AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE
we make life better™

2111 Wilson Boulevard Suite 500 Arlington VA 22201-3001 USA
Phone 703 524 8800 | Fax 703 562 1942
www.ahrinet.org

November 20, 2015

Ms. Brenda Edwards
U.S. Department of Energy
Building Technologies Program, Mailstop EE-5B
1000 Independence Avenue SW
Washington, DC 20585-0121

Re: Energy Conservation Standards for Residential Boilers; Proposed Rule
Docket Number EERE-2012-BT-STD-0047

Dear Ms. Edwards:

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) has submitted several comments in response to the Department of Energy's (DOE) notice of proposed rulemaking (NOPR) regarding amended efficiency standards for residential boilers issued in the March 31, 2015 *Federal Register*. Those comments noted several concerns with technical aspects of the NOPR analysis. In the interest of adequately characterizing those concerns, we contracted with Mr. John Batey of Energy Research Center, Inc. to review the NOPR analysis. That work has been completed and we are providing the attached report prepared by Mr. Batey, "Engineering Analysis and Technical Comments Related to Proposed US DOE AFUE Minimum Efficiency Standards for Residential Boilers," as a supplement to our comments.

The report provides additional information on issues involving the estimated energy savings, safe and proper venting, and the estimated payback period of higher efficiency boilers. Although this is a late submittal, we ask DOE to consider this information.

Respectfully Submitted,

Frank A. Stanonik
Chief Technical Advisor

Attachment

Engineering Analysis and Technical Comments Related to Proposed US DOE AFUE Minimum Efficiency Standards for Residential Boilers

Submitted to: Frank Stanonik, Chief Technical Advisor, AHRI
Submitted by: John E Batey, PE, Energy Research Center, Inc

October 10, 2015

The following engineering analysis and comments were prepared in response to the US Department of Energy's Proposed Rule for Energy Conservation Standards for Residential Boilers that is currently under review. These comments are based on review and analysis of the following referenced documents:

1. Notice of Proposed Rulemaking - Energy Conservation Program: Energy Conservation Standards for Residential Boilers, dated March 31, 2015
2. USDOE Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers, dated March 12, 2015
3. The Effect of Reduced Boiler Water Temperature on Cycle Efficiency, JE Batey, TW Allen, Brookhaven National Laboratory, BNL 50712, July 1977
4. Recent survey of vent system manufacturers, suppliers, and installers, July 2015
5. US Energy Information Administration, Table C5. Residential Sector Energy Consumption Estimates, 2012

The findings in this report are also based on forty years of engineering experience as a research and applications engineer, as a Professional Engineer, and as an expert witness with 30 years of field experience in the area of boiler/burner design, testing, field investigations, and review of industry practices related to the installation, operation and performance of residential and commercial oil and gas boilers. Review and analysis of the referenced documents and related field experience form the basis for the findings, conclusions and recommendations presented in this report.

Laboratory and Field Testing of Boiler Efficiency and Boiler Water Temperature Reset

Brookhaven National Laboratory (BNL), NBS, NIST and other highly respected organizations have measured and documented residential and commercial boiler efficiencies for a range of designs and operating conditions over the past forty years. One energy-saving option evaluated was Boiler Water Temperature Reset. Lowering boiler water temperature is an energy-saving option that is known to increase the efficiency of gas and oil boilers because it lowers heat loss during the burner on- and off-cycles. Automatic Boiler Water Temperature Reset (ABWTR) improves the overall efficiency of gas and oil boilers. The savings produced by lowering boiler water temperature was first evaluated at BNL at the Burner-Boiler/Furnace Test Facility in 1977. Direct measurement of efficiency using heat flow input-output testing was applied to produce part-load thermal efficiency plots for two boiler water temperatures.

Part-load efficiency tests were conducted for the same hot water boiler at 185 F and again at 150 F boiler water temperature (ref 3). Figure 1 presents the results of these tests, and shows that the part-load efficiency is higher at 150 F in the upper plot than at 185 F in the lower plot. Boiler efficiency in the upper plot at 150 F drops off more slowly as boiler heat loss is reduced when compared to the same boiler operating at 185 F. The test results have been substantiated by field testing.

