

Consortium for Energy Efficiency
Commercial Boiler Systems
Initiative Description



For information, contact:
George M. Chapman
Senior Program Manager
gchapman@cee1.org
617-337-9262
Consortium for Energy Efficiency
98 North Washington Street, Suite 101
Boston, MA 02114

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1 Introduction

Commercial boiler systems represent a major energy end use in the commercial sector across the US and Canada, consuming 1,040 trillion Btu (British thermal units) of natural gas annually in the US to provide space and hot water heating. About 700 trillion Btu are used to heat 32 percent, or 20 billion square feet, of commercial floor space.¹ This represents 51 percent of total natural gas expenditures for non-mall commercial buildings. There are approximately 120 thousand commercial boilers in the United States. Of this, approximately 79 thousand are gas-fired units under 10 million Btu/h.²

Natural gas saving opportunities abound with the availability of more efficient boiler technologies, system control schemes, and auxiliary equipment that optimize overall energy use, along with proven quality installation and maintenance practices as well as holistic system design concepts that emphasize energy conservation. Energy efficiency measures also provide attractive nonenergy benefits in the form of lower emissions of hazardous combustion by-products, reduced wear and longer life of mechanical components, and smaller physical footprints of heating systems. Energy efficient commercial boiler systems also emphasize and demonstrate sustainability or environmentally conscious practices in an industry where businesses constantly seek opportunities to stand out and attract customers or tenants.

One major challenge associated with these opportunities is that the pace of industry innovation has exceeded installer education and testing procedures. Boiler technology improvements have gone from a 50-year life cycle to a 10-year life cycle³ leading to great successes, but also to complications, such as those associated with the shift from conventional to condensing boilers. Condensing boilers have different installation requirements than conventional boilers, including system design

¹ US Department of Energy, 2003. Commercial Buildings Energy Consumption Study for Non-mall Buildings.

² Energy and Environmental Analysis, Inc., May 2005. “Characterization of the US Industrial Commercial Boiler Population”. Section 3: Estimates 93,000 boilers with less than 10 million Btu/h input, of which 85 percent are fired with natural gas. Note, this estimate is likely understated, as this report relies almost entirely on data from existing ABMA data at the time.

³ Industry Interviews.

considerations for return water temperatures, venting, and condensate drainage as well as different operational characteristics. Condensing boilers accounted for about 40 percent of the commercial market in 2013 and are projected to reach between 47 and 57 percent market share by 2018.^{4,5} Condensing sales are expected to surpass those of conventional boilers for the first time in the coming year.⁶ However, despite the proven efficacy of the technology, these condensing boilers are at risk of performing below the rated efficiency due to improper, uninformed installation procedures as well as efficiency metrics and test procedures that inadequately reflect in-field operation.

To address the implications of industry developments while seeking to accelerate the adoption of more efficient technologies and practices with a cost-effective approach, CEE has developed an Initiative focusing on (1) new construction, (2) boiler replacement and system retrofit, and (3) systems optimization that helps energy efficiency programs build and deliver leveraged, informed, and cost-effective commercial boiler programs. Currently, there are over 40 CEE members running a wide variety of programs to address commercial boiler system efficiency. By voluntarily adopting CEE program recommendations that address whole system energy use and losses as well as the real-world technical and market challenges, efficiency programs achieve greater energy savings through consensus approaches that provide consistent signals to the market across state and national boundaries.

2 Background

2.1 Technology Definitions

A commercial boiler system includes the packaged boiler(s) with control functionality, auxiliary equipment, feedwater and gas supply; the hot water boiler loop consisting of pipes and pumps; and the heat distribution system that transfers heat from the boiler water into the conditioned space. System efficiency begins with the boiler, the performance of which is affected by the flue gas temperature and stack losses, system water temperatures, radiation and convection losses, excess air levels, ambient air temperature, and the burner turndown and modulation capability.⁷ Once the heated water leaves the boiler, it is pumped through a system of pipes to the heat distribution elements (such as radiators, convective baseboard units, fan coils, or radiant tubing) before the water is sent back to the boiler to be

⁴ A.O. Smith. *Summer 2014 Analyst Presentation*. Data from BRG Building Solutions North American Commercial Boiler Report

⁵ DOE EERE Commercial Packaged Boiler National Impact Analysis, Condensing Market Share, December 17, 2014

⁶ Industry interview

⁷ American Boiler Manufacturers Association, 2008. "Determining & Testing Boiler Efficiency for Commercial/Institutional Packaged Boilers." <http://www.abma.com/technical-industry.html>. Accessed March 17, 2015.

reheated. Heat loss can be minimized throughout the boiler loop by adequately insulating pipes and using a variable speed pumping scheme that matches the heating demand to reduce radiant circulation losses. Finally, heat distribution systems with the greatest surface area, such as radiant floor or wall tubing, are most efficient at transferring heat into the space because of the lower water temperatures required. Furthermore, lower system water temperatures allow condensing boilers to operate more often in condensing mode.

For the purposes of this Initiative and to maintain consistency with US Department of Energy (DOE) definitions, a commercial packaged boiler is defined as a low pressure boiler with a capacity of 300,000 Btu/h or more for heating, space conditioning, or service water heating applications in buildings. This Initiative focuses on boilers used primarily for space conditioning in commercial buildings. Conventional boilers have the longest lifetime of all major commercial HVAC equipment, estimated to be between 24 and 35 years,⁸ however many conventional cast iron boilers can live well beyond these estimated lifetimes. Only recently has the use of condensing boilers become widespread, so a final determination on the expected service life of condensing equipment is still premature. The average manufacturer warranty on condensing heat exchangers, which experience the most wear being exposed to acidic condensate, is 12 years.⁹ Industry estimates that the average condensing boiler lifetime is 15 years.¹⁰

Commercial boilers fall into three main efficiency categories: low efficiency (80 percent thermal efficiency (TE)), mid-efficiency (83 to 88 percent TE), and condensing (88 percent TE and above).¹¹ All boilers operate under the same thermodynamic principles and a theoretical maximum efficiency can be calculated for a given system design, although it is generally not representative of the actual operating efficiency. The efficiency of a commercial boiler is highly dependent on the return water temperature of the system. As shown in Figure 1, high efficiencies are attained when the return water temperatures drop below 130 degrees F allowing flue gases to condense and the boiler to operate in condensing mode. Condensing boilers capture some of the latent heat resulting from that phase change of the water vapor in the exhaust gases.¹² The resultant condensate is acidic and requires corrosion-resistant materials, such as stainless steel, to be used for all heat exchanger

⁸ DOE, “Buildings Energy Data Book”, Sept. 2007, Table 5.3.9. <http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.3.9>. Accessed March 17, 2015. Note: Lifetimes from 1978 data with the exception of 2005 data for water-to-air heat pumps.

⁹ Crown Boiler Comment Letter to ENERGY STAR, Version 3.0 Draft 2 Product Specification for Residential Boilers, August 29, 2013

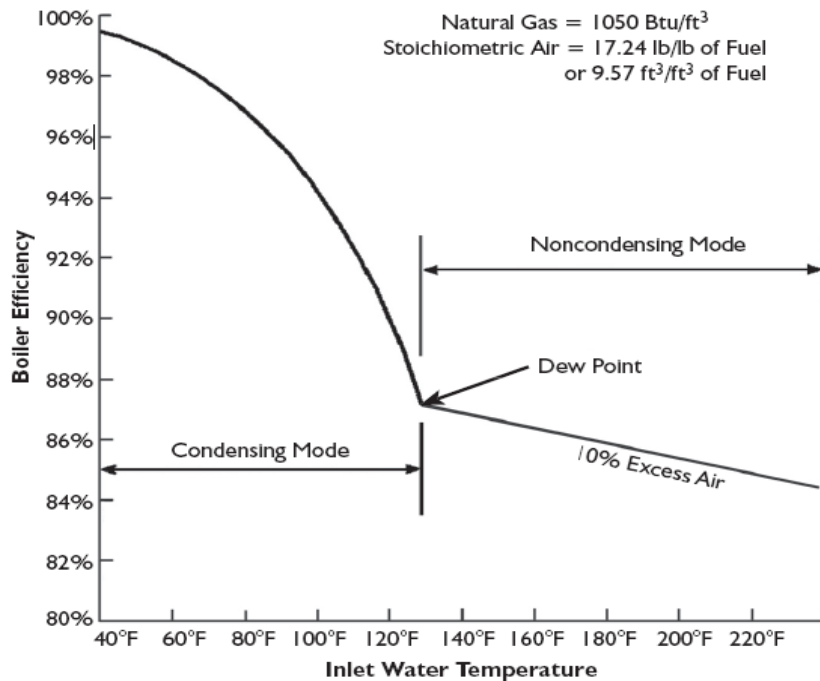
¹⁰ Industry interviews.

