ENERGY AND ENVIRONMENTAL ANALYSIS, INC.

Characterization of the U.S. Industrial Commercial Boiler Population

Submitted to:

Oak Ridge National Laboratory

May 2005

Submitted By:

Energy and Environmental Analysis, Inc.

1655 N. Fort Myer Drive, Suite 600
Arlington, Virginia 22209

Acknowledgement

The authors wish to thank Merrill Smith of the U.S. DOE and Patti Garland, Steve Fischer and Barry Olander of the Oak Ridge National Laboratory for their support and helpful comments in the development of this report. We also thank Bob Bessette of the Council of Industrial Boiler Owners and Randy Rawson of the American Boiler Manufacturers Association for their helpful comments in the development of the report.

Table Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

The U.S. industrial and commercial sectors consume large quantities of energy. Much of this energy is used in boilers to generate steam and hot water. EEA estimates that there are almost 163,000 industrial and commercial boilers in the U.S. with a total fuel input capacity of 2.7 million MMBtu/hr. These boilers consume about 8,100 TBtu per year, accounting for about 40 percent of all energy consumed in these sectors. This report characterizes the boilers in the industrial and commercial sector in terms of number of units, aggregate capacity, unit capacity, primary fuel, application and regional distribution. The report also includes analysis of boiler fuel consumption and the age of boiler units. It does not include an inventory of individual boilers.

ES-1 Combined Boiler Inventory

The combined inventory of industrial and commercial boilers includes about 163,000 boilers with an aggregate capacity of 2.7 million MMBtu/hr (fuel input basis). Table ES-1 lists the summary statistics for the combined inventory including a breakdown by unit capacity.

The inventory includes 43,000 industrial boilers with a total capacity of 1.6 million MMBtu/hr and 120,000 commercial boilers with a total capacity of 1.1 million MMBtu/hr. Industrial boilers tend to be larger than commercial units. There are 19,500 industrial boilers larger than 10 MMBtu/hr, including more than 1,300 larger than 250 MMBtu/hr. Commercial facilities have 26,000 boilers larger than 10 MMBtu/hr but only about 130 larger than 250 MMBtu/hr. The vast majority of commercial boilers are smaller than 10 MMBtu/hr. Overall, the size of the average industrial boiler is 36 MMBtu/hr, compared to 9.6 MMBtu/hr for the average commercial boiler.

In addition to the industrial boilers included in the primary analysis, EEA estimates that there are approximately 16,000 industrial boilers in the nonmanufacturing sector with an aggregate capacity of 260,000 MMBtu/hr. Because these units are not well characterized, they were not included in the industrial boiler results listed in the analysis.

Over 70 percent of the boiler units are less than 10 MMBtu/hr heat input, mostly in the commercial sector. These boilers account for only15 percent of boiler capacity and typically have lower utilization than the larger industrial boilers. Due to the small size of these boilers and the lack of detailed information on them, this report focuses primarily on boilers larger than 10 MMBtu/hr.

Table ES-1 Combined Boiler Inventory

Number of Units			
Unit Capacity	Manufacturing Boilers	Commercial Boilers	Total
<10 MMBtu/hr	23,495	93,650	**117,145**
10-50 MMBtu/hr	12,380	21,850	**34,230**
50-100 MMBtu/hr	3,570	3,040	**6,610**
100-250 MMBtu/hr	2,210	1,120	**3,330**
>250 MMBtu/hr	1,360	130	**1,490**
Total	**43,015**	**119,790**	**162,805**
Total Units >10 MMBtu/hr	**19,520**	**26,140**	**45,660**

Fuel Input Capacity (MMBtu/hr)			
Unit Capacity	Manufacturing Boilers	Commercial Boilers	Total
<10 MMBtu/hr	102,306	301,202	**403,508**
10-50 MMBtu/hr	277,810	463,685	**741,495**
50-100 MMBtu/hr	243,128	208,980	**452,108**
100-250 MMBtu/hr	327,327	140,110	**467,437**
>250 MMBtu/hr	616,209	33,639	**649,848**
Total	**1,566,780**	**1,147,617**	**2,714,397**
Total Units >10 MMBtu/hr	**1,464,474**	**846,415**	**2,310,889**

ES-2 Industrial Boiler Inventory

Approximately 226,000 manufacturing facilities and approximately 21,000 facilities have boilers.[1] Five major steam-intensive industries are host to most of the industrial boilers. Food, paper, chemicals, refining and primary metals have 71 percent of the boiler units and 82 percent of the boiler capacity. The chemicals industry has more boilers (12,000) and capacity (413,000 MMBtu/hr) than any other industry. The paper industry has a fraction of the number of the boilers (3,400) of the chemicals industry but nearly as much capacity (376,000 MMBtu/hr) due to the large size of the boilers used in the paper industry. Like the paper industry, the refining industry has larger than average boilers (1,200 units, 172,000 MMBtu/hr capacity). The food industry has 11,000 units and 210,000 MMBtu/hr of capacity, resulting in the smallest average boiler size (20 MMBtu/hr) of the major boiler-using industries. The primary metals industry has 3,300 units and 113,000 MMBtu/hr of capacity, which is the least of the major industries.

[1] Table N1.1, Manufacturing Energy Consumption Survey, Energy Information Administration, DOE, 1998.

Natural gas is the most common fuel for industrial boilers and is identified as the primary fuel for 78 percent of boiler units and 56 percent of boiler capacity. Some industries use by-product fuel in a large portion of their boiler capacity, including paper (48 percent), refining (49 percent) and primary metals (42 percent). Coal, oil and wood are important fuels in certain industries and regions, but fuel a small fraction of the boiler capacity on a national basis.

Industrial boilers are found in every census region, but are more concentrated in the East North Central (ENC), South Atlantic and West South Central regions, which contain more than 60 percent of the capacity. The East North Central has the greatest number of boilers (10,700) and the West South Central has the most boiler capacity (380,000 MMBtu/hr). The average size of boilers in the East North Central and Mid Atlantic regions is smaller than average while the average size in the West South Central is larger than average.

ES-3 Nonmanufacturing Boiler Inventory

The nonmanufacturing boiler inventory is not a primary focus of this report, as it is smaller than the other sectors and the energy-related data are less complete. The nonmanufacturing segment of the industrial sector includes agriculture, mining and construction. On an energy basis, this segment consumes about 11 percent of all industrial energy, suggesting that boiler fuel consumption is a similarly small fraction of manufacturing boiler fuel consumption.

EEA estimates the nonmanufacturing boiler inventory to be approximately 16,000 units with an aggregate capacity of approximately 260,000 MMBtu/hr or about 14 percent of the manufacturing boiler capacity.

ES-4 Commercial Boiler Inventory

There are 4.7 million commercial buildings in the U.S. and 581,000 (12 percent) are served by boilers. More than one-half million commercial facilities are classified by EIA as having boilers, but many of these "boilers" are powered by electricity or have capacities estimated to be below 1 MMBtu/hr. EEA estimates that there are 22,000 electric boilers (185,000 MMBtu/hr total capacity) and 387,000 boilers with capacities smaller than 1 MMBtu/hr (98,000 MMBtu/hr total capacity). This report excludes the electric units from the analysis because they do not fit the definition of a boiler because they do not combust a fuel. The units smaller than 1 MMBtu/hr are excluded because they are so small that they effectively are water heaters.

With these adjustments, EEA estimates that the commercial boiler inventory includes 120,000 units with an aggregate capacity of 1.1 million MMBtu/hr. Although greater in number than the industrial inventory, the commercial boilers are smaller, including more than 93,000 units smaller than 10 MMBtu/hr. Compared to industrial units, commercial boilers on average are smaller and operate at lower pressures and temperatures.

Commercial boilers at office buildings, health care facilities and educational establishments account for more than half of commercial boiler units and capacity. The boilers at educational facilities are small (3.6 MMBtu/hr average) and these account for 11 percent of commercial boiler capacity, although they include 30 percent of boiler units. Although fewer in number than other categories, the boilers at health care facilities are larger than averge (20.9 versus 9.6 MMBtu/hr) and account for 28 percent of commercial capacity. Other building types with boilers include warehouse, retail, public assembly, lodging and "other" facilities.

Natural gas fires the vast majority of commercial boilers, including 85 percent of commercial boiler units and 87 percent of boiler capacity. Coal boilers represent 1.3 percent of commercial boiler units and 5 percent of capacity, reflecting their larger size. Oil boilers are smaller than average, accounting for 11 percent of boiler units but only 6 percent of capacity. "Other" fuels are less commonly fired in commercial boilers comprising 2 percent of commercial boiler units and capacity.

Unlike industrial boilers, which serve production processes, commercial boilers provide space heating and hot water for buildings and the geographic distribution of boilers reflects this fact. Two-thirds (66 percent) of commercial boilers are located in the New England, Mid Atlantic, East North Central and West North Central census regions. Buildings in the East South Central and West South Central regions have the fewest boilers.

ES-5 Energy Consumption in Boilers

Industrial boilers consume 6,500 TBtu or about 37 percent of all energy (excluding electricity) at industrial facilities. By-product and waste fuels are the largest source of boiler fuel in the industrial sector (3,249 TBtu/year). These include wood waste in the paper industry and refinery and byproduct gases in the chemicals, refinery and primary metals industries. Natural gas is the second largest energy source and the largest purchased energy source for boilers (2,100 TBtu/year). Natural gas and byproduct/waste fuels account for more than 80 percent of boiler fuel consumption.

The biggest consumers of boiler fuel are the paper industry (2,200 TBtu/year) and chemicals industry (1,800 TBtu/year). The chemicals industry consumes more than one-third (775 TBtu/year) of the natural gas used in industrial boilers and the paper industry consumes 43 percent (1,406 TBtu/year) of the by-product fuel used in industrial boilers. Coal, coke and breeze are important fuels for the paper, chemicals and primary metals industries. The other energy inputs, residual oil, distillate oil and liquefied petroleum gas (LPG), represent less than 5 percent of industrial boiler inputs. The average capacity factor for industrial boilers is 47 percent.

Commercial boilers consume approximately 1,630 TBtu/year, which is 28 percent of all energy consumption at commercial facilities. Consistent with the inventory, natural gas accounts for the largest share (83 percent) of boiler fuel, coal (8 percent), oil (7 percent)

and other fuels (2 percent). The average capacity factor of commercial boilers is 16 percent.

ES-6 Age of Boilers

Total sales of new boilers over the past four decades are smaller than the current boiler inventory, suggesting that many boilers are more than 40 years old. Total sales of boilers larger than 10 MMBtu/hr for 1964 to 2002 were 17,500 units and 1.3 million MMBtu/hr of capacity compared to a combined boiler inventory (including nonmanufacturing boilers) of 45,600 units and 2.3 million MMBtu/hr of capacity in this size range. The sales data for units larger than 10 MMBtu/hr suggests that 47 percent of boiler capacity is at least 40 years old. Approximately 7 percent of boiler capacity is less than 10 years old.

ES-7 The Market in 10 MMBtu/hr and Smaller Units

Despite a long-term decline in boiler sales, there continues to be a substantial market in boilers smaller than 10 MMBtu/hr. Small CHP technologies using reciprocating engines, small combustion turbines, microturbines and fuel cells are suitable alternatives in many of these applications and can add value by reducing costs and enhancing reliability.

ABMA reports sales of 4,000-5,000 boilers per year since 1992 in the <10 MMBtu/hr market segment with an average unit size of 3.5 MMBtu/hr. Boilers in this segment of the boiler inventory are most likely found in the food, chemical and other industries and at education and health care facilities.

1 INTRODUCTION

1.1 Overview

Boilers are a critical component of U.S. commercial and industrial facilities and operations. They are also a major energy consumer, particularly in the industrial sector. Despite their importance, the commercial/industrial (C/I) boiler sector is not well characterized or documented. The objective of this analysis was to characterize the U.S. C/I boiler population in terms of:

- Application
- Size
- Fuel shares
- Geographic region
- Vintage
- Energy use

There is no comprehensive source of data on C/I boilers, so EEA reviewed a variety of private and public data sources as the basis for analyzing these issues. This report is based on composite data developed by EEA. The EEA composite data set is believed to be a reasonable representation of the population of boilers at industrial and commercial facilities, but is not a survey or explicit inventory of boilers.

Chapter 2 of this report summarizes the characterization of the boiler population disaggregated by boiler size, fuel type, industry and region. The linkages between these characteristics and the factors that drive them are also discussed. Chapter 3 discusses the commercial boiler population, which also is disaggregated by boiler size, fuel type, application and region. Chapter 4 reviews historic trends in boiler sales and industrial boiler energy use. Chapter 4 also discusses the age of boilers in the composite inventory.