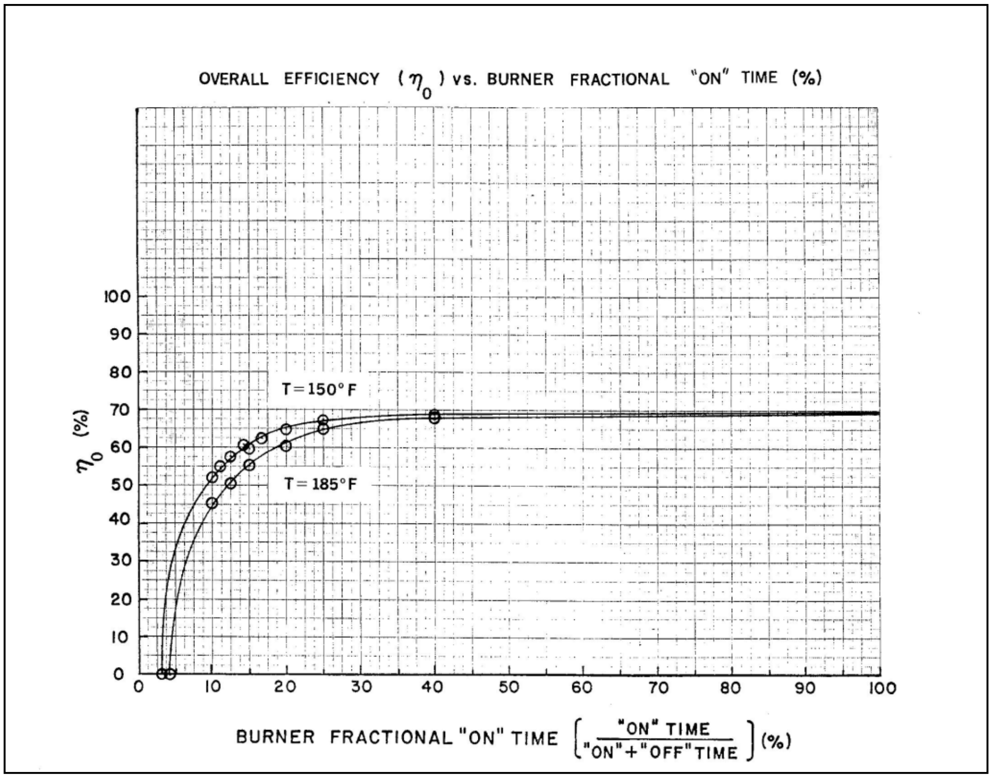

Figure 1. BNL tests of Boiler Water Temperature Reduction

These part-load efficiency plots were evaluated by BNL over a typical heating season to determine the savings that are produced corresponding to increased boiler operating efficiency. This analysis showed that boiler off-cycle heat loss is reduced by 30 percent and annual fuel use is lowered by 6 percent.

BNL conducted continuing research into advanced hydronic controls to lower heat loss and increase boiler efficiency. This includes "weather compensated" or outdoor reset of boiler water temperature. These controls measure the outdoor air temperature and lower the boiler water temperature as the outdoor temperature rises and the building heat load decreases. Automatic devices produce lower boiler water temperatures during the heating season, lower boiler off-cycle heat losses, and improve system efficiency and reduce fuel use. Dr Thomas Butcher of BNL discussed these control options in a technical article in Oilheating Journal in March 2009, entitled "Saving Energy with Hydronic Boiler Controls". The projected savings for Boiler Water Temperature reset is 6 percent.

Dr. Butcher also prepared a PowerPoint summary entitled: “Energy Impact of Advanced Hydronic Controls” for the US Department of Energy’s Building America Program that was presented on July 13, 2011. In this presentation, he concluded that hydronic boiler controls offer significant energy savings and the primary source of savings are reduced off-cycle heat loss. The energy savings potential from several studies are cited which include BNL lab studies at 5% to 8% savings, a Minnesota study with commercial boiler with 10% to 18% savings, and a Wisconsin study of commercial boilers with an average savings of 7.3%. Clearly, Boiler Water Temperature Reset offers important fuel savings and improvement of gas and oil boiler overall efficiency. This option also lowers boiler flue gas temperature during burner off-cycles which lowers the temperature of the vent system and chimney.

USDOE Analysis of Energy Savings by Boiler Water Temperature Reset

The USDOE Technical Support Document (ref 2) includes an analysis of the change in AFUE rating for boilers with Boiler Water Temperature Reset. Page 7B-31 includes Table 7B.2.22 which shows "Adjustment to Existing AFUE Based on RWT and Automatic Means (for adjusting boiler water temperature) Option for Single-Stage Boilers". For Non-Condensing boilers the AFUE adjustment is - 1.02 %. That is a <u>1.02 % reduction</u> in AFUE by increasing boiler water return temperature.