¹¹ Durkin, Thomas, P.E., July 2006. “Boiler System Efficiency”, ASHRAE Journal, Vol. 48, p. 52.

¹² Consortium for Energy Efficiency, 2001. “A Market Assessment for Condensing Boilers in Commercial Heating Applications.”

and flue surfaces. Additionally, the venting and condensate drainage must include corrosion-resistant materials. Depending on the boiler and system design and operation, a condensing boiler can increase the efficiency between 6 and 18 percent over a conventional boiler system.¹³

Figure 1. Impact of Return Water Temperature on Efficiency¹⁴



When the return water temperature of the system is higher than 130 degrees F, a condensing boiler operates like a mid-efficiency boiler. Under such operation, the system will not achieve the expected savings. This, coupled with the cost differential of a condensing system, generally means that a condensing boiler is not cost-effective in a system where it does not condense.¹⁵ Therefore, when specifying condensing boilers, it is important to understand the building heat loads, radiation load, seasonal operation, and the required return water temperature of the system. Factors such as having higher delta T coils, employing a piping design with two-way valves, variable flow pumping, and minimal bypass and mixing of supply and return water, as well as supply water temperature reset controls all help to achieve lower system water temperatures.¹⁶ Hybrid boiler systems (section 5.1.3), which

¹³ Cutler, Dylan; Dean, Jesse; Acosta, Jason; Jones, Dennis. *Condensing Boilers Evaluation: Retrofit and New Construction Applications*. June 2014. Prepared for US GSA by NREL

¹⁴ Ibid.

¹⁵ Raypak. "Hybrid Heating Systems." http://www.raypak.com/support/tech_corner/hybrid_heating_systems. Accessed March 17, 2015

¹⁶ Cutler, Dylan; Dean, Jesse; Acosta, Jason; Jones, Dennis. *Condensing Boilers Evaluation: Retrofit and New Construction Applications*. June 2014. Prepared for US GSA by NREL

combine both condensing and conventional boilers into a single system, can also provide a cost-effective means of achieving efficiencies close to that of all condensing systems.

Certain control capabilities and auxiliary boiler equipment (section 5.1.8) improve system efficiency by increasing the time spent in condensing mode and reducing the cycling frequency and resultant purge losses. With respect to control capabilities, CEE is not defining a specific technical path, but rather the functionality desired. For example, supply water temperature reset control functionality, as defined by CEE, is a means of reducing the temperature of the boiler supply water to the lowest temperature required to meet the system demand, an important feature when trying to condense as often as possible. Through this ability to adjust the water temperature, the system achieves a better match between the boiler output and the actual space heating needs, which in turn reduces the cycling of the boiler and radiant heat losses. Supply water temperature reset control functionality can increase the efficiency of the system by four to eight percent.^{17,18}

Another essential operational and energy saving control is a multiple boiler sequencing control that differentiates between each boiler, both condensing and conventional, and their associated modulation to stage the boiler units in response to the load. A sequencing control contributes to an optimized operating efficiency by considering and often firing the most efficient boiler unit or combination of boiler units first. Additional capabilities include load sharing, which operates boilers in parallel so that multiple boilers can fire at a lower rate (more efficient for condensing boilers) to meet the demand as opposed to one boiler running at high fire, and PID control logic, used to determine when to fire the boilers. Most commercial boilers on the market, both condensing and conventional, include a supply water temperature reset functionality using an outdoor temperature sensor as well as a multiple boiler sequencing control, either as a built-in or optional component.¹⁹

Modulating boiler burners with linkageless controls provide improved control over the combustion of flue gases, while modulation allows the burner to reduce the firing rate when there is lower demand. Modulation is typically defined by the turndown ratio, which is an indication of the burner's minimum firing capability compared to the maximum firing rate. Most commercial packaged, condensing boilers on the market have fully modulating burners with a 5:1 turndown,^{20,21}

¹⁷ Natural Gas Boiler Burner Consortium. *Boiler Reset Control*. http://www.cleanboiler.org/Eff_Improve/Efficiency/Boiler_Reset_Control.asp. Accessed May 8, 2015.

¹⁸ Survey of Illinois, Massachusetts, Minnesota, New York, and Wisconsin Technical Reference Manuals

¹⁹ Industry interviews

²⁰ Raba, James. Energy Conservation Standards: Preliminary Analysis for Commercial Packaged Boilers. US DOE EERE Public Meeting Presentation. December 9, 2014

²¹ Industry interviews

meaning the boiler can turn down continuously until one-fifth of the nameplate rating. Manufacturers offer turndown rates on packaged boilers as high as 35:1. Although boilers operating at such a low fire can reduce or eliminate cycling and therefore heat lost during the purge process, turndown rates higher than 10:1 can result in greater losses from the significantly increased excess air levels at low firing rates and the small system temperature differentials that make it harder for the boiler to condense.^{22,23} Additionally, the standby or jacket losses, though constant, become a greater percentage of total heat loss as the firing rate decreases.²⁴ These issues illustrate the importance of conducting heat load calculations and rightsizing the boiler.

Standard or staged modulation, implying an incremental turndown instead of a continuous one, is found on some older, conventional boilers and allows for less flexibility in the firing rate. Existing boilers without modulating burners may benefit from a burner retrofit, especially if the existing burner is oversized and cycles often. Less than five cycles per hour is considered acceptable by industry.²⁵ New burner replacements are usually only feasible on boilers with gun-style burners as opposed to integrated burners and more often occur due to changes in NO_x emissions or backup fuel requirements.²⁶

Linkageless burner controls, also known as parallel positioning, use independent actuators for the fuel and air valves on the boiler burner, as opposed to the traditional setup of mechanically linked actuators, known as a single-point positioning system, that wear down and result in erratic fuel to air ratios over time. Dedicated actuators allow for an optimized and more consistent fuel to air ratio across the entire turndown range, which reduces the amount of heat lost in excess air up the boiler stack and increases overall efficiency.²⁷ An efficient natural gas burner requires 10 to 15 percent excess air, but a single-point positioning system is unable to maintain those levels throughout the burner firing range. In general, every 15 percent increase in excess air results in a one percent efficiency loss.²⁸ Almost all new commercial packaged boilers with modulating burners use linkageless controls. Older boilers with mechanically linked actuators may benefit from an upgrade to

²² Johnston Boiler Company Technical Brief. *Efficiency Comparison: 4:1 Turndown & 10:1 Turndown*. March 17, 2003

²³ Lobdell, Sean. *Effects of Ultra-High Turndown in Hydronic Boilers*. CleaverBrooks, January 2014. P. 4

²⁴ Swagelok Energy Advisors. *Boiler optimization*. Best Practice Design, Technology and Management, Module 5. <http://www.swagelokenergy.com/download/BONZ.pdf>. Accessed June 10, 2015

²⁵ Ibid.

