A Market Assessment for Condensing Boilers in Commercial Heating Applications

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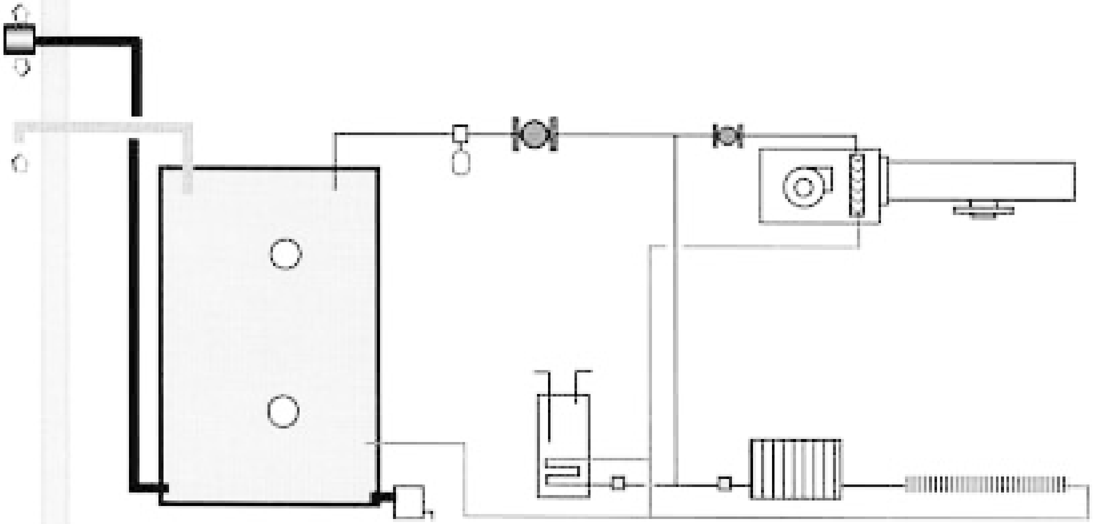

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Chapter 1: Executive Summary and Introduction

1.1 Background

The Consortium for Energy Efficiency (CEE) sought to assess the market for gas-fired condensing boilers in the commercial buildings sector. Specifically, CEE's goals were to perform a commercial evaluation and market assessment of gas-fired condensing boilers that would identify probable areas of application, determine the size and character of potential markets, and identify barriers to successful commercialization. The results of this project would provide CEE with the information required to decide whether or not to launch a market transformation initiative for commercial gas-fired condensing boilers.

This project was funded by the CEE, with the support of its Gas Committee. The Condensing Boiler Subcommittee of reviewers included:

- Mr. Ray Albrecht, New York State Energy Research & Development Authority
- Mr. Ed Becker, Southern California Gas Company
- Mr. Steve Bicker, Northwest Natural Gas
- Mr. Derek Buchler, Bay State Gas
- Mr. Lance DeLaura, Southern California Gas Company
- Mr. Chuck Farmer, Union Gas Ltd.
- Ms. Martha Hewett, Center for Energy & Environment
- Mr. Bruce Johnson, Boston Gas Company
- Mr. Alex Kim, Southern California Gas Company
- Ms. Cynthia Nickerson, Consortium for Energy Efficiency
- Mr. Sam Nutter, Boston Gas Company
- Mr. Jean Francois Tremblay, Gaz Metropolitain
- Ms. Michelle Ware, Lawrence Berkeley National Laboratory

We thank the Subcommittee for their ideas, constructive criticism, and support of the work.

For this project, DeLima Associates assembled a team with Harvey Sachs (Sachs & Sachs, Inc.) as project manager with primary responsibility for the boiler feature set and the marketing chapters; Henry DeLima (DeLima Associates) with responsibility for the boiler technology, product availability, and competing technology sections; and Fred Goldner (Energy Management Research Associates, Inc.) with responsibility for developing the assessment template and case studies.

1.2 Gas-Fired Condensing Boiler Technology

A condensing boiler is one that is designed to capture the latent heat of condensation of water vapor in the exhaust stream. By extracting this latent heat, condensing boilers can achieve high efficiency levels. The critical factor that ensures maximum efficiency from a condensing boiler is the return water temperature, which is generally kept below 120°F. The return water temperature determines whether the boiler operates in condensing mode.

To capture as much latent heat as possible, and because the products of combustion include materials that are highly corrosive, condensing boilers require specialized materials for fabrication. To withstand these corrosive conditions, condensing boilers are made of stainless steel and other corrosion resistant (and sometimes costly) materials. They can require more sophisticated controls, and more careful installation, to achieve their potential. In addition, the terminal units (radiators, convectors, and fan-coils) connected to the condensing boiler tend to be more expensive due to the greater heat exchanger surface required to operate at lower water temperatures.

1.3 Gas-Fired Condensing Boiler Current Market Size

We estimate the market to have been $9.5 million in 1999. For that year, we estimate that only 700 +/-250 commercial-scale units were sold in the U.S. This represents only about 2% of the total commercial-scale boiler market. While the market for residential-scale units is estimated to have been in the order of $25 million in 1999, condensing boilers still represent only about 2%, or about 7000 +/-700 units sold in 1999. We estimate that less than 5% of the residential-scale units were actually sold into commercial applications. The primary reason for the small current market size for condensing boilers is its first cost premium. An informal survey of manufacturers and review of a popular cost estimating manual suggests that the price premium for a condensing boiler is up to 3 times that of a conventional boiler, depending on boiler size. The price premium appears to be greater for the larger commercial size boilers, probably in part due to lower sales volume.

1.4 Goal of the Study

The primary goal of this study is to assess the potential for pursuing a formal market transformation initiative for condensing boilers.

1.5 Methodology

The first set of tasks consisted of developing a functional definition of a condensing boiler, identifying boiler models and operational configurations available today that meet that definition, and identifying competing technologies. Details of the methodology are provided in Chapters 2, 3, 4 and 5.

We next studied two actual boiler retrofits, selected by the Subcommittee, in which conventional boilers were replaced with condensing boilers in a school and a large Federal office building. The specific school building was selected because it is typical of the large number of older vintage (heating-only) school buildings in the Northeast that are ready for equipment retrofits. In addition, since the local gas utility was heavily involved in this retrofit, extensive pre and post retrofit fuel consumption data and installation cost data were readily available. The specific Federal office building was selected because it had recently been retrofitted with gas condensing boilers and the General Services Administration (GSA) project manager responsible for the retrofit had extensive documentation on the building’s energy usage and retrofit costs. The primary goal of these studies was to better understand first costs, benefits, and life cycle costs of condensing boilers for specific applications. We used the data obtained from these studies to develop a computer spreadsheet-based screening tool to conduct cost-benefit analyses of boiler installations. With appropriate changes to the spreadsheet inputs, the screening tool may be used by others to perform additional cost-benefit analyses. Details of the methodology are presented in Chapter 6.

We next developed market size estimates followed by estimates of future market growth under two scenarios: Business as Usual, where we assume a constant 4% annual sales growth and Fully Supported Market Transformation, where we assume the positive impact of a combination of factors causing a varying growth rate that approximates a “logistic” or “S’ curve with annual maximum growth limited to 25%. Details of the methodology are presented in Chapter 7.

We next conducted market assessments for condensing boilers in four segments selected by the CEE Subcommittee. The segments are schools, commercial office buildings, federal office buildings and small low-rise apartment buildings. For each segment, we characterized the types of buildings and equipment, developed market share estimates for condensing boilers and identified players and influencers and barriers that might impede the penetration of condensing boilers. Details of the methodology for the four segments are presented in Chapters 8, 9, 10 and 11. Chapter 12 summarizes findings for the four segments and presents recommendations to CEE.

Detailed findings of this study are presented in the following chapters:

- Chapter 2, Definition of High Efficiency Boiler
- Chapter 3, Condenser Boiler Technology
- Chapter 4, Competing Technologies
- Chapter 5, Condensing Boiler Products
- Chapter 6, Case Studies and Screening Tool
- Chapter 7, Market Size and Projections
- Chapter 8, Market for Condensing Boilers in Schools
- Chapter 9, Market for Condensing Boilers in Office Buildings
- Chapter 10, Market for Condensing Boilers in Federal Buildings
- Chapter 11, Market for Condensing Boilers in Apartment Buildings
- Chapter 12, Summary and Recommendations

1.6 Findings

The findings of this study are summarized in the sections below.

1.6.1 Current Market Characteristics

Condensing boilers are a very small fraction (about 2%) of the total current boiler market. We estimate that the 1999 market for commercial scale (≥ 300,000 Btuh) condensing boilers was about 700+/-250 units or $9.5 million/year. We estimate that sales of smaller condensing boilers (<300,000 Btuh) was about 7000+/-700 residential-sized units or $25 million sold in 1999. We estimate that less than 5% of the residential-scale units were actually sold into commercial applications. These numbers suggest the current market is a small niche with lots of room for improvement in sales of condensing boilers.

1.6.2 Market Projections

Due to the limitations discussed below, we estimate that the market share of condensing boilers in 2020 under a “Business As Usual” scenario would remain at 2% of all boilers shipped that year, or approximately 1,500 units. Under a “Fully Supported Market Transformation” scenario, however, the market share could potentially rise to 28%, or approximately 22,600 units, in 2020.

It is estimated that 1.37 trillion more Btus would be saved that year under the Market Transformation scenario.

1.6.3 Technical Barriers

Technical requirements limit the suitability of condensing boilers in many commercial applications. The need for low return water temperatures and 2-pipe (minimum) hydronic distribution systems severely limits the penetration of condensing boilers into the large retrofit market. While existing terminal units can be used with lower than rated water temperatures, their heating output will be lowered, unless their temperature control systems can be adjusted.

Competitive alternatives such as unitary roof-top packaged air conditioning and heating units and combination space conditioning-water heating systems severely limit the applicability of condensing boilers in all market segments. These alternatives not only provide zoning and reasonably precise temperature control but also allow for individual billing of energy costs.

1.6.4 Economic Barriers

Condensing boilers require specialized corrosive-resistant materials and sophisticated controls resulting in installed costs that are up to 3 times higher than that for a conventional boiler. Most commercial building owners, who do not pay their tenants' energy bills, will often make boiler purchase decisions based solely on the magnitude of the total installed cost and will therefore not purchase the higher-cost condensing boiler.

1.6.5 Institutional Barriers

Beyond the technical and competitive limitations of condensing boilers, the most significant barrier is the absence of an infrastructure or organization to promote this technology and provide training, marketing and design tools. One reason that other emerging technologies are increasing their market penetration more quickly than condensing boilers, despite having similar technical and competitive limitations, is that others have organized advocacy groups that provide the necessary support, such as the American Gas Cooling Center and the Ground Source Heat Pump Consortium that promote gas cooling technologies and ground-source heat pumps, respectively.

1.6.6 Attractive Market Segments

Of the four market segments that we studied, two appear to offer potential opportunities to begin market transformation efforts. Condensing boilers appear attractive in the school and Federal buildings segments because the decision makers in these two sectors rely more on the magnitude of the life cycle costs of the boilers than on first costs to make their purchase decisions. A properly sized condensing boiler system will generally beat out a less efficient boiler system on the basis of life cycle cost analysis.

While the apartment buildings (boiler retrofit) segment appears attractive, many economic and institutional barriers will prevent this potential from being realized due to the manner in which retrofit opportunities arise. There appear to be few opportunities for condensing boilers in new apartment construction because of their higher first cost and the inability to bill individual tenants for a central boiler space heating system. Virtually all new apartments are designed for individual unitary forced-air systems which can be installed in each rental unit so that occupants can be billed for energy usage.

The market for condensing boilers in office buildings (smaller than 100,000 square feet) is very small because the predominant load is for space cooling which is often provided by relatively inexpensive rooftop air conditioning units with integral gas or electric forced air heating. A separate unit can be provided for each office tenant who is then fully responsible for its operating costs.

1.7 Key Findings and Recommendations

The authors find that:

1. If CEE or others are to develop market transformation programs for commercial scale boilers, we find advantages in focusing on true condensing boilers, rather than on "near-condensing" boilers with efficiencies just a few points above those for conventional atmospheric draft units. The condensing boiler is readily identified by its installation features (condensate drain, sealed and corrosion resistant stack).

2. We believe that the sales of commercial scale boilers are highly concentrated in the Northeast and Midwest (for space heating applications). Thus, we recommend that any program that is offered be started in one or both of these regions.

3. The schools market is the most likely to lead adoption of condensing boilers. It is followed by the Federal sector, apartment buildings, and offices, roughly in that order.

4. The key strategic decision for program sponsors is the division of resources between infrastructure support and financial incentives. It is clear that rebates and other incentives boost sales in the short run. However, manufacturers believe that rebates create a "false market" that will disappear when rebates are halted. Investing in infrastructure can help build a self-sustaining market. This includes training for market players, and the development and dissemination of support tools such as generic specifications, design software, case studies, marketing articles, and fact sheets with environmental benefits.

   Thus, the team recommends that the Consortium for Energy Efficiency consider a market transformation program for commercial-scale condensing boilers. Such a program would probably start in the Northeast (New England plus New York), judging from present interest among utilities and state agencies (and inferred present sales). This could be under a two-phased program. In the first phase CEE could target the schools market since condensing boilers match school needs and values better than those of any of the other sectors investigated and purchase decisions are made on the basis of life-cycle costs rather than purely on first costs. CEE could develop an in-house program that targets the decision-makers in the schools market: owners, design engineers and facilities managers. Fact sheets could be developed for the owners, school board members, facilities managers and design engineers that will present the economic and environmental benefits of condensing boilers with case studies of recent installations. Design guidelines and sizing software could be developed for design engineers to help them properly size not only the boilers but also the terminal units and auxiliary service water devices. Maintenance guides will need to be developed for facilities managers to help them service and maintain the efficiency of the heating system. CEE should work with local gas utilities in identifying specific applications through school construction alert services and encouraging schools to consider condensing boilers in their requests for building construction/renovation proposals. CEE should also work with gas utilities to present papers on condensing boilers at school facility management type trade association meetings and local ASHRAE chapter meetings. The first phase would last three years with a budget estimated at $300,000[1]. In the second phase, CEE could take the lead in setting up a special interest group to promote condensing boilers with an annual budget of approximately $500,000. The membership would be drawn from gas utilities, state and federal energy offices and manufacturers of condensing boilers, controls and accessories.

1.8 Additional Considerations

The condensing boiler is a very competitive technology in Europe due to somewhat higher energy prices, stricter government regulations and a more favorable market interest in energy efficiency. In addition, because central air conditioning is not generally provided in buildings in Europe, the condensing boiler has only to compete with conventional boilers, which it does successfully due to its low operating costs. Due to the attractiveness of this technology, condensing boilers are very common in Europe, and even make up over half of the total market for boilers in Holland.[2] The European market was not a focus of this study, but if CEE desires an understanding of this market it should undertake a study to determine the reasons for the spectacular growth of the condensing boiler market in Europe.

The team attempted to develop market size and projections for condensing boilers in Canada. Since building energy consumption and building characteristics data were not readily available during the study period, we were not able to develop any market projections for condensing boilers in Canada.

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[1] Year 1: Fact sheets and promotional materials ($50,000), design guidelines and software ($65,000), maintenance guidelines ($15,000), share subscription to construction alert services ($20,000), outreach ($20,000)
Years 2 and 3 total: Outreach ($90,000), alert services ($40,000)

[2] www.energy-efficiency.gov.uk. Environmental Best Practice Programme. The Building Research Establishment Conservation Support Unit (UK).

Chapter 2: Definition of High Efficiency Boiler

2.1 Background

At the outset of the program, CEE and the project team agreed to focus on commercial applications of condensing boilers*,* that is, boilers that capture at least some of the latent heat of water vapor in the flue gas. Combustion of hydrocarbons (natural gas, oil) in air yields two primary products, carbon dioxide and water vapor, entrained in the relatively inert nitrogen of the air. Conventional boilers transfer most of the sensible heat of this reaction to water as hot water or steam. Condensing boilers are designed to capture a fraction of the latent heat*,* the energy released by condensing water vapor in the flue gas. To capture this energy, the flue gas must "see" a heat sink that is cool enough to allow condensation. For heating boilers that use the returning water from the system for this heat exchange, in practical terms this requires return water temperature <140°F, and little excess air.

We can group hot water boilers into three categories:

- **Non-condensing boilers.** Typically, these boilers have atmospheric burners, cast iron heat exchangers and metal or masonry chimneys (flues). The products of combustion (flue gases) are maintained at a sufficiently high temperature (resulting in low heat transfer efficiency) to allow them to exit the system using natural convection. If the flue gases do not contain enough heat to maintain proper stack action, the combustion products will spill back into the building. In addition, if the internal flue surface temperature is allowed to drop below the dew point, moisture in the combustion products will condense on the internal walls of the heat exchanger and flues. The condensate is very acidic and will corrode the heat exchanger walls and damage metal and masonry chimneys. By not capturing any latent heat from flue gases, non-condensing boilers operate at low efficiency. However, due to their relatively low cost of fabrication, they dominate the market, and can use either natural gas or distillate for fuel.
- **"Near-condensing" boilers**. Typically, near-condensing boilers use forced-draft power burners instead of atmospheric draft to pull gases through the firebox and heat exchanger. These boilers are equipped with stainless steel or other corrosion-resistant material since they are designed to tolerate the transient presence of condensate in the boiler, as during start-up. Because they have relatively high efficiency and relatively low flue gas temperatures, they require flue construction that accommodates condensation downstream of the boiler. Otherwise, expensive (and potentially dangerous) stack damage may occur.
- **Condensing boilers**. Typically, condensing boilers run at positive pressure (power burner or pulse combustion) with precisely-controlled hot surface or spark ignition. All heat exchanger and flues surfaces are of corrosion-resistant material such as stainless steel due to the presence of corrosive gases and condensate (by design) in all heat transfer pathways. Condensing boilers require National Fuel Gas Code Category IV flues due to the presence of pressurized wet gas in the exhaust stream. Condensing boilers operate at high efficiency by capturing some of the latent heat and virtually all of the sensible heat of combustion. In addition these boilers operate at high efficiency even at part-load conditions when return water temperatures from space heating equipment are usually low.

As stated in Chapter 1, CEE decided to evaluate the potential of condensing boilers as the focus of a potential market transformation program. Reasons to focus on this class of product include the following:

- Because condensing boilers have efficiencies much higher than that of the base-line atmospheric boilers that dominate the market, they offer the potential for a significant step up in installed efficiency. Federal (EPAct, 1992) requirements mandate 80% combustion efficiency for commercial boilers[1] > 300,000 Btuh[2]. The bulk of the market is thought to be near the minimum requirement. From an analysis of California Energy Commission data, CEE found that more than half of the 3600 listed boiler models (all sizes) were at 80% efficiency, and another 28% were rated at 80-82%. By contrast, the minimum efficiency for a natural gas condensing boiler is at least 88%.
- The market share of condensing boilers is very small, as discussed further in Chapter 7. We estimate that total sales of commercial-scale condensing boilers are about 700 units/year in the US. This means that a CEE program would have great potential to complement the limited efforts that manufacturers can make on their own to develop this market.

There are reservations about retrofitting "near-condensing" boilers in buildings whose stacks may not be able to handle increased condensate loads[3]. To minimize the potential for such problems, the CEE Subcommittee preferred to focus on true condensing boilers, which require National Fuel Gas Code Category IV flues. Thus, the remainder of this chapter discusses how we developed a specification for models that qualify for program purposes as condensing boilers, and the meaning of the specification.

2.2 Development of a Feature Set

We began by developing a consensus set of concerns to be met by a "feature set" or "specification" for condensing boilers. Some of these concerns are outlined in Appendix 1, which was the "background" section for early versions of the feature set draft. Concerns included:

- Standby losses, expressed as a desire for thermal efficiency measurements instead of combustion efficiency determinations.
- Adequate combustion control, because excess air makes it much harder to achieve high sensible heat efficiency and hard to realize any latent heat work.
- Proper system control, to ensure that the installed system will have opportunities to see low enough return water temperatures to recover latent heat.
- A specification that reduces the likelihood that a manufacturer might qualify with a boiler that is unlikely to operate efficiently and unlikely to capture latent heat in applications.

Next, we reviewed some available literature[4]. In particular, we began with a review of the available test and rating methods. The field is marked by some confusion in terminology. In addition, for historical reasons different types and sizes of boilers have been rated under different conditions. For our purposes, the most important concepts are:

- **Annual Fuel Utilization Efficiency (AFUE)**. All boilers <300,000 Btuh sold in the US must be rated by this method, which is defined in ANSI/ASHRAE 103[5]. AFUE is defined

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[1] CEE Discussion Draft, 11/12/1998, p. 5

[2] In this report "Btuh," "Mbtuh," and MMBtuh are abbreviations for British thermal unit per hour, thousands of British thermal units per hour and millions of British thermal units per hour respectively.

[3] CEE Discussion Draft, 11/12/1998, p. 2, quoting ASHRAE, 1996.

[4] Including I=B=R, CEE Discussion Draft, CEE listings, ASHRAE/ANSI 103-1998, ASHRAE Handbook of Systems and Equipment, etc.

[5] 103-1993. Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers. American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc. Atlanta, GA.

as "the ratio of annual output energy to annual input energy, which includes any non-heating-season pilot input loss and, for gas or oil-fired furnaces or boilers, does not include electric energy." Unfortunately for the sake of consistency, AFUE is not determined for larger boilers. Since CEE wished to focus on commercial boilers but include units < 300,000 Btuh that are often used in multiple boiler installations for apartment buildings and similar structures, it is necessary to use AFUE for the small boilers.
- **Combustion Efficiency (CO).** Combustion Efficiency is defined as [100 times (1 – energy lost to flue) divided by input energy] in this report. It is measured under steady state conditions as defined by the Hydronics Institute, at full rated output, 140°F supply water temperature from the boiler and 120°F return water temperature to the boiler.
- **Thermal Efficiency (TE).** Thermal Efficiency is defined as (100 times useful energy output divided by input energy) in this report. This is measured under steady state conditions as defined by the Hydronics Institute, at full rated output, 140°F supply water temperature from the boiler and 120°F return water temperature to the boiler.
- **Overall Efficiency** is defined by ASHRAE[6] as gross output divided by input and is thus equivalent to thermal efficiency. Overall efficiency seems to be less commonly used than thermal efficiency, and is readily confused with combustion efficiency. The term overall efficiency is not used in this report.
- **Appliance Seasonal Efficiency (ASE)** provides an estimate of annual energy consumption for space heating in buildings with boilers having a total heating capacity greater than 300,000 Btuh. The ASE takes into account the laboratory-tested performance of individual boilers under full and part-load conditions, the number of boilers, type of primary/secondary circulation pumping and controls, type of building and corresponding heating loads, and weather data for the building location.

We then developed a "strawman" feature set for discussion among CEE Subcommittee members. This discussion draft went through successive iterations and reviews by a broader circle of experts. We began with the CEE Subcommittee, and broadened the review to industry experts including researchers, manufacturers and ASHRAE technical committee members. After incorporating the boiler industry perspective, it was circulated again to the CEE group. The next iteration was made available to boiler manufacturers for their review, their comments were weighed and incorporated where possible, and that revision was reviewed by the CEE Subcommittee.

2.3 Definition of Feature Set

The resulting condensing boiler specification is presented in Appendix 2. It suggests that participating units qualify on five criteria:

1. Efficiency, as measured by AFUE or thermal efficiency, depending on size. After polling manufacturers and other experts, we settled on two thresholds. We chose 88% AFUE for units < 300,000 Btuh input, and 90% thermal efficiency for larger boilers. In both cases, we believe that these are the lowest values that guarantee that qualifying units will actually be designed to capture latent heat energy. Higher levels would exclude some true condensing boilers, while lower levels might open the program to "gaming" by units that do not actually capture latent heat to achieve high efficiency.

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[6] ASHRAE Systems and Equipment Handbook, 1966, p. 27.5

2. Emissions, to conform to South Coast Air Quality Management District specifications. CEE anticipates that air quality considerations may require documented low emissions performance in numerous metropolitan areas in the future. More broadly, the requirements can be met readily, so the only burden is thought to be certification.
3. Controls that help assure that the boiler will run in condensing mode as large a fraction of the time as feasible. Unless the boiler and system are properly controlled, return water temperatures will be too high too much of the time for condensation and latent heat recovery to occur. Interestingly, manufacturers rather strongly supported this requirement.
4. Venting through Category IV stacks. These stacks are designed to be tightly sealed to prevent leaks from positive pressure systems, which include forced draft boilers in general, and condensing boilers in particular. Category IV stacks also resist corrosion from condensate. Since the flue gas output of a condensing boiler will be saturated with water vapor whenever the boiler is in condensing mode, this is necessary to prevent stack failure.
5. Capacity modulation for boilers 500,000 Btuh and larger. This was a topic of some discussion. From manufacturers, we concluded that most larger boilers sold today are equipped for capacity modulation.

These features all refer to the boiler as designed, built, and tested in the laboratory. They are all factors for which the manufacturer can be held responsible. In addition, we present an addendum to the boiler specification which is a set of four possible on-site efficiency tests, to measure the efficiency of the system as installed. Field indicators (which are not all applicable to all boilers) include:

1. Temperature difference between return water and exhaust gas.
2. CO_2 concentration in the flue gas.
3. Combustion efficiency.
4. Condensate yield.

We anticipate that some utilities or other organizations that offer programs will require on-site tests for accepting boiler installations as eligible for rebates or other incentives. We also note that final specification of the on-site or field indicators must be done by those organizations; this addendum only indicates tests that may be relevant.

2.4 Issues

We believe that the specification given in Appendix 2 provides a good basis for launching a program. It intentionally sets the bar just high enough to exclude boilers that cannot operate indefinitely in condensing mode yet include boilers available today in the market. We found that there are only about 30 commercial scale condensing boiler models (capacity ≥ 300,000 Btuh) on the market, in all sizes. They include products from nine different manufacturers who compete in a market where total annual sales are only in the hundreds of units per year. Further restricting the market by requiring higher efficiency would make it harder for customers to find appropriate units, and would reduce manufacturer interest in the program.

However, this specification is not all-inclusive. It measures “gas efficiency,” not “energy efficiency,” because it does not include the electrical energy used by the fan and pumps. This is consistent with US practice for boiler rating for other functions. However, in the long run it may be worthwhile to reconsider this point. Condensing boilers must have their fireboxes made of corrosion resistant materials such as stainless steel. Beyond this, to make boilers more efficient, designers will want to increase heat exchanger size, while keeping the boiler "box" as small and as light as possible. Less material costs less to fabricate and ship (in general). Smaller boxes mean larger boilers still fit through doors for installation, without requiring extensive on-site assembly. The way to increase heat exchanger area in a constant box size is to decrease the cross section of flow through the fire and water passages. This will increase the power required to pump water through the boiler (on terminal equipment, we call this static pressure or "head") and the power needed to pump the gases through the system to the flue. Because conventional US test methods do not measure the parasitics or energy used by the electric motors associated with the boiler, this electrical energy is a "free lunch" for the designer. We believe that it is premature to worry about this issue now, but it should be kept in mind for future work by CEE and other organizations.

We note one other issue related to boilers as applied in building heating systems. If program interest moves from requiring particular levels of boiler performance to evaluating installed system performance, it will be necessary to evaluate the parameters chosen for the "on-site" or "field" performance indicators. The best boiler in the world will not meet the performance suggested by the specification if it is attached to an inappropriate system. These conditions include:

- Inappropriate system layout and condition. If the system has such poor heat delivery to the last terminals on the distribution system that supply and return temperatures must be set at levels that do not provide a heat sink for condensation, then there will be no latent heat recovery, and there is no obvious reason to have installed and paid for a condensing boiler.
- Lag boilers in some Lead/Lag configurations. In multiple boiler installations, the lead boiler serves to meet light loads, when conditions should favor latent heat capture. In contrast, the last boiler in the line, used only for peak load conditions, will never see low enough return temperatures in most applications to warrant the investment in a condensing boiler.

Chapter 3: Condensing Boiler Technology

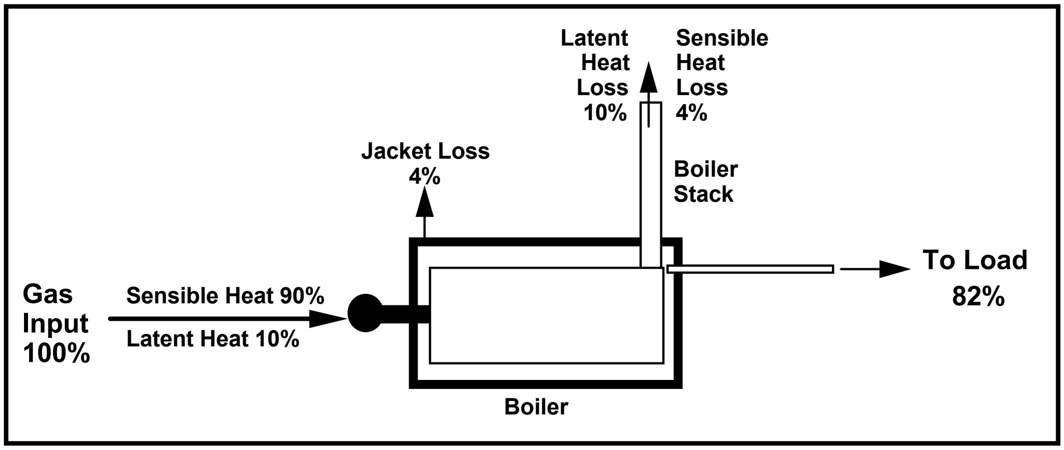
3.1 Background

A space heating boiler is a pressure vessel consisting of a tank or water tubes, heat exchangers, fuel burners, exhaust vents and controls. A boiler is designed to transfer the heat value of a fuel by means of a burner to a heat transfer fluid which, for condensing boilers, is water. In this chapter we will define conventional and condensing boilers. We also will describe the operation of condensing boilers and explain the impact of return water temperature on efficiency of condensing boilers.

3.2 Conventional Boilers

In a conventional boiler, only the sensible heat value of the fuel is used to heat the fluid as shown in Exhibit 3-1. A varying portion of the sensible heat value of the fuel is transferred to the fluid depending upon the efficiency of the heat exchanger. The unused portion of the sensible heat and all the latent heat is released through the exhaust vent. Exhibit 3-1 depicts a conventional boiler with 82% thermal efficiency. In a conventional boiler all of the incoming latent heat is lost up the boiler stack.

Exhibit 3-1: Efficiency of Conventional Boiler



3.2.1 Conventional Boiler Efficiency Improvement

The overall efficiency of a conventional boiler can be improved by the incorporation of several features and controls as described below:

- **Air Preheaters** transfer energy from exhaust gases to incoming combustion air resulting in improved combustion conditions and an overall efficiency improvement of 2.5% for each 100°F decrease in exhaust gas temperature. Care must be taken to prevent condensation of exhaust gases and the potential for corrosion. Increased combustion air temperatures may have an adverse effect on NO_x emissions.

- **Economizers** transfer energy from exhaust gases to the feedwater, thereby reducing the boiler firing rate necessary to generate steam or hot water, improving overall boiler efficiency. An increase in feedwater temperature of 10°F will result in fuel savings of about one percent. Economizers are generally preferred over air preheaters since they have lower first costs and no impact on emissions. However, as with air preheaters, care must be taken to prevent condensation of exhaust gases and the potential for corrosion.

- **Turbulators** are baffles inserted into firetubes in the upper passes of firetube boilers to induce turbulence in the hot gas stream thereby increasing the convective heat transfer to the tube surface.

- **Combustion Controls** are installed to control the excess air required to ensure complete combustion of the fuel. High levels of excess air translate into higher NO_x emission levels, increased mass flow and increased energy losses in the exhaust stream. Overall efficiency can improve by 0.25% for each 1% decrease in excess O_2 depending on the exhaust gas temperature.

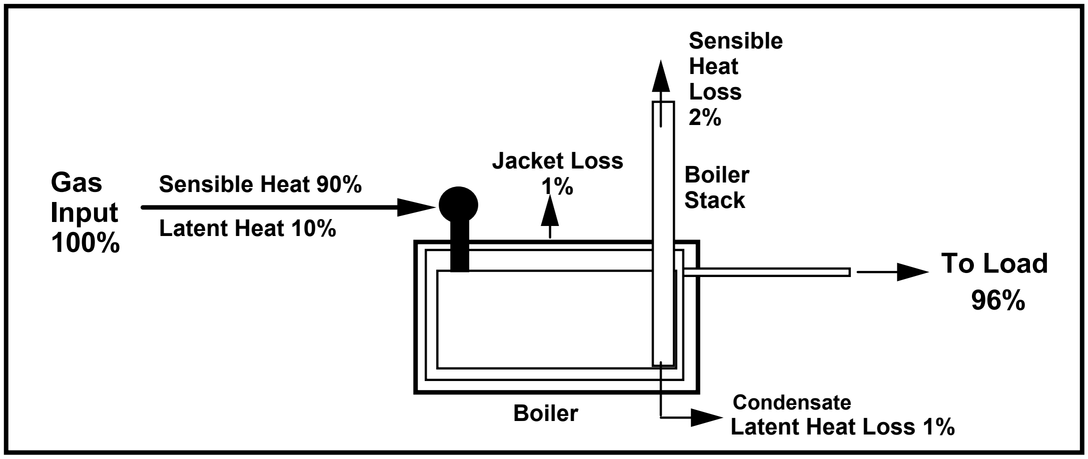
- **Jacket Insulation** that is properly applied can reduce radiation losses. Radiation losses tend to increase with decreasing load and can be as high as 7% for small units or larger units operating at reduced loads.

- **Blowdown** is the procedure used to remove boiler water impurities that can result in tube scale deposits. Blowdown Recovery is the process of extracting energy from the blowdown water. Efficiency can be improved by 1-3% depending on blowdown quantities.

3.3 Condensing Boilers

As discussed above, the efficiency of a conventional boiler can be improved by incorporating auxiliary equipment and controls. In many cases, efficiency improvements will cause the exhaust gas temperatures to decrease to a point where condensation may occur, which may result in corrosion of flues and heat exchange surfaces. Boilers that are designed to operate under these conditions are called condensing boilers and are fabricated from materials that are not affected by corrosive gases and fluids. A condensing boiler uses very high efficiency heat exchangers designed to capture virtually all the available sensible heat from the fuel as well as some of the latent heat of vaporization as shown in Exhibit 3-2. The boiler stack uses a National Fuel Gas Code Category IV type vent system.

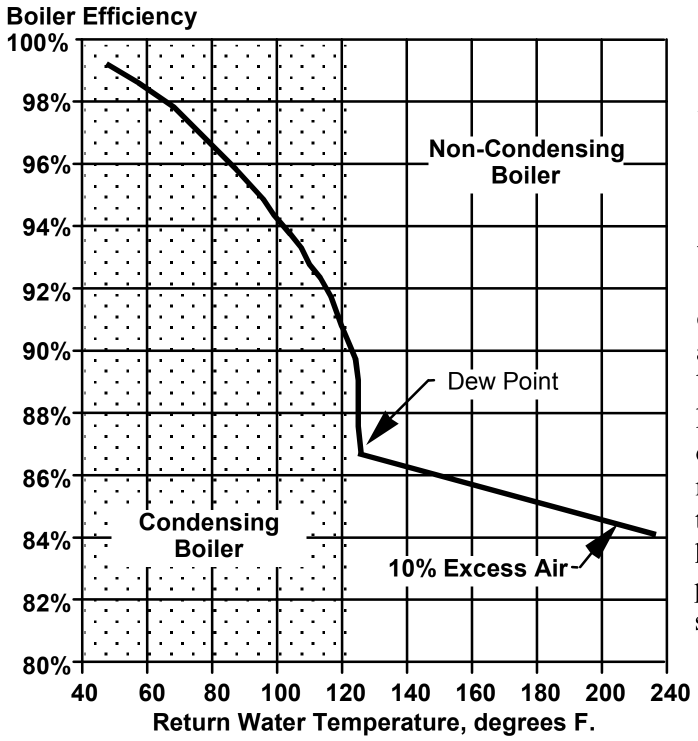
Exhibit 3-2: Efficiency of Condensing Boiler



3.3.1 Efficiency and Return Water Temperature

It is important to note that low return water temperatures are essential to obtain the high condensing efficiencies associated with condensing boilers. The effect of return water temperature on the efficiency of boilers is shown in Exhibit 3-3.

Exhibit 3-3: Impact of Return Water Temperature on Efficiency[1]



Natural Gas HHV = 1050 Btu/cu.ft.
Stoichiometric Air: 17.24 lb./lb. of fuel or 9.57 cu.ft./cu.ft.

As shown in this figure, very high efficiencies are attained as the return water temperature drops below 130°F. We see that the same boiler operates as a conventional boiler with efficiencies below 88 percent when the return water temperature is above 130°F. It is important for the condensing boiler specifier to perform a comprehensive analysis of the building load and to select terminal heating equipment that is designed to operate at the low water temperatures needed for optimum performance of the boiler selected. Radiant floor heating systems and water-source heat pump systems are two examples of space heating systems that require operating water temperatures in the 80°F to 100°F range for optimal performance.

3.3.2 Operation of Condensing Gas Boilers

Condensing gas boilers are currently produced by less than 10 U.S. manufacturers but are available in a wide range of capacities (See Chapter 5). Typical configurations of condensing space heating boilers are shown in Exhibits 3-4 to 3-7.

Boiler operation is similar for the four configurations. When the master space thermostat calls for heat, the combustion chamber is first purged and the outdoor air temperature sensor sends a signal to the burner modulation controller. Combustion air is drawn through an air inlet pipe into the combustion chamber where it mixes with natural gas piped through the gas inlet. A spark or hot surface ignitor lights the gas/air mixture, starting a self-sustaining flame. The heat of combustion is transferred to water that is heated by contact with the walls of the combustion chamber. Hot exhaust gases are forced through very high efficiency heat exchangers within the insulated boiler enclosure where additional heat is transferred to the supply water.