Boiler efficiency ratings were adjusted by DOE for raising boiler return water temperature from 120 F to 158 F in an attempt to evaluate energy savings produced by ABWTR. Page 7B-30 Figure 7B.2.4 shows DOE’s estimates that the effect of raising boiler return water temperature from 120 F to 158 F, is an AFUE decrease of 1.07 percent. The net impact of ABWTR is shown in Table 7B.2.22 and it is the difference between -1.07 percent <u>without</u> Automatic Means and -1.02 <u>with</u> Automatic Means, or 0.05 percent. The Department's analysis determined that the energy saving by installing Automatic Boiler Water Temperature Reset is only 0.05 percent. This is inconsistent with prior research and testing by BNL and others that show energy savings of 6 percent to as much as 18 percent.

Proposed Boiler AFUE Increases Do Not Include Efficiency Increases Already Produced by the ABWTR Mandate

The Department of Energy Notice of Proposed Rulemaking (ref 1) states that the EPCA requires the USDOE to periodically determine whether more stringent amended standards would be technologically feasible and economically justified, and would save a significant amount of energy. The proposed AFUE increase in gas hot water boilers is 3 percent from 82 to 85 and for Oil hot water boilers is 2 percent from 84 to 86.

Automatic Boiler Water Temperature Reset was mandated for gas and oil hot water boilers since 2012. As discussed earlier, the USDOE TSD (ref 2) evaluated the impact of Boiler Water Temperature Reset in the Table entitled "Adjustment to Existing AFUE Based on RWT and Automatic Means" and determined that efficiency increases by only 0.05% which is not reconcilable with past laboratory and field research studies of 6 percent or more. The USDOE must re-evaluate their calculated savings and related efficiency and AFUE improvement for boilers with Automatic Boiler Water Temperature Reset before new AFUE targets are proposed. These adjusted AFUE ratings for boilers with ABWTR must be known before moving forward with the AFUE increases as proposed.

Safety Concerns for Increasing AFUE before BWTR Efficiency Improvement is Fully Incorporated into DOE's Analysis

Mandated increases in AFUE ratings for gas and oil boilers produce higher combustion efficiency which reduces the flue gas temperature of the boiler. Therefore, to improve boiler efficiency ratings, flue gas temperatures must decrease for non-condensing gas and oil boilers. Many years of investigation by gas and oil researchers has shown that we are reaching a critical condition where, if efficiency levels are increased further, the rate of flue and vent gas condensation will rapidly increase for gas and oil boilers that are designed for non-condensing operation, increasing the potential for condensation-induced corrosion to heating equipment, vent connectors, vents and chimneys. The failure of a venting system due to corrosion presents a verifiable safety hazard as homeowners and building occupants may become exposed to products of combustion including carbon monoxide.

Gas and oil boiler exhaust contains gases which are acidic and condense within the heating equipment, flue connector, and chimney. Extensive research related to condensation and related damage to heating systems has been completed for gas and oil furnaces and boilers and their venting systems. Increased furnace and boiler efficiencies over the past 30 to 40 years have caused lower flue gas temperatures and increased condensation of flue and vent gas and increased potential for heating system damage.

Vent gas condensation in chimneys during the burner on-cycle and during burner on-off cycle damages chimney mortar and linings and contributes to chimney failure by causing bricks, mortar, and parts of chimney liners to break off and fall down into the chimney. The chimney flue can become partially or fully blocked which prevents exhaust gases from fully venting and allows some or all of the exhaust to enter the house or building. This exhaust contains carbon monoxide which at elevated concentrations presents a health hazard to building occupants. The rate of chimney degradation is directly related to lower flue gas temperatures and higher operating efficiencies.

Similarly, lower flue gas temperatures increase the rate of flue gas condensation onto metal flue connectors that allows corrosion damage and vent perforations to occur. This offers a path for escape of flue gas containing hazardous components into the house. Vent pipe (flue connector) failure is commonly observed in cases of Carbon Monoxide poisoning in residences.