²⁶ Industry interviews.

²⁷ Zala, Rakesh. *Retrofitting Controls Reduces Fuel Costs*. ABMA, Today's Boiler, Spring 2012. P. 9-10

²⁸ Washington State University Cooperative Extension Energy Program. *Boiler Combustion Monitoring and Oxygen Trim Systems*. 2003

linkageless controls if the existing burner is modulating. Otherwise, the entire burner or boiler itself may need replacing for a more efficient system.

Both economizers and turbulators are types of auxiliary boiler equipment with potential to increase the overall efficiency of the boiler system. Economizers are installed on the boiler stack and capture the sensible and, if condensing, latent heat of the flue gases. The Initiative will further explore economizers to determine their suitability and cost-effectiveness for commercial boiler systems. Turbulators, although an inexpensive piece of equipment (\$10 to \$15 installed cost per boiler tube), achieve nominal savings in commercial hydronic systems. DOE recommends the installation of turbulators in firetube boilers where stack gas temperatures are at least 100 degrees F above the system water temperature to improve heat transfer between the hot combustion gases and the boiler water.²⁹ Typical flue gas temperatures for conventional boilers are around 300 degrees F with system temperatures around 180 degrees F rendering turbulators an option with marginal energy savings potential.

2.2 Incremental Price

A truly accurate analysis of incremental pricing often relies on historical transaction data that is not always publicly available. However, the US DOE, in support of a proposed rulemaking for commercial packaged boilers, collected and analyzed manufacturer selling prices for multiple equipment classes and efficiency levels. These are outlined in the table below. The methodology used to determine these incremental prices is explained in the Technical Support Document cited.

²⁹ US DOE EERE Advanced Manufacturing Office. *Steam Tip Sheet #25*. January 2012

Table 1. DOE Incremental Price Estimates by Product Class and Efficiency Level³⁰

Boiler Class	Efficiency Level	Incremental Price	Baseline Price
Small gas-fired hot water, natural draft (800 thousand Btu/h representative capacity)	80% TE	\$0	\$3,799
	81% TE	\$529	
	82% TE	\$1,307	
	85% TE	\$3,078	
Large gas-fired hot water, natural draft (3 million Btu/h representative capacity)	82% CE	\$0	\$16,898
	83% CE	\$2,075	
	84% CE	\$4,343	
Small gas-fired hot water, mechanical draft (800 thousand Btu/h representative capacity)	80% TE	\$0	\$7,120
	83% TE	\$1,710	
	85% TE	\$3,078	
	87% TE	\$4,665	
	92% TE	\$6,819	
	95% TE	\$11,211	
Large gas-fired hot water, mechanical draft (3 million Btu/h representative capacity)	82% CE	\$0	\$22,256
	84% CE	\$4,343	
	86% CE	\$9,533	
	94% CE	\$31,784	
	97% CE	\$35,892	

The price of a condensing commercial boiler can be two to four times that of a mid-efficiency unit.^{31,32} Estimates vary dramatically depending on the input capacity, level of modulation, any additional features, and the pricing decisions or markups made by distribution channel players. In general, incremental price increases nonlinearly with capacity such that larger capacities have larger differentials in price across efficiencies. As a result, the incremental price of boilers larger than 3 million Btu/h may significantly exceed that of the US DOE representative capacity used above.

2.3 Minimum Performance and Testing Standards

DOE previously adopted energy standards effective March 2, 2012 for commercial packaged boilers based on the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1–2007, which bases its classes on fuel type, size, output, and draft type.³³ The Federal Energy Management Program (FEMP) has its own definitions, breaking boilers into four classes based on fuel type

³⁰ US DOE EERE Preliminary Technical Support Document Executive Summary for Commercial Packaged Boilers. Section ES.3.3.2. November 6, 2014

³¹ Durkin, Thomas, P.E., July 2006. “Boiler System Efficiency”, ASHRAE Journal, Vol. 48, p. 52

³² Industry Interviews

³³ Federal Register, March 20, 2009. Department of Energy. 10 CFR Part 431. Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards and Test Procedures for Commercial Heating, Air-Conditioning, and Water-Heating Equipment. Vol. 74, No. 53, p. 12004.

and heating medium.³⁴ Table 2 summarizes the various boiler equipment classes and respective energy conservation standard for each of these parties as well as the DOE Energy Policy and Conservation Act.

Natural Resources Canada’s 2014–2016 Forward Regulatory Plan includes the introduction of new minimum energy performance standards and associated reporting and compliance requirements for commercial boilers as part of Amendment 14 to Canada’s Energy Efficiency Regulations. The plan is to align these requirements with US standards unless there are unique Canadian circumstances.³⁵

Table 2. **Current Federal and Industry Commercial Boiler Classes and Standards**

Boiler Class	EPCA ³⁶	FEMP	ASHRAE
Small* gas-fired hot water		94% TE	80% TE
Large† gas-fired hot water			82% CE
Small gas-fired steam, all, except natural draft	80% CE		79% TE
Large gas-fired steam, all, except natural draft		80% TE	79% TE
Small gas-fired steam, natural draft			77% TE
Large gas-fired steam, natural draft			77% TE
Small oil-fired hot water		85.5% TE	82% TE
Large oil-fired hot water	83% CE		84% CE
Small oil-fired steam		83.5% TE	81% TE
Large oil-fired steam			81% TE

*Between 300,000 Btu/h and 2.5 million Btu/h

†Larger than 2.5 million Btu/h

The US DOE recognizes the Hydronics Institute Division of AHRI Testing Standard BTS–2000: *Method to Determine Efficiency of Commercial Space Heating Boilers* as the method to determine steady state efficiency of boilers with inputs equal to or greater than 300,000 Btu/h. Other boiler standards include ANSI Z21.13/CSA 4.9 *Gas-Fired Low Pressure Steam and Hot Water Boilers*. There are no federal minimum performance

³⁴ Federal Energy Management Program. *Covered Product Category: Commercial Boilers*. <http://energy.gov/eere/femp/covered-product-category-commercial-boilers> Accessed July 22, 2015.

³⁵ Natural Resources Canada. *Amendment 14 to Canada’s Energy Efficiency Regulations*. Modified April 17, 2015. <https://www.nrcan.gc.ca/energy/regulations-codes-standards/6855>. Accessed May 1, 2015

³⁶ The Energy Policy and Conservation Act (EPCA) defines a “commercial packaged boiler” as “a type of packaged low pressure boiler that is industrial equipment with a capacity (rated maximum input) of 300,000 Btu per hour (Btu/h) or more, which, to any significant extent, is distributed in commerce: (1) For heating or space conditioning applications in buildings; or (2) For service water heating in buildings but does not meet the definition of ‘hot water supply boiler’ in [part 431 of 10 CFR].” (10 CFR 431.82) “Packaged” implies a “boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls; usually shipped in one or more sections.” (42 U.S.C. 6311(11)B). DOE further refined this definition to exclude a boiler that is “custom designed and field constructed,” and allows for boilers shipped in more than one section and that “the sections may be produced by more than one manufacturer, and may be originated or shipped at different times and from more than one location.” (10 CFR 431.102)

standards in Canada. Test methods within these standards determine combustion efficiency and thermal efficiency, which are defined as:

- **Combustion Efficiency (CE)** Measures the ability of the boiler burner to burn fuel and equals 100 percent minus the percentage of fuel energy lost in the exhaust gases (i.e. flue loss).
- **Thermal Efficiency (TE)** Measures the ratio of the heat energy output to the heat energy input, exclusive of jacket losses, and can be considered combustion efficiency minus jacket losses.

