Establishing an Energy Efficiency Recommendation for Commercial Boilers

Michelle J. Ware, Lawrence Berkeley National Laboratory

ABSTRACT

To assist the federal government in meeting its energy reduction goals, President Clinton's Executive Order 12902 established the Procurement Challenge, which directed all federal agencies to purchase equipment within the top 25th percentile of efficiency. Under the direction of DOE's Federal Energy Management Program (FEMP), the Procurement Challenge's goal is to create efficiency recommendations for all energy-using products (e.g. commercial boilers, chillers, motors) that could substantially impact the government's energy reduction goals. When establishing efficiency recommendations, FEMP looks at standardized performance ratings for products sold in the U.S. marketplace. Currently, the commercial boiler industry uses combustion efficiency and, sometimes, thermal efficiency as metrics when specifying boiler performance. For many years, the industry has used both metrics interchangeably, causing confusion in the market place about boiler performance. This paper discusses the method used to establish FEMP's efficiency recommendation for commercial boilers in lieu of the various, and somewhat confusing, efficiency ratings currently available. The paper also discusses potential energy cost savings for federal agencies that improve the efficiency of boilers specified and purchased.

Introduction

Why Establish an Efficiency Recommendation for Commercial Boilers?

In 1994, President Clinton's Executive Order 12902 directed federal agencies to purchase equipment in the top 25th percentile of efficiency. As a result of this executive order, DOE's Federal Energy Management Program (FEMP) implemented its "Procurement Challenge," also known as the *Buying Energy Efficient Products* Program. The Procurement Challenge was a signed agreement among 22 federal agencies to promote and encourage energy-efficient purchasing. With this signing, FEMP started developing energy efficiency recommendations based on the top 25th percentile criterion. Since 1996, efficiency recommendations have been developed for commercial and residential space heating equipment, air conditioning equipment, appliances, and lighting products. Because agencies are encouraged to evaluate two or more competitive bids for federal projects, FEMP establishes efficiency levels that can be met by at least two, preferably, three manufacturers. These recommendations are developed using current industry test standards and commercially available listings of models for sale.

The 1995 CBECS (Commercial Building Energy Consumption Survey) reported that 30% of federally owned commercial floor space with space heating used boilers.[1] CBECS also shows that agencies consumed 19 trillion Btu's of natural gas fuel and 6 trillion Btu of

[1] Applies to boilers used as primary source of heating equipment, and does not include district heating as defined by CBECS.

oil for its buildings with space heating (EIA 1998, 325-26).[2] A commercial boiler efficiency recommendation used by federal purchasers could help reduce fuel consumption and costs. But with current issues surrounding the accuracy of performance claims and test standards for boilers, how feasible was it to create an efficiency recommendation for commercial boilers? Furthermore, could a federal recommendation encourage energy-efficient purchasing and help pull the market to greater efficiency, without adding confusion to the current boiler market?

Selecting a Performance Standard and Efficiency Metric

Boilers can be classified by gross output capacity into three market segments: residential (< 0.3 million Btuh), small commercial (≥ 0.3 to 10 million Btuh) and large commercial/industrial (> 10 million Btuh) (Rouleau 1998).[3] Since there are different boiler applications, different performance standards are used to rate a boiler's efficiency (refer to Table 1). For example, the DOE's (U.S. Department of Energy) National Test Standard requires boilers with capacities less than 0.3 million Btuh be rated to an Annual Fuel Utilization Efficiency (AFUE) (HI 1999). Commercial-size boilers are typically rated to the American National Standards Institute's (ANSI) Z21-13 test method for combustion efficiency (ANSI 1991, 18). The HI test method for commercial boilers measures and rates the gross output capacity and thermal efficiency of a boiler at steady-

Table 1: Various Performance Standards for Commercial Space Heating Boilers

Performance Metric	Performance Standard	Date	What does it measure?
Annual Fuel Utilization Efficiency (AFUE)	U.S. Department of Energy National Test Standard, 10 CFR 430	March 1984	Measures (at steady state) the annual heating efficiency of a boiler or furnace (< 0.3 million Btuh), which is the heat transferred to the conditioned space divided by the fuel energy supplied.
Combustion Efficiency (E_C)	ANSI Z21.13	1991	Measures the ability of a boiler to burn fuel E_C = 100 – flue loss (or the % of heat input rate)
Thermal Efficiency (E_T)	HYDRONICS INSTITUTE[4]	June 1989	Measures (at steady state conditions) the ratio of heat energy output to the heat energy input, exclusive of jacket and heat losses through the boiler shell (> 0.3 million Btuh)
	ASHRAE 90.1–99	June 1999	$E_T = \frac{\text{Total heat output x 100}}{\text{Total heat input}}$
Application Seasonal Efficiency	ASHRAE 155P(proposed)	2003	Measures part-load and seasonal performance of commercial space heating boilers (> 0.3 million Btuh)

state, full load conditions (HI 1989, 27-29).[5] Combustion efficiency is a measure of the burner's ability to burn fuel, where thermal efficiency is a measure of the effectiveness of the