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[1] 2000 ASHRAE Systems and Equipment Handbook, p. 27.4, American Society of Heating, Refrigerating and Air Conditioning Engineers, 1791 Tullie Circle NE, Atlanta, GA 30329

Exhibit 3-4: Boiler Configuration A

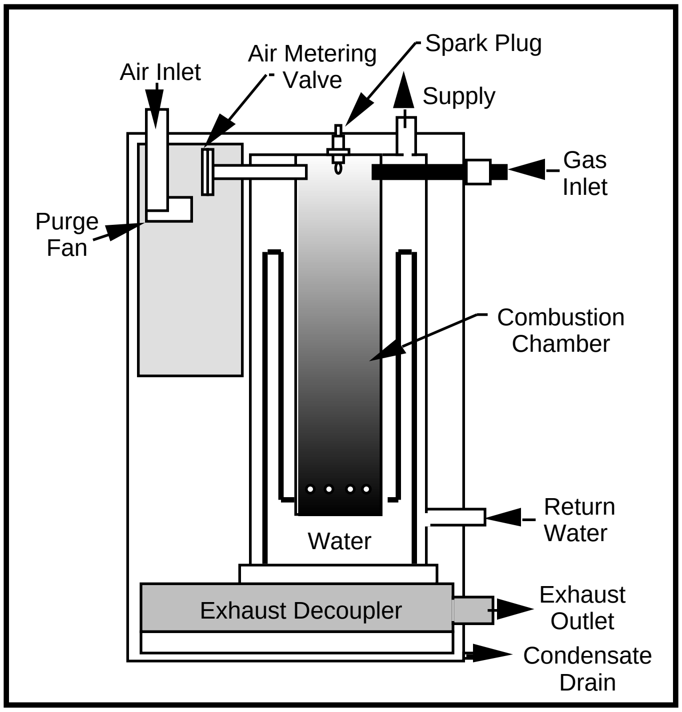


Exhibit 3-5: Boiler Configuration B

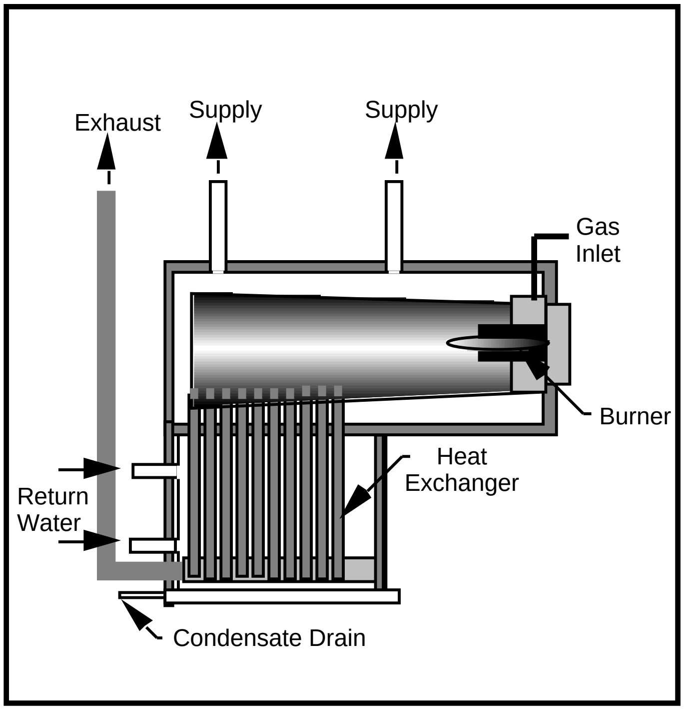


Exhibit 3-6: Boiler Configuration C

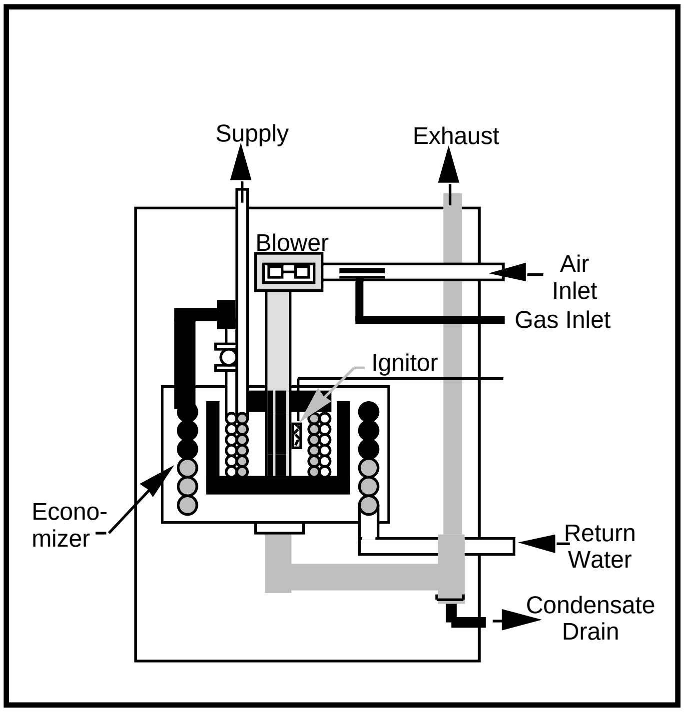
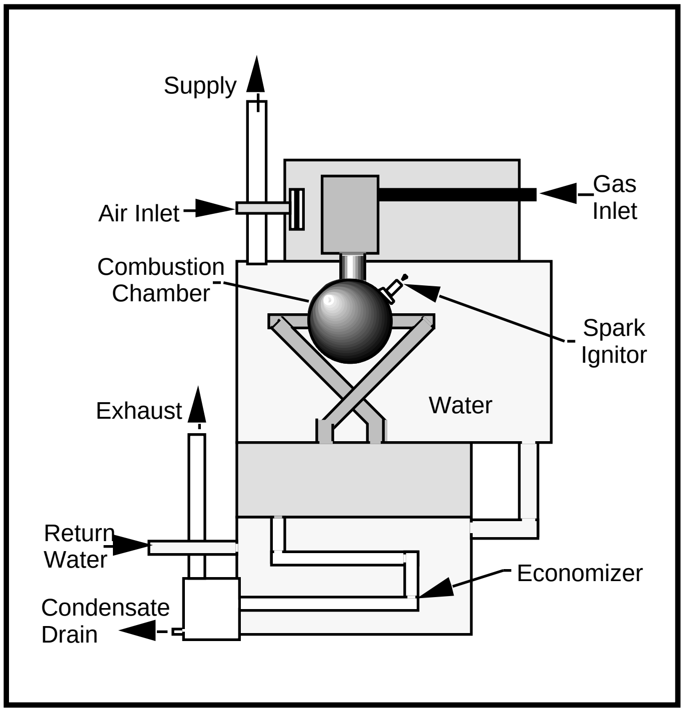


Exhibit 3-7: Boiler Configuration D



This supply water is distributed from the boiler to the building load. Condensation occurs at the base of the heat exchanger, giving off additional heat to the supply water. The condensate formed in the heat exchanger is piped to a drain. The cooled exhaust gases are saturated with water vapor. Any cooling in the stack will lead to additional condensation. Since the stack sees positive as well as the corrosive effects of condensate, Category IV flues are required for condensing boilers.

3.3.2 General Features of Condensing Boilers

All models produced are of relatively low mass, have heat exchangers and exhaust gas outlets fabricated of stainless steel or other non-corroding material, and have outdoor temperature reset devices to control capacity. Most condensing boilers incorporate controls to modulate capacity and avoid losses due to cycling at less than full load. When installing central heating systems of large capacity, there are advantages in dividing the output over several smaller capacity boilers. Higher overall efficiency, greater reliability, simpler control and generally lower capital cost are among the major advantages that these cascade systems offer compared with the conventional arrangement of one or two large boilers. The risk of a major heating system failure is greatly reduced with several small boilers, since the loss of a single small boiler will have minimal or no effect on overall comfort conditions. In many cases, lower cost, residential size (< 300,000 Btuh.) 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. The multi-boiler system may be controlled from internal, external, or remote setpoints by means of a boiler management system for sequential boiler firing with outlet temperature feedback. The capability of the system to maintain tight temperature control, modulate firing rate with load, and operate in the condensing mode eliminates the need for hot water storage, temperature blending valves, and primary-secondary pumping systems.

3.4 Boiler Emissions

Combustion is the process of releasing heat energy in a fuel through the exothermic reaction of carbon and hydrogen with oxygen in the air to produce carbon dioxide and water vapor. However, in real life combustion systems, other combustion products such as NO_x, CO, particulates and unburned hydrocarbons can be released into the atmosphere. Since some of these combustion products are considered environmental pollutants and can be toxic in themselves or pose health risks by virtue of their ability to react with other ambient pollutants to form hazardous compounds, regulating authorities such as the U.S. Environmental Protection Agency (USEPA) and the South Coast Air Quality Management District (SCAQMD) in California have set maximum emission levels for these substances. Brief descriptions of these substances are given below.

3.4.1 Nitrogen Oxides

Nitric oxide (NO) and nitrogen dioxide (NO_2) are the two forms of nitrogen oxides generated by gas boilers and are together referred to as total oxides of nitrogen or NO_x. This yellow-brown colored gas mixture affects atmospheric visibility. NO_2 can be fatal when inhaled at concentrations above 100 ppm and can cause cumulative lung damage and respiratory disease at much lower concentrations.

California currently has some of the most restrictive and complex NO_x emission regulations. The state has thirty-seven separate air quality control districts with different compliance plans. The SCAQMD comprising Southern California adopted Rule 1146 which set NO_x emission limits at 30 ppm for boilers from 2.5 to 5.0 million Btu and 40 ppm for boilers from 5.0 to 40 million Btu.

Control options for reducing NO_x emissions include low excess air firing of burners, flue gas recirculation (non-condensing operation), low-NO_x burners and catalytic reduction.

3.4.2 Carbon Monoxide

Carbon monoxide (CO) is a product of incomplete combustion caused by improper burner settings and insufficient air for combustion. CO measurements at the stack are often used as an indicator of poor combustion conditions. CO is an invisible, odorless gas that can cause CO poisoning, and can be fatal. Following proper combustion control procedures can eliminate CO.

3.4.3 Particulates

Particulate matter consists of all solid and liquid materials suspended in stack gases and is composed of dust that finds its way into the combustion chamber and unburned fuel.

Chapter 4: Competing Technologies

4.1 Background

The most obvious technologies that compete with commercial condensing gas boilers are conventional (non-condensing) commercial gas and oil-fired boilers and commercial electric boilers. All these competing boilers have substantially (by at least a factor of 2) lower installed costs but higher operating costs, due either to higher energy prices (for electric boilers), or lower thermal efficiencies (for non-condensing gas and oil-fired boilers). It should be noted, that for the purpose of this discussion, we do not treat multiple-ganged (or cascade) residential condensing boilers (each >125,000 Btuh.) as a competing technology.

In this chapter we will explore the applicability of other competing technologies in three market segments:

- Schools
- Office Buildings
- Multifamily Housing

4.2 Schools

Several types of HVAC systems are installed in schools. Older schools have central boiler systems that supply hot water or steam to radiators or unit heaters located throughout the facility. Some of the competing systems are shown in Exhibit 4-1.

The competing systems discussed in this section are:

- Four-Pipe Heating and Cooling System
- Rooftop Packaged Heating and Cooling System
- Water Source Heat Pump Heating and Cooling System

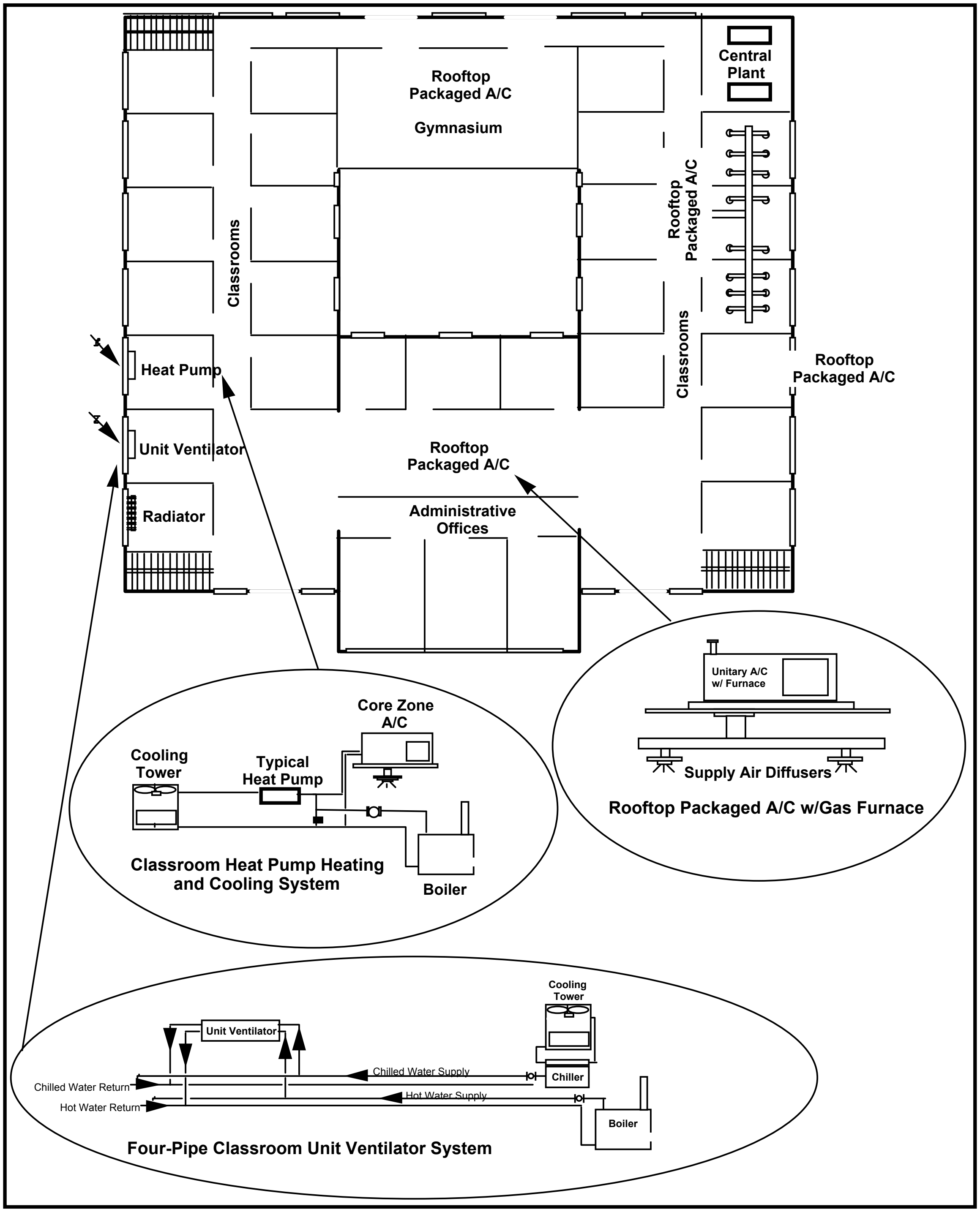
4.2.1 Four-Pipe Heating and Cooling System

A gas hot water boiler and a gas or electric chiller provide hot and chilled water to heat exchangers in unit ventilators in classrooms, and to air handling units in common areas, auditoriums and gymnasiums by means of hot and chilled supply and return water pipes as shown in Exhibit 4-3. The unit ventilators provide individual classroom control of heating, cooling and outside ventilation air. Condensing hot water boilers will perform very efficiently if the heat exchangers in the unit ventilators and air handlers are sized to operate with water temperatures below 140°F which often requires more expensive terminal air-handling units with larger coil surface area.

4.2.2 Rooftop Packaged Heating and Cooling System

Single packaged unitary systems, where all the components are placed in a weather-tight enclosure, are usually installed on the roof. The main supply duct from the rooftop-packaged unit penetrates the roof and is connected to branch ducts that serve the classrooms (if unit ventilators are not used), administrative offices and common spaces.

Exhibit 4-1: Typical Floor Plan of School Building



4.2.3 Water Source Heat Pump Heating and Cooling System

Water-source electric heat pumps can heat or cool classrooms by absorbing or rejecting heat from a water loop. This system is ideal for schools in colder climates where the central core zone always needs cooling and the perimeter zone requires many hours of heating each year. This system is very efficient in the winter, since it can recover heat from the central core spaces (which have high internal heat gains) and use it as the heat source for heating the perimeter zones. As shown in Exhibit 4-1, a cooling tower and (backup) boiler ensure that the loop water temperature is in the 60°F to 90°F range, thereby minimizing the amount of pipe insulation. Individual temperature control can be realized in each classroom and other spaces by installing a separate heat pump in each space to be conditioned. A boiler is connected to the loop to raise the water loop temperature above 60°F. A cooling tower is also connected to the loop to reject unwanted heat from the loop. Individual classroom control can be achieved by adjusting the heat pump thermostat located in the classroom.

4.3 Office Buildings

Large office buildings tend to be divided into two kinds of occupancy zones: a perimeter zone of offices with window exposure to the outside and a central core zone. The two zones of a typical floor of an office building are shown in Exhibit 4-2. The perimeter zones are directly impacted by weather conditions and have varying heating and cooling loads. The central core zone, however, is shielded from direct exposure to the outside weather conditions, and is almost only impacted by internal loads caused by lights, equipment and people and therefore has only a cooling load.

A conventional gas boiler can provide heating to all zones by means of radiators, terminal fan coil units and ducted air handling units.

Radiators and finned-tube baseboard units are supplied with hot water by central space heating boilers. While individual control is often impossible, zoned control is possible if the water distribution system is well designed.

Terminal fan-coil units are essentially radiators with thermostatically controlled fans that cycle on and off to satisfy the thermostat in the office suite.

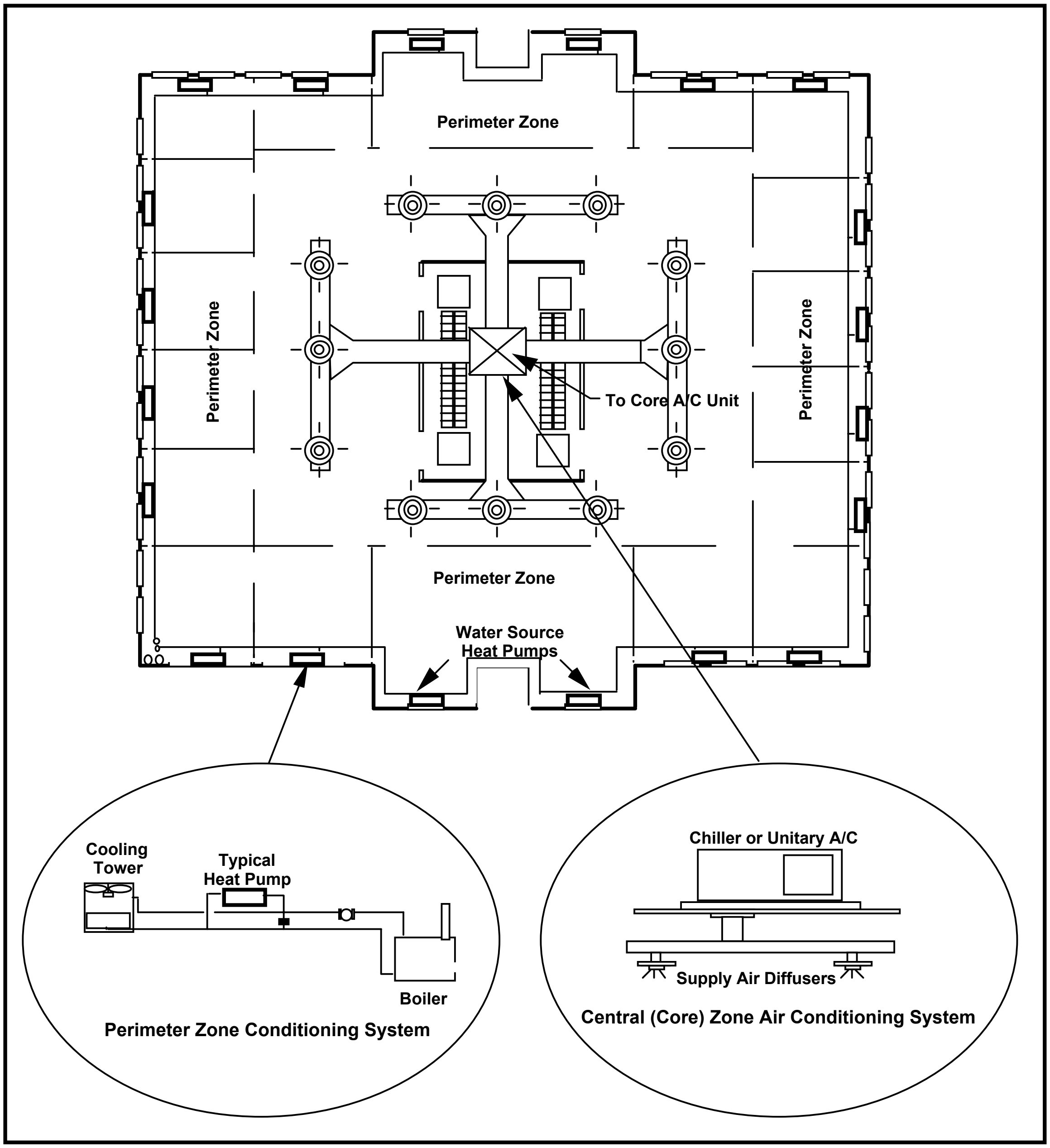
Ducted air handling units are large ducted fan coil units that have separate heating coils fed by the central boiler and cooling coils fed by the air conditioning chiller. Air handling units can be sized to supply one zone or multiple zones by means of air distribution ductwork and air diffusers. A properly designed system will allow occupants of each office suite to have control of space temperature.

The above systems are not suitable for individual tenant metering and billing since all tenants share the boilers that serve these systems. While individual temperature control is possible for some office suites, tenants do not have control over boiler operation.

The competing systems are:

- Unitary Heating and Cooling System
- Water-Source Electric Heat Pump System

Exhibit 4-2: Typical Floor Plan of Office Building



4.3.1 Unitary Heating and Cooling System

Unitary heating and cooling systems consist of one or more factory-made assemblies that may include a furnace/blower, evaporator section and a compressor/condenser. Unitary systems having more than one factory-made assembly are called split systems. The indoor section of the split system may be ducted to the office suites while the outdoor section may be placed on grade or on the roof. Single packaged unitary systems, where all the components are placed in a weather-tight enclosure, are usually installed on the roof. The main supply duct from the rooftop-packaged unit penetrates the roof and is connected to branch ducts that serve the office spaces that need to be conditioned. Energy used by each unitary system can be metered and billed to occupants of the space served by that unit. Unitary systems are available in a multitude of configurations, sizes and efficiencies for gas furnaces, electric air conditioners and electric heat pumps. Gas absorption and engine-driven air conditioners are also available in a limited number of sizes.

4.3.2 Water-Source Electric Heat Pump Systems

Water-source electric heat pumps can heat and cool office spaces by absorbing or rejecting heat from a water loop. This system is ideal for large office buildings in colder climates where the central core zone always needs cooling and the perimeter zone requires many hours of heating each year. This system is very efficient in the winter, since it can recover heat from the central core spaces (which have high internal heat gains) and use it as the heat source for heating the perimeter zones. As shown in Exhibit 4-2, a cooling tower and (backup) boiler ensure that the loop water temperature is in the 60°F to 90°F range, thereby minimizing the amount of pipe insulation. Individual temperature control can be realized in each office suite by installing a separate heat pump in each suite. Energy used by the heat pumps in each office suite can be metered and billed to occupants with lighting and receptacle usage. However, energy used for cooling towers, backup boilers and pumps cannot easily be allocated to each office tenant.

4.4 Apartment Buildings

Prior to the 1980s the energy used by the majority of multifamily rental housing units was master-metered. Over 80 percent of apartment units built since 1990 have individual meters for gas usage compared to 64 percent of units built prior to 1990[1]. As energy prices have risen, landlords have attempted to make their tenants responsible for energy used in their apartments by retrofitting their buildings with decentralized space conditioning and water heating systems. Central boiler systems are being replaced by unitary heating and air conditioning systems and the majority of all new multifamily buildings are being designed for individual heating and cooling systems[2].

The competing systems are:

- Gas Furnace with Electric Unitary Air Conditioning with separate Gas Water Heater
- Electric Heat Pump with separate Electric Water Heater
- Combination Gas Space and Water Heating System

Exhibit 4-3 shows the partial floor plan of a multi-floor apartment building. Four identical 2-Bedroom apartments are shown with four vent chases that run the full height of the building. A conventional hydronic system with radiators/convectors is drawn in the lower right apartment. In a central space heating boiler system, the radiators from all the apartments would be connected to a single or multiple-boiler system, often located in the basement, and controlled by a master thermostat. An indirect storage or instantaneous domestic water heater connected to the central space-heating boiler or a dedicated boiler would provide domestic hot water to all apartments. A domestic hot water recirculation system might be needed when the farthest fixture is greater than 100 feet from the water heater.

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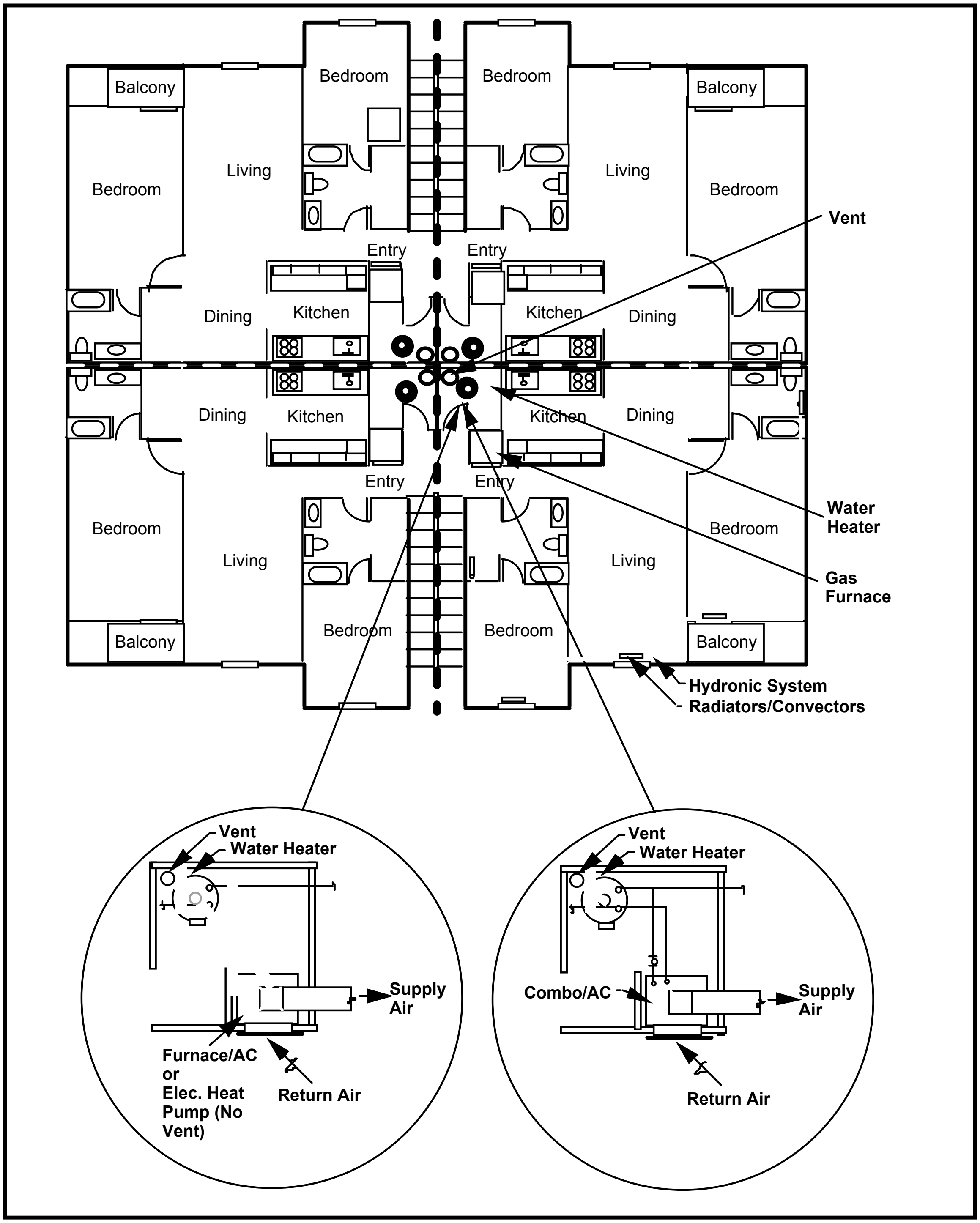
[1] Based on the National Multi Housing Council's tabulations of unpublished data from the U.S. Census Bureau's American Housing Survey for 1995.

[2] A minimum of 80 percent of all new multifamily housing units built each year in the U.S. during the 25-year period 1975-2000 were equipped with unitary central air-conditioning systems, based on the U.S. Census Bureau's Characteristics of New Housing Surveys (C-25 Series).

Exhibit 4-3: Partial Floor Plan of Apartment Building



4.4.1 Gas Furnace with Electric Unitary Air Conditioning and Separate Gas Water Heater

A split-system gas furnace with direct-expansion (DX) electric air conditioning is most commonly installed in the Northeast and Midwest. As shown in Exhibit 4-3, each apartment has its own furnace and air conditioner located in a closet off the entryway. Supply air is distributed by means of a duct system and returned to the unit, as shown. The DX coil is connected to condensing units on the roof or at grade level. A domestic water heater is located as shown and common-vented with the furnace. Tenants have full control over their heating, air conditioning and water heating systems and can therefore be individually billed for their energy usage.

4.4.2 Electric Heat Pump with Separate Electric Water Heater

The split-system electric heat pump is found in all regions but has its greatest penetration in multifamily housing in the South. As shown in Exhibit 4-3, each apartment has its electric heat pump located in a closet off the entryway. Supply air is distributed by means of a duct system and returned to the unit, as shown. The DX coil is connected to condensing units on the roof or at grade level. It is also possible to install a “through-the-wall” ducted packaged unit in a closet adjacent to an exterior wall. An electric domestic water heater is located as shown and does not need combustion air and venting. Many multifamily buildings in California with electric heat pumps have gas-fired domestic water heaters in order to comply with state efficiency standards which discourage the use of electric water heaters. Tenants have full control over their heating, air conditioning and water heating systems.

4.4.3 Combination Gas Space and Water Heating System

The combination space and water heating system (combo system), in which a gas storage water heater is used to provide both domestic hot water and space heating, provides a promising way for utilities to quickly expand sales of natural gas in the multifamily housing market. Combo systems are being installed mostly in the South and West. With proper sizing of the gas water heater, combo systems can be used anywhere in the U.S. or Canada. When compared with a stand-alone gas furnace and a stand-alone gas water heater, the combo system offers a smaller footprint and requires only a single vent. If the air handler is wall or ceiling mounted, the only floor space required is the two-foot diameter circle needed for the water heater. As shown in Figure 4.3, each apartment has its own combo system located in a closet off the entryway. Supply air is distributed by means of a duct system and returned to the unit, as shown. The DX coil is connected to condensing units on the roof or at grade level. The combo system is very flexible since its air-handling unit can be placed anywhere within the apartment as long as space is available to run small diameter water piping from the water heater to it. As with the other two systems, tenants have full control over their heating, air conditioning and water heating systems.

4.5 Summary

It will be very difficult for condensing boilers to successfully compete with the unitary type technologies discussed in this chapter. There is no typical school HVAC system in the U.S. However, the current trend is to address not only the space heating and cooling needs but also the ventilation and air quality needs with the classroom. These needs can be easily met by unitary systems; however, it is not difficult to justify the replacement of existing inefficient space heating boilers with condensing boilers since school districts tend to make their purchasing decisions based on long-term benefits.

Nationwide, most office buildings are small, and the predominant load is for space cooling. A rooftop unitary air conditioning unit with gas forced air heating is the preferred system for this sector since the appropriate size unit can be installed at a relatively low cost for each tenant who is then fully responsible for its operating costs. The condensing boiler could be used to replace an inefficient or failed boiler; however, office building owners are not usually willing to pay the first cost premium associated with this technology as discussed in Chapter 9.

In the multifamily housing sector, virtually all new rental units are being individually metered and require air conditioning, thereby eliminating any boiler option. In the multifamily retrofit market the decision maker is the building owner or property manager, who typically does not plan for boiler replacement until the existing unit fails, usually in the middle of the peak heating season, and needs immediate replacement. At that point, the property manager's first priority is to provide comfortable conditions for his tenants. In accomplish this he opts to replace the failed boiler with a similar unit as discussed in Chapter 8 instead of studying the long-term benefits of replacing the failed conventional boiler with a higher cost condensing boiler.

The competing technologies described in this chapter provide features that are in great demand by building owners today such as:

- The ability to measure and charge each (apartment and office building) tenant separately for their energy usage
- The ability to provide individual indoor environmental control levels (temperature and ventilation for each classroom, apartment and office suite)
- The ability to shut down space conditioning to one space (a vacant apartment or office suite or unoccupied classroom) without affecting comfort conditions in other spaces
- The ability to maintain comfort conditions in most spaces when individual HVAC units are shut down for maintenance or repairs

Chapter 5: Condensing Boiler Products

5.1 Background

The purpose of this chapter is to identify condensing gas boiler products for commercial building space heating applications that are available in the market today. Only those boilers that comply with the requirements of the feature set defined in Chapter 2 are included here. Boiler efficiency levels[1] shall not be less than the following:

Boiler Capacity	Efficiency
125,000 to 300,000 Btuh.	AFUE = 88 %
Greater than 300,000 Btuh.	Thermal Efficiency = 90 %

5.2 Condensing Boiler Models Available

The names of manufacturers of gas-fired space heating boilers were obtained from CEE Gas Subcommittee members and from the latest directory of Air Conditioning, Refrigeration and Heating News [2] in March 2000. The following manufacturers were contacted to obtain product literature and specifications.

- A.O. Smith Company
- Aerco International
- Bryan Steam Corporation
- Buderus Hydronic Systems
- Burnham Corporation
- Cleaver Brooks
- Dunkirk Boilers
- Fulton Boiler Works
- GasMaster Industries
- Hydrotherm
- Kewanee Boiler Manufacturing Co.
- Lochinvar Corporation
- Patterson-Kelly Corporation
- Peerless Heater Company
- PVI Industries
- Raypack
- RBI Water Heaters
- Slant Fin Corporation
- Teledyne Laars
- Viessmann Manufacturing Co.
- Weben-Jarco
- Weil McLain

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[1] The CEE definition of condensing boiler is discussed in Chapter 2.
[2] Year 2000 Edition of the HVACR Directory of the Air Conditioning, Heating and Refrigeration News.

Product literature was obtained from all 22 manufacturers who were contacted. A review of product data from these manufacturers indicated that only 9 of the 22 U.S. and Canadian manufacturers of commercial gas boilers listed in the directory, produce condensing models in the above capacities with efficiencies as defined in Chapter 2. Capacities and efficiencies for the qualifying models are shown in Exhibit 5-1.

Exhibit 5-1: List of Available Condensing Boiler Models

Line Number	Boiler Manufacturer	Model Number	Output MBtuh	AFUE **	Thermal*** Efficiency	Web Address
1	A. O. Smith	LB-500	500.0		90.0%	www.hotwater.com
2	A. O. Smith	LB-750	750.0		90.0%	www.hotwater.com
3	A. O. Smith	LB-1000	1,000.0		90.0%	www.hotwater.com
4	A. O. Smith*	LW-500	500.0		90.0%	www.hotwater.com
5	A. O. Smith*	LW-750	750.0		90.0%	www.hotwater.com
6	A. O. Smith*	LW-1000	1,000.0		90.0%	www.hotwater.com
7	AERCO	KC-1000	1,000.0		93.0%	www.aerco.com
8	AERCO	BMK 2.0	2,000.0		92.0%	www.aerco.com
9	Dunkirk	QL-100	100.0	95.0		www.dunkirk.com
10	Dunkirk	Q90-100	100.0	90.0		www.dunkirk.com
11	Fulton	PHW-0300	300.0		96%	www.fulton.com
12	Fulton	PHW-0500	500.0		95%	www.fulton.com
13	Fulton	PHW-0650	650.0		95%	www.fulton.com
14	Fulton	PHW-0750	750.0		95%	www.fulton.com
15	Fulton	PHW-950	950.0		95%	www.fulton.com
16	Fulton	PHW-1000	1,000.0		95%	www.fulton.com
17	Fulton	PHW-1400	1,400.0		95%	www.fulton.com
18	Hydrotherm	AM-150	150.0	90.6		www.hydrotherm.com
19	Hydrotherm	AM-299	299.0	90.1		www.hydrotherm.com
20	Lochinvar	IBN-1500	1,500.0		97%	www.lochinvar.com
21	Lochinvar	IBN-1700	1,700.0		97%	www.lochinvar.com
22	Lochinvar	IBN-2000	2,000.0		97%	www.lochinvar.com
23	Laars Heating	CB-150	150.0	88.6		www.laars.com
24	Laars Heating	CB-175	175.0	88.7		www.laars.com
25	Laars Heating	CB-200	199.9	88.5		www.laars.com
26	Laars Heating	CB-250	250.0	88.1		www.laars.com
27	Viessmann	VSB-05	191.0	90.0		www.viessmann.com
28	Viessmann	VSB-08	300.0	90.0	94.9%	www.viessmann.com
29	Viessmann	VSB-10	396.0		94.9%	www.viessmann.com
30	Viessmann	VSB-13	488.0		94.9%	www.viessmann.com
31	Viessmann	VSB-17	638.0		90.2%	www.viessmann.com
32	Viessmann	VSB-22	846.0		90.2%	www.viessmann.com
33	Viessmann	VSB-28	1,071.0		90.2%	www.viessmann.com
34	Viessmann	VSB-37	1,389.0		90.2%	www.viessmann.com
35	Viessmann	VSB-46	1,726.0		90.4%	www.viessmann.com
36	Viessmann	VSB-57	2,160.0		90.4%	www.viessmann.com
37	Viessmann	VSB-72	2,702.0		90.4%	www.viessmann.com
38	Viessmann	VSB-89	3,361.0		90.4%	www.viessmann.com
39	Weben Jarco	VJH-WB75	750.0		94.0%	www.weben-jarco.com
40	Weben Jarco	VJH-WB100	1,000.0		94.0%	www.weben-jarco.com
41	Weben Jarco	VJH-WB75	1,500.0		94.0%	www.weben-jarco.com
42	Weben Jarco	VJH-WB75	2,000.0		94.0%	www.weben-jarco.com

** Domestic Water Heater Model*
*** Annual Fuel Utilization Efficiency for Models with Output below 300,000 Btuh*
****Thermal Efficiency for Models with Output of 300,000 Btuh and greater*

Chapter 6: Case Studies and Screening Tool

6.1 Background

As part of this project two actual boiler retrofits were studied where oil hot water boilers and conventional gas boilers were replaced with condensing gas hot water boilers. The purpose of these studies was to obtain real world installation cost and energy cost data for use in developing a screening tool that could be used by utility marketing representatives, building owners, equipment specifiers and others in conducting cost-benefit analyses. Data from these two retrofit cases were used in the screening tool to conduct life-cycle cost analyses. The detailed results are presented in Appendix 3. The screening tool, developed using MicroSoft Excel™, is included with this document.

6.2 Case Studies

Two boiler retrofit case studies will be discussed in this chapter. The CEE Gas Subcommittee selected the specific cases studied. The first was Waltham High School in Waltham, MA, and the second was the U.S. Federal Building and Courthouse office in Sioux City, Iowa.

6.2.1 Waltham High School

Waltham is a city located about 10 miles west of Boston. The High School is a 365,000 square feet, three-story facility built in 1957. Space heating was provided by an oil-fired conventional hot water boiler system that was 40 years old. This project involved replacing the existing conventional oil-fired boilers with condensing gas-fired boilers. The project was completed during the 1999 school summer vacation.

The local school board decided to convert the school's boilers to gas because of past environmental problems associated with its aging underground oil storage tanks. Initially, a conventional gas-fired boiler system was considered, but after an informed engineering consultant presented the benefits of a condensing boiler system the School Committee decided to install the condensing boiler alternative. As a result of this decision, the school received a $22,500 "High Efficiency Heating Equipment Rebate" from the local utility, Boston Gas. (The rebate was $4,500 for each boiler over 1.7 MMBtuh, which applied in this case to each of the five boilers installed.) It should be noted that the scope of this boiler retrofit was limited only to work within the boiler room.

The school's original heating system consisted of 3 conventional hydronic boilers approximately 11.5 MMBtuh each. The new system is comprised of five condensing (AERCO Brand) boilers rated at 2.0 MMBtuh each. The total installed cost of the new condensing boiler system was $304,015 (this does not take into account the rebate, because that was paid to the school after the project was completed). The Annual Energy Consumption for this system was 197,586 therms. Upon entering the actual project-related data provided to us by the design engineer and school authorities, and entering economic assumptions (including a 4% discount rate, EIA Annual Energy Rate Escalations for the various energy sources and an annual Maintenance Rate Escalation of 1%) into our screening tool, we obtain a Net Present Cost of $1,853,304 over a 20-year assumed life span for the condensing boiler system. This compares favorably to the 20-year Net Present Cost of $2,250,329 calculated for the conventional boiler system by the screening tool as shown in Exhibit 6-1. While the Building Combined Heat and Power (BCHP)[1] system does have a considerably lower 20-year net present cost of $1,181,722, it also has an initial system installation cost that is more than double that for the condensing boiler system.

Exhibit 6-1: Results of Cost-Benefit Analysis for Waltham High School Case Study*

System Type	Installed Cost of System	Annual Energy Consumption (Therm Eq.)	Energy Cost	Maintenance Cost	Net Present Cost	Net Present Cost Compared to Conventional Gas Boiler
Condensing Gas Boiler	$304,015	197,586	$1,446,342	$102,947	$1,853,304	($397,026)
Conventional Gas Boiler	$246,450	262,670	$1,935,248	$68,631	$2,250,329	-
BCHP	$695,950	404,489	($155,929)	$641,701	$1,181,722	($1,068,607)

**Results are based on 20-year system life*

As mentioned earlier, the installation cost data for the condensing boilers were obtained from school records. The costs for the conventional system were determined from the Means Mechanical Cost Data book. The costs for the BCHP system were estimated based on the experience of the team (in regard to primary BCHP equipment and hours to install) and Means Mechanical Cost Data for labor rates and ancillary equipment (i.e. piping). Greater detail on the specific costs associated with each of these systems is presented in the printouts that are included in Appendix 3.

It is important to note that the user of the screening tool must provide the “Weather Adjusted Energy Consumption.” To determine this input, one must have 12 – 24 months of fuel consumption data for a facility. For Waltham High School these data were provided by the school’s business office. In order to avoid some problematic records that were affected by an oil tank leak, it was necessary to use “pre-data” from July 1997 to June 1998 which was for a year prior to the actual conversion. (In the FY ’99 period it was reported that the school had fuel removed from the oil storage tanks and had used some fuel from temporary tanks outside the building during the conversion to gas.) The time frame for the “post usage” period was from November 1999 to October 2000, which was well after the time that the conversion was fully completed.