I have investigated more than two dozen carbon monoxide injury cases involving residential heating equipment as a Professional Engineer and expert witness. Vent system failure or malfunction is one of the failures that can lead to exposure to unsafe levels of carbon monoxide in houses in many of these cases. In one case involving two fatalities, an opening in the vent pipe was the path for CO entrance into the house. In another case with multiple fatalities, the vent pipe failed on a boiler in a house with a high efficiency boiler. In a case in New Hampshire, a father and son died in their home from Carbon Monoxide poisoning after the boiler vent pipe corroded and fell apart due to vent gas condensation, allowing vent gases with CO to escape into the house. Maintaining venting system integrity is critically important to providing safe and properly operating gas and oil fired heating systems in residences, including those with high efficiency boilers. Raising boiler AFUE minimum standards above current levels will lower flue gas temperatures for new and replacement boilers to a level that is not compatible with many or most existing homes, especially those with older chimneys which are frequently located in colder regions in the Mid-Atlantic and Northeast regions.

Boiler manufacturer installation and operating instructions as a rule specify venting system requirements including minimum chimney (flue) and over-fire draft, as applicable, for reliable and safe operation of their equipment. If the chimney cannot meet these requirements, then the boiler cannot be installed. The proposed AFUE standards will lower flue gas temperatures that will not be compatible with many existing chimney venting systems especially those in houses with older chimneys. The proposed AFUE standard will eliminate all boilers that now exist with AFUE ratings less than 85 for gas and less than 86 for oil that have higher flue gas temperatures that are needed to produce the required chimney draft. If these lower efficiency boilers are not available, then a replacement boiler with flue gas temperature that is compatible with the existing venting system may not be available for installation. This creates an unacceptable hardship, especially for lower income and elderly homeowners where older chimneys are most common. Costly chimney relining or side-wall venting will be required that substantially increases the cost of replacement boiler installation, and produces higher payback periods in these cases that will be imposed on those least able to afford the added cost.

The National Fire Protection Association standard NFPA-31 - Standard for the Installation of Oil-Burning Equipment, 2011 Edition, Annex E, shows venting tables for oil fired equipment. Oil boilers with 86 AFUE will require a combustion efficiency of about 87%. Interpolating between Tables E.5.4(a) and E.5.4(b) shows that the flue gas temperature at this combustion efficiency level is 335 F. For many oil boilers the manufacturer typically specifies a minimum flue gas temperatures on the order of 350 F to produce the required chimney draft for safe venting of combustion gases, and to minimize boiler, vent system, and chimney corrosion damage. The DOE analysis has not evaluated the relationship of the NFPA 31 venting tables to proposed increased minimum efficiency standards for oil boilers.

DOE's analysis in the TSD appears to over-estimate the number of lined chimneys currently serving gas and oil boilers and under-estimates average installation costs, which lowers DOE's estimates of the average Payback Periods for new boilers. NFPA-31, the standard for installing of oil burning equipment, does not require chimney liners or relining before installing new boilers or furnaces. Section 6.2.3 of the 2011 Edition states: "The venting system and chimney shall be designed, constructed, and maintained to ensure that a positive flow is developed and that this flow is sufficient to remove products of combustion to the outside atmosphere". Section 6.3.1 states: "A chimney shall be capable of producing the minimum draft recommended by the manufacturer of the appliance". The provisions of NFPA-31 are performance based and do not require chimney relining when new heating equipment is installed, but require that the existing chimney produce the chimney draft and minimum flue temperature as required by the boiler manufacturer. Raising AFUE minimum efficiencies for new gas and oil boilers as proposed will require that virtually all chimneys are relined or side-wall vent systems are installed. The draft that is produced in existing chimneys after the new 85% and 86% AFUE boilers are installed may be too low to meet manufacturer requirements for new boiler installations.

The proposed AFUE minimum standard for gas and oil boilers is moving all appliances into a critical near-condensing mode of operation by lowering flue gas temperatures to the point where existing chimneys can no longer be used for venting. Gas and oil boiler manufacturers must upgrade boiler design and materials of construction to accommodate flue gas condensation safely at a cost that is much higher than DOE's linear extrapolation by simply adding heat transfer surface area at minimal additional cost.

A second concern with safe venting of gas and oil boilers is the impact of Automatic Boiler Water Temperature Reset that was mandated in 2012 on vent system and chimneys. Research determined that flue gas condensation is an important determinant of vent system deterioration rates. Lower flue temperatures cause higher condensation rates, but the amount of time a vent system remains wet when the burner is not firing is another important factor in the potential for vent system damage. If boiler water temperature is lower, which is the function of Automatic Boiler Water Temperature Reset, then it may take longer for the vent to dry out after the burner cycles off and the potential for vent degradation may increase. This has not yet been fully evaluated in the field, and it must be fully tested and evaluated before proposing new minimum AFUE standards that will lower the flue gas temperature of the boiler.

