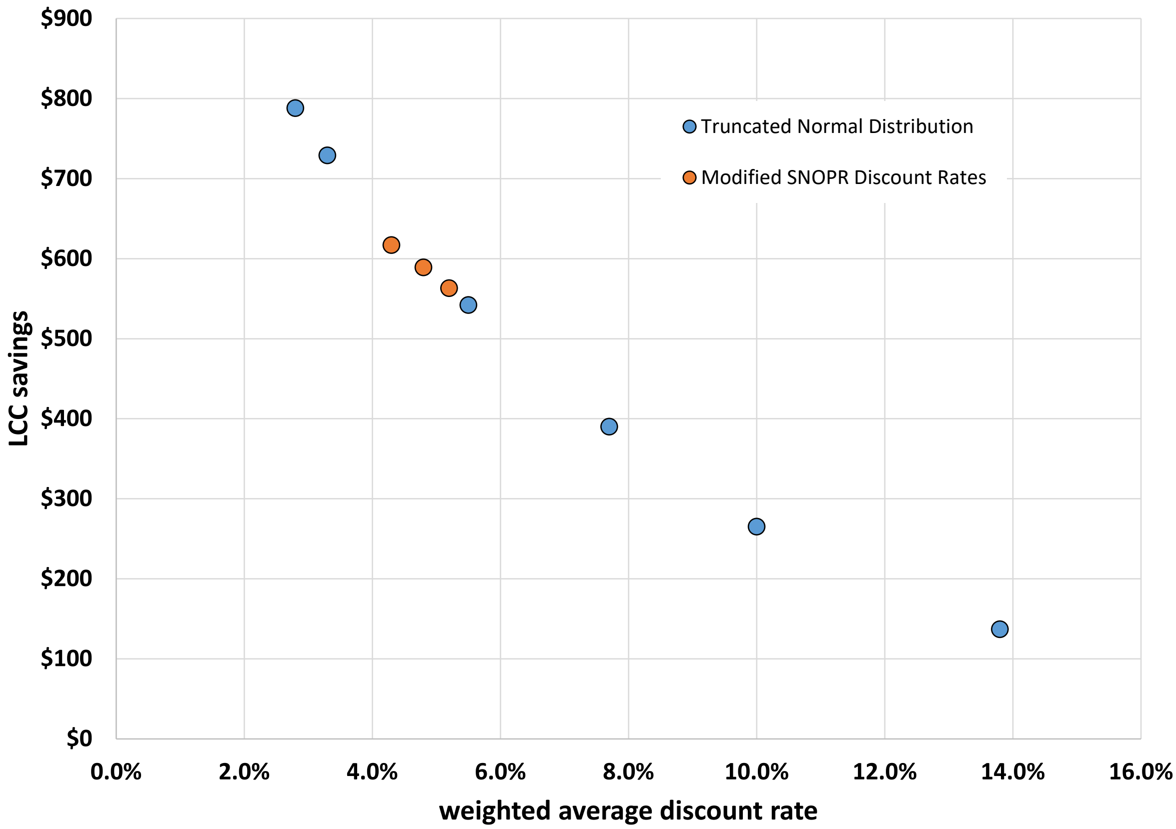


Figure 35: LCC Savings vs. Discount Rate with Truncated Full Normal Distribution

Table 43: LCC Savings – DOE SNOPR vs. GTI Incremental Discount Rate Scenarios

Scenario	weighted average discount rate	LCC savings, single standard	LCC savings, ≤55 kbtu/hr exempt
SNOPR Scenario 0	4.3%	$617	$692
SNOPR Scenario 0 with 0.5% increase in discount rate	4.8%	$589	$661
SNOPR Scenario 0 with 1.0% increase in discount rate	5.2%	$563	$633
SNOPR Scenario 0 with truncated normal distribution with mean 1% and stdev 5%	2.8%	$788	$858
SNOPR Scenario 0 with truncated normal distribution with mean 2% and stdev 5%	3.3%	$729	$799
SNOPR Scenario 0 with truncated normal distribution with mean 5% and stdev 5%	5.5%	$542	$609
SNOPR Scenario 0 with truncated normal distribution with mean 7.5% and stdev 5%	7.7%	$390	$452
SNOPR Scenario 0 with truncated normal distribution with mean 10% and stdev 5%	10.0%	$265	$319
SNOPR Scenario 0 with truncated normal distribution with mean 15% and stdev 5%	13.8%	$137	$187
GTI Scenario Int-14	4.3%	-$149	-$118
GTI Scenario Int-19 (Int-14 with I5 with discount rate mean 5% stdev 5%)	5.5%	-$194	-$176
GTI Scenario Int-19 (Int-14 with I5 with discount rate mean 10% stdev 5%)	10.0%	-$378	-$364
GTI Scenario Int-12	4.3%	-$179	-$157
GTI Scenario Int-20 (Int-12 with I5 with discount rate mean 5% stdev 5%)	5.5%	-$221	-$211
GTI Scenario Int-20 (Int-12 with I5 with discount rate mean 10% stdev 5%)	10.0%	-$391	-$381

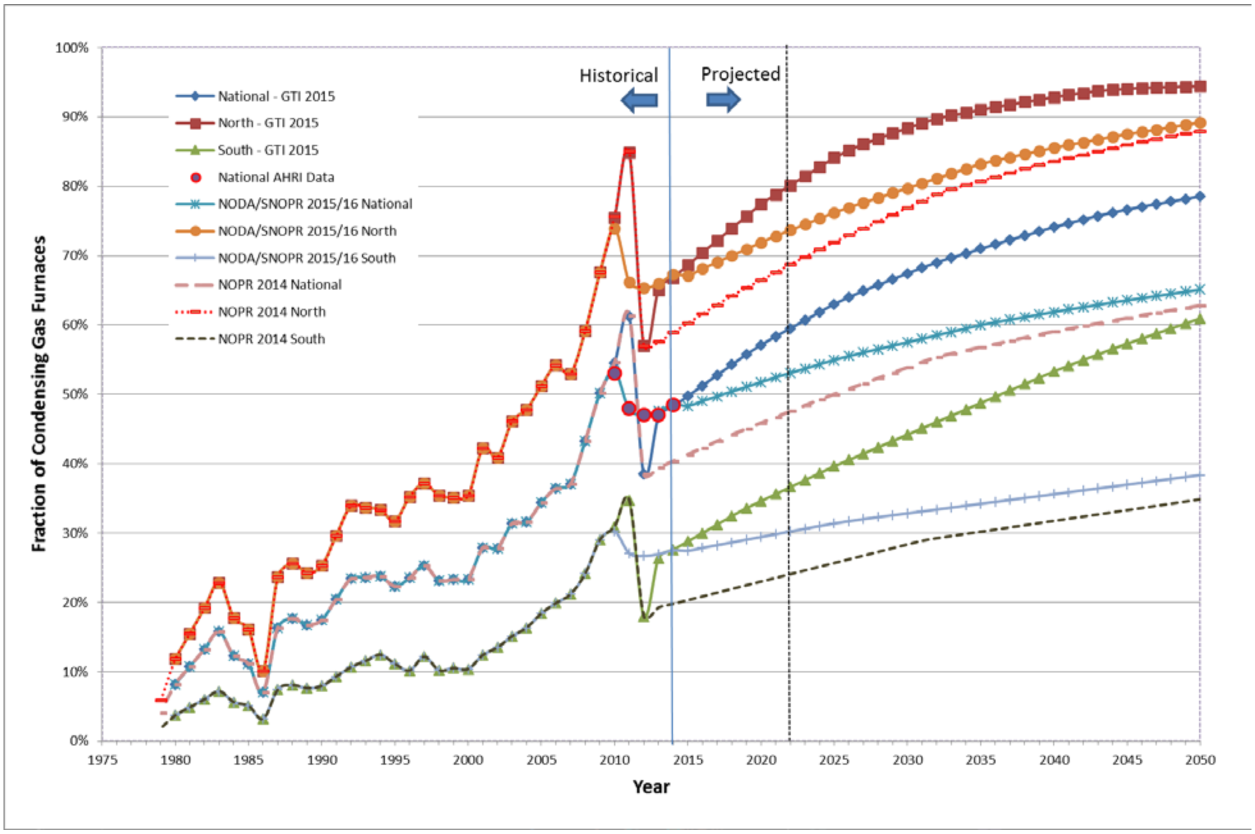


Figure 36 Condensing Furnace Trends – DOE SNOPR Model vs. GTI Parametric I13

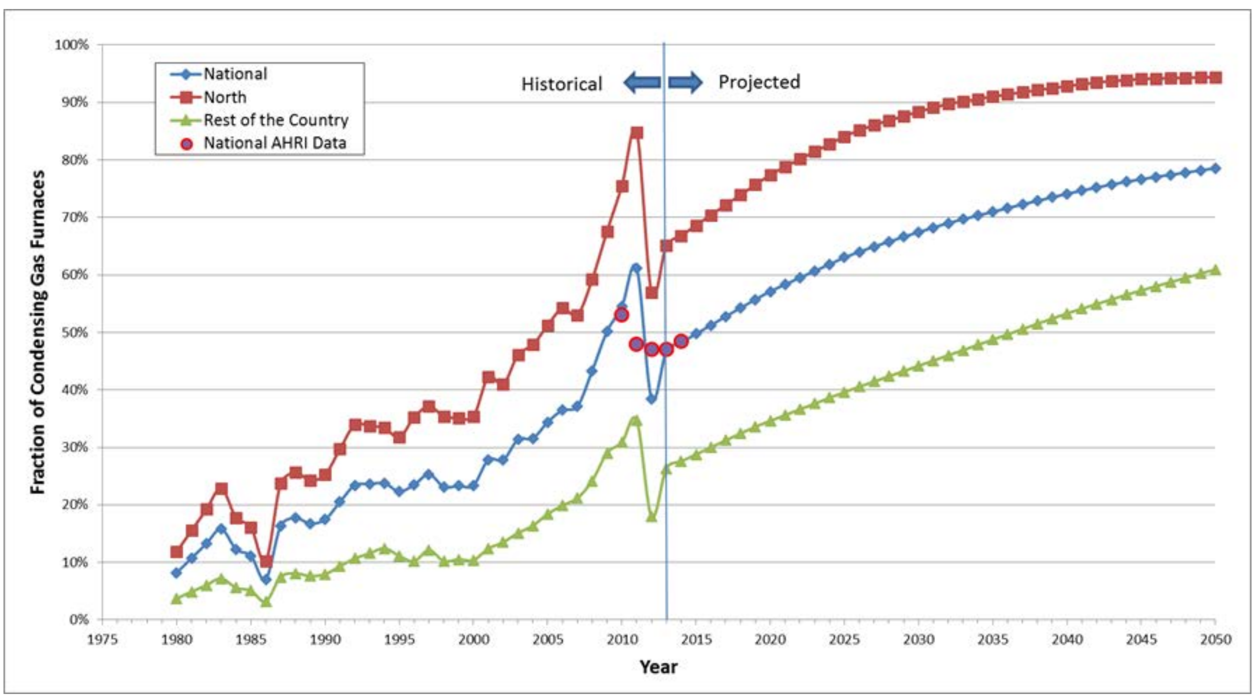


Figure 37 Historical and Projected Condensing Furnace Fractions – GTI Parametric I13

A.6 GTI Input Data and Furnace Sizing Scenarios

The parametrics in the preceding section were incorporated into scenario combinations according to the matrix shown in Table 11.

A.6.1 Scenario Combinations I-2, I-6, I-13, and I-17

Each of these scenario combinations contains the listed input parametrics as described in the previous section. All show reductions in LCC savings compared to the DOE SNOPR LCC Model. Compared to the decision making scenarios, impact on fuel switching is relatively small with the exception of GTI Scenario I-2 that examines retail furnace pricing.

A.6.2 Scenario F-1

GTI Sizing Scenario F-1 uses a furnace capacity algorithm for each of the 10,000 trial cases based on the RECS database annual heating consumption rather than home size. The GTI furnace sizing methodology provides the expected trend of increased LCC savings and reduced number of impacted homes as the 80% AFUE furnace capacity limit increases, whereas the DOE SNOPR methodology, based on building size, is insensitive to incremental changes in capacity limits due to the poor correlation between home size and required furnace capacity to meet the home heating load.

To better show the distribution of heating loads within the furnace size bins, Figure 38 and Figure 39 show the distribution of heating loads for a range of kBtu/h furnace size bins. The distributions overlap substantially, and all of the distributions contain a significant fraction of buildings with very low heating loads. These distributions clearly illustrate the disconnect between the DOE furnace sizing methodology and annual heating load.

A.6.3 Results Summaries for Input Data and Furnace Sizing Scenarios

Summary results for LCC savings, fuel switching, and energy use for the input variable scenarios are given in the spreadsheets accompanying this report.

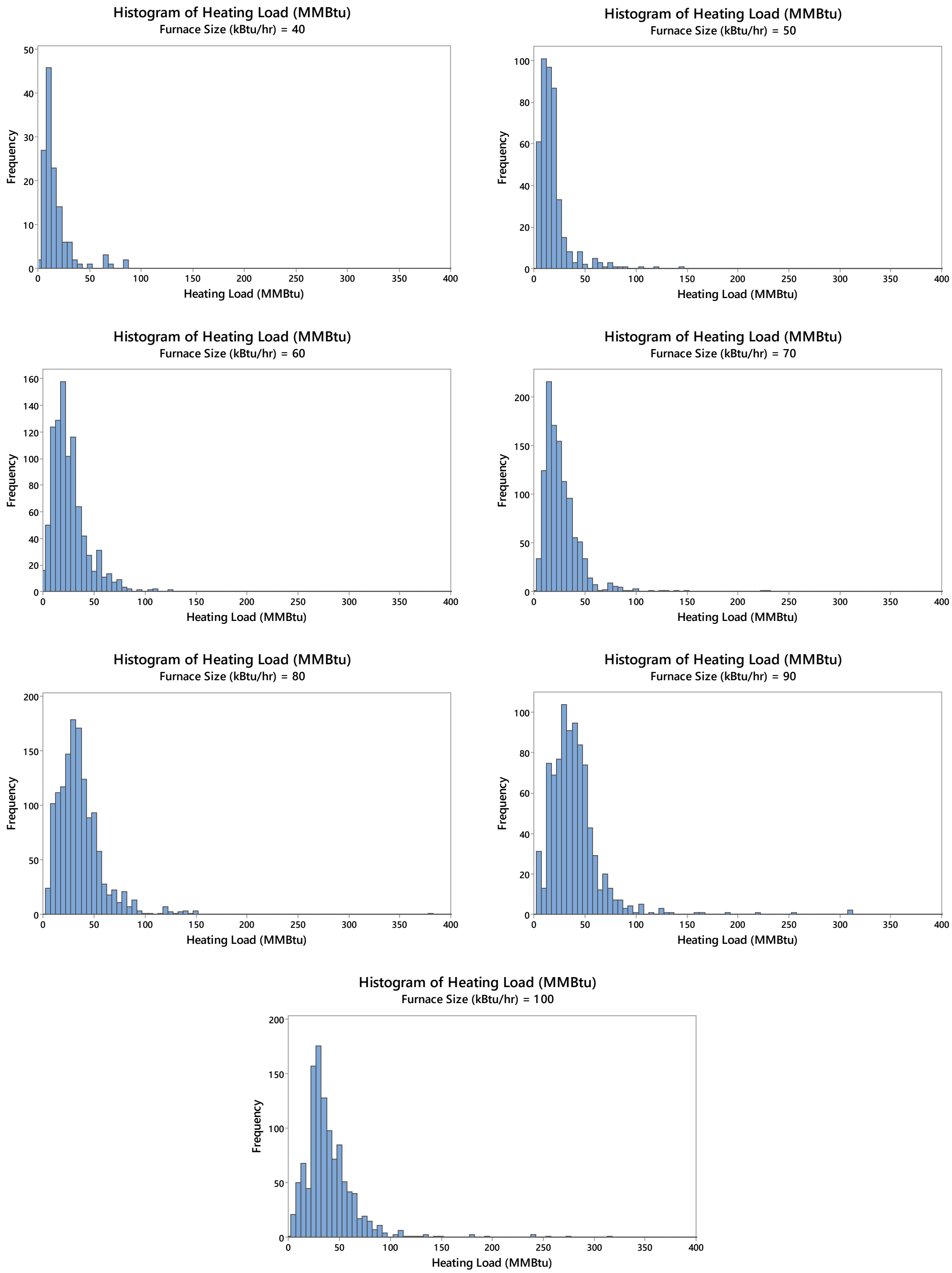


Figure 38: Heating Load Distribution for Selected Furnace Size Bins (40 to 100 kBtu/hr)

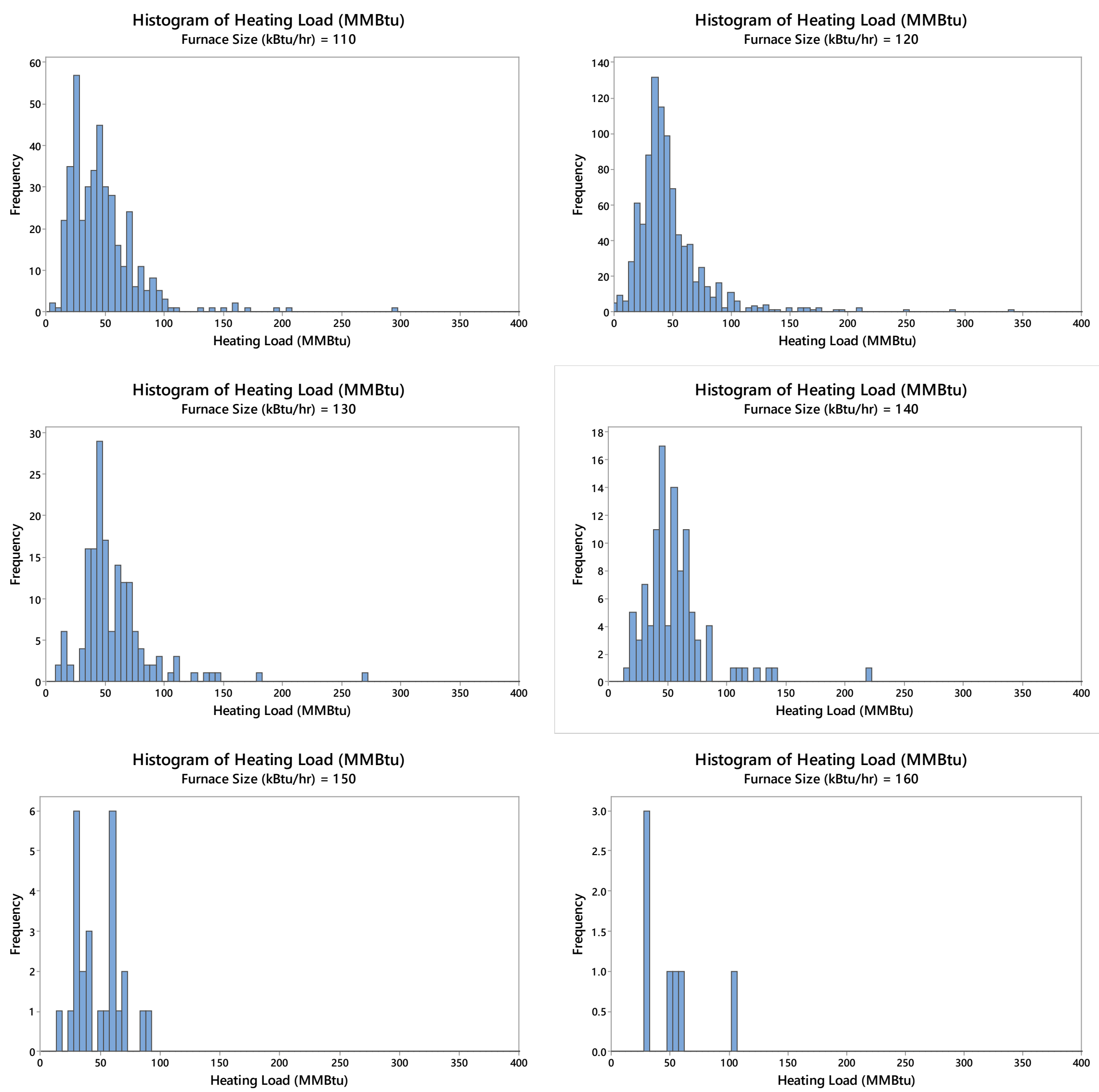


Figure 39: Heating Load Distribution for Selected Furnace Size Bins (110 to 160 kBtu/hr)

A.7 Integrated Scenarios

GTI analysts combined selected parametrics that comprise technically defensible decision making and input scenarios into integrated scenarios to examine the impact of these combinations. Table 11 shows the parametric matrix that defines these scenarios. All of the chosen integrated scenarios include parametrics that address Base Case AFUE selection (D4 with D5, or D14), remove fuel switching that would occur in the absence of a rule (D8), and modify switching paybacks (D2). In addition, all of the integrated scenarios include the modified condensing furnace shipment data in alignment with the AHRI data trend line (I13), AGA marginal rates (I6), and the updated AEO forecast (I17) inputs. Integrated scenarios also include modified retail prices found in the 2013 Furnace Price Guide (I2).

A.7.1 Scenarios Int-11 and Int-12

Scenarios Int-11 and Int-12 are updated versions of GTI NOPR Integrated Scenario Int-5, and use the GTI CED framework (Scenario 24) as the basis of the economic decisions. Int-11 uses AEO 2015 forecasts, while Int-12 uses AEO 2016 forecasts. Scenarios Int-11.55 and Int-12.55 include a second product class for 80% AFUE furnaces at or below 55 kBtu/h.

A.7.2 Scenarios Int-13 and Int-14

Scenarios Int-13 and Int-14 are also updated versions of GTI NOPR Integrated Scenario Int-5. However, these scenarios and use the GTI CED framework updated to incorporate non-economic decision factors (Parametric D14 instead of D4 and D5) as the basis of the economic decisions. Int-13 uses AEO 2015 forecasts, while Int-14 uses AEO 2016 forecasts. Scenarios Int-13.55 and Int-14.55 include a second product class for 80% AFUE furnaces at or below 55 kBtu/h.

A.7.3 Integrated Scenario Results

The summarized results for LCC savings, fuel switching, and energy use and greenhouse gases can be found in the spreadsheets accompanying this report.

A.8 Mobile Home Gas Furnaces

In the SNOPR (pg 65817) DOE asserts that, "*The payback periods for all MHGF AFUE TSLs meet the rebuttable-presumption criterion*." As noted in Section 4.5 of this report, that assertion is highly suspect since the DOE rebuttable presumption payback period was calculated incorrectly for this purpose.

As noted in TSD page 8J-1 footnote a, "*DOE did not analyze switching for mobile home gas furnaces (MHGFs) because the installation cost differential is small between condensing and non-condensing products, so the incentive for switching is insignificant.*" This assertion is misleading and incomplete. Installation cost differential is only one element of the consumer fuel switching decision criterion. The correct criterion is total installed cost differential, including both furnace price and installation cost. By failing to include this important fuel switching decision, the DOE SNOPR LCC model overstates LCC savings compared to a fuel switching impact analysis.

When possible, GTI made parametric modifications to mobile home gas furnaces. Unfortunately, there is no way to include a fuel switching option in the MHGF analysis without fully re-writing the DOE LCC model. The following discussion therefore focuses only on the changes in methodology and input data that show a significant reduction in LCC savings compared to the DOE SNOPR LCC analysis.