[2] This is significantly different from FEMP's Annual Report to Congress (FY 1996), which shows the federal government consuming 120 trillion Btu of natural gas, and 49 trillion Btu of oil (DOE 1998). This report does not provide a breakdown for energy end use type and heating equipment type.

[3] Boilers with capacities less than 10 million Btuh are used in residential and commercial space heating including water heating applications. Some residential size boilers can be found in light commercial applications. Boilers larger than 10 million Btuh can be considered non-packaged units, which are constructed at the site, and used in industrial or manufacturing/processing applications (DOE 1999).

[4] HI is a division of the Gas Appliance Manufacturer Association (GAMA).

heat exchanger of the boiler (Cleaver Brooks 1999). The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), under its building energy standard 90.1-99, recently adopted HI's test method and cites thermal efficiency (E_T) as the performance metric for some commercial boiler sizes (ASHRAE 1999).[6]

Although ASHRAE has adopted HI's test method, ASHRAE's Standard Project Committee155P is currently working on a test method for rating the seasonal and part-load efficiency of commercial space heating boilers (Hewett 1998). Because commercial boilers typically operate at part-load conditions, ASHRAE's proposed part-load and seasonal performance metric would be ideal for measuring actual boiler performance and calculating operating costs among boiler options (Hewett 1992). However, ASHRAE's 155P standard will not be available till 2003 or beyond (Bixby 1999).[7] With the current boiler standards situation in such transition, it was difficult to determine which performance metric to use for FEMP's boiler recommendation. With ASHRAE's adoption of HI's E_T test method, it was evident that the industry was making a transition from an old rating, combustion efficiency (E_C), to a new rating, thermal efficiency (E_T). In addition, boiler manufacturers participating in HI's voluntary certification program must arrange performance verification testing of the boilers offered for sale in the U.S. (Demaria 1999). These verified ratings are then published annually in the IBR directory.[8] To minimize confusion for federal purchasers and support the industry's trend, FEMP used HI's thermal efficiency test method and IBR directory. This was justified because 1) the test method is standardized, 2) the method was adopted by ASHRAE 90.1-99, 3) the IBR directory included annually verified performance ratings, and 4) the directory lists more than 50% of all commercial space-heating boilers currently available for sale in the U.S.[9]

Evaluating the IBR Directory and its Thermal Efficiency Ratings

Hydronics Institute's (HI) IBR directory was the best source of thermal efficiency (E_T) ratings, but it has some inconsistencies. These inconsistencies create a hodgepodge of gross output capacities based on both combustion and thermal efficiencies. An excerpt from the1999 IBR directory can be found in Figure 1. In an effort to make the published data more intelligible, HI created a designation to differentiate boilers tested for E_T from those tested for E_C.[10] To the untrained eye, this can provoke some initial confusion. However, E_T can simply be calculated by dividing the rated gross input capacity into the gross output capacity for those model groupings listed without a "#" sign. Converting E_C to E_T should have been

---

[5] HI's steady state condition is an outlet water temperature of 200 °F ±5 °F for water boilers, and deliverable steam @ 0 – 2 lbs./in^2 (psi) for steam boilers (HI 1989).

[6] Table 6.2.1F of ASHRAE 90.1-99 cites both thermal (E_T) and combustion efficiency (E_C), with a minimum E_T of 75% (gas) and 78% (oil) for boilers >0.3 to 2.5 million Btuh. For boilers > 2.5 million Btuh, 90.1-99 lists a minimum E_C of 80% (gas) and 83% for (oil) (ASHRAE 1999).

[7] There is no definitive date on the completion and adoption of ASHRAE's 155P standard.

[8] IBR ("I=B=R") stands for the Institute of Boiler and Radiator Manufacturers. This was a trade organization in the early 1900's that preceded HI and GAMA.

[9] The California Energy Commission (CEC) has a database of residential, commercial, and industrial boiler ratings (from manufacturers and wholesale distributors). These ratings are based on combustion efficiency only (Martin 1999).