Appendix A provides additional background on the data sources for the analysis. Appendix B discusses the methodology for calculating the boiler inventory and Appendix C lists acronyms used in the report. Appendix D illustrates the geographic regions used in the report.

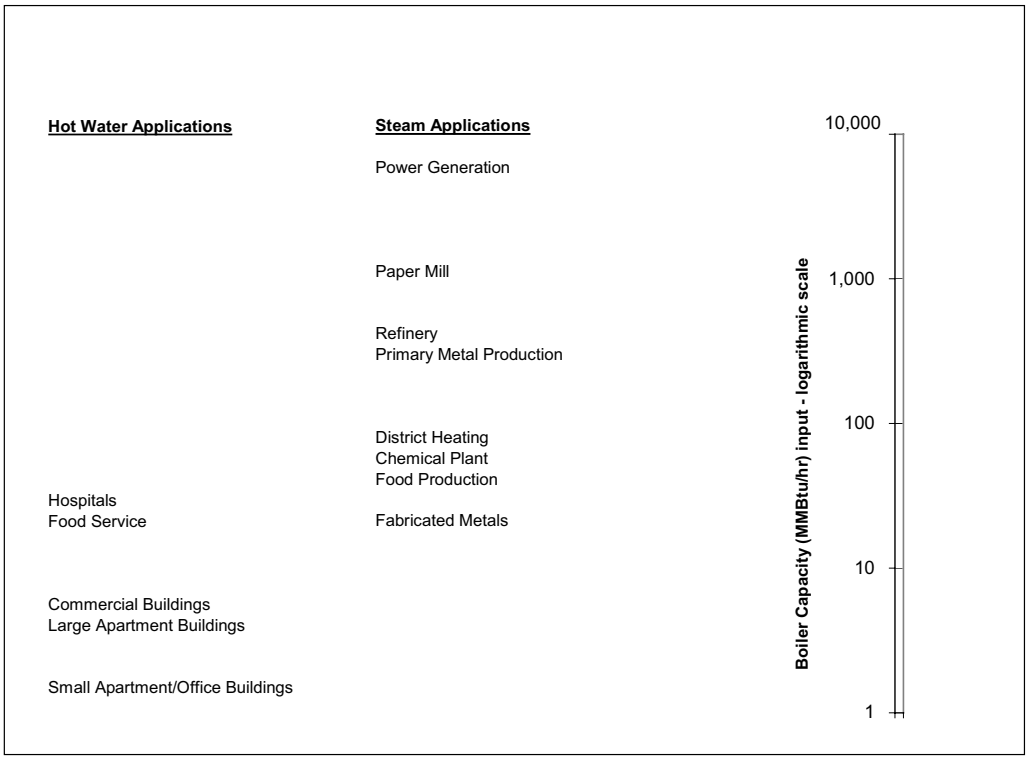
The remainder of this chapter provides some basic background information on boilers and boiler types.

1.2 Boiler Basics

Boilers use a heat source, usually combustion of a fossil fuel, to heat water to produce hot water or steam. Boilers fired with coal, wood and other solid fuels powered major industries in the 19th century. Boilers today burn natural gas and oil as well as solid fuels and continue to play a major role in manufacturing, heating and electricity generation. Boilers are essential in many energy-intensive industries and comprise a significant component of U.S. energy consumption.

Boilers are differentiated by their configuration, size, and the quality of the steam or hot water produced. Boiler size is most often measured by the fuel input in million Btu per hour (MMBtu/hr). Size may also be measured by output in pounds of steam per hour (pph). Output may also be measured in boiler horsepower. One boiler horsepower = 33,475 Btu/hr evaporation capacity or about 34.5 pph. Since large boilers are often used to generate electricity, it may also be useful to relate boiler size to power output in electric generating applications. Using typical boiler and generating efficiencies, 100 MMBtu/hr heat input is equal to about 10 MW electric output. Figure 1-1 shows some typical boiler applications and the corresponding boiler size in heat input.

Figure 1-1 Boiler Applications and Approximate Unit Capacity



The other important operational consideration is the temperature and pressure of hot water or steam that is required. Hot water installations tend to be smaller than steam installations, and many hot water boilers are installed for commercial food service and

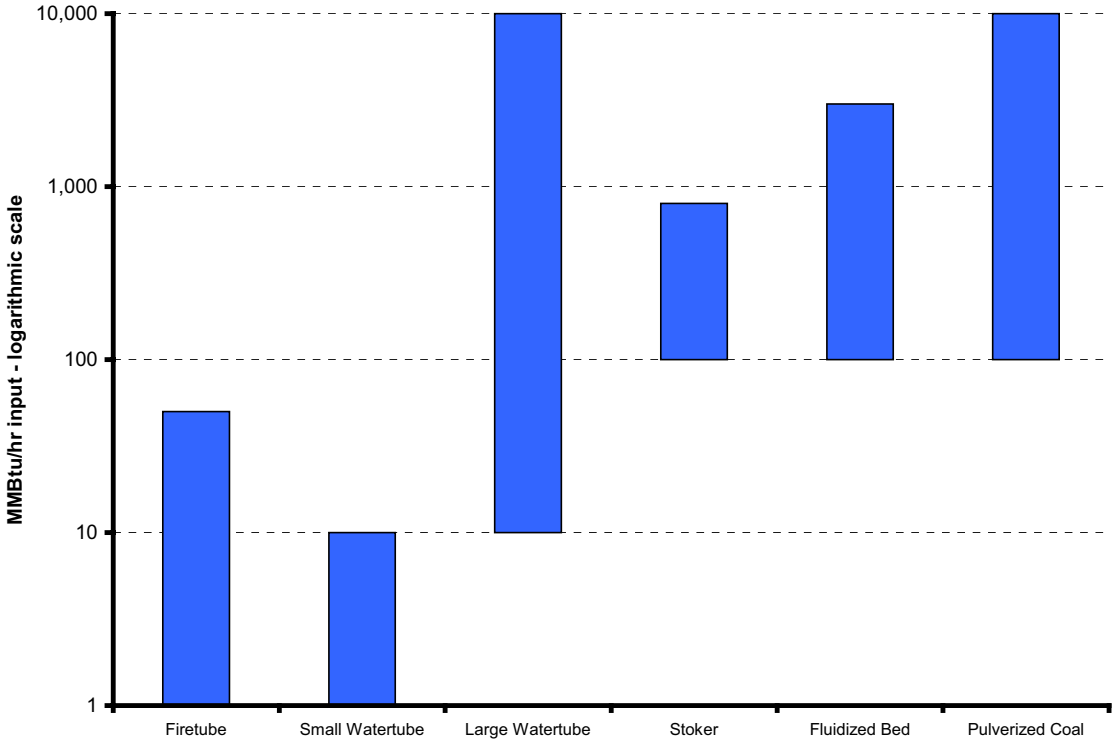
space heating applications in hospitals, schools and apartment buildings. Hot water boilers generally heat water to 250°F or less at pressures of 250 pounds per square inch (psig) or less.

Large numbers of small low-pressure steam boilers (<10 MMBtu/hr) have been used at small facilities or operate in support of larger manufacturing processes. Low-pressure steam boilers generally produce saturated steam at temperatures of 350°F to 400°F at pressures between 125 and 250 psig. The larger steam applications are for industry, power generation and district heating. The major steam consuming industries are refining, chemicals, paper, food and primary metals. Large industrial and power generation boilers produce high-pressure steam and may be rated at 250 to 10,000 MMBtu/hr. High-pressure boilers can produce steam temperatures above 700°F and pressures exceeding 3,000 psig.

1.3 Boiler Types

Boilers can be characterized by the configuration of the heat transfer surfaces – either firetube or watertube - and by the fuel-burning system. The appropriate configuration is determined by the desired fuel, steam conditions and capacity. Figure 1-2 shows the typical capacity ranges for some of the common boiler types on a heat input basis.

Figure 1-2 Boiler Types and General Capacity Ranges

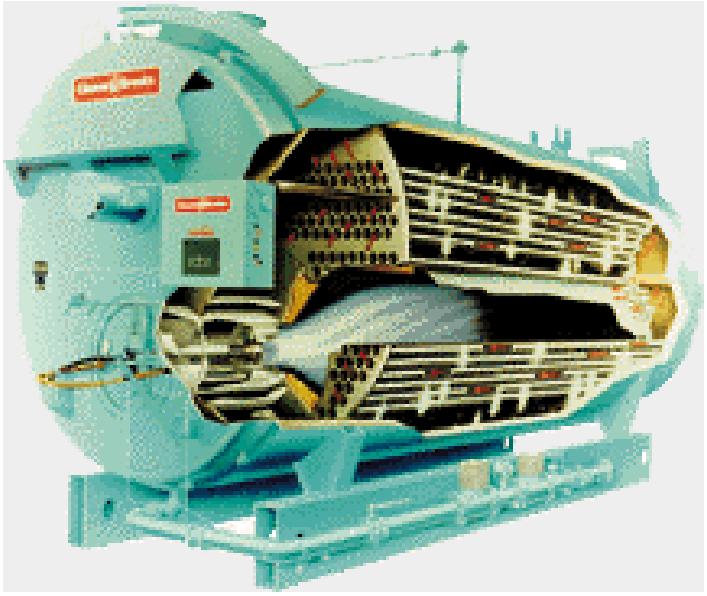


Firetube units are typically the smallest boilers, with most units less than 10 MMBtu/hr in capacity. Watertube boilers can be separated into two classes by size. Most existing watertube boilers have a capacity of less than 10 MMBtu/hr. A smaller number of watertube boilers are between 10 and 10,000 MMBtu/hr, including almost all large industrial and power generation boilers. Although fewer in number than the firetube and small watertube boilers, these large watertube boilers account for most steam production. The large watertube boilers are also the boilers most likely to use solid fuel and there are several different solid fuel combustion technologies in use at these larger size ranges, including stoker, fluidized bed and pulverized coal boilers.

1.3.1 Heat Exchanger Configuration

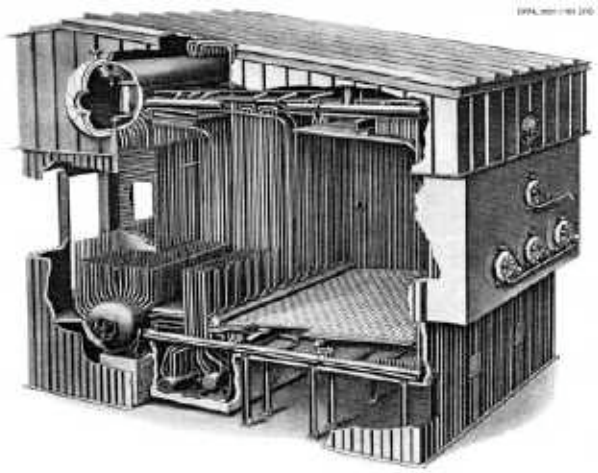
There are two broad categories of boiler heat exchanger design. In a firetube boiler the water is stored in the main body of the boiler and the hot combustion gases pass through one or several metal tubes that pass through the body of the boiler. Heat is transferred to the water by conduction from the firetube(s) to the surrounding water. Increasing the number of "passes" that the hot combustion gases make through the boiler enhances heat extraction. The advantages of firetube boilers are their simplicity and low cost. Almost all firetube boilers burn oil, natural gas or both. The mixing of the water in one large chamber makes a firetube boiler well suited to producing hot water or low-pressure steam. One reason that firetube designs are not desirable for high pressure (>200 psig) or high capacity (>10 MMBtu) applications is that the entire boiler would be under pressure and a failure of the pressure vessel would be more serious than a failure of a single tube in a watertube boiler.

Figure 1-3 Cut-Away View of Firetube Boiler



In watertube boilers the fuel is combusted in a central chamber and the exhaust gases flow around metal tubes that contain the water. Heat transfer to the watertubes is achieved by radiation from the flames as well as by conduction and convection from the hot combustion gases. There may be several dozen or several thousand watertubes in a boiler, depending on the size of the unit. The watertubes are often welded together to form the walls of the combustion chamber in a "waterwall." Water circulates through the pipes and the flow is designed to take advantage of different thermal zones to achieve specific steam conditions. Watertube boilers can produce steam at very high temperatures and pressures but these boilers tend to be more complex and expensive than firetube units. Smaller watertube boilers generally fire oil or natural gas but larger units (i.e., above 100 MMBtu/hr) also use coal, refuse, wood wastes and by-product liquids and gases. Watertube boilers generally are used to produce steam, whether it is low-pressure steam or supercritical steam such as is used in some of the largest power generation stations.