As shown in Table 44, LCC savings never goes negative in the case of MHGFs, but are reduced by nearly $600 when incorporating improved decision making and input data. DOE has decided that MHGFs are less likely than NWGFs to switch to electric options. This decision is disconnected from the marketplace in which owners of mobile homes tend to be on the lowest end of the income distribution and are even more motivated to save first cost expense than owners of NWGFs. The difficulty in changing from gas to electric options in mobile homes that DOE cites certainly does not apply to electric resistance heaters, including low-cost space heaters, that many of these consumers would switch to if they were unable to finance a replacement furnace, reducing rule benefits significantly.

Table 44: LCC Savings – DOE SNOPR vs. GTI Scenarios for MHGFs

Increment	GTI Decision and Input Parametrics and Scenario Changes Compared to DOE SNOPR TSL 5 (92% AFUE Minimum)	LCC Savings (TSL 5)
0	DOE SNOPR	$1,049
1	Change Increment 0 using annual fuel consumption based furnace sizing. (F1)	$1,043
2	Add to Increment 1 AHRI shipment data, AGA marginal natural gas prices. (I6, I13, F1)	$1,037
3	Change Increment 2 using AEO 2016 with CPP. (I6, I13, I17, F1)	$1,042
4	Remove from Increment 0 cases with negative payback period in Base Case AFUE assignment; use annual fuel consumption based furnace sizing. (F1, D5)	$794
5	Change Increment 3 to give consumers limited ability to make decisions based on economics, aligned with projected shipment fractions; replace payback period for Base Case AFUE assignment with a normal distribution with mean equal to the calculated payback period and standard deviation 50% of calculated payback period. (D14 w/SD 50%, I6, I13, I17, F1)	$465
6	Change Increment 3 to give consumers reasonable ability to make decisions based on economics, aligned with projected shipment fractions. (D4, D5, I6, I13, I17, F1)	$433

The DOE SNOPR LCC model analysis for MHGFs shows a 10%, 19%, and 22% average installed price increase for 92%, 95%, and 96% AFUE MHGFs respectively, as shown in Table 45. This installed cost difference is high enough that simple payback periods for 92% AFUE MHGFs are less than 3.5 years less than 20% of the time, as shown in Figure 40. This is the same “payback period” DOE defined for fuel switching decisions, which clearly indicates a high probability of rule-driven fuel switching in the mobile home market. Furthermore, mobile home owners typically have lower incomes than other single family home owners and are more likely to have lower payback period tolerance (i.e., <3.5 years), and are therefore at least as likely as the NWGF group to fuel switch, if not more so. Out of the 10,000 trials there are 432 low-income households in the NWGF sample and 1,410 low-income households in the MHGF sample for TSL 5. This finding strongly suggests that the DOE assertion that fuel switching for mobile homes can be safely ignored is wrong. However, because the DOE LCC Model was not constructed to allow mobile home fuel switching and would have required a substantial re-coding of the model to include, the analysis presented here is incomplete as it also does not consider fuel switching for mobile homes.

Table 45: MHGF LCC Analysis Summary Results – DOE SNOPR TSL 5

		Average LCC Results									Payback Results		
Level	Description	Installed Price	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	LCC Savings	Simple LCC Savings	Net Cost	No Impact	Net Benefit	Simple PBP	Average	Median
0	MHGF 80%	$1,515	$785	$12,216	$13,731	NA	NA	NA	100%	NA			
1	MHGF 92%	$1,667	$698	$10,924	$12,591	$1,049	$1,140	8%	29%	63%	1.7	5.6	1.2
2	MHGF 95%	$1,800	$680	$10,643	$12,443	$1,020	$1,288	14%	15%	71%	2.7	8.5	3.5
3	MHGF 96%	$1,846	$677	$10,599	$12,445	$864	$1,286	25%	0.20%	75%	3.1	10.1	4.6

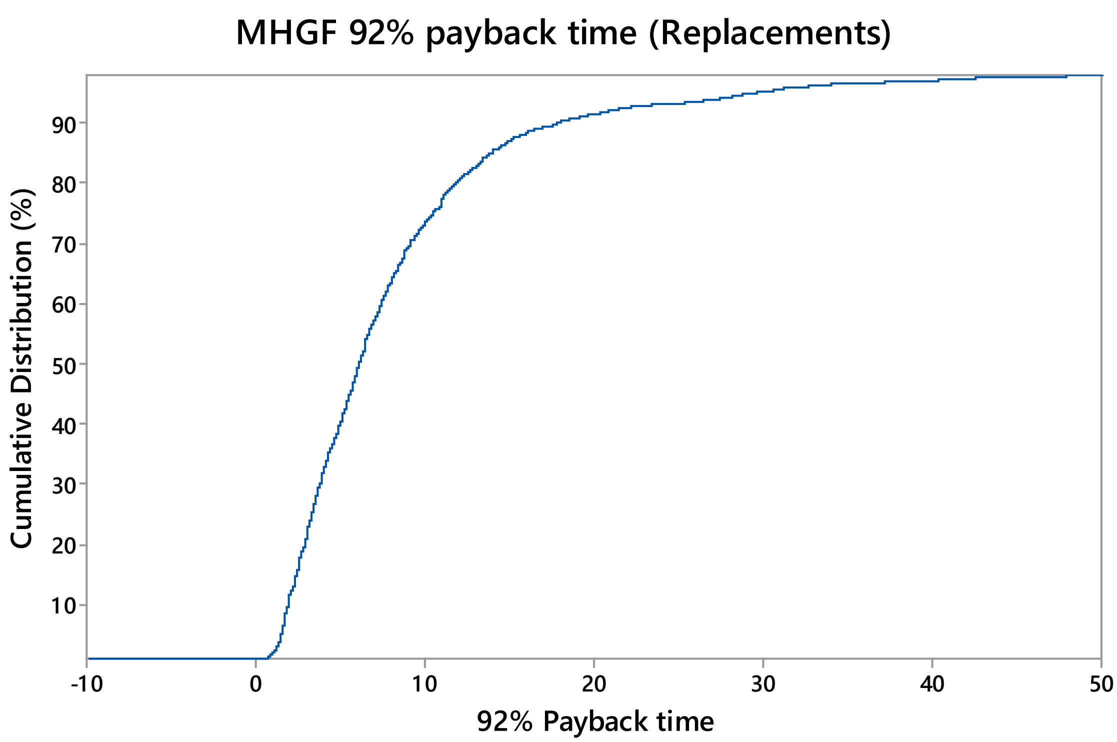


Figure 40 MHGF Payback Distribution – 92% AFUE

Several incremental scenarios for decision making that do not involve fuel switching were run for mobile homes, with results shown in Table 44 above. The scenario most closely aligned with GTI Integrated Scenario Int-14 is Increment 5, including Parametrics D14, I6, I13, I17, and F1. The scenario most closely aligned with GTI Integrated Scenario Int-12 is Increment 6, including Parametrics D4, D5, I6, I13, I17, and F1. However, since the DOE LCC model does not include an ability to examine the impact of fuel switching, Parametrics D2 and D8 could not be included in the GTI MHGF analysis. Table 46 compares the DOE SNOPR LCC model results with Increments 5 and 6. When CED is used for Base Case AFUE assignment, LCC Savings are substantially reduced at all TSLs. The percentage of "No Impact" cases also increases significantly, particularly at low TSLs. It is very likely that the addition of fuel switching Parametrics D2 and D8 to Increment 5 would show negative LCC savings as occurred in the NWGF case. As a minimum, DOE should have permitted this scenario to be examined.

Table 46 MHGF LCC Analysis Summary Results – DOE SNOPR vs. CED Framework

Simulation Results NATIONAL - 10000 samples		SNOPR MHGF Scenario 0			
Level	Description	LCC Savings	Net Cost	No Impact	Net Benefit
MHGF					
0	MHGF 80%			100%	
1	MHGF 92%	$1,049	8%	29%	63%
2	MHGF 95%	$1,020	14%	15%	71%
3	MHGF 96%	$864	25%	0%	75%

Simulation Results NATIONAL - 10000 samples		MHGF Increment 5			
Level	Description	LCC Savings	Net Cost	No Impact	Net Benefit
MHGF					
0	MHGF 80%			100%	
1	MHGF 92%	$465	10%	65%	25%
2	MHGF 95%	$989	13%	20%	67%
3	MHGF 96%	$1,061	18%	6%	76%

Simulation Results NATIONAL - 10000 samples		MHGF Increment 6			
Level	Description	LCC Savings	Net Cost	No Impact	Net Benefit
MHGF					
0	MHGF 80%			100%	
1	MHGF 92%	$433	11%	62%	28%
2	MHGF 95%	$954	14%	14%	72%
3	MHGF 96%	$1,050	18%	1%	81%

Similar to NWGFs, DOE's random assignment methodology caused 3236 trials to be considered impacted by the rule when the payback period was negative. This accounts for 32% of total trials and 58% of the total LCC savings attributed to mobile homes. The bulk of these, 3200 trials, come from new installations. Again, as in the NWGF case, builders of mobile homes will not, in any meaningful numbers, spend more money to buy a lower efficiency product that does not help them sell homes.

As shown in Figure 41, DOE reports market penetration for replacement furnaces that is correlated with DOE's expected market share. However, in the case of mobile homes DOE does not project high rates of market adoption in either the replacement market or new construction. DOE does not project condensing furnace market share above 48% for either new or replacement MHGFs even though their own results show that 63% of the new MHGF have negative payback periods. Either DOE has miscalculated costs or expected market share, or both.

As shown in Figure 42, the DOE SNOPR MHGF furnace sizing uses the same home size-based methodology as in the NWGF analysis, and produces a similar lack of correlation to heating load. Using the same methodology as in the NWGF, GTI replaced this methodology with parametric F1, with similar resulting improved correlation with heating load as shown in Figure 43.

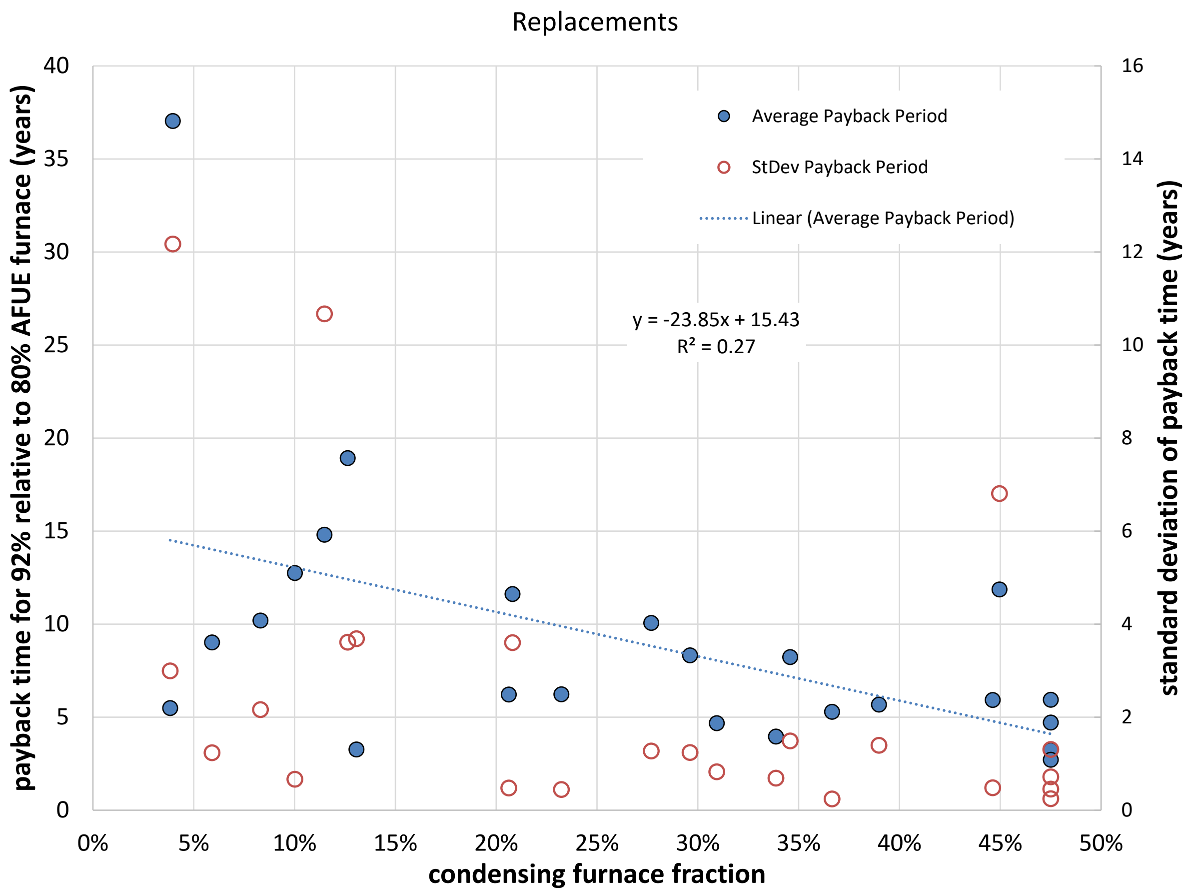


Figure 41: DOE SNOPR LCC Market Penetration for Replacement MHGFs

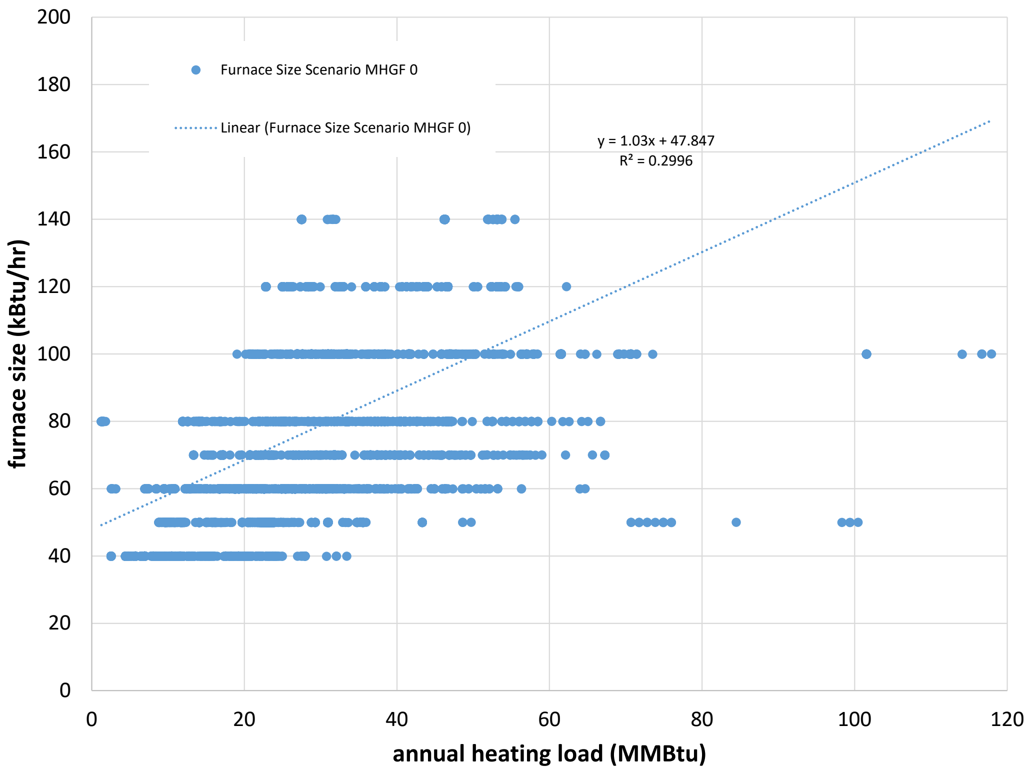


Figure 42: Furnace Size vs. MHGF Annual Heating Load – DOE SNOPR Methodology

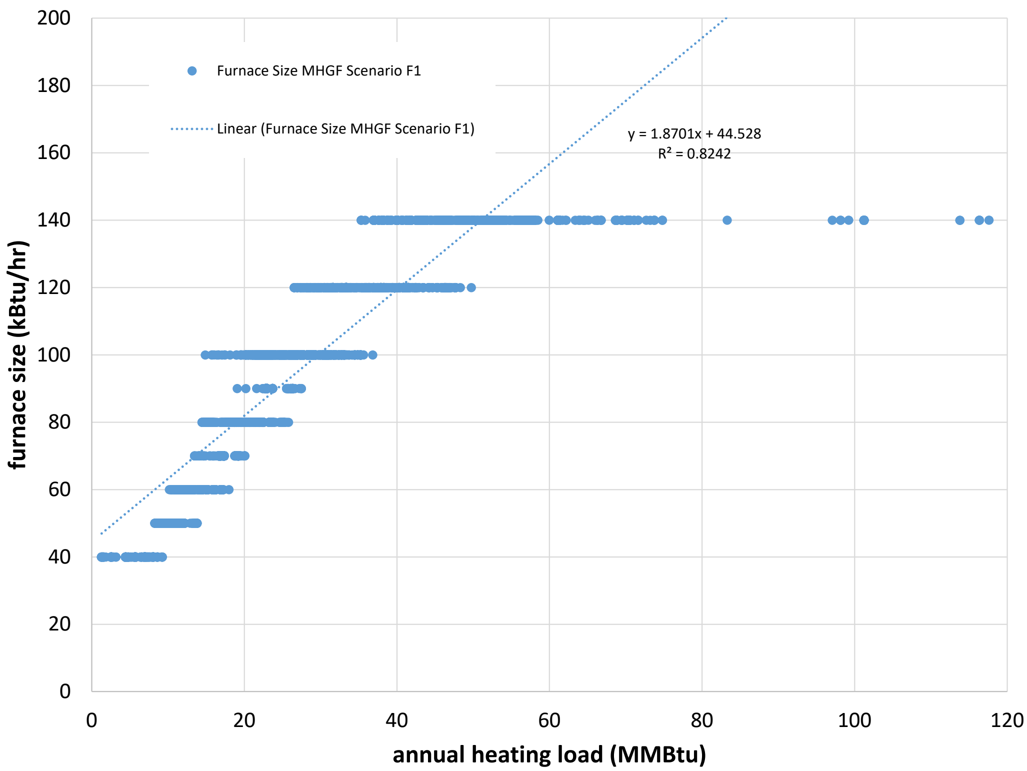


Figure 43: Furnace Size vs. MHGF Annual Heating Load – Consumption Methodology

TOPICAL REPORT GTI-16/0003

GTI PROJECT NUMBER 21917

Empirical Analysis of Natural Gas Furnace Sizing and Operation

Report Issued:
November XX, 2016

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Executive Summary

This report encompasses analysis of minimum natural gas furnaces capacity requirements in the United States, yielding insights on the distribution of furnaces sizes based on region, home attributes (e.g., weatherization), and occupant lifestyle choices such as thermostat setting and use of smart thermostats for energy savings. The report includes: (1) detailed hourly furnace and thermostat operational data for 21 homes obtained during the winter of 2013-2014 in the Chicago metropolitan region and (2) monthly natural gas use and home attributes for over 21,000 homes in various regional markets in Northern Illinois, Minnesota, Eastern Missouri, Arkansas, and Oklahoma. Together, these data were used to empirically determine furnace capacity requirements. These five regions cover four of the DOE/IECC Climate Zones, which encompasses the vast majority of natural gas home heating energy use.

The detailed hourly heating load analysis for Northern Illinois encompassed 21 randomly selected homes, including dwellings with varying levels of furnace capacity and efficiency, size (i.e., real estate square footage), and year of construction. Hourly thermostat, furnace run-time data, and outside temperature data were examined to identify peak space heating loads and furnace capacities during the months of December through February under: (1) **steady-state** thermostat setpoint values and (2) thermostat **setback recovery** operating modes. Analysis of the detailed hourly information yielded equations that were subsequently employed to ascertain the steady-state and setback recovery furnace sizing required for over 21,000 homes in five different climate zones.

Table 1 summarizes the nominal furnace size requirements for the overall dataset as well as the regional breakdown, assuming an 80% furnace efficiency. Taking furnace setback recovery operation as a valuable and preferred consumer option that saves energy, furnaces in the size range of 68,000 Btu/hour (median, 50th percentile) to 84,600 Btu/hour (80th percentile) should satisfactorily meet the needs of most natural gas customers; steady-state operational data with an appropriate DOE/ACCA sizing factor of 1.35 are consistent with these findings.

Table 1: Summary Furnace Capacity Requirements (80% efficient furnace)

All Five Regions	**Steady-State Operation (Btu/hour) With 1.35 DOE/ACCA Sizing Factor**	**Setback Recovery Operation (Btu/hour)**
80th Percentile Capacity	83,070	84,627
Average Capacity	67,607	70,538
Median Capacity	65,147	68,031
Regional Findings	80th Percentile Steady-State Operation (Btu/hour)	80th Percentile Setback Recovery Operation (Btu/hour)
Minnesota	61,931	65,376
Missouri	80,055	81,860
Illinois	83,353	84,859
Oklahoma	97,035	97,303
Arkansas	100,717	100,652

Perhaps counterintuitively, the furnace sizing requirements increased for homes located in DOE/IECC Climate Zone 3 which encompasses Southern, cooling-dominated regions (e.g., around Little Rock, Arkansas and Oklahoma City, Oklahoma). The data give clear findings that these homes exhibit distinctly lower levels of weatherization that translate into higher levels of building heat loss during the peak heating months of December through February. These weatherization attributes of these homes necessitate higher than anticipated peak furnace capacity ratings in the two Climate Zone 3 Southern regions included in this analysis.

Background

According to the U.S. Bureau of Census (2014 data), there are approximately 57 million homes using natural gas to meet their space heating requirements. An estimated 52.6% of owner-occupied homes across the U.S. use natural gas for home heating. Furnaces represent about 80% of the market, the balance being steam and hot water systems. Nearly 3 Quads of natural gas is used for home heating.

Sizing natural gas furnaces to meet the space heating needs of homes can be done using procedures, for example, in Manual J published by the Air Conditioning Contractors of America and ASHRAE technical publications. These provide a detailed analytical framework for estimating the surfaces of the building envelope, insulation level, window and door attributes, house infiltration rates, and other factors.

In practice, houses have widely varying construction attributes as well as a range of choices made by homeowners in terms of how they live. For example, homes may have differences in the performance of windows or insulation based their quality, how they were installed, or due to deterioration. These differences can be systematic – for example, differences in regional building practices – or specific to the behavioral attributes and lifestyle choices people make. For example, homeowners have widely varying views regarding preferred thermostat setpoints for indoor comfort (Figure 1).