[10] Gross output capacities rated to E_T are listed in the IBR directory without a "#" sign. Gross output capacities rated to E_C are listed in the IBR directory with a "#" sign. (HI 1989) For no.2 oil boilers, a conversion of 140,000 Btuh/gal should be used.

relatively simple. But some reporting errors by manufacturers hindered the process (e.g. there were models listed in the IBR directory where $E_T > E_C$ or $E_T = E_C$). In addition, the HI test standard and rating method outlines provisions for manufacturers to de-rate (by 3%) boilers using dual fuel burners (HI 1989, 6-7). Manufacturers may also interpolate ratings for a model line of products without actually testing the entire model line (Bixby 1999). These factors, along with the ability of manufacturers to "self-select" boilers they will certify to HI, helped create a directory with some misleading ratings. Furthermore, HI's testing program is a "witnessed" boiler test at a manufacturer's facility (Demaria 1999). In other words, HI has not designated a

Boiler Model	Input Gas (MBh)	Oil gph	Gross Output MBh	Combustion Effic. %	Steam Sq. Ft.	Steam MBh	Water MBh	Vent Size Oil
			Axeman-Anderson Company					
PO-2 Series								
189PO		2.4	277	82.7	867	208	241	8x10x15
			Buderus Hydronic Systems					
#G334X Series					**Inter.Ign, Natural, Propane**			
G334X-73	301		249	82.7			217	
G334X-92	378		314	83.1			273	
G334X-116	476		396	83.2			344	
G334X-132	541		450	83.2			391	
314 Series					**Power Burner, Natural Gas**			
G315-5	433		350	84.2			304	8x12x15
G315-6	556		454	84.3			395	12x12x15
G315-7	678		559	84.4			486	12x12x15
G315-8	801		663	84.4			577	12x16x15
G315-9	924		768	84.5			668	12x16x15

Figure 1: Excerpt from IBR Directory[11] (HI 1999)

test chamber exclusively for HI boiler testing; and, HI does not certify manufacturers' test facilities (Demaria 1999). Although HI's test standard does have certain requirements for instruments used in the test, how well these instruments are calibrated may differ among various testing chambers (HI 1989, 8-9). Taking into account all of these factors (i.e. HI's de-rating procedures, varying test chambers, and submittal of erroneous ratings), it seems likely that some of the E_T measurements listed in the 1999 IBR directory were erroneous.[12] However, federal purchasers, using ASHRAE 90.1-99 to specify boiler performance, will need a commercial source of boilers offered for sale in the U.S., so the IBR directory was used in the analysis.

Although the IBR directory was the best available source for the analysis, not all IBR listed boilers were rated for thermal efficiency (E_T). The 1999 IBR directory listed 2,265 commercial boilers with gross-output capacity ranging from 0.3 to10 million Btuh. Of the total listings, 57% of the boilers had performance ratings for both E_T and combustion efficiency (E_C). The remaining listings were based only on E_C. Some of the ratings needed to

[11] The IBR directory defines "Mbh" as MBtuh, which equals 100,000 Btuh. Btuh stands for British thermal units and gph means gallons per hour.

[12] Currently, HI's IBR directory is the only commercially available source of E_T performance ratings.

be adjusted to ensure that most (if not all) ratings could be used. In addition, was a significant bias in the models with only E_C ratings versus those listed with E_T? Theoretically, using models with only E_T ratings as the sample set for calculating the top 25th percentile of efficiency would not be truly representative of the commercial boiler market. But if a direct relationship between E_T and E_C could be derived, perhaps the sample size could include most, if not all, of the 2,265 IBR models. Industry experts indicate that, typically, E_T is approximately 3 to 5% lower than combustion efficiency (E_C) (Bisette 1999).[13] But without concrete evidence to prove the "3 to 5%" convention for all boiler classes, it could not be used in the analysis. Furthermore, a quick overview of the IBR directory showed varying percentage point differences between E_T and E_C, a convincing reason to further investigate the relationship between E_T and E_C for various boiler classes.