Being metrics that measure only steady state efficiency, neither CE nor TE adequately measure the system or seasonal efficiency since commercial boilers typically operate at part loads. This is particularly true due to advances in modulating burners and boiler sequencing that yield more savings, but are not currently captured in the BTS–2000 and ANSI Z21.13 referenced testing standards. Additionally, the required test inlet and outlet water temperatures, which impact boiler performance, do not necessarily replicate actual infield temperatures. Thermal efficiency goes one step beyond combustion efficiency to account for jacket losses, and it is the more common metric for commercial packaged boilers within the scope of this Initiative, therefore, it is the chosen metric for CEE specifications. There is no direct mathematical correlation between the two metrics, which is a consideration for efficiency programs.

Over the last two decades, ASHRAE has been developing a national test standard to provide a more meaningful representation of infield conditions of commercial steam and hot water systems. Standard 155P, *Method of Test for Rating Commercial Space Heating Boiler Systems*, proposes procedures for determining part-load and application-specific seasonal efficiency ratings at more realistic return water temperatures. It is considered to be near completion and approaching the next comment period.

2.4 Commercial Packaged Boiler Distribution

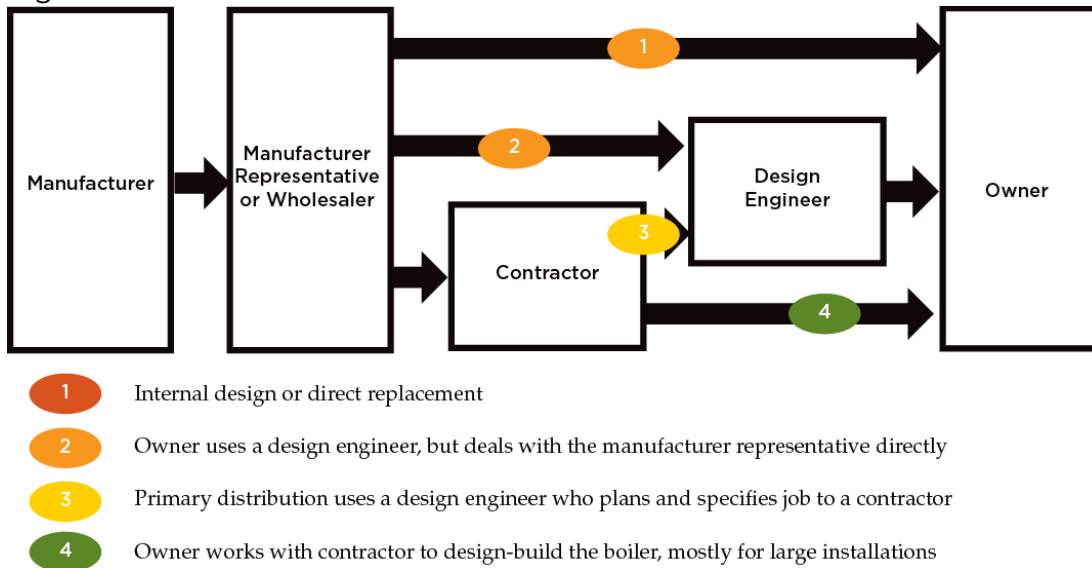
In new construction, the typical distribution channel (channel 3 in Figure 2) for a commercial boiler includes five primary players: manufacturer, manufacturer representative or wholesaler, contractor, design engineer, and owner.³⁷ In the typical distribution, an owner will work with a design engineer to plan and specify the boiler system. The design engineer or contractor then consults with a specifier list that provides information about the models meeting the specifications and contact the manufacturer representative or wholesaler to purchase the desired model. Manufacturers perceive being on the specifier list to be critical to their business. It is rare for an owner to work directly with the manufacturer representative or wholesaler, known as a direct replacement (channel 1).³⁸ The significant majority of

³⁷ Quantum Consulting, 2003 and Industry Interviews.

³⁸ Quantum Consulting, 2003 and Industry Interviews.

commercial boiler sales are handled by manufacturer representatives, especially sales of large boilers.³⁹

Figure 2. Commercial Boiler Distribution Channels⁴⁰



In the replacement market, the building owner often works directly with the contractor to design-build the boiler systems (channel 4). There are two common paths for boiler replacement: 1) the boiler is at the end of its useful life or, 2) the replacement is conducted as part of an energy upgrade. For those at the end of their useful life, the costs of boiler maintenance often begin to outweigh the cost of replacement.⁴¹ This decision, however, is driven by available funds. While funds may be available for regular maintenance of the boiler system, sufficient funds for the capital cost of replacing the boiler may not be available,⁴² which may result in a boiler lasting several more decades before replacement.

Typically, early replacement of boilers is driven by recommendations based on simple payback or internal rates of return⁴³ and may be incentivized by high fuel prices, efficiency program rebates, and tax incentives.⁴⁴ As noted previously, forced replacement due to emissions regulation is a third pathway for boiler replacement. There is also a fraction of large, custom-built boilers sold directly by manufacturers

³⁹ US DOE EERE Preliminary Technical Support Document Executive Summary for Commercial Packaged Boilers. Section ES.3.3.2. November 6, 2014

⁴⁰ Quantum Consulting, 2003 and Industry Interviews.

⁴¹ Industry Interview

⁴² Industry Interview

⁴³ Industry Interview

⁴⁴ Industry Interview

through national accounts of certain commercial customers for both new construction and replacement projects.⁴⁵

3 Initiative Objectives

Because commercial boiler systems are technically complex in terms of both equipment and installation, understanding the relationship between the system design and various energy solutions is important to help maximize energy savings over time. To better help members address energy savings opportunities in commercial boiler systems, the objectives of this Initiative are to:

- Increase the number of new commercial boiler systems operating in the condensing range
- Increase the number of existing commercial boiler systems that are optimized to operate at the highest efficiencies allowable for the given system throughout the year
- Increase the number of quality installed and maintained high efficiency commercial boiler systems
- Educate building owners, design engineers, and contractors on what constitutes high efficiency in a given system and options for maintaining high efficiencies throughout the life of the boiler
- Educate contractors on the importance of, and how to conduct, quality installations and maintenance for high efficiency commercial boiler systems
- Encourage creation of an enhanced efficiency metric for commercial boiler systems—in place of the current steady state boiler metrics—that better captures the infield operating efficiency of the boiler system throughout the year

4 Initiative Scope

This Initiative addresses hot water, commercial packaged boiler systems with capacities between 300,000 and 12.5 million Btu/h, or all commercial boilers covered by ANSI-Z21.13/CSA 4.9 *Gas-fired low pressure steam and hot water boilers*. The Initiative recognizes that total system capacities can either fall within this range or exceed it, as multiple boilers can be staged to provide loads greater than 12.5 million Btu/h. In addition to the boiler itself, this Initiative addresses system operations and maintenance and most other system components, such as multiple boiler systems, including hybrid systems, new and retrofit controls, auxiliary boiler equipment, pipe insulation as well as other system improvements that can aid in optimizing the system efficiency. Currently, the Initiative does not address pumping or heat distribution systems, but will explore these areas for potential inclusion in future versions. The scope does not include steam systems, systems used for process heating, or boilers primarily used for domestic hot, potable water.

⁴⁵ US DOE EERE Preliminary Technical Support Document Executive Summary for Commercial Packaged Boilers. Section ES.3.3.2. November 6, 2014

5 Initiative Approach

This Initiative focuses on achieving savings through a system approach, recognizing the role each system component plays in overall system efficiency. The approach provides Commercial Boiler Equipment and Functionality Specifications defining cost-effective efficiency levels for boilers and related functionality requirements for optimizing the boiler regardless of the system design. Also included is a Minimum Piping Insulation Thickness Specification based on ASHRAE standards. To ensure a system focus, the Initiative also provides requirements for multiple boiler systems, such as hybrid systems, retrofit controls and equipment for conventional boilers, and quality installation, maintenance, and operation. Section 6 summarizes and outlines the required elements to be considered a participant of this Initiative. For all elements, the Initiative requires contractor compliance with manufacturer instructions and all federal and local standards for boiler system installation, operations, and maintenance safety.