Figure 1-4 Cut-Away View of Watertube Boiler



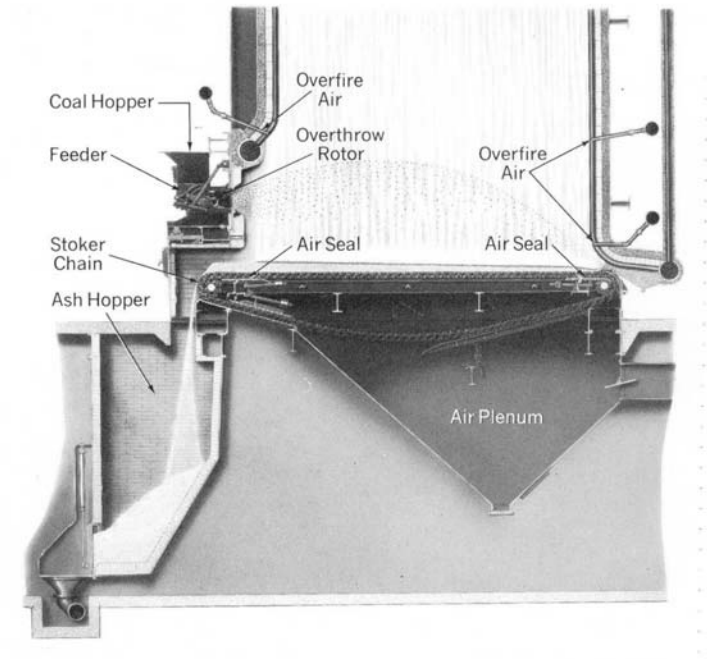
1.3.2 Fuel Firing Types

The fuel firing configuration is the second major identifier of boiler type. While they can be highly complex and sophisticated, fuel burners for gaseous and liquid fuels are relatively similar in metering and mixing the fuel and air they supply to the combustion zone. For solid fuels, however, there are several very different approaches to fuel combustion.

Stoker boilers are the oldest technology for automatically supplying solid fuels to a boiler. Stoker units use several means of mechanically shifting and adding fuel to a fire that burns on and above a grate near the base of the boiler. Heat is transferred from the fire and combustion gases to watertubes on the walls of the boiler. The fuel is not kept fluidized and combustion occurs either in the thin bed of fuel on the grate or in the fuel fines above the grate. Stokers can burn a variety of solid fuels including coal and various wood and waste fuels.

Stoker boilers are described by their method of adding and distributing fuel. The most common type is the spreader stoker, which projects the fuel above the grate, allowing the fines to combust in suspension while the heavier pieces fall to the grate. Underfeed stokers push the fuel, usually coal, into the bottom of the bed of fuel and heat causes volatilization and complete combustion of the fuel by the time it rises to the top of the bed as ash and is discharged. Chain grate, traveling grate and water-cooled vibrating grate stokers are less common configurations that use various means to maintain an even, thin bed of burning fuel on the grate. Stokers burning crushed coal were very common before 1960 when they gave way to pulverized coal boilers. Sales of stokers have fallen in recent decades and most new stoker units are fired with wood or wood waste.

Figure 1-5 Cut-Away View of a Traveling Grate Stoker Boiler



Pulverized coal (PC) boilers succeeded stokers as a more efficient method of burning coal. PC watertube boilers are the predominant technology for power generation coal boilers but are also used in some large industrial units. In PC boilers, the coal is pulverized to a dust-like consistency and blown with air into the boiler, where it burns in suspension in the furnace. PC boilers are characterized by the burner configuration (tangential, wall, cyclone) and whether the bottom ash exits the boiler in solid or molten form (wet bottom vs dry bottom).

Fluidized-bed combustors (FBC) are the most recent type of boiler developed for solid fuel combustion. FBCs burn solid fuel suspended in a bed of inert material at the base of the furnace. Combustion air is injected from the bottom of the combustor to keep the bed in a floating or "fluidized" state. Mixing in the fluidized bed provides efficient heat transfer that allows a more compact design than in conventional watertube designs. The efficient mixing allows improved combustion at a lower temperature, which reduces the

formation of nitrogen oxides (NO_x). The excellent mixing of the bed makes FBCs well suited to burn solid refuse, wood waste, waste coals and other non-standard fuels. Use of limestone as the bed material helps remove sulfur dioxide (SO_2) from the flue gas. Despite these advantages, sales of FBCs are a small fraction of the boiler market.

Figure 1-6 Cut-Away View of a Pulverized Coal Boiler

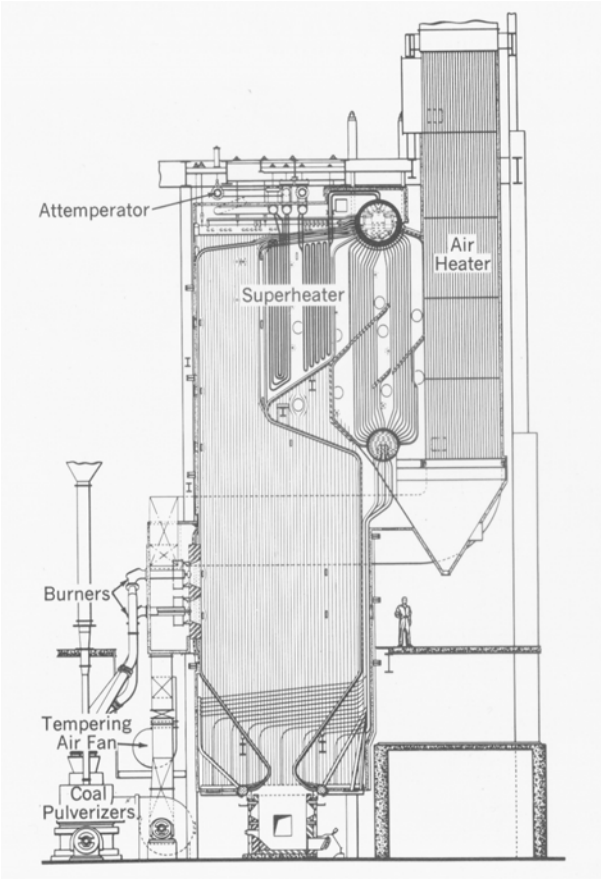
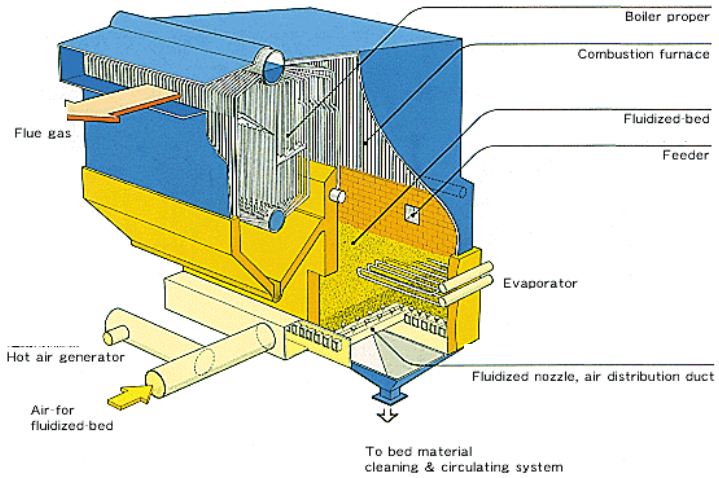


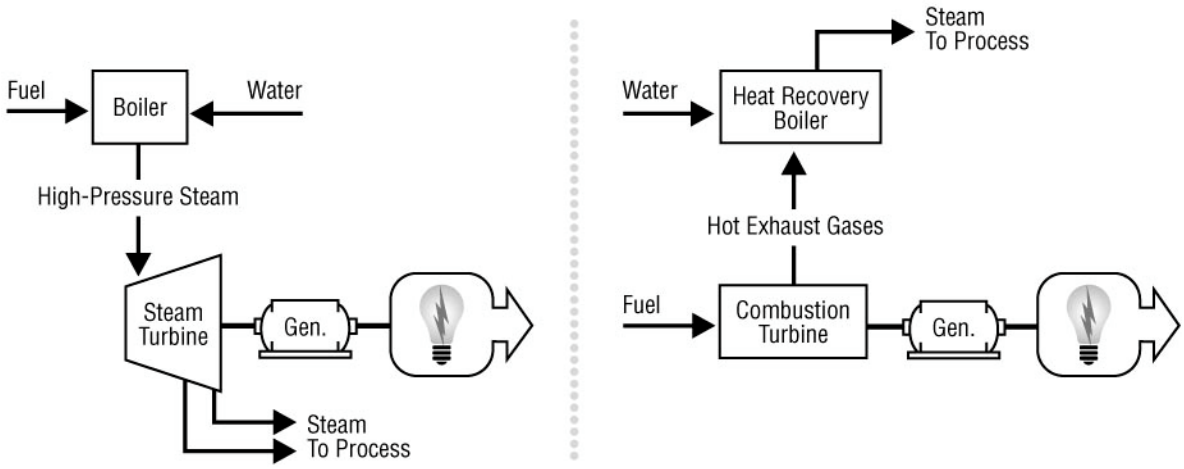
Figure 1-7 Cut-Away View of a Fluidized Bed Combustion Boiler



1.4 CHP Technologies

Standalone boilers are not the only option for producing steam at commercial and industrial facilities. Combined heat and power (CHP) or cogeneration technologies produce electricity and steam or hot water from a single heat input. Two common configurations for CHP systems, shown in Figure 1-8.

Figure 1-8 Typical CHP System Configurations



The steam boiler/turbine approach includes a conventional boiler and historically has been the most widely used CHP system. In newer CHP systems, a combustion turbine, reciprocating engine or fuel cell is used to generate electricity, and thermal energy is recovered from the exhaust stream to make steam or supply other thermal uses. Turbines and engines have become the dominant CHP technologies in recent years as their cost and performance have improved. These types of CHP systems can use very large

(hundreds of MW) gas turbines or very small (tens of kW) microturbine, engine, or fuel cell systems.

In the last 10 years, distributed generation (DG) has emerged as an important growth market for power generation and this includes relatively small-scale CHP systems, including reciprocating engines, small combustion turbines, microturbines and fuel cells. These smaller systems produce steam comparable to a 1 to 10 MMBtu/hr boiler. The turbines and engines power an electricity generator, with the hot exhaust gases being used in a waste heat boiler to produce the required steam or hot water.

Each of these small CHP technologies has characteristics appropriate for certain applications. The two key parameters are:

- The power-to-heat ratio (P/H) – the ratio of electricity generated to thermal energy produced. Most of the DG technologies have a P/H in the range of 0.7 to 1.0. The smallest DG technologies can produce relatively small quantities of steam or hot water, comparable to a boiler smaller than 10 MMBtu/hr as shown in Table 1-1. CHP systems in the 3 to 10 MW range can produce as much steam as a 10 to 40 MMBtu/hr boiler (10,000 to 50,000 pph).
- Temperature of available thermal energy – Most fuel cells and microturbines can recover heat at a maximum of 250^{o}F, suitable for generating hot water or low pressure steam. Reciprocating engines can provide higher temperatures, up to about 30 psig steam. Combustion turbines can produce steam at temperatures as high as 900^{o}F and 1250 psig.

Table 1-1 CHP Thermal Output/Input

	Electric Output (kW)	Power/ Heat	Thermal Output (MMBtu/hr)	Heat Input (MMBtu/hr)
Small Microturbine	60	0.4	0.5	0.6
Fuel Cell	200	1.0	0.7	0.9
Large Microturbine	250	0.4	2.0	2.5
Reciprocating Engine	250	0.7	1.3	1.6
Reciprocating Engine	1,000	0.9	4	5
Reciprocating Engine	5,000	0.9	19	23
Small Combustion Turbine	1,000	0.4	8	10
Small Combustion Turbine	5,000	0.6	28	36
Small Combustion Turbine	12,000	0.6	68	85
Large Combustion Turbine	50,000	0.9	190	237

2 CHARACTERIZATION OF INDUSTRIAL BOILERS

2.1 Overview

EEA estimates that there are approximately 43,000 industrial boilers in the United States with an aggregate capacity of 1.5 million MMBtu/hr input. Slightly more than half of these boilers are less than 10 MMBtu/hr capacity but these small boilers account for less than seven percent of the total capacity. The majority of the boilers and the largest boilers are located at facilities in the food, paper, chemicals, refining and primary metals industries. Almost 78 percent of boiler units and 56 percent of industrial boiler capacity are identified as natural gas-fired, although certain industries (refining, paper, primary metals) have large shares of boiler capacity that are fired with by-product fuels. Industrial boilers are found in every census region but are more concentrated in the East North Central (ENC), South Atlantic (SA) and West South Central (WSC) regions,[2] which contain more than 60 percent of the capacity.