Once this pre and post data had been compiled the next step was to subtract the baseload (domestic water heating load in this case) resulting in the annual space heating consumption. Given that this load was supplied from the main boiler system, it was necessary to use monthly heating degree days (HDD) data for the location to ascertain shoulder periods in which the school was operating but little to no space heating was occurring. Next, a baseload level for fuel consumption for domestic water heating production was computed. After subtracting the domestic water heating load, the remainder of the fuel (the weather driven load) was adjusted by HDD for the periods. The next step was to compute weather driven load for a ‘normal year’ (using the normal HDDs for the location) and, finally, re-add that to the baseload.

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[1] See discussion of BCHP at the end of this section.

With regard to the three different fuel rates for the different energy sources in this case, it was necessary to retain some level of an "apples to apples" type comparison for what we were trying to accomplish. We decided to use a fuel cost for a given point in time, rather than the actual cost of oil in the pre-period and the actual cost of gas in the post period (which would have been biased due to time of supply and inflation). We therefore set the fuel rates to create an equal cost (on a Btu basis) for all fuels to allow us to compare the true benefits of each technology regardless of the impact of competing costs for different fuels.

6.2.2 Federal Office Building

The existing heating system in the Federal Building/US Courthouse in Sioux City, Iowa, utilized two low-pressure steam boilers for space heating. One of the boilers was more than 60 years old, while the other boiler was more than 30 years of age. Each of the boilers was sized to handle the entire design heating load of the building in accordance with General Services Administration (GSA) policy. Thus, if one boiler was incapable of operating, the other boiler would be available to serve all of the building's needs. Typically, only the newest boiler was used to provide steam, while the older boiler was used only as a backup.

The boilers were fired by combination gas-oil burners, capable of using natural gas or No. 2 fuel oil as a backup. (The building was not on interruptible natural gas service.) The steam produced by the boilers was piped to a central steam-to-hot water heat exchanger, which was used to heat the water in the hydronic space heating distribution system. The heated water was provided to the perimeter radiant heater system and to the hot water coils of air handling units located throughout the building.

The impetus for this upgrade was twofold. First, the National Energy Conservation Policy Act, the Energy Policy Act of 1992, and Executive Order 12759 require that all Government agencies reduce energy consumption in Federal buildings. Second, even though the existing boilers were capable of serving the building, the boilers had begun to experience many maintenance problems and there was a concern that both boilers could become inoperable at some point in the near future. The decision to select gas-fired condensing boilers was based on the results of an engineering analysis and a life cycle cost analysis required under Federal government regulations[2].

The GSA's policy is to provide one spare boiler so that the building would have heating, even on a design heating day. Thus, the cost estimate for the conventional boilers assumed providing two boilers of equal size, each one capable of serving the entire building. Each of the two hot water boilers was assumed to be natural gas-fired cast-iron, with insulated jacket and standard controls, with a total gross output of 4,480,000 Btuh.

The new system included five condensing boilers, with one of the boilers designed to function as a spare. Note that each boiler was sized to be 1,000,000 Btuh, the largest size of condensing boilers available on the market at the time (1995). Since the condensing boiler system consisted of smaller modular boilers, the spare boiler was not sized to satisfy the entire heating load for the building. Instead, it was deemed acceptable by the GSA Project Manager to install this extra boiler for instances in which one boiler was not operable.

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[2] As reported by Mr. Perry Boeschen, P.E. the GSA Energy Coordinator, in his paper entitled "a Case Study of Condensing Boiler Savings". ASHRAE Transactions 2000, V. 106.

The total installed cost of the new condensing system consisting of 5 boilers (1,000,000 Btuh capacity each) was $154,791 compared to $130,204 for the 2 conventional boiler system (2,240,000 Btuh capacity each). The Annual Energy Consumption for this system was 48,465 therms. Upon entering the actual project-related data and entering economic assumptions (including a 3% discount rate, EIA Annual Energy Rate Escalations for the various energy sources and an annual Maintenance Rate Escalation of 1%) into our screening tool, we obtained a Net Present Cost of $580,891 over a 20-year assumed life for the condensing boiler system. This compares favorably to the 20 year Net Present Cost of $618,920 calculated for the conventional boiler system by the screening tool as shown in Exhibit 6-2. In this case the BCHP system actually has a slightly higher 20 year net present cost, of $658,543. This is due in large part to the lower prevailing electricity cost (and hence lower value of the system's output) in the region.

Exhibit 6-2: Results of Cost-Benefit Analysis for Federal Office Building, Sioux City*

System Type	Installed Cost of System	Annual Energy Consumption (Therm Eq.)	Energy Cost	Maintenance Cost	Net Present Cost	Net Present Cost Compared to Conventional Gas Boiler
Condensing Gas Boiler	$154,791	48,465	$350,969	$75,131	$580,891	($38,028)
Conventional Gas Boiler	$130,204	60,639	$439,129	$49,587	$618,920	-
BCHP	$463,950	254,648	($507,884)	$702,477	$658,543	$39,623

**Results are based on 20-year system life*

The installation costs of the hot water condensing boilers were determined from records of the actual retrofit project. The estimated construction costs for installing conventional boilers were determined at a time just prior to the retrofit from the Means Mechanical Cost Data book. The costs for the BCHP system were estimated based on the experience of the team (in regard to primary BCHP equipment and hours to install) and Means Mechanical Cost Data book for labor rates and ancillary equipment (i.e. piping). Greater detail on the specific costs associated with each of these systems is presented in the printouts that are included in Appendix 3.

Construction activities on this project began in June 1995 and were completed in October 1995. The "pre fuel use" data were taken from facility records for the FY 1993 and FY 1994 periods, and the "post fuel use" data were taken from facility records for the FY 1996 and FY 1997 periods. HDD weather adjusted analysis was performed in a manner similar to that used in the school case study.

6.3 Building Combined Heat and Power System (BCHP)

The economic analyses in the case studies presented here consider the alternative of a BCHP system in addition to the condensing and conventional boiler systems that were considered for both of these facilities. While the BCHP system was not actually considered by the facilities at the time of retrofit, the CEE Gas Subcommittee felt that it would be worthwhile to address this type of system as a competing system.

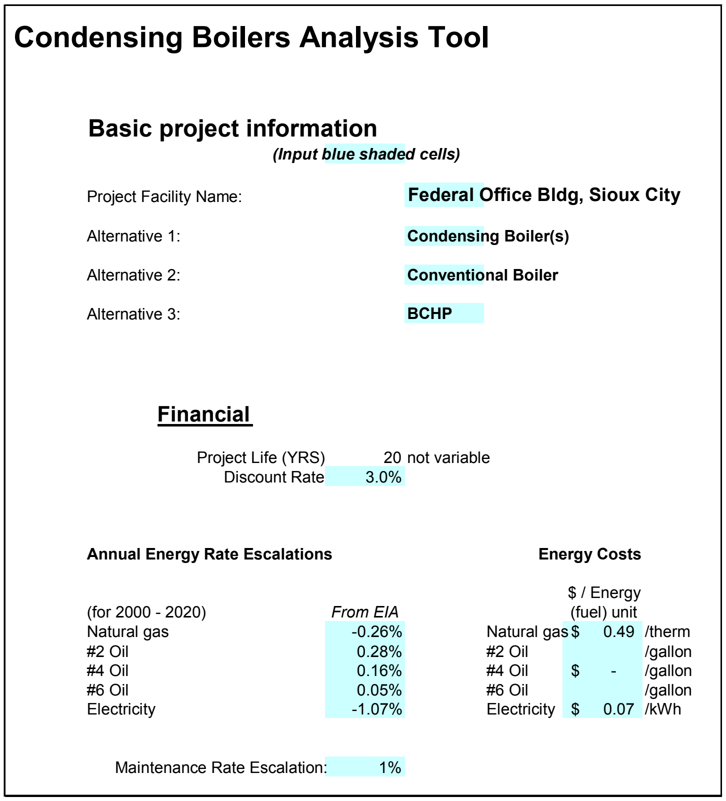
A BCHP system burns a single fuel (most often natural gas) and produces both heat and electricity, essentially cogeneration. Today the term BCHP is most often used to refer to the emerging technologies of micro-turbines and fuel cells. For the purposes of this project we employed the costs and energy consumption & outputs of the micro-turbines that are currently available on the market. We did not consider fuel cells as there have been no free-market sales of these units to date (and hence no reliable cost data were available), and it appears that it may be quite a few years before fuel cells actually appear on the market. Micro-turbines on the other hand appear to both be seen as a technology for the future (and hence a potential competitor to condensing boilers in certain installations) and to be currently available for purchase and utilization in buildings.

The BCHP systems evaluated for the two case studies were each sized to provide the same thermal output as the condensing and conventional boilers against which they are compared. We could not obtain the historical electrical consumption at the two facilities, so the only assumption made here is that the facilities can make full use of the electric output of the units. If they cannot, then the value of the energy savings would be lowered and the net present cost would rise in direct proportion. With recent developments caused by electricity deregulation, it is likely that there would exist the possibility of selling any excess power that might be available from these units.

6.4 Screening Tool

The screening tool is set up as 4 main worksheets in MicroSoft Excel. The user enters project-related and financial assumptions in the first worksheet (Exhibit 6-3). Energy consumption data for the condensing unit and competing systems are entered into the second worksheet, which results in the calculation of annual operating costs. After installation cost data are entered in the third worksheet, the screening tool presents the life cycle cost comparisons for all competing systems in tabular and graphic formats.

Exhibit 6-3: Basic Information Sheet from Screening Tool



Condensing Boilers Analysis Tool

Basic project information

(Input blue shaded cells)

Project Facility Name:	**Federal Office Bldg, Sioux City**
Alternative 1:	**Condensing Boiler(s)**
Alternative 2:	**Conventional Boiler**
Alternative 3:	**BCHP**

Financial

Project Life (YRS)	20	not variable
Discount Rate	3.0%	

Annual Energy Rate Escalations

(for 2000 - 2020)	*From EIA*
Natural gas	-0.26%
#2 Oil	0.28%
#4 Oil	0.16%
#6 Oil	0.05%
Electricity	-1.07%

Energy Costs

	$ / Energy (fuel) unit	
Natural gas	$ 0.49	/therm
#2 Oil		/gallon
#4 Oil	$ -	/gallon
#6 Oil		/gallon
Electricity	$ 0.07	/kWh

Maintenance Rate Escalation: 1%

6.5 Summary

The case studies allowed us to determine real world installation and operating costs for commercial size condensing boilers in two of the most promising market segments, schools and Federal buildings. These two segments (and owner-occupied commercial buildings) are the only markets where purchase decisions are made based on the results of life cycle cost computations. These two case studies indicate that condensing boilers have lower life cycle costs than conventional boilers despite the lower installed cost advantage of conventional boilers. The advantages of the condensing boiler improve as gas costs increase since these boilers, due to their higher efficiencies, have lower operating costs than conventional boilers.

Data from these two cases were used to develop a screening tool that allows users to compare the economics of condensing boilers to two competing technologies, conventional boilers and BCHP systems. The screening tool is provided as an attachment to this report.

Chapter 7: Market Size and Projections

7.1 Background

This chapter develops two scenarios for the future market for condensing boilers in commercial applications. For each, we first (exogenously) stipulate a sales growth curve. This is supported in the scenario by noting the market forcing functions that could lead to that growth rate. Section 7.2 below describes how the growth curves were constructed. The scenarios chosen are:

- Business as Usual (BAU)
- Fully Supported Market Transformation (MT)

7.1.1 "Business as Usual" Assumptions

In this scenario, we use conventional market diffusion[1] assumptions to estimate the growth of the market. Here, we assume a constant 4% annual growth in sales. This growth is accounted for by continuing boiler manufacturer marketing efforts. Energy price forecasts in justifying the scenario are from the US Energy Information Administration *Annual Energy Outlook 2000*[2]. This scenario is considered to be the expected growth rate, absent any external marketing activities beyond those supported now by manufacturers and utilities.

7.1.2 "Fully Supported Market Transformation" Assumptions

In this scenario, we postulate an environment in which many agents work together to increase installations as quickly as possible. These factors could include any combination of the following, among others:

- Strong market transformation efforts by utility consortia such as CEE. This would include programs such as financial support, marketing support, design assistance, environmental benefits and system monitoring, rebates and dissemination of support tools such as generic specifications, design software, case studies and fact sheets.
- Efforts such as the Federal sector Executive Order 13123 and Federal Energy Management Program (FEMP) support for decisions for DOD and civilian Federal sector purchases.
- Federal or state/local government coordinated purchasing arrangements, designed to increase installations and control costs through competitive bids for much larger numbers of units than are conventionally installed in a given region or market niche.
- Major policy initiatives, such as mandatory minimum performance standards that require condensing boiler installations wherever applicable, or pollution credits and trading.
- Rapid increases in the price of energy, with widespread expectations of continuing price run-ups.
- Significant price declines for condensing boilers as a result of greater production and installation experience and greater competition among manufacturers in an expanded market.

The MT scenario is expected to be an upper bound on sales growth for commercial condensing boilers. We argue (below) that sustained growth at rates greater than 25% to 30% per year is very

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[1] Kydes, Andy S. *Diffusion and Learning-by-Doing*. In U.S.EIA Report #:EIA/DOE-0607 (99)

[2] Annual Energy Outlook 2000 with Projections to 2020. U.S. EIA Report # Report#:DOE/EIA-0383 (2000)

unlikely, based on penetration rates of other technologies and supported by considerations of infrastructure and diffusion.

7.2 Methods – What we did

The methodology used for estimating the size of the condensing boiler market consisted of the following steps:

- Estimating Sales of Condensing Boilers
- Establishing Growth Curves for the Market
- Determining Condensing Boiler Prices
- Obtaining Energy Cost Projections

7.2.1 Estimating Sales of Condensing Boilers

Since market data on condensing boiler sales are not available we used two approaches to estimate the current sales level for commercial condensing boilers. The first was based on extrapolation from published data, particularly BSRIA[3], a significant and independent survey of the market, which focused on the years from 1991 to 1996. The second approach was an informal "Delphi" (wise person) survey of industry participants. As explained below, for both commercial and residential sectors, our trends are based on extrapolation from historical data. However, our 1999 sales baseline estimates are based on interviews with manufacturers. Thus, sales projections are based on extrapolation from published data, using our survey to establish the baseline for 1999.

Extrapolation from Published Data, Commercial Sector

From BSRIA, the 1996 market for all kinds of commercial boilers was about 34,000 units, very close to 10% of residential-scale boiler sales[4]. Inter-annual sales variability can be greater than 10%, driven by exogenous factors such as interest rate changes that impact the building industry[5]. However, the market pool in which condensing boilers initially compete is much smaller than 35,000 units per year, because that number includes all construction types and all fuel types. Thus, we have to reduce the number to exclude materials that cannot support condensing operations, and to remove oil-fired and dual-fuel boilers. We find no currently marketed condensing boilers that accept fuel oil. These decrements include (with BSRIA table numbers):

- **20,675 commercial gas-fired boilers sold (BSRIATable 3.4).** Over time, some condensing boiler sales will replace oil fired units, but condensing boilers are not oil-fired or dual-fuel units[6]. Where dual fuel capability is required by the owner, it will have to be provided by "lag" non-condensing boilers in multiple boiler installations, which could become common. Traditionally, utilities have favored programs that encouraged customers to "lock in" gas as their fuel.

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[3] BSRIA, 1998. U. S. Market for Hydronic Heating and Burners. Building Services Research and Information Association, Report 11973/4, BSRIA, Bracknell, Berkshire, England RG12 7AH

[4] BSRIA, 1998, Table 1.1

[5] Graphically interpolated by HMS from BSRIA Figure 1., "Boiler sales by sector and material…"

[6] The latent heat fraction of fuel oil energy (6.50%, ANSI/ASHRAE Standard 103, Table 7) is much lower than that of natural gas (9.55%, same source), so there is much less gain in making oil-capable boilers condense. In addition, oil is more corrosive.

- **4800 steel boilers sold (BSRIA Table 3.2).**The commercial market is dominated by cast iron (non-condensing) boilers. Over time, condensing boilers will replace cast iron non-condensing boilers. The average value of these steel boilers was $41,000. Almost all condensing boilers are made of stainless steel (a subcategory within steel boilers, not reported separately), with some copper and aluminum units also sold. These last materials are estimated to represent a small number of condensing boilers in commercial sizes.
    - Although 35% more copper than steel commercial boilers were sold in 1996 (BSRIA estimates: 6,500 v. 4,800), the copper boilers were worth only an average of $5,700/unit, while the average steel boiler was $40,800. The much lower average cost argues that the copper boilers were (on average) either much smaller or much less efficient, or both. We conclude that copper boilers are not a numerically important part of the condensing market in the commercial sector, although they are present.
    - We found no sales data for aluminum boilers, but they were too few to break out in the BSRIA study. In addition, we found only one manufacturer. Again, we conclude that they are not numerically important in our estimate.
- **3380 commercial steel hot water (not steam) boilers (BSRIA Table 3.17).** Some boilers are designed, and generally applied, in steam applications. Virtually no steam boilers will "see" condensing conditions, so steam boilers should be excluded from the potential sales universe. In addition, essentially all (97%) steel gas fired boilers use power burners (BSRIA Table 3.16).

Thus, one estimate of the upper limit of 1996 sales of commercial size condensing boilers in the United States is the number of steel hot water boilers plus a small number of copper or aluminum boilers. That would be 3,380 steel plus aluminum and copper units. We could estimate this upper bound as no more than 4,000 units. Of course, condensing boilers are only a fraction of these (mostly steel) boilers. Since manufacturers report that "almost all" condensing boiler sales are supported by utility rebates[7], we conclude that certainly less than 10%, and probably less than 5%, of these sales are condensing units.

Thus, we would estimate, if we had only this input, that the total baseline sales volume of commercial scale condensing boilers (>300,000 Btuh) in 1996 was substantially less than 1,000 units per year, and probably only 300 +/- 100 units/year from this line of reasoning. However, as we will see below (in the section on "Delphi" surveys), the BSRIA data are likely to systematically underestimate sales of commercial scale condensing boilers.

Inferences from Published Data, Residential Sector

Table 3.15 of BSRIA suggests that gas-fired steel boilers have an inconsequential share of the residential market, approximately 200 units out of 27,500, or less than 1% (in fact, there were also too few dual-fuel residential boilers sold for BSRIA to estimate). In contrast, BSRIA reports sales of 190,000 gas-fired cast iron residential boilers in 1996 (Table 3.10). We believe that in this case, the BSRIA table is in error. Given allowances for time and promotional efforts (by utilities, among others) since 1996, extrapolating from BSRIA would suggest sales in 1999 no greater than 400 +/- 300 residential units sold in 1999. The reasons for our estimate of 7000 units/year are given below.

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[7] Conversations with Manufacturers, March and April, 2000

The Informal "Delphi" (wise person) Survey of Industry Participants

Although the scope of work excluded primary research, during this project the team needed to interview industry experts about several issues. The representatives included utility experts, staff of boiler manufacturing firms, and consultants. We sought comments on our Condensing Boiler Specification (Chapter 2)and insights into market influencers, players, and barriers for Chapters 8-11. In response to our questions, one manufacturer estimated the market for commercial scale condensing boilers to be about 900 units, and another estimated it to be 700. We have chosen to accept the manufacturers' estimates for 1999 sales of condensing boilers, rather than an extrapolation from BSRIA 1996 data. Our reasons include the following:

- **The manufacturers representatives would be unlikely to overestimate the total market size and thus underestimate their own market shares**. It is possible, but we can't figure out what internal incentives would lead to this systematic bias, so we are inclined to accept their estimates.
- **The BSRIA estimates may be too low because of errors in their methods.** In particular, BSRIA did not seek data on condensing boilers, and thus may have missed the relatively large sales in the residential market.
- **The most recent BSRIA data are for 1996, and there may have been significant growth in the years since that date.** Since 1996, new firms and models have entered the commercial boiler market. On the other hand, utility demand side management programs (which typically include rebate programs) have been declining for a number of years,[8] lowering the incentives that supported sales of these expensive units.

Based on the manufacturers' input, we conclude that a reasonable estimate for 1999 US sales of commercial condensing boilers is 700 units. Our qualitative estimate of the error in this estimate is +/- 250 units. Because manufacturers generally are extremely reluctant to discuss either sales or market share, and because these concerns seem to be greatest in the smallest markets, we know of no way to refine these estimates.

Similarly, based on the manufacturers' input, we conclude that a reasonable estimate for 1999 US sales of residential-scale condensing boilers is 7,000 units. Our qualitative estimate of the error in this estimate is +/- 2,000 units. These numbers are used as the 1999 sales basis for our Business as Usual (BAU) and Fully Supported Market Transformation (MT) projections of sales, discussed in the next section.

7.2.2 Establishing Growth Curves for the Market

In a very large-scale program, it would be possible to build an econometric model that would look at the effects of fuel price changes, technology costs, and all other conceivable factors to predict sales growth rates for both the BAU and MT scenarios. Given inherent uncertainties, such a model would likely be more precise than accurate as a forecast. In any event, such a bottom-up

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[8] "DSM costs continued to decrease from $1.6 billion in 1997 to $1.4 billion in 1998. This is the fifth consecutive year that DSM costs [utility expenditures] have decreased from the high of $2.74 billion in 1993" EIA, Electric Utility Demand Side Management 1998 Executive Summary. http://www.eia.doe.gov/cneaf/electricity/dsm/dsm_sum98.html
In the four years from 1994 to 1998, total utility expenditures decreased from $2.7 billion to $1.4 billion, a drop to 52% of the 1994 value in four years: http://www.eia.doe.gov/cneaf/electricity/dsm98/table1.htm, from Table 1 of the full document.

model is not possible within the scope of this Technology and Market Assessment. Instead, we use a top-down approach that assigns a growth trajectory for the years 2000 – 2024. The values chosen are given in Exhibit 7-1 and illustrated in Exhibit 7-2.

Exhibit 7-1: Projected Commercial Boiler Sales in the Business as Usual and Fully Supported Market Transformation Scenarios*

Year	BAU Baseline, 4% annual growth	MT Market Transformation, growth as per right column	Growth Rate
2000	700	700	--
2001	728	728	4%
2002	757	764	5%
2003	787	841	10%
2004	819	967	15%
2005	852	1,160	20%
2006	886	1,450	25%
2007	921	1,813	25%
2008	958	2,266	25%
2009	996	2,833	25%
2010	1036	3,541	25%
2011	1078	4,426	25%
2012	1121	5,533	25%
2013	1166	6,916	25%
2014	1212	8,645	25%
2015	1261	10,807	25%
2016	1311	12,968	20%
2017	1364	15,562	20%
2018	1418	17,896	15%
2019	1475	20,580	15%
2020	1534	22,638	10%
2021	1595	24,902	10%
2022	1659	26,147	5%
2023	1725	27,455	5%
2024	1794	28,827	5%

**The BAU scenario assumes a constant 4% growth rate, while the MT scenario uses variable rates (rightmost column) to approximate predicted growth trajectory.*

For BAU, the trajectory is a constant-value growth factor of 4% per year. This growth rate is our best estimate, as noted above: First, we assume that overall sales of commercial steel boilers grow at the same 3.1% per year as the overall commercial boiler market, from the BSRIA compounded growth estimates for 1991-1996[9], because the same forces operate on the market. That is, the market moves because of the efforts of manufacturers and the interest of other market players (designers, contractors, owners). We then infer that the condensing boiler market will grow

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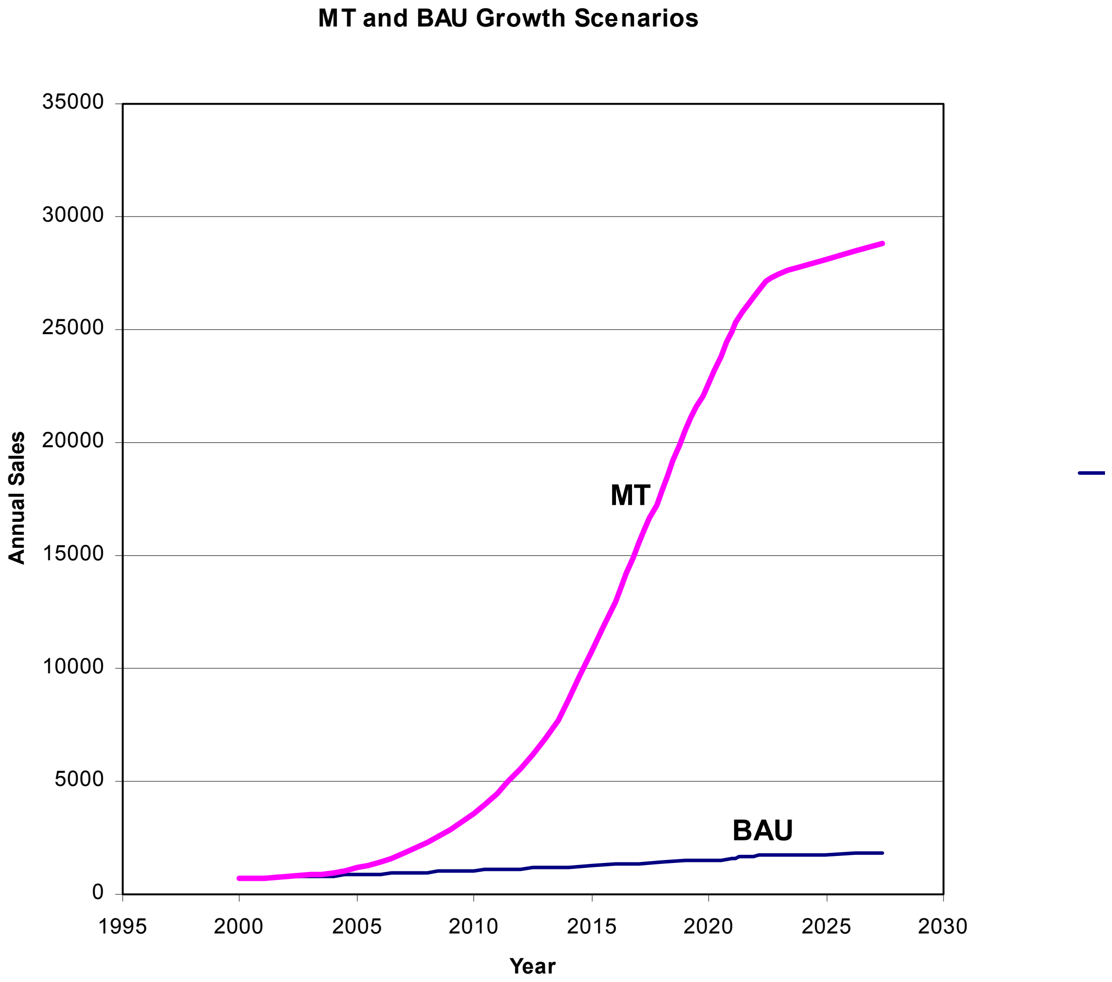
[9] BSRIA, 1998, Table 3.27

somewhat faster, by diffusion, as the number of installations grows. We assume that the combined, expanded efforts of the manufacturers, coupled with "word-on-the-street" success stories and greater numbers of professionals who are familiar with the technology will lead to sales expanding somewhat relative to the lower cost, lower efficiency, products.

Exhibit 7-2: Growth in cumulative installations for BAU (lower line) and MT (upper line) scenarios, with data from Exhibit 7-1



For MT, we developed a varying growth rate that approximates a "logistic" or "S" curve. This shows slow initial growth as the product is rolled out and the middle market and customers are made aware of the benefits of the product. During this interval, sales go to "early adopters" for whom there is a compelling value proposition. They become supporters of the technology, and growth increases as the much larger mainstream market begins installations. Finally, sales growth tapers off as the market becomes saturated before a large replacement market for the product itself develops, or as the product begins to see competition from yet more advanced products. The MT scenario represents the "best case" or upper bound of projected annual sales. These S-curves are well documented for products such as automobile tires (bias to bias-belted to radial). In our case, we limited maximum growth to 25% per year. This upper bound was assigned on the basis of examination of maximum growth rates for other products, for example those shown in Exhibit 7-3.

Exhibit 7-3: Peak Growth Rates for Four High-Cost Consumer Products[10]

Product	Interval	Average Annual Increase
Projection TV	1993-1995	27%
Projection TV	1984-1997	14%
Personal Computers through Dealers	1991-1997	18%
Direct-to-Home Satellite	1994-1997	51%
Direct-to-Home Satellite	1994	278%
VCRs	1982-1985	71%
VCRs	1990-1996	6%

7.2.3 Determining Condensing Boiler Prices

Different customers use different value systems in selecting equipment. Some seek the lowest first cost while others seek the lowest life cycle cost. Some rank other factors as important: they want to be technology leaders, need to have "100%" reliability, or care greatly about noise level, because the boiler room is near high-value rental space. In any event, first cost matters in moving the market. We looked at the common commercial size ranges (300,000 Btuh – 3,000,000 Btuh). In those ranges, we looked at baseline atmospheric boilers, boilers with power burners, and true condensing boilers. For one representative manufacturer[11], a boiler designed for and shipped with a power burner (medium efficiency) was about 50% more expensive than a baseline boiler, with some variation across sizes as shown in Exhibit 7-4. The condensing boiler was in the range of 3 times as expensive as the low-cost boiler. Thus, there is a very substantial capital cost premium for efficiency. We believe that this reflects the small numbers sold and the consequent need for the manufacturer or his representatives to provide a great deal of custom support for installations. Exhibit 7-4 gives a generalized view of cost ratios as technology type and boiler size vary, estimated from data for one product line (which may not be very representative of the industry). The cost of a 300,000 Btuh atmospheric boiler is set at 1.0, and all others are normalized to that

Exhibit 7-4: Ratios of Boiler Price Compared to Price of 300,000 Btuh Atmospheric Boilers

Boiler Type		Boiler Size	
	300,000 Btuh	500,000 Btuh	1,000,000 Btuh
Atmospheric	1.0	1.2	1.7
Power Burner	1.2	1.9	2.8
Full Condensing	3.0	3.6	4.8

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[10] GHPC RP-031, Table 4, *Counting GeoExchange Systems.* Available from Geothermal Heat Pump Consortium, Washington, DC.

[11] Estimates provided on condition that we not identify the manufacturer.

value. We believe that the price premium for condensing, about a factor of 3 in any given size class, is relatively high in this example, but that condensing boilers typically cost at least twice as much as base-level products.

For a given size, cast iron boilers are estimated to cost about $^2/_3$ as much as comparably sized steel boilers[12]. Roughly, for the cost data given in BSRIA Table 3.40, cast iron boilers cost about \$8/MBtuh; steel boilers cost about \$12/MBtuh. For one manufacturer's cast iron boilers, the cost (in the year 2000) was closer to \$12/MBtuh[13]

An alternative approach to cost estimation is to use "Means" construction cost estimating data[14] which provides cost breakouts as shown in Exhibit 7-5.

Exhibit 7-5: Estimated Installed Cost Breakouts for 3 Types of Small Boilers from 1999 Means Mechanical Cost Data Book

Cost Element	Pulse Combustion* 134,000 Btuh	Steel, 132,000 Btuh	Cast Iron, 122,000 Btuh
Purchase Price	$3575	$2235	$1350
Labor Cost	$635	$690	$1450
Overhead & Profit	$640	$585	$900
Total	$4850	$3600	$2800

** Proxy for "Condensing Boiler," which is not listed in Means*

In the example shown in Exhibit 7-5, the pulse combustion boiler, at the point of purchase, carries a 60% price premium over the steel boiler. In this example, we use the point of purchase to keep consistency with Exhibit 7-4. The discussion in the section below draws out implications of these numbers for cost-effectiveness.

If the market for condensing boilers expands, the price premium will decrease somewhat. Factors favoring cost reduction include:

- "Learning by doing" in manufacturing. As manufacturers build more products, they can afford increasing automation. They get better quantity discounts for purchased parts. Other factors also enter. Typically, each doubling in "manufacturing experience" leads to a 15% - 20% decline in costs. The difficulty in applying this rule of thumb is that it can be hard to determine the appropriate starting point -- that "first unit" from which to measure the doublings.
- Greater experience in the "middle market". Some manufacturers today include the cost of a technician to check out the installation and fire the boiler in their prices. With increasing field installation rates, distributor staff or field representatives will be experienced in this work, cutting installation costs.
- Greater access to specifications, and more experience, by contractors and design engineers. This will reduce their costs to meet design requirements.

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[12] Regressions on data in BSRIA Table 3.40

[13] The small data samples available (three models in one sample, four (of two different kinds) in the other) do not warrant 2-parameter models with both slope and intercept; these numbers are meant only to be illustrative.

[14] Means Building Construction Cost Data 1999. Published by R.S. Means http://www.rsmeans.com/. Data supplied by F. Goldner.

However, we believe that condensing boilers will always carry some premium. They are made of expensive and hard to work stainless steel and other costly materials. They require more sophisticated controls and more careful installation to achieve their potential. We would be surprised if the costs fell to the range of 1.5 times the price of the base level (barely legal efficiency) boiler.

7.2.4 Obtaining Energy Cost Projections

One of the factors that affect sales of high efficiency equipment, such as condensing boilers, is customer expectation of future fuel costs. Falling natural gas prices will tend to reduce the benefits of condensing boilers. Rising natural gas prices will increase the benefits of condensing boilers versus conventional gas boilers by reducing the payback period. For perspective on this driver, we offer projections from the U.S. Energy Information Administration *Annual Energy Outlook 2000* commercial sector forecasts. We chose the EIA estimates because they represent a very large and sophisticated analysis of energy in the economy, because the National Energy Modeling System (NEMS)[15]on which they are based has been thoroughly peer-reviewed (so the estimates are considered objective), and because these estimates are available to all potential users. *Annual Energy Outlook 2000* projects stable (virtually unchanging) prices for natural gas and distillate oil, but a decline of about 1% per year for commercial sector electricity prices, caused by increasing competition among suppliers in a restructured market. In fact, "(b)y sector, projected prices in 2020 are 19, 21, and 24 percent lower than 1996 prices for residential, commercial, and industrial customers.[16]"

Exhibit 7-6: Energy Price Projections*

Year	Energy Price Projections ($1998/Million Btu)		
	Natural Gas	Distillate Oil	Electricity
1997	5.705	5.028	22.323
1998	5.265	3.926	21.76
1999	5.122	4.701	21.427
2000	5.474	5.432	21.188
2001	5.438	5.305	20.713
2002	5.42	5.295	20.134
2003	5.427	5.348	19.912
2004	5.451	5.364	19.692
2005	5.484	5.384	19.305
2006	5.522	5.421	19.264
2007	5.554	5.454	19.125
2008	5.56	5.497	18.902
2009	5.545	5.574	18.596
2010	5.53	5.561	18.654
2011	5.521	5.553	18.400
2012	5.511	5.577	18.282
2013	5.498	5.583	18.255
2014	5.486	5.6	18.318
2015	5.48	5.627	18.366
2016	5.473	5.631	18.304
2017	5.471	5.631	18.292
2018	5.468	5.667	18.275
2019	5.474	5.696	18.181
2020	5.496	5.731	18.166

** Price projections for commercial sector natural gas, distillate oil, and electricity from EIA Annual Energy Outlook for 2000-Supplement.*

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[15] NEMS was developed and is maintained by the Office of Integrated Analysis and Forecasting of USDOE's Energy Information Administration

[16] Annual Energy Outlook 98, http://www.eia.doe.gov/oiaf/aeo98/ele_pri.html

Example of Present Cost-Effectiveness of Condensing Boilers

For this chapter we established estimates of the price differential for condensing boilers, a differential that seems rather high. We then looked at fuel prices, which is the other key ingredient for determining cost-effectiveness. Although more detailed economic analyses are presented with the case studies in Chapter 6, it is worth considering a simple example at this point, to frame the environment in which market players and influencers operate, as developed in Chapter 12.

Exhibit 7-7: Estimate of Savings from Condensing Boilers*

Estimates from CBECS data for offices:	
15,000 ft^2	average office building size
24,300 Btu/ ft^2	heating energy intensity
50%	assumed efficiency, present
12,150 Btu/ ft^2	heating energy delivered
80%	best case, condensing boilers
15,188 Btu/ ft^2	heating energy intensity, best case
364,500,000 Btu	base level energy bought for heating, per year
3,645 therms	base level energy bought for heating, per year
$2,005	base level $ spent for heating
60%	improvement (best annual efficiency vs. today's)
9,113 Btu	per square foot annual savings
38%	percent of energy saved by advanced boilers
136,687,500 Btu	per building annual savings
0.55 $/therm	$/100,000 btu, from EIA
$752	annual value of heating energy saved
0.05 $/ ft^2	annual savings, per ft^2

** Based on average office building from Commercial Buildings Energy Conservation Survey.*

Let us assume that the designer would specify 30,000 Btu peak capacity per 1000 ft^2, or 750,000 Btuh of boilers in this building. Using the data from Exhibit 7-4, consider the example of Exhibit 7-7 above. Assume that 5 pulse combustion boilers at 134,000 Btuh would suffice, and can be compared with 5 steel boilers. This gives a best-case estimate of cost effectiveness, since we are computing energy savings based on the efficiency of cast iron boilers while using the somewhat higher installed costs of steel boilers. Based on an incremental cost of $6,250 for the five installed boilers[17], the estimated $750 annual energy saving means a payback over 8 years. Interestingly, this is within the window of interest for Federal systems, but too long to be of interest to most commercial owners who generally will not tolerate payback periods greater than 3 years. Higher gas prices, however, will tend to favor the cost effectiveness of the condensing boiler.

7.3 The Business as Usual Scenario

7.3.1 Premises narrative

The “premises narrative” sketches one view of the business environment for the BAU scenario. This sketch does not “drive” a growth projection model, but it should illustrate the factors that

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[17] From the table, 5*($4850 - $3600) = $6250.

influenced our decision to set a 4% annual growth for BAU. The scenario is based on three primary premises.

First, we assume that overall sales of commercial steel boilers grow at the same 3.1% rate per year as the overall commercial boiler market, from the BSRIA compounded growth estimates for 1991-1996[18], because the same forces operate on the market. That is, the market moves because of the efforts of manufacturers and the interest of other market players (designers, contractors, owners). On a present estimated sales base of 700+/- 250 commercial scale condensing boiler units per year in an overall market of about 35,000 boilers/year[19], manufacturers have only limited cash flow to support major marketing efforts or large price reductions. Because the first cost premium for condensing boilers is at least a factor of two relative to minimum efficiency commercial boilers, this is a major market barrier. Some units are sold, because the industry and its allies (specifying designers, contractors, and so on) include some "champions" who can convince owners of the value of the condensing boiler for their applications.

The second assumption is that there are no sustained price shocks for the major fuel choices available to commercial building owners. In particular, our conceptual model assumes that fuel prices for natural gas, electricity, and fuel oil change only moderately both in absolute terms and relative to each other. This means that the relative competitive positions do not change significantly. As noted above, we use the U. S. Department of Energy/Energy Information Administration reference case from the *Annual Energy Outlook 2000*.

Third, in this scenario, from conventional market diffusion[20] assumptions we postulate that the market remains in a low-growth, constant-growth, pre-take-off stage through the end of the forecast period. In fact, this assumption asserts that doubling the sales of commercial scale condensing boilers in the next two decades will not put them into the rapid growth portion of the market saturation "S" curve; they will remain a specialty product in a particular suite of small niches.

Change in sales in this scenario is driven by continued utility rebate programs at their current level and continued boiler manufacturer marketing efforts. Because energy prices are projected to remain stable (or decline modestly), energy prices do not impact this scenario. Realistically, this scenario is offered as a lower bound for the growth of the condensing boiler market in the US for the next decade.

7.3.2 Basis for Condensing Boilers Projected Sales Growth

As noted above, the compound average annual growth of the commercial boiler market between 1991 and 1996 was 3.1%[21], although the sales of steel boilers were essentially flat (0.4% compound annual growth rate for the same interval). Exhibits 7-1 and 7-2 reflect the assumption of continuing 4% annual growth for the condensing boiler market, exceeding the overall market growth by 1% per year. This relative growth reflects a gradual displacement of less efficient boilers as more customers come to understand their advantages. For the residential market, we assume the same 4% annual growth in the BAU scenario.