It has been demonstrated that the Department's engineering analysis does not reliably account for savings by Boiler Water Temperature Reset, and will not be able to account for increased rates of vent damage and failure by increasing AFUE levels as proposed. The proposed increases in AFUE rating (producing lower flue gas temperatures) in combination with ABWTR can create a condition of accelerated degradation of vent systems, increased vent failure rates, and an increased risk to the hazards presented by exposure to combustion gases. Additional testing is needed to investigate these safety concerns, and the impact of ABWTR on efficiency improvement and on flue gas temperatures reduction before the proposed AFUE standards for boilers are implemented

Payback Analysis Assumptions and Corrections

Review of the DOE TSD and Appendices reveals a number of key assumptions that directly impact calculated Payback Period and Life Cycle Costs that need further evaluation and adjustment before the proposed rulemaking is finalized. These include the following.

1. Installed Boiler Costs are Under-Estimated for Increased Efficiency Levels

Table 8.2.5 of the TSD estimated the Total Installed Cost for Residential Boilers at Baseline and increased AFUE levels. The table indicates that Gas Hot Water Boilers have a Baseline installed cost of $5,405 and at 85% AFUE the installed cost is $5,585. This is an increase of $180. Oil Hot Water Boilers have a Baseline Installed cost of $7,089 and for 86% AFUE the installed cost is $7,527. This is an increase of $438. These estimated installed costs for higher AFUE boilers are too low, and average payback periods will be longer than as determined by DOE analyses.

DOE estimates of increased installed costs for oil and gas boilers do not adequately account for vent system upgrades including chimney relining or side-wall vent systems that will be required for many or most boiler installations. These are predominantly located in the Mid-Atlantic and Northeast regions which are commonly populated with older houses (30 to 60 years old) and older, over-sized and often unlined chimneys. In these cases, and for other installations without stainless steel chimney liners or side-wall venting systems, vent system upgrade often will be required before installing gas boilers with 85 AFUE and oil boilers with 86 AFUE ratings.

Typical costs to install a stainless steel chimney liner or a new side-wall venting system are $1675 and $2200 (ref 4), respectively, for an average cost of $1940. This added cost which is expected for most systems in the Mid-Atlantic and Northeast regions, where boilers are commonly used, increases the average installed cost of 85 AFUE Gas Hot Water Boilers to $7525, and the installed cost of 86 AFUE Oil Hot Water Boilers to $9467. The adjusted simple Payback Periods for 85 AFUE Gas Hot Water Boilers and 86 AFUE Oil Hot Water Boilers become 10.4 years and 9.6 years for gas and oil hot water boilers, respectively. It is highly likely that oil and gas hot water boiler manufacturers will require chimney relining or side-wall vent system upgrades before 85 AFUE gas and 86 AFUE oil boilers are installed. These higher AFUE rated boilers will be operating in a near- or partially-condensing mode of operation with flue gas temperatures that are too low to operate safely with existing chimney draft and existing vent systems.

2. Incremental Equipment Costs for Higher AFUE Boilers are Under-Estimated

A second cost factor estimated by DOE that is too low is the added equipment cost for higher AFUE gas and oil boilers. When these costs are corrected, installed equipment costs increase and average Payback Periods also increase substantially. Table 8.2.4 shows DOE estimates for the incremental consumer prices for new boilers based solely on increased heat exchanger area compared to baseline gas and oil boilers. The estimated incremental cost is $186 for an 85% AFUE gas hot water boiler and $360 for an 86% AFUE oil boiler. These estimates do not consider other required changes that will include: increased thickness of heat transfer surfaces, corrosion resistance coatings, higher cost corrosion-resistant materials of construction, and other design and material changes to produce a reliable and safe consumer products during partial flue gas condensing operation. These costs are highly variable from manufacturer to manufacturer but could reasonably approach a 50 percent (or higher) increase over the baseline boiler. This adjustment further increases the Payback Period above the estimates produced by DOE.

3. Average Fuel Use Estimated by DOE for Oil and Gas Boilers are Too High

Table 7B.2.1 of the TSD indicates gas and oil Heating Energy Use from RECS 2009 and CBECS 2003 as the basis for evaluating and estimating annual energy use by gas hot water boilers, gas steam boilers, oil hot water boilers, and oil steam boilers. The average annual energy use in Million BTU per year is estimated to be 95.3, 98.1, 98.1, and 99.9, respectively for each of the boiler classes. These values are too high, and average Payback Periods will be longer than those estimated by DOE.