2.2 Breakdown by Industry

Table 2-1 (units) and Table 2-2 (capacity) present the summary statistics by industry for industrial boilers.

Table 2-1 Industrial Boiler Inventory – Number of Units

Boiler Units							
	Food	Paper	Chemicals	Refining	Metals	Other Manufacturing	**Total**
< 10 MMBtu/hr	6,570	820	6,720	260	1,850	7,275	**23,495**
10-50 MMBtu/hr	3,070	1,080	3,370	260	920	3,680	**12,380**
50-100 MMBtu/hr	570	530	950	260	330	930	**3,570**
100-250 MMBtu/hr	330	540	590	200	110	440	**2,210**
>250 MMBtu/hr	70	490	350	220	120	110	**1,360**
Total	**10,610**	**3,460**	**11,980**	**1,200**	**3,330**	**12,435**	**43,015**

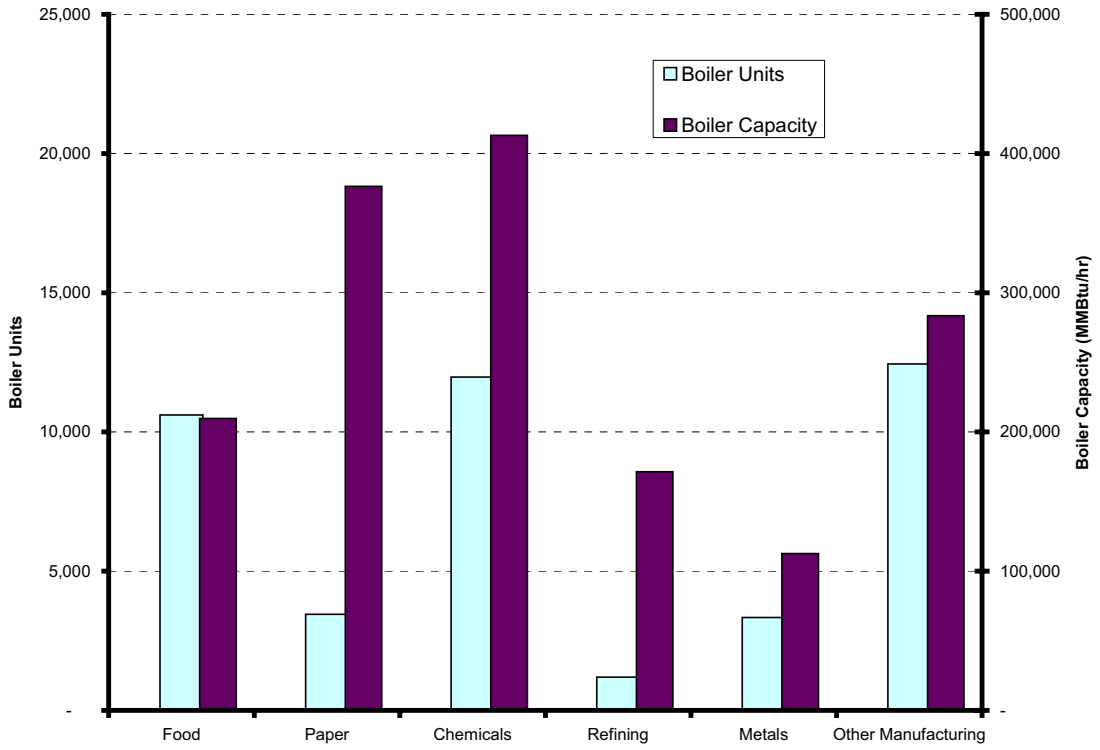
[2] A map of the census regions is included in Appendix D.

Table 2-2 Industrial Boiler Inventory - Boiler Capacity

Boiler Capacity (MMBtu/hr input)							
	Food	Paper	Chemicals	Refining	Metals	Other Manufacturing	**Total**
< 10 MMBtu/hr	31,070	4,105	28,660	1,255	7,505	29,710	**102,305**
10-50 MMBtu/hr	64,970	24,490	81,690	6,670	19,405	80,585	**277,810**
50-100 MMBtu/hr	37,885	36,665	64,970	18,390	22,585	62,630	**243,125**
100-250 MMBtu/hr	47,950	81,500	8,640	30,480	17,775	62,790	**249,135**
>250 MMBtu/hr	27,860	229,590	150,915	114,720	45,365	47,760	**616,210**
Total	**209,735**	**376,350**	**334,875**	**171,515**	**112,635**	**283,475**	**1,488,585**

Most industrial boiler capacity is located in five major industries that have steam-intensive processes (see Figure 2-1). The food, paper, chemicals, refining and primary metals industries have the majority of the boilers (71 percent) and boiler capacity (82 percent). These industries also have 92 percent of the largest (>250 MMBtu/hr) boilers. The remaining industries comprise the balance of the industrial boiler inventory.

Figure 2-1 Industrial Boilers and Boiler Capacity by Industry Group



2.2.1 Food Industry

The food industry has over 10,000 boilers with a total capacity of 24,000 MMBtu/hr. While the food industry has some large boilers, such as for wet corn milling, the largest number are natural gas-fired package boilers with a capacity of less than 10 MMBtu/hr.

The average boiler size for the industry is 20 MMBtu/hr. The food industry has smaller and more numerous facilities than the other steam-intensive industries, yielding the large number of boiler units. The large number of small units is one reason that there is a higher percentage (58 percent) of natural gas-fired boilers in the food industry than in any other major industry, since very small boilers tend to burn natural gas. The average capacity factor of boilers in the food industry is 31 percent, which is less than the 47 percent average of all industries. The seasonal nature of some parts of the food industry is one reason for the low capacity factor.

2.2.2 Paper Industry

The paper industry has about 3,400 boilers with a total capacity of 376,000 MMBtu/hr. The industry has more than 200 steam-intensive pulp mills and this is reflected in the boiler inventory, which has almost 500 boilers larger than 250 MMBtu/hr. The paper industry includes some of the largest industrial boilers. The large boilers comprise more than half (230,000 MMBtu/hr) of the industry's total capacity. The average boiler size for the industry is 109 MMBtu/hr. Pulp mills consume large quantities of electricity in addition to steam and the industry utilizes large boiler CHP systems to meet both requirements. The average capacity factor is 66 percent for the industry's boilers.

Almost two-thirds of the fuel used in paper industry boilers is "other" or by-product fuels. The dominant by-product fuel is black liquor, a waste product from the chemical pulping process. Black liquor has a low heat content (about 6,000 Btu/lb) and boilers fired with black liquor have an efficiency of about 70 percent, compared to 80 percent-85 percent for coal or natural gas boilers of the same size. In addition to black liquor, the industry uses bark, wood chips and production wastes. More than 80 percent of paper industry boiler capacity is located in five regions (East North Central, South Atlantic, East South Central, West South Central and Pacific) and the greatest concentration is in the South Atlantic, which includes 26 percent of the capacity.

2.2.3 Chemicals Industry

The chemicals industry has almost 12,000 boilers with a total capacity of 335,000 MMBtu/hr, more than any other industry. Slightly more than half of the boilers (6,700 units) are smaller than 10 MMBtu/hr and 347 are larger than 250 MMBtu/hr. The average capacity factor of chemical industry boilers is 50 percent. The high number of large and small boilers is consistent with the nature of the industry, which includes large, integrated facilities as well as small plants making specialty products such as dyes and cosmetics. The primary fuels for chemical industry boilers are natural gas (43 percent), by-products (39 percent) and coal/coke/breeze (15 percent). The chemicals industry has 51 percent of its boiler capacity in the West South Central region with the East North Central, East South Central and South Atlantic accounting for another 33 percent.

The chemicals industry is one of the most complex and diverse industries in the U.S., and simple characterizations are impossible. While the EIA Manufacturing Energy

Consumption Survey (MECS) identifies 10 significant steam-consuming product categories within the chemical industry, it identifies only nine for the food, paper, refining and primary metals industries, combined.[3] Nevertheless, the major steam-consuming processes in the chemical industry include stripping, fractionalization, power generation, mechanical drive, quenching and dilution.

2.2.4 Refining Industry

The refining industry has 1,200 boilers with a total capacity of 172,000 MMBtu/hr, and its average boiler size of 143 MMBtu/hr is the largest of any of the major industries. Over 200 boilers have capacities above 250 MMBtu/hr. The refining industry primarily converts crude oil into thousands of refined products including vehicle fuels, lubricants and feedstocks for the chemical industry. There are about 200 U.S. petroleum refineries and the industry includes almost 2,000 smaller facilities that manufacture products such as asphalt and roofing materials. The MECS and census data suggest that the steam-intensive processes are most common at the large refineries. The average capacity factor of all boilers in the refining industry is 25 percent.

Crude oil is the primary feedstock for the refining industry and by-product fuels (primarily refinery gas) are the largest fuel source for boilers (58 percent), followed by natural gas (29 percent) and residual oil (11 percent). Refinery gas and carbon monoxide are two by-product fuels that are used in refinery boilers. The refining industry is concentrated in the West South Central region, where 47 percent of the boiler capacity is located. Other regions with significant refining boiler capacity are the West North Central (13 percent), Pacific (10 percent) and East North Central (10 percent) regions.

2.2.5 Primary Metals Industry

The primary metals industry has over 3,300 boilers with a total capacity of 113,000 MMBtu/hr. About half of the boiler capacity (63,000 MMBtu/hr) is in boilers larger than 100 MMBtu/hr and the industry has 1,800 boilers smaller than 10 MMBtu/hr. More than 70 percent of primary metals boiler capacity is located at integrated steel mills, where boilers produce steam for on-site power generation, turbine-driven equipment such as blast furnace fans and machine drives. However, integrated steel making is no longer the dominant technology for domestic steel production and the newer electric "mini-mills" are not large steam users. The average capacity factor of boilers is 47 percent at primary metals facilities.

By-product fuels, including coke oven gas and blast furnace gas, supply the largest share (63 percent) of boiler fuel in the primary metals industry. Coke/coke/breeze (6 percent) and natural gas (29 percent) provide most of the balance of the boiler fuel. Natural gas

---

[3] Table N6-2, Manufacturing Energy Consumption Survey, Energy Information Administration, DOE, 1998.

often is blended with coke oven gas or blast furnace gas because these by-product fuels have relatively low heating value (e.g., 500 Btu/cf for coke oven gas, 80 Btu/cf for blast furnace gas). The primary metals industry is concentrated in the East North Central region, where 54 percent of boiler capacity is located. Much of the rest of the boiler capacity is located in the Mid Atlantic and South Atlantic regions.

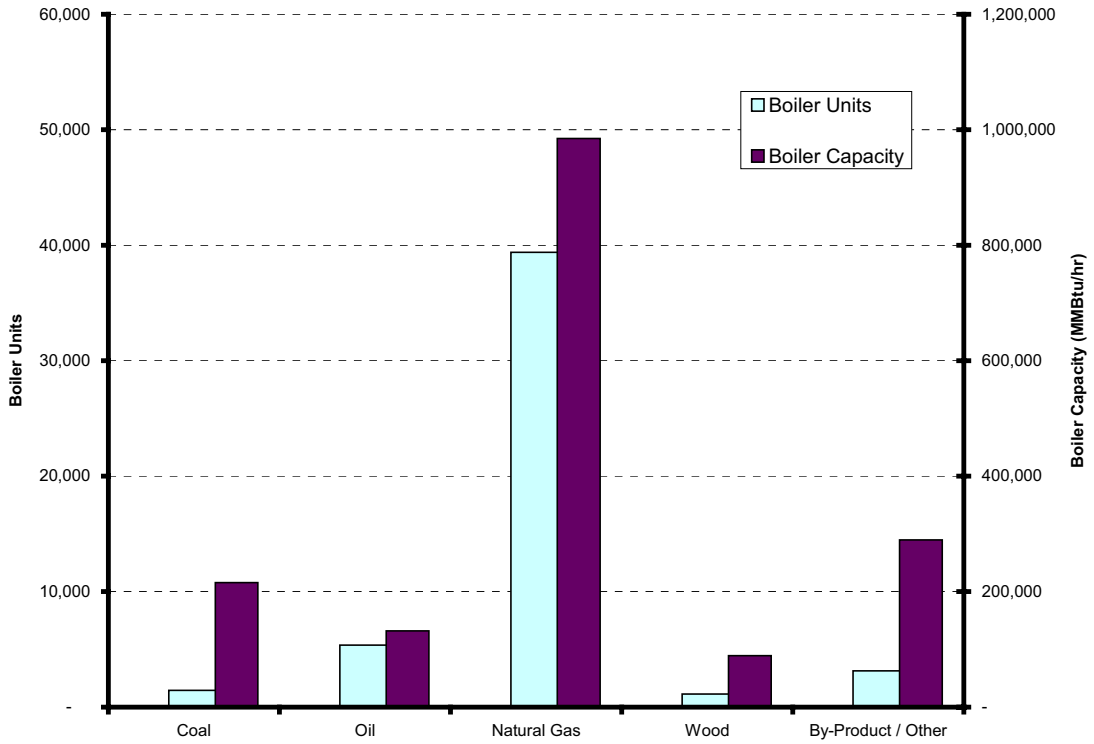
2.2.6 Other Manufacturing

The remaining industries account for about 29 percent of industrial boilers (12,000 units) and just 18 percent of industrial boiler capacity. Boilers at these facilities have an average capacity of 23 MMBtu/hr and most are smaller than 10 MMBtu/hr. Approximately 100 boilers at other manufacturing facilities have capacities larger than 250 MMBtu/hr.