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[18] BSRIA, 1998, Table 3.27

[19] BSRIA, 1998, Table 1.1. Extrapolation by present authors from 1996 data and 1997 projection by BSRIA

[20] Kydes, Andy S. *Diffusion and Learning-by-Doing*. In U.S.EIA Report #:EIA/DOE-0607 (99)

[21] BSRIA, 1998, Table 3.27

7.4 The "Fully Supported Market Transformation" Scenario

7.4.1 Premises narrative

This "premises narrative" sketches one view of the business environment for the MT scenario. It is important to note that the MT scenario represents an upper bound. This sketch does not "drive" a growth projection model, but it should illustrate the factors that influenced the design of the logistic or "S" curve for market penetration that we posit. This scenario projects growth when all feasible factors are in alignment to increase sales and utilization of commercial condensing boilers, where their application is appropriate. As noted in the introduction, the kinds of factors that could influence the market in this scenario could include:

- Strong market transformation efforts by utility consortia such as CEE. This would include programs such as marketing support, design assistance and financial support, development of case studies and system monitoring and rebates.
- Efforts such as the Federal sector Executive Order 13123 and FEMP support for wise decisions for DOD and civilian Federal sector purchases.
- Federal or state/local government coordinated purchasing arrangements, designed to increase installations and control costs through competitive bids for much larger numbers of units than are conventionally installed in a given region or market niche.
- Major policy initiatives, such as mandatory minimum performance standards that require condensing boiler installations wherever applicable, or pollution credits and trading. These could be driven by "Kyoto" (climate change/carbon dioxide) concerns that raise the importance of energy efficiency. They could also be driven by regional air quality regulations that require very clean burning for all retrofits or new construction. As an example, in Southern California, new sources of criteria pollutants such as NO_x may have to purchase offsets, which are reductions of emissions from present sources. This might lead to a market in NO_x reduction, in which parties wishing to install new facilities purchase NO_x rights from existing facilities, which would give them a large incentive to install the most clean-burning equipment available. Under these circumstances, the incremental cost of a condensing boiler may be worthwhile, if it yields very low emissions and very high efficiency. Some policy analysts project similar programs for CO_2, which would directly stimulate sales of the highest efficiency equipment.
- Rapid increases in the price of energy, with widespread expectations of continuing price run-ups.
- Feedback of the factors above, which lead to early sales growth, and thus signal manufacturers that sales and market share may increase significantly if prices decline.

7.4.2 Basis for Condensing Boilers Projected Sales Growth

The result of these policy initiatives and economic factors would be to support much larger sales growth than in the BAU scenario, as suggested by Exhibit 7-1. The increments in that table were based on the following considerations:

- The initial growth rate should be that of the "pre-take-off" phase of market transformation "S" curves. That is, it should be about the same as those in BAU 4% per year. This reflects the time lag in the first years, when sales climb slowly, although great investments are made in upgrading awareness and the infrastructure.
- The final growth rate would be that of the "market saturation" phase, when the saturation fraction of appropriate installations has been achieved. At this point, the market is forecast to

grow at 5% per year, slightly higher than the rate of the overall commercial boiler market growth, projected at about 4% per year. In a quarter century, this leads to sales of 20,000 units per year. By 2024, the total commercial boiler market would be projected to have grown (at 4%/year) to about 91,000, giving condensing boilers a 22% share of the market. This is probably not a bad estimate of the fraction of commercial boiler installations for which condensing boilers are cost-effective[22].

- We limit peak growth rates, the high-slope portion of the sales curve, to 25% per year. As suggested by Exhibit 7-3, sustained growth at higher rates is unlikely. Growth of high-cost products that require sophisticated installation and field efforts, and have a fairly long sales cycle, is limited by knowledge diffusion to owners. More importantly, it is limited by the number of installers and other specialists who can be trained and supervised. For comparison, the ground source heat pump market grew at about 20% - 25% per year during the late 1990s.

The projection in Exhibits 7-1 and 7-2 shows 4% growth for the first two years, followed by a ramp-up to 25% per year over five years. We show 25% annual growth for 10 years, followed by a transition back to 5% per year over a seven year period. We are confident that this projection is wrong: It would be purely coincidental if all the “stars came into alignment” to yield exactly this pattern of annual growth. However, it does illustrate the important concepts behind market transformation.

The MT scenario is considered to be an upper bound on sales growth for commercial condensing boilers. We believe that sustained growth at rates greater than 25% to 30% per year in a logistic type curve is very unlikely, based on penetration rates of other technologies, and supported by considerations of infrastructure and diffusion. Exhibit 7-3 shows market penetration rates for several consumer products. While these are not completely comparable to business purchases, they give a sense of the actual limitations in the market.

To us, infrastructure includes all of the “middle-market” participants, such as manufacturers’ marketing and field staff, independent representatives, specifying design engineers, and mechanical contractors. It is the knowledge, experience, and attitudes of the design engineers, contractors, and building owners involved in selecting equipment. As discussed in later chapters, there are limits to the speed with which these people become supporters of any new technology, because it takes time to get them the information they need. We believe that efforts to grow markets at rates greater than 30% per year are self-correcting, in the sense that the rates of bad results rise (because, for example, installation or design errors by inexperienced workers increase). This spreads bad news, which dampens enthusiasm.

Developing a sustainable market requires persistence (multi-year efforts). Market transformation for expensive equipment that has low visibility to decision makers will require patience and persistence. Third parties will need to strongly signal that they are in the market for the long haul, to counter fears of “false markets” that are driven by rebates or other incentives. The third parties will be well advised to invest in infrastructure, because the manufacturers and their middle-market allies do not have the resources to carry the burden alone. The first few years will largely be spent developing a supportive infrastructure: training technicians, getting design tools to engineers, developing case studies that convince owners, etc. This process is analogous to the evolution of a road. It might start unpaved, as a one-lane gravel path with fords at streams. A small amount of traffic can pass, at low speed. If a decision is made to upgrade the road to all-weather standards, with bridges, pavement, and shoulders, traffic flow will not improve until the

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[22] The scope of this project did not allow the cost-effectiveness simulations required to test this hypothesis, beyond the work done for the case studies.

improvements are completed. This may take a couple of years. That is why our market transformation scenario does not begin any acceleration (by 1%) until the second year, and postpones significant growth until at least the second year.

A second reason for limiting growth rates is to avoid the impression in the marketplace that CEE or its members are creating a "false market," one that is sustained only by financial incentives that may be terminated at any time. Under these conditions, manufacturers are unlikely to invest significantly in new product development. Instead, they are likely to buy and re-badge (private label) equipment from Europe, where the condensing boiler is said to be more mature. That strategy protects market share at the least investment, although it may not be the most profitable strategy.

7.5 Summary

90% of boilers are residential size (<300,000 Btuh); only about 35,000 commercial units are sold each year in the US. Condensing boilers are a very small fraction (about 2%) of the total boiler market. By weighing two lines of evidence, we conclude that the 1999 market for commercial scale condensing boilers was about 700 +/- 250 units/year. We estimate that sales of smaller condensing boilers are about 7000 +/- 700 residential units sold in 1999.

The growth rate of the commercial boiler market in the US has been modest, and is projected to remain low. We project 4% annual growth of the condensing boiler market in our baseline scenario.

The price differential for commercial-scale condensing boilers is large, generally at least twice the cost of base boilers that meet Federal standards. At residential sizes, the price differential is smaller: 1.5x for one manufacturer, and thought to be comparable for others.

Our baseline (lower bound) scenario would lead to commercial condensing boiler sales of about 1,530 units per year in 2020, given 4% annual growth increments.

Our fully supported (upper bound) market transformation scenario is built on an imposed logistic-like growth curve, with annual increments gradually increasing from baseline to 25% per year, and then falling back to baseline in 2015. In this scenario, sales would grow to about 22,600 units per year in 2020, about 28% of the estimated market for about 77,000 units at that time. Market transformation for expensive equipment that has low visibility to decision makers will require patience and persistence. Third parties will need to strongly signal that they are in the market for the long haul, to counter fears of "false markets" that are driven by rebates or other incentives. The third parties will be well advised to invest in infrastructure, because the manufacturers and their middle-market allies do not have the resources to carry the burden alone.

Chapter 8: Market for Condensing Boilers in Schools

8.1 Background

This chapter considers the opportunities for increasing installations of condensing boilers in schools. This segment was chosen because schools are a large market. Between near-term demographic growth and a renewed focus on school construction and renovation, increasing amounts of money are being allocated for school construction. Indeed, New England utility members of CEE report that schools (K-12) are already an important early market for condensing boilers there.

It is easier to penetrate an expanding market with a new technology than a static or declining market, since individual actors are less focused on protecting market share when the market is growing. Our goal in this section is to show that a value proposition can be established that will lead school decision makers to select condensing boilers to meet heating needs. For several reasons, schools have a good match to condensing boiler attributes. School owners (generally elected or appointed school boards dominated by laymen) often take a long-term economic perspective, which leads to understanding life cycle costs. Public schools generally have access to low-interest, tax-free bonds for construction including renovation. In many cases, school owners want to "walk the walk," choosing systems that support the environmental stewardship and energy efficiency lessons taught in many curricula. For school owners, accountability thus takes a broad meaning, rather than a more narrow profit and loss focus. Of course, this also means that system reliability, low maintenance costs, and similar attributes are an important component of the value proposition.

Finally, we will attempt to show that both the traditional and the emerging ways that schools purchase services lend themselves to adoption of commercial-scale condensing boilers. In the traditional procurement model, it turns out that HVAC and energy design services are typically provided to most school systems in a region by a relatively small number of design engineering firms that specialize in the school market. Reaching them has powerful leverage. In the new model, schools are sometimes built by private firms to be leased by school boards. More frequently, ESCOs provide energy services, including the equipment. If these firms are convinced that condensing boilers will help them make money and not jeopardize client relationships, they can be very powerful agents of change.

Schools are a relatively large commercial market. There are more than 110,000 elementary, middle, and high school buildings nationwide[1], with 73% built before 1970, with an average age of 42 years[2]. Of these, 77,000 were built before 1960, and 28,000 are considered to have inadequate HVAC systems[3].

The biggest advantage of the schools market is its tight focus. There are relatively few decision-makers and decision-influencers. Values are consistent with condensing boiler advantages. While the market for heating equipment in schools is very large, the market for boiler heating systems is relatively small. In Chapter 12 we estimate that the total school boiler market is about 2,000 units per year, based on the number of school construction projects and the fraction of schools with

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[1] Source for the figure of 110,000 buildings: "EnergySmart Schools", Briefing July 30, 1998 by Dan Reicher, Assistant DOE Secretary for Efficiency and Renewables. Many schools have multiple buildings.

[2] http://www.eren.doe.gov/energysmartschools/about_stat.html

[3] Source: "EnergySmart Schools", Briefing July 30, 1998 by Dan Reicher, Assistant DOE Secretary for Efficiency and Renewables.

boilers. We believe that this total market, and its relatively high inferred concentration in the Northeast and New England, is an appropriate focus for an initial market transformation effort.

8.2 Methods - What we did

Our work was based on web-based research, individual interviews of market participants such as boiler manufacturers, consulting engineers, and utility marketing representatives, and a review of available literature. Among the more important resources available on the web were the following:

- The US Energy Information Agency (EIA), web site, http://www.eia.doe.gov. The EIA is a semi-independent statistical agency within the Department of Energy (DOE). It compiles comprehensive energy price, supply, and consumption data. Its products include the Residential Energy Consumption Survey (RECS) and the Commercial Buildings Energy Consumption Survey[4], (CBECS). We used CBECS for basic statistics and the distribution of heating equipment in buildings. CBECS 1995 is comprehensive, but much of the data on equipment cannot be broken out by building type.
- The US Department of Energy EnergySmart Schools web site[5], which has a great deal of general information, although little baseline data on performance.
- The Pacific Northwest National Laboratory "EE/BTS Test Site[6], which includes an elegant reconnaissance tool called the Commercial Buildings Energy Consumption Tool[7]. This is a simple tool for estimating end-use consumption in commercial buildings (based on a subset of CBECS). This tool allows the user to define a set of buildings by principal activity, size, vintage, region, climate zone, and fuels (main heat, secondary heat, cooling and water heating), and then view the energy consumption and expenditure estimates in tabular format.

Another major resource is an annual compendium in a trade magazine: the 2000 Construction Report, in School Planning & Management Magazine[8]. Finally, the Geothermal Heat Pump Consortium, the "champion" for another emerging technology, has worked to encourage adoption by schools, and its experiences have relevance for condensing boilers.

8.3 Characteristics of School Buildings and Equipment

8.3.1 School Buildings

This chapter focuses on the potential of condensing boilers in schools serving students in kindergarten through grade 12. There are about 300,000 such schools in the United States. The average school building is 42 years old with 73% built before 1970[9]. Schools represent 13%[10] of

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[4] "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures." (DOE/EIA-0625, 1998) 1995 data is the latest available; the report of 1999 data is in preparation

[5] http://www.eren.doe.gov/energysmartschools/

[6] http://208.226.167.195/

[7] http://energydata.wdc.pnl.gov/webcbecs/cbecs.htm

[8] Abramson, Paul, School Planning and Management Construction Report. *School Planning and Management,* February 2000, p. 17. Published by Peter Li Publications, 330 Progress Rd, Dayton, OH 45449, <www.spmmag.com>

[9] http://www.eren.doe.gov/energysmartschools/about_stat.html

[10] The inconsistency between the building population in footnote 1 and CBECS is partially accounted for by multiple buildings on a single school campus.

the commercial floor space in the US[11]. America's schools spend more than $6 billion each year on energy. The DOE estimates that schools could save 25% of that money—$1.5 billion nationally—through better building design, widely available energy-efficient and renewable energy technologies, and improvements to operations and maintenance[12]. The cost of energy is about $100 per student per year[13], which is equivalent to about $2,000 - $3,000 per classroom per year. As is common for energy expenditures, the numbers are large, but only in the range of 5% of the loaded cost of the salary, management, and fringes for the teacher in that classroom. Thus, a proportionate investment of management time in energy decisions will not be large.

However, there is another perspective on school decision-making: In many jurisdictions, bonds approved by voter referenda are used to pay construction costs. Although the planning process has a cost discipline, many decision-makers will argue that a small increase in budget to buy much lower operating costs is beneficial, and unlikely to lead to defeat of the bonds. If successful, the savings can be expressed in the currency that matters to educators: Reasonable energy savings can be equivalent to a significant fraction of a teacher's salary for a medium sized building[14]. By investing in efficiency, scarce operating dollars can be extended[15].

Academic buildings account for 13% of commercial building space[16]. The average academic building uses 32.8 MBtu/ft^2 for space conditioning, and 17.4 MBtu/ft^2 for water heating[17]. These are respectively 135% and 200% of the comparable values for office buildings[18]. Academic buildings use somewhat more energy than the average commercial building even though they typically operate fewer hours per year.

If, as an exercise, one were to develop a prototypical school to represent all schools, its size would be in the range of 20,000-40,000 ft^2 (averaging 25,000 sq.ft [19]), with newer buildings tending to be larger than older ones. The building would have gas boilers for both space conditioning and service water heating[20]. Clearly, this is not always the case, since some schools use electric boilers and many now use packaged equipment such as rooftop "gas-pack" forced air furnaces with integral air conditioning. As another way to think about school prototypes, the Geothermal Heat Pump Consortium (GHPC) developed a screening package to allow school

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[11] Pacific Northwest National Laboratory BTS Core Data Book, Table 2.2.2. http://208.226.167.195/btscore98/core98frmset.htm

[12] http://www.eren.doe.gov/energysmartschools/about.html

[13] http://www.eren.doe.gov/energysmartschools/about_stat.html

[14] Consider an efficient system that reduces expenses from $100 to $75 per student per year. For 600 students, that would save $15,000 per year (assuming equivalent maintenance, etc).

[15] By way of example, monitored data of buildings with ground source heat pump systems suggest that common system inefficiencies (such as poor pumping controls) make it relatively easy to improve performance greatly in many schools.

[16] Pacific Northwest National Laboratory BTS Core Data Book, Table 2.2.2. http://208.226.167.195/btscore98/core98frmset.htm.

[17] N.B: The CBECS data upon which the BTS Core Data Book is built clusters collegiate with "school" in the k – 12th grade sense, so the data are not completely characteristic of k-12th grade school buildings. On the other hand, the vast majority of "educational" buildings will be k-12, so the distortion is relatively small. Pacific Northwest National Laboratory BTS Core Data Book, Table 1.3.6, http://208.226.167.195/btscore98/core98frmset.htm.

[18] Pacific Northwest National Laboratory BTS Core Data Book, Table 7.4.3, http://208.226.167.195/btscore98/core98frmset.htm.

[19] Pacific Northwest National Laboratory BTS Core Data Book, Table 2.2.7, http://208.226.167.195/btscore98/core98frmset.htm.

[20] Pacific Northwest National Laboratory BTS Core Data Book, Table 7.4.3, http://208.226.167.195/btscore98/core98frmset.htm.

officials and others to quickly check the life cycle cost advantages of different approaches[21]. It uses 5 building sizes, from 42,000 ft^2 to 160,000 ft^2 to represent its view of the range of school sizes being constructed or renovated today. This size distribution corresponds more closely to the DOE's estimates of sizes of (1997) school buildings being constructed today as shown in Exhibit 8-1[22].

Exhibit 8-1: DOE Estimates of Typical Size of New Schools

School Type	Floor Space, ft^2	Enrollment
Elementary	67,000	550
Middle	105,000	709
High	140,000	762

The difference between the CBECS size estimates ("average" of 25,000 ft^2, with wide distribution) and these may result from several factors: First, the CBECS data are historical, and the "average" school building is 42 years old[23]. It is not unlikely that newer buildings are, on average, larger. Second, the CBECS data include all academic buildings, including colleges, which may skew the distribution. Finally, the term "average" may be used for several measures of central tendency. If the population distribution is not normal (gaussian), there may be a large difference between the median (which splits the population into two groups of equal size) and the mean, which weights entries by size. The discrepancy is large because CBECS tends to use the mean and EnergySmart Schools tends to use the median.

8.3.2 Heating Equipment

We found relatively little data documenting the types of HVAC equipment in schools. As noted above, the "average" or prototype school uses natural gas boilers for both service water and heating purposes; 35% of all schools have boilers for heating[24]. However, distribution systems vary, including:

- Cast iron radiators, steam or hot water
- 2-pipe systems with unit ventilators
- 4-pipe systems with unit ventilators
- VAV (Variable air volume) systems with hot decks

This has some importance, since some systems (e.g., steam) are incompatible with condensing boilers, while others will work with them. This would be particularly true of modern systems, with forced air distribution systems that integrate space conditioning with ventilation. In this case, air volumes moved are high, but in moderate heating demand conditions, lower temperature (condensing) water can be used in the hot decks of the air handlers. In this sense, building renovation may lead to additional opportunities for condensing boilers.

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[21] "Energy-Smart Choices for Schools: an HVAC Comparison Tool" Developed by R. J. Dooley and Associates. It allows quick comparisons of schools of 5 sizes from 42,000 – 160,000 ft2, with six HVAC types (4-pipe or VAV with boiler and chiller, air source heat pumps, water source heat pumps, ground source heat pumps, and gas-fired roof-top packaged units. The program will "move" the buildings to any of about 150 locations in the US.

[22] http://www.eren.doe.gov/energysmartschools/about_stat.html

[23] http://www.eren.doe.gov/energysmartschools/about_stat.html

[24] CBECS '95 Table BC-33,

8.4 The Market

8.4.1 Market Growth Projections

According to Abramson (2000), 1999 school construction totaled $18 billion, and $23 billion is projected to be spent in 2000, a 28% increase in one year[25]. This is despite the fact that school enrollment is projected to rise only about 3% in the decade between 1998 and 2007, according to the DOE's Smart Schools program[26]. Abramson suggests that school districts are responding to economic and political factors:

- He correlates greater willingness to spend with increasing average family wealth, which leads to greater willingness to pass referenda that mean higher taxes.
- Schools have become politically popular as a cause. Some states are substantially increasing state contributions to local school construction.
- Just as the "baby boom echo" cohorts are passing from elementary to middle and high schools, the districts are finally moving from plans to actual construction, in what has been historically a continual catch-up game.

Although there is some variability among regions, school construction expenditures break out roughly as follows:

- 45% for new buildings
- 33% for building additions
- 22% for renovation

Each of these, even renovation, typically has important HVAC components. In particular, extensive additions or renovation generally trigger requirements to bring the entire structure up to current building codes. In some states, School Codes are more stringent than those for other buildings. In particular, substantial investments may be required to comply with the ventilation requirements of ANSI/ASHRAE Standard 62. The effect of this standard is to give strong encouragement to central ventilation systems, because the operating problems of classroom unit ventilators have been so large that maintenance personnel often block the intake dampers. Except in the mildest climates, these ventilation systems will require heating capability. Even some ground source heat pump systems have used gas-fired "make-up air" systems[27], and these systems are often less expensive than available heat recovery systems. Exhibit 8-2 provides a regional breakout of projected construction investments[28].

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[25] Abramson, Paul, School Planning and Management Construction Report. *School Planning and Management,* February 2000, p. 17.

[26] http://www.eren.doe.gov/energysmartschools/about_stat.html

[27] See examples such as the Lincoln (NE) elementary schools treated in Geothermal Heat Pump Consortium case studies and in ASHRAE Transactions articles by Hughes, Martin, Shonder, and their colleagues at Oak Ridge National Laboratory.

[28] Adapted from Abramson, 2000, 2000 School Planning and Management Construction Report, Table 4.

Exhibit 8-2: Projected School Construction Estimates by Region[29]

Region	States	New Construction	Additions	Renovation	% Regional Spending of National $
1	New England	40%	32%	28%	8%
2	PA, NJ, NY	21%	4%	34%	16%
3	WV, VA, MD, DE, DC	56%	25%	19%	4%
4	KY, TN, NC, SC	45%	34%	21%	8%
5	FL, GA, AL, MS	58%	28%	14%	9%
6	OH, IN, MI,	54%	33%	13%	11%
7	IL, MI, MN	40%	24%	36%	7%
8	WI, MO, IA, KS	30%	58%	11%	4%
9	AR, TX, LA, OK	64%	29%	8%	14%
10	MT, CO, NM, ND, SD, UT, WY	54%	24%	22%	3%
11	AZ, CA, HI, NV	50%	82%	22%	14%
12	AK, ID, WA, OR	54%	33%	14%	4%
National		44%	35%	21%	100%

The data in Exhibit 8-2 are presented as percentages; the total projected expenditure is $22 billion. Given that the HVAC system is typically about 15% of project costs, this represents a $3.3 billion HVAC market.

Understanding the regional variations would require state-by-state investigations. For example, it is intuitively reasonable that the rapidly growing Southeastern states (roughly, much of regions 4 and 5) would undertake higher than average fractions of new construction, it is not clear why these fractions are even higher in Region 9 (comprising the following states: AR, TX, LA, OK), unless the data are dominated by metropolitan growth in the Houston, Dallas, Austin, and similar markets.

8.4.2 Potential Condensing Boiler Share

We developed a rough estimate of the size of the boiler market in schools: Abramson[30] provides an estimate of the school's new construction market ($9.7 billion to be completed in 2000), and the distribution of costs among elementary, middle, and high schools. From his data, we computed that the total new construction budget would produce about 900 new schools nationally that first open their doors in 2000. We derived an estimate of the retrofit market by taking the standing stock of K-12 schools (about 110,000 buildings) and multiplying that number by our estimate of turnover, 3% per year. The resulting number was multiplied by an estimated fraction of schools with boilers. We used 0.5 instead of the CBEC proportion (0.35), since the older buildings are more concentrated in colder climates. This resulted in an estimate of 1,965 buildings per year. Some of these will be able to use multiple condensing boilers. If we assume that one

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[29] "% Regional spending of national $," means the percentage of the total US construction investments predicted to be made in the region represented on that row. For example, Abramson predicts that Region 1 will account for 8% of national spending of $22 billion, or $1.8 billion. Region 1=New England; 2=PA, NJ, NY; 3=WV, VA, MD, DE, DC; 4=KY, TN, NC, SC; 5=FL, GA, AL, MS; 6= OH, IN, MI; 7= IL, MI, MN; 8=WI, MO, IA, KS; 9=AR, TX, LA, OK; 10=MT, CO, NM, ND, SD, UT, WY; 11=AZ, CA, HI, NV; 12=AK, ID, WA, OR. The projections may be subject to rounding errors, and the projected values do not quite match current expenditure commitments.

[30] Abramson, Paul, School Planning and Management Construction Report. *School Planning and Management,* February 2000, p. 17.

quarter of the retrofit schools cannot adopt condensing boilers at all, because they have steam systems or other limitations, our estimate is reduced to 1,550 schools per year.

8.5 Players and Influencers

Traditionally, schools go through a multi-step process to obtain space. The customary steps usually include (although some may be omitted):

1. Needs Identification. This may be based on actual overcrowding, formal needs analysis with consultants, or the gradual emergence of need for capabilities that do not exist (such as a gymnasium for an elementary school).
2. Architect Selection. In general, the architect is selected by the Board of Education using some selection process. In some cases, there is a standing consulting agreement, and in others it is done on a project-by-project basis. The architect will select the HVAC design engineer, among other professionals.
3. Conceptual Design. This is the interaction of wants, needs, and budget, and leads to a concept that the Board feels can be sold to the community.
4. Bond Referendum.
5. Design Development and Bid Documents.
6. Bidding and Contractor Selection. Some states require separate contracts with mechanical, electrical, and other specialists, while others seek general contractors to manage the process. Almost always, contracts are awarded to the lowest bidder from a state or other list of qualified contractors.
7. Construction.

The process is time consuming. In the view of many educators, construction is not a core competency, but a frustrating diversion. Thus, they have helped pass legislation that may allow buildings to be erected to the authority's specification, and then leased to the school board. As a popular alternative, an Energy Service Company (ESCO) or utility may provide the HVAC systems under an Energy Savings Performance Contract (ESPC)[31]. In some states, including New Jersey, this approach is becoming common. Shared savings and energy savings performance contracts are discussed in greater detail in Chapter 10, on the Federal sector.

8.5.1 Players

The first and most important player is the owner. School owners (generally elected or appointed school boards dominated by laymen) often take a long-term economic perspective rather than making decisions only on the basis of first cost. Other players are design engineers and facilities staff.

- **The Owner.** The introduction to this chapter suggests that schools are often a good match to condensing boilers. School owners almost always require that life cycle cost determinations be done[32]. In addition, they often have been conditioned by state and Federal grants and loans to think in terms of values associated with investments that last, are reliable, and have decent economics. Because they expect equipment to last decades, and do not often go through retrofit cycles, even a 10-year payback can be attractive. This

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[31] These terms are more fully developed in Chapter 9, on the Federal sector.

[32] One team member for this project, Sachs, served for six years as an elected school board member in New Jersey. In addition, as Technical Director of the Geothermal Heat Pump Consortium, he supervised several efforts to expand the schools market for that technology.

has additional leverage since they can use tax-free, low-interest bonds to finance the projects. This financing decreases the impact of higher first costs relative to the value of out-year energy savings. In many cases, school owners want to "walk the walk," choosing systems that support the environmental stewardship and energy efficiency lessons taught in many curricula. Even more than government agencies, school system owners have shown themselves responsive to these values. CO_2 emissions reduction, acid rain avoidance, and similar values are important to them. For school owners, accountability thus takes a broad meaning, rather than a more narrow profit and loss focus. Of course, this also means that system reliability, low maintenance costs, and similar attributes are an important component of the value proposition. Given good support from the design team, allies, and a solid manufacturer, schools have shown themselves to be willing to be early adopters. Nationally, schools have been very prominent early adopters of ground source heat pumps, another "emerging technology[33]."

- **Design Engineer.** Whether with retrofit or new construction, and whether with traditional contract methods or an ESPC, the key player is probably the HVAC designer. The architect has high-level concerns related to HVAC, which are expressed as cost ($\$/ft^2$), mechanical space required, noise, and classroom impact. If she can be convinced that the designer's "pet" HVAC system does not threaten these values or her reputation (through cost overruns or operating problems), she usually has little further concern with the system. In contrast, the HVAC designer may have a strong professional interest in innovation for its own sake. As discussed also in Chapter 9 (Office Buildings), Janda[34] has shown that a relatively small fraction of design engineers are likely to evaluate, adopt, and persist with emerging technologies. The designers who are likely to encourage early adopters are the ones whose practice focuses on mid-sized, semi-custom buildings such as schools and offices (as opposed to smaller and cookie-cutter applications, or very large and complex hospitals and skyscrapers). Within this group, Janda has also shown that those engineers who are driven by professional values (peer esteem, etc.), rather than, the bottom line are the most likely to bring emerging technologies into their portfolios. These engineers are the most likely to see and present the advantages of condensing boilers to customers. For some, application of emerging technologies to appropriate clients is a way to differentiate their practices. For others, innovating is a way to show excellence as engineers, and they are likely to enthusiastically adopt condensing boilers[35]. Although Janda did not speculate on the point, we believe that these advocates are likely to be participants in ASHRAE technical committees, and in other activities that give them the professional exposure and esteem that they value. It is important to most designers that the technology be well supported. In part, this means availability of the tools and references he sees for mainstream technologies: good articles in the journals he reads, accessible design software, good guide specifications, and confidence that the vendor's equipment will work without problems – and that the vendor will stand behind it if there is trouble.

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[33] See, for example, case studies posted at <www.ghpc.org>.

[34] Janda, Katherine, 1998. Building Change: Characteristics of design firms and their effect on energy efficiency adoption. 1998 ACEEE Summer Study on Energy Efficiency in Buildings: Energy Efficiency in a Competitive Environment.

[35] As an anecdote, when Sachs attended a condensing boiler training class offered by a manufacturer, several of the participants were experienced ground source heat pump system designers. Both condensing boilers and ground source heat pumps are emerging technologies that appeal to the same constituencies.

- **Facilities staff.** One of the overlooked potential champions for improved HVAC, particularly for building additions and retrofit projects, is the building engineer and the school district facilities staff. If they are opposed to it, innovations like condensing boilers will have a much harder path; if they become advocates, they can be very influential. After all, if the system is adopted on their recommendation, they will work hard for its success. In our experience with the commercial sector market transformation, we have never found a participant who felt that he had invested too much in working with the facilities people, who are the day-to-day owners.

- **New *vs.* Retrofit School Markets.** Broadly speaking, these markets are rather similar, involving similar decision processes and players. As seems to have been the experience in New England to date, retrofit may be an even better opportunity than new construction in the schools market. Usually the scope of a retrofit project is somewhat more limited than new construction, so the owner can allocate more time to considering HVAC issues. If the owner is determined to only replace his steam boilers, there is no opportunity. If the entire HVAC system is to be brought to modern standards, condensing boilers can show real savings as lead boilers. With some designs, supplying the lowest temperature supply water to the incoming ventilation air, it may be possible to use condensing boilers exclusively, since the return temperatures can stay in the condensing range. Low temperature water can often be cooled further by using it in a snowmelt system. In the most favorable situation of a "gut-rehab(ilitation)" project or new construction, design with radiant floors will guarantee utility of condensing boilers.

8.5.2 Influencers

CEE uses the term *influencers* to refer to external agencies that shape the market. That is, those who are not part of the value chain for sales, but whose actions influence the market. Examples include utility programs, public sector programs, and Federal and state standards.

- **Utility Programs.** The Waltham High School case study (Chapter 6) shows that schools can have reasonable paybacks without utility incentives such as rebates. Utility information programs, including design assistance, thus may suffice for public sector buildings. In these cases, the owner may be convinced of the benefits if it appears that the product is well supported, well backed by the utility, and will achieve the reliability and economic benefits promised.
- **Public Sector Programs** could be very important in raising visibility of condensing boilers for school systems. As Moore pointed out in 1991[36], there is an essential paradox in moving emerging technologies beyond early adopters to the mainstream market: The mainstream demands that the product be "surrounded" or fully supported by a complete infrastructure of informed designers, good design tools, case studies, and peers who have praised the product. The emerging product has none of these attributes, and does not have the cash flow to support them. NYSERDA, as a result of a competitive solicitation, proposes to launch a program to construct this infrastructure for another emerging technology, commercial heat pump water heaters; the model could well be adapted to condensing boilers by CEE or others.
- **Building Codes** are important influencers. In particular, ASHRAE/ANSI 90.1 (energy performance) and 62 (ventilation for indoor air quality) will have important effects. Standard

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[36] Moore, G. A., 1991. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers.* HarperBusiness.

90.1 is interpreted as requiring specified levels of performance, but allowing attainment options. Creative designers with good simulation programs may specify very efficient equipment to allow relaxing stringent requirements in other areas, such as glazing. Excellent case studies and journal articles could effectively illustrate this process, and raise the popularity of condensing boilers with architects as well as designers. Similarly, Standard 62 places great responsibility on the designer to provide enough ventilation air, which must be heated (and often humidified) in winter, and cooled (and dehumidified) in summer. Because of the internal gains of buildings, the balance point at which heating is required may be much less than 55°F. This means that the water used to warm ventilation air can be returned to the boiler at condensing temperatures, so the potential efficiency of the condensing boiler can be realized throughout the heating season.

- **Mandatory National Equipment Standards** such as those implemented under EPAct are unlikely to play a role in the evolution of the condensing boiler market for heating for a number of years. At this point, there simply are not enough manufacturers with enough market penetration to make a strong case for an efficiency floor that would require condensing boilers. In addition, the technical discussion in Chapter 7 has shown that the most likely early application is as lead boilers in lead-lag configurations. Thus, to the extent that our arguments are correct, economics favor *not* pushing non-condensing boilers out of the market. In many respects, the complexity of this situation resembles that of the water heating market. When DOE proposed a standard that would have removed electric resistance boilers from the market, the manufacturers and their allies were able to show many situations in which the alternative heat pump water heaters were inapplicable or too expensive to install. Because DOE can regulate manufacture but not application, this kept DOE from establishing the proposed regulations at that time. In contrast, standards for voluntary regional or national programs may have an important role.

8.6 Barriers

We find the following major barriers to greater penetration of condensing boilers in schools:

- **Cost**. Economics and EIA projected natural gas prices do not provide a compelling argument to owners considering boiler purchases today. Typical paybacks are greater than five years, but may still be attractive to school owners, who care greatly, in many cases, about life cycle costs.
- **Notification**. Too many utility representatives and others who would support installation of condensing boilers do not hear about projects until after the specifications are fixed in the design. The best way to reduce this barrier may be to subscribe to services called “construction alerts” that systematically poll Architectural and Consulting engineering (A&E) firms and/or owners to advise clients of upcoming projects.
- **Learning curves**. For best results, the system downstream of the boiler needs to be designed with efficiency in mind. This does not only include the shell, but low-temperature radiation that allows condensation all or almost all the time. Of course, this raises costs further (for the additional heat transfer surface required), and tends to compound the perceived economic barrier. Of course, it is also a problem for the engineer who has to learn new ways to work.

All of these barriers are significant in the schools market, but less so than for commercial office buildings. These barriers may not offset the advantages that condensing boilers offer to schools in life cycle cost, efficiency, low emissions, installation flexibility, and reduced space requirements, offering hope that a schools-oriented program may succeed.

8.7 Summary

Condensing boilers match school needs and values better than those of any other sector studied. Schools demand reasonable payback and excellent service. Because of their access to tax-exempt financing, they can accept higher first costs if the life cycle costs are lower than those of the alternative heating systems. Condensing boilers fit well with the environmental values schools teach, and administrators and other decision-makers like to “walk the walk” by making decisions that are consistent with values.

The only drawback to the schools market is that its small size (estimated at about 2,000 units/year nationally) means that it should be considered a first segment, but one that is not large enough to build a robust industry to sustainability. School buildings are also sized well for multiple condensing boiler applications, with an average school needing on the order of 10 million Btuh of heating capacity. The opportunity is concentrated in New England and contiguous northeastern states with high concentration of older buildings needing retrofit, low air conditioning use, and traditions of hydronic heating.

Success will require building a “virtual” or real infrastructure of committed people who have the tools needed to show schools that condensing boilers make sense for their applications. These tools include robust software for design, good guide specifications for selection and contract wording, and connections to peers who have had positive experiences with the product. Virtual contact through case studies, journal articles, and presentations to professional meetings is part of this process.

If CEE or others launch a schools program, one of its first actions should be to subscribe to a school construction alert service[37] on behalf of its members. These services systematically poll A&E firms and/or owners to advise clients of upcoming projects, and provide the information to equipment vendors, general and specialty contractors, and others on a subscription basis.

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[37] Such as Market Data Retrieval, A company of The Dun and Bradstreet Corporation, 1 Forest Parkway, P.O. Box 907, Shelton, CT 06484-0947

Chapter 9: Market for Condensing Boilers in Office Buildings

9.1 Background

This chapter considers the opportunities for increasing installations of condensing boilers in office buildings smaller than 100,000 square feet. This size range was selected for the following reasons:

- The vast majority (98%) of office buildings are found in this size range
- As buildings get larger, the internal heat gains predominate, eliminating the need for space heating boilers.

The total commercial office buildings segment is very large, with more than 700,000 buildings, or 18% of commercial floor space. However, the overall office buildings market is projected to grow slowly for the next two decades. New construction is attractive, as it is relatively easy to design for high quality features (such as in-floor radiant heat) that are well matched to the need of condensing boilers for low return water temperatures. However, as internal loads continue to grow, there may be less opportunity for advanced boilers in new commercial construction, because the remaining heating loads become progressively less important to designers. The retrofit market is potentially very large, but each installation will require systematic evaluation. Unless there is excess installed radiation surface area, so return water temperature can be dropped to condensing levels, or unless the retrofit includes redesign of the distribution system, opportunities will be relatively limited. Condensing boilers may serve best where designers understand the potential of lead-lag installations. We conclude that there are relatively few office buildings (outside the Federal sector) for which a compelling value proposition can be made for installing condensing boilers.

According to an interactive "scoping" tool developed by Pacific Northwest National Laboratory[1] for analysis of the EIA Commercial Building Energy Consumption Survey (CBECS)[2], the office sector less than 100,000 ft^2 can be characterized as shown below in Exhibit 9-1.

Exhibit 9-1: Some Characteristics of Office Buildings

Office Buildings by Size	Floor Area of Natural Gas Heated Buildings *Square Feet /Building*	Floor Area of Oil Heated Buildings *Square Feet /Building*	Floor Area of All Office Buildings *Avg. Sq.Ft/Bldg.*
1001-100,000 ft^2	3,441,000; *8,900 /bldg*	356,000 *6,000 /bldg*	6,415,000 *9300/bldg*
5001 - 100,000 ft^2	2,836,000 *18,800 /bldg*	249,000 *10,800 /bldg*	5,331,000 *18,000 /bldg*

First, note that natural gas serves approximately ten times more buildings than oil, whether we use 1000 ft^2 or 5000 ft^2 as the lower size limit. Second, the average gas-heated building is 50-75% larger than the average oil-heated building. We infer that the oil market is dominated by buildings that do not have gas service (rural installations), and suspect that these buildings are, on average,

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[1] <http://energydata.wdc.pnl.gov/webcbecs/cbecs.htm

[2] http://www.eia.doe.gov/emeu/cbecs/contents.html

older than the gas heated buildings.

The CBECS tool does not differentiate office building HVAC systems within the "commercial" category. Thus we assume that office buildings are similar to all commercial buildings in terms of HVAC systems. Among our reviews of the opportunities in the office (and Federal buildings) segment, apartments, and schools, we try to identify for CEE most of the important market player and influencer categories, and most of the barriers to increased market penetration.

This chapter focuses on office buildings in the non-Federal parts of the market. To the extent that the data allow, we focus on the potential of condensing boilers in buildings smaller than 100,000 ft^2. This includes government, institution, and private sector ownership and use. In Chapter 10 we discuss ways to approach the Federal (military and civilian) markets. These are very large, but the procurement channels available offer different opportunities from those in most other sectors.

9.2 Methods – What we did

Our work was based on web-based research, individual interviews of market participants such as boiler manufacturers, consulting engineers, and utility market representatives, and a review of available literature.

Among the more important resources available on the web were the following:

- The US Energy Information Agency (EIA), web site, http://www.eia.doe.gov. The EIA is a semi-independent statistical agency within the Department of Energy (DOE). It compiles comprehensive energy price, supply, and consumption data. Its products include the Residential Energy Consumption Survey (RECS) and the Commercial Buildings Energy Consumption Survey[3] (1995 data is the latest available; the report of 1999 data is in preparation). We used CBECS for basic statistics and the distribution of heating equipment in buildings. CBECS 1995 is comprehensive, but much of the data on equipment cannot be broken out by office buildings.
- The Pacific Northwest National Laboratory "EE/BTS Test Site"[4], which contains an elegant reconnaissance tool called the Commercial Buildings Energy Consumption Tool[5]. This is a simple tool for estimating end-use consumption in commercial buildings (based on a subset of CBECS). This tool allows the user to define a set of buildings by principal activity, size, vintage, region, climate zone, and fuels (main heat, secondary heat, cooling and water heating), and then view the energy consumption and expenditure estimates in tabular format.
- The *"Annual Energy Outlook 2000"* (EIA, Washington) is perhaps the most thoroughly documented, independent, projection of energy prices into the future.
- The Federal Energy Management Program, accessed through the DOE Energy Efficiency and Renewable Energy home page, http://www.eren.doe.gov. The emphasis of this site is on programs and opportunities rather than data.