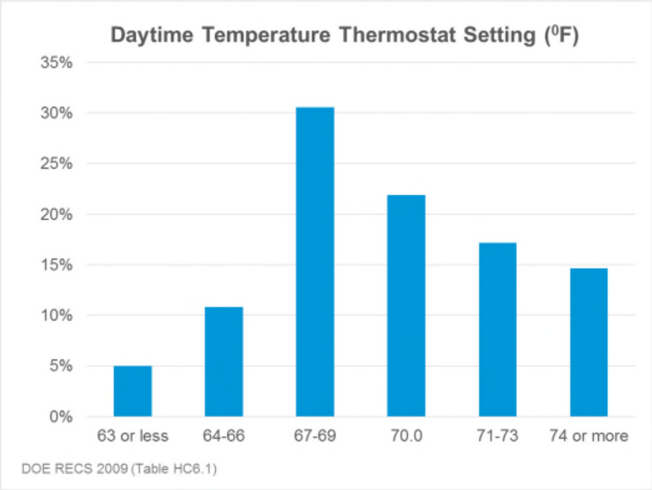


Figure 1: Distribution of Homeowner Choices on Space Heating Thermostat Setting

Minimum furnace size requirements to meet occupant needs and preferences becomes even more complicated when considering the increasing market impact of programmable or smart thermostats. These devices provide homeowners with energy saving features such as multiple thermostat setback options during overnight periods or during the day when the home is not occupied. Smart thermostats go even further by providing highly dynamic, learned thermostat setpoint operation based on occupant preferences and weather patterns. To examine the impacts of these complexities on furnace sizing recommendations and guidelines, empirical data is needed to supplement design guidelines such as ACCA Manual J that employ simplified assumptions about home characteristics and occupant behavior. Empirical data can provide insights into actual home heating needs based on the true physical condition of homes, the lifestyle choices that energy consumers make, and the role of new technology such as smart thermostats. This empirical data can help to calibrate computer models used in guidelines such as ACCA Manual J to ensure that furnace capacities meet a wide range of consumer needs and building types and condition.

Project Introduction

The objective of this project was to analyze empirical, real-world information on the sizing and operation of natural gas furnaces in homes across the US. This initially looked at detailed furnace and thermostat operation for homes in the Chicago metro area. These data provide insights on home weatherization as well as furnace and thermostat operation that enabled the derivation of furnace sizing equations based upon real-world homes and consumer behavior.

From this, GTI analysts extended the study to a larger set of homes (about 18,000) in the Chicago area using monthly natural gas consumption for one year. Methodologies were derived to ascertain (1) the approximate home monthly space heating loads during the peak heating months of December through February and (2) building UA Value – a measure which incorporates home weatherization attributes (defined in a subsequent section of this report). This approach was then applied to homes in Minnesota, Missouri, Arkansas, and Oklahoma to provide a better understanding of regional building characteristics. In total, this analysis of gas company billing databases analyzed the space heating requirements for over 21,000 homes in five DOE/IECC climate zones.

As part of an Nicor Energy emerging technology program measurement and verification project, GTI previously collected information to quantify smart thermostat energy (heating and cooling) savings on Chicago metro area homes during a twelve month period in 2013-2014. This included 54 thermostats in 49 homes – both single-family and multi-family dwellings. For each site, 8,760 hourly datapoints were gathered (excluding instances of data unavailability).

For this furnace sizing analysis, a subset of 42 homes were identified as single-family dwellings with a single furnace. From this, GTI randomly selected 21 homes for detailed analysis. This group of 21 homes fairly represents the larger group of homes, including dwellings with varying levels of efficiency (as measured by UA Value), size (i.e., square footage), and year of construction.

As shown in Figure 2, Chicago falls in the DOE/IECC Climate Zone 5. This represents a significant portion of the country's population – particularly in the Midwest and Northeast. Less densely populated Zone 6 and Zone 7 have greater heating degree days (HDD). Notably, the detailed furnace and thermostat operational data were obtained during the winter of 2013-2014 in Chicago – a particularly harsh winter – which is helpful in terms of understanding empirical furnace sizing requirements.

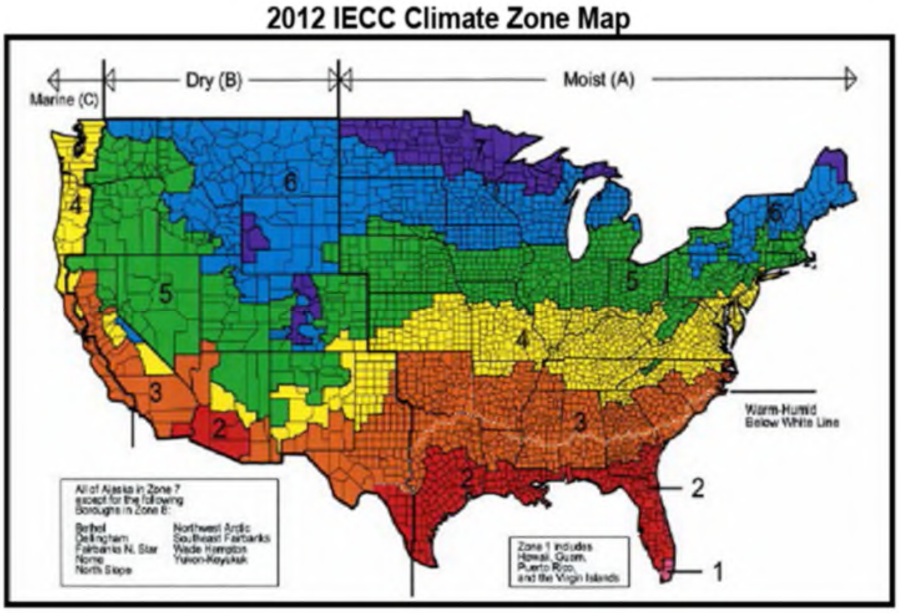


Figure 2: DOE/IECC Climate Zone Map

The Chicago metropolitan region lies in the upper portion of DOE/IECC Climate Zone 5 – and below more extreme regions in Climate Zones 6 and 7. The following table provides ASHRAE information on extreme heating design temperature (99^{th} percentile) and heating degree days (HDD, 65°F base) for a select number of cities. This includes areas encompassed in this analysis – Chicago, Minneapolis, St. Louis, Little Rock, and Oklahoma City – as well as other more extreme northern tier locations.

Nationally, Chicago is representative of a heating-dominated region, with a 99 percentile design temperature of 3.7°F and 6,209 HDD. There are many locations in Zones 6 and 7 with more extreme space heating requirements. For example, Minneapolis has an annual HDD value of 7,472 (20% more than Chicago) and Fargo, ND has a HDD value of 8,729 (40% greater than Chicago). The 99^{th} percentile design temperatures for Minneapolis and Fargo are, respectively, minus 6.2°F and minus 14.5°F (differential of 9.9 and 18.2 degrees from Chicago). Using the equation for UA Value (described in a following section), the same home in Chicago would nominally require a furnace with 3.6% larger capacity in Minneapolis and 15.7% larger in Fargo.

Empirical, real-world data is needed to ascertain specific furnace sizing requirements for homes located in different climate zones. As illustrated in this report, actual furnace and thermostat operation – and home construction attributes – result in highly variable and, in some instances, counterintuitive results. This necessitates an empirical, rather than a purely analytical, approach to understanding real-word residential space heating requirements.

Table 2: ASHRAE Handbook (2013) Heating Design Values

City	ASHRAE 99% Heating Design Temperature (°F, dry bulb)	ASHRAE Heating Degree Days (65°F base)	Heating Degree Days (for year analyzed in this report)
Chicago, IL	3.7	6,209	7,548 (2013/14)

			6,657 (2010/11)
Minneapolis, MN	-6.2	7,472	6,283 (2015/16)
St. Louis, MO	11.7	4,436	4,552 (2008/09)
Oklahoma City, OK	18.2	3,487	1,944 (2015/16)
Little Rock, AR	23.3	3,158	1,453 (2015/16)
Buffalo, NY	7.4	6,508	N/A
Milwaukee, WI	3.2	6,684	N/A
Billings, MT	-3.2	6,705	N/A
Sioux Falls, SD	-7.3	7,470	N/A
Fargo, ND	-14.5	8,729	N/A

Methodology and Data Analysis

The data analysis includes two primary sections:

- Detailed hourly analysis of furnace and thermostat operation to derive furnace sizing equations based upon empirically calculated home UA Value (see below).
- Application of furnace sizing equations to over 21,000 homes in five different DOE/IECC climate zones. This uses monthly natural gas consumption, methodologies to ascertain space heating load, meteorological data (i.e., heating degree day) to derive to home UA Value and thereby determine furnace sizing.

UA Value is used extensively throughout this report and is shown to be the most appropriate metric for determining home space heating requirements in a given region. UA Value can be empirically (and conveniently) found using the following equation:

$$\text{UA (Btu/hr-F)} = \text{Q (Btu/hr)}/[T_{indoor}\text{ (F)} - T_{outdoor}\text{ (F)}]$$

Q is the energy input into the home – for example the delivered energy from a gas furnace net of flue gas losses and T represents the temperature difference between the interior of the home (e.g., thermostat setting) and the outside environment. Importantly, these quantities can be readily measured.

The terminology "UA" is used in engineering heat transfer analysis to capture: (1) U, the overall heat transfer coefficient (in Btu/hr-F-ft^2) of the building multiplied by (2) A, the building's surface area (in ft^2). This square footage is not the floor area, but is the heat exchange surface area (i.e., walls, roof, etc.) defined at the thermal envelope boundaries – that is, where the insulation begins/ends. The magnitude of U for a given home can be lowered through weatherization techniques such adding insulation, using energy efficient windows, air sealing, etc. The value of A can be influenced by building design – for example by reducing the exposed area for energy loss (especially through the roof). In practice, knowing the individual numeric value of U or A is difficult, but the above equation permits an empirical approach to understanding U*A for a given building using readily measured values of furnace energy use, efficiency, and temperature readings inside and outside the home.

Detailed Hourly Chicago Area Home, Furnace, and Gas Use Attributes

The dataset from the smart thermostat program included hourly data on 42 homes with a single furnace. Table 3 summarizes key attributes of the homes and furnaces. The homes have a random distribution of year built, square footage, furnace size, and UA Values (described in a subsequent section). From these 42 homes, a subset of 21 homes were randomly selected for more detailed data analysis, while ensuring a fair distribution of UA Values.

Table 3: Home and Furnace Characteristics

City in Illinois	Furnace Size Btu/hr input	Efficiency AFUE, %	UA Value	Heating Degree Days	Space Heating Gas Use (Therms/yr)	Year Built	Square Footage
Arlington Heights	122,222	90	517	7,406	1,103	1977	3,002
Arlington Heights	77,778	90	449	7,406	1,062	1948	1,728
Aurora	86,957	92	215	7,728	508		
Barrington	125,000	80	643	7,329	1,508	1988	1,615
Bartlett	125,000	80	408	7,546	1,001	1995	2,040
Belvidere	90,000	80	371	7,848	995	1930	1,132

Buffalo Grove	125,000	80	616	7,213	1,675	1978	2,018
Buffalo Grove	187,500	80	1,104	7,394	2,718		
Carpentersville	187,500	80	1,127	7,750	2,879	2001	3,264
Cherry Valley	112,500	80	741	7,872	2,123		
Diamond	100,000	90	336	7,200	745	2003	2,320
Geneva	168,750	80	959	7,703	2,274		
Geneva	168,750	80	603	7,746	1,343		
Glenview	168,750	80	765	7,400	1,696		
Hillside	87,500	80	521	7,311	1,275	1958	1,073
Homer Township	125,000	80	432	7,501	1,092	1988	1,288
McHenry	137,500	80	528	8,065	1,464	1981	1,950
Montgomery	86,957	92	426	7,644	920		
Montgomery	125,000	80	567	7,822	1,560	2002	2,750
Montgomery	165,000	80	667	7,684	1,647		
Mount Prospect	157,143	70	420	7,405	1,072		
Naperville	87,500	80	424	7,749	1,160		
Naperville	125,000	80	706	7,749	1,632	1987	2,012
Oak Park	187,500	80	908	7,036	2,383		
Plainfield	125,000	80	301	7,307	786	1996	1,510
Romeoville	137,500	80	662	7,528	1,865	2002	2,254
Romeoville	93,750	80	290	7,538	853		
Romeoville	100,000	80	475	7,487	1,286	2000	1,427
Round Lake	87,500	80	217	7,549	522		
Round Lake	137,500	80	784	8,002	1,895	2002	3,006
Schaumburg	93,750	80	677	7,319	1,596		
Skokie	112,500	80	419	7,255	1,122		
South Holland	125,000	80	966	7,712	2,347	1967	1,461
Streamwood	142,857	70	387	7,690	1,219		
Sugar Grove	97,826	92	597	7,818	1,384	2004	2,818
Volo	87,500	80	268	7,879	729	2004	1,656
Wheaton	100,000	80	440	7,751	1,013		
Wheaton	112,500	80	350	7,689	856	1977	1,377
Wheaton	171,429	70	699	7,288	1,832		
Woodridge	150,000	80	469	7,185	1,178		
Woodstock	137,500	80	393	8,870	1,073		
Worth	125,000	80	651	6,818	1,673		

Table 4 provides summary statistics of the homes and furnaces included in the detailed hourly study.

Table 4: Summary Statistics on Homes and Furnaces

	Home Square Footage	Furnace Rating (Btu/hr)	UA Value	Therm Use
Average	2,036	125,403	560	1,406
Standard Deviation	671	31,179	224	557
Minimum	1,073	77,778	215	508
Maximum	3,264	187,500	1,127	2,879

Using furnace gas consumption data, efficiency rating, and available indoor and outdoor temperatures, GTI analysts calculated an empirical UA Value for each home. Daily UA Values were derived, summed, and averaged to provide an overall UA Value for each home during an entire year. Figure 3 shows the strong correlation between a home's UA Value and space heating energy use (R^2=0.96).

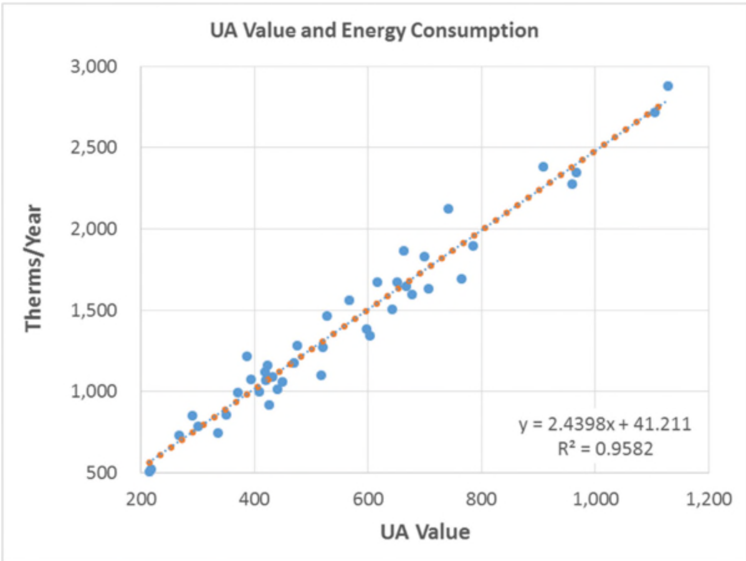


Figure 3: Relationship Between UA Value and Furnace Natural Gas Use

Figure 4 shows the highly variable relationship between home size (i.e., square footage) and energy use. There is a positive, but weak, correlation between these factors (R^2=0.26). This poor correlation corroborates that even homes of equal size in a given region can have dramatically different heating requirements based upon (1) the as-built building "tightness" and efficiency and (2) homeowner behavior such as thermostat setting and setback strategies.

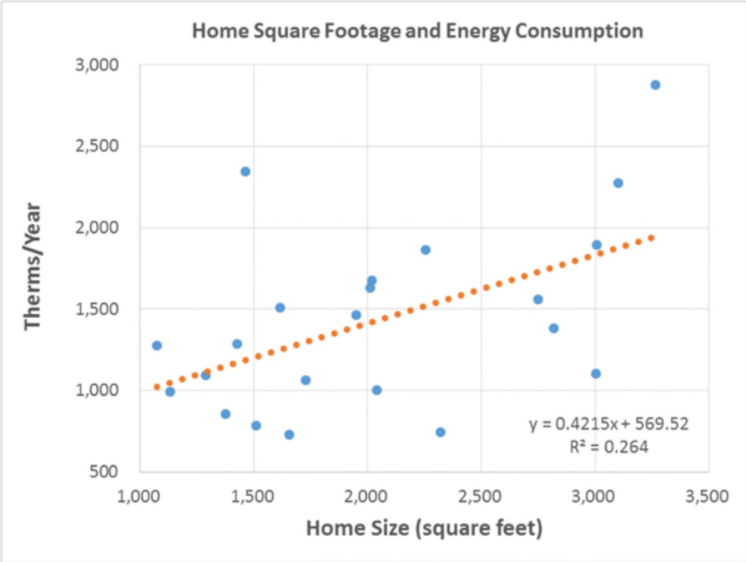


Figure 4: Home Size (ft^2) and Energy Use

Figure 5 highlights the poor correlation between home UA Value and the home's square footage of living area. Homes of equal size can have widely varying UA Value and energy consumption attributes, including peak load and furnace capacity needs.

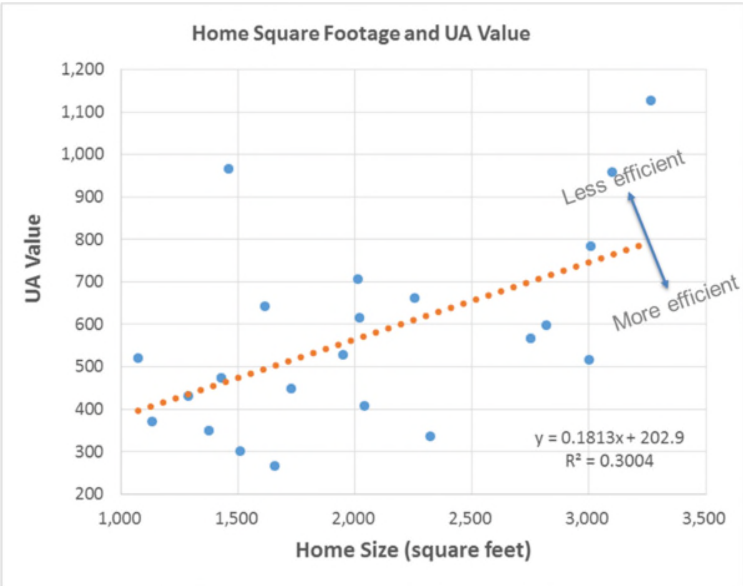


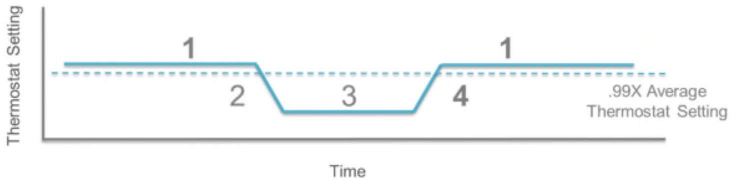
Figure 5: Home Size and UA Value

Detailed Hourly Chicago Area Thermostat and Furnace Operation Analysis

GTI analysts conducted an analysis of hourly thermostat setpoint and furnace operation during the months of December 1, 2013 through March 19, 2014. This included a total of 2,616 hours (part of a complete

8,760 year-round monitoring of furnace and air conditioning operation) for 21 homes in the Chicago metro area.

Figure 6 illustrates prototypical programmable or smart thermostat operating states with setback operation. For this furnace sizing analysis, hourly thermostat and furnace run-time data were examined to identify two key operating modes: (1) **steady-state** thermostat setpoint values and (2) thermostat **setback recovery**. These two furnace operating states can be used to characterize nominal furnace energy input capacity requirements for home heating. Mathematical algorithms based on actual temperature at the thermostat were employed to determine these operating states.



Thermostat State	Description
1	**Steady State Operation**
2	Setback Ramp Down
3	Setback Dwell
4	**Setback Recovery**

Figure 6: Thermostat Operating States

Data from two other thermostat states – that is, during thermostat setback periods of ramp down and dwell at temperatures below average setpoint values – were not analyzed since they represent atypical operating points from a furnace capacity sizing perspective. By analogy, setback ramp down and dwell are similar to a vehicle going downhill or an engine idling; these would not be particularly relevant to an automotive design engineer looking to size the power requirements of an engine.

Determination of Steady State Setpoint and Setback Recovery Operation

Within the database, an hourly "heating slope" value was calculated by taking the difference in thermostat setting for the previous and subsequent hour (a three-hour span). Slopes in close proximity to zero represent steady-state operation; a negative value directionally indicates thermostat ramp down, while a positive value directionally indicates thermostat recovery (ramp up).

Steady-state operation was defined as a timeframe where, over a three hour period, the thermostat setting changed very little and was in close proximity to the average thermostat setting for the home. The logic for this was defined as being above 0.995 of the average thermostat setting and a heating slope of less than 0.3^{o}F. To eliminate potential transition periods between thermostat operating states, hourly furnace run times of less than six minutes were excluded.

Setback recovery was defined as having a heating slope value greater than 2^{o}F per hour. Similarly, to eliminate potential transition periods between thermostat operating states, hourly furnace run times of less than six minutes were excluded.

Table 5 shows summary statistics from detailed analysis of 21 homes. The manner in which homeowners employed smart thermostats varied in terms of frequency of setpoint changes and the amplitude of changes (e.g., setback temperature). Some homeowners used a thermostat setback as large as 7 to 10^{o}F, while others more commonly used values ranging from 2-4 °F. In all cases, steady state operating hours exceeded setback recovery hours.

Table 5: Summary of Thermostat Steady-State and Setback Recovery Operating Hours

Number of Hours	Steady-State Operation	Setback Recovery Operation
Average	780	169
Standard Deviation	311	110
Minimum	398	11
Maximum	1,665	362

Figure 7, Figure 8, and Figure 9 illustrate the highly variable nature by which homeowners operate smart thermostats. There were significant differences in the frequency and amplitude in thermostat settings. The mathematical algorithms provided a consistent manner for screening these data to determine steady-state operation and setback recovery periods.