Performing the Top 25th Percentile Analysis

Combustion efficiency (E_C) measures the burner's efficiency, while thermal efficiency (E_T) also measures heat transfer capability of the heat exchanger. In either case, the amount of fuel burned and the heat transfer is used to define the boiler's performance, which is its ability to maintain the desired temperature of the deliverable fluid. The E_T of a boiler can also vary by the amount of boiler-shell insulation, jacket losses, and capacity of the boiler. So regardless of boiler class, there will always be a relationship between E_C and

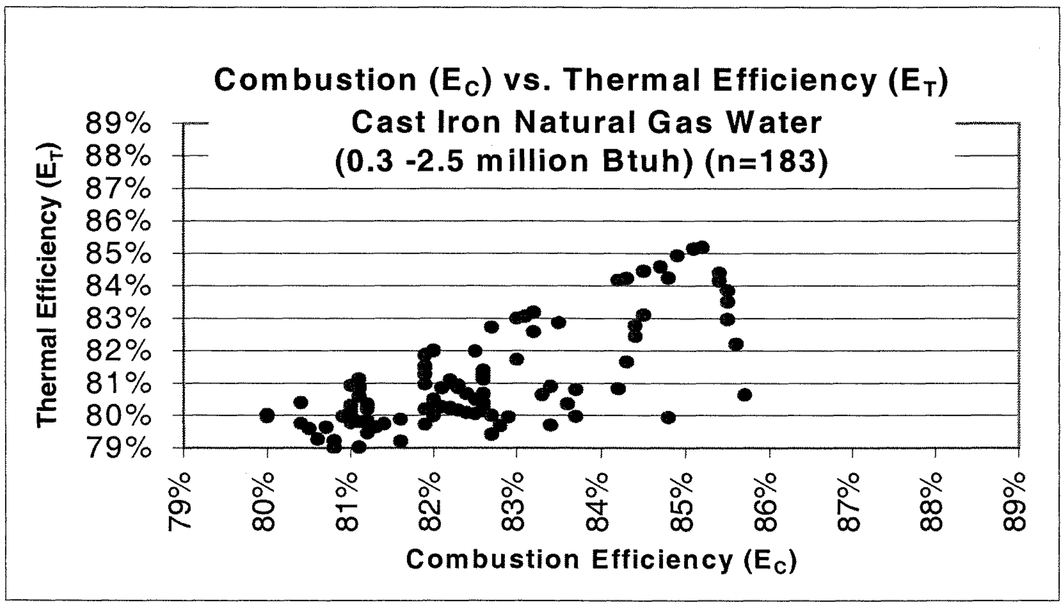

Figure 2: Example of a scatter plot E_C vs. E_T (HI 1999)

E_T. In some boiler classes, the difference may be larger than in other boiler classes. For each boiler class, a scatter plot of E_T versus E_C was created (see Figure 2). These scatter plots were created to identify percentage point differences between E_T and E_C ratings within boiler

[13] This conversion factor is an accepted industry practice, as indicated through several verbal communications with various sources. The author was unable to find specific evidence or literature showing this conversion.

classes.[14] The percentage point differences were also used to extract incorrect ratings from the data set. In some cases, such as heavy oil boilers in the 1999 IBR directory, E_T was greater than E_C, a physical impossibility!

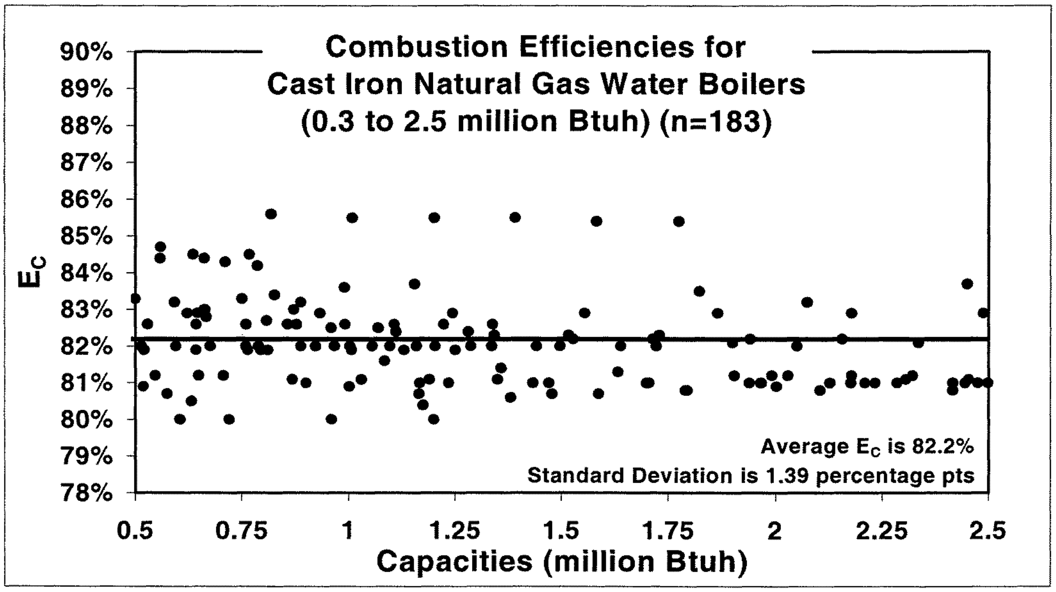

Figure 3: Standard Deviation for Cast Iron, Natural Gas Boilers (HI 1999)