5.1 Required Initiative Participation Components

5.1.1 Commercial Boiler Equipment and Functionality Specifications

This tiered specification defines both high efficiency boilers, tier 1, and provides necessary flexibility for programs that achieve savings with mid-efficiency boilers, tier 0, based on regional differences in building stock, climate, cost-effectiveness, and other considerations. To meet either the tier 0 or tier 1 equipment specification requirements, the boiler must be tested to BTS–2000 standards in the US and ANSI Z21–13 standards in Canada to ensure a basis of comparison. In addition to boiler efficiency levels, this specification provides functionality and application requirements to help ensure system optimization regardless of application. For members that must use CE, programs should consider adding 2.2 percent to the Equipment Specification to account for average jacket losses.⁴⁶

⁴⁶ This guidance is based on an analysis of reported CE and TE data for commercial boiler models in the [AHRI Directory](#). CEE used only models that reported both CE and TE, removing any models where CE was equal to or less than TE, to determine the average percent difference. This estimate is in line with average jacket loss estimates.

Table 3. **Commercial Boiler Equipment and Functionality Specifications**

Tier	Equipment	Functionality and Application
Tier 0	85% TE	Modulating burner with linkageless control (minimum 4:1 turndown) Supply water temperature reset control installed according to manufacturer instructions Multiple boiler sequencing control (for multiple boiler systems) Retrofit projects only, unless part of a hybrid system in a facility requiring high system water temperatures
Tier 1	90% TE	Fully modulating burner with linkageless control, minimum 5:1 turndown Supply water temperature reset control installed according to manufacturer instructions Multiple boiler sequencing control for multiple boiler systems System has the ability to achieve low return water temperatures, <130 degree F, causing the boiler to produce condensate

5.1.2 Minimum Piping Insulation Thickness Specification

Standby and radiant circulation loop heat loss can range between 5 and 10 percent.⁴⁷ Insulating all bare pipes carrying heated water and ensuring that insulation is replaced following system maintenance or upgrades can significantly reduce circulation loop heat loss and improve occupant comfort because the system water is being delivered at the intended temperature. Adding the minimum required insulation thickness can reduce radiant heat loss from pipes by about 90 percent.⁴⁸ Programs should incorporate the ANSI/ASHRAE/IES *Standard 90.1–2013* Table 6.8.3–1 Minimum Piping Insulation Thickness for hot water systems⁴⁹ or 2012 *International Energy Conservation Code (IECC)* Section C403.2.8 HVAC System Piping Insulation requirements to optimize overall system efficiency and communicate to building owners and contractors that insulation is a key component of optimizing and maintaining a high efficiency system. Typical payback of insulating hot water pipers to these standards is around two years.⁵⁰

Table 4. **Minimum Piping Insulation Thickness Requirement**

Incorporation of ANSI/ASHRAE/IES *Standard 90.1-2013* Table 6.8.3-1 or 2012 IECC Section C403.2.8

⁴⁷ Vastyan, John, “‘New Millennium’ of hydronic technology asserts itself”, *Engineered Systems*, Sept. 2005. <http://www.esmagazine.com/articles/86156-new-millennium-of-hydronic-technology-asserts-itself?v=preview>. Accessed March 17, 2015. P. 2 Paraphrase of Bill Root, Laars Heating System Company.

⁴⁸ Heat loss estimations calculated using 3E Plus Insulation Thickness Computer Program, NAIMA. Default values were used in both energy and economic models unless otherwise specified. Boiler efficiency was set to 80 percent.

⁴⁹ ANSI/ASHRAE/IES Standard 90.1-2013 *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Table 6.8.3-1

⁵⁰ Hart, Gordon H. *Saving Energy by Insulating Pipe Components*. ASHRAE Journal October 2011, p.44

5.1.3 Multiple Boiler Systems

The large majority of boiler systems consist of multiple boilers,⁵¹ necessitating that program administrators provide guidance on multiple boiler systems and develop programs that encourage the use of multiple boilers to meet the required heat load.

For multiple condensing and hybrid systems, proper boiler sequencing is a necessary factor in meeting the building heat load and optimizing the boiler system. Boiler sequencing should be controlled from internal, external, or remote set points by means of a multiple boiler control for sequential boiler firing with outlet temperature feedback. When the heating demand is low for a building, only the boiler or boilers required to meet the demand fire. Once the heating demand increases, additional boilers fire to meet the increase.

Higher overall efficiency, simpler control, generally lower capital cost, and greater reliability and redundancy are among the major advantages that sequenced systems offer compared with the traditional arrangement of one or two large boilers, each sized to handle the entire load for redundancy. In many cases, lower cost, residentially sized boilers may be used as part of a multi-boiler arrangement with the lead boiler sized to meet the minimum load condition and each additional boiler sized to meet the incremental heating loads. Program administrators should apply the guidance specification above to residential boilers in commercial applications.⁵²

Ideally, fully condensing hydronic systems should be promoted for new system design in conjunction with low water temperature systems. However, some applications require noncondensing boilers (high water temperature system, backup fuel oil, very large central plant or district heating, capital budget restrictions, etc.) so that a hybrid approach may be the only viable alternative to obtain the highest boiler and system efficiency.⁵³

5.1.4 Hybrid Boiler Systems

A hybrid boiler system combines both condensing and conventional boilers into a single system, taking advantage of the benefits of each type of boiler to achieve efficiencies near to that of an all condensing system, but with an installed cost savings of 30 to 50 percent. Cost savings increase for larger boiler capacities.⁵⁴ The hybrid boiler system approach takes advantage of the fact that condensing boilers perform similarly to mid-efficiency boilers when operating outside of condensing mode (see Figure 1). Because of this, a typical hybrid configuration incorporates

⁵¹ Hewett, Martha J. *Inside ASHRAE Standard 155P*. Boiler Systems Engineering Magazine. June 2005. P. 10-21

⁵² For additional guidance, performance specifications for residential boilers are available as part of the CEE Residential Heating and Cooling Systems Initiative.

⁵³ Industry interviews.

⁵⁴ Industry interviews.

condensing boilers sized to meet the percentage of the load when inlet water temperatures are below the threshold at which flue gases start to condense at about 130 degrees F, or when the outdoor temperature is at or above about 32 degrees F.⁵⁵ For many climates, this accounts for the vast majority of the heating season and the shoulder seasons. For example, temperatures in New York City are above 34 degrees F for about 80 percent of the hours in a year, representing around half of the heating load.⁵⁶ If an entirely new system, the conventional boilers are sized to satisfy the remaining load when outdoor temperatures drop below 32 degrees. This design helps to ensure that return water temperatures are above 140 degrees F while the conventional boiler is in operation to avoid condensation and corrosion of the boiler.⁵⁷

Central to the efficiency of these systems is a multiple boiler sequencing control capability that can differentiate between the condensing and conventional boilers and their associated modulation to most efficiently stage the boiler units in response to the load. This capability does not refer to a specific technical path, but rather the functionality desired. This functionality can be achieved through many commercially available, competitive proprietary pathways. Controls of this kind typically establish the condensing boiler(s) as first-on. Additionally, if load sharing is used to operate boilers in parallel, multiple boilers can fire at a more efficient, lower rate to meet the demand as opposed to one boiler running at high fire.⁵⁸ The control scheme typically incorporates a supply water temperature reset functionality that often uses outdoor air temperature. Many control methods of staging boilers exist, but one of the most efficient methods uses a proportional-integral-derivative (PID) control logic.⁵⁹ PID control logic considers how far the indoor temperature is from the setpoint, how long it has been there, and also how fast the temperature is changing to achieve the greatest accuracy with the least amount of boiler cycles for overall improved system efficiency.⁶⁰ Most new control systems utilize PID control logic.⁶¹

⁵⁵ Cleaver Brooks Fact Sheet: *Maximizing Heating System Gains with Hybrid Boiler Plants*.