We did not find a broad and well-documented set of summaries on HVAC in office buildings, but other emerging technology market transformation efforts have been active in this area. We would

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[3] "A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures." (DOE/EIA-0625, 1998)

[4] http://208.226.167.195/

[5] http://energydata.wdc.pnl.gov/webcbecs/cbecs.htm

note particularly a review of the Federal civilian sector was written several years ago for the Geothermal Heat Pump Consortium, *"Potential for Geothermal Heat Pumps in the Federal Civilian Buildings Market*[6]*."*

To better understand the market structure of the sector, we also interviewed specialists, querying them about players, influencers, and barriers to greater utilization of condensing boilers for office buildings. We also drew upon our own professional experience in market transformation for this sector.

9.3 Characteristics of Office Buildings and Equipment

9.3.1 Office Buildings

This chapter focuses on the potential of condensing boilers in office buildings smaller than 100,000 ft^2 in the non-Federal segments of the commercial buildings sector. By default, this includes private sector, institutional, and state/local government buildings (in this report, we evaluate schools separately).

The following items from CBECS help focus attention on the real opportunities in the commercial sector:

- There are about 705,000 office buildings in the US, comprising some 10 billion square feet of space, or 18% of commercial buildings space[7]. The aggregate annual energy consumption of office buildings is about 1 quad. EIA projects very slow growth in the office market segment, about 0.9 percent a year between 1998 and 2020 compared with an average of 1.5 percent a year over the past two decades[8].

- The average office building encloses 15,000 ft^2, smaller than the average of 25,000 ft^2 for education buildings, but somewhat larger than the average commercial building of all types (12,400 ft^2).

- The average pre-1980 office building used 98.2 MBtu/ft^2 of on-site energy, while the average 1990-1995 office building used 85.5 MBtu/ft^2. The 12% improvement was typical for the commercial sector[9].

- Natural gas is clearly the fuel of choice for heating commercial buildings as shown in Exhibit 9-2. It is used in almost twice as many installations as the second choice, electricity (56% vs. 29%), and more than six times as frequently as oil (56% vs. 9%).

- Offices use 11% more energy per square foot than the average for all commercial buildings (100,000 Btu/ ft^2 vs. 90,000 Btu/ ft^2). However, only one sector with lower energy intensity, service and merchandise (stores), has lower intensity of use and comparable or greater operating hours. Only 24.3 MBtu/ft^2 was used for space heating, which ranked third to lighting (28.1) and miscellaneous (27.0).[10]

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[6] Geothermal Heat Pump Consortium, Washington, document RP-008. <www.ghpc.org>

[7] *BTS Core Databook:* Table 2.2.2. Pacific National Laboratory, web site 208.226.167.195

[8] http://www.eia.doe.gov/oiaf/aeo/demand.html#comm

[9] *BTS Core Databook:* Table 1.3.10. Pacific National Laboratory,

[10] *BTS Core Databook:* Table 1.3.6. Pacific National Laboratory,

Exhibit 9-2: Heating Fuels in Office Buildings

Building Type			Heat Source				
All Data from CBECS Table BC-23	All Commercial Buildings[11]	All Heated Buildings	Electricity	Natural Gas	Fuel Oil	District Heat	Propane
No. of Commercial Buildings (thousands)	4,579	4,024	1,007	2106	439	107	260
No. of Office Buildings (thousands)	705	704	204	391	60	20	small
% of Buildings Heated by Heat Source Indicated			22%	**46%**	9%	2%	

9.3.2 Heating Equipment

Compared to commercial buildings as a group, US office buildings are about as likely as others to have boilers, as seen in Exhibit 9-3. On the other hand, office buildings are twice as likely as others to have heat pumps installed (35% vs. 17%)[12]. From CBECS 1995 Table BC-1, the average size of a building heated with boilers is about twice as large as a heat pump building (27,500 ft^2 vs. 14,800 ft^2), which is intuitive: Office buildings tend to be larger than average commercial buildings, and the larger office buildings tend to use boilers in preference to heat pumps. CBECS does not differentiate between steam heat and hot water heat distribution. It also does not differentiate between boilers used for heat and reheat in forced air distribution systems, vs. boilers used with radiators.

Exhibit 9-3: Heating Equipment in Office Buildings*

Building Type			Type of Heating Equipment						
All Data from CBECS Table BC-23	All Buildings	All Heated Buildings	Heat Pumps	Furnaces	Individual Space Heaters	District Heat	Boilers	Packaged Heating Units	Other
All Buildings	4,579	4,024	394	1,676	1,188	115	610	1,031	161
Offices	709	704	136	245	148	21	118	229	20
% of Office Buildings with Heating System Indicated		17%	35%	15%	12%	18%	**19%**	22%	12%
% of Buildings with Heating System Indicated		17.5%	3.4%	6.1%	3.7%	0.5%	2.9%	5.7%	0.5%

** Exhibit shows that 19% of office buildings use boilers for space heating*

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[11] From Table BC-3, CBECS '95

[12] In contrast, Canadian data suggest the following: Of 30,000 office buildings smaller than 108,000 ft^2 (527 million square feet) 24% have electric baseboard, 19% have gas boilers, 12% have gas forced-air ducted, 10% have electric forced air, 9% have oil boilers, and 6% have electric boilers *(A ranking of Commercial and Industrial Energy-Using Equipment, Centre de recherche industrielle du Quebec, October, 1994, Natural Resources Canada*

From the data in Exhibits 9-2 and 9-3 we can draw some inferences about HVAC in office buildings.

- First, the relatively high saturation of heat pumps (35%) reflects the high saturation of forced air systems in commercial buildings. In larger buildings, forced air systems may use boilers in one of two ways: (1) directly supporting radiators, which is prevalent in older buildings and as perimeter baseboard radiation in some newer buildings, and (2) providing hot water to heating coils in central forced air systems.
- We believe that rooftop "gas-pack" forced air furnaces, a less expensive installation, dominate the mid-sized low-rise commercial buildings market.
- We believe that gas furnaces with split air conditioners dominate in smaller buildings built in the last few decades.

Thus, the potential retrofit market for condensing boilers is probably centered on two classes of buildings:

- Relatively large office buildings, particularly with government or institutional owners.
- Owner-occupied older buildings may be an important secondary target.

The best opportunities in new office buildings are likely to be "high-end" structures in which the HVAC designer has separated the ventilation and space conditioning functions. In these buildings, there will often be hydronic heating, which is superbly adapted to the use of condensing boilers. These will be a niche market, typically owner-occupied structures.

9.4 The Market

9.4.1 Market Growth Projections

According to the *Annual Energy Outlook 2000:*

> "Projected energy use trends in the commercial sector show stable shares for all fuels, with growth in overall consumption slowing from its pace over the past two decades… Slow growth (0.8 percent a year) is expected in the sector, for two reasons. Commercial floor space is projected to grow by only 0.9 percent a year between 1998 and 2020 compared with an average of 1.5 percent a year over the past two decades. Lower growth in floor space reflects the labor force growth expected later in the forecast. Additionally, energy consumption per square foot is projected to decline by 0.1 percent a year, as a result of efficiency standards, voluntary government programs aimed at improving efficiency, and other technology improvements[13]."

Commercial floor space growth is projected to be from 61.2 to 73.8 billion square feet [14] between 1998 and 2020

However, EIA also projects:

> "Electricity accounts for three-fourths of commercial primary energy consumption throughout the forecast. Expected efficiency gains in electric equipment are offset by continuing penetration of new technologies and greater use of office equipment. Natural gas accounts for 20 percent of

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[13] http://www.eia.doe.gov/oiaf/aeo/demand.html#comm

[14] http://www.eia.doe.gov/oiaf/aeo/images/figure_51.jpg

> commercial energy consumption in 1998 and maintains that share throughout forecast. Distillate fuel oil makes up only 2 percent of commercial demand in 1998, down from 6 percent in the years before deregulation of the natural gas industry. The fuel share projected for distillate remains at 2 percent in 2020, as natural gas continues to compete for space and water heating uses[15]."

And,

> "The highest growth rates are expected for end uses that have not yet saturated the commercial market. Energy use for personal computers grows by 2.4 percent a year and for other office equipment, such as fax machines and copiers, by 2.1 percent a year. The growth in electricity use for office equipment reflects a trend toward more powerful equipment, the response to a projected decline in real electricity prices, and an increase in the market for commercial electronic equipment. Natural gas use for such miscellaneous uses as cooking, district heating, and self-generated electricity is expected to grow by 0.9 percent a year[16]."

From these paragraphs, it becomes hard to project rapid growth in the office buildings sector for commercial-scale boilers. In particular, we must consider the growth of "free heating" from the electric energy dissipated by the increasing amounts of office equipment installed[17]. The effect of these heating sources is to push down the building balance point, the outside temperature at which there is the first heating call to the thermostat. As heating becomes a smaller fraction of the building energy demand, the designer will predict that the boiler will be dispatched less often. Since savings from more efficient equipment are projected to be a smaller fraction of the energy budget, owners and designers may tend to pay less attention to it.

9.4.2 Potential Condensing Boiler Share

We believe that condensing boilers of commercial scale will account for a small fraction of all boilers installed in office buildings. In addition to the arguments above with respect to the declining share of the office building energy budget represented by heating, the economics do not look overwhelmingly attractive. Consider the example from Chapter 7. Assume the CBECS average 15,000 ft^2 building with heating energy intensity of 24,300 Btu/ft^2-year. Assume that its boiler has a seasonal average efficiency[18] of 50% (that is, the efficiency of fuel conversion, as seen by the heat distribution system over the heating season). In this case, the distribution system would receive 12,250 Btu/ft^2-yr. This demand could be met with a condensing boiler system whose seasonal average efficiency was 80% by using only 15,200 Btu/ft^2 delivered to the boiler, a savings of 9100 therms, or $750/year at $0.55/therm. This is likely to have a payback longer than 8 years, which is unlikely to be attractive to private sector office building owners. For commercial-scale boilers, the incremental cost is likely to be much greater.

We thus conclude that office buildings in the commercial sector are unlikely to be high priority targets for a market transformation program. This does not exclude the possibility of programs directed toward public sector offices, for which different arguments may be compelling.

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[15] http://www.eia.doe.gov/oiaf/aeo/demand.html#comm

[16] http://www.eia.doe.gov/oiaf/aeo/demand.html#comm

[17] Of course, despite the success of the Energy Star and other programs, office equipment is not as efficient as it might be. In projecting future heat contributions from office equipment, there is a need to balance the net result of increasing penetration of electricity using devices, but increasing efficiency for these products.

[18] Seasonal efficiency includes cycling and standby losses.

9.5 Players and Influencers

9.5.1 Players

The first, and most important, player is the owner. The owner's interest in the potential for condensing boilers varies greatly across office building ownership types. The following is a generalized ranking of small-to-moderate sized office building owners from most interested to least interested:

- **Owner-occupied retrofit.** This is likely to be one of the more likely targets in these buildings. In this segment, the building owner pays the energy bill. In a retrofit situation, his full attention is focused on the equipment and mechanical system, giving more opportunities to talk about values. Also, in a retrofit the ability to reclaim boiler room space by removing oversized equipment and replacing it with new, smaller, units can be compelling.
- **Government owner-occupied, retrofit.** As discussed in Chapter 7, legislation and executive orders now allow Energy Service Companies (ESCOs) to make capital investments that save energy in Federal facilities. An ESCO might install condensing boilers in some buildings in this size range, but only as part of a much larger, base-level or campus-level program. ESCO contracts tend to run larger than $1 million, which is beyond the cost of retrofitting most buildings in this size class. Less is known about state and local government facilities (except schools, treated separately in this report), but we would offer one suggestion: In moderate-sized towns and cities, there are often close working relations between design firms and government clients. In these situations, the designer (see below) may find a willing audience in the government for this emerging technology.
- **Private owner-occupied, new construction.** If the firm has a close connection to the construction industry, or otherwise has a mission that stresses energy or the environment, the HVAC system may be "visible" to the owner. This occurs when she wants to showcase the building for customers or the community[19]. Otherwise, it is generally a small consideration, dwarfed by space, layout, features, and aesthetics. Since the mechanical system represents only a few percent of the cost of the building, mainstream owners will not allocate much time to it. They will, however, rely on the design engineer (below).
- **Private owner, leased space.** Historically, energy efficiency has rarely been an important element of the decision "space" for developers. They have been perceived as interested in lobby aesthetics and increasing the number of corner offices, not better boilers (or windows, for that matter). Particularly when the tenant pays the energy bills, these developers are unlikely to adopt condensing boilers in competitive markets, absent a strong policy environment that would give them compelling reasons. Such an environment might be one in which energy codes or utility tariffs give buildings tight energy budgets, but allow the designer trade-offs. For example, a better boiler in a northern climate might allow more windows, which would provide amenity that the owner desires.

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[19] An example would be a gas utility adopting absorption or engine-driven chillers and condensing boilers for its headquarters or a training facility.

Other players in the design process include:

- **Design engineers**. Janda[20] has shown that a relatively small fraction of design engineers are likely to evaluate, adopt, and persist with emerging technologies. The designers who are likely to encourage early adopters are ones whose practice focuses on mid-sized, semi-custom buildings such as schools and offices (as opposed to smaller and cookie-cutter applications, or very large and complex hospitals and skyscrapers). Within this group, Janda has also shown that those engineers who are driven by professional values (peer esteem, etc.) rather than the bottom line are the most likely to bring emerging technologies into their portfolios. These engineers are the most likely to see and present the advantages of condensing boilers to customers. For some, application of emerging technologies to appropriate clients is a way to differentiate their practices. For others, innovating is a way to show excellence as engineers, and they are likely to enthusiastically adopt condensing boilers[21]. Although Janda did not speculate on the point, we believe that these advocates are likely to be participants in ASHRAE technical committees, and in other activities that give them the professional exposure and esteem that they value.
- **Manufacturers and their representatives.** The condensing boiler is the flagship product for companies that manufacture or sell them. There is pride (and, we expect, substantial profit) in successful customer installations. Manufacturers and their representatives want to sell these products, and they want to show their successes to other customers. They will be strong advocates. However, other players and influencers must understand that manufacturers' representatives are and must be opportunists: They will sell to the market segments that are most receptive. If they are selling one tenth of their condensing boilers to offices and 80% to schools, they will allocate resources almost entirely to incremental sales in the schools market. And, of course, vice versa. At the present time, we believe that they are more likely to focus on sectors (such as schools) where they can build on successes. Given our estimate of economics, we do not expect private sector offices to be a primary target for them.
- For smaller office buildings, the **mechanical contractor** is the key player. As discussed in the chapter on apartment buildings, they often have a long-standing relationship with a building owner, based on system maintenance over a period of decades. In such cases, they make the recommendations and presentations, and they install the systems, typically without competing bids. For larger buildings, the mechanical contractor generally has much less influence on the HVAC decisions, but bids from the designer's specifications.
- The **architect** is less likely to be strongly influential on medium to larger projects. For her, the most obvious advantage of a condensing boiler *in new construction* would be space efficiency: Does the system need a smaller mechanical room than alternatives, freeing more space for use. If the architect does get involved in mechanical system matters, the influence may not be positive. For example, the architect may insist (rarely) on a "clean" roofline without cooling towers, packaged HVAC equipment, chimneys, or other elevated mechanical features. Such buildings would be expected to use electric technologies.

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[20] Janda, Katherine, 1998. Building Change: Characteristics of design firms and their effect on energy efficiency adoption. 1998 ACEEE Summer Study on Energy Efficiency in Buildings: Energy Efficiency in a Competitive Environment.

[21] As an anecdote, when Sachs attended a condensing boiler training class offered by a manufacturer, several of the participants were experienced ground source heat pump system designers. Both condensing boilers and ground source heat pumps are emerging technologies that appeal to the same constituencies.

9.5.2 Influencers[22]

CEE uses the term *influencers* to refer to external agencies that shape the market. That is, those who are not part of the value chain for sales, but whose actions influence the market. CEE lists utility programs, public sector programs, Federal and state standards, and the Department of Energy's Federal Energy Management Program (FEMP). We consider these individually, in our guess of rank order from most to least urgent.

- **Utility Programs.** Our economic estimate suggests that few office buildings will have attractive paybacks for private sector owners. Large-scale rebates (or the equivalent in low-cost loans) that bring the payback to less than 3 years will attract many otherwise indifferent owners. Indeed, buying down to 4 years may suffice for many owner-occupied buildings. Utility information programs, including design assistance, may suffice for public sector buildings. In these cases, the risk-taking owner's representative may be convinced of the benefits, if it appears that the product is well supported, is well backed by the utility, and will achieve the reliability and economic benefits promised.
- **FEMP** activities are treated separately, in Chapter 10 on Federal facilities. FEMP can be very important in encouraging condensing boiler installations nationally.
- **Public Sector Programs** could be very important in raising visibility of condensing boilers. As Moore pointed out in 1991[23], there is an essential paradox in moving emerging technologies beyond early adopters to the mainstream market: The mainstream demands that the product be "surrounded" or fully supported by a complete infrastructure of informed designers, good design tools, case studies, and peers who have praised the product. The emerging product has none of these attributes, and does not have the cash flow to support them. NYSERDA, as a result of a competitive solicitation, proposes to launch a program to construct this infrastructure for another emerging technology, ground source heat pumps; the model could well be adapted to condensing boilers.
- **Codes and Standards** are unlikely to play a role in the evolution of the condensing boiler market for a number of years. At this point, there simply are not enough manufacturers with enough market penetration to make a strong case for an efficiency floor that would require condensing boilers. In addition, the technical discussion in this report has shown that the most likely early application is as lead boilers in lead-lag configurations. Thus, to the extent that our arguments are correct, economics favor *not* pushing non-condensing boilers out of the market. In many respects, the complexity of this situation resembles that of the water heating market. When DOE proposed a standard that would have removed electric resistance boilers from the market, the manufacturers and their allies were able to show many situations in which the heat pump water heaters were inapplicable or too expensive to install. Because DOE can regulate manufacture but not application, this kept DOE from establishing the proposed regulations at that time.

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[22] This section closely parallels the treatment in the schools segment, Chapter 8

[23] Moore, G. A., 1991. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers.* HarperBusiness.

9.6 Barriers

We find the following major barriers to greater penetration of condensing boilers in office buildings:

- **Cost**. Economics and EIA-projected natural gas prices do not provide a compelling argument to owners considering boiler purchases today. Typical paybacks are greater than five years, which is beyond consideration for the bulk of commercial building developers in the private sector.
- **Split incentives**. Too many buildings are owned by developers or landlords who do not pay the utility bills, and thus have very little interest in efficiency.
- **Occupied niches**. In some downtown locations district heating by high temperature water or steam is available as a utility. Where it is available, it competes strongly with local boilers, because it requires less mechanical space in the building. Where rents are high, as in downtown locations, any boiler room is space that could otherwise be rented. Conversely, in many suburban locations, the major competition for boilers is the low-cost option of packaged rooftop “gas-pack” combined forced-air furnaces and air-cooled air conditioners. There may be an exception for very high-quality or custom new construction.
- **Visibility**. The major HVAC focus of designers of commercial offices is the cooling load, since it will dominate operating costs in most cases. It is hard to raise the visibility of technologies that are not considered to play a large role in operating costs or customer needs.
- **Notification**. Too many utility representatives and others who would support installation of condensing boilers do not hear about projects until after the specifications are fixed in the design. The best sway to reduce this barrier may be to subscribe to services called “construction alerts” that systematically poll A&E firms to advise clients of upcoming projects.
- **Learning curves**. For best results, the system downstream of the boiler needs to be designed with efficiency in mind. This does not only include the shell, but low-temperature radiation that allows condensation all or almost all the time. Of course, this raises costs further (for the additional heat transfer surface required), and tends to compound the perceived economic barrier. Of course, it is also a problem for the engineer who has to learn new ways to work.

All of these barriers are significant in the office buildings market, and tend to more than offset the advantages that condensing boilers offer in life cycle cost, efficiency, low emissions, installation flexibility, and reduced space requirements.

9.7 Summary

The office buildings market is very large, and has very high penetration of natural gas. Gas is the space heating fuel of choice for the majority of commercial buildings (56%), with electricity a distant second. The penetration of boilers is small, at 19% compared to forced air gas systems. In addition, the heating load of the average office building is small relative to the capacity of the smallest “commercial” condensing boilers.

We believe that roof-top “gas-pack” forced air furnaces, a less expensive installation, dominate the mid-sized low-rise commercial buildings market, with gas furnaces/split air conditioners in the smaller buildings. Thus, the potential market for condensing boilers is much smaller, in the average size office building, than a forced air gas furnace.

Other than the Federal sector, the office buildings we believe are most likely to adopt condensing boilers will be in new construction, by firms that want to demonstrate advanced natural gas technologies (as a result of the natural gas industry's outreach programs). We expect this to be a small fraction of a total market that is only growing 0.9% per year.

From this discussion, we conclude that there are relatively few office buildings (outside the Federal sector) for which a compelling value proposition can be made for installing condensing boilers. Too many are owned by developers or landlords who do not pay the utility bills. For almost all, the economics fail their hurdle rate requirements. And finally, few try to market themselves in ways that build on the environmental and efficiency advantages of condensing boilers.

Chapter 10: Market for Condensing Boilers in Federal Buildings

10.1 Background

This chapter introduces the Federal sector as another potential market for condensing boilers. This segment was selected because the Federal government is the largest single user of energy and the largest landlord in the United States.[1] The Federal buildings market[2] is huge, approximately 500,000 buildings with an aggregate 3.1 - 3.8 billion square feet of space[3]. This is approximately 11% of the number of commercial buildings and 5% of its gross floor space in the US.

In terms of technology, Federal buildings' HVAC systems are considered broadly similar to those in other markets. The older district heating and cooling systems for campus-scale facilities are being phased out, and the focus now is on building-scale equipment[4].

Legislation and Executive Orders require major changes in present operations. This opens doors for emerging technologies that can establish a solid value proposition from the perspectives of efficiency and greenhouse gases. Within the Department of Energy, the Federal Energy Management Program (FEMP) has been given major responsibilities to coordinate agency responses, assist agencies, and develop tools that enable staff and outside vendors to streamline their work and improve their productivity. Because of the top-down pressure, facility managers are actively seeking to outsource energy-related programs. In their environment, buying *energy services* (equipment, energy, and often maintenance; generally through an Energy Service Company, or ESCO) can save money and increase reliability relative to their other options.

From the perspective of those who would sell equipment or provide services, Federal procurement options are rather intimidating to non-specialists more accustomed to working with commercial, institutional, and state/local government buildings. The two basic approaches are using appropriated funds, and using some form of third party ownership, such as the Energy Savings Performance Contract (ESPC) with an ESCO or utility. Some investments have also used utility demand side management funds.[5] The time scale for projects is typically longer than for non-Federal projects, sometimes several times longer.

If this were a single market that could be addressed with a specific marketing tool kit, it would be a tremendous target because of its size, willingness to use life cycle costing, and access to external financing. However, it is not homogeneous: Not only are there differences between

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[1] Executive Summary, Geothermal Heat Pump Consortium RP-008, Potential for Geothermal Heat Pumps in the Federal Civilian Sector, as posted at http://www.geoexchange.org/FederalWeb/summary.htm

[2] In this discussion, we abandon the focus of the Office Buildings segment on structures <100,000 ft^2, and consider Federal buildings without a size cutoff.

[3] Brad Gustafson, FEMP (personal communication, 3/00). Mr. Gustafson is a staff member at the Lawrence Berkeley National Laboratory, currently serving as Utility Program Manager for the Federal Energy Management Program.

[4] Millard Carr interview. Mr. Carr is a consultant and former program manager for DOD. This was confirmed by Dr. Gordon Bloomquist, Washington State University, a specialist in district heating systems.

[5] Executive Summary, Annual Report to Congress on Federal Government Energy Management and Conservation Programs, Fiscal Year 1996, FEMP, 1998. For that year, when ESPC funding was ramping up and DSM funding was declining, FEMP reported $12 million in DSM funding *vs.* $2.4 million in ESPC resources.

civilian and military markets, but within each of these different agencies have different styles. Success requires persistence and individualized approaches.

10.2 Methods – What We Did[6]

To gain some understanding of the sector, we pursued three complementary avenues: interviews with experts in this market, web-based research, and reviews of work done for another emerging technology actively trying to penetrate the Federal market. We found no single resource has all the information that would be needed to launch market transformation programs geared toward Federal facilities. Indeed, all the databases together are not sufficient for precise targeting. In particular, there is no comprehensive set of information on HVAC systems in Federal facilities. To a greater or lesser extent, individual agencies maintain their own data; access to the data by others than Federal employees is generally difficult.

All of the data we were able to find addresses existing Federal buildings. We were not able to find new construction data without access to detailed analysis of agency-by-agency authorization legislation. We believe that the new construction market is a few percent of the existing market (since the Federal government on the whole is down-sizing), and that its construction includes a relatively high proportion of special-purpose buildings such as laboratories and remote facilities. Because we believe that the potential of the retrofit market is large compared to new construction, we have not further analyzed the new construction market.

Although some smaller agencies (such as the National Aeronautics and Space Administration and the Environmental Protection Administration) maintain central buildings databases, most do not. There is also a General Services Administration (GSA) data resource for buildings GSA owns or leases for Federal agencies. The United States Postal Service (USPS) maintains its own data. There is some information in regional FEMP offices, but neither these data nor the agency data have been widely accessible. A summary of characteristics of the Federal civilian buildings was published in 1996 by the Geothermal Heat Pump Consortium for member use[7].

FEMP[8] is the principal coordinating resource for Federal action in this area. FEMP maintains the FEMPTracks database, which "…follows energy audit results and progress on action plans to see which projects are successfully implemented. Data include cost and energy savings, emissions reduction, and job creation. Reviewing the data helps track progress in meeting EPAct goals and identifies a need for additional activities or incentives. It also provides insight into the most cost-effective opportunities for future Federal energy and water conservation activities[9]."

The most comprehensive guide to building HVAC system characteristics is the Commercial Buildings Energy Consumption Survey (CBECS) carried out by the Energy Information Agency[10]. The sixth survey, the most recent for which data have been published, was carried out in 1995. CBECS considers buildings by use category rather than ownership. The commercial sector includes not only offices, but also education, food sales, food service, health care, lodging,

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[6] Except as otherwise cited, this section is based on a discussion with Brad Gustafson, FEMP (personal communication, 3/23/00).

[7] *Potential for Geothermal Heat Pumps in the Federal Civilian Buildings Market.* GHPC RP-008, summary available at <http://www.geoexchange.com/Federalweb/summary.htm>

[8] www.eren.doe.gov/femp/

[9] http://www.eren.doe.gov/femp/techassist/savenergyover.html

[10] http://www.eia.doe.gov/emeu/cbecs/contents.html.

mercantile and services (retail), public assembly, public order and safety, religious worship, warehouses and storage, "other," and vacant. Its characterization is at a very high level, such as percentage of buildings with boilers, and fraction of buildings that use natural gas as primary heating fuel.

10.3 Characteristics of Federal Buildings and Equipment

10.3.1 Federal Buildings

By themselves, Federal buildings are a very significant segment of all commercial buildings, as suggested by Exhibit 10-1.

Exhibit 10-1: Size of Federal Buildings Sector

	Commercial Sector[11]	Federal Sector[12]	Federal Share
Number of Buildings	4,579,000	500,000	11%
Square footage	58,772,000,000	3,000,000,000[13]	5%
Energy Intensity, yr.	77,480 Btu/sq. Ft.[14]	118,720 Btu/sq.Ft.[15]	

Exhibit 10-1 suggests several inferences:

- Accounting for 11% of the commercial buildings market, the Federal segment is large enough to warrant real attention. This is true if it is homogeneous enough for a coherent market approach, and if there are vehicles that encourage it to adopt emerging technologies.
- Because the Federal share of occupied space is so much smaller than the Federal share of number of buildings, we infer that the average Federal building is *smaller* than the average commercial building. In part, this may reflect the large share (25%) of housing in the Federal sector[16]. This suggests that aggregation of multiple buildings, as on a military base for Federal campus, may be an attractive option for ESCOs trying to minimize transaction costs.

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[11] Based on estimates using the CBECS "Commercial Buildings Energy Consumption Tool" developed by Pacific Northwest National Laboratory (PNNL). Estimate based on all commercial subclasses, all fuels, all vintages, and all regions.

[12] http://www.eren.doe.gov/femp/aboutfemp/98report_chal.html.

[13] Different numbers, ranging from 3 to 3.8 billion square feet, are found on the FEMP site. The number includes something less than 10% of Federal occupied leased space.

[14] From CBECS Web Gadget, http://energydata.wdc.pnl.gov/webcbecs/cbecs.htm, set for all fuels, all regions, all climates, all commercial building types.

[15] From the Summary to the 1996 FEMP Annual Report, On a Btu-per-gross-square-foot basis, the 15.2% reduction in buildings energy puts the Federal Government on track to meet the 20% reduction goal for 2000. 140,000 Btu/ft2 (the 1985 number, from http://www.eren.doe.gov/femp/aboutfemp/business_plan/environ.htm, multiplied by [1-15.2 (percent reduction)] gives 118,720 Btu/ft2. According to B. Gustafson, personal communication, 5/10/00, the Federal buildings data are based on site energy (not primary energy for electricity), so the two sets should be reasonably comparable.

[16] 1996. Potential for Geothermal Heat Pumps in the Federal Civilian Buildings Market. RP-008, Executive Summary, p. v. Geothermal Heat Pump Consortium, Washington.

- Since the data suggest that the average Federal building uses more than 50% more energy per square foot than the average commercial building, there are likely many opportunities for retrofits that yield very substantial energy savings at reasonable cost.

Clearly, this comparison is not exact, but indicative of the size and attractiveness of the existing Federal buildings market.

The Department of Defense (DOD) accounts for 70% to 80% of all Federal buildings space (square feet)[17], and 62% of the energy use in buildings[18]. On the civilian side, no single agency accounts for as much as 10% of Federal buildings energy[19]. These buildings are fairly concentrated by location: the top three states (California, Texas, and Virginia) have over ¼ of the Federal floor space, and the top ten states account for half of the total DOD and civilian space[20].

10.3.2 Heating Equipment

As noted above, FEMP sources suggest that the CBECS data for the commercial sector are the best available proxy for Federal HVAC equipment. From Chapter 9, Market for Condensing Boilers in Office Buildings, we repeat key findings:

- Over half (56%) of office buildings are expected to use natural gas as their primary heating fuel (Chapter 9, Exhibit 9-2). That would be about 280,000 buildings.
- About one fifth (19%, or 95,000 office buildings) will use boilers to supply the heat (Chapter 9, Exhibit 9-3).

Again, at least 70% of these buildings would be expected to be military, including large numbers of military housing units. No breakdown is available on their heat distribution systems.

10.4 The Market

The Federal buildings market is extremely large, approximately 11% of the number of commercial buildings and 5% of its gross floor space. In addition to its size, there is strong top-down determination to make this sector a leader in energy efficiency. This is expressed through law and executive orders. Federal procurement is unlike that in other sectors, and requires patience and knowledge. The most likely route by which condensing boilers would enter this sector in significant numbers would be through Energy Savings Performance Contracts in which vendors (Energy Service Companies or utilities) install, operate and own the equipment. In turn, they share the value of the energy savings with the government for the 15 – 25 year life of the contract.

We consider the existing buildings Federal sector to be an attractive target, and see a potential market of about 3,000 commercial boiler installations per year in this sector. The Federal market is larger than the estimated schools market (which is about 2,000 units per year). As for all other sectors, this number must be "hedged"; some buildings will be able to use more than one

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[17] http://www.eren.doe.gov/femp/aboutfemp/business_plan/environ.htm

[18] *BTS Core Databook: 1.4.2 Federal Buildings and Facilities Energy Consumption.* http://208.226.167.195/btscore98/core98frmset.htm

[19] *BTS Core Databook: 1.4.2 Federal Buildings and Facilities Energy Consumption, http://208.226.167.195/btscore98/core98frmset.htm* shows Postal (7.6%), DOE (7.3%), VA (6.9%), and GSA (4.9%)

[20] Technology Prospects, Inc. 1996. Potential for Geothermal Heat Pumps in the Federal Buildings Market. Published as RP-008, by Geothermal Heat Pump Consortium, Inc, Washington DC.

condensing boiler (buildings with lead-lag multiple boiler systems). On the other hand, many buildings will have one-pipe steam systems or other barriers (such as poorly designed distribution systems) that will require return temperatures too high for condensing at all times the boiler is running.

10.5 Players and Influencers

In general, significant new construction follows Congressional authorization and requires congressionally-appropriated funds. From the perspective of an agency that wants a new building, this is a queuing process: The request has to "float up" the chain of command and responsibility, being chosen at each step while others are rejected. This filtering reflects agency triage in anticipation that there will be far more requests than the Office of Management and Budget (gate-keeper for the Executive Branch) or Congress will approve. Some projects are delayed for one or more years in Congress, as "the process" allocates funds among agencies (and Congressional districts). Although we understand that appropriations can include funds for retrofits and renovations, this has the same inherent uncertainties as the process for new buildings. Between the 3-5 years for the appropriations cycle and the 2-3 years for design, bidding, and construction, this is a very long process[21]. The primary benefit of direct appropriations is the low cost to the government. The chief obstacle in most agencies is that energy use is only tangentially related to core missions, so efficiency upgrades compete poorly with alternatives perceived as more central to the services provided by the agency.

Over the past few years, a new type of financing mechanism has emerged and is becoming very important for Federal facilities. It is usually called an Energy Services Performance Contract, and is negotiated between the building owner and an Energy Service Company. The contract elements typically include the following:

- The ESCO, at its own expense, evaluates a building or set of buildings (base or campus) for its energy savings potential. The ESCO develops a budget for the investment required to reduce the energy budget as much as feasible.
- Owner and ESCO negotiate a contract (which has occasionally taken more than two years).
- ESCO retrofits the facility or facilities with energy-conserving equipment and makes such other modifications as agreed. In addition to lighting and HVAC, this could involve envelope improvements such as new windows, upgraded distribution systems, and added insulation.
- Frequently, the contract stipulates that ESCO will provide all required system maintenance.
- By a formula established under the contract, the owner and the ESCO share the actual energy savings attributable to the retrofit work.
- At the end of a stipulated interval, typically 15-25 years, ownership of any equipment bought and installed by the ESCO transfers to the owner of the building.

The typical ESCO or utility-financed project is in the range of $1-2 million[22]. According to FEMP[23], the key benefits of ESPC are that it:

- Reduces energy costs.
- Improves Federal energy efficiency and helps meet the Federal energy savings requirements.

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[21] Brad Gustafson, personal communication, March 23, 00.

[22] Brad Gustafson, personal communication, March 23, 00.

[23] See http://www.eren.doe.gov/femp/financealt.html for a more extensive (and current) treatment from the government perspective.

- Eliminates the maintenance and repair costs of aging or obsolete energy-consuming equipment.
- Places the operations and maintenance responsibilities on the contractor.
- Stimulates the economy by allowing energy service companies to profit from their up-front investments in Federally owned buildings by receiving a share of the utility bill savings.

The contractor also provides for training government personnel and measuring energy savings. Millard Carr[24] identifies one additional benefit from transferring maintenance responsibility to external sources with a vested interest in efficiency. The continuing cutbacks in funds available for maintenance make this a major consideration for many managers. According to authorities including Carr, one major incentive for these contracts is the restructuring of government that is occurring. Each year, budget pressures have forced reductions in operations and maintenance (O&M) budgets, so preventive maintenance of equipment is less likely to be done, and systems become both less efficient and less reliable. To many facility managers and their superiors, the ESCO contract begins to look like the only way out of the squeeze between declining resources and the high expectations of building users.

Public Law 105-388 (the Energy Conservation Reauthorization Act) extends through September 2003 the authority of Federal agencies to enter into ESPCs. ESPCs are specifically designed to reduce the cost of energy consumption in Federal buildings without requiring capital investment by the building owner. They also eliminate the cost to the agency of maintenance and repair of aging or obsolete equipment, place operation and maintenance responsibilities on the contractor, and help stimulate the economy by allowing the ESCOs to profit from up-front investments in Federally-owned buildings[25]. To complement this, Agencies can use future energy savings to fund projects, freeing up money currently wasted on energy inefficiency and making it available for facility improvements and sustained maintenance[26].

10.5.1 Players

As in the private sector, the first, and most important player is the owner. Other players are the “champions”, and FEMP.

- **The Owner.** We begin with the perspective of the managers responsible for facilities. If engaged, they can be very effective in making installations happen. Some have altruistic motivations for doing the right thing as part of public service. On the other hand, even managers who take a narrower view will find one aspect of ESPC contracting very influential. Agencies keep the savings that they negotiate with the contractor[27]; these are not returned to the general Treasury account. Within agencies, funds that are not designated for specific uses are a scarce resource, and we expect that more and more managers will get a certain sparkle about new sources of such funds.

- **The “top-down champion”.** This leads directly to the concept of the “top-down champion” (probably at or near the Assistant Secretary level), the person who realizes the advantages of new approaches, and pushes hard for innovation in facilities management.

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[24] Millard Carr, personal communication, May 1, 00.

[25] This paragraph is adapted from *GeoExchange in Federal Facilities,* page 14. Published by Geothermal Heat Pump Consortium, Inc. <www.ghpc.org>

[26] See http://www.eren.doe.gov/femp/financealt.html for a more extensive (and current) treatment from the government perspective.

[27] http://www.eren.doe.gov/femp/financing/espc_intro.html

EPA and DOE are becoming active this way, as would be expected. Energy efficiency is a core mission value at DOE, and pollution prevention (for both "criteria" pollutants like NO_x and climate change threats like CO_2) is a core EPA mission. There are also signs of increasing interest at the Veterans Administration and the Department of Commerce[28]. To emphasize the importance of the top-down champion, Carr points out that the uniformed services (Department of Defense) have some major commands that are becoming very active, while others show less interest.

- **The "bottom-up champion"** is a misnomer, but the logical complement to the top-down champion. Carr identifies these as absolutely essential players. They are typically mid-level facility managers, responsible for a military base or the civilian equivalent. In the military sector, Carr notes the complementary roles of two key actors, the military staffer and his/her civilian counterpart. The base energy officer is almost always a civilian base employee[29]. They tend to be long-term staff at specific installations. The public works manager is generally a military officer who will rotate to new responsibilities at the end of a two or three year tour. S/he is very interested in getting things done. Committed projects can help with performance reviews – if they get done without disturbing powerful antagonists. The civilian base energy officer generally has detailed knowledge of people, equipment, and problems, and is the institutional memory for the facility. The typical facility manager is a certified energy manager (CEM), professional engineer (PE), or both. They are knowledgeable and want to do the right things. They go to meetings, read, confer with peers, and listen to vendors to find solutions to their problems. They must be respected and made part of the process.

  Carr's point, which is extremely important, is that the process is a player in Federal facilities. The ESCO or other market player who does not carefully engage all of the players at a facility and build a consensus for action is not going to walk away with a project. Key people in this process will certainly include the base commander or his designee, the base facility person and energy officer, the contracts officer and the lawyers, the budget staff and other technical experts. Carr recommends identifying these people at the very beginning, getting them involved and giving them some "ownership" of the process from the very first. Carr suggests that a workshop involving the ESCO, the equipment vendor, the design engineer, and all of the internal staff is the very first step. Carr makes a chilling observation: Anyone can say no to a project, but only everyone together can say yes. That's why the process is so important.

  Carr believes that the "push" for energy efficiency investments in general and emerging technologies in particular is generally the vendor of the equipment, working through the ESCO. Thus, the ESCO (and its complement, the utility "area-wide" contract) are key players. If the ESCO/utility can bundle retrofit investments into a package from a million dollars up, and if the numbers give good cash flow, the ESCO will bear primary responsibility for engaging the Federal agency or facility, for bringing together a team, and for selling the job. Thus, the advocates of the technology are advised to make the best possible case for presentation to the ESCO as well as the facility.

  One implication of this is that the design engineer is likely to play less of a role as advocate in the Federal sector than in the non-Federal commercial building. For Federal

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[28] Millard Carr, personal communication, May 1, 00.

[29] G. Phetteplace, CRREL, personal communication, 56/1/00.

facilities, the designer will be part of the ESCO/utility team, but may not have access to the customer except through the others.

10.5.2 Influencers

CEE uses the term influencers to refer to external agencies that shape the market. That is, those whose actions influence the market. Examples include project financing programs, technical guidance, infrastructure development and executive orders.