Table 2: Average Percentage Point Differences Between E_T & E_C (HI 1999)

Fluid	Heat Exchanger	0.3 – 2.5 million Btuh		2.5 – 10 million Btuh	
		Natural Gas	Oil (no.2)	Natural Gas	Oil (no.2)
Steam	Cast Iron	2.1	2.4	1.5	1.6
Water	Cast Iron	1.6	2.4	1.4	1.6
	Steel	2.2	3.4	na[15]	na

Defining and Analyzing Data Set 1 (DS1). The first data set (DS1) was defined with IBR models E_T ratings (57% of 2,265 models). E_T for these models was ranked from best to worst. The efficiency level that represented the top 25th percentile was identified. This percentile analysis was repeated for each boiler classification. But only 57% of all the commercial boilers in IBR directory had E_T ratings, so DS1 was incomplete. If the boilers with E_T ratings represented the entire market it would have been sufficient to simply find the top 25th percentile level of DS1. To test the hypothesis that there was not a significant difference between efficiencies of models with and without E_T, a variance test was performed on the E_C ratings for models with E_T. The variance test looked at the standard deviation of the models from the mean average of E_C ratings. In the example of cast iron natural gas water boilers, the average E_C rating was 82.2% and the standard deviation for a sample size n=183 was 1.39% points (see Figure 3). Of the 183 models, 91% had fell within the standard

[14] Boiler classifications used in the analysis were based on IBR directory listings. The directory categorizes boilers by deliverable fluid (water and steam), fuel type (oil, propane gas, and natural gas), heat exchanger (copper, stainless steel, and cast iron), and deliverable capacity (0.3 to 2.5 million Btuh and 2.5 to 10 million Btuh).

[15] "na" represents the case for which E_T ratings were not available for a boiler class, which was also true for all copper boilers and steam, steel boilers.

deviation. This variance test was repeated for all the other boiler classes, proving similar results. With this justification, the average percent point differences between E_C and E_T ratings was considered a valid method to incorporate models having E_C ratings only into the analysis. But if the average percent point differences were included, how would this impact the top 25th percentile levels? To evaluate this method another data set was created using an "adjusted" thermal efficiency.

Defining and Analyzing Data Set 2 (DS2). The average percent point differences found in DS1 proved useful when defining the second data set (DS2). This new data set was created to evaluate the impact on the top 25th percentile after increasing the sample size. DS2 was defined by DS1 plus the remaining IBR models (i.e., the 47% of IBR models with only E_C ratings). These E_C ratings were converted to an "adjusted thermal efficiency" (E^*_T). This adjusted efficiency was derived from the average percent point difference between E_T and E_C ratings within each specific boiler classification (see Table 2). In some cases, E_T and E_C were reported to be equal, which is impossible; so these models were thrown out of the data set.[16] For the boiler classes used, the average percent point difference was then subtracted from models with E_C ratings only. The resulting efficiency became the adjust E^*_T. The new E^*_T rating, along with models in DS1, defined

Table 3a: Top 25th Percentile of DS1 Cast Iron Boilers

Boiler Gross Output Capacities	Steam				Water			
	natural gas		oil (no. 2)		natural gas		oil (no. 2)	
	n[17]	%-ile	n	%-ile	n	%-ile	n	%-ile
0.3 to 2.5 million Btuh	99	80.5%	115	82.9%	183	81.9%	210	83.5%
2.5 to 10 million Btuh	106	80.8%	95	83.0%	122	80.9%	112	83.0%

Table 3b: Top 25th Percentile of DS2 Cast Iron Boilers (E_T & E^*_T)

Boiler Gross Output Capacities	Steam				Water			
	natural gas		oil (no. 2)		natural gas		oil (no. 2)	
	n	%-ile	n	%-ile	n	%-ile	n	%-ile
0.3 to 2.5 million Btuh	334	79.6%	115	82.9%	423	80.4%	218	80.1%
2.5 to 10 million Btuh	137	80.4%	95	83.0%	180	80.7%	122	82.9%

the second data set (DS2). The models in DS2 were then ranked from best to worst. The E_T level corresponding to the top 25th percentile was identified. Tables 3a and 3b shows the results of the top 25th percentile analysis for cast iron boilers. This method was repeated for each boiler classification. This percentile level was compared to the percentile level found in DS1 for the same boiler class.