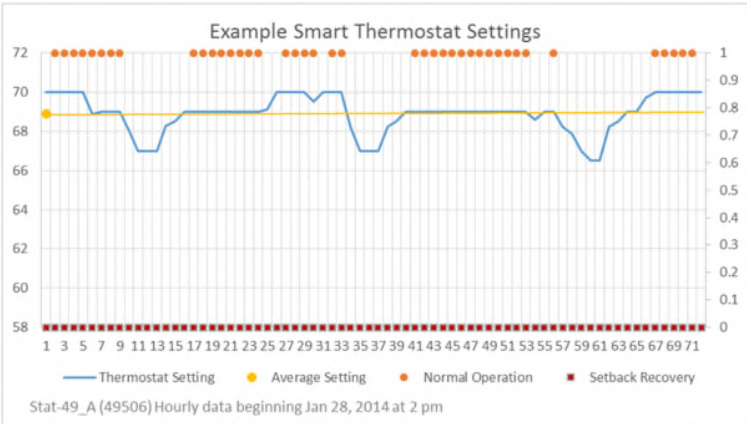


Figure 7: Thermostat Operation With Low Frequency and Amplitude

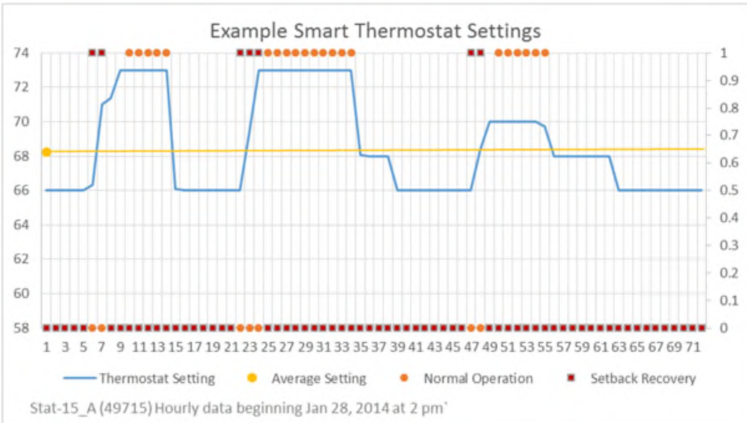


Figure 8: Thermostat Operation With Moderate Frequency and Amplitude

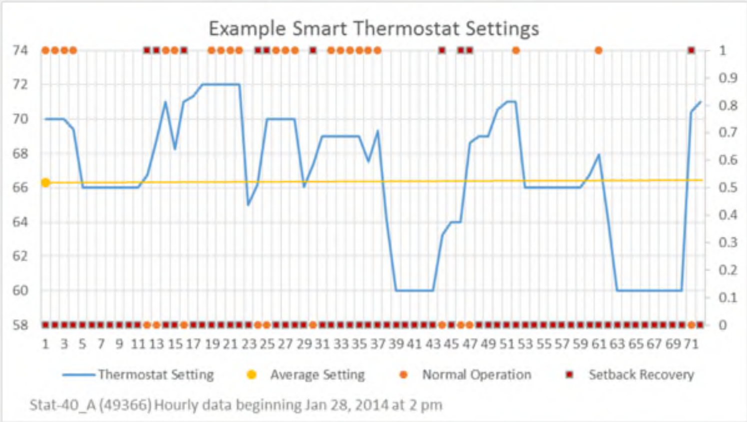


Figure 9: Thermostat Operation With High Frequency and Amplitude

Furnace Capacity Requirements During Steady-State and Setback Recovery Operation

Using the previously described algorithms to identify steady-state and setback recovery operating states, a more detailed analysis of the 21 sites was undertaken. For each hour, data were available on furnace run time as well as indoor and outdoor temperature. Using the run time information and furnace input rating, a calculation was made of the estimated hourly Btu energy input into the furnace.

Figure 10 illustrates hourly run time information for one home as a function of outdoor temperature and furnace operating state (steady-state and setback recovery modes). This example home has a 125,000 Btu/hour furnace and a relatively efficient UA Value of 432. There is significant data scatter, but trend lines show anticipated increases in run time with colder temperatures. Further, run times are generally higher during setback recovery periods. An appendix to this report contains scatter plots for all 21 homes.

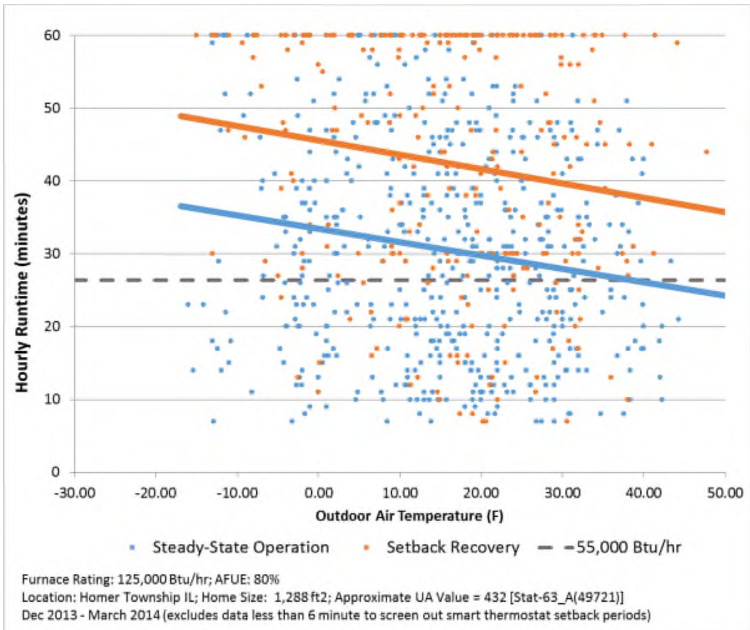


Figure 10: Example Furnace Steady-State and Setback Recovery Operation

From these data, a furnace rating requirement was derived for steady-state operation and setback recovery. The capacity requirement was defined as the 80th percentile value of data for each operating state. Table 3 shows this value for the data illustrated in Figure 10. To interpret these figures, 80% of the steady-state operating hours required a furnace rated at 93,750 Btu/hour or less (75% of the furnace's actual 125,000 Btu/hour rating). During setback recovery, the 80th percentile figure was equal to the furnace capacity, meaning that at least 80% of the setback recovery operational hours used the full 125,000 Btu/hr furnace capacity. This highlights the typically extended furnace operation, and higher input firing rate, necessary to raise the home's temperature from a thermostat setback point.

Table 6: Homer Township (Thermostat 63) Furnace Capacity Requirement

	Steady State Operation	**Setback Recovery**
80th Percentile Value	93,750	125,000
Count	535	270

Table 7 summarizes the steady-state and setback recovery capacities for the 21 homes analyzed. The average steady-state operating furnace capacity was about 77,500 Btu/hour (77,527 Btu/hour) and about 108,000 Btu/hour (107,859 Btu/hour) for setback recovery operation. The average setback recovery capacity was about 30,000 Btu/hour greater than required for steady-state operating periods. As discussed, home attributes (specifically, UA Value) and homeowner lifestyle choices result in highly variable outcomes. For example, the magnitude of thermostat setback varies; some homeowners employ temperature setback ranging from 7-10^{o}F, while others would typically be in the range of 2-4 ^{o}F of thermostat setback.

Table 7: Summary of Furnace Steady-State and Setback Recovery Capacity Requirements

City in Illinois	**Furnace Rating Btu/hr input**	**UA Value**	**Gas Use (Therms/year)**	**Steady-State Operating Capacity (80th percentile)**	**Setback Recovery Capacity (80th percentile)**
Average	**125,403**	**560**	**1,406**	**79,244**	**110,627**
Plainfield	125,000	301	786	39,583	68,750
Arlington Heights	77,778	449	1,062	45,371	77,778
Belvidere	90,000	371	995	49,500	61,500
Romeoville	100,000	475	1,286	51,667	65,667
Volo	87,500	268	729	52,500	86,042
Wheaton	112,500	350	856	56,250	112,500
Diamond	100,000	336	745	56,667	98,333
Hillside	87,500	521	1,275	56,875	87,500
Bartlett	125,000	408	1,001	65,000	125,000
Barrington	125,000	643	1,508	68,750	93,750
McHenry	137,500	528	1,464	68,750	119,625
Buffalo Grove	125,000	616	1,675	72,917	125,000
Montgomery	125,000	567	1,560	72,917	125,000
Romeoville	137,500	662	1,865	75,625	98,542

Sugar Grove	97,826	597	1,384	89,674	97,826
Homer Township	125,000	432	1,092	93,750	125,000
Arlington Heights	122,222	517	1,103	101,852	122,222
Naperville	125,000	706	1,632	116,667	125,000
South Holland	125,000	966	2,347	125,000	125,000
Carpentersville	187,500	1,127	2,879	131,250	187,500
Round Lake	137,500	784	1,895	137,500	137,500

Figure 11 provides an illustration of a "load duration curve" distribution for steady-state furnace input firing rates (535 hours) for the Homer Township home shown in Figure 10 as well as operation during setback recovery (270 hours). Of the hours firing at steady-state conditions, 80% of them were at 93,750 Btu/hour or less; conversely, 20% were above this firing rate. For comparison, a 55,000 Btu/hour furnace would be sufficient for about 42% of the steady-state operating hours. For purposes of operation during setback recovery, this home spent 89% of the setback recovery time above 55,000 Btu/hour. Even for this relatively efficient home, with UA Value of 432, substantial time (161 hours) was spent at firing rates well above 55,000 Btu/hour of heat input.

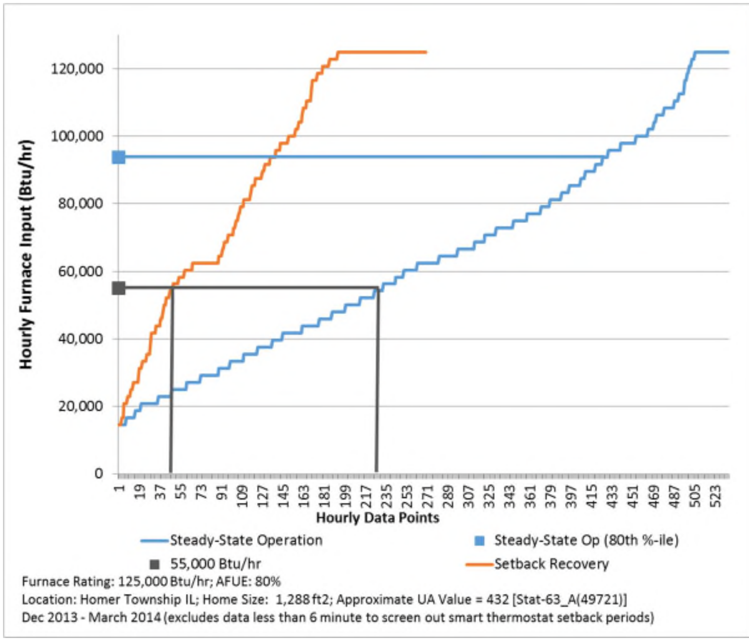


Figure 11: Steady-State Operating Mode Hourly Furnace Input Rate Distribution (Homer Township)

Figure 12 shows a similar "load duration curve" for a more efficient home (UA Value 350). In this example, a 55,000 Btu/hour furnace could meet about 75% of the steady-state furnace input firing rate need, but as shown there remain significant peak heating hours requiring larger hourly heat input. A smaller furnace could only meet 25-30% of the setback recovery hourly needs. About 275 hours were at firing rates above 55,000 Btu/hour, a sizeable portion of which were nearly double this firing rate.

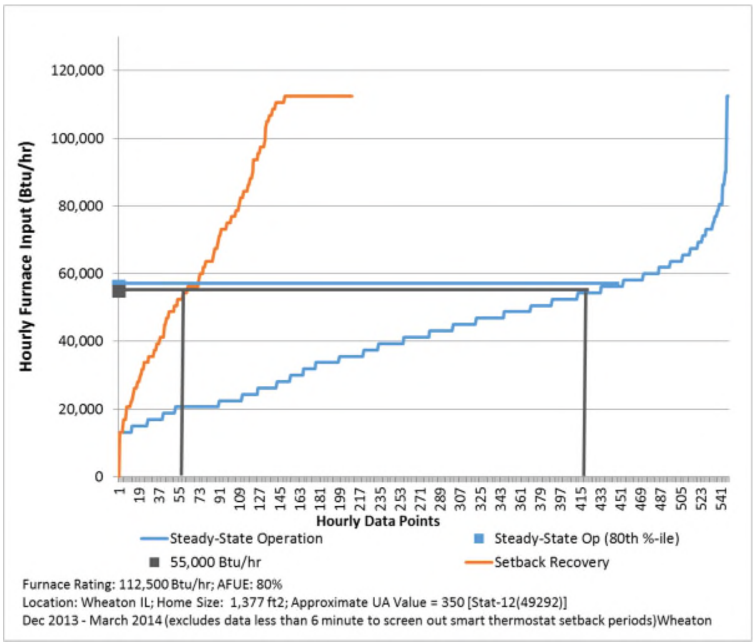


Figure 12: Steady State Operating Mode Hourly Furnace Input Rate Distribution (Wheaton)

Figure 13 shows a similar "load duration curve" for a home (UA Value 567) that is representative of an average home in this analysis. In this particular home, a 55,000 Btu/hour furnace would meet about 53% of the steady-state furnace input firing rate need, leaving significant number of peak heating hours requiring larger hourly heat input. A 55,000 Btu/hour furnace could only meet 29% of the setback recovery hourly needs. About 590 hours were at firing rates above 55,000 Btu/hour, a meaningful portion of which are at 50% to 100% higher firing rates.

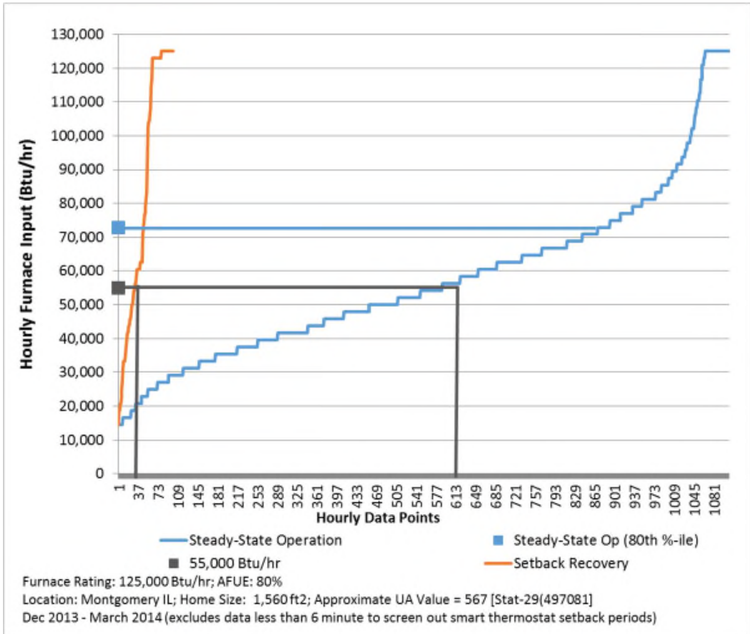


Figure 13: Steady-State Operating Mode Hourly Furnace Input Rate Distribution (Montgomery)

Based on this analysis, an average home – and even more efficient homes – furnace ratings well in excess of 55,000 Btu/hour are needed for a significant portion of the peak heating months of December through February. Even smaller and more efficient homes would likely see meaningful loss in heating function if required to install a 55,000 Btu/hour furnace.

Figure 14 shows the main results from this analysis, with the following three key points:

1. A small minority of homes (UA Values of 400 and less) from this analysis may be able to see most, but not all, their steady state space heating needs met by a 55,000 Btu/hour furnace. However, even these relatively efficient homes would see extended hours where a 55,000 Btu/hour furnace would likely be undersized and could compromise homeowner comfort.
2. In the vast majority of homes (UA Values over 400), a 55,000 Btu/hour furnace is increasingly insufficient in meeting their peak heating demand requirements as UA Value increases above 400.
3. In all cases, a 55,000 Btu/hour furnace would likely compromise setback recovery performance. Homeowners would be likely be inclined to limit the extent, or stop employing, thermostat setback as an energy efficiency measure.

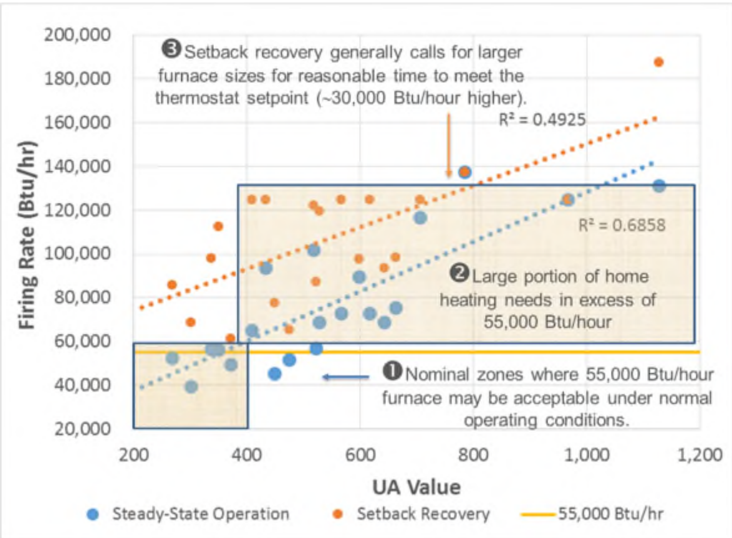


Figure 14: UA Value (Dec-Feb) and Furnace Capacity Requirements

As shown in Figure 15, <u>all</u> homes exhibited periods that called for more than 55,000 Btu/hour during peak heating periods (January-February). Even smaller and "tighter" homes (UA Value below 400) had 10-30% of on-time hours employing more than 55,000 Btu/hour. The vast majority of homes over UA Value 400 spent 40-90% of on-time at firing rates above 55,000 Btu/hour.

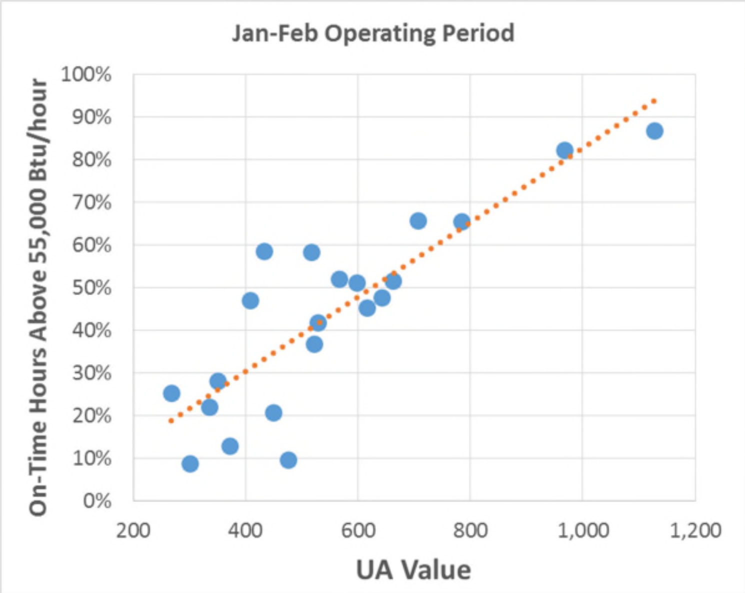


Figure 15: Peak Heating Operating Hours Above 55,000 Btu/hour

For these 21 homes, GTI analysts derived equations that relate UA Value to peak heating period capacity for (1) steady-state capacity and (2) for thermostat setback recovery operation. Figure 16 shows the data used to derive these equations. From the 21 homes, GTI analysts selectively removed outlier data to lower scatter and maximize the R^2 value (0.8251 and 0.8056, respectively); these changes uniformly acted to reduce calculated furnace capacity compared to the full dataset. Note that the net energy delivery rate in this figure and the equations would need to be divided by efficiency to obtain gross furnace input capacity.

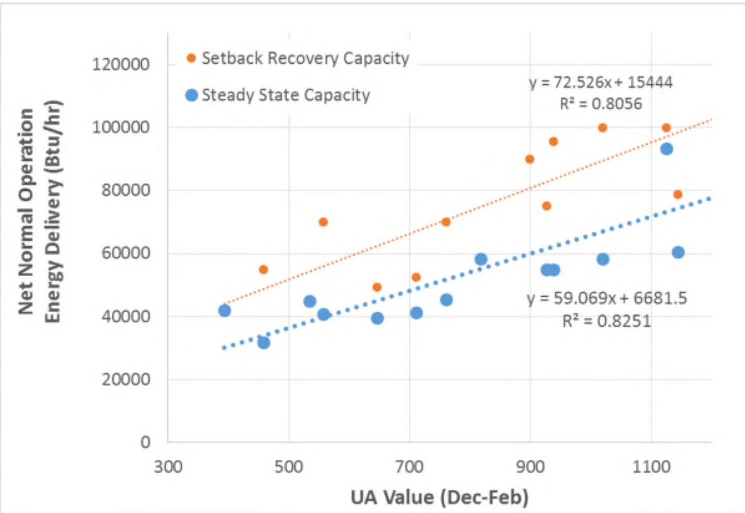


Figure 16: UA Value (Dec-Feb) and Delivered Energy Rate for Steady-State and Setback Recovery

To facilitate peak heating requirements from a larger dataset of natural gas use in homes, we calculated UA Values for the peak months of December through February. For this population of homes, this UA

Value (Dec-Feb) averaged 12% higher than the UA Value calculated over the entire year. The two equations are:

Net Steady-State Energy Deliver Rate (Btu/hr) = 1.35 * [59.069 * UA Value (Dec-Feb)] + 6681.5

Net Setback Recovery Energy Delivery Rate (Btu/hr) = [72.526 * UA Value (Dec-Feb)] + 15,444

The DOE/ACCA furnace sizing factor of 1.35 was applied to the steady-state energy delivery rate to accommodate for a range of uncertainty in furnace sizing, consistent with ACCA Manual S and DOE analysis.

Space Heating Analysis of a Larger Population of U.S. Homes

GTI conducted an analysis of a much larger population of homes using monthly natural gas energy use data supplied by various natural gas utilities across the U.S. This encompassed homes in Northern Illinois (Chicago metro area), Minnesota (Minneapolis/St. Paul metro area, Eastern Missouri (St. Louis metro area), Arkansas (Little Rock and surrounding areas), and Oklahoma (Oklahoma City and surrounding areas). Where possible, this data was supplemented with information about the home – for example, year of construction and square footage – along with meteorological data such as outdoor temperature and heating degree day.

The largest of these datasets was in the Chicago metro area, encompassing monthly natural gas use and furnace efficiency for over 18,000 homes. These data were coupled with local monthly heating degree day data to determine home UA Values during the December through February period (as described below). GTI then extended this methodology for determining UA Value to other homes in Minnesota, Missouri, Arkansas, and Oklahoma. Using the relationships described previously linking UA Value to steady-state and setback recovery furnace operation, GTI analysts calculated the estimated furnace capacity for all these homes.

As described earlier, UA Value is defined as:

$$UA\ (Btu/hr\text{-}F) = Q\ (Btu/hr)/[T_{indoor}\ (F) - T_{outdoor}\ (F)]$$

From this larger data set of monthly natural gas use, GTI used the following steps to estimate home UA Value during the December through February peak heating season.

1. Summed up December, January, and February total gas use.
2. Found the average summer monthly natural gas use (during June-August). This represents the nominal monthly gas use for non-space heating loads (e.g., mainly water heating along with cooking and drying).
3. Subtracted 3.X times (i.e., three months) the value from Step 2 from the results of Step 1, multiplied by furnace efficiency, and divided this number the total number of hours in December, January, and February. This value is Q in the above equation – average net Btu/hr of delivered energy from the furnace. GTI applied a factor of 3 times months the average summer months use plus an amount (.X) to account for greater heating energy required to raise water temperature in the winter as compared to the summer (i.e., due to lower below ground temperatures during the winter). For Minnesota, GTI analysts used 3.35, Illinois and Missouri a factor of 3.3, and Arkansas and Oklahoma a factor of 3.25.
4. The heating degree days for December, January, and February were summed and divided by the number of days in those three months to get the average indoor – outdoor temperature difference.
5. Divided Step 3 by Step 4 to derive the UA Value for December through February.
6. The analysis focused on homes with a UA Value of 250 to 1100. The numbers below 250 likely represent multi-family residences, while values above 1100 are more likely large homes (which may in some instances use more than one furnace).
7. The prior equations linking furnace capacity to home UA Value were used to ascertain the steady-state furnace size (with the DOE/ACCA sizing factor) and the setback recovery capacity.

Illinois (Chicago Area) Homes

Figure 17 shows the results of the UA Values (Dec-Jan) calculation for this larger population of nearly 18,000 Northern Illinois area homes (using December 2010 – February 2011 data). Note that the data in this figure excludes homes below UA Value 250 and above 1100 (less than 10% of all the homes in this dataset). Table 8 provides summary statistics on this population of 17,978 Chicago metro area homes. Using the relationship between UA Value (Dec-Feb) and net delivered energy required, GTI analysts calculated steady state with the DOE/ACCA 1.35 sizing factor and setback recovery furnace capacity requirements for 80% efficient furnaces.