For oil hot water boilers, the estimated fuel use for heating is 98.1 Million BTU per year which is equivalent to 707 gallon of oil consumed each year for heating. The US Energy Information Administration data for residential energy consumption for 2012 show total distillate oil use of 486.6 Trillion BTU (ref 5). Recent surveys indicate there are approximately 8 million oil heated houses which yields an average energy use per house in the US of 60.8 Million BTU per year or 438 gallon of fuel oil per year. The correction factor and Payback Period adjustment follows:

Table 7B.2.1 estimate of average Heating Energy Use Oil Boilers:		707 gals per year
US EIA Table C5 for 2012 divided by 8 million houses		438 gals per year
Correction factor:	707 gal / 438 gal =	1.61

The DOE TSD over-estimates average household fuel consumption by 61 percent. When the fuel use adjustment is applied, the average calculated energy savings are reduced by 61 percent and the Payback Period for upgrading oil hot water boilers is increased proportionately. A similar correction is expected for oil steam boilers and gas boilers.

4. Oil Prices are Too High - Based on 2012 Baseline

Figure 8D.5.7 of the TSD shows Projected Residential National Fuel Oil Price Factors from 2010 to 2040 with an increase of approximately 20 percent from 2010 to 2012 and shows a steadily increasing oil price trend to 2040. The analysis fails to account for the drop in oil prices in 2015 from $4.02 to $2.98 per gallon which is a 25.9 percent decrease (Ref: US EIA, U.S Weekly No. 2 Heating Oil Residential Price - July 8, 2015). Figure 8D.5.7 shows only a 5 percent price decrease from 2012 to 2015, thereby producing an over-prediction of oil prices to 2040 by approximately 20 percent. Updating and revising DOE’s assumptions related to oil price projections to actually occurring values decreases DOE's calculated heating costs by approximately 20 percent, and increases the average Payback Periods that are calculated by DOE by 20 percent.

Overall impact of Adjusted DOE Estimates of Payback Periods

The four factors listed above combine to over-estimate energy cost savings for oil boilers and under-estimate Payback Periods that were a basis for DOE’s selection of economically justified increases in AFUE standards. Many of these factors also apply to gas boilers. A summary of these factors follow with an estimated impact on Payback Periods for oil hot water boilers.

	Revised Payback Factor
1. Installed Boiler Costs are Under-Estimated for Increased Efficiency Levels	+ 1.26
2. Incremental Equipment Costs for Higher AFUE Boilers are Under-Estimated	+ 1.27
3. Average Fuel Use Estimated by DOE for Oil and Gas Boilers are too High	+ 1.61
4. Oil Prices are too high - based on 2012 baseline	+ 1.20
Overall Impact	**+ 3.09**

When these adjustments to DOE's estimated cost factors are applied, the expected Payback Period for oil hot water boilers increases from 7.6 years to 23.5 years.

Revised Payback Period = 7.6 years X 3.09 = 23.5 years

The adjusted Payback Period of 23.5 years is higher than DOE's calculated Payback Period for EL 4 - 91% AFUE of 21.4 years shown in Table 8.4.3 of the TSD which was not selected by DOE for implementation. Similar adjustments to Payback Periods are expected for gas boilers that make them also economically unattractive.

Concluding Remarks

The Department of Energy has increased residential boiler AFUE averages from 1978 levels of 65% for gas boilers and 76% for oil boilers to current minimum efficiencies of 82% for gas and 84% for oil. These ratings do not incorporate the efficiency increase for Automatic Boiler Water Temperature Reset that is 6% or higher based on reliable laboratory and field investigations. It is well established that when gas and oil boiler efficiencies approach the mid-80 percent range, increased flue gas condensation occurs and the potential for vent system and chimney safety and performance degradation increases. Past AFUE increases have increased boiler efficiency and lowered heating costs, but we are now on the threshold of the critical condition of rapid acceleration of flue gas condensation and damage to existing vent systems and chimneys. The added costs of the proposed AFUE increases cannot be evaluated by simple linear extrapolation of the cost to extend heat exchanger surface area, but must consider all the added costs as near-condensing boiler operation is entered that is not adequately addressed in the TSD. We are clearly entering an area of diminishing returns as minor increases in efficiency create substantial increases in installed costs. Vent safety concerns are paramount as higher AFUE levels now increase the likelihood of accelerated vent system and chimney damage, causing excessive added costs for equipment upgrades and vent modifications to assure continued safe equipment operation.