⁵⁶ Riverside Hydronics. *Design guidelines for hybrid boiler systems*. Technical Paper. P.1 <http://www.riversidehydronics.com/pdf%20documents/Tech%20Papers/design%20guidelines%20for%20hybrid%20systems.pdf>. Accessed May 8, 2015

⁵⁷ Cleaver Brooks Fact Sheet: *Maximizing Heating System Gains with Hybrid Boiler Plants*.

⁵⁸ Riverside Hydronics. *Design guidelines for hybrid boiler systems*. Technical Paper. P.1 <http://www.riversidehydronics.com/pdf%20documents/Tech%20Papers/design%20guidelines%20for%20hybrid%20systems.pdf>. Accessed May 8, 2015

⁵⁹ Vastyan, John. *Modern Hydronics: Socialized Efficiency*. HPAC Engineering, September 2012, P. 36-41

⁶⁰ Tekmar PID Zone Temperature Control. 2012. http://tekmarcontrols.com/support/tekmar_glossary/33-support/glossary/198-pid-zone-temperature-control.html. Accessed May 4, 2015

⁶¹ Industry interview

Including conventional boilers in a multiple boiler system can significantly reduce the initial installation cost of the project.⁶² Hybrid boiler systems often achieve substantial cost and energy savings in retrofits of commercial or institutional facilities with high water temperature heating systems. The cost savings increase when condensing units replace only part of the system or are simply added alongside the existing conventional boiler(s).

Due to the potential savings opportunities and the challenges of moving all retrofit projects to condensing, programs should incorporate measures for hybrid boiler systems to provide a cost-effective option for high temperature heating applications. Expected savings vary based on the specific configuration, heat load, distribution system, and regional climate, but are near that of entirely condensing systems. In supporting these systems, members should incorporate the following guidance requirements into their programs.

Table 5. Hybrid Boiler System Requirements

Incorporation of both CEE tier 0 and tier 1 boilers into a single system excluding existing boilers that includes: <ul style="list-style-type: none"> • Modulating burners with linkageless controls on all new boilers, minimum turndown according to tier level • Supply water temperature reset control functionality installed according to manufacturer instructions • Full system connection to boiler sequencing controls, including existing boilers
Incorporation of existing boilers within their effective equipment lifetime that have undergone a tune-up within the last year (see Section 5.1.4)
Required heat load calculation based on <i>2013 ASHRAE Handbook—Fundamentals</i>

5.1.5 Fully Condensing Multiple Boiler Systems

In the long term, efficiency programs should look at solutions that shift the market towards fully condensing systems that are designed for low system water temperatures. In supporting fully condensing systems, members should incorporate the following guidance requirements into their programs.

Table 6. Fully Condensing Multiple Boiler System Requirements

Incorporation of only tier 1 boilers into a single system that includes: <ul style="list-style-type: none"> • Fully modulating burners with linkageless controls on all boilers, 5:1 turndown • Supply water temperature reset control functionality according to manufacturer instructions • Incorporation of boiler sequencing control functionality • System designed to achieve low return water temperature, less than 130 degrees F, causing the boiler to produce condensate year around
Required heat load calculation based on <i>2013 ASHRAE Handbook—Fundamentals</i>
Should be applied to new construction, major renovation projects, and retrofits on existing systems that can accommodate low system water temperatures

⁶² Raypak. *Hybrid Heating Systems*. http://www.raypak.com/support/tech_corner/hybrid_heating_systems. Accessed March 17, 2015.

5.1.6 Boiler Rightsizing and Quality Installation, Operations, and Maintenance

Rightsizing is critical for conventional, nonmodulating boilers to operate efficiently, but is beneficial to all types of boilers and systems. Generally, a nonmodulating boiler operates at its maximum efficiency when producing the rated heating output.⁶³ This results from reductions in the cycling and relative jacket losses of a boiler. Therefore, in order to achieve the savings associated with a specific performance level, it is essential that a boiler is sized correctly to meet the demands of a specific application. Additionally, an optimally sized boiler reduces the upfront equipment cost as well as maintenance costs, as the reduced cycling generally causes less wear on the boiler.⁶⁴ Conducting a heat load calculation is an excellent first step in determining the required boiler capacity. There is no industry standard heat load calculation method or tool, but calculations that use basic HVAC&R principles and data included in the *2013 ASHRAE Handbook—Fundamentals*, such as the *ACCA Commercial Load Calculation (Manual N)*, are considered most reliable.

System maintenance items are ongoing, routine actions that are conducted over the life of the product to keep the system in good working order—generally conducted every year or two. One resource that some member programs use to address maintenance is the *ASHRAE/ACCA Standard 180: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*.

In comparison, tune-ups go beyond traditional maintenance and focus on reestablishing the manufacturer specified air-to-fuel mix for the operating range of the boiler to provide safe and efficient combustion comparable to that of the equipment's original performance. Due to the complexity of the adjustments and skill required associated with working on boiler burners, tune-ups must be conducted by qualified, experienced technicians who comply with manufacturer instructions and all federal and local standards for boiler system installation, operations, and maintenance safety. A tune-up procedure typically includes preparatory actions prior to the actual tuning and concludes with verification and safety checks.⁶⁵ The procedure itself can be long and detailed, but Table 7 outlines five essential elements of a boiler tune-up procedure that can form the basis of a tune-up checklist, but alone do not sufficiently outline the complete tune-up procedure. These elements are drawn from US EPA requirements for emission standard compliance of industrial and commercial boilers.⁶⁶ For the most accurate

⁶³ Manczyk, Henry, December 2001. "Optimal Boiler Size and its Relationship to Seasonal Efficiency."

⁶⁴ Ibid.

⁶⁵ US EPA. *Boiler Tune-up Guide*. National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers. 40 CFR Part 63 Subpart JJJJJ

⁶⁶ US EPA. *Small Entity Compliance Guide for Area Source Boilers*. National Emission Standards for Hazardous Air Pollutants for Area Sources: Industrial, Commercial, and Institutional Boilers. 40 CFR Part 63 Subpart JJJJJ. Table 5, P. 15-16

results, it is best to conduct the tune-up in the spring or fall to avoid ambient air temperature swings.⁶⁷

Table 7. **Tune-up Elements**

Element	Description
Inspect the burner	Clean or replace any burner components as necessary
Inspect and adjust the flame pattern as necessary to optimize	Adjustments should be consistent with the manufacturer’s specifications, if available
Inspect the system controlling the air-to-fuel ratio	Ensure that it is correctly calibrated and functioning properly
Optimize total emissions of carbon monoxide (CO)	Optimization should be consistent with the manufacturer’s specifications
Measure CO and oxygen levels before and after tune-up adjustments	Report units in parts per million, by volume. Measurements may be either on a dry or wet basis as long as it is the same basis before and after adjustments

These tune-up elements are included as a reference for programs supporting hybrid boiler systems that incorporate legacy boilers (see previous section) and are not independently a required component of Initiative participation. However, programs should consider providing measures—ranging from messaging to incentives—to encourage energy efficient installations of commercial boiler systems as well as proper operation and maintenance throughout the life of the boiler. The voluntary incorporation of rightsizing measures into programs emphasizes the importance of correctly sizing a boiler to optimize the system efficiency and encourage contractors to move away from the current practice of like for like replacement. Additionally, compliance with manufacturer instructions ensures that contractors incorporate appropriate venting materials and design into a given system while maintaining optimal boiler efficiency as the equipment ages. To increase market demand for quality installed, operated, and maintained boiler systems and ensure that the systems are operating at optimal efficiencies; members should incorporate the following guidance requirements into their programs.