Table 8: Characteristics for Illinois Homes (Chicago Area)

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
Average	568	67,871	70,779
Median	543	65,447	68,574
80th Percentile	723	83,353	84,859
Standard Deviation	185	17,978	17,978

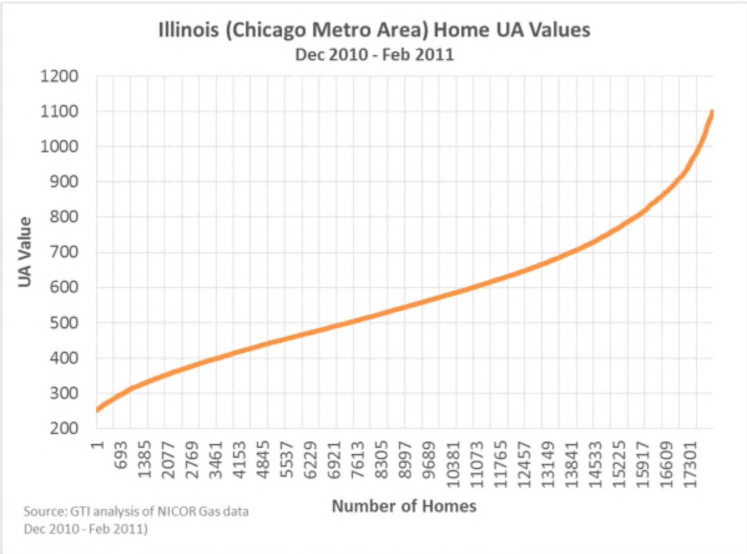


Figure 17: Distribution of UA Values for Illinois Homes (Chicago Metro Area)

Figure 18 shows the distribution of the steady-state and setback recover furnace capacity requirements for the nearly 18,000 homes in the Chicago metro area. An 80th percentile value for steady state and setback recovery operation is about 83,000 to 85,000 Btu/hour.

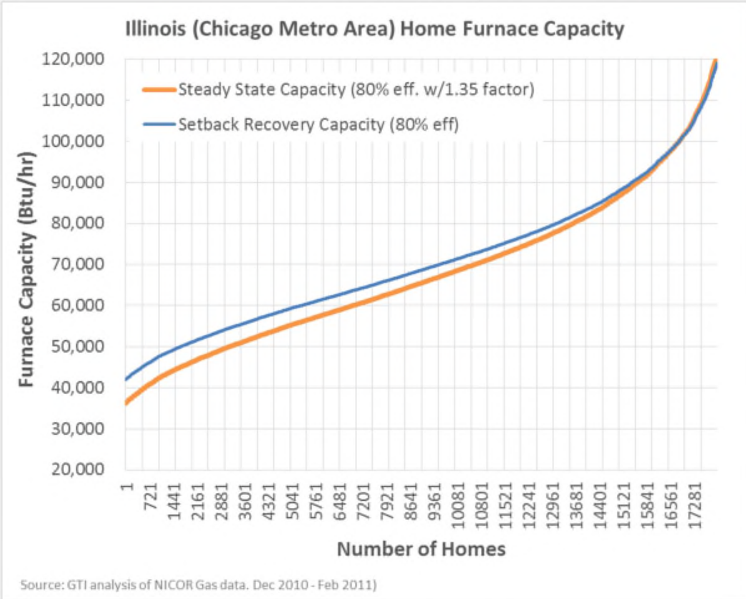


Figure 18: Distribution of Furnace Capacity for Illinois Homes (Chicago Metro Area)

Missouri (St. Louis Area) Homes

Figure 19 shows the results of the UA Values (Dec-Jan) calculation for this larger population of 2,235 St. Louis area homes (December 2008 – February 2009). In this data, the furnace efficiency was assumed to be 78% (these data were gas use prior to installing high-efficiency furnaces). The data in this figure excludes homes below UA Value 250 and above 1100 (less than 6.3% of all the homes in this dataset). Table 9 provides summary statistics on this population of St. Louis area homes. Using the relationship between UA Value (Dec-Feb) and net delivered energy required, GTI analysts calculated steady state and setback recovery furnace capacity requirements for 80% efficient units.

Table 9: Characteristics for Missouri (St. Louis Area) Homes

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
Average	552	66,284	69,336
Median	528	63,933	67,197
80th Percentile	690	80,055	81,860
Standard Deviation	176	17,570	15,980

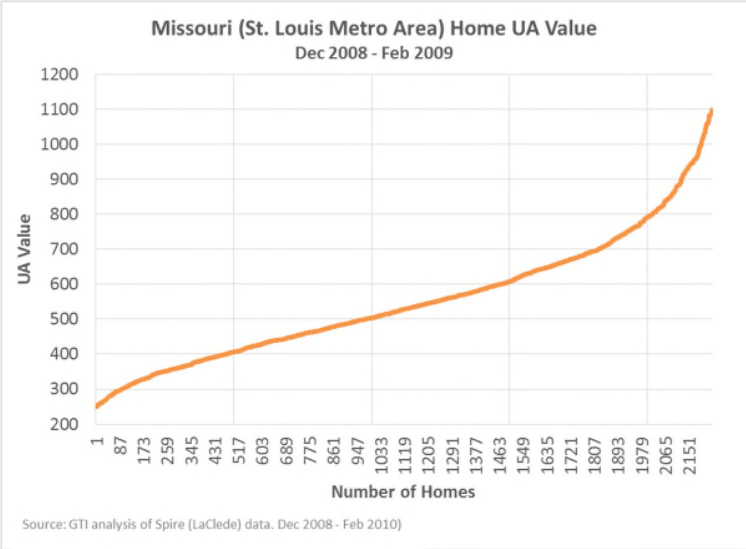


Figure 19: Distribution UA Values (Dec-Feb) for Missouri Homes (St. Louis area)

Figure 20 shows the distribution of the steady-state and setback recover furnace capacity requirements for the 413 homes in the St. Louis metro area. An 80th percentile value for steady state and setback recovery operation is about 80,000 to 82,000 Btu/hour.

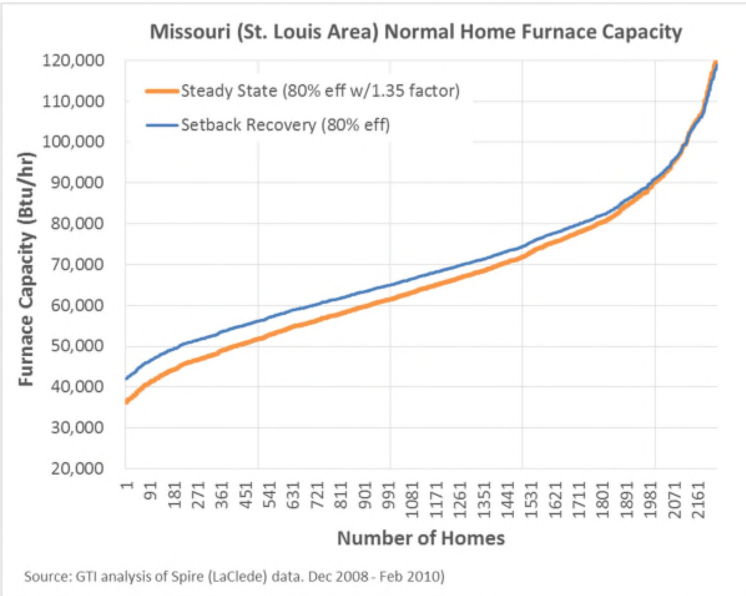


Figure 20: Distribution of Furnace Capacity for Missouri (St. Louis Area)

Minnesota (Minneapolis/St. Paul Area) Homes

Figure 21 shows the results of the UA Values (Dec-Jan) calculation for 413 homes in the Minneapolis/St. Paul area (December 2015 – February 2016). The data in this figure excludes homes below UA Value 250 and above 1100 (this is about 17% of the homes in this dataset). Table 10 provides summary statistics on this population of Minneapolis area homes. Using the relationship between UA Value (Dec-Feb) and net delivered energy required, GTI analysts calculated steady state and setback recovery furnace capacity requirements for 80% efficient units.

Table 10: Characteristics for Minnesota Homes (Minneapolis/St. Paul)

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
Average	416	52,774	57,048
Median	381	49263	53,855
80th Percentile	508	61,931	65,376
Standard Deviation	139	13,812	12,562

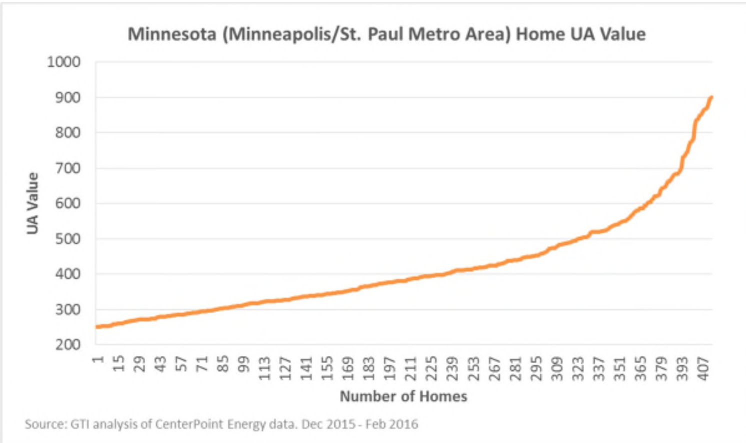


Figure 21: Distribution UA Values (Dec-Feb) for Minnesota Homes (Minneapolis/St. Paul)

Figure 22 shows the distribution of the steady-state and setback recover furnace capacity requirements for the 413 homes in the Minneapolis metro area. An 80th percentile value for steady state and setback recovery operation is about 62,000 to 65,000 Btu/hour.

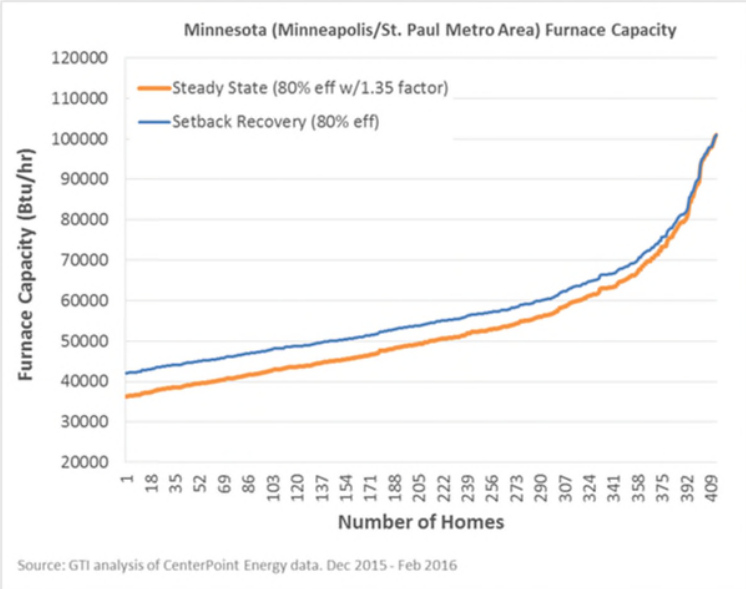


Figure 22: Distribution of Furnace Capacity for Minnesota Homes (Minneapolis/St. Paul)

The Minnesota data set, while relatively small, has uniquely low UA Values in relation to findings for the Chicago and St. Louis metro area. Counterintuitively, these results indicate average furnace sizing for steady state operation that are about 10,000 to 15,000 Btu/hour lower than typical homes in Chicago and St. Louis. This may reflect the nature of building codes in Minnesota that have promoted weatherized homes or a potential bias in this data set towards homes that have undergone a high level of weatherization. One further consideration is the winter of 2015-2016 was relatively warm, with total heating degree days that were 25.5% lower than the winter of 2013-2014. A colder winter would act to shift these curves upward and reduce the disparity. Additional data may be warranted to further investigate home construction and thermostat operation in Minnesota.

Arkansas (Little Rock Area) Homes

Figure 23 shows the results of the UA Values (Dec-Jan) calculation for 308 homes in the Little Rock, Arkansas area (December 2015 – February 2016). The data in this figure excludes homes below UA Value 250 and above 1100. This is about 28% of the homes in the dataset. Notably most of the excluded homes had UA Values above 1100. These results highlight the relative poor cold weather insulation attributes – and higher rates of heat loss – in these homes. This is a clear finding from the higher home UA Values. Table 10 provides summary statistics on this population of Arkansas homes. Using the relationship between UA Value (Dec-Feb) and net delivered energy required, GTI analysts calculated steady state and setback recovery furnace capacity requirements for 80% efficient units.

Table 11: Characteristics for Arkansas Homes (Little Rock Area)

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
Average	675	78577	80,141
Median	659	76,921	78,828
80th Percentile	897	100,717	100,652
Standard Deviation	209	20,881	19,095

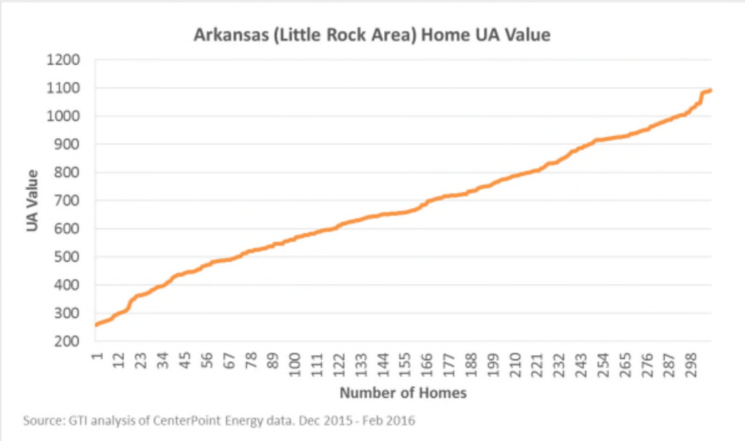


Figure 23: Distribution UA Values (Dec-Feb) for Arkansas Homes (Little Rock Area)

Figure 24 shows the distribution of the steady-state and setback recover furnace capacity requirements for the 308 homes in the Little Rock and surrounding area. An 80th percentile value for steady state and setback recovery operation is about 101,000 Btu/hour.

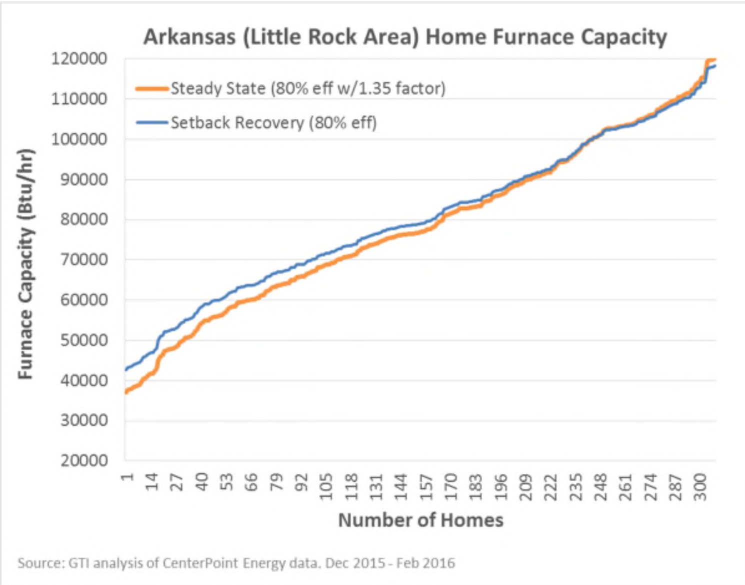


Figure 24: Distribution of Furnace Capacity for Arkansas Homes (Little Rock Area) Homes

The Arkansas data set is unique in the way it highlights higher UA Values for peak heating periods compared to information for the Chicago, St. Louis, and Minneapolis metro areas. Counterintuitively, these results indicate furnace sizing for steady state operation and setback recovery that are nearly 10,000 Btu/hour higher than typical homes in Chicago or St. Louis. This finding suggests that the building stock in Southern cooling-dominated may have lower levels of weatherization than the building stock in heating dominated Northern climate zones.

Oklahoma (Oklahoma City Area) Homes

Figure 25 shows the results of the UA Values (Dec-Jan) calculation for 125 homes in the Oklahoma City, Oklahoma area (December 2015 – February 2016). The data in this figure excludes homes below UA Value 250 and above 1100. These are about 14% of the homes in the dataset. Most of the excluded homes had UA Values above 1100. These results highlight the relative poor cold weather insulation attributes – and higher rates of heat loss – in these homes. This is a clear finding from the higher home UA Values. Table 10 provides summary statistics on this population of Oklahoma homes. Using the relationship between UA Value (Dec-Feb) and net delivered energy required, GTI analysts calculated steady state and setback recovery furnace capacity requirements for 80% efficient units.

Table 12: Characteristics for Oklahoma (Oklahoma City Area) Homes

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
Average	645	75,607	77,814
Median	610	72,105	74,629
80th Percentile	860	97,035	97,303
Standard Deviation	210	20,916	19,023

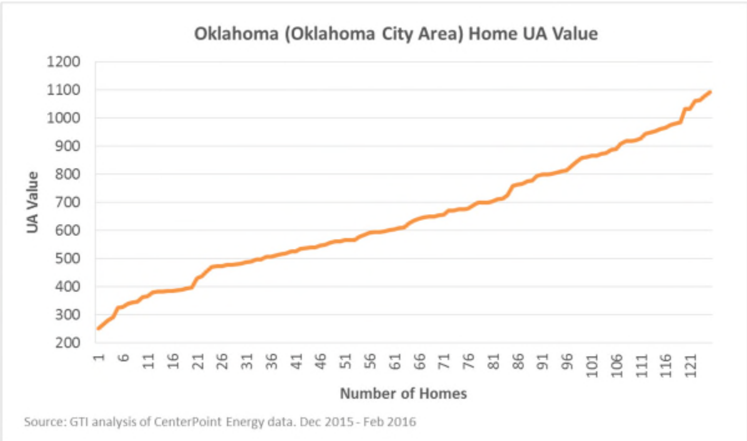


Figure 25: Distribution UA Values (Dec-Feb) for Oklahoma Homes (Oklahoma City Area)

Figure 26 shows the distribution of the steady-state and setback recover furnace capacity requirements for the 125 homes in the Oklahoma City and surrounding area. An 80th percentile value for steady state and setback recovery operation is about 97,000 Btu/hour.

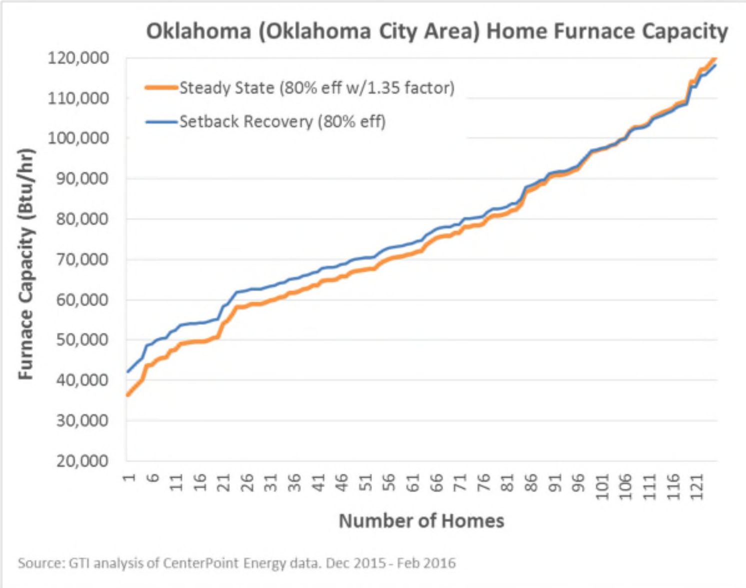


Figure 26: Distribution of Furnace Capacity for Oklahoma Homes (Oklahoma City Area)

The Oklahoma data set closely mirrors the Arkansas results and reinforce the nature of Southern home construction that points to the need for larger capacity furnaces during peak heating periods. As seen in the Arkansas data, homes in Oklahoma counterintuitively need average furnace sizing for steady state operation that are 10,000 Btu/hr higher than typical homes in Chicago or St. Louis; this number could be even higher taking into account thermostat setback recovery operation. This appears to clearly reflect the nature of the building stock in Southern climates and the lower level of weatherization.

Summary Furnace Sizing Results

For these five metropolitan and surrounding regions – Chicago, St. Louis, Minneapolis, Little Rock, and Oklahoma City – GTI analyzed over 21,000 homes to understand: (1) their peak space heating months natural gas use, (2) inferred home weatherization level through calculation of the home's UA Value, and (3) derived furnace capacity for steady-state and smart thermostat setback recovery operation.

Table 13 summarizes the results for the 21,059 homes with UA Values greater than 250 and less than 1100. The 80th percentile for steady state and setback recovery furnace capacity is around 83,000 Btu/hour to 85,000 Btu/hour.

Table 13: Summary Empirically Derived Furnace Sizing Results

	UA Value (Dec-Feb)	Steady State Furnace Capacity With 1.35 DOE/ACCA Sizing Factor (Btu/hr, 80% efficiency)	Setback Recovery Furnace Capacity (Btu/hr, 80% efficiency)
80th Percentile	721	83,099	84,629
Average	565	67,609	70,541
Median	540	65,147	68,301
Standard Deviation	185	18,486	16,813

Table 14 provides a summary of all the monthly natural gas use data and the set of information included in the above summary analysis. GTI set a range of UA Values from 250 to 1100 as being most representative of conventional single-family homes. Values below this are more probable to be multi-family residences such as apartment and condominium units which would not need larger furnaces. Values above UA Value 1100 are likely to include much larger residences which may require bigger (or multiple) furnaces. By restricting the data range to UA Values of 250 to 1100, there is a more uniform and representative population of single-family homes likely to exist. The data demonstrate exclusions were balanced between the upper and lower ends of the entire population of homes.

Table 14: Data Inclusion and Exclusion

	Excluded Data UA Value 50 to <250	Included Data UA Value 250 to <1100	Excluded Data UA Value 1100 to <3000
Illinois	823	17,978	777
Missouri	78	2,235	71
Minnesota	90	413	4
Arkansas	20	308	92
Oklahoma	9	125	13
Total	**1,020**	**21,059**	**957**
% of Total	4.4%	91.4%	4.2%

Figure 27 shows the overall distribution of steady-state and setback recovery furnace capacity ratings. As noted, the 80th percentile range for steady-state and setback recovery furnace capacity is around 83,000 to 85,000 Btu/hour.