In the case of natural gas cast iron boilers with capacities of 0.3 to 2.5 million Btuh (see Tables 3a and 3b), the top 25th percentile level decreased from 81.9% E_T (n=183) to 80.4% E_T (n=423). When the E^*_T for some of the other boiler classes were included in the analysis, as expected the top 25th percentile levels decreased. In most cases, however, the percentile level changed by less than 0.75%. This was not considered significant and justified

[16] This is not possible because E_T accounts for jacket losses and is always lower than E_C. This may be a result of incorrect de-rating, manufacturers submitting incorrect data, data entry errors, or bad test result.

[17] "n" refers to the total number of models in the boiler class.

incorporating more IBR models in the analysis. But some models did not have E_T ratings, so E^*_T could not be derived. Thus, boiler classes in DS2 were now limited to only steel and cast iron boilers (refer back to Table 2). If the efficiency table for FEMP's recommendation was created based on these categories, it would discriminate against copper (and some steel) boilers which represent some of the most energy-efficient boilers available (Bixby 1999). To resolve this, the top 25th percentile analysis was repeated on the DS2 exclusive of the heat exchanger.

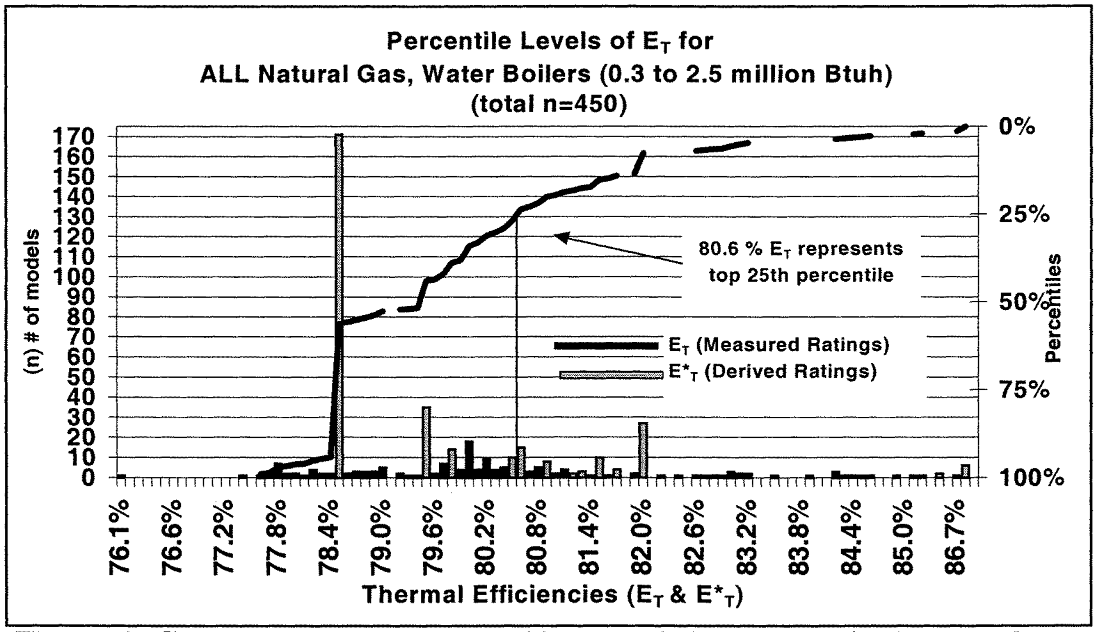

Figure 4: Cumulative Distribution of Percentile Levels for ALL natural gas water boilers

Narrowing the Boiler Classes. Because a boiler's heat exchanger plays a significant role in E_T, it was important to observe its effects on the top 25th percentile level identified in DS2. So boilers in DS2 were re-categorized by capacity, deliverable fluid, and fuel used – exclusive of heat exchanger type (i.e., all natural gas, water boilers between 0.3 and 2.5 million Btuh were grouped together). Re-categorizing the boilers like this not only increased the sample, but it also changed the percentile levels. For example, the top 25th percentile for cast iron, natural gas boilers (0.3 to 2.5 million Btuh) was 80.4% E_T (see Table 3b) as opposed to 80.6% E_T for all natural gas water boilers in the same size-category (regardless of the heat exchanger) (see Figure 4). Since there was only a 0.24% decrease in the top 25th percentile level, this consolidation of boiler classes was repeated for DS2; and in doing so, there did not appear be a significant shift in the top 25th percentile levels after regrouping the models exclusive of heat exchanger type. From these results, FEMP developed its recommended levels shown in Table 4. These E_T levels for commercial boiler may appear to be conservative. For example, some boiler manufacturers are claiming E_T ratings from 90 – 95% (AERCO 1999). In addition, some condensing boilers (with cooper heat exchangers) claim to have thermal efficiencies better than 96%. Simply stated, federal agencies have a wide range of boilers (with or without boiler accessories) that can improve a boiler's thermal efficiency beyond the FEMP recommended levels.