2.3 Breakdown by Fuel

Almost 80 percent of boiler units and 51 percent of industrial boiler capacity are identified as natural gas-fired, although certain industries have large shares of boiler capacity that are fired with by-product fuels (e.g., refining - 49 percent and primary metals – 42 percent). The distribution of boiler units and capacity is shown in Figure 2-2.

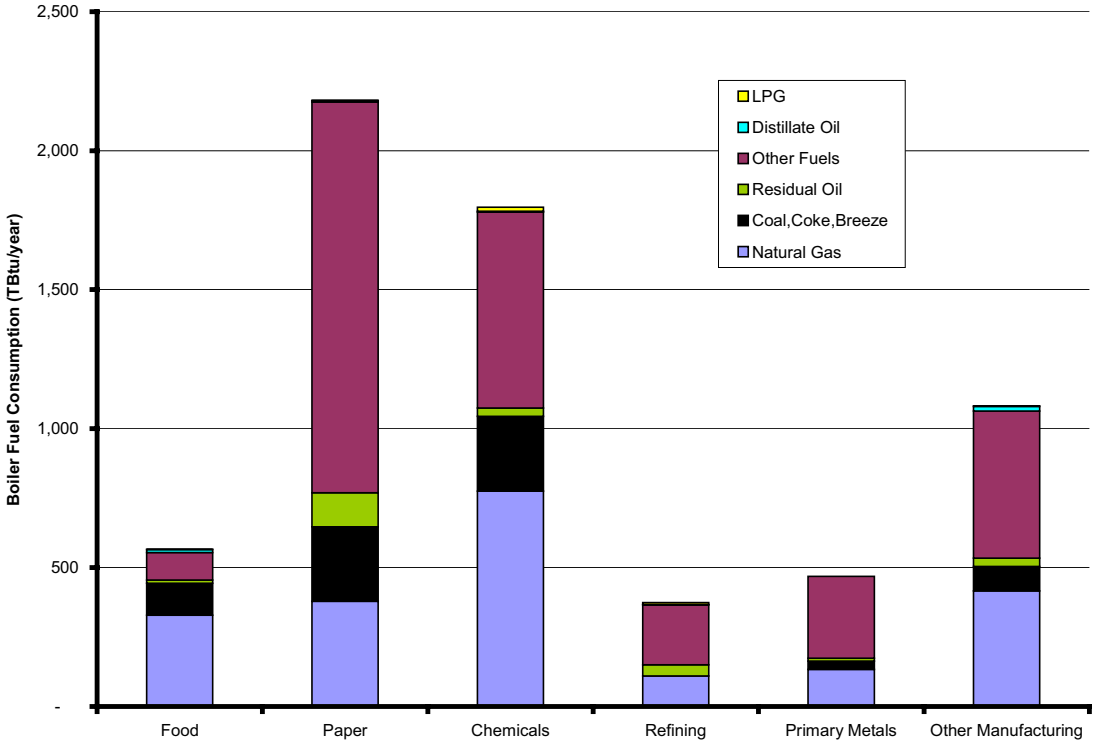
Figure 2-2 Industrial Boilers and Boiler Capacity by Primary Fuel



Coal, oil and wood are important fuels in some regions and industries but are designated as the primary fuel for only 3 percent, 11 percent and 2 percent of boiler units and 14 percent, 8 percent and 6 percent, respectively, of boiler capacity overall. The relative shares of capacity and units indicate that coal boilers and waste/byproduct fuel boilers are much larger than average size.

According to the MECS, industrial boilers consume 6,467 TBtu or about 37 percent of all energy at industrial facilities and 44 percent of industrial fuel consumption (i.e., after electricity is subtracted). The summary of fuel consumption is shown in Figure 2-3. The largest boiler fuel input is by-product or other fuels at 3,249 TBtu/year or about 50 percent. The paper industry uses the largest share (1,406 TBtu/year) of by-product fuels, especially black liquor and wood waste. Other major consumers of by-product fuels are the chemicals (705 TBtu/year), other manufacturing facilities (530 TBtu/year – wood wastes) and primary metals industries (294 TBtu/year – blast furnace and coke oven gas).

Figure 2-3 Industrial Boiler Fuel Consumption



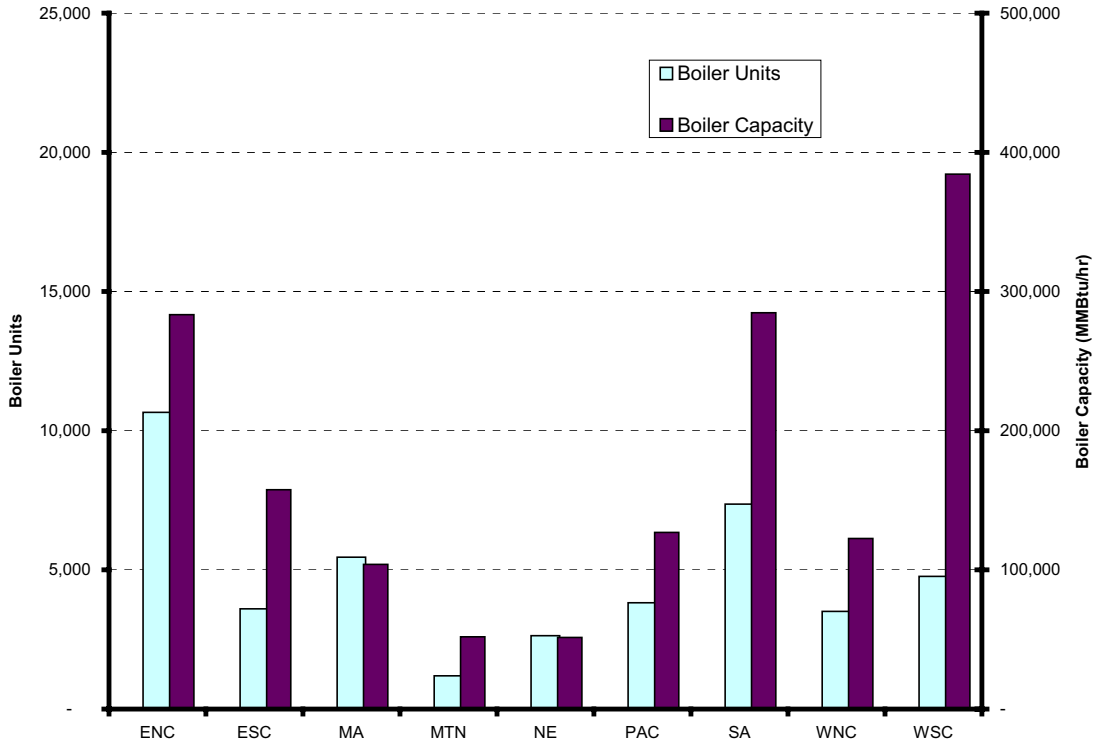
Natural gas makes up 67 percent of purchased boiler fuel (2,141 TBtu/year). The chemicals industry consumes more than one-third of the natural gas (775 TBtu/year). Other large consumers of natural gas are the paper (379 TBtu/year) and other industries (416 TBtu/year). Coal is the second largest purchased boiler fuel, making up about 24 percent of purchased fuel. The paper and chemicals industries each use about 35 percent of the 770 TBtu/year of coal. The food industry is the other big coal consumer, mostly in

segments such as wet corn milling and other large steam applications. Residual oil is the other significant component boiler fuel at about 8 percent of purchased fuel. Most of the residual fuel is consumed in the paper industry according to the MECS data.

2.4 Regional Breakdown

Industrial boilers are found in every census region but are more concentrated in the East North Central (ENC), South Atlantic (SA) and West South Central (WSC) regions where more than 60 percent of the capacity is located. The Mountain and New England regions have the fewest industrial boilers. The geographic distributions of boilers and boiler capacity are illustrated in Figure 2-4.

Figure 2-4 Industrial Boilers and Boiler Capacity by Region



The East North Central has 10,700 boilers and 283,000 MMBtu/hr of capacity, giving it the greatest concentration of boiler units, although unit size is smaller than average. Almost 22 percent of the boiler units in this region are in the food industry, which tends to have smaller boilers. Although fewer in number, the East North Central also has more than 1,000 boilers larger than 10 MMBtu/hr in the paper and primary metals industries.

The South Atlantic has the second highest number of boilers (7,400 units) and the second highest total boiler capacity (285,000 MMBtu/hr) of all regions. The South Atlantic has more paper industry boiler capacity than any region and one of the highest concentrations of chemical industry boilers. Both of these industries are steam-intensive, with the paper

industry utilizing large black liquor-fueled boilers and the chemical industry using somewhat smaller natural gas and by-product fueled boilers.

The West South Central, with its chemicals and refining industries, has 4,800 boilers and 384,000 MMBtu/hr of capacity, which is the most of any region. The chemical industry accounts for more than half of the boiler units and capacity in the West South Central. The refining industry, which is characterized by very large boilers, accounts for almost one-quarter of the boiler capacity in the region.

The East North Central, South Atlantic and West South Central Regions include over 60 percent of total industrial boiler capacity.

2.5 Nonmanufacturing Boilers

The nonmanufacturing boiler inventory is not a primary focus of this report as it is smaller than the other sectors and energy-related data are less complete. The nonmanufacturing segment of the industrial sector includes agriculture, mining and construction. On an energy basis, this segment consumes about 11 percent of all industrial energy, much of which is vehicle fuel, suggesting that boiler fuel consumption is a similarly small fraction of manufacturing boiler fuel consumption.

EEA estimates the nonmanufacturing boiler inventory to be approximately 16,000 units with an aggregate capacity of approximately 260,000 MMBtu/hr or about 14 percent of the manufacturing boiler capacity.

3 CHARACTERIZATION OF COMMERCIAL BOILERS

3.1 Overview

EEA estimates that there are about 120,000 commercial boilers in the United States with an aggregate capacity of 1.1 million MMBtu/hr. Boilers most commonly serve office, education, health care and other facilities for space conditioning, food services, domestic hot water, laundries and other special applications. Although greater in number than the industrial inventory, the commercial boilers are typically smaller, including more than 93,000 units smaller than 10 MMBtu/hr and 26,000 boilers larger than 10 MMBtu/hr. Compared to industrial units, commercial boilers are smaller and operate at lower pressures and temperatures. Space heating accounts for about two-thirds of commercial boiler demand and hot water accounts for most of the rest. A small number of commercial boilers are used for food service. Some of the units smaller than 10 MMBtu/hr might be considered to be large hot water heaters.

The average commercial boiler is small (9.6 MMBtu/hr), but EEA estimates that there are 130 commercial boilers larger than 250 MMBtu/hr and many of these are coal-fired. Based on limited survey data, EEA projects that 80 of these boilers are fired by coal and 50 are fired with natural gas. Approximately half of these large boilers serve health care facilities, where large quantities of reliable hot water and steam are required for cleaning, sterilizing and space heating. About one third of the large boilers are located at educational facilities, especially universities with student housing. The balance of the large boilers provides space heating and hot water for offices and public assembly facilities.