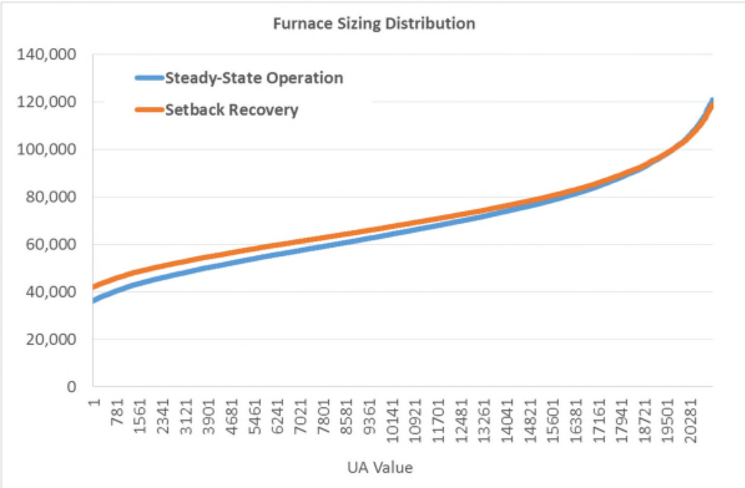


Figure 27: Distribution of Furnace Capacity for Steady-State and Setback Recovery Operation

The results of this analysis indicate there are strong regional differences in building construction. Homes in Minnesota, for example, appear to have much higher levels of weatherization than homes in Arkansas and Oklahoma. This leads to a counterintuitive result that homes in Arkansas and Oklahoma actually require, on average, larger furnaces than are needed in Minnesota. The results show UA Values of homes in the South are considerably higher than in Minnesota and require larger furnaces during peak heating periods to compensate for the greater rate of building energy losses.

Table 15 and Figure 28 shows these findings. Compared to Minnesota homes, residential buildings in Chicago use 57% more gas per HDD, 77% more in St. Louis and Oklahoma, and 133% more in Arkansas. Regional building practices clearly have a substantial impact on furnace sizing requirements and lead to findings that counterintuitively indicate Southern homes need larger furnaces to meet their peak heating needs. More Minnesota data would be helpful to confirm this finding along with results during a colder winter period in that region.

Table 15: Summary Regional Findings

	Average UA Value (Dec-Feb)	80th Percentile Setback Recovery Operation (Btu/hour)	Ratio of Dec-Feb Space Heating Use to HDD	Ratio Relative to Minnesota Homes	Dec-Feb Space Heating Degree Days
Minnesota	416	65,376	0.0957	1.0000	3690
Illinois	568	83,353	0.1505	1.5734	3561
Missouri	552	81,860	0.1697	1.7736	2835
Oklahoma	645	97,303	0.1711	1.7882	1438
Arkansas	675	100,652	0.2233	2.3340	1151

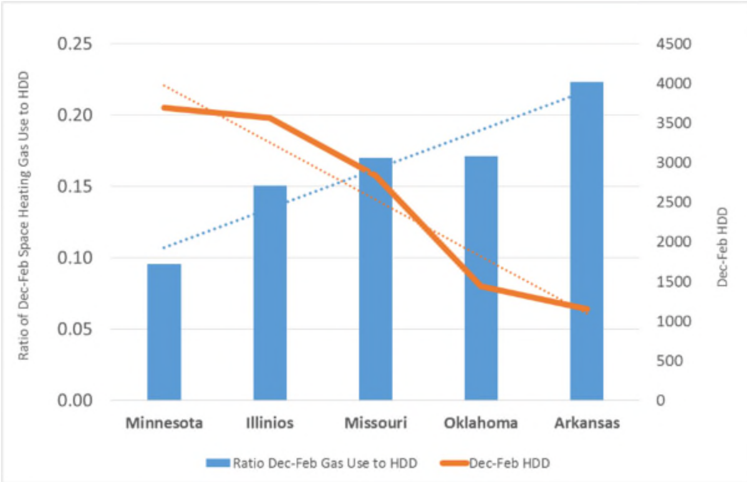


Figure 28: Regional Differences In Specific Peak Home Heating Rates

Conclusions

The findings from this report demonstrate that homes vary considerably in their annual space heating needs. The most accurate predictor of annual and peak space heating energy needs is captured by home UA Value. Home square footage, by comparison, has a relatively weak correlation.

Home occupants can differ considerably in their lifestyle choices used for space heating their homes. This includes a wide distribution in nominal thermostat setpoint values – this can differ by over 10°F – as well as the way in which programmable or smart thermostats. The use of smart thermostats necessitates greater furnace capacity to enable timely recovery of indoor temperature setting after larger (over 2 °F) thermostat setbacks during overnight periods or during the day if the home is unoccupied then.

Table 16 summarizes the average furnace size requirements for the overall dataset as well as the regional breakdown. The 80th percentile values for steady-state and setback recovery operation was in the range of 83,000 Btu/hour to 85,000 Btu/hour. This should satisfactorily meet the needs of most natural gas customers.

Table 16: Summary Furnace Capacity Requirements (80% Efficient Furnace)

All Five Regions	**Steady-State Operation (Btu/hour) With 1.35 DOE/ACCA Sizing Factor**	**Setback Recovery Operation (Btu/hour)**
80th Percentile Capacity	83,070	84,627
Average Capacity	67,607	70,538
Median Capacity	65,147	68,031
Regional Findings	80th Percentile Steady-State Operation (Btu/hour)	80th Percentile Setback Recovery Operation (Btu/hour)
Minnesota	61,931	65,376
Missouri	80,055	81,860
Illinois	83,353	84,859
Oklahoma	97,035	97,303
Arkansas	100,717	100,652

Perhaps counterintuitively, the furnace sizing requirements increased for homes located in Southern, cooling-dominated regions (e.g., Arkansas and Oklahoma). The data give clear findings that these homes exhibit lower levels of weatherization that result in higher levels of building heat loss during peak heating months of December through February. This necessitates higher than anticipated peak furnace capacity ratings in Southern climate zones.

Additional research would help evaluate the regional differences in home construction and the apparent significant impact on peak furnace capacity requirements. These findings indicate that homes in Minnesota have an impressive level of weatherization. Additional research would be helpful to confirm this finding and to ascertain whether these results apply to other DOE/IECC climate zone 6 or 7 regions (or are they specific to Minnesota's building codes).

The findings about the poor weatherization attributes in Southern, cooling dominated regions would benefit from extension of this analysis to other states to confirm the findings.

Based upon this analysis, it is evident a 55,000 Btu/hr furnace is insufficient for meeting the space heating needs of the vast most single-family homes in the U.S. – cold climate and more temperate climate zones (due to the poor weatherization attributes). This type of unit could be marginally satisfactory for smaller homes or larger "tight" homes with UA Values below about 400. Even for these types of homes, occupants could experience hours where such a unit would be undersized to meet steady-state heating requirements; this compromise in performance and comfort becomes more accentuated during smart thermostat setback recovery periods.

References

Air Conditioning Contractors of America, “Manual J Residential Load Calculation (8th Edition)”.

ASHRAE, “2013 ASHRAE Handbook: Fundamentals,” 2013.

Burdick, A., “Strategy Guideline: HVAC Equipment Sizing,” U.S. Department of Energy Building Technologies Program, February, 2012.

Gas Technology Institute, “1022: Home Energy Management System Utilizing a Smart Thermostat,” Report For Nicor Gas and Commonwealth Edison, May 4, 2015.

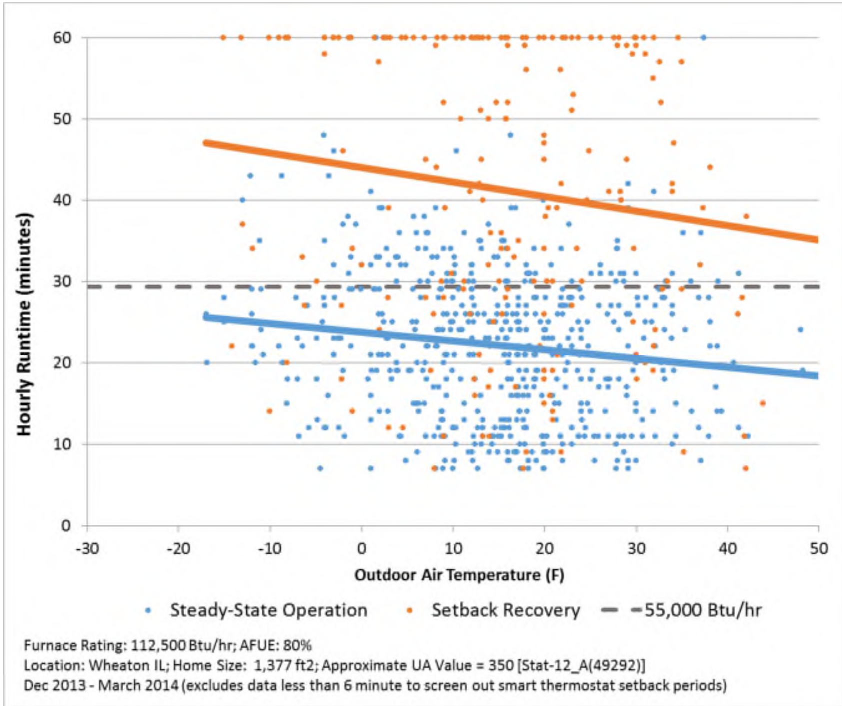
Gas Technology Institute, “Technical Analysis of Furnace Sizing for the DOE Notice of Proposed Rulemaking on Residential Furnace Minimum Efficiencies,” Report for American Public Gas Association, September 9, 2015.

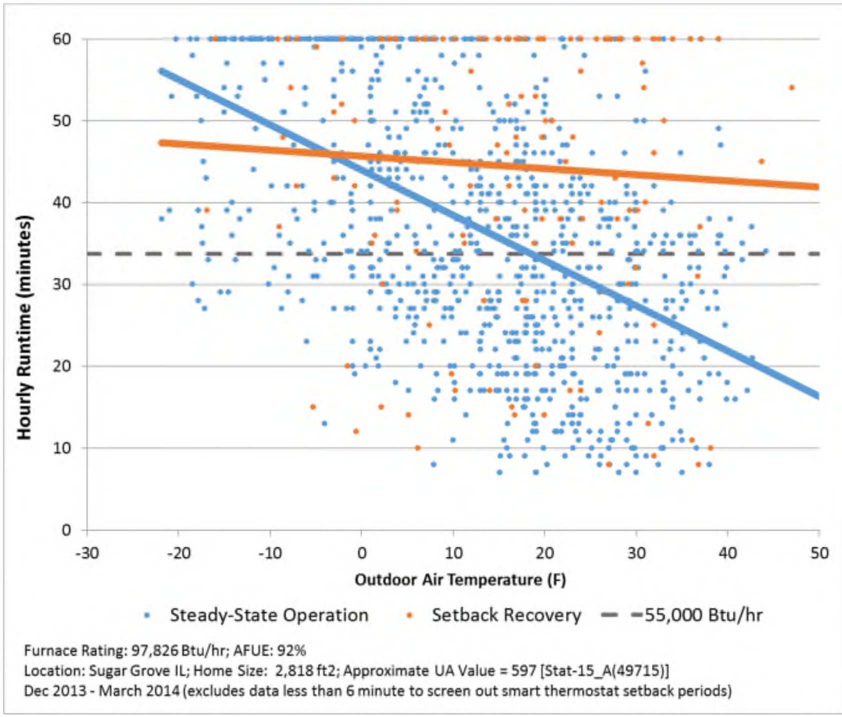
Lucas, R.G. and Pratt, R.G., “As Operated Heat Loss Coefficients of Residential Buildings in the Pacific Northwest—An Analysis of Empirical Space-Heating Energy Data,” December 31, 1992.

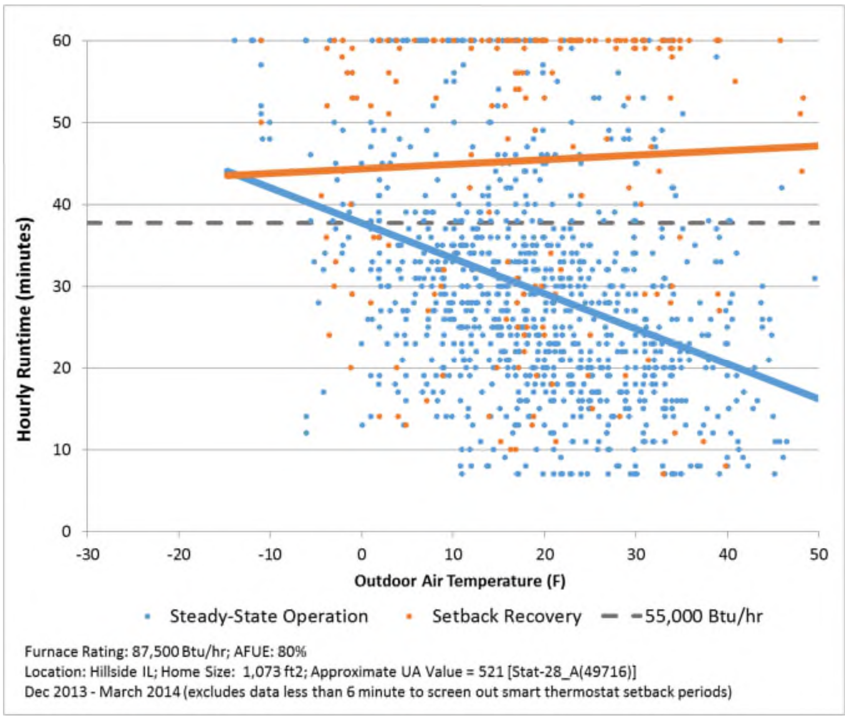
Pigg, S., “Electricity Use by New Furnaces: A Wisconsin Field Study,” Energy Center of Wisconsin, October, 2003.

Appendix A. Detailed Furnace Run Time Plots (21 Homes)

Furnace run time data are included in this appendix. Each graph is annotated with information identifying the home, home size (ft^2), furnace size, furnace efficiency, and UA Value. Data cover operation in the Chicago metropolitan area from December 1, 2013 – March 19, 2014.






60
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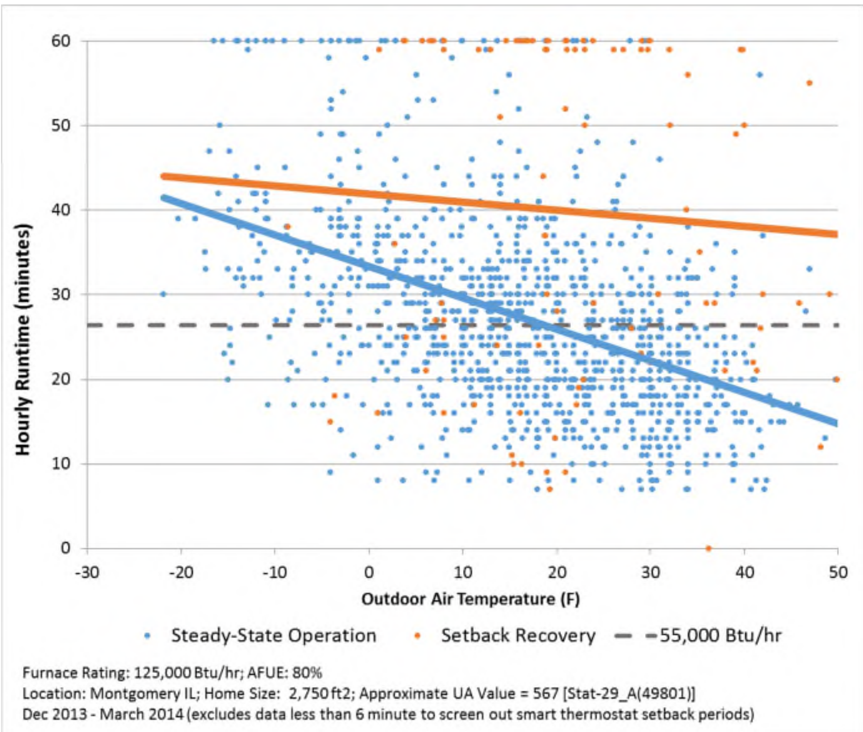
50
Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 87,500 Btu/hr; AFUE: 80%
Location: Hillside IL; Home Size: 1,073 ft2; Approximate UA Value = 521 [Stat-28_A(49716)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)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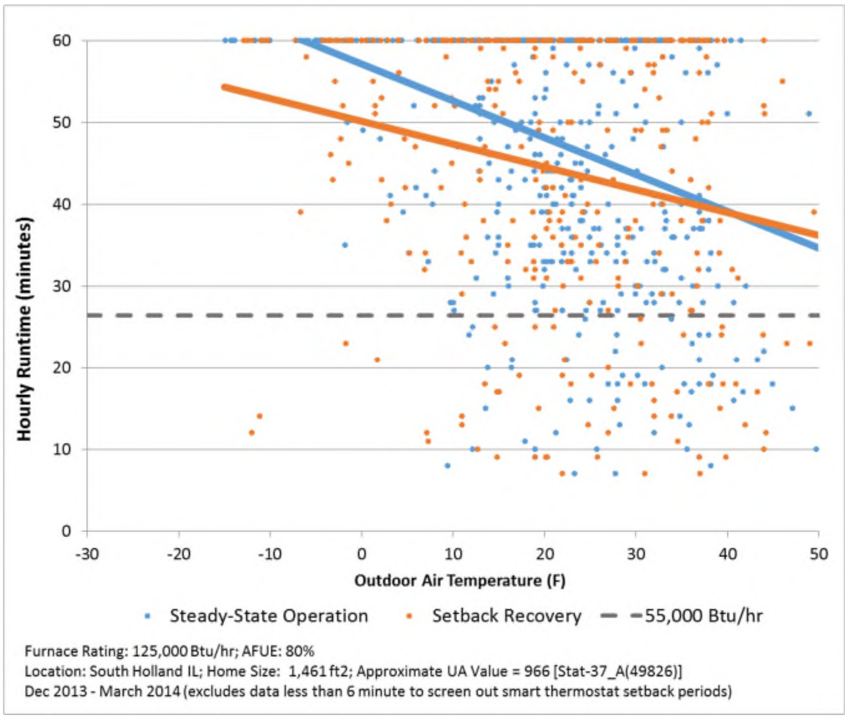
Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Montgomery IL; Home Size: 2,750 ft2; Approximate UA Value = 567 [Stat-29_A(49801)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)



Hourly Runtime (minutes)
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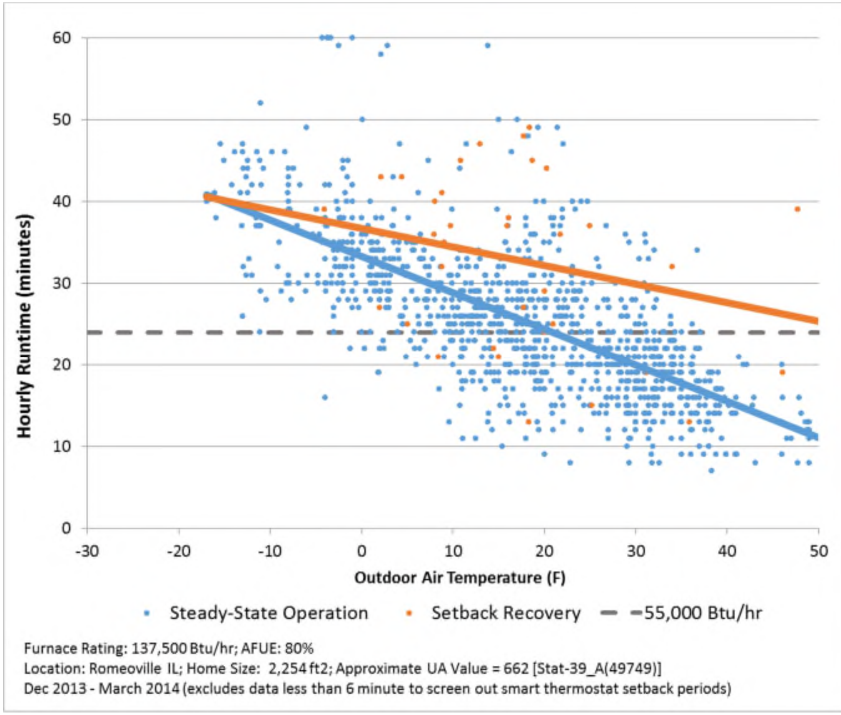
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: South Holland IL; Home Size: 1,461 ft2; Approximate UA Value = 966 [Stat-37_A(49826)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)



Hourly Runtime (minutes)
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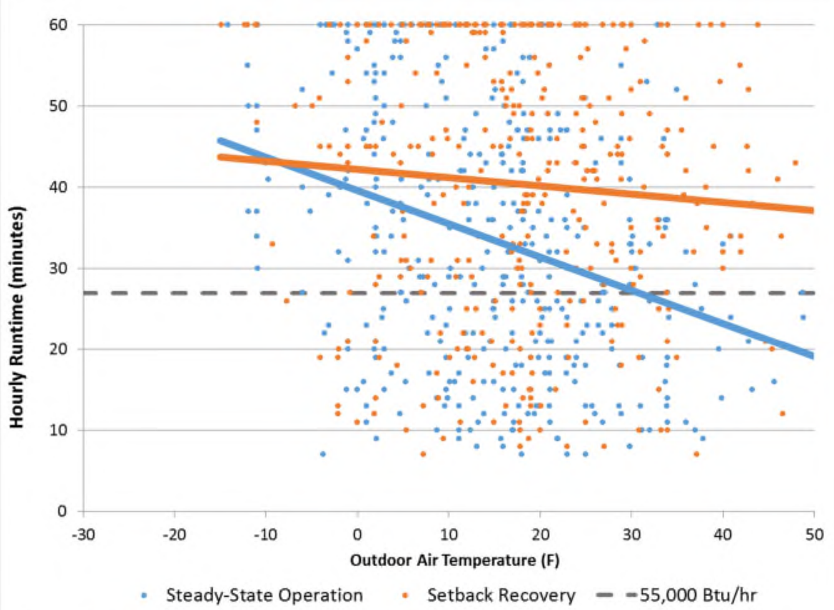
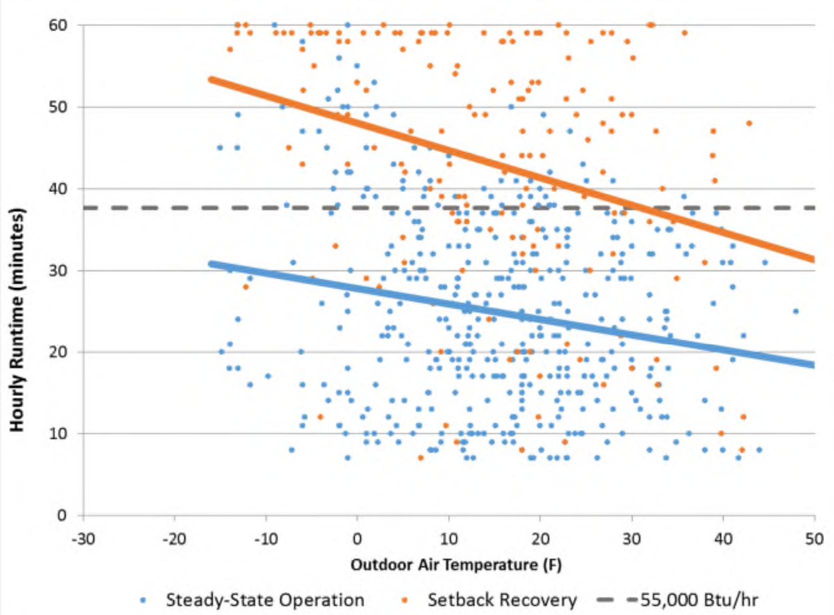
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 137,500 Btu/hr; AFUE: 80%
Location: Romeoville IL; Home Size: 2,254 ft2; Approximate UA Value = 662 [Stat-39_A(49749)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)