Table 8. **Quality Installation, Operations, and Maintenance Requirements**

Required contractor compliance with manufacturer instructions and all federal and local standards for boiler system installation, operations, and maintenance safety
Required heat load calculation based on <i>2013 ASHRAE Handbook-Fundamentals</i>

5.1.7 Retrofit Controls and Equipment for Conventional Boilers

In order to address the objective seeking to optimize efficiencies of existing boilers, this Initiative includes guidance for programs regarding retrofit controls and equipment options suitable for conventional boilers. These options target the stock of legacy boilers that have been well maintained and are still within their effective lifetime, but do not have the sophisticated controls and equipment that are more

⁶⁷ Cleaver-Brooks Webinar. *The Art of Boiler Tuning*. Steve Connor. February 26, 2014

available today. It is important to keep in mind that a complete boiler replacement, as opposed to retrofit controls or equipment, may be the more efficient option for boilers that have been in use well past the average equipment lifetime. The following retrofit energy efficient technologies are discussed in order of consideration when assessing an existing boiler system based on associated costs and savings. When implementing these measures, it is important to ensure the flue gas temperatures do not drop below the dew point and put the boiler in condensing mode. Since the condensate is acidic, it will corrode the heat exchanger and damage the flue in a typical conventional boiler.⁶⁸

Supply Water Temperature Reset Control There are a few considerations with respect to retrofitting conventional boilers with this control. First, the supply water reset curve must be set such that the return water temperature does not fall so low that there is a risk of flue gases condensing. The control or boiler manufacturer typically provides precise instructions that should be closely followed, but a general rule of thumb is that the return water temperature should not fall below 140 degrees F with a conventional boiler. Greater savings are possible if installed on a modulating burner. Only one control package is needed per system.

Multiple Boiler Sequencing Control If an existing boiler system has multiple boilers, a multiple boiler sequencing control should be considered simultaneously with the installation of a supply water temperature reset control. If the boilers have modulating burners, this control can optimally stage the boilers using their respective modulation to most efficiently match the load as it changes. If the boilers are strictly On/Off, the control can improve system efficiency by creating a system “modulation” as it adjusts the firing of each boiler to meet the demand. Only one control package is needed per system.

Linkageless Controls Linkageless controls should be promoted for existing boilers with modulating burners controlled by a single-point positioning system only. Retrofitting linkageless controls to nonmodulating burners requires additional components that increase installation costs enough to reduce or eliminate the cost-effectiveness of the control. Savings associated with linkageless controls for commercial hot water boilers are typically one to two percent. Linkageless control systems typically cost between \$12,000 and \$14,000 with annual maintenance costs between \$1,500 and \$2,000.⁶⁹ Each boiler burner requires a separate linkageless control system.

(OPTIONAL) Modulating Burner If the existing boiler burner is not modulating, programs may consider including a complete burner replacement with a rightsized, minimum 5:1 turndown modulating burner with linkageless controls. Modulating

⁶⁸ Ibid.

⁶⁹ Carpenter, Kevin. *Common Boiler Excess Air Trends and Strategies to Optimize Efficiency*. 2008 ACEEE Summer Study on Energy Efficiency in Buildings

burner upgrades are typically only an option on boilers with gun-style burners. There are also many compatibility issues to consider when replacing the entire burner, so the boiler should be inspected for burner retrofit suitability. Due to high equipment costs, a new modulating burner is generally more cost-effective if it is replacing a significantly oversized or aged burner to get a combined savings from improved combustion efficiency, the ability to modulate to better match the load, and reduced purge losses from fewer cycles.⁷⁰ On average, modulation will result in 1.5 percent savings, linkageless controls another one to two percent savings, and additional savings from rightsizing occurs depending on how severely the original burner was oversized and how much the load has been reduced. The average life of boiler burners is 15 years.⁷¹

5.1.8 Outreach to Key Market Players

In order to help transform the market towards higher efficiency commercial boiler systems, efficiency programs should conduct outreach activities to key market players. The typical distribution channel relies on five main players—manufacturer, manufacturer representative or wholesaler, contractor, design engineer, and building owner—but facility managers are also key stakeholders for moving the market towards high efficiency commercial boiler systems, especially in retrofit applications. This Initiative will explore opportunities for supporting efficiency program efforts in reaching out to these various market actors. By voluntarily adopting consistent messaging and definitions, efficiency programs will be better positioned to engage these key decision makers in encouraging the transition to higher efficiency commercial boiler systems. The sections below provide additional context for efficiency programs.

Building Owner and Design Engineer Education and Awareness In new construction, boiler systems are traditionally designed “on spec”. This process emphasizes keeping the costs low, rather than improving the efficiency of the system. Changing these specs to incorporate high efficiency is a key component of transforming the market for high efficiency systems and requires providing information to building owners and design engineers regarding the attributes and benefits of high efficiency commercial boiler systems. For the retrofit market, programs should educate these parties about the necessary considerations for upgrading to condensing systems. Through this Initiative, CEE can work with member programs to develop talking points and other guidance that programs can use in outreach to these groups.

Contractor Training It is important for contractors to understand the technical requirements for quality installation related to condensing equipment to help ensure

⁷⁰ US EPA, Office of Air and Radiation. *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers*. October 2010, P.12

⁷¹ CleaverBrooks Webinar. *Burner Retrofitting: What, why and how*. May 28, 2014

the system achieves the expected savings. Initiative participants are encouraged to sponsor contractor training opportunities that focus on quality installation and the value of high efficiency equipment. Programs should provide guidance on advanced venting, condensate drains, local energy code requirements, quality maintenance practices, and matching controls to the system. Additionally, programs should provide educational training to contractors on marketing and selling energy efficient systems and quality installations. This can help contractors to both work with design engineers to include more high efficiency considerations and make a higher value sale.

Facility Managers In many commercial buildings, facility managers are the decision makers regarding energy and system operation. Educating facility managers on the importance of quality maintenance and opportunities for efficiency upgrades may help in transforming the market for high efficiency commercial boiler systems. Programs should explore training and other educational opportunities for facility managers to promote enhanced energy management through efficient commercial boiler system operation.

5.2 Optional Initiative Participation Components

5.2.1 Nitrogen Oxides (NO_x) Emissions Requirement

In addition to efficiency, boiler emissions, such as NO_x, are another consideration for high efficiency systems. While currently only a few areas regulate emissions for boilers, if this becomes a trend across other regions, it may create situations of forced replacement, which in turn creates implications for efficiency programs. To create greater consistency in defining a low emissions boiler, CEE developed the optional specification for low NO_x emissions below, based on the regulations of the South Coast Air Quality Management District (SCAQMD) in California.⁷² NO_x includes both nitrogen oxide and nitrogen dioxide in the flue gas.

Table 9. **Optional Specification for NO_x Emissions**

Tier	Specification
≥ 300,000 and ≤ 2 million Btu/h	≤ 20 ppm
> 2 million and < 4 million Btu/h	≤ 9 ppm

⁷² South Coast Air Quality Management District. Rules and Regulations: Regulation XI: Source Specific Standard; Rule 1146.2: Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters. Adopted January 9, 1988. Last Amended May 5, 2006 (for ≤ 2 million Btu/h boilers). South Coast Air Quality Management District. Rules and Regulations: Regulation XI: Source Specific Standard; Rule 1146.1: Emissions of Oxides of Nitrogen from Small Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters. Adopted October 5, 1990. Last Amended September 5, 2008. (for > 2 million and < 5 million Btu/h boilers)

5.2.2 Early Replacement Programs

Due to the significantly long lifetimes of conventional boilers and the ability to maintain boilers to operate well beyond these lifetimes, this Initiative will explore opportunities for early replacement programs. The goal of such programs is to replace older, for example, 30 plus years, functioning boilers performing at low efficiencies with high efficiency options. These programs often encourage replacements prior to the heating season to prevent failure during operation and to avoid a total system shutdown to allow installation.