3.2 Breakdown by Sector

Table 3-1 lists the summary statistics for the commercial sector by sector. The Commercial Building Energy Consumption Survey (CBECS) estimates that 581,000 commercial buildings use boilers for space heating or hot water. Taking into account the fact that commercial buildings may be part of a multi-building facility and that one facility may be served by more than one boiler, EEA estimates the total number of boilers of all types to be 530,000 based on the CBECS data. Most of these units are excluded from this analysis because they are electricity-powered units or are smaller than 1 MMBtu/hour. EEA estimates a population of 22,000 electric “boilers” (185,000

MMBtu/hr total capacity) and 387,000 boilers with capacities smaller than 1 MMBtu/hr (98,000 MMBtu/hr total capacity) at commercial facilities. Electric units are excluded from the analysis because they do not combust a fuel and do not fit the definition of a boiler. The units smaller than 1 MMBtu/hr are excluded due to their small capacities, which are close to the size of household heating systems (0.1 MMBtu/hr).

Table 3-1 Commercial Boiler Inventory

Building Type	Number of Boilers	Boiler Capacity (MMBtu/hr)	Average Size (MMBtu/hr)
Office	28,030	297,090	10.6
Warehouse	5,365	72,385	13.5
Retail	5,585	47,230	8.5
Education	35,895	128,790	3.6
Public Assembly	7,280	55,205	7.6
Lodging	10,545	140,830	13.4
Health	15,190	317,110	20.9
Other	11,900	88,970	7.5
Total	**119,790**	**1,147,610**	**9.6**

Commercial boilers at office buildings, health care facilities and educational establishments account for almost two-thirds of commercial boiler units and capacity. The boilers at educational facilities are small (3.6 MMBtu/hr average) and these account for 30 percent of commercial boiler units and 11 percent of commercial boiler capacity. Although fewer in number than offices and educational facilities, the boilers at health care facilities are larger than averge (20.9 versus 9.6 MMBtu/hr) and account for 28 percent of commercial capacity. The distribution of boilers and capacity is shown in.Figure 3-1

The greatest number of boilers serve educational facilities, 36,000 units, and these boilers have a total capacity of 129,000 MMBtu/hr. Offices have 28,000 boilers with a total capacity of 297,000 MMBtu/hr. Health care facilities have 15,000 boilers but a total capacity of 317,000 MMBtu/hr, reflecting the large size and high demand nature of these buildings. "Other" or miscellaneous facilities have 12,000 boilers with a total capacity of 89,000 MMBtu/hr. Lodging facilities have 10,500 boilers and a total capacity of 141,000 MMBtu/hr.

The other facility categories, warehouses, retail and public assembly, combine to include 18,000 boilers and 175,000 MMBtu/hr of capacity.

3.3 Breakdown by Fuel

Natural gas fires the vast majority of commercial boilers, including 85 percent of the commercial boiler units and 87 percent of capacity. The distribution of commercial boiler fuel types is shown in Figure 3-2.

Figure 3-1 Commercial Boilers and Capacity by Building Type

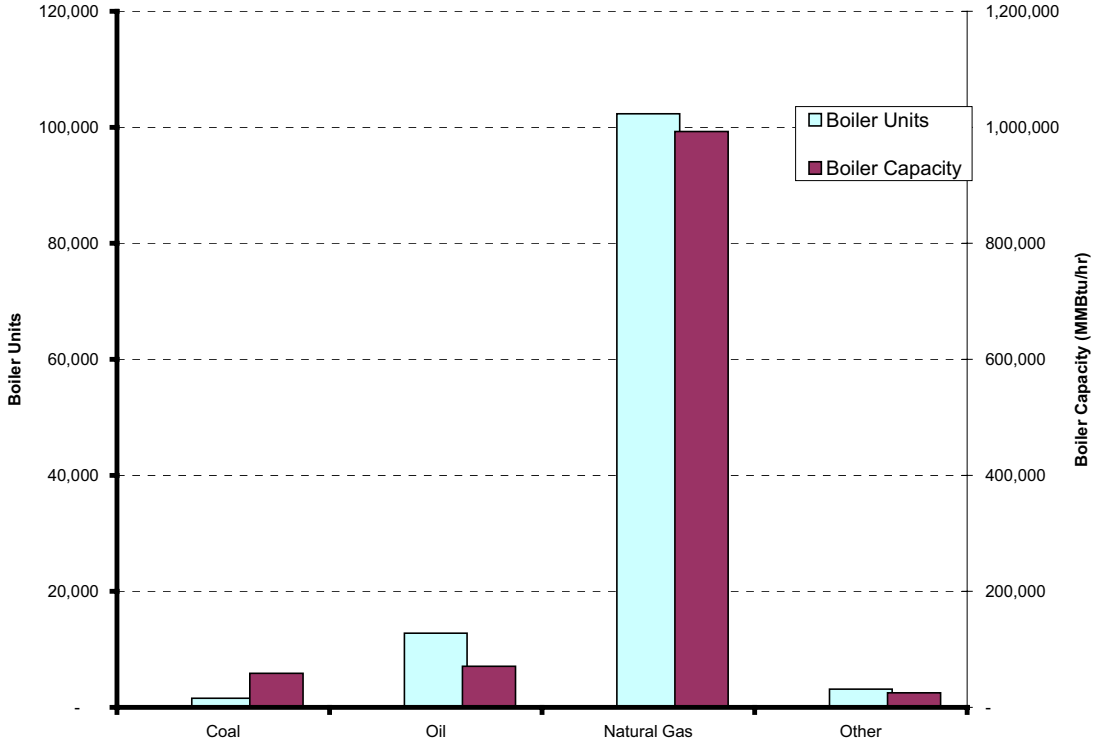
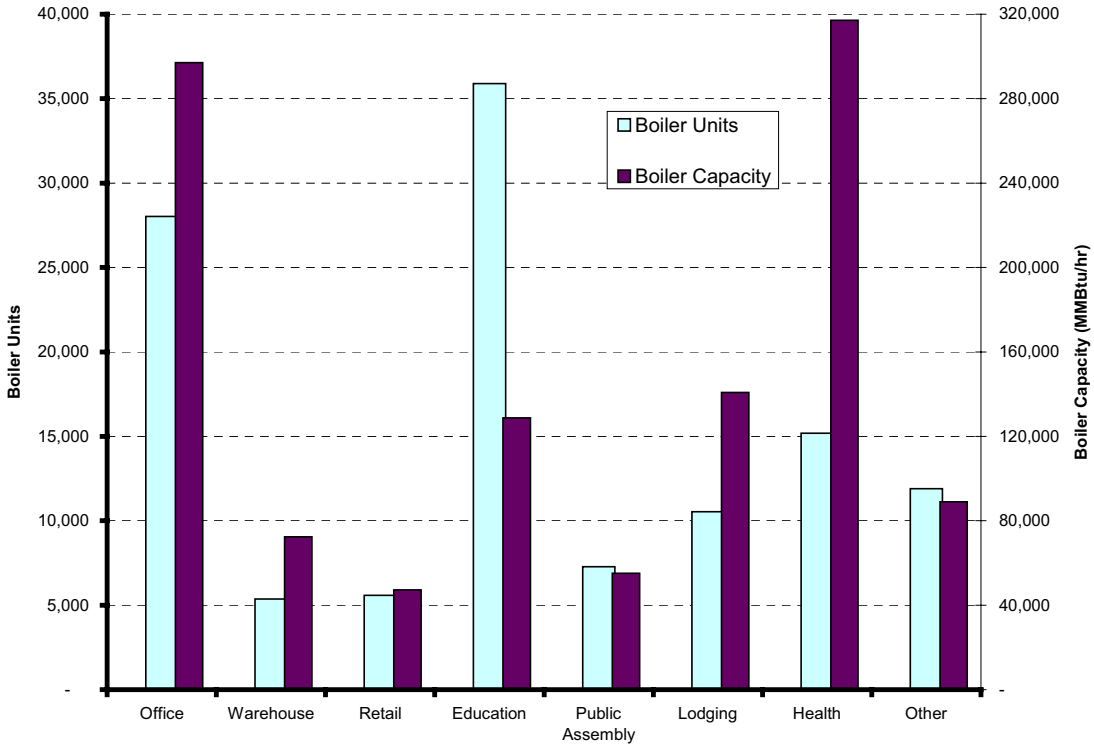


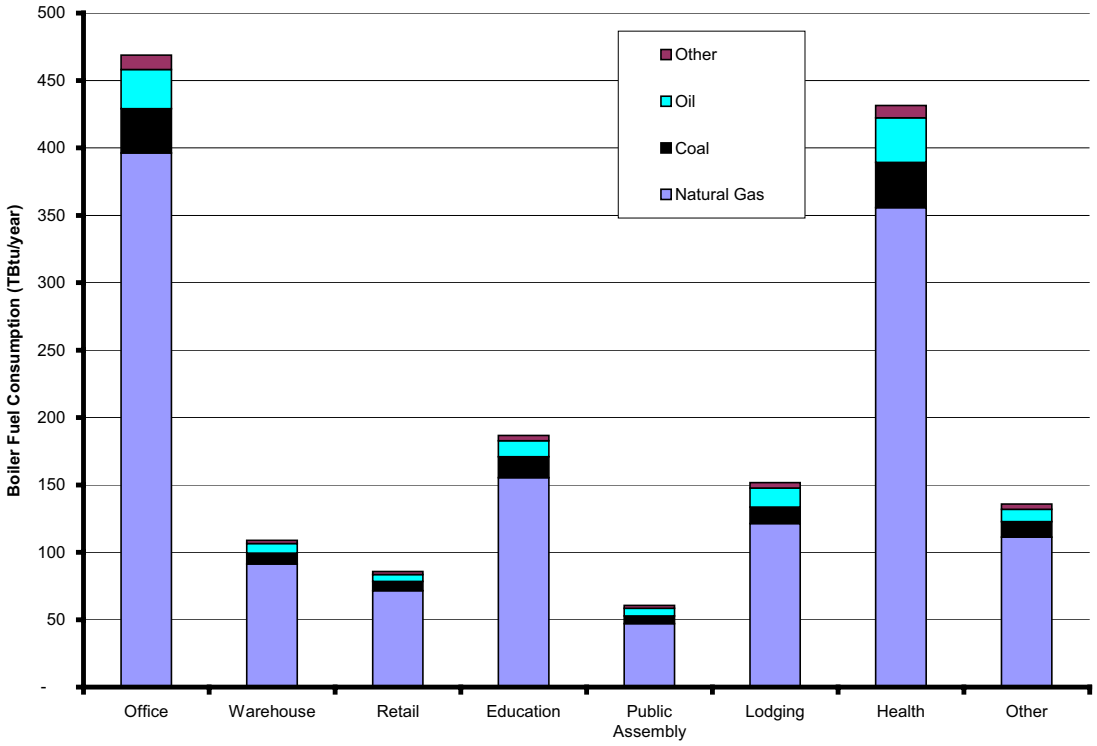
Figure 3-2 Commercial Boilers and Capacity by Base Fuel



Oil is the designated primary fuel for about 11 percent of boiler units and 6 percent of capacity, reflecting the smaller than average size of these firetube units. Whereas oil-fired industrial boilers use a great deal of residual oil, the majority of commercial boiler oil consumption is distillate. Coal boilers are larger, accounting for 1.3 percent of boiler units and 5 percent of capacity. Other fuels, including propane, fuel approximately 2 percent of boiler units and capacity.

Commercial boilers consume approximately 1,630 TBtu/year, which is 28 percent of all energy inputs in the sector. Energy consumption in commercial boilers by building type is listed in Figure 3-3. The mix of energy consumption is consistent with the designated fuel types in the inventory and is similar across different building types. Natural gas (1,350 TBtu/year) fuels most of the boilers and is the dominant input at all building types. Coal (127 TBtu/year) and oil (115 TBtu/year) are consumed in all building types but are used most in educational facilities, offices and health care facilities. Other fuels (38 TBtu/year) including propane are consumed in a relatively small number of facilities, making characterization of their use difficult.