- **Project Financing.** More than $4 billion is available from the private sector to make projects happen. FEMP assists agencies in choosing and implementing projects through their partnerships with the private sector. ESPCs allow ESCOs to assume the capital costs of installing energy and water conservation equipment and renewable energy systems. The ESCO guarantees a fixed amount of energy savings throughout the contract life and is paid directly from those savings. The agency retains the remainder of the energy cost savings, and assumes full ownership of the equipment and all the savings after the contract expires. Super-ESPCs are regional or technology-specific contracts that allow agencies to negotiate site-specific ESPCs with an ESCO without having to start the contracting process from scratch, saving time as well as money. Once all Super ESPCs are awarded, contracts with a total investment ceiling of more than $6 billion will be in place. FEMP's utility incentive activities will leverage roughly $1 billion for energy projects between FY 1995 and FY 2005 and may streamline procurement of energy efficiency. FEMP works to ensure that Federal facilities served by public and private utilities receive financial and technical assistance from utilities[30].

- **Technical Guidance.** FEMP offers the technical and procurement expertise and services any agency needs when implementing an alternatively financed energy project. In addition, FEMP supports agencies dealing with the Super ESPC delivery order process. Services include assisting with Requests for Proposals, including measurement and verification requirements, and proposal submission and evaluation criteria. At the end of FY 1998, FEMP was working with various agencies to develop more than 150 projects, with private-sector investment in five delivery orders totaling more than $7 million[31].

- **Infrastructure Development.** We believe that one of the more important vehicles for accelerating deployment of emerging technologies is building an infrastructure of people and documents that gives the potential buyer the sense that the product is "mainstream" and has a strong network of support services. Toward this end, FEMP has developed model procurement documents; the Measurement and Verification Guideline for Federal Energy Projects; a how-to manual for ESPCs; a home page on the Internet; and educational videos for management, legal, and contracting personnel. In addition, FEMP is developing training videos to assist agency personnel in preparing site-specific ESPCs. Because ESPCs depend on proper measurement and verification of promised energy savings, FEMP supported the development of a collaborative effort to produce a consensus document for measuring and verifying energy savings that Federal energy managers, procurement officials, and private sector energy services providers could use. DOE developed the North American Measurement and Verification Protocol and, as the first application, FEMP issued the Measurement and Verification Guideline for Federal Energy Projects. The new FEMP guideline speaks the Federal language and provides

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[30] http://www.eren.doe.gov/femp/aboutfemp/fempoverview.html
[31] http://www.eren.doe.gov/femp/aboutfemp/fempoverview.html

standard procedures for quantifying savings from the installation of energy conservation measures. Intended for use in ESPC, the FEMP guideline provides the methodology for establishing cost savings called for in the ESPC regulation[32].

- **Planning, Reporting, and Evaluation.** Coordinating and reporting to Congress on interagency activities that achieve Federal energy management goals is one of FEMP's primary responsibilities. FEMP is the lead agency coordinating activities of the Federal Interagency Energy Policy Committee and the Interagency Energy Management Task Force. Collecting and transferring information on energy use in Federal facilities is another way FEMP helps agencies make the best decisions on energy savings[33].

- **FEMP and Emerging Technologies.** FEMP's mandate includes activities to encourage evaluation and adoption of emerging technologies such as commercial-scale condensing boilers. One early attempt was the use of a "technology-specific SuperESPC," a program designed to encourage adoption of specific technologies that it was thought would benefit from the attention. One of the first of these was for ground source (geothermal) heat pumps. This has been considered successful, but the success is considered a coincidental outcome of other causes. In particular, strong advocacy within the ASHRAE community built a constituency for these units, and gave decision makers the tools needed to support adoption. These tools[34] included case studies, engineering studies, design software, and ASHRAE-sponsored short courses. According to B. Gustafson of FEMP, it is considered relatively unlikely that new technology-specific ESPCs will be launched. If the technology works as part of the solution to attaining optimum efficiency at a particular site, it doesn't need the special route. If it needs the route, the numbers probably won't compute[35]. FEMP also identifies Federal market opportunities and works with procurement organizations to aggregate purchases, reduce costs, and expand markets. FEMP's product recommendations series on energy-efficiency further assists agencies in procuring best-practice products, when they meet specific performance requirements and are cost effective[36]. FEMP not only identifies the upper quartile of efficiency product performance levels, but FEMP also considers the variety of available models and ensures that at least 3 manufacturers have products that meet the recommended level. FEMP recognizes that condensing boilers have higher thermal efficiency performance levels than conventional, non-condensing boilers. FEMP periodically revises its efficiency recommendations and will consider including condensing boilers as more products become available to Federal purchasers[37].

- **Executive Orders.** A national commitment to energy efficiency was expressed in the Energy Policy Act (EPAct 1992). The Act calls for a 20% reduction from 1985's Federal energy consumption (per square foot) levels by 2000. This was followed by two Executive Orders issued by President Clinton. In 1992, Executive Order (EO) 12902

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[32] http://www.eren.doe.gov/femp/financing/espcoverview.html

[33] http://www.eren.doe.gov/femp/aboutfemp/fempoverview.html

[34] We regard the ASHRAE SPC 155 process under the leadership of Martha Hewett to be an important start on this work for condensing boilers. It will, however, require an estimated 2 – 3 years more work before its ratings methods are ready to go. In the meantime, we know of no systematic efforts on an industry-wide basis to develop the remainder of the other infrastructure or "tools" developed for geothermal under the leadership of ASHRAE, the Geothermal Heat Pump Consortium, and the International Ground Source Heat Pump Association.

[35] B. Gustafson, personal communication, March 23, 00.

[36] http://www.eren.doe.gov/femp/aboutfemp/fempoverview.html

[37] Michelle Ware, LBNL, personal communication, March 23, 00.

directed Federal agencies to reduce energy use per square foot 30 percent by 2005, relative to the 1985 baseline of about 140,000 Btu/ft2-yr[38]. One of the primary requirements of EO 12902 is for each agency to develop a program "designed to speed the introduction of cost-effective and energy efficient technologies" that would contribute to "reducing energy consumption by 30 percent by the year 2005." Another requirement is a 25-percent reduction in greenhouse gas emissions by 2005, relative to 1990 levels. In 1999, EO 13123 stiffened the directive to 35-percent energy-use reduction over 1985 levels, and also required a decrease in greenhouse gas emissions of 30 percent relative to 1990 levels - both to be accomplished by 2010[39]. It also requires an agency "scorecard." This process, which allows comparing activities and results across agencies, has just completed its first round. The next round is to specifically include success in performance contracting, with metrics[40]. The oversight committee for this work is filled at the Assistant Secretary level, which sends a signal to the bureaucracy that the mission is to be taken seriously. At first glance, these requirements seem stringent. However, as suggested in Exhibit 10-1, Federal building energy intensity seems to be about 50% higher than that suggested by CBECS for the overall commercial sector. This suggests that Federal buildings, for whatever reasons, may be very fertile fields from which to harvest energy savings[41]. EO 13123 also directs agencies to purchase ENERGY STAR labeled products or, for product groups where ENERGY STAR programs do not yet exist, FEMP has designated products that are in the upper 25 percent of energy efficiency[42]. In November 1999, FEMP published its efficiency recommendation *How to Buy an Energy-Efficient Commercial Boiler*[43]. This efficiency recommendation does not cover condensing boilers; however, FEMP mentions in the document that condensing boilers have higher thermal efficiencies than conventional, non-condensing boilers. Unfortunately, there are so few condensing boilers on the market that the upper 25% of thermal efficiency for commercial boilers predominantly comprises non-condensing boilers[44]. Nonetheless, Federal agencies are directed to purchase boilers that meet or exceed the efficiency recommendation when found cost effective; and inherently, based on a boiler's thermal efficiency performance, this will include some condensing boilers currently available for sale to Federal purchasers.

Chapter 91 of EPAct is codified as 42 USC Sec. 8287, dated 01/16/96, which allows Federal agencies to enter into ESPCs with contractors. This sets the stage for procuring

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[38] http://www.eren.doe.gov/femp/aboutfemp/business_plan/environ.htm

[39] According to Brad Gustafson, FEMP (Interview, March 23, 00), the E.O. 13123 requirement will be a reduction per agency, not per square foot of space used. If an agency doubled its space between 1985 and 2010, this would be a requirement of 70% reduction per square foot.

[40] Guidelines are due in June 2000, according to Brad Gustafson, FEMP (personal communication, 3/00).

[41] Some analysts will note that the average Federal building may be smaller than the average commercial building, and thus may have a higher surface/volume ratio than the average commercial building. Certainly, the "fine structure" of the available data makes firm conclusions difficult to reach, but we would note that he Federal sector includes large amounts of military housing among the "small" buildings. Besides, the size of the market is so large that there are very large numbers of relatively large buildings which will prove to have high energy consumption. The tail of the distribution of a very large universe is still a large pool of opportunity!

[42] FEMP's Buying Energy Efficient Products Program uses the upper quartile criterion to establish energy efficiency recommendations for various energy using products purchased by Federal agencies. These *Recommendations* can be found at <http://www.eren.doe.gov/femp/procurement/begin.html>

[43] The document can be found at http://www.eren.doe.gov/femp/procurement/pdfs/boiler.pdf

[44] Spreadsheet prepared by Michelle Ware of Lawrence Berkeley National Laboratory, technical support for FEMP's commercial boiler recommendation. The FEMP recommendation shows the Best Available non-condensing boiler on the market has a peak thermal efficiency of 86.7%.

efficiency just like buying trucks or natural gas. These performance contracts may represent a major opportunity to expand use of condensing boilers in this key segment, by enabling contractors to profit from installing this advanced equipment in Federal buildings.

The Clinton administration had shown commitment to leadership in energy efficiency (and renewable energy) by the Federal sector, and to the success of the processes established. The "paper" structure of law and Executive Orders implies action, but little happens until some key individuals decide that action to comply with – or exceed – requirements will lead to advancement (or avoid punishment). In the next section of this chapter we will discuss the "champions" and the structure within which they operate, to explore opportunities for success in the Federal sector. We will see that the level of action varies across agencies, and that "bottom-up" commitment by "champions" is a key to achieving the "top-down" goals of energy efficiency.

We conclude that those manufacturers, utilities, and others who would participate in this market need to either dedicate staff to the market, or form strategic relationships with organizations that specialize in this area. We do not believe that half-hearted efforts will be cost-effective for getting condensing boilers into the Federal markets. We predict that the most successful enterprises will focus on the agencies they find to be most receptive, where they find "champions." Champions are decision-makers and decision-influencers in the agencies who actively support acquisition, deployment, and evaluation of emerging technologies. For those that work, they actively propagate the good news.

10.6 Barriers and Strategies for Success

We find the following major barriers to greater penetration of condensing boilers in the Federal buildings sector. Strategies for success are also presented below:

- **Economics.** The package of measures for an ESPC project must have a 10-year payback at standard Federal assumptions (discount rate, etc.). In addition, to the ESCO, "cash flow is king[45]." That is, the vendor and other advocates of condensing boilers will have to demonstrate that the installation of a high-priced condensing boiler will help their economics by deep, early reductions in energy outlays, and that it will continue to produce these savings (and the resulting flow of cash from the energy savings) for the life of the project. For them, profitability is the result of beating expectations on costs.

- **Technical.** Condensing boilers cannot be used in the older building stock currently equipped with one-pipe steam or inadequate distribution systems. Distribution systems and terminal heat exchangers (convectors or radiators) must be replaced in order to provide the desired space temperatures while operating at the low heating water temperatures supplied by condensing boilers.

- **Procurement.** This discussion has attempted to introduce the mechanisms (ESPCs through ESCOs and utility area-wide contracts) that are most likely to lead to installation of commercial condensing boilers in Federal buildings. The procurement process remains challenging, and delays from initial contact to contract are routinely much longer than in the commercial sector. For this reason and the importance of contract terms, Federal

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[45] M. Carr, personal communication, May 1, 00.

procurement is generally a specialty unto itself, and the authors have encountered subspecialists who focus (for example) on the military, or on one service or perhaps some of its commands.

- **Problem Solutions and Scale.** Condensing boilers are most likely to enter this sector as part of major retrofits whose bundled value is greater than a million dollars per contract. This puts the emphasis on convincing the ESCO and his/her engineer that condensing boilers are part of a sound solution. Gustafson is quite firm that selling boxes is much less likely to succeed than selling solutions to problems of inefficiency (non-compliance with 13123) and maintenance headaches.

- **Finding, Encouraging, and Supporting Champions.** Without internal advocates, the technology will not be adopted. "Everyone has to say yes, but anyone can say no," and thus kill a project. Vendors, utilities, and others who would encourage adoption of condensing boilers must find internal advocates, and must be sure that these people, who take risks to improve efficiency by adopting new technologies, must never be let down. A disappointed champion may become an implacable foe, as happened to ground source heat pumps at one base.

- **Infrastructure**. One reason that other emerging technologies are increasing their market penetration more quickly than condensing boilers is that others have organized advocacy groups that give the emerging technology the appearance of a mainstream technology[46]. For photovoltaics and wind, trade associations and Federal support have been critical. For ground source heat pumps, these efforts have been supplemented by a strong ASHRAE technical committee (TC 6.8) that has sponsored development of tools, presentation of symposia and articles, and generally shaped the research and development agenda. We do not yet find such an effort for condensing boilers, except for the purely technical activities of ASHRAE SPC 155, which is focused on efficiency measurement methods, a key early step. We believe that market transformation will be greatly accelerated by development of a dedicated support infrastructure with third party financial support and vendor involvement. The external financial support is likely to be required, because the cash flow of a few thousand unit sales per year will not support the required efforts.

- **Privatization.** There is much discussion about, and some action toward, turning Federal buildings over to the private sector through might what be called leaseback arrangements. The motives are similar to those leading to ESPCs – greater control over costs, better operations, etc. There is some danger that some agencies will hesitate to implement ESPC contracts that might make privatizing buildings more difficult. At this point, this is still speculative.

10.7 Summary

The Federal buildings market is extremely large, approximately 11% of the number of commercial buildings and 5% of its gross floor space. In addition to its size, there is strong top-down determination to make this sector a leader in energy efficiency. This is expressed through law and executive orders. Federal procurement is unlike that in other sectors, and requires

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[46] For a discussion of the concept, see Moore, Geoffrey A, 1991: *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*. HarperBusiness.

patience and knowledge. The most likely route by which condensing boilers would enter this sector in significant numbers would be through ESPCs in which vendors (ESCOs or utilities) install, operate and own the equipment. In turn, they share the value of the energy savings with the government for the 15 – 25 year life of the contract.

We consider the existing buildings Federal sector to be an attractive target and see a potential market of about 3000 commercial boiler installations per year in this sector. Some buildings will be able to use more than one condensing boiler (buildings with lead-lag multiple boiler systems).

Chapter 11: Market for Condensing Boilers in Apartment Buildings

11.1 Background

This chapter considers the opportunities for increasing installations of condensing boilers in the small retrofit apartment building segment. This sector consists of the existing stock of apartment buildings that are not more than 3 stories high and contain up to 30 dwelling units each. This category of apartments was selected for the following reasons:

- The vast majority of existing apartment stock (74%) consists of buildings in this size range
- These buildings are relatively old – 30% nationally and 70% in New York City were built before 1950
- This category has a high saturation of steam and hot water space heating systems

The building stock seems to have a high saturation of one-pipe steam systems, with 2-pipe hydronic systems largely confined to newer buildings. Some of the newer buildings also have hot air (particularly outside New York City). This makes the actual market for condensing boilers a relatively small fraction of the 16 million multi-family units in the US (5 units and larger).

We infer that most properties in this segment are not professionally managed, and that the owners or managers rely on contractors both to maintain the systems and to make recommendations for upgrades, new equipment, and other significant purchases. Thus, the contractor is the key to this market. We believe that contractors will encourage condensing boiler installations if they are provided with incentives and support. Incentives may include a mixture of money and (for example) drawings for prizes like vacation cruises. Support includes engineering analysis, materials, and presentations to the client. It includes training, and may include on-site assistance with early jobs.

We conclude that there is essentially no new construction market for condensing boilers in this class of apartment buildings, because virtually all new units are equipped with central air conditioning. This implies forced air systems using unitary equipment, with one forced air furnace and split A/C per apartment. We further conclude for existing structures that the retrofit market for commercial-scale condensing boilers in these relatively small buildings is on the order of 1,000 boilers/year. The market for residential scale condensing boilers is probably about 3,000 boilers/year, since we estimate that only one fourth of the buildings otherwise suitable are large enough to warrant commercial-scale equipment.

While this retrofit market appears to have a maximum potential of 4,000 boilers/year, many economic and institutional barriers will prevent this potential from being realized due to the manner in which retrofit opportunities arise. Retrofit opportunities may arise in several ways, including:

- In this market, virtually all boiler replacements occur due to a mid-winter failure. It will rarely be a good opportunity for condensing boilers, since the foremost decision drivers will be first cost; unit availability *immediately;* and “plug-and-play” interchangeability, with minimum changes in system plumbing or controls that could delay getting back on line.
- The second most common reason for boiler replacement is the result of an ownership change and/or a decision to change the building’s position in the market. This could, for example, reflect a decision to convert the building from rentals to cooperatives or condominiums. In

some cities, it might reflect a decision to invest to warrant change in rents in a rent-controlled environment if these relatively small apartment buildings are important for conversions.

For the above reasons we do not recommend an early market transformation focus on this sector.

This chapter deals with new and retrofit opportunities in the smaller apartment market, in both new buildings and retrofits. Our inquiry is focused on apartment buildings that are from one to three stories high and contain from 5 to 30 dwelling units each. We note that apartments are a minority share of the 101 million (1997) US dwelling units[1]. We focus on the market for heating boilers, and do not explicitly treat service water heating boilers[2]. One out of six residents in the US lives in an apartment building with five or more units. This is a significant number, four times larger than the number in mobile homes, but only ¼ the number in single family (attached and free-standing) houses[3]. 83% of single family dwellings are owner-occupied, while 88% of multifamily units are occupied by renters[4].

We include various individual, non-profit, and for-profit building ownership types, but we do not explicitly consider government-owned residential units. Opportunities in the Federal sector are treated in Chapter 10, which concludes that the major opportunities for condensing boilers will be through utility area-wide contracts and ESCOs. These groups can use ESPCs to invest in and profit from improvements to HVAC systems, lighting, and other energy using features of buildings. The Federal sector includes military base housing, which is a substantial market in itself. For example, twenty-six percent of all building space owned by the Federal government is in California, Texas, and Virginia. One third of the California holdings are residences, mostly military housing[5].

Housing Authorities may be an important target. There are many of them, in cities of all sizes, in every region. They are under some pressure to change their historical ways of doing business. However, it has been felt that their ways of doing business are somewhat different from those in commercial and non-profit segments. Within the scope of the project, it has not been possible to investigate this sub-segment.

The segments considered lead to the conclusion that this market sector is strongly concentrated in older “snow-belt” cities of the Northeast and Midwest. For many reasons, this segment has not been the most hospitable to innovation, as discussed in the next section.

11.2 Methods – What We Did

Our work was based on web-based research, individual interviews of market participants such as boiler manufacturers, consulting engineers, and utility market representatives, and a review of available literature.

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[1] U.S. Department of Energy, Energy Information Administration, “*A Look at* Residential Energy Consumption in 1997, Overview. Available as a “pdf” (Adobe Acrobat) file from the EIA web site, www.eia.doe.gov

[2] As per project scope.

[3] Pacific Northwest National Laboratory BTS Core Databook, Table 2.1.2. web site at URL=208.226.167.195

[4] Pacific Northwest National Laboratory BTS Core Databook, Table 2.1.2, web site at URL=208.226.167.195

[5] Potential for Geothermal Heat Pumps in the Federal Civilian Buildings Market. Geothermal Heat Pump Consortium RP-008, Executive Summary, http://www.geoexchange.org/FederalWeb/summary.htm

The most important resource available on the web was the US Energy Information Agency (EIA), web site, http://www.eia.doe.gov. The EIA is a semi-independent statistical agency within the Department of Energy (DOE). It compiles comprehensive energy price, supply, and consumption data. The 1997 Residential Energy Consumption Survey (RECS)[6] report, published in November 1999, was used in this study. We used RECS for basic statistics and the distribution of heating equipment in buildings. RECS is comprehensive, but much of the data on equipment cannot be broken out by 1 to 3- story apartment buildings.

11.3 Characteristics of Apartment Buildings and Equipment

11.3.1 Apartment Buildings

Exhibit 11-1 suggests that multifamily apartment buildings actually use *more* energy per square foot than single family buildings, despite the generally lower ratio of outside exposure to floor space. This suggests that there are opportunities to improve performance of multifamily buildings, without suggesting whether the potential reflects poor equipment, poor distribution, poor maintenance, or poor building shells. Multifamily units use much less energy per household, because the average apartment is much smaller than the average single family house (1200 ft^2 vs. 2300 ft^2)[7].

Exhibit 11-1: Energy Intensity of Various Housing Types[8]

Housing Type	Energy Usage Per Sq. Ft. (10^3 Btu)	Energy Usage Per Household (10^6 Btu)	Energy Usage Per Person (10^6 Btu)	Percent of Residences
Single-Family:	52.0	118.5	43.0	79.1%
- Detached	52.0	121.2	43.0	72.1%
- Attached	53.0	96.3	37.0	7.0%
Multi-Family:	69.0	67.3	31.0	16.3%
- 2 to 4 units	83.0	99.5	32.0	8.0%
- 5 or more units	60.0	51.5	41.0	8.3%
Mobile Homes	84.0	81.9	26.0	4.6%
All				100.0%

In turn, Exhibit 11-2 suggests that building age is important: Across housing types, pre-1980 housing uses substantially more energy per square foot than does more recently built housing.

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[6] "A Look at Residential Energy Consumption in 1997", (DOE/EIA-0632, 1997)

[7] According to http://energydata.wdc.pnl.gov/webrecs2/recs95.htm, the average single family detached house is 2300 ft^2. (printed) The average multifamily was 1200 ft^2.

[8] From BTS Core Databook: Residential Sector Energy Consumption, 1.2.6, 1993 Residential Delivered Energy Consumption Intensities, by Housing Type

Exhibit 11-2: Energy Intensity of Housing Types, by Vintage[9]

Housing Type	Energy Usage Per Sq. Ft (10^3 Btu)		Energy Usage Per Household (10^6 Btu)		Energy Usage Per person (10^6 Btu)	
House Vintage >	Pre-1980	1980-1993	Pre-1980	1980-1993	Pre-1980	1980-1993
Single-Family	55.9	40.1	124.0	99.9	45.7	33.0
- Detached	55.6	39.4	125.9	103.6	46.3	33.1
- Attached	59.4	44.9	104.1	84.1	39.7	33.0
Multi-Family	75.5	47.7	73.8	45.6	34.2	22.8
- 2 to 4 units	88.5	46.4	106.7	53.1	43.9	23.3
- 5 or more units	64.7	48.1	54.6	43.7	27.4	22.6
Mobile Homes	73.8	73.8	82.7	80.8	33.8	28.2

Exhibit 11-3 shows that, across all housing types, energy use intensity is much higher in the Northeast and Midwest. This greater use contributes to the larger opportunity for more expensive condensing boilers: One is more likely to pay to reduce a large expenditure than a small one.

Of the 15.8 million buildings with 5 or more apartments (the largest multifamily class in the EIA's, RECS, '97), 3.8 million are in the Northeast (0.7 million in New England and 3.1 million in the Mid-Atlantic); 2.2 million in the East North Central census region; 2.9 million in the South Atlantic; and 2.5 million in the Pacific division[10]. 22% of multifamily housing was built before 1950.

Exhibit 11-3: Residential Delivered Energy Consumption Intensities by Region[11]

Region	Energy Usage Per Square Foot (10^3 Btu)	Energy Usage Per Household (10^6 Btu)	Energy Usage Per Person (10^6 Btu)	Percent of National Consumption
Northeast	60.0	122.4	47.0	24%
Midwest	62.0	134.3	52.0	31%
South	52.0	87.9	34.0	30%
West	46.0	76.0	28.0	15%
				100%

11.3.2 Heating Equipment

It is interesting to compare residential heating equipment changes between 1978, the first RECS, and 1997, the most recent RECS, (Exhibit 11-4). Even though the market is dominated by single-family houses, the data illustrate general trends of importance for the apartment market. Although the number of households grew, the fractions in the Northeast and Midwest declined relative to the South and West. Thus, the average dwelling in the first two regions is older than in the South

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[9] From BTS Core Databook: Residential Sector Energy Consumption, 1.2.10, 1993 Residential Delivered Energy Consumption Intensities, by Housing Type

[10] RECS, 1997, Table HC1-4a

[11] From BTS Core Databook: Residential Sector Energy Consumption, 1.2.7, 1993 Residential Delivered Energy Consumption Intensities, by Housing Type

and West. Central air conditioning has doubled its market penetration, both nationally (23% to 47%) and in the Northeast, which has the lowest penetration of central air.[12] (It rose in that region from 9% to 22%.)

Central air conditioning requires forced air ductwork, which also can be used by forced air heating. In contrast, steam and hot water distribution systems use pipes and either radiators or hydronic systems (in floor heat) for distribution. Most builders are unwilling to install both ducts for central air conditioning and pipes for hot water heating, except for custom, high-end systems, so sales of hot water systems decline relative to forced air systems. As a result of the increase in demand for air conditioning, the fraction of forced air furnaces rose during this interval.

This is a major contrast with Northern Europe, where residential air conditioning is said to be much less common.

Exhibit 11-4: Residential Heating Market Changes from 1978-1997

Parameter	1978	1997	Change
National number of housing units[13]	76.6	101.5	32%
Fraction in NE[14]	23%	19%	-4%
Fraction in Midwest[15]	27%	24%	-3%
Space Heating MMBtu/household[16]	91	51	-44%
Fraction of dwellings with central heating[17]	69%	78%	9%
Central heat with steam or hot water distribution[18]	18%	13%	-28%
Forced air furnaces[19]	38.4	56.6	47%
Central Air Conditioning[20]	23%	47%	104%

Consistent with the relatively small growth of the Northeast and Midwest markets and the rapid growth of central air conditioning, steam and hot water heating had more than half the central heating market for dwellings built before 1950, but a declining share since then. For the most recent decade, the share was only 1%[21] for all dwelling units

Finally, multifamily apartment buildings are (not unexpectedly) predominantly city "creatures" as shown in Exhibit 11-5. Of the stock of 15.8 million units, fully 11.2 million are actually in cities, not towns, suburbs, or rural areas. Thus, we see that the story of multifamily housing, 5 units/building and more, is focused on cities, and further focused on older buildings. There is a high concentration of these buildings in the Northeast (assumed to be Philadelphia and points North and East, New York City, and Boston), and large numbers in the Midwest and other regions. The RECS data do not separately treat the 5-30 unit buildings from the buildings with more than 30 units, so we can only guess about differences in distribution.

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[12] RECS, 1997, p 13, Figure 2.17
[13] RECS, 1997, p. 7
[14] RECS, 1997, p. 9, Figure 2.6a
[15] RECS, 1997, p. 9, Figure 2.6a
[16] RECS, 1997, p. 10, Figure 2.8
[17] RECS, 1997, p. 11, Figure 2.12
[18] RECS, 1997, p. 11, Figure 2.13
[19] RECS, 1997, p. 22, Figure 3.8
[20] RECS, 1997, p. 12, Figure 2.16
[21] RECS, 1997, p. 22

Exhibit 11-5: Concentration of Multifamily Units in Cities[22]

Setting	Number of Units, millions
City	11.2
Town	2.2
Suburb	2.0
Rural	0.4
Total	15.8

We expect that the largest buildings are concentrated in the larger cities, and guess that the 5-30 unit buildings are well represented in medium-sized cities such as Providence, Hartford, and Syracuse.

New York City is in many ways the acme of an older city, in terms of its housing stock. One could argue that the political environment (rent control) discouraged investment for some decades. New York also has a higher than customary number of very large apartment complexes. For example, Co-Op City, in the Bronx, houses about 50,000 people in approximately 50 buildings of 15 stories and more.[23] Although New York is not typical, it probably is only a bit exaggerated relative to other cities:

- 70% of the NYC buildings were constructed before 1950, versus 30% for all multifamily units (5 units and more) in the US[24]. In the same survey, almost 1 in 5 buildings will soon reach (or has reached) the age of 100 years.
- In NYC, the majority (over ¾ in a survey of hundreds of systems) have 1-pipe steam distribution; only 6% used hydronic systems (2-pipe hot water). These 1 pipe systems will be very difficult and expensive to re-engineer for condensing boilers: they need 2-pipe distribution, and much more radiant surface to work with lower temperature heat transfer fluids. The only significant opportunity here is during gut rehab (total rehabilitation), which primarily occurs in government-sponsored programs.

Is New York City a good target for a condensing boiler market transformation program? If there are 120,000 five-unit and larger apartment buildings, but only 6% have hydronic heating systems, this is still a potential market for more than 7,000 installations, some with multiple condensing boilers. Of course, this estimate must be "tuned" by considering other effects: How many buildings have sufficiently oversized radiation to work well with condensing boilers, or can be retrofitted feasibly? We also assume that the 2-pipe distribution systems can carry enough water at lower temperatures during shoulder seasons to make condensing feasible (without an enormous penalty for increased pumping). Finally, New York City's population will tend to be larger than the 5 – 30 unit focus of the present study, but larger boilers are available. NYC is unique, and there may be good opportunities in (for example) postwar apartment buildings in cities where 2-pipe hot water distribution systems are more common.

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[22] RECS, 1997, Table HC1-4a

[23] Served in this case by a two-pipe district heating system, with boilers in a central power plant.

[24] RECS, 1997, Table HC1-2a.

In addition to having high-temperature (usually one-pipe steam) distribution systems, our interviews suggested that boiler controls in the smaller buildings are typically primitive; frequently there is not even an outdoor reset control. The typical apartment-level temperature controller is said to be the ‘windowstat’ – as in the old Soviet Union.

11.4 The Market

11.4.1 Market Growth Projections

It does not appear that the new multifamily construction market will be much more favorable for condensing boilers (except possibly for service water heaters, which is also true for existing buildings). Exhibit 11-6[25] presents data suggesting that new construction in this sector is dominantly equipped with air conditioning. This suggests to us that these units are being equipped with unit-sized forced air furnaces and individual apartment duct systems, in general. Some may have alternative systems, such as water source heat pumps, or central VAV or 4-pipe systems, which would tend to be found in very up-scale buildings. In this table, the West has the lowest penetration (61%) of central air followed by the Northeast (with 80%).

Exhibit 11-6: Characteristics of New Apartment Construction[26]

	Percent Distribution				
Number of Units per Building	**US**	**Northeast**	**Midwest**	**South**	**West**
5-9 units	28	16	27	26	33
10-19 units	25	11	20	31	29
20-29 units	17	21	15	19	16
30-49 units	12	5	20	12	6
50 + units	18	47	18	12	16
5-29 units	*70*	*48*	*62*	*76*	*78*

	Percent Distribution for "5 units +" buildings				
Number of Floors per Building	US	Northeast	Midwest	South	West
1-3 floors	83	61	90	85	84
4 + floors	17	39	10	15	16

	Percent Distribution				
Apartment Units with Central A/C	**US**	**Northeast**	**Midwest**	**South**	**West**
With central A/C	87	80	95	99	61
Without central A/C	13	20	5	1	39

We estimate that the number of new 5 – 30 unit apartment buildings that might have boilers is too small to be significant as a potential target. Although we estimate that about 8,400 apartment buildings in this size range will get boiler retrofits annually we conclude that this market will not

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[25] Characteristics of New Housing, 1995, Series C-25 Reports, U.S. Bureau of the Census

[26] RECS, 1997, Tables HC1-4a, HC3-4a, and HC4-4a.

support very many sales of commercial scale equipment, since building loads will be better served by residential scale equipment. As shown below, although the actual market for commercial scale condensing boilers in this market is very small, residential scale condensing boilers could serve the needs of this market. The evidence of the lack of a new construction market is the very high saturation of central air conditioning and the economics of forced air furnaces with split air conditioning units for the 1-3 story buildings in the defined segment.

11.4.2 Potential Condensing Boiler Share

Our inference about the size of the condensing boiler market in the 5 – 30 unit apartment segment is based on the following logic:

1. There are about 2.8 million apartment housing units (apartments, not buildings) with boilers (split at 1.4 million each for oil and natural gas)[27]. We assume that all of the oil-equipped buildings could be converted to gas, which leads to an overestimate.
2. We estimate that 3% of these buildings will be retrofitted each year, comparable to a 30-year life for the boilers[28]. That reduces the 2.8 million unit number down to 84,000.
3. We estimate a median of 10 units per building, bringing the 84,000 unit number down to 8400 existing buildings retrofitted per year.
4. The total boiler capacity required for a 30 unit apartment building is relatively small. For new construction to present codes, it would be 15,000 Btuh/unit, or 450,000 Btuh[29]. Assume that existing units with poor windows, insulation, and distribution systems require three times the capacity, so a 10 unit building would require 450,000 Btuh total, and a 30 unit building would require 1,350,000 Btuh.
5. The 10 unit building would probably use a pair of 225,000 – 250,000 Btuh *residential* boilers, one condensing and one non-condensing, in a lead-lag configuration. Only the largest apartment buildings in this class would use commercial-scale equipment. Assume this to be ¼ of the 8400 buildings, or 2100 boilers/year. The remaining 6300 buildings would absorb one residential size condensing boiler each or 6300 boilers/year.
6. Of course, not all of these buildings can use condensing boilers: some have one-pipe steam heat (a large majority in NYC, for example), and others have distribution systems that require high temperature returns to assure adequate heating in remote apartments. An additional fraction will not find natural gas available or attractive (From point 1, above, ½ of these buildings are oil-heated).

Thus, we conclude that the maximum potential national market for commercial-scale and residential-scale condensing boilers in 5 – 30 unit apartment buildings is of the order of 1,000 and 3,000 boilers/year respectively.

11.5 Players and Influencers

11.5.1 Players

The first, and most important player is the owner or property manager followed by contractors and manufacturers' representatives.

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[27] Total of oil- and gas-heated units (not buildings) from RECS 97, Table HC3-4a

[28] ASHRAE, 1999 Applications Handbook, p. 35.3, Table 3, gives service life estimates of 24 years (steel water tube), 25 years (steel, fire tube), and 35 years (cast iron).

[29] Model based on 13°F design temperature, 5300 DD.

- **Owners and property managers**. Our interviews suggested that the actual owners in the 5 – 30 unit apartment market work through intermediaries. "Owners" may be individuals (who often live in one of their buildings), co-op associations, corporations, or public agencies. In most cases, the hands-on management work is done by professional real estate property managers or building operators. We have been led to understand that few of these groups employ technically savvy staff. Instead, they tend to rely on contractors who maintain the boilers, ensure that they keep running, and advise on needed investments. Retrofits and repairs rarely involve a professional engineer. This means that replacements are often installed based on the existing equipment's ratings (which are usually much too large), rather than being sized by a proper radiation or heat loss calculation. Because condensing boilers are expensive, and oversized ones are even more expensive, this works against selecting condensing boilers.

- **Contractors** become key players on behalf of the owners, so their values are important to understand. Their greatest fear is callbacks for repairs or adjustments of new installations. In this situation, they incur uncompensated costs. As important, repeated callbacks jeopardize the trust relation with the customer. If the customer loses trust, he will look for another contractor, or start to consider competitive bids to find another contractor. Thus, the contractor will always choose equipment he knows, from vendors whose equipment has worked and whose distributor or representative has been willing to go the extra mile when there is an emergency. The reader will note that "efficiency" is not on this list of contractor concerns. He doesn't pay the bills. Whatever he installs will (he thinks) use less energy and require fewer repairs than the asbestos-covered hulk he has replaced, so the customer will be happy if it works.

- **Distributors and manufacturers' representatives** are likely to be important players in this kind of market. The contractor is likely to use them for technical assistance. From them, he is likely to receive various "spiffs" (incentives) and nice trinkets like hats and jackets for his mechanics. In many parts of the HVAC industry, the distributor is the source of training on new equipment. We believe that third parties (utilities, CEE) can have significant influence with this part of the chain.

While players in the schools and Federal buildings segments make purchase decisions based on the cost of owning and operating equipment over its lifetime, apartment owners often are only concerned with the first cost of the equipment. How do these players (and others) decide when to replace boilers?

- **Emergency replacement.** This will be the contractor's call. He is likely to advise the owner of the approximate bill (low-ball, in all likelihood), do the work, and then bill for it. There will not be an engineering review, heat loss calculation, or other niceties.
- **Replacing an obsolete unit, end of service life.** Not infrequently, after several years of increasingly desperate measures to keep the building warm, the contractor and owner's representative will agree that it is time to consider a boiler replacement. In this case, the sales cycle is long enough (sometimes several years) that condensing boilers could be considered for buildings with 2-pipe or better hydronic systems. As for emergency failures, the contractor is likely to "own" the sales process. This suggests that the best route in this situation is providing reasons why condensing boilers are the right choice. Direct incentives to the contractor are one way to have influence. This might be supplemented with decision-support materials to be shared with the owner. Rebates are likely to be highly effective in this corner of the market. Technical and presentation assistance by the utility may be very

effective: If the contractor knows he will be rewarded directly and will get help if he calls the utility, he is likely to take advantage of the opportunity. (This can also be packaged with fuel switching incentive programs.) Support should include engineering analysis (heat loss calculations for sizing), and participating in presentations to the owner. Our interviews suggest that these approaches are likely to be more successful with more sophisticated owners and managers (who are associated with larger buildings, in many cases), and with the most savvy contractors.

- **Fuel conversion.** When an owner is doing a planned conversion (as from oil to gas), the gas company may be notified in time to encourage higher efficiency products. It is not clear that all local distribution companies have internal communications that would support this effort by giving timely information to the marketing staff.
- **Moving in the market.** We expect that this kind of activity, such as moving a rental property to condominiums with a major overhaul to make the building marketable, is the best opportunity for presenting the case for condensing boilers. First, these conversions are planned, and require enough work that the projects are visible through building permits, stories in real estate magazines, etc. Second, an upgraded HVAC system may be an element of preparing the conversion. For those cases in which this repositioning does not involve central air conditioning, condensing boilers may have a chance, particularly for smart owners who want to differentiate their product by its low monthly fees and even, perhaps, position it as environmentally optimized. In addition, the combination of central air conditioning and hydronic heat will be perceived as deluxe by many consumers. This may be the best shot at having an architect work on behalf of the condensing boiler; some architects actively promote efficiency as part of a green package.
- **New construction.** As suggested above, we regard this as a very small opportunity, limited to situations where the owner has chosen water source heat pumps[30]. In most cases, we believe that these units are getting unitary forced air systems with integrated air conditioning, and no boilers (except possibly for service water heating).

11.5.2 Influencers[31]

CEE uses the term *influencers* to refer to external agencies that shape the market. That is, those who are not part of the value chain for sales, but whose actions influence the market. CEE lists utility programs, public sector programs, and codes and standards. We consider these individually, in our guess of rank order from most to least influential.

- **Utility Programs.** As suggested above, in the section on "Players," utilities have different opportunities to help get condensing boilers into appropriate apartment applications. The traditional route is through rebates, which buy down the incremental cost of the more efficient equipment. Our interviews suggest that, for this sector, a strong focus on the contractor as key player is most worthwhile, as discussed in the summary section.
- **Public Sector Programs** could be very important in raising visibility of condensing boilers. As Moore pointed out in 1991[32], there is an essential paradox in moving emerging

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[30] Water source heat pump systems ("California systems") use unitary heat pumps to heat and cool building zones, responding to demand for either from each zone. The heat pumps exchange heat with a water distribution loop that serves as the primary energy carrier. A boiler is used to keep the loop temperature at or above a lower set point, usually 60°F, and a cooling tower keeps the loop temperature below an upper set point, typically 95°F. A condensing boiler might prove cost-effective in this application, where it will always receive very cool (60°F) return water.

[31] This section closely parallels the treatment in the schools and offices segments.

technologies beyond early adopters to the mainstream market. The mainstream demands that the product be "surrounded" or fully supported by a complete infrastructure of informed designers, good design tools, case studies, and peers who have praised the product. The emerging product has none of these attributes, and does not have the cash flow to support them. NYSERDA, as a result of a competitive solicitation, proposes to launch a program to construct this infrastructure for another emerging technology, ground source heat pumps; the model could well be adapted to condensing boilers. CEE could play a similar role.