Table 4: FEMP's Energy Efficiency Recommendation for Commercial Boilers[18]

Product Type	Rated Capacity (Btuh)	Recommended Thermal Efficiency
Natural Gas/Water	300,000 - 2,500,000 2,500,001 - 10,000,000	80% 80%
Natural Gas/Steam	300,000 - 2,500,000 2,500,001 - 10,000,000	79% 80%
#2 Oil/Water	300,000 - 2,500,000 2,500,001 - 10,000,000	83% 83%
#2 Oil/Steam	300,000 - 2,500,000 2,500,001 - 10,000,000	83% 83%

Potential Fuel Savings from Improving a Boiler's Thermal Efficiency

After having established an energy efficiency recommendation, what incentive can FEMP provide federal purchasers for installing a more energy efficient boiler? The answer lies in the lifetime energy cost savings for a typical commercial boiler. According to FEMP's efficiency recommendation, a 5 million Btuh natural gas water boiler, with a thermal efficiency (E_T) of 80%, can have lifetime energy cost savings of up to $38,000 when compared to a boiler with an E_T of only 75% (see Table 5).[19] But how do these savings compare relative to the entire federal stock of commercial space heating boilers?

Table 5: Estimated Annual Energy Cost Savings of E_T for a 5 million Btuh Natural Gas Water Boiler

	Existing Boiler	ASHRAE 90.1-99	FEMP Recommended Level	Best[20] Avail.
Thermal Efficiency (E_T)	**70%**	**78%**	**80 %**	**83%**
Annual Energy Costs	**$42,800**	**$38,500**	**$37,500**	**$36,100**
Annual Energy Costs Savings	**-----**	**$4,300**	**$5,300**	**$6,700**

CBECS reports that of all the natural gas consumed by space heating equipment in 1995, 530 trillion Btu went to fueling boilers (EIA 1998, 325-26). If the federal government represents 2% of commercial market, then 10 trillion Btu of natural gas went to fueling federally owned boilers. FEMP recently reported potential savings on federal purchasing of energy efficient products. In this report, FEMP looks at four purchasing scenarios of federal agencies and estimates that if boilers were purchased at FEMP's recommended level of 80% E_T, the federal government could save 0.4 trillion Btu/year (by 2010) on fuel for its boiler stock (Harris & Johnson 2000).[21] This is roughly 4% of the 10 trillion Btu of natural gas

---

[18] This efficiency recommendation does not cover condensing boilers (DOE 1999).

[19] In FEMP's "Cost Effectiveness Example" for commercial boilers the savings calculation assumes an average federal gas price of $0.40/therm, a federal discount rate of 3.1%, 1,500 equivalent full-load hours of boiler operation, and a 25-year boiler life (DOE 1999).

[20] "Best Available" excludes condensing boilers.

[21] This calculation is based on Scenario III found in the Harris and Johnson report, which assumes that 20% of federal boiler purchases in 2000 will comply with FEMP's recommended level of 80 % E_T. The scenario ramps purchasing at the FEMP level to 80% in 2010, with no early replacement of boilers (Harris & Johnson 2000).

consumed in 1995, and is approximately $1.7 million saved annually by 2010. As discussed earlier, the FEMP recommended level was fairly conservative considering condensing boilers, copper boilers, and steel boilers tend to have higher thermal efficiencies. So if federal agencies purchased boilers with higher efficiency levels, the potential savings of $1.7 million should increase.

Conclusion: Was it the Right Metric to Use?