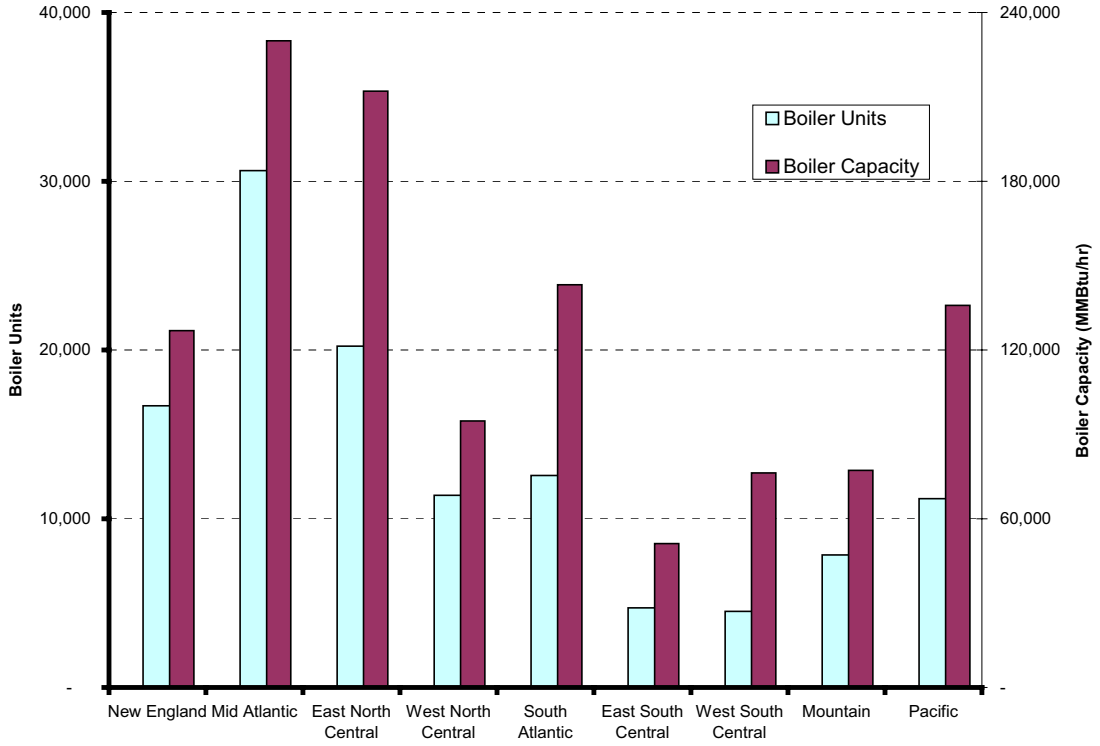
Figure 3-3 Energy Consumption in Commercial Boilers



3.4 Breakdown by Region

Unlike industrial boilers that serve production processes, commercial boilers primarily provide space heating and hot water for buildings and the geographic distribution of boilers reflects this fact. Figure 3-4 shows that 66 percent of commercial boilers are located in the New England, Mid Atlantic, East North Central and West North Central census regions. The distribution also reflects the fact that boilers are more common in older commercial buildings, which are common in these regions.

Figure 3-4 Commercial Boilers and Capacity by Region



The Mid Atlantic has the highest number of commercial boilers (31,000) and the most boiler capacity (230,000 MMBtu/hr). The East North Central has a similar total capacity with 212,000 MMBtu/hr but a smaller number of units (2089,000), indicating larger average capacity. The South Atlantic (143,000 MMBtu/hr), Pacific (136,000 MMBtu/hr) and New England (127,000 MMBtu/hr) regions also have substantial boiler capacity. The West South Central, which has a large quantity of industrial boiler capacity, and the East South Central have the fewest commercial boilers and smallest total capacity.

4 HISTORIC TRENDS

4.1 Boiler Sales Trends

There are several sources of historic data on boiler inventories. These sources show that sales of large boilers have been quite slow for almost 30 years. This also means that the majority of the existing boiler inventory is more than 30 years old.

Figure 4-1shows the long-term trend in sales of watertube and firetube boilers larger than 10 MMBtu/hr for the years 1964-2003 based on data from the ABMA. The bulk of boiler unit sales throughout the period has been the smaller, firetube boilers. However, sales of these firetube boilers also have been generally declining throughout the period shown, from about 3,000 per year in 1964 to about 500 per year in 2002. Sales of small watertube boilers – 10 to 100 MMBtu/hr also declined slowly from 1964 through 1973, then abruptly dropped to 100 to 150 units per year in the mid-1970s and continuing for the next 25 years. This segment experienced a brief sales boom from 1997 through 2002. The reason for this short sales increase is not clear but it seems to have passed.

Historic sales trends for larger watertube boilers (>100 and >250 MMBtu/hr) are shown in Figure 4-2. Sales of these boilers also dropped dramatically after the 1974 energy crisis and economic recession. Sales dropped from hundreds per year to dozens per year and have not recovered except for a brief surge in sales of the 100 – 250 MMBtu/hr boilers during 1999 to 2002. These sales were primarily for natural gas and waste heat recovery boilers, possible related to the gas power plant construction boom during this period.

Given the low sales over the last 30 years, the existing inventory is now quite old. Total sales of boilers larger than 10 MMBtu/hr for 1964 to 2002 were 17,500 units and 1.3 million MMBtu/hr of capacity compared to a combined boiler inventory (including nonmanufacturing boilers) of 56,000 units and 2.8 million MMBtu/hr of capacity in this size range. The sales data for units larger than 10 MMBtu/hr suggests that 47 percent of boiler capacity is at least 40 years old and 76 percent is at least 30 years old

shows the approximate age distribution for the combined inventory. Approximately 7 percent of the capacity is less than 10 years old, 8 percent is 10 to 20 years old, 10 percent is 20 to 30 years old, 29 percent is 30 to 40 years old and 47 percent is over 40 years old. Of the 1,350 very large boilers (>250 MMBtu/hr) about 900 are more than 30 years old.

Figure 4-1 Sales of Boilers >10 MMBtu/hr – 1964-2002

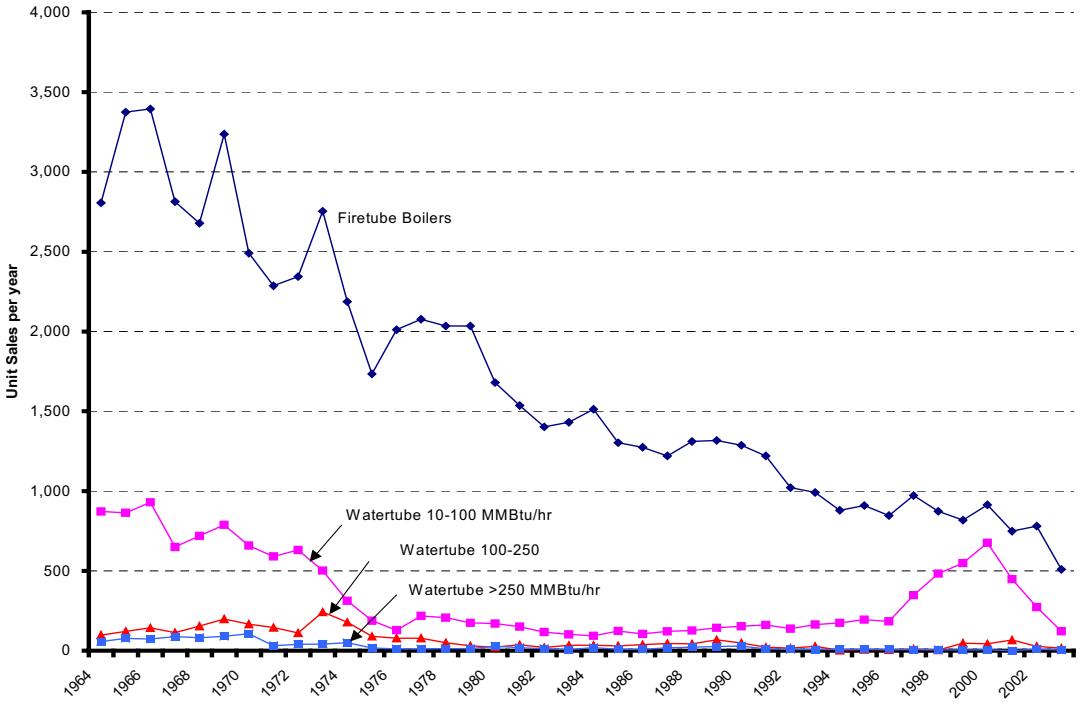


Figure 4-2 Sales of Large Watertube Boilers - 1964-2002

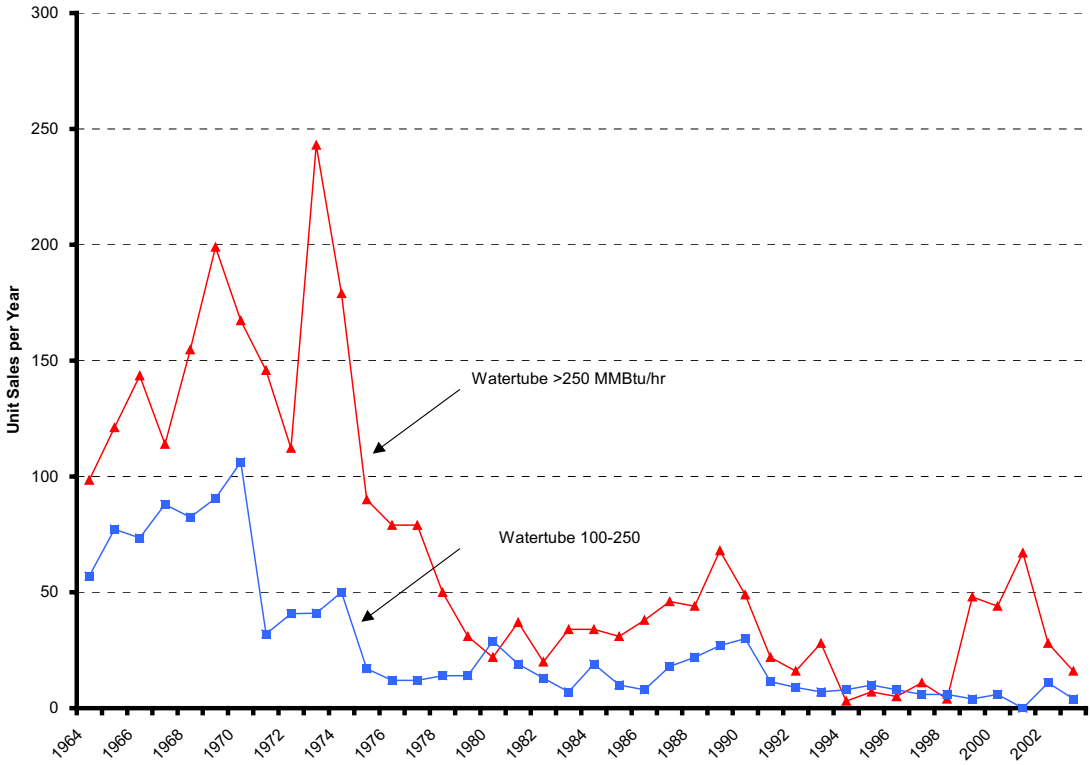
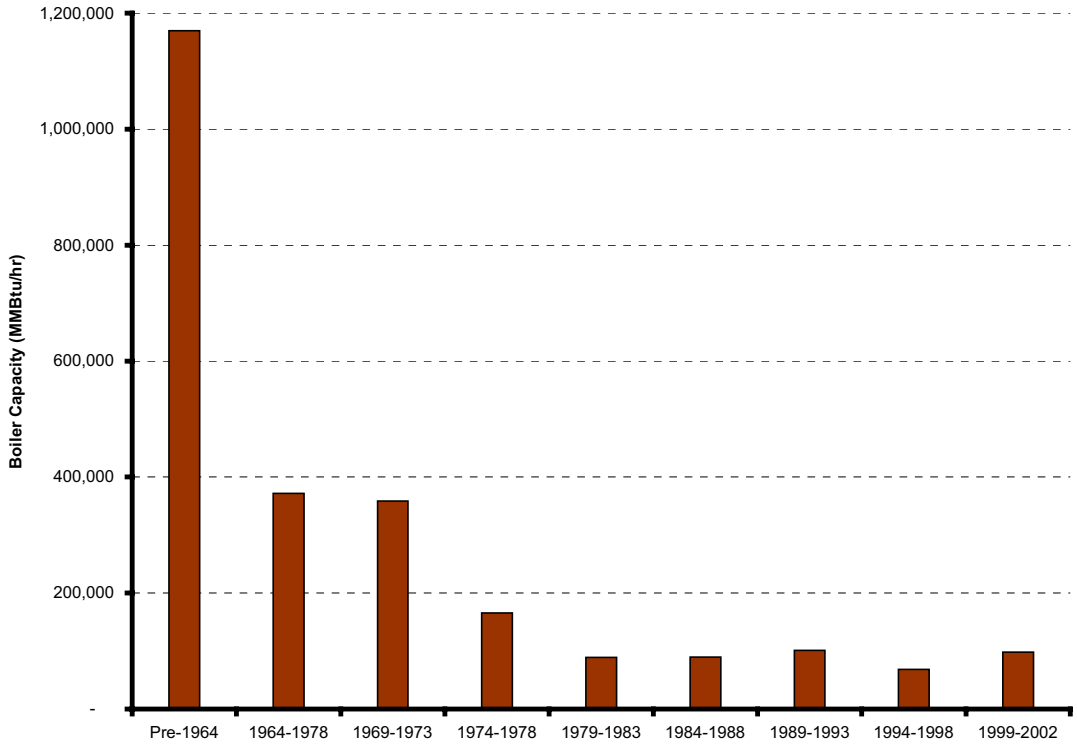