- **Codes and Standards** are unlikely to play a role in the evolution of the condensing boiler market for a number of years. At this point, there simply are not enough manufacturers with enough market penetration to make a strong case for an efficiency floor that would require condensing boilers. In addition, the technical discussion in this report has shown that the most likely early application is as lead boilers in lead-lag configurations. Thus, to the extent that our arguments are correct, economics favor *not* pushing non-condensing boilers out of the market. In many respects, the complexity of this situation resembles that of the water heating market. When DOE proposed a standard that would have removed electric resistance boilers from the market, the manufacturers and their allies were able to show many situations in which the heat pump water heaters were inapplicable or too expensive to install. Because DOE can regulate manufacture but not application, this kept DOE from establishing the proposed regulations at that time.

11.6 Barriers

We find the following major barriers to greater penetration of condensing boilers in apartment buildings:

- **Technical Barriers.** Our analysis suggests that the 5 – 30 unit apartment building market has a relatively small fraction of situations in which condensing boilers are likely to be successful. Most buildings in this class are relatively old, with high-temperature, one-pipe steam systems. These have no heat sink for condensing, and the cost of retrofitting to a 2-pipe hot water system with enough radiation to support lower temperature circulation, good control, and condensing operation is considered prohibitive by knowledgeable experts.

- **Economic Barriers**. Smaller apartment buildings such as these are likely to need substantially less than one million Btuh peak capacity. Thus, where they have appropriate 2-pipe distribution systems, they could be equipped with multiple boilers of residential scale (<300,000 Btuh per unit). The price premium for smaller condensing boilers is much less than for commercial scale units, and their market penetration (in numbers, not percentages) is higher. This, combined with good economics for stack installation in many cases, may prove condensing boilers to be (life cycle cost) competitive for 5 – 30 unit apartment buildings in some areas. Using these boilers for indirect service water heating improves economics further.

- **Institutional Barriers**. Some options that might be technically feasible and might be economically attractive may not be considered, because they fall into a void between the areas of interest of important influencers. For example, consider a new apartment/condominium building. To provide the greatest flexibility for each unit, whether it wants heating or cooling, the owner specifies a water source heat pump system

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[32] Moore, G. A., 1991. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers.* HarperBusiness.

for each unit, with a desuperheater[33] to provide hot water for a small storage tank in each apartment. To modulate the water loop temperature, she specifies a closed circuit fluid cooler and a gas-fired condensing boiler. The electric utility likes the design, except for the boiler, and suggests substituting another emerging technology, the ground heat exchanger (which will also pick up much of the cooling load, downsizing the fluid cooler). The gas utility thinks the condensing boiler system is wonderful (we hope), but hates to lose load to the heat pumps. They suggest instead that the boiler be supplemented with a reciprocating or absorption gas air conditioner. From a long-term perspective, sharing the load might be a better solution for the customer, both utilities, and the environment. One interviewee suggested a different kind of institutional barrier, one within the utility, even within a single-fuel utility. It is hard, in a large organization, to keep to a single, coherent message. The marketer may be committed to this technology, because it meets corporate goals (or because he receives incentives to succeed). The account representative may have assimilated the lesson that customers come first, and may be reluctant to potentially jeopardize a trust relationship by recommending something that he feels is not yet ready for prime time. We have heard independent stories, from different regions and with different energy sources, of exactly this problem. The balance among corporate objectives is a high-level management issue for which there are no simple solutions.

- **Lack of Timely Information**. Utility representatives suggest they are often frustrated by not having the opportunity to work with customers before choices are frozen. While the school construction market has “alert” services that advise designers, contractors, and equipment vendors about upcoming opportunities, we have no experience with comparable services for the apartment market[34]. If such services do not exist, there are no substitutes for networking with the industry. One effective vehicle might be working with the contractors. For example, offer a drawing for a week-long tropical cruise, with one entry for each good lead given in time to work with the contractor and his client. In this market, the contractor is the key information source.

- **Countering Tall Tales.** Around every relatively new approach, there quickly develops a hoary ball of horror stories about failures. It is important to put out case studies, engineering guides, and other tools that will keep slander and exaggeration at bay. The market is not nice, and competing technology advocates will do everything possible to “trash” condensing boilers.

11.7 Summary

The maximum potential market, on the order of 4,000 boilers per year, for installation of commercial-scale condensing boilers in 5 – 30 unit apartment buildings appears attractive.

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[33] A desuperheater is a small refrigerant-to-water heat exchanger installed at the outlet of the compressor. In the air-conditioning cycle, it uses reject heat to heat hot water and improve system efficiency. Desuperheaters are commonly installed with water source heat pumps, but very rarely with air source heat pumps.

[34] The schools market is predominantly a public sector market. It is much more transparent than most private markets, in that all significant purchases require bidding or other competitive procurement that is announced to potential vendors. This makes it inexpensive to gather information, relative to a much more widely distributed and largely private market such as apartments.

There are, however, several economic and institutional barriers that need to be addressed for the maximum potential to be realized. Property owners will not consider replacing boilers until they completely break down. Since boiler failures always occur in the heating season there is no time for other players such as contractors or “influencers” to educate the property owner about the lifetime advantages of condensing boilers. Instead, the immediate availability of a low-cost similar type/size boiler that can use existing flues, controls and terminal radiation or fan-coil units will be the only decision driver. The only other opportunity for heating system replacement will occur when the building undergoes major renovation/conversion to cooperatives or condominiums. At that point the decision is often made to install decentralized heating/cooling forced-air systems in each dwelling unit to allow for individual energy metering.

For the above reasons we do not recommend that small apartment buildings be considered as a high priority market segment.

Chapter 12: Summary and Recommendations

12.1 Background

This chapter summarizes the results of our assessment of the market for condensing boilers in the school, office, apartment and Federal building sectors addressed in detail in Chapters 8 through 11. Our goal here is to compare the market segments, and to pull together the players, influencers, barriers and recommendations for all of these chapters. We began this part of the project by preparing a list of potential market segments for study of their potential for successful market transformation for condensing boilers (Appendix 4). The candidate market segments are listed in Exhibit 12-1, with the selected segments in bold type.

Exhibit 12-1: Candidate Market Segments*

Apartment Buildings, 1 – 3 story, up to 30 units, retrofit
Schools Built Since 1945, Space Heating
Senior Complexes and Similar Institutional, 100 units and larger, New Construction
Apartment Complexes, up to 30 units, New Construction
Apartment Buildings, > 3 story, 30 – 100 units, Retrofit
Federal Facilities
Service Water Heating
Office Buildings, up to 100,000 ft^2, Retrofit and New
Boilers for Water-Source Heat Pump Commercial Systems ("California heat pump systems")

*Segments selected for this project are shown in **bold** face type

From this list of nine segments, the CEE Subcommittee selected three for consideration. These were schools, office buildings, and smaller multi-family apartment buildings (1 to 3 story, 5 to 30 units each). CEE also asked us to consider Federal facilities as a subset of office buildings. Because the procurement methods for the Federal market are rather different from those used in other segments, we chose instead to treat it as a "bonus" fourth segment.

12.2 Ranking of Potential Market Segments

From our research, we have concluded that these sectors should be ranked as follows:

1) Schools (Chapter 8)
2) Federal Facilities (Chapter 10)
3) Apartments (Chapter 11)
4) Offices (Chapter 9)

One parameter in this ordering is the estimated size of the market for commercial scale condensing boilers in each of these segments as shown in Exhibit 12-2.

Exhibit 12-2: Estimates of Potential Market Size for Segments Studied

Market Segment	New Construction, Units/yr	Estimated Number with Boilers	Standing Stock, Units w. boilers	Annual Retrofit Potential Buildings	Total Annual Market (buildings, not boilers)
[1]**Schools, post-1960**	[2]900	[3]315	[4]110,000	[5]1,650	1,965
[6]**Federal**	no data	Unknown	500,000	[7]3,000	[8]3,000+
[9]**Apartments, 5-30 units, with Resid. Size Boilers**	28,000 total	virtually none	2,800,000	84,000	4,000
[10]**Offices, <100,000 ft^2**	no data	Unknown	[11]47,000	268	[12]500

Our reasons for this ranking arise from the segment-specific chapters, as summarized below.

12.2.1 Schools

The value system in schools fosters consideration of life cycle costs over first cost (in more cases than in other segments). School decision makers often value efficiency and environmental protection as inherent values, and condensing boilers can meet these tests (high efficiency, low emissions). There are already successful school installations that can be used as case studies. As important, school facilities managers network extensively with each other, so word of success can be carried to the state association and others for rapid and persuasive dissemination. In short, the elements are in place and may only require coordination and "seeding" to make condensing boilers a preferred technology in many school applications.

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[1] See Chapter 8 for justification for this row

[2] Based on data in Abramson, 2000.

[3] Fraction of schools with boilers taken from CBECS BS-33.

[4] "EnergySmart Schools, Briefing July 30, 1998 by Dan Reicher

[5] As in the schools chapter (8), we multiply the standing stock (pre- and post-1945) times 0.03 (roughly considering 30 life time) times 0.5 (fraction of estimated standing stock of schools with boilers. We use 0.5 instead of the lower value (0.35) because we believe that older schools are more likely to have boilers than the newer ones: newer ones are preferentially in the South, SE, SW, and West (Abramson, 2000, p. 19)

[6] See Chapter 10 for justification for this row.

[7] Assuming 3%/year retrofitted, and 19% of buildings have boilers (CBECS, from Chapter on Office Buildings)

[8] Larger than 3000 by the number of new buildings that have potential for condensing boilers

[9] See Chapter 11 for justification for this row.

[10] See Chapter 9 for justication for this row.

[11] From CBECS 1995, buildings between 25,000 - 100,000 ft^2 only

[12] From the estimated fraction of buildings big enough to use commercial scale boilers, augmented to allow for ESPC impact

12.2.2 Federal Facilities

We rank Federal facilities lower than schools only because these facilities require persuading two individual decision-making teams to act. The Federal route most likely to adopt condensing boilers is the ESPC offered by a vendor to a Federal facility. This means that the third party ESCO or utility must be persuaded that offering condensing boilers as part of a contract will make it more interesting to a Federal client. So, the ESCO must be sold. This means selling the Federal facility manager too. While other advanced technologies such as gas cooling and geothermal heat pumps are backed by well-funded special-interest groups that promote their technologies directly to ESCOs and to in-house energy management offices at Federal agencies, condensing boilers have no such support or exposure. If the Federal facility manager decides that a condensing boiler should be part of the solution, he will need to sell the benefits of this technology to the ESCO.

In addition, the focus of an ESPC is typically a complete building, base, or campus, with HVAC projects in the $1 -$2 million class. Since these projects generally include many other measures and technologies, it is harder to make the benefits of the condensing boiler more visible to the ESCO or the client. It is unlikely that the boilers will account for a large fraction of the contract value.

12.2.3 Apartment Buildings

This retrofit market appears to have a maximum potential of 4,000 boilers/year. Unfortunately, many economic and institutional barriers will prevent this potential from being realized due to the manner in which retrofit opportunities arise.

In this market, virtually all boiler replacements occur due to a mid-winter failure. It will rarely be a good opportunity for condensing boilers, since the foremost decision drivers will be first cost, immediate unit availability, and “plug-and-play” interchangeability, with minimum changes in system plumbing or controls that could delay getting back on line.

The second most common reason for boiler replacement is the result of an ownership change and/or a decision to change the building’s position in the market. This could, for example, reflect a decision to convert the building from rentals to cooperatives or condominiums. In some cities, it might reflect a decision to invest to warrant change in rents in a rent-controlled environment if these relatively small apartment buildings are important for conversions.

12.2.4 Offices of Less than 100,000 ft^2

The office buildings market is very large, and has very high penetration of natural gas. Gas is the space heating fuel of choice for the majority of commercial buildings (56%), with electricity a distant second. However, the penetration of boilers is much smaller, at 19%. In addition, the average office building is small relative to the size of commercial condensing boilers.

We believe that roof-top “gas-pack” forced air furnaces, a less expensive installation, dominate the mid-sized low-rise commercial buildings market, with gas furnaces/split air conditioners in the smaller buildings. Thus, the potential market is much smaller. It includes relatively large office buildings, and (probably) owner-occupied older buildings.

Other than the Federal sector, the office buildings we believe are most likely to adopt condensing boilers will be in new construction, by firms that want to demonstrate advanced natural gas technologies (as a result of the natural gas industry's outreach programs). We expect this to be a small fraction of a total market that is only growing 0.9% per year.

From this discussion, we conclude that there are relatively few office buildings (outside the Federal sector) for which a compelling value proposition can be made for installing condensing boilers. Too many are owned by developers or landlords who do not pay the utility bills. For almost all, the economics fail their hurdle rate requirements. And finally, few try to market themselves in ways that build on the environmental and efficiency advantages of condensing boilers.

12.2.4 Potential Size of Market for Condensing Boilers

Exhibit 12-3 summarizes our estimate of the annual market for condensing boilers in each of the four segments studied. We estimate that, under ideal conditions, more than 15,000 commercial-size condensing boilers could be absorbed by the Federal sector each year. The next largest market for commercial-size boilers is that for schools, followed by apartment buildings and offices. We estimate that the apartment market can absorb about 1,000 commercial-size and 3,000 residential size (<300,000 Btuh) condensing boilers.

Exhibit 12-3: Estimates of Potential Annual Shipments of Condensing Boilers

Market Segment	Total Annual Market for Condensing Boilers	
	Number of Buildings that Need Boilers	Number of Boilers Needed[13]
Schools, post-1960	1,965	[14]5,900
Federal	3,000+	[15]15,000+
Apartments, 5-30 units, with Resid. Size Boilers	4,000	[16]4,000
Offices, <100,000 ft^2	500	[17]1,000

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[13] Estimates are based on market size from Exhibit 12-2 and assumptions below that account for technical barriers, standard design practice and geographical factors

[14] School building assumptions: 1,965 buildings x 3 boilers each @ 330 Mbtuh input.

[15] Federal building assumptions: Predominant building is a 178,000 sq.ft. office with 5 boilers each @1.5 MMBtuh input.

[16] Apartment building assumptions from Chapter 11: 1,000 buildings with one boiler each @ 675 MBtuh input and 3,000 buildings with one boiler each @ 250 MBtuh input.

[17] Office building assumptions: 500 buildings with two boilers each @ 300 Mbtuh input.

12.2.5 Potential Annual Energy Savings from Condensing Boilers

Exhibit 12-4 summarizes our estimate of the annual energy savings in each of the four segments studied if all boilers installed in 1999 were condensing boilers. Energy savings estimates are based on the number and capacity of the condensing boilers identified in Section 12.2.4. The estimates assume that condensing boilers replace all existing boilers that have a thermal efficiency of 80%.

Exhibit 12-4: Estimates of Potential Annual Savings from Condensing Boilers

Market Segment	Total Annual Energy Savings from Condensing Boilers	
	Number of Buildings that Need Boilers	Energy Savings[18] Trillion Btu/Year
Schools, post-1960	1,965	0.271
Federal	3,000+	2.538
Apartments, 5-30 units, with Resid. Size Boilers	4,000	0.234
Offices, <100,000 ft^2	500	0.034

We estimate the market share of condensing boilers in 2020 at the national level to be approximately 22,600 units under the "Fully Supported Market Transformation" scenario versus approximately 1,500 units under a "Business As Usual" scenario (Chapter 7). This translates to energy savings of 1.52 trillion Btus[19] across all four market segments, during 2020.

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[18] Energy consumption was calculated using the average of the full-load equivalent operating hours (FLEOH) for 3 cities, Providence, Detroit and Minneapolis from "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment", Pacific Northwest National Laboratory (PNNL-13232), April 2000. It was assumed that only 20% of the buildings used night set-back. The following FLEOH were used for each segment: Office and Federal – 1,015 hours; Schools – 1,253 hours and Apartments – 1,635 hours.

[19] If average boiler capacity for all applications is 500,000 Btuh gas input, heat load is 500,000/0.80 = 400,000 Btuh for 80% efficient conventional boiler. Gas input for 90% efficient condensing boiler is 400,000/0.90 = 444,444 Btuh. Gas savings for each boiler (per FLEOH) = 500,000 – 444,444 = 55,556 Btuh. Gas savings in 2020: 55,556 Btuh x 1,300 average FLEOH x (22,600 – 1,500) boilers sold in 2020 = 1.52 trillion Btus.

12.3 Players and Influencers

12.3.1 Players

Exhibit 12-5 indicates the importance of different groups of players for the market segments studied. For clarity in this summary, we treat FEMP as a third party, an influencer, rather than a "player." As discussed in the section on the Federal sector, FEMP has aspects of both an owner (representing an arm of the Federal government as building owner) and an influencer, since it does not have line responsibility for building procurement and operation decisions.

Exhibit 12-5: Estimate of Importance of Players in Each Market Segment*

Players	Market Segment			
	Schools	Federal	Apartments	Offices
Owners	2	1	2	1
Design Engineers	1	4	5	2
Contractors	5	5	1	4
Energy Savings Companies (ESCOs)	4	2		
Outside Agencies (FEMP, etc.)		1	5	
Mfg. Representatives, Distributors			3	3
Internal "Champions" and Facilities Staff	3	3		
HQ "Champions"		3		
Architects	6	6	5	5

**In each column the player group we judge most important in reaching decisions is given a "1," and the least important player is ranked 6. Rankings are estimates, and may not be accurate for sub segments within the segments.*

The role of each type of player in each segment is discussed below:

- **The Owner**. Owners who have a long-run economic perspective (i.e., who are more interested in life cycle costs than first costs) are the most likely to support condensing boilers. *Schools* are often a good match. School owners often have been conditioned by state and Federal grants and loans to think in terms of values associated with investments that last, are reliable, and have decent economics. Because they expect equipment to last decades, and do not often go through retrofit cycles, even a 10 year payback can be attractive. Schools have additional leverage for such projects since they can use tax-free, low-interest bonds to finance the projects. This financing decreases the impact of higher first costs relative to the value of out-year energy savings. Given good support from the design team, allies, and a solid manufacturer, they have shown themselves to be willing to be early adopters. Nationally, schools have been very prominent early adopters of ground source heat pumps, another "emerging technology[20]." One of the overlooked potential champions for improved HVAC, particularly for building additions and retrofit projects, is the building engineer and the school district facilities staff. School facilities staff can play a role comparable to that of the facility managers in the Federal sector: They are the gatekeepers of acceptable practices, and can be agents of change. If they are opposed to it, innovations like condensing boilers will have a much harder path; if they become advocates, they can be very influential. After all, if the system is adopted on their recommendation, they will work hard for its success. And vice versa. In the authors' experience with the commercial sector market transformation, we have never found a participant who felt that he had invested too much in working with the facilities people, who are the day-to-day owners.

In the *Federal sector*, the "owners" are the managers responsible for facilities[21]. If engaged, they can be very effective in making installations happen. Some have altruistic motivations for doing the right thing as part of public service. On the other hand, even managers who take a narrower view will find one aspect of ESPC contracting very influential: Agencies keep the savings that they negotiate with the contractor[22]; these are not returned to the general Treasury account. Within agencies, funds that are not designated for specific uses are a scarce resource, and we expect that more and more managers will get a certain sparkle about new sources of such funds. Often these people can be characterized as "bottom-up champions" with base- or campus-level responsibilities. There are also "top-down champions," (probably at or near the Assistant Secretary level), who realize the advantages of new approaches, and push hard for innovation in facilities management. EPA and DOE are becoming active this way, as would be expected. To emphasize the importance of the top-down champion, Carr[23] points out that the uniformed services (Department of Defense) have some major commands that are becoming very active in promoting ESPCs, while others show less interest.

The potential for condensing boilers varies greatly across office building ownership types:

- **Owner-occupied retrofit** is likely to be one of the more likely targets in these buildings, because the building owner pays the energy bill. Also, in a retrofit situation, his full attention is focused on the equipment and mechanical system, giving more opportunities to talk about values.
- **Private owner-occupied, new construction.** If the firm has a close connection to the construction industry, or otherwise has a mission that stresses energy or the environment, the HVAC system may be "visible" to the owner. This occurs when she

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[20] See, for example, case studies posted at <www.ghpc.org>.

[21] As noted above, we treat the Federal Energy Management Program, FEMP, in this chapter as an *influencer* rather than a player.

[22] http://www.eren.doe.gov/femp/financing/espc_intro.html

[23] Millard Carr, personal communication, May 1, 00.

wants to showcase the building for customers or the community[24]. Otherwise, it is generally a small consideration, dwarfed by space, layout, features, and aesthetics. Since the mechanical system represents only about 15 percent of the cost of the building, mainstream owners will not allocate much time to it. They will, however, rely on the design engineer.

  - **Private owner, leased space.** Historically, energy efficiency has rarely been an important element of the decision "space" for developers. They have been perceived as interested in lobby aesthetics and increasing the number of corner offices, not better boilers (or windows, for that matter). Particularly when the tenant pays the energy bills, these developers are unlikely to adopt condensing boilers in competitive markets, absent a strong policy environment that would give them compelling reasons.

For *apartments***,** the owner's agent is usually a professional building operator or property manager. They tend to rely on contractors who maintain the boilers, assure that they keep running, and advise on needed investments. Retrofits and repairs rarely involve a professional engineer. This means that replacements are often installed based on the existing equipment's ratings (which are usually much too large), rather than being sized by a proper radiation or heat loss calculation. Because condensing boilers are expensive, and oversized ones are even more expensive, this works against selecting condensing boilers.

- **Design Engineer.** The design engineer is a key player in those segments that require a Professional Engineer's stamp to obtain a building/mechanical permit for boiler replacement. It is important to most designers that the technology be well supported. In part, this means availability of the tools and references he sees for mainstream technologies: good articles in the journals he reads, accessible design software, good guide specifications, and confidence that the vendor's equipment will work without problems – and that the vendor will stand behind it if there is trouble. Some HVAC designers have a strong professional interest in innovation for its own sake. Janda[25] has shown that a relatively small fraction of design engineers are likely to evaluate, adopt, and persist with emerging technologies. The designers who are likely to encourage early adopters are ones whose practice focuses on mid-sized, semi-custom buildings such as schools and offices (as opposed to smaller cookie-cutter applications, or very large and complex hospitals and skyscrapers). Within this group, Janda has also shown that those engineers who are driven by professional values (peer esteem, etc.) rather than the bottom line are the most likely to bring emerging technologies into their portfolios. These engineers are the most likely to see and present the advantages of condensing boilers to customers. For some, application of emerging technologies to appropriate projects is a way to differentiate their practices. For others, innovating is a way to show excellence as engineers, and they are likely to enthusiastically adopt condensing boilers[26]. Although Janda did not speculate on the point, we believe that these advocates are likely to be

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[24] An example would be a gas utility adopting absorption or engine-driven chillers and condensing boilers for its headquarters or a training facility.

[25] Janda, Katherine, 1998. Building Change: Characteristics of design firms and their effect on energy efficiency adoption. 1998 ACEEE Summer Study on Energy Efficiency in Buildings: Energy Efficiency in a Competitive Environment.

[26] As an anecdote, when Sachs attended a condensing boiler training class offered by a manufacturer, several of the participants were experienced ground source heat pump system designers. Both condensing boilers and ground source heat pumps are emerging technologies that appeal to the same constituencies.

participants in ASHRAE technical committees, Association of Energy Engineers (AEE), and in other activities that give them the professional exposure and esteem that they value. In addition to his lack of a role in the smaller apartment buildings retrofit market, the design engineer is likely to play less of a role as advocate in the Federal sector than in the non-Federal commercial building. For Federal facilities, the designer will be part of the ESCO/utility team, but may not have access to the customer except through the others players.

- **Contractors** are the key players in the smaller apartment market, but less influential in other sectors. The contractor's greatest fear is callbacks for repairs or adjustments of new installations. In this situation, they incur uncompensated costs. As important, repeated callbacks jeopardize their trust relation with the customer. If the customer loses trust, he will look for another contractor, or start to consider competitive bids to find another contractor. Thus, the contractor wants to choose equipment he knows, from vendors whose equipment has worked and whose distributor or representative has been willing to go the extra mile when there is an emergency. The reader will note that "efficiency" is not on this list of contractor concerns: He doesn't pay the bills. Whatever he installs will (he thinks) use less energy and require fewer repairs than the asbestos-covered hulk he has replaced, so the customer will be happy if it works. Mechanical contractors are key players for smaller office buildings, too. As discussed in the chapter on apartment buildings, they often have a long-standing relationship with a building owner, based on system maintenance over a period of decades. In such cases, they make the recommendations and presentations, and they install the systems, typically without competing bids. For larger buildings, the mechanical contractor generally has much less influence on the HVAC decisions, but bids from the designer's specifications.

- **Energy Service Companies, Energy Savings Performance Contracts.** This mechanism for providing energy services is emerging rather strongly, particularly in Federal facilities, schools in some states (notably New Jersey), and in some parts of the office sector. In these relationships, a third party (the ESCO) renovates the building, and usually operates it (or becomes responsible for its performance) for a fixed term of 15 – 25 years. During that period, the ESCO and the owner share the savings from the improved and retrofitted building. The ESCO takes the risk, makes the investment, and may earn up to 85% of the savings in some contracts. On the other hand, this method of operations is very attractive to at least two types of organizations:

    - **Capital-starved groups**. Particularly in government, where the queue for appropriated funds for renovation can be very long, the ESCO concept allows immediate renovation, which often improves comfort and system quality as well as providing savings.
    - **Groups focused on core missions.** The ESPC is best considered as simply another form of "out-sourcing," in which companies allow one firm to handle payroll, another to do logistics (shipping and receiving), and so on. If a firm's strength is design and marketing, it may let others manufacture its products. In this frame of mind, operating buildings is simply a nuisance, best outsourced to a specialist firm. Some of the firms undertaking this work have their roots as energy providers (utilities), some as controls firms, and others in yet other segments.

Clearly, for the military, both factors operate. ESCOs are actively marketing their services to a wide range of potential clients, in both government and the private sector.

- Distributors and Manufacturers' Representatives. The condensing boiler is the flagship product for companies that manufacture or sell them. There is pride (and, we expect, substantial profit) in successful customer installations. Manufacturers and their representatives want to sell these products, and they want to show their successes to other customers. They will be strong advocates. They are likely to be important players in the apartment and small office markets, and often provide important behind-the-scenes support for design engineers working on schools and similar sized facilities. For example, the vendor may provide equipment specifications for the bid, or assistance in sizing equipment. The distributor may provide the contractor with various "spiffs" (incentives) and nice trinkets like hats and jackets for his mechanics. In many parts of the HVAC industry, the distributor is the source of training on new equipment. Other players and influencers must understand that manufacturers' representatives are and must be opportunists: They will sell to the market segments that are most receptive. If they are selling one tenth of their condensing boilers to offices and 80% to schools, they will allocate resources almost entirely to incremental sales in the schools market. And, of course, vice versa. At the present time, the authors believe that they are more likely to focus on sectors (such as schools) where they can build on successes.

- **Architect.** The architect is not a heating system specialist, but she has high-level concerns related to HVAC. She is concerned about cost ($\$/ft^2$), mechanical space required, noise, and other environmental impacts. If she can be convinced that the designer's "pet" HVAC system does not threaten these values or her reputation (through cost overruns or operating problems), she usually has little further concern with the system. In some cases, the architect may not be supportive. For example, the architect could insist on a "clean" roofline without cooling towers, packaged HVAC equipment, chimneys, or other elevated mechanical features. Such buildings might lean toward electric technologies.

12.3.2 Influencers

CEE uses the term *influencers* to refer to external agencies that shape the market. That is, those who are not part of the value chain for sales, but whose actions influence the market. Examples include utility programs, public sector programs, and Federal and state standards. The potential roles and importance of influencers are shown in Exhibit 12-6.

Exhibit 12-6: Estimate of Importance of Influencers in Each Market Segment*

Influencer	Market Segment			
	Schools	Federal	Apartments	Offices
FEMP		1		
CEE and other infrastructure support consortia	2		3	2
Utility rebates	1	3	1	1
Mfg. Representatives, Distributors	4	4	2	4
Building Codes	3		4	3
Equipment Standards	5	5	5	5

**In each column (schools, Federal, etc.), the influencer group we judge most important in reaching decisions is given a "1," and the least important influencer is ranked 6. Rankings are estimates, and may not be accurate for sub segments within the segments.*

This part includes consideration of FEMP as an influencer. As discussed above and in the section on the Federal sector, FEMP has aspects of both owner (representing an arm of the Federal government as building owner) and an influencer, since it does not have line responsibility for building procurement and operation decisions.

- Perhaps the most striking example of the potential role of an influencer is the **Federal Energy Management Program (FEMP).** " FEMP, part of the U.S. Department of Energy (DOE), helps agencies reduce their costs, increase energy efficiency, use renewable energy, and conserve water. FEMP's role is to serve as the advocate, enabler and facilitator of Federal energy management, leading Federal agencies to accomplish energy efficiency, renewable energy, and water conservation goals[27]." The mission of the FEMP is to reduce the cost of government by helping agencies reduce energy and water use, manage utility costs, and promote renewable energy. "As the largest energy consumer in the world, the U.S. government's cost- and energy-saving opportunity is enormous. In Fiscal Year (FY) 1996, the government spent nearly $8 billion for its 500,000 buildings, its vehicles, and process energy. FEMP's three major work areas include project financing; technical guidance and assistance; and planning, reporting, and evaluation[28]." At this point, FEMP must be considered a success, since the Federal government is on schedule for achieving very aggressive energy efficiency goals: On a Btu-per-gross-square-foot basis, the 15.2% reduction in buildings energy [by 1996] put the Federal Government on track to meet the 20% reduction goal for 2000[29].

As understanding of market transformation deepens, we see a strong role for CEE, regional consortia, and even state energy agencies such as NYSERDA[30] that consider market transformation as a core mission. From the work of Geoff Moore[31], we understand that the market can be divided into "early adopters" and "mainstream buyers." Early adopters buy "boxes," that is, they will buy equipment for its potential to give them a market advantage. Mainstream buyers do not buy anything that their peers are not using. They are happy to be second on the block, and thereby avoid the challenges faced by the early adopter. Agencies like CEE can serve a vital function by providing services that emulate those provided by a mainstream market. These include (but are not limited to) design software, generic specifications, case studies, a literature of performance studies, and directories that help customers find experts. These services include providing enough trade articles to make the technology appear familiar, and enough research publications to give a "buzz" of interest in the product. In addition to their direct support of such activities, groups like CEE can provide frameworks for coordinating other programs, such as utility rebates and bulk purchases.

- **Utility Programs.** The Waltham High School case study (Chapter 6) shows that schools can have reasonable paybacks with utility incentives such as rebates. Utility information programs, including design assistance, thus may suffice for public sector buildings. In these cases, the owner may be convinced of the benefits, if it appears that the product is well supported, well backed by the utility, and will achieve the reliability and economic benefits promised. Utility rebates (or loan buy-downs) can bring the product within the

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[27] FEMP Business Plan. <<http://www.eren.doe.gov/femp/aboutfemp/business_plan/environ.htm, >>

[28] http://www.eren.doe.gov/femp/aboutfemp/fempoverview.html

[29] http://www.eren.doe.gov/femp/aboutfemp/annual_reports/ann96_overview.html

[30] New York State Energy Research and Development Administration, www.nyserda.org

[31] Moore, G. A., 1991. *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers.* HarperBusiness

customer's hurdle rate for capital, which may be so high as to require two or three year payback.

- **Building Codes** are important influencers. In particular, ASHRAE/ANSI Standards 90.1 (energy performance) and 62 (ventilation for indoor air quality) will have important effects on design practice. Standard 90.1 is interpreted as requiring specified levels of performance, but allowing attainment options. Creative designers who properly employ (sophisticated) simulation programs may specify very efficient equipment to allow relaxing stringent requirements in other areas, such as glazing. Excellent case studies and journal articles could effectively illustrate this process, and raise the popularity of condensing boilers with architects as well as designers. Similarly, Standard 62 places great responsibility on the designer to provide enough ventilation air, which must be heated (and often humidified) in winter, and cooled (and dehumidified) in summer. Because of the internal gains of buildings, the balance point at which heating is required may be less than (or much less than, in some cases) 55°F. This means that the water used to warm ventilation air can be returned to the boiler at condensing temperatures, so the potential efficiency of the condensing boiler can be realized throughout the heating season.

    - On the other hand, **Equipment Standards** are unlikely to play a role in the evolution of the condensing boiler market for heating for a number of years. At this point, there simply are not enough manufacturers with enough market penetration to make a strong case for an efficiency floor that would require condensing boilers. In addition, the technical discussion in this report has shown that the most likely early application is as lead boilers in lead-lag configurations. Thus, to the extent that our arguments are correct, economics favor *not* pushing non-condensing boilers totally out of the market. In many respects, the complexity of this situation resembles that of the water heating market. When DOE proposed a standard that would have removed electric resistance boilers from the market, the manufacturers and their allies were able to show many situations in which the heat pump water heaters were inapplicable or too expensive to install. Because DOE can regulate manufacture but not application, this kept DOE from establishing the proposed regulations at that time.

12.4 Barriers

We find the following major barriers to greater penetration of condensing boilers:

- **Technical Suitability.** Only a small fraction of the buildings in any of these sectors is feasible for conversion to condensing boilers. Many buildings in each of these sectors will have one-pipe steam systems that cannot be economically converted to 2-pipe hot water systems. As steam systems, they do not have an adequate heat sink to condense flue gases. Many of the 2-pipe systems would require extensive reworking, at high cost, to use condensing boilers. This is because some buildings with 2-pipe hot water distribution have water loops that deprive some owners of heating services when return water temperatures are reduced to condensing levels, even in swing seasons. Unless the distribution system can return low-temperature (<120°F) water to the boiler, there will not be enough condensing of flue gases to warrant using a condensing boiler.

- **Cost.** Economics and EIA-projected natural gas prices do not provide a compelling argument to owners considering boiler purchases today, in many situations. Typical paybacks are greater than five years, but may still be attractive to school owners, who care greatly, in many cases, about life cycle costs. These paybacks are beyond consideration for the bulk of commercial building developers in the private sector. It is important to note, however, that payback periods will become more attractive as gas prices increase. In the Federal sector, the package of measures for an ESPC project must have a 10-year payback at standard Federal assumptions (discount rate, etc.). In addition, to the ESCO, "cash flow is king[32]." That is, the vendor and other advocates of condensing boilers will have to demonstrate that the installation of a high-priced condensing boiler will help their economics by deep, early reductions in energy outlays, and that it will continue to produce these savings (and the resulting flow of cash from the energy savings) for the life of the project. For them, profitability is the result of beating expectations on costs.

  For smaller buildings such as the 5 to 30 unit apartments studied, multiple residential-sized condensing boilers could be attractive for retrofits where they have appropriate 2-pipe distribution systems. The price premium for smaller condensing boilers is much less than for commercial scale units, and their market penetration (in numbers, not percentages) is higher. This, combined with good economics for stack installation in many cases, may prove condensing boilers to be fully competitive (cost effective) for 5 – 30 unit apartment buildings in some areas. Using these boilers for indirect service water heating improves economics further.

- **Split Incentives**. Too many buildings are owned by developers or landlords who do not pay the utility bills, and thus have very little interest in efficiency. This is clearest in the office segment, but there are analogues in many other facilities. For example, a major task for FEMP is just "closing the loop" so those who make decisions have energy bill information. The new provisions that allow agencies to keep energy savings to supplement program funds may help capture decision-maker attention.

- **Finding, Encouraging, and Supporting Champions.** Without internal advocates, the technology will not be adopted. "Everyone has to say yes, but anyone can say no," and thus kill a project. Vendors, utilities, and others who would encourage adoption of condensing boilers must find internal advocates, and must be sure that these people, who take risks to improve efficiency by adopting new technologies, must never be let down. A disappointed champion may become an implacable foe, as happened to ground source heat pumps at one military base.

- **Information Problems.** This category aggregates a diverse suite of issues impacting different players and influencers.
  - **Notification**. Too many utility representatives and others who would support installation of condensing boilers do not hear about projects until after the specifications are fixed in the design. The best way to reduce this barrier may be to subscribe to services called "construction alerts" that systematically poll A&E firms and/or owners to advise clients of upcoming projects.
  - **Countering tall tales.** Around every relatively new approach, there quickly develops a host of horror stories about failures. It is important to put out case studies,

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[32] M. Carr, personal communication, May 1, 00.

engineering guides, and other tools that will keep slander and exaggeration at bay. The market is not nice, and competing technology advocates will do everything possible to "trash" condensing boilers

- **System Design Issues**
  - **Learning curves**. For best results, the system downstream of the boiler needs to be designed with efficiency in mind. This does not only include the shell, but low-temperature radiation that allows condensation all or almost all the time. Of course, this raises costs further (for the additional heat transfer surface required), and tends to compound the perceived economic barrier. Of course, it is also a problem for the engineer who has to learn new ways to work.
  - **Lack of focus on heating loads**. The major HVAC focus of designers of commercial offices is the cooling load, since it will dominate operating costs in most cases. It is hard to raise the visibility of technologies that are not considered to play a large role in operating costs or customer needs.

- **Infrastructure.** One reason that some emerging technologies are increasing their market penetration more quickly than condensing boilers is that others have organized advocacy groups that give the emerging technology the appearance of a mainstream technology[33]. For somewhat more mature technologies like photovoltaics and wind, both trade associations and Federal support have been critical. For ground source heat pumps, advocates formed two trade associations to provide information, develop tools, and publicize opportunities. These efforts have been supplemented by a strong ASHRAE technical committee (TC 6.8) that has sponsored development of tools, presentation of symposia and articles, and generally shaped the research and development agenda. We do not yet find such an effort for condensing boilers, except for the purely technical activities of ASHRAE SPC 155 (which is focused on efficiency measurement methods, a key early step). We believe that market transformation will be greatly accelerated by development of a dedicated support infrastructure with third party financial support and vendor involvement. The external financial support is likely to be required, because the cash flow of a few thousand unit sales per year will not support the required efforts[34].

- **Procurement** (Federal): Even with ESCO involvement and greater experience that is being accrued, the procurement process remains challenging, and delays from initial contact to contract are routinely much longer than in the commercial sector. For this reason and the importance of contract terms, Federal procurement is generally a specialty unto itself, and the authors have encountered sub specialists who focus (for example) on the military, or on one service or perhaps some of its commands.

- **Privatization** (Federal): There is much discussion about, and some action toward, turning Federal buildings over to the private sector through what might be called

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[33] For a discussion of the concept, see Moore, Geoffrey A, 1991: *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers*. HarperBusiness.

[34] Programs such as the SuperEfficient Refrigerator Program (SERP) and the Geothermal Heat Pump Consortium have required substantial investments, typically more than $100 per unit sold during the activities of the program. Manufacturers of emerging technologies cannot individually support efforts of such a large scale without impacting prices and decreasing sales. For this reason, states, the Federal government, and utilities increasingly supports "market transformation" programs with public funds.

leaseback arrangements. The motives are similar to those leading to ESPCs – greater control over costs, better operations, etc. There is some danger that some agencies will hesitate to implement ESPC contracts that might make privatizing buildings more difficult. At this point, this is still speculative.

- **Competition and Occupied Niches**. In some downtown locations district heating by high temperature water or steam is available as a utility. Where it is available, it competes strongly with local boilers, because it requires less mechanical space in the building. Where rents are high, as in downtown locations, any boiler room is space that could otherwise be rented. Conversely, in many suburban locations, the major competition for boilers is the low-cost option of packaged rooftop "gas-pack" combined forced-air furnaces and air-cooled air conditioners. There may be an exception for very high-quality or custom new construction.

- **Institutional Barriers**. Some options that might be technically feasible and might be economically attractive may not be considered, because they fall into a void between the areas of interest of important influencers. For example, consider a new apartment/condominium building. To provide the greatest flexibility for each unit, whether it wants heating or cooling, the owner specifies a water source heat pump system for each unit, with a desuperheater[35] to provide hot water for a small storage tank in each apartment. To modulate the water loop temperature, she specifies a closed circuit fluid cooler and a gas-fired condensing boiler. The electric utility likes the design, except for the boiler, and suggests substituting another emerging technology, the ground heat exchanger (which will also pick up much of the cooling load, downsizing the fluid cooler). The gas utility thinks the condensing boiler system is wonderful (we hope), but hates to lose load to the heat pumps. They suggest instead that the boiler be supplemented with a reciprocating or absorption gas air conditioner. From a long-term perspective, sharing the load might be a better solution for the customer, both utilities, and the environment.

  One interviewee suggested a different kind of institutional barrier, one within the utility, even within a single-fuel utility. It is hard, in a large organization, to keep to a single, coherent message. The marketer may be committed to this technology, because it meets corporate goals (or because he receives incentives to succeed). The account representative may have assimilated the lesson that customers come first, and may be reluctant to potentially jeopardize a trust relationship by recommending something that he feels is not yet ready for prime time. We have heard independent stories, from different regions and with different energy sources, of exactly this problem. The balance among corporate objectives is a high-level management issue for which there are no simple solutions.