6 Initiative Participation

As with all CEE Initiatives, participation in the Commercial Boiler Systems Initiative is voluntary. To be considered an Initiative participant, however, a program must meet a minimum set of requirements. For this Initiative, these requirements emphasize the need for programs to go beyond incentivizing the boiler alone and to provide a comprehensive strategy for capturing savings through system optimization. Participant requirements are as follows:

- Offer an educational or incentive based program that incorporates the following:
 - CEE Equipment and Functionality Specifications
 - Minimum Piping Insulation Thickness Requirements
 - Hybrid Boiler System and Fully Condensing Multiple Boiler System Requirements
 - Quality Installation, Operations, and Maintenance Requirements
 - Retrofit control and equipment options for existing conventional boilers
- Undertake awareness and system optimization measures related to quality installation and quality operations and maintenance
- Conduct outreach to key market players within the distribution channel, including facility managers

7 CEE Role in Initiative Promotion

The CEE role in accomplishing these objectives is to:

- Facilitate collective member understanding of the energy efficiency opportunities in commercial boiler systems
- Encourage the adoption of the Initiative into voluntary programs
- Develop guidelines, tools, and other resources to support programs in all aspects of the Initiative approach and serve as a clearinghouse for relevant information

- Reach out to industry stakeholders to identify potential opportunities for collaborating on the development of abovementioned guidance, tools, and other resources
- Provide to members and industry stakeholders information on member program efforts via annual program summaries that capture all voluntary program measures addressing commercial boiler system
- Work closely with manufacturers and industry associations to track industry and government efforts related to commercial boiler systems and provide regular updates to CEE members

Appendix A Acronyms

ABMA—American Boiler Manufacturers Association

ACCA—Air Conditioning Contractors of America

AHRI—Air-Conditioning, Heating and Refrigeration Institute

ANSI—American National Standards Institute

ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers

ASME—American Society of Mechanical Engineers

BTS—Boiler Testing Standard

Btu—British thermal unit

CB ECS—Commercial Buildings Energy Consumption Survey

CE—Combustion Efficiency

CEE—Consortium for Energy Efficiency

DOE—United States Department of Energy

EPA—United States Environmental Protection Agency

EPCA—Energy Policy and Conservation Act

FEMP—Federal Equipment Management Program

h—hour

HVAC—Heating, Ventilation, and Air Conditioning

NO_x—Nitrogen oxides

ppm—parts per million

TE—Thermal Efficiency

Appendix B Definitions

Boiler cycling—the turning on and off of the boiler as it receives calls for space heating

Boiler system—the entire heating system, including the boiler, controls, auxiliary equipment, piping, pumps, and heat distribution elements

Building heat load—the amount of heat that must be supplied to a building in order to maintain a specific temperature in the space; this takes into account the building type and size, infiltration rates, shell loss, and ambient air temperatures

Combustion Efficiency (CE)—measurement of efficiency for commercial boilers; measures how completely the burner transforms the fuel into useable heat, also equal to 100 percent minus the energy lost through exhaust gases; measurement does not take into account changes in the boiler operation throughout the year

Commercial boiler—a low pressure boiler with rated capacity of 300,000 Btu/h or more used for space heating and service water heating; the DOE excludes boilers used for domestic water heating in their definition of “commercial packaged boiler”

Condensing boiler—a boiler with a power burner or pulse combustion that can operate at efficiencies above 88 percent by capturing some of the latent heat resulting from the phase change of the water vapor in the exhaust gases

Convection—the transfer of heat by the circulation of the heated gas

Convection losses—loss of energy through the convection of heated gas from the boiler to the surrounding space

Conventional boiler—a boiler with an atmospheric draft burner and cast iron heat exchangers, which uses natural convection for venting and results in efficiencies between 80 and 83 percent

Design day—in regards to heating, this is defined as the temperature experienced for the coldest 2.5 percent of the year, which is used to determine the heat load requirements of a building in sizing the heating system

Domestic hot water heating—water used in any building for domestic purposes, principally drinking, food preparation, sanitation, and personal hygiene; also considered to be potable water; this does not include water used for space heating or process heat

Early replacement—replacement of the boiler before the end of its useful life

Full load operation—the operation of a unit, in this case a boiler, at 100 percent of the rated load of that unit

Fully modulating burner—a type of burner that is able to reduce the firing rate continuously over the turndown range instead of in staged increments

Heat exchanger—a device for transferring the heat of one substance to another, i.e., the heat of combustion air to the water in a boiler used for space heating

Hot water supply boiler—a type of boiler used to heat domestic hot water, or potable water; these boilers are not included in the DOE definition of a “commercial packaged boiler”

Hybrid boiler system—a system that combines both condensing and conventional boilers

Latent heat—heat absorbed or radiated during a change of phase, i.e. from gas to water

Major renovation project—a project in an existing building that goes beyond the replacement of only the boiler or a couple components, but rather addresses a redesign of the entire system

Manual N—manual developed by ACCA for commercial load calculations that provides instruction to help contractors and designers satisfy energy, ventilation, and comfort requirements

Mid-efficiency boiler—a boiler with a forced draft power burner that has relatively high efficiencies between 83 and 88 percent and may condense during a transition period such as start up of the boiler

Modulating burner—a type of burner that is capable of more than a single firing rate in response to a varying temperature or heating load⁷³

New construction—a project in a new building where there are limited constraints on the design of the boiler system

Oversizing (as related to a boiler)—sizing a boiler such that it exceeds the demand of a specific application

Packaged boiler—a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls, and that is usually shipped in one or more sections⁷⁴

Part load operation—a unit (or boiler) operating at less than 100 percent of the rated unit capacity

Quality Installation—a standard of key actions that must be undertaken during installation of the boiler system to help ensure the system operates efficiently

⁷³ ANSI/ASHRAE/IES *Standard 90.1-2013*

⁷⁴ *Ibid.*

Quality Maintenance—performing a set of ongoing, routine actions that are conducted over the life of the product to keep the system in good working order and ensure it is operating efficiently

Radiation—the process in which energy is emitted, in this case transmitted through the boiler jacket or piping to the surrounding space

Radiation losses—loss of energy from radiation (see radiation above)

Residential boiler—a low pressure boiler with a rated capacity of less than 300,000 Btu/h used for space heating

Retrofit—a project in an existing facility that looks only at replacement of the boiler itself or some components within the system

Return water temperature—the temperature of the water returning to the boiler from the distribution system (also the inlet water temperature), which dictates the efficiency of the boiler

Seasonal efficiency—a measure of the efficiency of the boiler throughout the year taking into account the variance in demand throughout the year

Rightsizing—sizing a boiler such that it meets and does not overly exceed the demands of a specific application

Service water heating—heating water for domestic or commercial purpose other than space heating and process requirements; this may include domestic water heating

Space heating—heating of the conditioned space of a building

Stack—a vertical vent pipe for gases resulting from the combustion process

Stack losses—the loss of energy via emission of combustion gases through the stack

Steady state efficiency—a measure of efficiency assuming the boiler is operating at the same rate throughout the year regardless of the demand

Steam boiler—boilers that generate steam, rather than hot water, used for space heating or process heating

Supply water temperature reset control functionality—a means of reducing the temperature of the supply water to the lowest required to meet the system demand

Thermal Efficiency (TE)—measurement of efficiency for commercial boilers; measures energy transferred to the system, also equal to 100 percent minus the energy lost through exhaust gases and jacket losses; measurement does not take into account changes in the boiler operation throughout the year

Tune-up—a set of maintenance actions on the boiler and system that aims to get the equipment back to its original performance

Turndown—an indication of the burner’s minimum firing capability compared to the maximum firing rate, typically represented by a ratio of the lowest firing rate to the maximum firing rate

Appendix C References and Resources

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