Furnace Rating: 122,222 Btu/hr; AFUE: 90%
Location: Arlington Heights IL; Home Size: 3,002 ft2; Approximate UA Value = 517 [Stat-40_A(49366)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)



Furnace Rating: 87,500 Btu/hr; AFUE: 80%
Location: Volo IL; Home Size: 1,656 ft2; Approximate UA Value = 268 [Stat-42_A(49713)]
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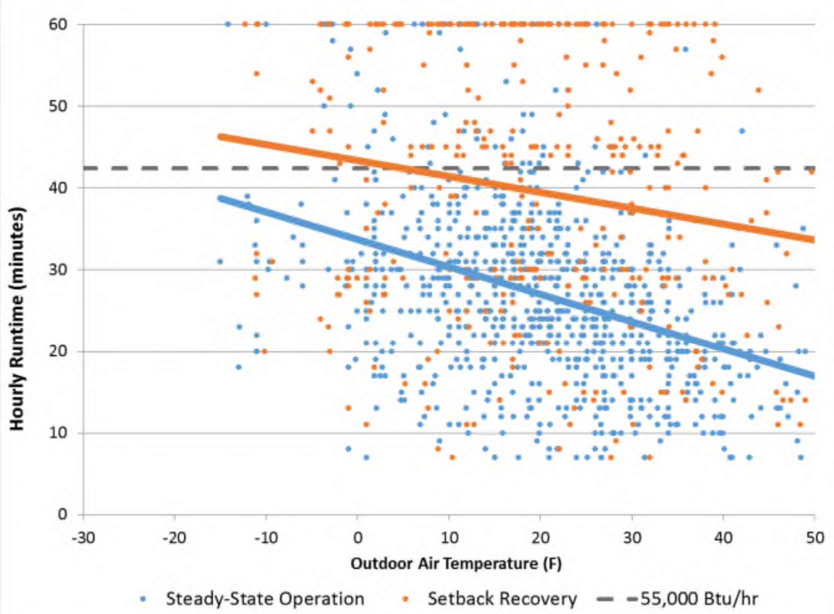

Furnace Rating: 77,778 Btu/hr; AFUE: 90%
Location: Arlington Heights IL; Home Size: 1,728 ft2; Approximate UA Value = 1062 [Stat-43_A(49615)]
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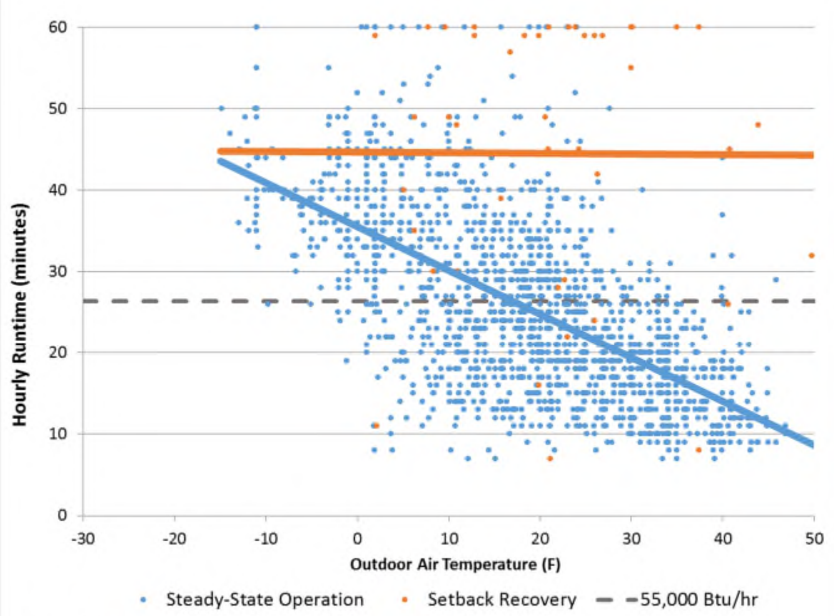
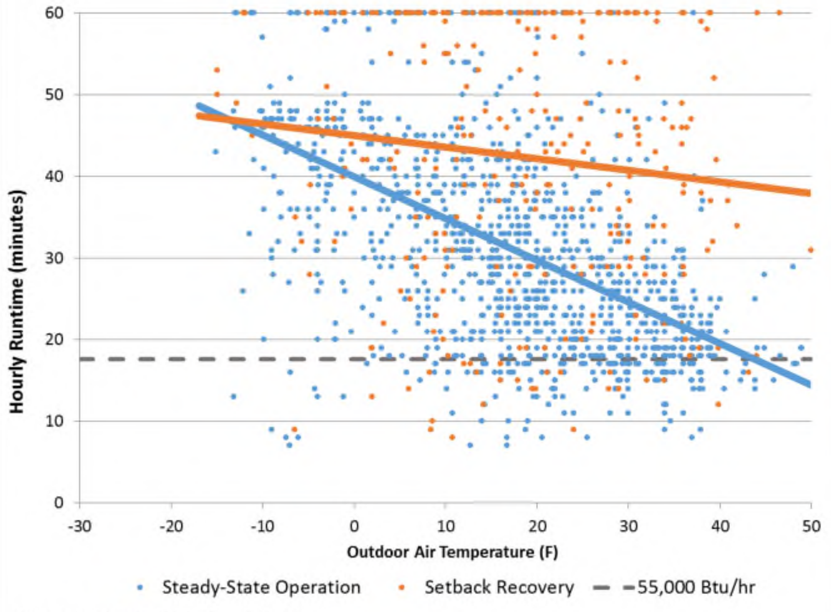
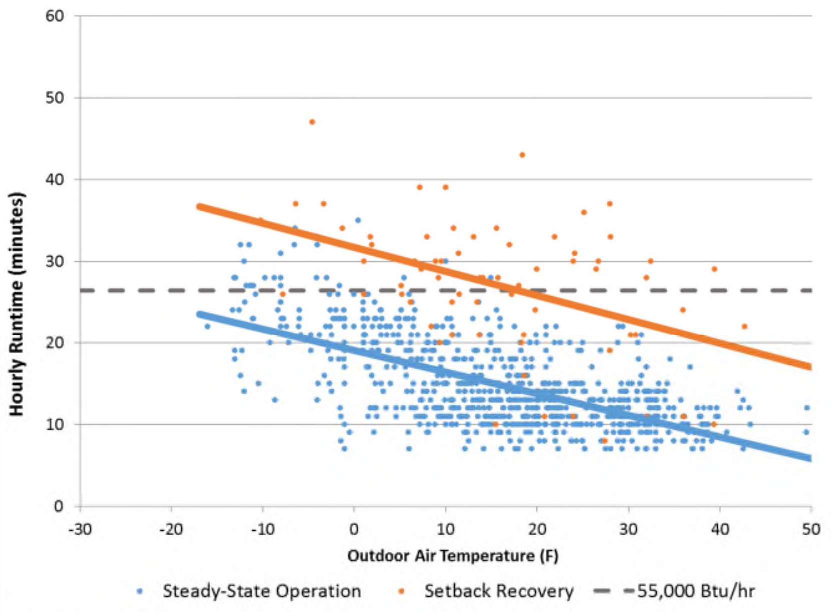


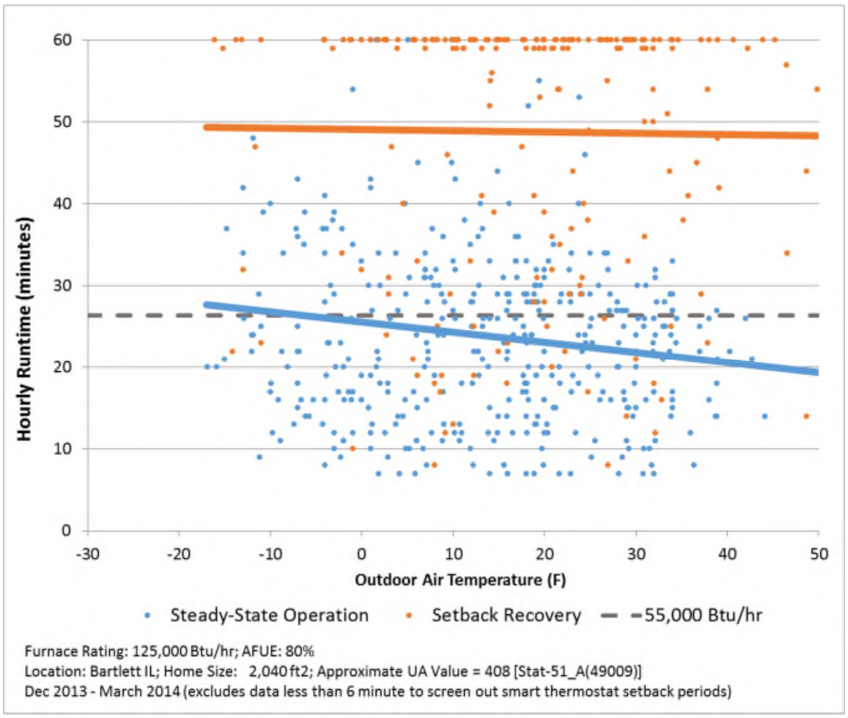
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Buffalo Grove IL; Home Size: 2,018 ft2; Approximate UA Value = 616 [Stat-45_A(49408)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

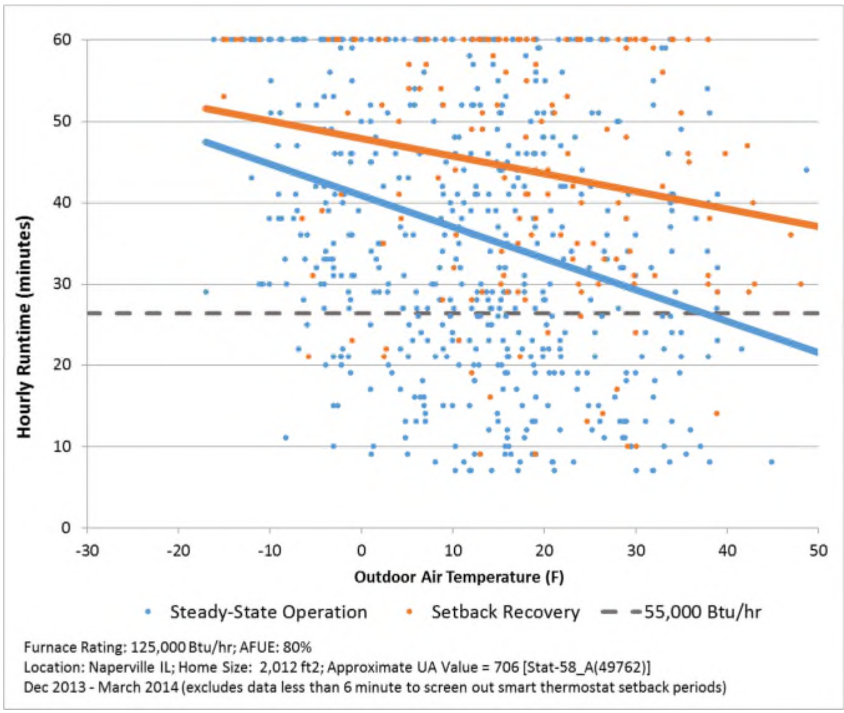


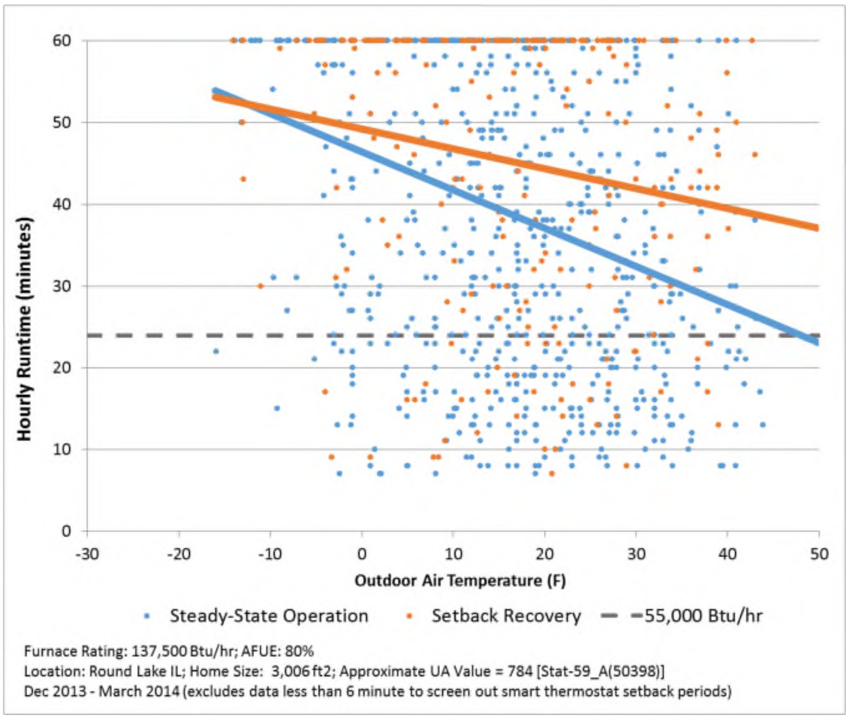
Furnace Rating: 187,500 Btu/hr; AFUE: 80%
Location: Carpentersville IL; Home Size: 3,264 ft2; Approximate UA Value = 1127 [Stat-46_A(49637)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

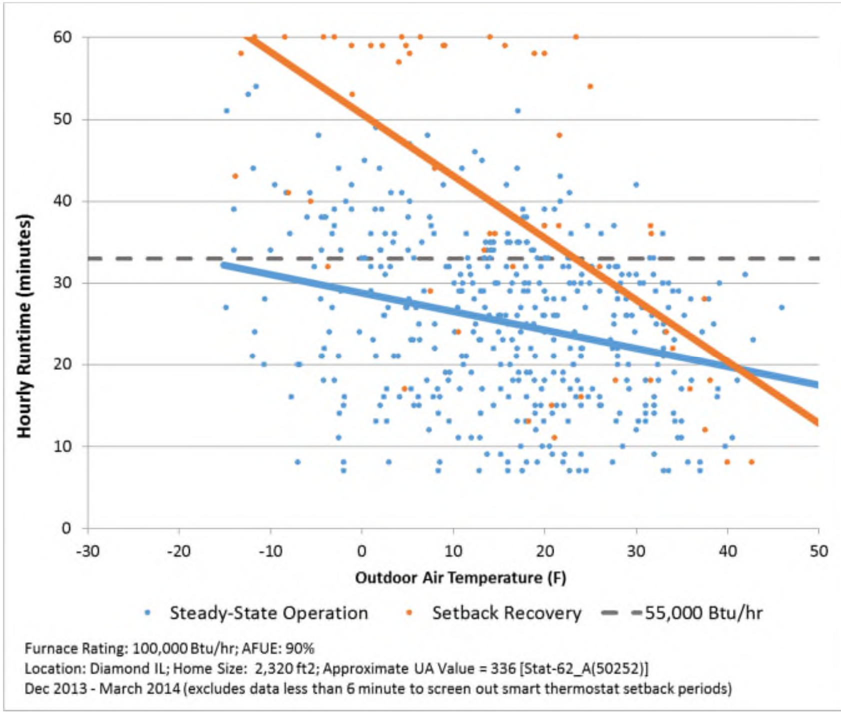


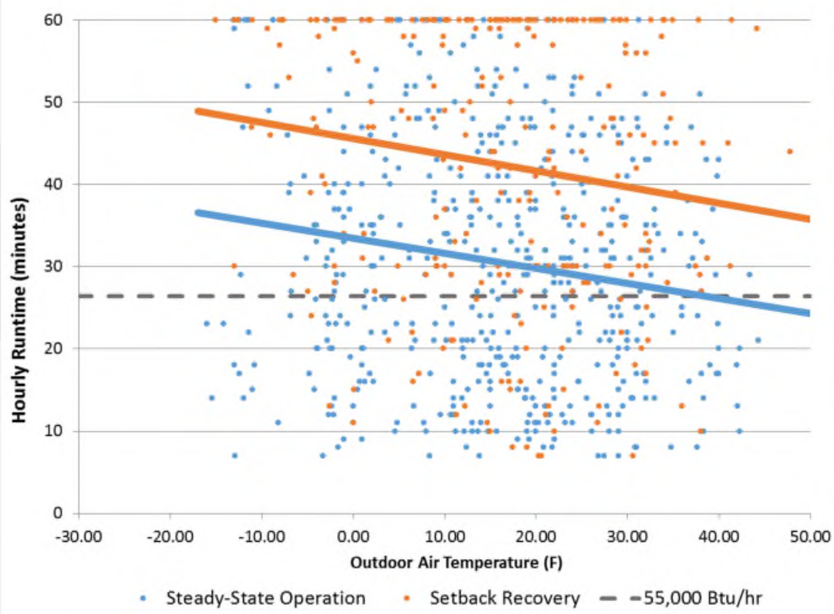
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Plainfield IL; Home Size: 1,510 ft2; Approximate UA Value = 301 [Stat-49_A(49506)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)


Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Bartlett IL; Home Size: 2,040 ft2; Approximate UA Value = 408 [Stat-51_A(49009)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

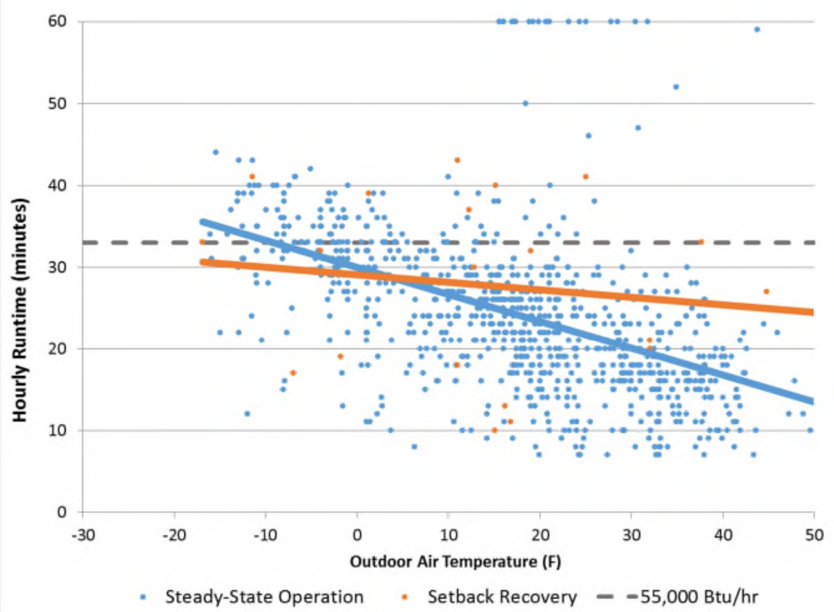

Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Naperville IL; Home Size: 2,012 ft2; Approximate UA Value = 706 [Stat-58_A(49762)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)


Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 137,500 Btu/hr; AFUE: 80%
Location: Round Lake IL; Home Size: 3,006 ft2; Approximate UA Value = 784 [Stat-59_A(50398)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

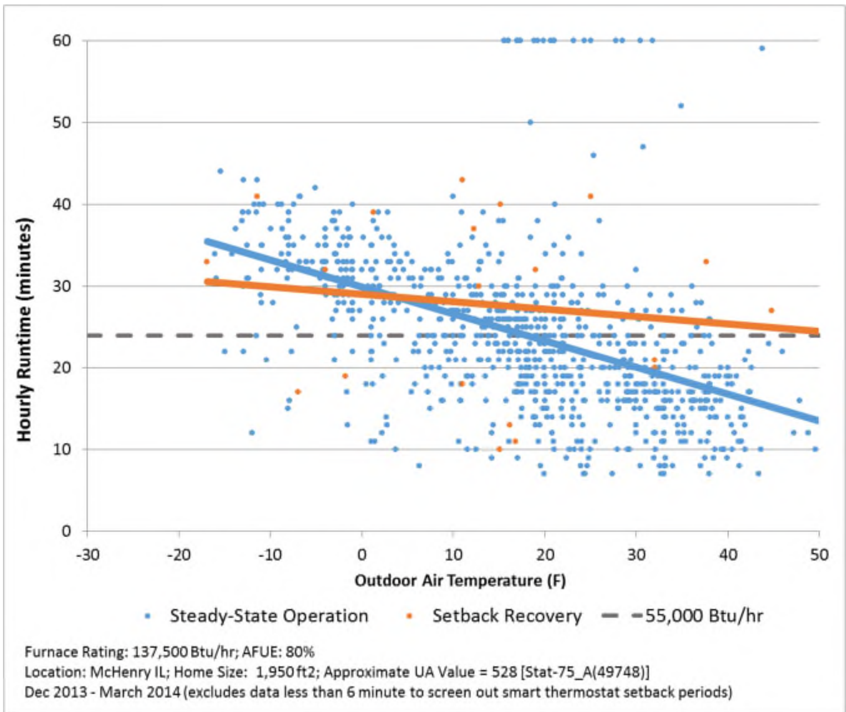

Hourly Runtime (minutes)
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 100,000 Btu/hr; AFUE: 90%
Location: Diamond IL; Home Size: 2,320 ft2; Approximate UA Value = 336 [Stat-62_A(50252)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

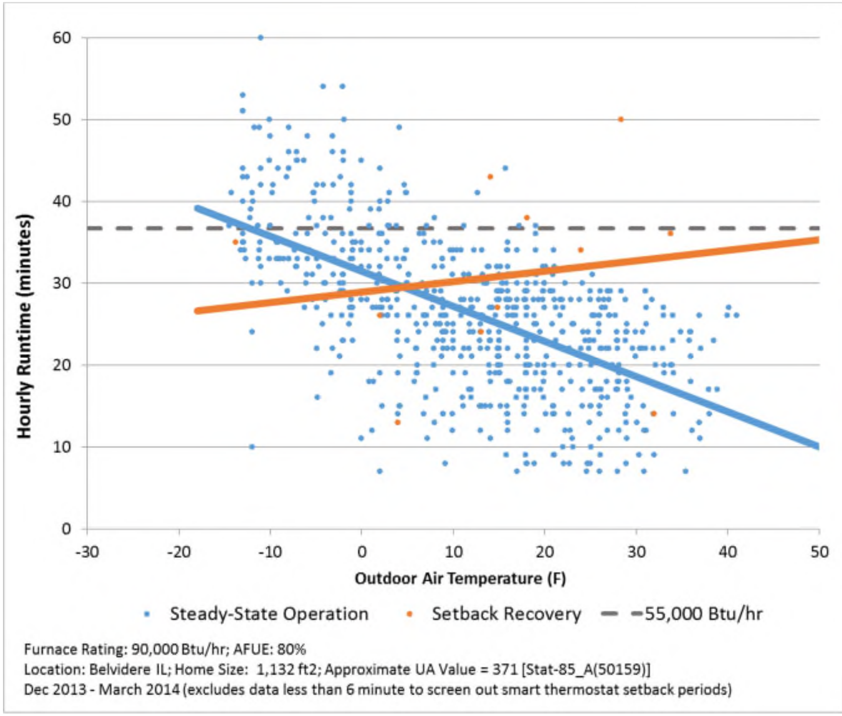


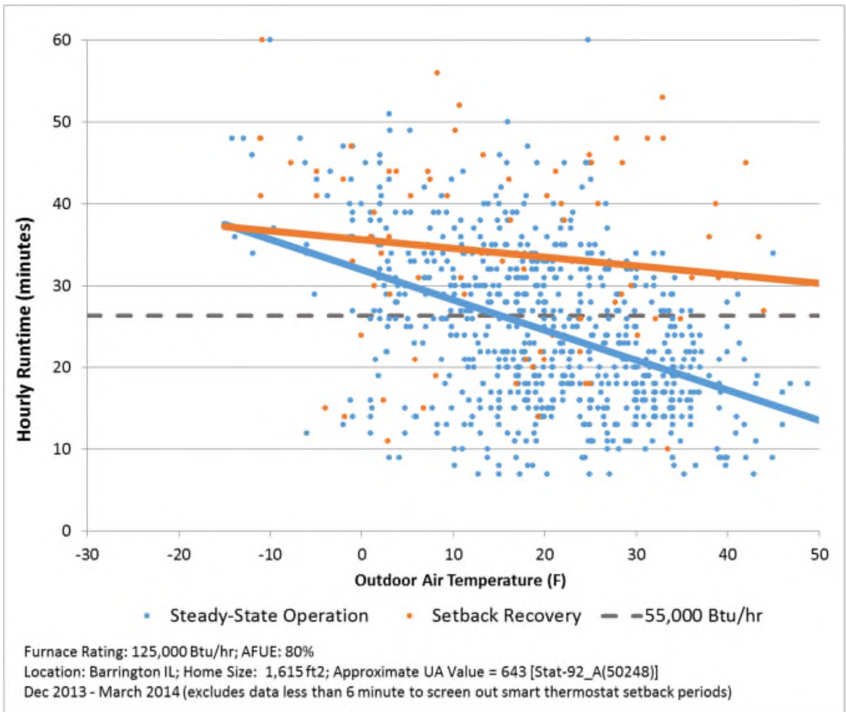
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Homer Township IL; Home Size: 1,288 ft2; Approximate UA Value = 432 [Stat-63_A(49721)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)



Furnace Rating: 100,000 Btu/hr; AFUE: 80%
Location: Romeoville IL; Home Size: 1,427 ft2; Approximate UA Value = 475 [Stat-73_A(49742)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)


60
50
40
30
20
10
0
Hourly Runtime (minutes)
-30
-20
-10
0
10
20
30
40
50
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 137,500 Btu/hr; AFUE: 80%
Location: McHenry IL; Home Size: 1,950 ft2; Approximate UA Value = 528 [Stat-75_A(49748)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)


60
50
40
30
20
10
0
Hourly Runtime (minutes)
-30
-20
-10
0
10
20
30
40
50
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 90,000 Btu/hr; AFUE: 80%
Location: Belvidere IL; Home Size: 1,132 ft2; Approximate UA Value = 371 [Stat-85_A(50159)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)


Hourly Runtime (minutes)
60
50
40
30
20
10
0
-30
-20
-10
0
10
20
30
40
50
Outdoor Air Temperature (F)
Steady-State Operation
Setback Recovery
55,000 Btu/hr
Furnace Rating: 125,000 Btu/hr; AFUE: 80%
Location: Barrington IL; Home Size: 1,615 ft2; Approximate UA Value = 643 [Stat-92_A(50248)]
Dec 2013 - March 2014 (excludes data less than 6 minute to screen out smart thermostat setback periods)

Attachment E

Impact of Any Lessening of Competition

Concerns of Spire Inc.