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[35] A device that captures excess hot gas energy from the compressor of a heat pump (the "superheat") and uses it to heat water for a storage tank. Use of this heat sink improves efficiency in the air conditioning cycle, and is common with ground source heat pumps in residential applications.

12.5 Recommendations

The authors find that:

1. If CEE or others are to develop market transformation programs for commercial scale boilers, we find advantages in focusing on true condensing boilers, rather than on "near-condensing" boilers with efficiencies just a few points above those for conventional atmospheric draft units. The condensing boiler is readily identified by its installation features (condensate drain, sealed and corrosion resistant stack).

2. The present sales volume for commercial scale condensing boilers is very low, hundreds of units per year, and we believe that it is highly concentrated in the Northeast and Midwest (for space heating applications). Thus, we recommend that any program that is offered be started in one or both of these regions. As just one reason, we do not believe that the manufacturers have interest in or the ability to support a truly national program yet, which would challenge the training infrastructure, installation support, and marketing focus.

3. The schools market is the most likely to lead adoption of condensing boilers. It is followed by the Federal sector, apartment buildings, and offices, roughly in that order.

4. The key strategic decision for program sponsors is the division of resources between infrastructure support and financial incentives. It is clear that rebates and other incentives boost sales in the short run. However, manufacturers believe that rebates create a "false market" that will disappear when rebates are halted. Investing in infrastructure can help build a self-sustaining market. This includes training for market players, and the development and dissemination of support tools such as generic specifications, design software, case studies, marketing articles, and fact sheets with environmental benefits.

Thus, the team recommends that the Consortium for Energy Efficiency consider a market transformation program for commercial-scale condensing boilers. Such a program would probably start in the Northeast (New England plus New York), judging from present interest among utilities and state agencies (and inferred present sales). We recommend that it begin with the schools market, and that it stress infrastructure development at least as much as financial incentives. Such a program should be designed to last 6 – 10 years, with modest process goals in the first years. Goals that are set too high in the initial years are not expected to be met, because it takes time to develop tools and awareness. It takes even more time for the information and "buzz" to diffuse from early adopters to the mainstream in a way that makes mainstream purchasers comfortable specifying commercial scale condensing boilers for their installations and those of their customers.

Appendix 1: Feature Set Discussion Points

Introduction

This section summarizes the discussion points that led to the feature set for the proposed specification for condensing boilers. The question that needed to be answered was:

WHAT CHARACTERIZES A HIGH EFFICIENCY BOILER IN THE REAL WORLD?

Over a wide range of operating conditions (part load to peak load), the high efficiency boiler converts the greatest feasible fraction of the input energy (natural gas flow) to heated water (mass flow times difference between water output and water input temperatures). From this,

1. We are really interested in thermal efficiency, not combustion efficiency. To get thermal efficiency high, jacket losses must be very low. Thus, focusing on thermal efficiency takes care of questions about high mass/low mass boilers. Where thermal efficiency data are not available, combustion efficiency data must be accepted, with a penalty for estimated losses.

2. In conventional designs, return water temperature control is critical. No boiler will condense (and give latent heat recovery) if the return water temperature is above a critical temperature (which depends on combustion gas dilution level, as tracked by CO_2 or O_2 concentration in the exhaust). Latent heat recovery can increase efficiency up to 10.6% in theory. What this means is that the boiler must be able to respond to low demand (or specific design needs, as for water source heat pump systems or service water heating) by accepting water cool enough to condense the water vapor. For example, the dew point of water vapor is about 135°F for 10.5% CO_2 in the exhaust. Above that combustion gas temperature, we get no latent heat recovery; below that we begin to get benefits.

   Corollary 1: This is why excess air is bad: If we have 8% CO_2 in the exhaust, the dew point drops to 124°F, so we use too much energy to heat the excess air, and work harder to get the latent heat.

   Corollary 2**:** Condensing capability has no benefit where the application never allows cool enough return water for condensation.

   Corollary 3: Some applications *always* have supply or return water temperatures in the condensing range. These include boilers for water source heat pump loop temperature support (60°F <= T <= 95°F); and service water heating.
   Note: Some boiler types use a flue-gas-to-combustion-air secondary heat exchanger to recover latent heat, instead of return-water-to-flue-gas heat exchange. Our intent is to accept such systems, if they capture latent heat and achieve high efficiency.

3. Good air control is needed. Since air is about 80% nitrogen that is just going along for the ride, the less excess air we heat, and the lower the exhaust temperature, the higher the efficiency. Air control is also needed for low emissions. This means that high efficiency boilers will not have atmospheric burners, so they will be installed without draft hoods or barometric dampers.

Note: As combustion approaches stoichiometric (from the excess air side), there is a tendency to produce rapidly increasing amounts of carbon monoxide. For this reason, few boilers run without several percent excess air.

4. An outside temperature-sensitive controller (or equivalent) is essential (and very inexpensive) to capture the gains of the condensing boiler installed for conventional boiler-based space heating systems. It is sometimes called an outdoor reset thermostat. We require the manufacturer to ship the unit with one, so that mild conditions give low return water temperatures. If a program does not require that the controller be included in the boiler specification, the contractor is likely to delete it, and set the controls to something that guarantees no callbacks (like 150°F return water temperature). This guarantees that the unit will never work in condensing mode, and that the customer will have wasted money to buy a condensing boiler. It may be important to allow waiving the controller requirement for boilers shipped for installations in "always condensing" applications such as outlined under "Corollary 3," above.

An Issue that will not be Addressed in the Specification

Electric power ("parasitics"). To make boilers more efficient, we want to increase heat exchanger size, while keeping the "box" as small and light as possible, so mechanics can get it through doors and install it. The way to increase heat exchanger area in a constant box size is to decrease the cross section of flow through the fire and water passages. Call it increasing "sinuosity" or "building labyrinth heat exchange surfaces." This will increase the power required to pump water through the boiler (on terminal equipment, we call this static pressure or "head"), and the power needed to pump the gases through the system to the flue. Because conventional US test methods do not measure the parasitics or energy used by the electric motors associated with the boiler, this is a "free lunch" for the designer. Prediction: If we are successful, the electric loads will grow, and the next iteration will worry about this.

Appendix 2: Proposed Specification for Condensing Boiler

Introduction

This document defines commercial-scale condensing boilers for the purposes of Consortium for Energy Efficiency (CEE) programs for commercial-scale boilers. It includes natural gas-fired boilers between 125,000 Btuh and 12,500,000 Btuh that capture the latent heat of condensation of water vapor in the exhaust gases. Because the latent heat content of distillate fuel is so much less than that of natural gas[1], dual fuel and oil-fired condensing boilers are not available in the market.

To reflect how boilers are rated, we recognize two classes by size:

Exhibit A2-1: Boiler Rating Methods, by Energy Input Rate

Size, Btuh	Rating Method
125,000-300,000	AFUE
300,000-12,500,000	Thermal Efficiency[2]

Modular boilers are treated for CEE purposes by their aggregate size. For multiple boiler installations, individual units are to be treated as appropriate for their sizes. For example, if a 500,000 Btuh installation comprises two boilers of 250,000 Btuh each, and if they are installed as multiple boilers (separate valves, redundant high limit cutouts on each boiler), then the units are individually rated on AFUE. If a 500,000 Btuh installation were built of two 250,000 Btuh units shipped to be installed together in a modular configuration, it would be rated as on thermal efficiency as a 500,000 Btuh boiler[3].

Existing law and practice require different test methods for the larger and smaller boilers. In particular, if CEE members wish to include multiple boiler installations where the individual units are <300,000 Btuh, the individual ratings must be on AFUE, according to federal law. In between, we run into the practical issue that the largest available condensing boilers in North America are < 3.4 MMBtuh.

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[1] ANSI/ASHRAE 103-1993. Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers. ASHRAE, Atlanta, GA. 1993.

[2] Except as noted below.

[3] We follow ASME practice in distinguishing *modular boilers* from *multiple boilers.* Modular boilers are limited to 400,000 Btuh per boiler and manifolded together as a larger “virtual” boiler. Installations may not have valves that isolate the modules in the system from each other, but may be fitted with circulating pumps that limit water circulation through off-line boilers. In contrast, multiple boilers are individual boilers that happened to be installed together, for lead/lag or simultaneous dispatch.

Specification for Condensing Boilers

For the purposes of a CEE commercial boiler program, conforming equipment shall have the following characteristics:

1. **Efficiency.**
   Conforming boilers shall meet the size-appropriate performance standards in Exhibit A2-2 below.

Exhibit A2-2: Minimum Acceptable Efficiency, by Energy Input Range

Size, Btuh	Rating Method[4]	Minimum Acceptable Value
125,000-300,000	AFUE[5]	>88.0%
300,000-12,500,000	Thermal Efficiency[6]	>= 90.0%

2. **Emissions.**
   Conforming units shall be certified by the manufacturer to meet South Coast Air Quality Management District (SCAQMD)/Rule 1146.2 for emissions[7]. A simple but not completely accurate summary is shown in Exhibit A2-3 below.

Exhibit A2-3: South Coast Air Quality Management District (Los Angeles Basin) Emissions Limits

Size, Btuh	Volumetric Emissions Limit	NOx/unit energy	Alternate
75,000 – 400,000	55 ppmv NOx @ 3% O_2	40 ng/joule (output)	
400,000 – 1,000,000	55 ppmv NOx @ 3% O_2	40 ng/joule (output)	
1,000,000 – 2,000,000	40 ppmv NOx @ 3% O_2		0.037 lb. NOx/MMBtu

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[4] In these calculations, only the energy of the natural gas used for combustion is included; electricity to power fans, pumps, and controls is excluded.

[5] As *per* ANSI/ASHRAE 103-1993: A Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers.

[6] *Thermal Efficiency* is defined as (100 times useful energy output divided by input energy). This shall be measured under steady state conditions as defined by the Hydronics Institute, at full rated output, 140°F supply from and 120°F return water temperature to the boiler. CEE proposes to require certified (I=B=R, or equivalent) Thermal Efficiency values for participating boiler models. Boilers installed shall have the same controls, burner, and boiler as certified. CEE may consider waivers for very large boilers with certified combustion efficiencies substantially greater than the threshold for thermal efficiency, and with low idling heat losses (=< 1% per hour).

[7] The rule itself is given at http://www.aqmd.gov/rules/html/r1146-2.html. Please note that *ad hoc* BACT rules are invoked for boilers > 2 MMBtuh, and are likely to approximate 12 ppmv NOx.

3. **Controls.**
   Conforming units will be shipped and installed with controls that allow the boiler to operate in condensing mode as large a fraction of the time as feasible[8]. A stand-alone outdoor reset control will qualify. Other strategies shown to accomplish the same goal are acceptable. This would include, for example, closed loop feedback control that sets supply temperature based on return water temperature. Manufacturer shall provide all such controls and components, except field-supplied wiring and fittings for mounting boxes on building surfaces, and shall supply appropriate installation, set-up, operating, and trouble-shooting instructions, for the boiler assembly itself. Manufacturer will certify to purchaser that the supplied control system type has been tested with the boiler model supplied, yielding results meeting the requirements in this document.

4. **Venting.**
   Conforming units shall require installation with National Fuel Gas Code[9] Category IV vents designed for positive vent static pressure and vent gas temperature that leads to condensate production in the vent.

5. **Capacity Modulation.**
   Conforming boilers with inputs greater than or equal to 500,000 Btuh will be able to operate at reduced output, down to 50% or less of maximum continuous output. This "turndown" can be achieved by varying fuel and air input quantities, by using short off and on cycles (as for a pulse burner), or other means, as long as the effect is to give stable but reduced output. Two-step systems with a high power stage at least twice as high as the low power output will be accepted for this program.

----- End of Specification-----

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[8] CEE has concluded that inappropriate controls and bad controls installation are major threats to customers who want the value of condensing boilers. Installation can't be made "idiot-proof," but CEE has concluded that requiring the manufacturer to bundle controls with the boiler will reduce the opportunities for inappropriate installation.

[9] National Fuel Gas Code, Section 6.

Addendum: Some Potential On-Site System Efficiency Indicators

For program design purposes, the Consortium for Energy Efficiency (CEE) has developed minimum program criteria based on manufacturers' certified Annual Fuel Utilization Efficiency (AFUE, for boilers < 300,000 Btuh) and thermal efficiency (for boilers >300,000 Btuh).

Programs offered by some participating utilities or agencies may also require demonstration of the efficiency of the *heating system,* as installed and applied. For these programs, CEE suggests that any of the following indicators may serve as a basis for systems with condensing boilers:

1. **Temperature difference between return water and exhaust gas**[10]. For return water temperatures between 100°F and 140°F, the exhaust flue gas temperature, measured as near the boiler as feasible (and certainly before any dilution air device), shall be low enough that condensation occurs within the boiler, and/or in a secondary heat exchanger that warms combustion air (or return water) and is sold as a component of the boiler as rated.

2. **CO_2 concentration**. Over the whole range of outputs, the minimum CO_2 concentration in the flue gas shall be at least 9.5% by volume.

3. **Combustion efficiency**. Under stipulated conditions (preferably matching the I=B=R 140°F/120F tests), the system as installed shall show a combustion efficiency level specified by the entity offering the program.

4. **Condensate yield**. System shall be equipped with separate condensate drains for the boiler and the flue. Condensate yields shall be determined by the protocols of ANSI/ASHRAE 103, (Section 9.2), adjusted if needed for larger boilers.

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[10] This is very specific to design. Some boilers manage with temperature differences <20°F. For condensing boilers that use an air-to-air heat exchanger (flue gas to incoming combustion air) to capture latent heat, the requirement would have to be replaced with one dealing with the temperature contrast across those streams, and would also have to stipulate a maximum exiting flue gas temperature (to be sure that the operation is in the condensing range).

Appendix 3: Case Study Results – Waltham High School

1. Basic Information and Assumptions

CEE Condensing Boilers Analysis Tool

Basic project information:

(Input blue shaded cells)

Project Facility Name:	**Waltham High School**
Alternative 1:	**Condensing Boiler(s)**
Alternative 2:	**Conventional Boiler**
Alternative 3:	**BCHP**

Project Life (YRS)	20	not variable
Discount Rate	4.0%	

Annual Energy Rate Escalations:

(for 2000 - 2020)	*From EIA*
Natural gas	-0.26%
#2 Oil	0.28%
#4 Oil	0.16%
#6 Oil	0.05%
Electricity	-1.07%

Energy Costs:

	$ / Energy (fuel) unit	
Natural gas	$ 0.54	/therm
#2 Oil		/gallon
#4 Oil	$ 0.78	/gallon
#6 Oil		/gallon
Electricity	$ 0.09	/kWh

Maintenance Rate Escalation: 1%

2. Operating Cost Results

Annual Cost Data

Energy Consumption			**Energy Cost**					**Maintenance Cost**		
Aternative 1	**Condensing Boiler(s)**									
	Weather Adjusted energy consumption (space & water heating only)	Energy (Fuel) unit		$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost	Total first year cost	Average year cost	NPV of 20 Year cost
Natural gas	197,586	Therms	Natural gas	$ 0.54	$ 106,696	$ 106,424	$1,446,342			
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0			
#4 Oil		Gallons	#4 Oil	$ 0.78	$ -	$ -	$0			
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0			
Electricity		kWh	Electricity	$ 0.09	$ -	-	$0			
Nat Gas equiv.	197,586	Therms			$ 106,696	$ 106,424	$ 1,446,342	$ 7,500	$ 7,575	$102,947

Aternative 2	**Conventional Boiler**						
	Weather Adjusted energy consumption (space & water heating only)			$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost
Natural gas		Therms	Natural gas	$ 0.54	$ -	$ -	$0
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0
#4 Oil	181,152	Gallons	#4 Oil	$ 0.78	$ 142,171	$ 142,399	$1,935,248
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0
Electricity		kWh	Electricity	$ 0.09	$ -	-	$0
Nat Gas equiv.	262,670	Therms			$ 142,171	$ 142,399	$ 1,935,248

Maintenance Cost, Aternative 2: $ 5,000 | $ 5,050 | $68,631

Aternative 3	**BCHP**						
	Weather Adjusted energy consumption (space & water heating only)			$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost
Natural gas	395,000	Therms	Natural gas	$ 0.54	$ 213,300	$ 212,756	$2,891,425
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0
#4 Oil	80,000	Gallons	#4 Oil	$ 0.78	$ 62,785	$ 62,886	$854,641
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0
Electricity	(3,120,750)	kWh	Electricity	$ 0.09	$ (290,230)	(287,116)	($3,901,994)
Nat Gas equiv.	404,489	Therms			$ (14,144)	$ (11,474)	$ (155,929)

Maintenance Cost, Aternative 3: $ 46,750 | $ 47,218 | $641,701

3. Installation Costs

Inputs for Equipment Costs

Trades Rates:

	Local Labor Rates ($/Hr)	
Electrician	$ 45.00	Average of Master & Helpers
Plumber	$ 45.00	Average of Master & Helpers
Htg Technician	$ 45.00	Average of Master & Helpers
Mechanic	$ 45.00	Average of Master & Helpers
		** (From Means)

New Equipment	Equipment Cost	Installation Time (hrs)	Labor Type (I.e. Electrician, plumber, -	Labor Rate ($/Hr)	Installation Cost	Sub-Total
Condensing Boiler(s)						
5 Aerco BM-2000-5 Boilers, FOB	$ 85,000.00					$ 85,000
Equipment delivery to site	$ 2,500.00					$ 2,500
mechanical & electrical installation		1,000	Mechanics, Plumbers, E	$ 45.00	$ 45,000	$ 45,000
Pumps	$ 4,500.00					$ 4,500
Venting or stack connection	$ 26,500.00	600	Mechanics	$ 45.00	$ 27,000	$ 53,500
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 12,000.00					$ 12,000
combustion air supply, if required	NA					
insulation	$ 3,000.00					$ 3,000
demolition	$ 3,000.00	280	Mechanics	$ 45.00	$ 12,600	$ 15,600
bonding/insurance	$ 4,800.00					$ 4,800
permitting	$ 300.00					$ 300
Overhead & Profit	$ 57,315.00					$ 57,315
Engineering fees	$ 20,000.00					$ 20,000
Local inspection fees	$ 500.00					$ 500
TOTAL	$ 219,415.00				$ 84,600	$ 304,015

Alternative # 2	Equipment Cost	Installation Time (hrs)	Labor Type	Labor Rate ($/Hr)	Installation Cost	Sub-Total
Conventional Boiler						
5 Conventional 2 MMBTUH (83% Effic.) Boilers, FOB	$ 50,000.00					$ 50,000
Equipment delivery to site	$ 2,500.00					$ 2,500
mechanical & electrical installation		1,000	Mechanics, Plumbers, E	$ 45.00	$ 45,000	$ 45,000
Pumps	$ 4,500.00					$ 4,500
Venting or stack connection	$ 11,250.00	600	Mechanics	$ 45.00	$ 27,000	$ 38,250
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 12,000.00					$ 12,000
combustion air supply, if required	NA					
insulation	$ 3,000.00					$ 3,000
demolition	$ 3,000.00	280	Mechanics	$ 45.00	$ 12,600	$ 15,600
bonding/insurance	$ 4,800.00					$ 4,800
permitting	$ 300.00					$ 300
Overhead & Profit	$ 50,000.00					$ 50,000
Engineering fees	$ 20,000.00					$ 20,000
Local inspection fees	$ 500.00					$ 500
TOTAL	$ 161,850.00				$ 84,600	$ 246,450

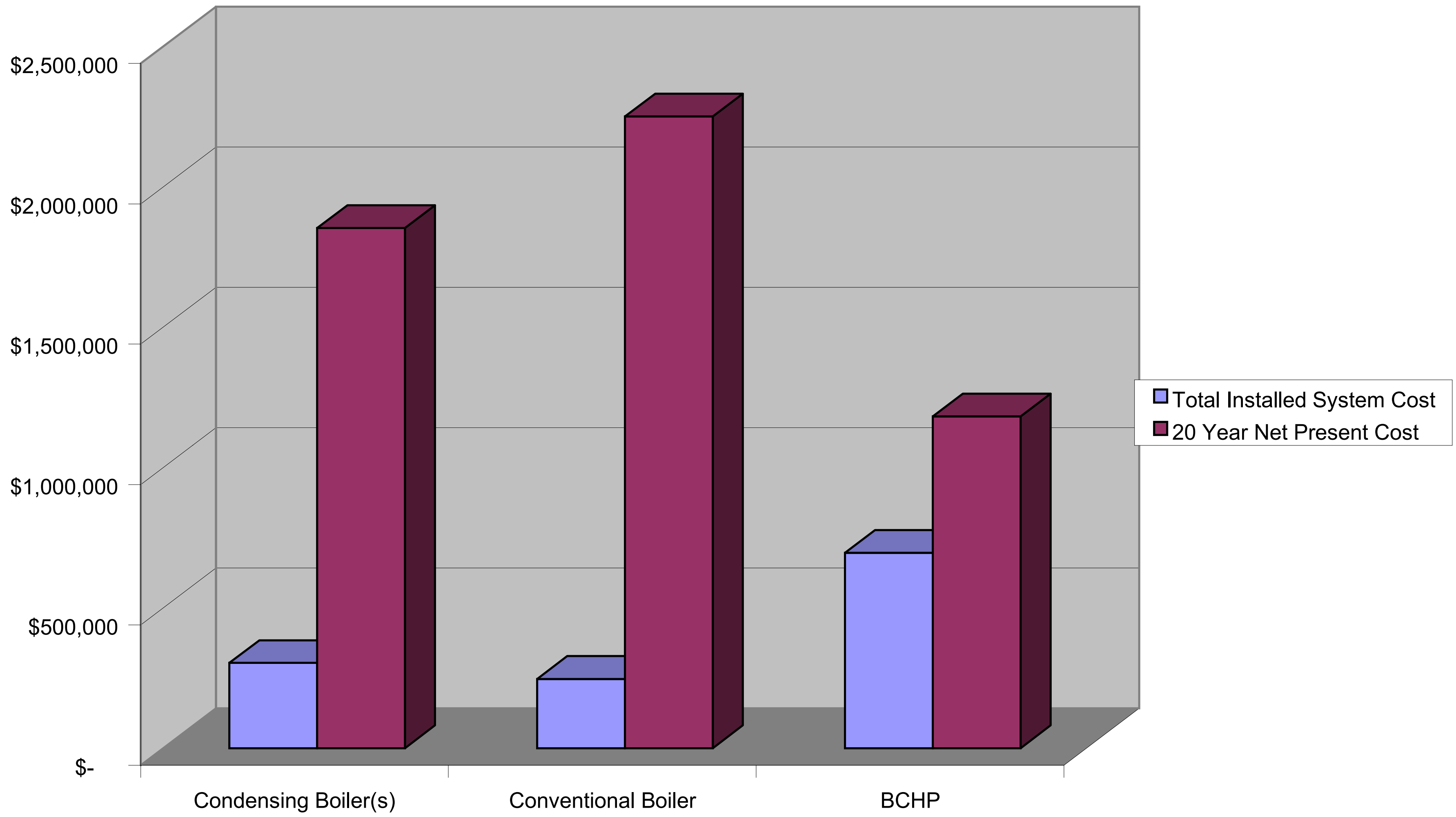
Alternative # 3						
5 BCHP 75 kW generator/heat exchangers (375 kW + 2 MMBTUH)	$ 300,000.00					$ 300,000
Plus 4 Conventional 2 MMBTUH (83% Effic.) Boilers, FOB	$ 40,000.00					$ 40,000
Equipment delivery to site	$ 5,000.00					$ 5,000
mechanical & electrical installation		1,800	Mechanics, Plumbers, E	$ 45.00	$ 81,000	$ 81,000
Pumps	$ 10,000.00					$ 10,000
Venting or stack connection	$ 11,250.00	1,080	Mechanics	$ 45.00	$ 48,600	$ 59,850
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 15,000.00					$ 15,000
combustion air supply, if required	NA					
insulation	$ 6,000.00					$ 6,000
demolition	$ 3,000.00	280	Mechanics	$ 45.00	$ 12,600	$ 15,600
bonding/insurance	$ 10,000.00					$ 10,000
permitting	$ 1,000.00					$ 1,000
Overhead & Profit	$ 110,000.00					$ 110,000
Engineering fees	$ 40,000.00					$ 40,000
Local inspection fees	$ 2,500.00					$ 2,500
TOTAL	$ 553,750.00				$ 142,200	$ 695,950

4. Summary of Results

Waltham High School

	Total Installed System Cost	Annual Energy Consumption (Therm Eq.)	Energy Cost	Maint. Costs	Net Present Cost	Net Present Cost Relative to Conventional Boiler
Condensing Boiler(s) (Current costs)	$ 304,015	197,586	$ 1,446,342	$ 102,947	$ 1,853,304	$ (397,026)
Conventional Boiler	$ 246,450	262,670	$ 1,935,248	$ 68,631	$ 2,250,329	$ -
BCHP	$ 695,950	404,489	$ (155,929)	$ 641,701	$ 1,181,722	$ (1,068,607)

Comparison of System Costs



Appendix 4: Case Study Results - Federal Office Building

1. Basic Information and Assumptions

CEE Condensing Boilers Analysis Tool

Basic project information:

(Input blue shaded cells)

Project Facility Name:	**Federal Office Bldg, Sioux City**
Alternative 1:	**Condensing Boiler(s)**
Alternative 2:	**Conventional Boiler**
Alternative 3:	**BCHP**

Project Life (YRS)	20	not variable
Discount Rate	3.0%	

Annual Energy Rate Escalations:

(for 2000 - 2020)	*From EIA*
Natural gas	-0.26%
#2 Oil	0.28%
#4 Oil	0.16%
#6 Oil	0.05%
Electricity	-1.07%

Energy Costs:

	$ / Energy (fuel) unit	
Natural gas	$ 0.49	/therm
#2 Oil		/gallon
#4 Oil	$ -	/gallon
#6 Oil		/gallon
Electricity	$ 0.07	/kWh

Maintenance Rate Escalation:	1%

2. Operating Cost Results

Annual Cost Data

Energy Consumption			**Energy Cost**					**Maintenance Cost**		
Aternative 1	**Condensing Boiler(s)**									
	Weather Adjusted energy consumption (space & water heating only)	Energy (Fuel) unit		$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost	Total first year cost	Average year cost	NPV of 20 Year cost
Natural gas	48,465	Therms	Natural gas	$ 0.49	$ 23,651	$ 23,591	$350,969			
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0			
#4 Oil		Gallons	#4 Oil	$ -	$ -	$ -	$0			
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0			
Electricity		kWh	Electricity	$ 0.07	$ -	-	$0			
Nat Gas equiv.	48,465	Therms			$ 23,651	$ 23,591	$ 350,969	$ 5,000	$ 5,050	$75,131

Aternative 2	**Conventional Boiler**									
	Weather Adjusted energy consumption (space & water heating only)			$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost			
Natural gas	60,639	Therms	Natural gas	$ 0.49	$ 29,592	$ 29,516	$439,129			
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0			
#4 Oil		Gallons	#4 Oil	$ -	$ -	$ -	$0			
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0			
Electricity		kWh	Electricity	$ 0.07	$ -	-	$0			
Nat Gas equiv.	60,639	Therms			$ 29,592	$ 29,516	$ 439,129	$ 3,300	$ 3,333	$49,587

Aternative 3	**BCHP**									
	Weather Adjusted energy consumption (space & water heating only)			$ / Energy (fuel) unit	Total first year cost	Average year cost	NPV of 20 Year cost			
Natural gas	361,159	Therms	Natural gas	$ 0.49	$ 176,246	$ 175,796	$2,615,403			
#2 Oil		Gallons	#2 Oil	$ -	$ -	$ -	$0			
#4 Oil	-	Gallons	#4 Oil	$ -	$ -	$ -	$0			
#6 Oil		Gallons	#6 Oil	$ -	$ -	$ -	$0			
Electricity	(3,120,750)	kWh	Electricity	$ 0.07	$ (212,211)	(209,934)	($3,123,287)			
Nat Gas equiv.	254,648	Therms			$ (35,965)	$ (34,138)	$ (507,884)	$ 46,750	$ 47,218	$702,477

3. Installation Costs

Inputs for Equipment Costs

Trades Rates:

	Local Labor Rates ($/Hr)	
Electrician	$ 30.00	Average of Master & Helpers
Plumber	$ 30.00	Average of Master & Helpers
Htg Technician	$ 30.00	Average of Master & Helpers
Mechanic	$ 30.00	Average of Master & Helpers
		** (From Means)

New Equipment	Equipment & subcontract Cost	Installation Time (hrs)	Labor Type (I.e. Electrician, plumber, - master, assistant	Labor Rate ($/Hr)	Installation Cost	Sub-Total
Condensing Boiler(s)						
5 Aerco BM-2000-5 Boilers, FOB	$ 68,000.00					$ 68,000
Equipment delivery to site	$ 2,000.00					$ 2,000
mechanical & electrical installation	$ 16,900.00	533	Mechanics, Plumbers, Electricians	$ 30.00	$ 15,990	$ 32,890
boiler controls installation		84	Mechanics, Electricians	$ 30.00	$ 2,507	$ 2,507
Venting or stack connection	NA	-				
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 8,000.00					$ 8,000
combustion air supply, if required	NA					
insulation	$ 10,676.00					$ 10,676
demolition, including asbestos abatement		330	Mechanics	$ 30.00	$ 9,900	$ 9,900
bonding/insurance	$ 1,828.00					$ 1,828
permitting	$ 300.00					$ 300
patching, painting, cleanup, misc.		248	Mechanics	$ 30.00	$ 7,440	$ 7,440
Engineering fees	$ 10,750.00					$ 10,750
Local inspection fees	$ 500.00					$ 500
TOTAL	$ 118,954.00				$ 35,837	$ 154,791

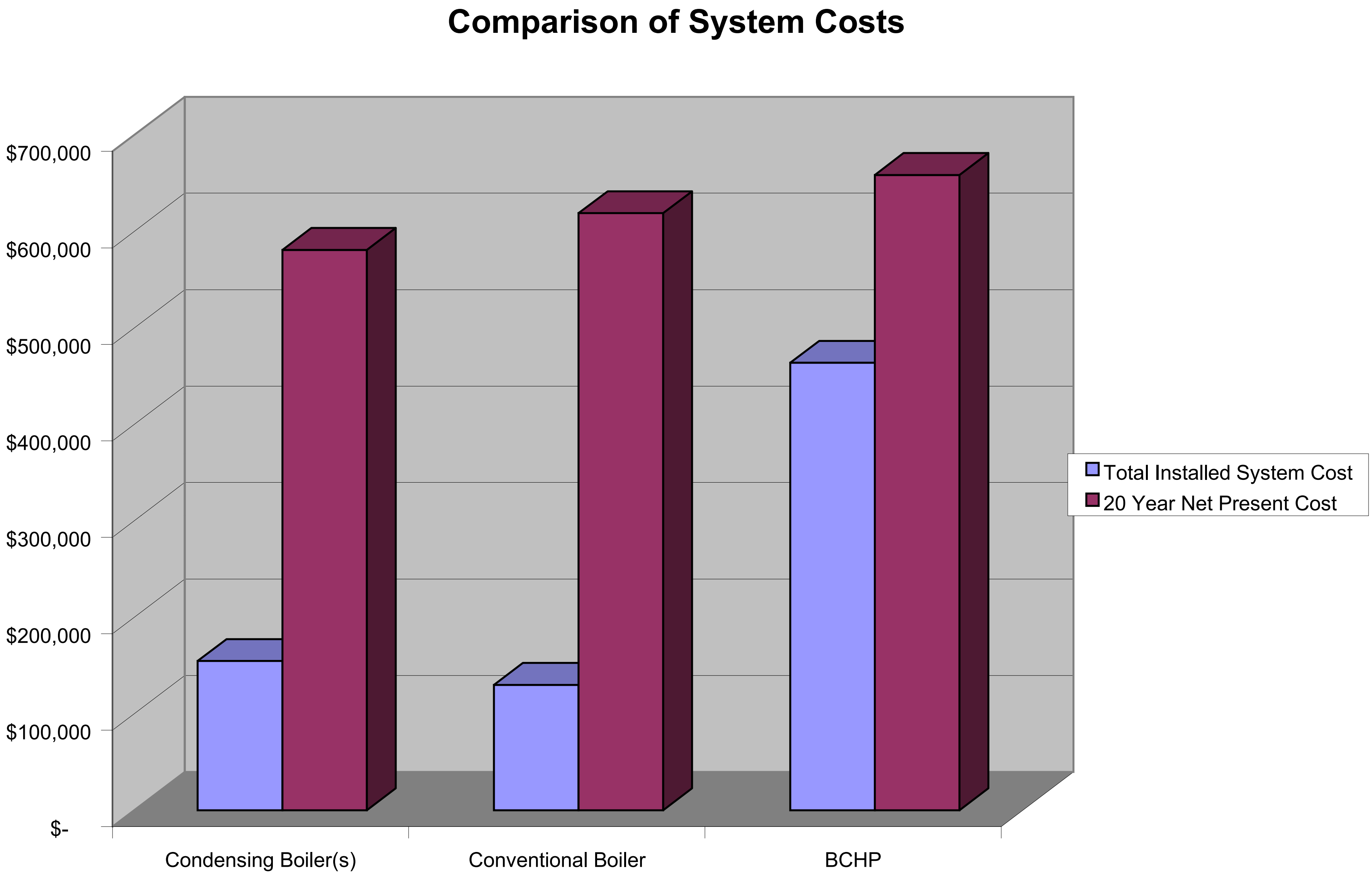
Alternative # 2	Equipment Cost	Installation Time (hrs)	Labor Type	Labor Rate ($/Hr)	Installation Cost	Sub-Total
Conventional Boiler						
Conventional 4,488 MBH Hot Water Boilers	$ 63,400.00					$ 63,400
Equipment delivery to site	$ 2,000.00					$ 2,000
mechanical & electrical installation	$ 13,500.00	420	Mechanics, Plumbers, Electricians	$ 30.00	$ 12,600	$ 26,100
boiler controls installation		84	Mechanics, Electricians	$ 30.00	$ 2,520	$ 2,520
Venting or stack connection	NA	-				
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 5,000.00					$ 5,000
combustion air supply, if required	NA					
insulation	$ 6,000.00					$ 6,000
demolition, including asbestos abatement		330	Mechanics	$ 30.00	$ 9,900	$ 9,900
bonding/insurance	$ 1,584.00					$ 1,584
permitting	$ 300.00					$ 300
patching, painting, cleanup, misc.		180	Mechanics	$ 30.00	$ 5,400	$ 5,400
Engineering fees	$ 7,500.00					$ 7,500
Local inspection fees	$ 500.00					$ 500
TOTAL	$ 99,784.00				$ 30,420	$ 130,204
Alternative # 3						
5 BCHP 75 kW generator/heat exchangers (375 kW + 2 MMBTUH)	$ 250,000.00					$ 250,000
Plus 4 Conventional 2 MMBTUH (83% Effic.) Boilers, FOB	$ 32,000.00					$ 32,000
Equipment delivery to site	$ 3,000.00					$ 3,000
mechanical & electrical installation		1,800	Mechanics, Plumbers, Electricians	$ 30.00	$ 54,000	$ 54,000
Pumps	$ 9,800.00					$ 9,800
Venting or stack connection	$ 7,350.00	1,080	Mechanics	$ 30.00	$ 32,400	$ 39,750
stack rebuild, if required	NA					
gas lines to units, if reqd	NA					
water pipe, valves and fittings	$ 12,250.00					$ 12,250
combustion air supply, if required	NA					
insulation	$ 5,880.00					$ 5,880
demolition, including asbestos abatement		280	Mechanics	$ 30.00	$ 8,400	$ 8,400
bonding/insurance	$ 6,370.00					$ 6,370
permitting	$ 1,000.00					$ 1,000
patching, painting, cleanup, misc.		200	Mechanics	$ 30.00	$ 6,000	$ 6,000
Engineering fees	$ 33,000.00					$ 33,000
Local inspection fees	$ 2,500.00					$ 2,500
TOTAL	$ 363,150.00				$ 100,800	$ 463,950

4. Summary of Results

SUMMARY

Federal Office Bldg, Sioux City

	Total Installed System Cost	Annual Energy Consumption (Therm Eq.)	Energy Cost	Maint. Costs	Net Present Cost	Net Present Cost Relative to Conventional Boiler
Condensing Boiler(s) (Current costs)	$ 154,791	48,465	$ 350,969	$ 75,131	$ 580,891	$ (38,028)
Conventional Boiler	$ 130,204	60,639	$ 439,129	$ 49,587	$ 618,920	$ -
BCHP	$ 463,950	254,648	$ (507,884)	$ 702,477	$ 658,543	$ 39,623


Comparison of System Costs
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$-
Condensing Boiler(s)
Conventional Boiler
BCHP
Total Installed System Cost
20 Year Net Present Cost

Appendix 5: User Instructions for Screening Tool

These User Notes are designed to provide you with some basic information about the spreadsheet, some of the data that are required, and how to use this economic evaluation tool. Please note that the user only needs to input data called for in the blue shaded cells.

The user is expected to come to the spreadsheet with certain data about individual projects (facilities) already in hand:

1. “Weather Adjusted Energy Consumption” - column B of the “Annual Costs data” tab:

One of the pieces of information that you must come to the spreadsheet with is the “Weather Adjusted Energy Consumption”. To determine this figure one must have 12 – 24 months of fuel consumption data for a facility. The first step is to remove the baseline (DHW load, in this case of say a multifamily or school building). Then the remainder of the fuel (the weather driven load) should be adjusted by heating degree days (HDD) for the period. The next step is to compute weather driven load for a ‘normal year’ (using the normal HDDs for the location), and finally re-add that to the baseload.

2. “New Equipment” - column A of the “Equip Costs data” tab:

The second piece of information that you must come to the spreadsheet with is the engineering analysis (basic design) of the various alternatives being considered for the facility. There are many readily available tools (software and manual methods, with varying levels of sophistication) to determine the heating system size required for a given application and technology. One of the keys to the economic effectiveness of condensing boilers is to not oversize the system; be aware of general “rules of thumb” used by contractors, as these often result in systems that are considerably oversized.

Certain data can be modified based on location, utility, time of evaluation or facility application:

3. Modifying the spreadsheet for different Energy Costs:

To modify the spreadsheet for different energy costs, simply go into the various input cells (F28 – F32) in the “Basic Info” tab and change the values.

4. Annual Energy Rate Escalations – cell B26 of the “Basic Info” tab

Determining accurate Annual Energy Rate Escalations is at best a difficult task, the staff at the Energy Information Agency (EIA, which is a division of USDOE) specialize in this task. While their predictions may not always be accurate in hindsight they have greater experience than any other group. More importantly this is a well recognized authority and hence a defensible set of assumptions.

Each Year EIA publishes a new set of both short term and long term (20 year) projections for different fuels and end use sectors. These are available in print form in the “Annual Energy Outlook”, or electronically in spreadsheet format off the web at: http://www.eia.doe.gov/oiaf/aeo/supplement/index.html (then download the file containing Supplement Tables 11 – 20, when you open the file they will be labeled “Energy Prices by Sector and Source”.)

5. Modifying the spreadsheet for different geographic locations:

To modify the spreadsheet for different areas, simply go into the various input cells and change the current default values. For example, if you are in an area where labor rates are lower, you would go into the input field for "plumbers" and change that to the value that you felt was appropriate (i.e. $25/hour).

6. Modifying the spreadsheet for different local labor rates and hours:

To modify the trade labor rates on the “Equip Costs data” tab, go to the Local Labor Rates ($/Hr) in cells G6-G9. The default values are from the Means Data Book. These can and should be changed to reflect the current contractor’s workers trade rates for the specific project location.

Please note that while it is possible to break the retrofit labor hours into more detailed itemization, the input into spreadsheet has been simplified by employing 3 general categories. (These are a catch-all “mechanical & electrical installation”, “Venting or stack connection” and “demolition”.) All labor hours should be broken down into 1 of these 3 categories and then entered into the appropriate (blue shaded) cells.

7. Modifying the spreadsheet for different technologies:

To modify the spreadsheet for different technologies go into the “Equip Costs data” tab and substitute items in one of the technology areas with the equipment appropriate to another system type (in column A), and it’s associated cost (in columns C & D).

Other notes:

8. On the “Equip Costs data” tab the cost in cells C18, C42, and C64 should include all controls provided by the manufacturer.

9. On the “Equip Costs data” tab the cost in cells C24, C48, and C71 should include the cost of connection from existing gas service, where this is necessary.