Despite the current standard and ratings situation for commercial boilers, a federal energy efficiency recommendation was created to help encourage energy-efficient purchasing and reduce some federal energy costs. ASHRAE's adoption of the metric is evidence that the industry has decided to use thermal efficiency (E_T) as the performance metric for packaged commercial boilers. However, ASHRAE is also developing a test method for rating the part-load efficiency, a true measure of real-time boiler performance. But this standard is years from being adopted, a situation that does not help federal agencies currently looking for guidance on boiler performance. Furthermore boiler manufacturers do not provide part-load efficiencies for their boilers.[22] Nonetheless, the HI voluntary testing program provides a readily available source of verifiable ratings based on E_T for boilers. In addition, energy cost savings can be obtained by using FEMP's recommended levels and improving a boiler's E_T. Hopefully, as federal purchasers comply with the presidential executive order and cite FEMP's recommended metric, using E_T to measure boiler performance will become more commonplace. It also appears that manufacturers are responding to ASHRAE 90.1-99. The number of boilers with E_T ratings in HI's 2000 IBR directory increased somewhat since the 1999 version. And as HI continues to increase its listings of boilers with E_T, agencies will have a larger selection of commercially available boilers, with E_T as the recommended metric of choice. This, to some degree, helps FEMP's position to encourage energy efficient purchasing and support the industry trend, without adding confusion to the market. Many consumers, including federal agencies, should welcome this change in an industry that has not been successful in monitoring, verifying, or representing accurate claims of boiler performance.

Acknowledgements

The author would like to thank the following for their valuable input to this work: Jeff Harris of Lawrence Berkeley National Laboratory; Phil Coleman of Lawrence Berkeley National Laboratory; Derek Buchler of Boston Gas Company; and Harvey Sachs of Sachs and Sachs.

References

AERCO International Inc, 1998. *Published Literature for Benchmark AERCO Boilers*. Northvale, NJ. January.

[22] The exception is with the condensing boiler technology, where some manufacturers publish marketing brochures with part-load performance curves for boilers.

American Society of Heating Refrigeration and Air Conditioning Engineers, ASHRAE/IESNA 90.1 Standard, *Energy Standard for Buildings Except for Low-Rise Residential Buildings.* 1999. June.

American National Standards Institute, ANSI Z21.13-1991, Z21.13a-1993, *Gas-Fired Low Pressure Steam and Hot Water Boilers.* 1991.

Bissette, Robert. 1999. (Council of Industrial Boiler Owners). Personal communication to the author. July 21.

Bixby, David. 1999. (Gas Appliance Manufacturer Association). Personal communication to author. February 18.

Cleaver Brooks. 1999. *Efficiency Facts.* Downloadable or viewable from http://www.cleaver-brooks.com/Efficiency1.html#15. Milwaukee, WI. March 25.

Demaria, Jim (Hydronics Institute, Division of Gas Appliance Manufacturer Association). 1999. Personal Communication to author. March 1.

Energy Information Administration (EIA). 1998. *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures.* DOE/EIA-0625(95), Energy Information Administration. Washington D.C. October.

Harris, Jeff and Frank Johnson. 2000. Potential Energy, Cost, and CO_2 Savings from Energy Efficient Government Purchasing. *In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings.* Asilomar, CA, August.

Hewett, Martha, 1999. "Background and Current Status of ASHRAE 155P Method of Testing for Rating Commercial Space Heating Boiler Systems." Center for Energy and Environment. Minneapolis, MN.

Hewett, M. and M. Lobenstein. 1992. *Commercial Gas Space Heating Equipment: Opportunities to Increase Efficiency.* CEUE/TR91-3-CM. Center for Energy and Environment. Minneapolis, MN. April.

Hydronics Institute, Division of Gas Appliance Manufacturer Association. 1989. *Testing and Rating Standard for Heating Boilers.* June Edition. Berkeley Heights, New Jersey.

Hydronics Institute, Division of Gas Appliance Manufacturer Association. 1999. *I=B=R Ratings For Boilers, Baseboard, Radiation, and Finned Tube (Commercial).* January 1 Edition. Berkeley Heights, New Jersey.

Martin, Michael, (California Energy Commission). 1999. Personal Communication with author. January 5.

U.S. Department of Energy, Federal Energy Management Program (DOE/FEMP).1998. *Annual Report to Congress on Federal Government Energy Management and Conservation Programs- Fiscal Year 1996*. Office of Federal Energy Management Programs. Washington D.C. July 17. DOE/EE-0192.

U.S. DOE/FEMP. 1999. *Buying Energy Efficient Products.* Federal Energy Management Program. (looseleaf, updated 9/99) Available on request from (800) 363-3732. Viewable or downloadable at http://www.eren.doe.gov/femp/procurement.

Rouleau, D. 1998. "Initial Market Assessment on Commercial Boilers." Consortium for Energy Efficiency. Boston, MA. February 1.