For

Department of Energy

Supplemental Notice of Proposed Rulemaking
Energy Conservation Standards for Residential Furnaces

Docket Number EERE–2014–BT–STD–0031

The Energy Policy and Conservation Act of 1975 (EPCA) requires the Department of Energy (DOE) to consider any lessening of competition that is likely to result from the adoption of proposed energy conservation standards, as determined in writing by the Attorney General of the United States per 42 U.S.C. 6313(a)(6)(B)(ii)(V). Spire Inc. (Spire), through its utility subsidiaries, provides natural gas distribution services to over 1.7 million residential, commercial and industrial customers in Missouri, Alabama and Mississippi, many of whom rely on the appliances and equipment subject to the energy efficiency standards established by DOE.

Spire understands that the U.S. Department of Justice (DOJ) is currently reviewing the DOE proposed Supplemental notice of proposed rulemaking (SNOPR) entitled Energy Conservation Standards for Residential Furnaces. Spire urges DOJ to consider the lessening of competition in the energy market that would result from adoption of the Proposed Rule.[1] The Proposed Rule is just one of a series of proposed DOE regulations that would effectively price natural gas appliances out of the market, with the apparently intended result of shifting energy demand from natural gas to electricity, thereby systematically restricting consumer appliance and energy choices, thereby lessening competition between electricity and natural gas. Specifically, DOE is increasingly seeking to limit consumer appliance and energy choices by adopting energy conservation standards for gas heating equipment that can only be achieved using condensing technology. Condensing technology imposes significantly higher product costs and severely disadvantage non-condensing gas products in the replacement market – which accounts for the clear majority of product sales – by making them incompatible with the vent systems provided in a substantial percentage of the existing buildings in which non-condensing replacement products must be installed.

In addition to the Proposed Rule, this trend is evidenced by the following additional proposed rules:

- Energy Conservation Standards for Commercial Packaged Boilers

[1] Spire views "any lessening of competition" broadly; as does 42 U.S.C. 6313(a)(6)(B)(ii)(V) and (C)(i). Consequently, DOJ should not constrain itself to potential matters of concentration of manufacturing according to Herfindahl-Hirschman Index (HHI) analyses.

- Energy Conservation Standards for Residential Furnaces

If consumers are denied the choice of non-condensing natural gas-fueled heating equipment because of minimum efficiency mandates, there will be a lessening of competition as manufacturers (both small and large) are denied the opportunity to build equipment to supply such consumer choices. In addition, there will be a lessening of competition in the energy market generally as high up-front equipment and disproportionate installation costs systematically force consumers to switch from natural gas to electricity despite higher electric energy costs. Gas-only utilities, manufacturers of gas appliances, and the consumers who lose their energy choices will all bear the costs of reduced competition as DOE continues to use efficiency regulation to put its thumb on the scale of competition in the appliance and energy markets.

Underlying Factors

DOE (through its "national labs") has publicly endorsed the concept of making America "all-electric." Examples include:

1. Lawrence Berkeley National Lab (LBNL): "Aggressive Efficiency and Electrification Needed to Cut California Emissions"
2. LBNL Pacific Northwest National Laboratory (PNNL): "Policy Implications of Deep Decarbonization in the United States."

The following graphics, excerpted from the "Deep Decarbonization" study, clearly illustrate the plan to phase-out natural gas direct use:

Figure 2. U.S. Energy System in 2014

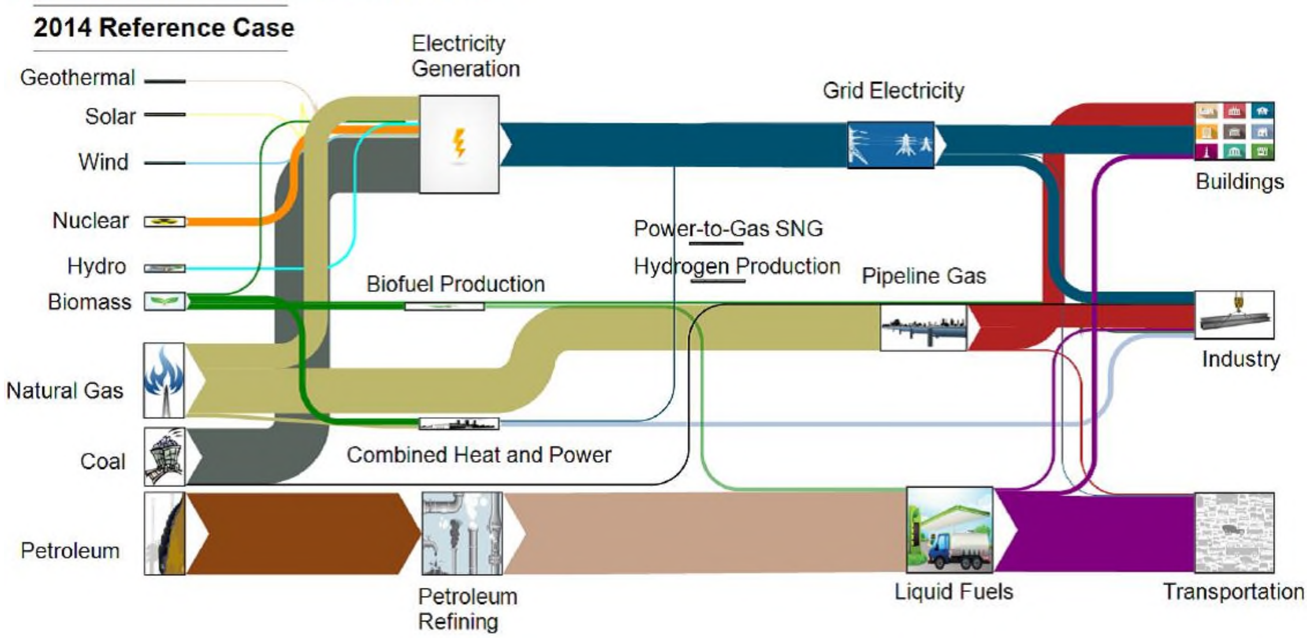
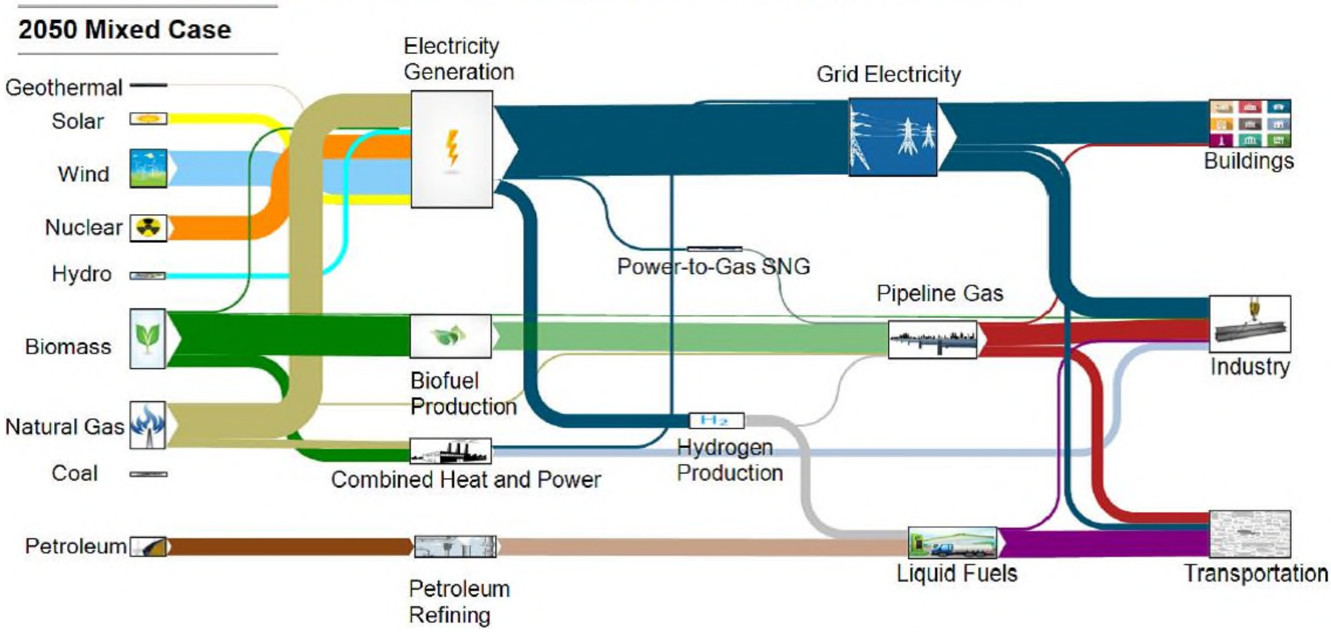


Figure 3. Deeply Decarbonized U.S. Energy System in 2050 (Mixed Case)



The essence of the above two figures is that natural gas markets for residential, commercial and industrial users will be substantially reduced or eliminated by conversion of residential, commercial and industrial gas consumption to electric consumption. The SNL News also summarized this study in an article titled: **Natural gas' role in low-carbon future is limited, study argues**. The following are excerpts from that article:

- The changes in the power generation fleet would underpin the impact of electrifying a number of energy applications that currently directly use fossil fuels, such as vehicles, boilers and furnaces.

- Under the deep de-carbonization scenario, 90% of final energy use in residential and commercial buildings would come from electricity, compared to about 50% today, the report stressed.

DOE has also demonstrated its support of the United Nations COP-21 (a.k.a. the "Paris Agreement") and has many pages discussing this "agreement" on its website. *See e.g*. DOE's **International Partnerships on Display in Paris**

According to numerous media reports, this "agreement" represents a pledge to wean the world off fossil fuels (which includes the direct use of natural gas). Examples include:

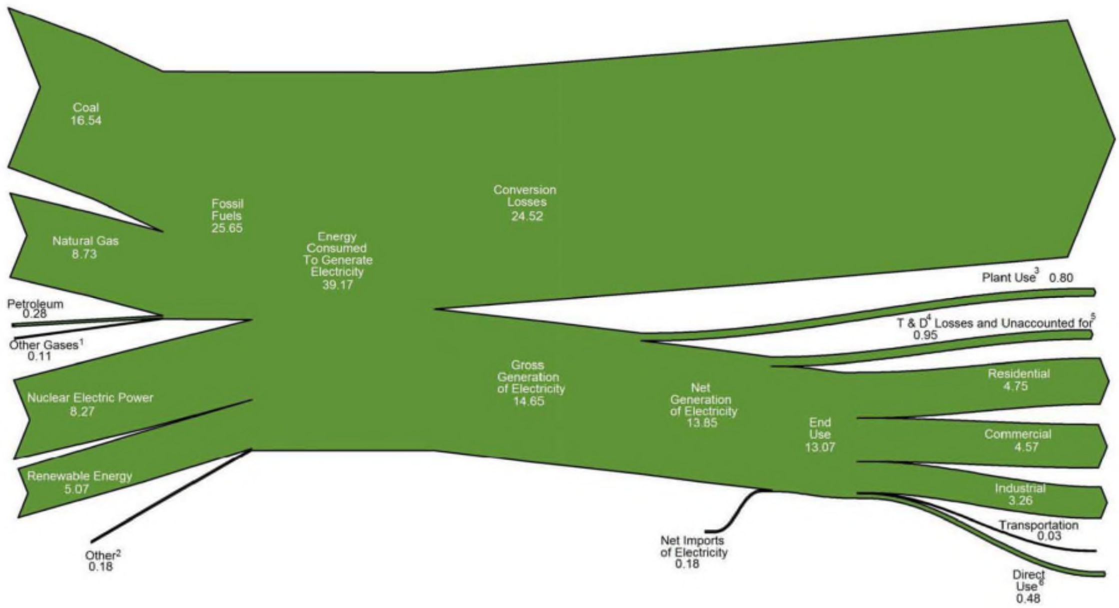
- **COP21: Paris climate change deal is end of fossil fuels - CNN.**
- **Paris climate deal: nearly 200 nations sign in end of fossil fuel**
- **COP21 deal signed, ending fossil fuel era**

Impact of the Proposed Standards

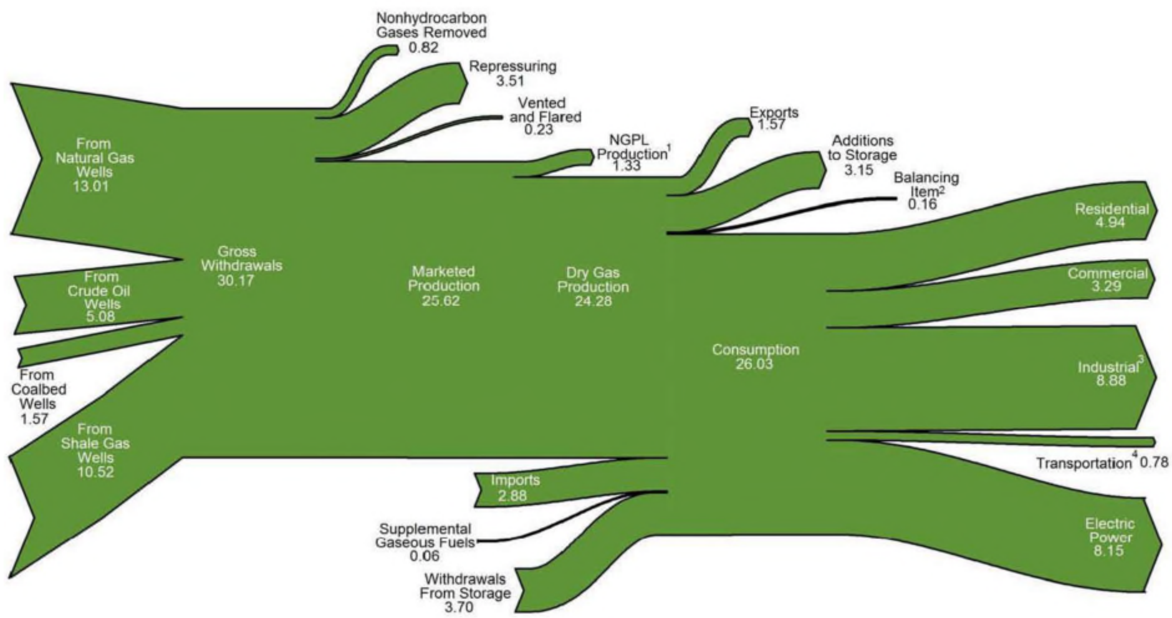
The bottom line is that American consumers are getting ripped and our economy is being undermined off by giving the electric utility a virtual monopoly over energy in an illogic hope that renewables will somehow economically fill the void.

Based upon the following two diagrams, the direct use of natural gas accounts for much more usable energy delivered to consumers than does electricity.

Graph 1: Electricity Flow, 2013 (Quadrillion Btu)[i]



Graph 2: Natural Gas Flow, 2013 (Trillion Cubic Feet)



As shown by the following table, this differences in delivered energy amounts to about 5 Quads:

Table 1: Quads of Energy Delivered to Select Sectors of End-Use Consumption

	Residential	Commercial	Industrial	Total
2013 Electric Utility Delivered Quads	4.75	4.57	3.26	**12.58**
2013 Gas Utility Delivered Quads	4.94	3.29	8.15	**16.38**

The following table convers Quads into Dollars and compares gas and electric revenues for residential, commercial and industrial sectors (again using EIA data):

Table 2: Cost of Energy Delivered to Select Sectors of End-Use Consumption

	Residential	Commercial	Industrial	Total
2013 Electric Utility Revenues[ii]	$170.5 Billion	$138.7 Billion	$66.9 Billion	$376.1 Billion
2013 Gas Utility Revenues[iii]	$42.9 Billion	$14.7 Billion	$5.7 Billion	$63.3 Billion

Having both revenue and Quads for electricity and natural gas for these three end-use sectors, costs per Quad can be calculated and compared. The following table does that:

Table 3: Cost of Energy per Quad Delivered to Select Sectors of End-Use Consumption

	Residential	Commercial	Industrial
Electricity $/Quad	$35.9 Billion	$30.4 Billion	$20.5 Billion
Natural Gas $/Quad	$8.68 Billion	$4.5 Billion	$0.70 Billion

Rule by rule, DOE is chipping away at consumer choice and the underlying economy. DOE is doing it again in this SNOPR. In the simplest terms, DOE is lessening competition by forcing higher levels of efficiency upon gas products while basically leaving much less efficient electric resistance appliances "off the hook." Simultaneously, DOE is waging war against non-condensing appliance venting systems under the guise of energy efficiency.

Efficiency mandates that effectively limit gas equipment to condensing technology impose significantly higher product costs, and severely disadvantage gas equipment in the replacement market – which accounts for the vast majority of equipment sales – by making them incompatible with the vent systems provided in a substantial percentage of the existing buildings in which replacement products must be installed. The basic venting issue is illustrated in the attached graphic. While the graphic illustrates the venting problem in the context of residential furnaces, the basic issues are the same for residential furnaces, commercial water heaters and commercial boilers, all of which – as noted above – are currently the subject of proposed energy conservation standards that effectively target non-condensing gas appliances and equipment for elimination.

In each case, equipment with condensing technology is significantly more expensive to purchase and maintain than similar equipment with non-condensing technology. Even more importantly, most existing residential and commercial structures were designed with a vertical venting systems designed for appliances or equipment with sufficiently high exhaust temperatures to minimize the potential for condensation to occur before exhaust gasses are vented through the roof of the structure (*i.e.*, non-condensing equipment). Condensing equipment has lower exhaust temperatures, which would cause excessive condensation – leading to corrosion and vent failure – in vent systems not designed for them. Building safety codes prevent this result by requiring that condensing equipment be installed with more exotic vent systems that typically require relatively short intake and exhaust vents penetrating the exterior wall of the building. As a result, existing non-condensing gas equipment cannot simply be replaced with equipment that uses condensing technology, because – at a minimum – a new vent system would be required, existing venting would need to be removed, and the facility to discharge condensation would need to be provided. In many cases, natural vent gas products are located too far below grade – or too far from an exterior wall – to accommodate condensing equipment, in which case building modifications to relocate the equipment would be required. This is particularly a problem in the case of equipment (such as commercial water heaters) located in centrally-located basement utility rooms. The worst-case scenario, however, is for homes built on slabs where gas furnaces are in unconditioned attics or crawlspaces that are subject to subfreezing temperatures. This usually results in situations where consumers are deprived of gas furnace options and costs can be so excessive as to move purchasers away from natural gas entirely.

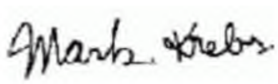
Summary & Conclusions

In short and at a minimum, by requiring gas appliances to become incrementally more efficient than their electric counterparts and establishing efficiency standards effectively requiring the use of condensing technology, DOE is systematically making gas appliances more expensive to purchase, install, and operate, and – in many cases – is making them incompatible with the vent systems provided in the existing buildings in which they must be installed. These effects skew the market towards electric products, lessening competition in both the equipment and energy markets, and the cumulative impact multiple DOE rules and proposed rules of similar effect would be substantial.

Spire understands and fully respects the importance of the regulatory process in addressing matters of critical national importance. Spire also believes, however, that regulatory powers must be exercised in an informed and economically supportable manner and that, on many occasions, the better public policy choice is to allow consumers and the private sector to function within a free-market economy as the best means for achieving efficiency and optimal consumer outcomes. This is one of those occasions. For that reason, as well as the other consideration stated in these comments, Spire respectfully requests that DOJ intercede to prevent a lessening of competition in the appliance and energy markets and to preserve consumer choice. At a minimum DOJ should instruct DOE that “any” (lessening of competition) means any and, if so, this situation easily qualifies

Respectfully submitted,

SPIRE INC.



Mark Krebs
Energy Policies and Standards Specialist

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[i] http://www.eia.gov/totalenergy/data/annual/archive/flowimages/2013/electricity.pdf
[ii] http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_2
[iii]Derived from Natural Gas Annual Respondent Query System (EIA-176 Data through 2013): http://www.eia.gov/cfapps/ngqs/ngqs.cfm?f_report=RP1