Figure 4-3 Age Distribution of Boilers >10 MMBtu/hr

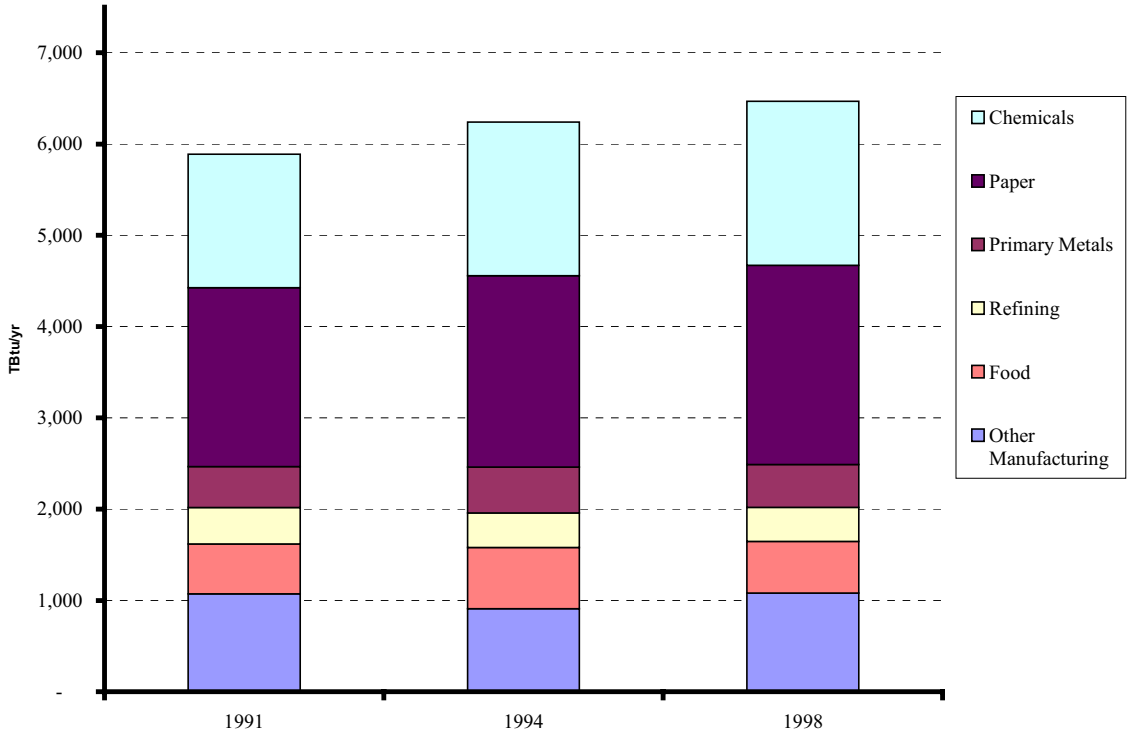


Approximately two thirds of the boilers in the 100 to 250 MMBtu/hr range are more than 30 years old.

4.2 Fuel Consumption - 1991 through 1998

The EIA Manufacturing Energy Consumption Survey (MECS) estimates industrial energy consumption every three to four years. This information can be used to estimate trends in industrial boiler fuel consumption. The 1991, 1994 and 1998 MECS data indicate that fuel consumption for boilers increased somewhat during this period despite numerous news reports on the closure of manufacturing facilities. Figure 4-4 shows that boiler fuel consumption increased by about 6 percent between 1991 and 1994 and increased 3.6 percent between 1994 and 1998. The largest increase in boiler fuel consumption occurred in the chemicals industry, which experienced a 23 percent (334 TBtu/year) increase between 1991 and 1998. Consumption in the paper industry increased by 13 percent over the same period. Most of this increased consumption is believed to be from increased utilization at existing boilers. Boiler fuel consumption at refineries decreased by about 7 percent between 1991 and 1998. Boiler fuel consumption was relatively unchanged in the other industries.

Figure 4-4 MECS Fuel for Boilers 1991-1998



APPENDIX A
ADDITIONAL BACKGROUND ON THE DATA SOURCES

Since there is no one complete source of data on boiler populations, this report is based on the analysis of a wide range of data sources. This section reviews the data sources and their strengths and weaknesses.

A.1 ABMA Sales Data

The American Boiler Manufacturers Association (ABMA) compiles sales data for boilers sold in the United States. EEA reviewed ABMA data from 1964 through 2002. Although other sources inventory large industrial boilers (larger than 10 MMBtu/hr), the ABMA sales data capture sales of the thousands of units that fall below this threshold. The most detailed information is for 1992 to 2002. Table A-1 shows a basic summary of sales by boiler type for this period. Unfortunately, we do not know the application for most of these units (85 percent), especially the small boilers.

Table A-1 ABMA Sales 1992-2002

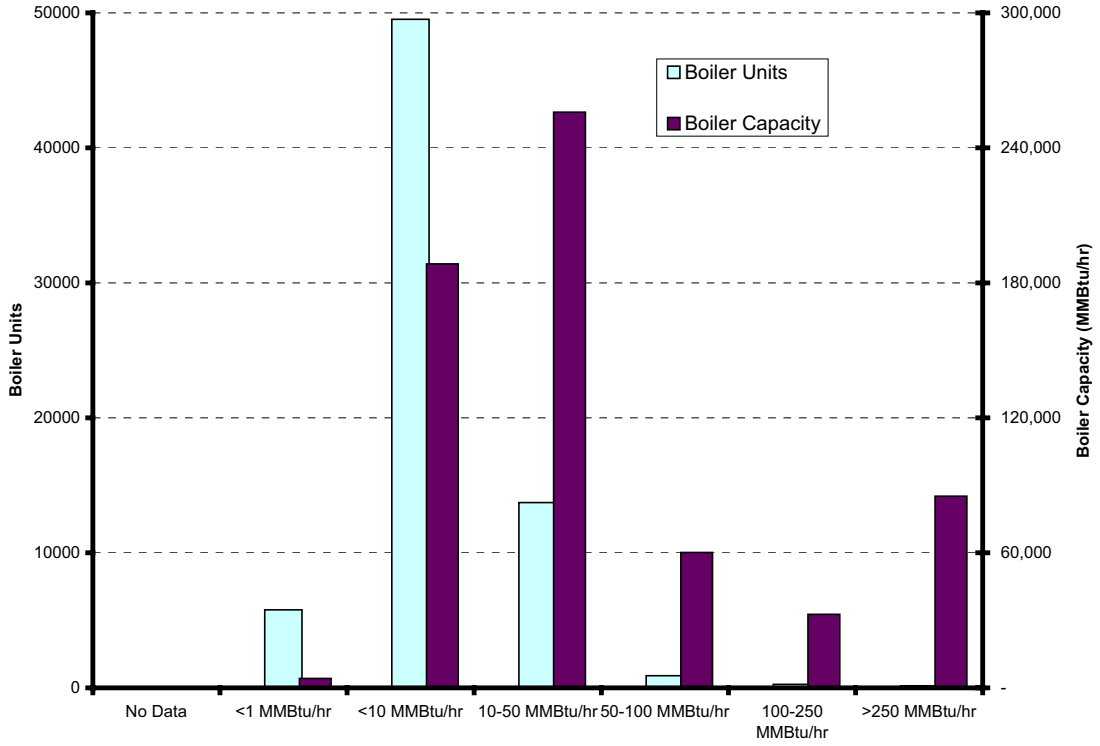
Boiler Type	Number of Units	Capacity (MMBtu/hr) input
Firetube	36,357	306,545
Watertube	33,873	260,539
Fluidized Bed Combusto	47	39,674
Stoker	68	19,665
Total	70,345	626,423

Firetube, typically smaller, boilers account for 52 percent of the units and 48 percent of the capacity sold during this period. Watertube boilers account for 48 percent of the units and 44 percent of the capacity during this period. The average capacity per unit for both the firetube and watertube boilers sold was about six MMBtu/hr. This shows that very few large watertube boilers were sold during this period. FBC and stoker boilers accounted for less than one percent of the units sold since 1990 but their average size was

585 MMBtu/hr and 208 MMBtu/hr, respectively. Although few in number, the FBC and stoker boilers accounted for 8.5 percent of the boiler capacity sold during this period.

The distribution of total boiler sales for 1992 through 2002 is shown in Figure A-1. By far, the greatest number of boilers (70 percent) sold were in the 1 to 10 MMBtu/hr size range. Boilers between 10 and 50 MMBtu/hr are the next most numerous, accounting for 20 percent of unit sales. The 1 to 10 MMBtu/hr boilers represent 30 percent of capacity. The largest segment is the 10 to 50 MMBtu/hr range, which accounts for 41 percent of capacity. Boilers larger than 250 MMBtu/hr represent 14 percent of capacity sold since 1992 but only a very few units.

Figure A-1 Size Distribution of Boilers Sold 1992-2002



Although no SIC data are available for more than half of the units in this size range, in cases where this data was available, most of the installations were for SIC 49, which includes electric services, natural gas production and transmission and refuse and sanitary services. Most recent boilers sales have been oil and natural gas-fired boilers in the South Atlantic and West South Central regions at facilities in SIC 49. Sales of watertube boilers larger than 250 MMBtu/hr dropped sharply in the early 1970's and have not recovered.

The AMBA database contains SIC data for some boiler sales, which provide some insight into where these boilers are being installed. Table A-2 lists the distribution of unit and capacity sales by 2-digit SIC. Unfortunately no SIC data are available for the smaller firetube and watertube boilers, which means that 87 percent of the units and 61 percent of

the capacity is not assigned. Of the known units, most were installed at educational, health service, utility service and miscellaneous manufacturing facilities. On a heat input basis, utility service facilities accounted for slightly more than half of the capacity and the food, refining, paper and chemical industries accounted for another quarter of the installed capacity. More than 10,000 MMBtu/hr of capacity was added or replaced in five manufacturing groups: food, paper, chemicals and refining.

Table A-2 ABMA Sales Data by SIC 1992-2002

Applications	Number of Units	Capacity (MMBtu/hr input)
No SIC Data	59,872	394,255
SIC 15 Buildings	171	812
SIC 20 Food	604	17,832
SIC 22 Textiles	124	1,244
SIC 24 Lumber and Wood	154	3,912
SIC 26 Paper	166	13,319
SIC 27 Printing	1	4
SIC 28 Chemicals	479	12,051
SIC 29 Refining	338	13,428
SIC 30 Rubber/Plastics	44	411
SIC 33 Primary Metals	56	5,986
SIC 37 Transportation Manuf.	158	1,427
SIC 39 Miscellaneous Manuf.	1,049	11,038
SIC 49 Services incl. Electricity and Gas	1,106	103,221
SIC 65 Real Estate	361	3,730
SIC 73 Services incl. Building Maintenance	245	4,202
SIC 80 Health Services	1,250	12,131
SIC 82 Education	2,709	17,671
SIC 999 Nonclassifiable Establishments	1,458	9,751
Total	**70,345**	**626,423**

Almost half of boiler capacity sold since 1992 was installed in the East North Central, South Atlantic and Mid Atlantic regions. The distribution of sales across all regions is shown in Figure A-2. The lack of complete SIC data for most of the boiler sales during this period makes a complete analysis difficult. The relatively large number of new boilers in these three regions likely reflects their large populations and existing industrial base. The sales do not seem tied to economic growth, especially in the East North Central where growth trailed the national average during the 1990-2001 period. In fact, the three regions with the most new boiler capacity experienced economic growth that was the same or less than the national average. Two regions with the highest rate of economic growth, Mountain and Pacific, also had some of the smallest additions of boiler capacity. This reflects in part the fact that much of the recent economic growth has been in sectors with little steam demand.

A.2 MECS

The Energy Information Administration (EIA) of the Department of Energy (DOE) performs the Manufacturing Energy Consumption Survey (MECS) approximately every four years to tabulate national energy consumption data for the manufacturing sector. The most recent MECS is based on responses from 18,000 establishments on their energy use in 1998. The survey data is extrapolated by EIA to represent the estimated 226,000 manufacturing establishments that use energy. The MECS estimated total manufacturing fuel consumption of 17,700 TBtu in 1998, including 6,467 TBtu for industrial boilers. The MECS does not provide an estimate of the number of boilers. A summary of the MECS results is shown in Tables A-3 and A-4.

Figure A-2 ABMA Sales by Region 1992-2002

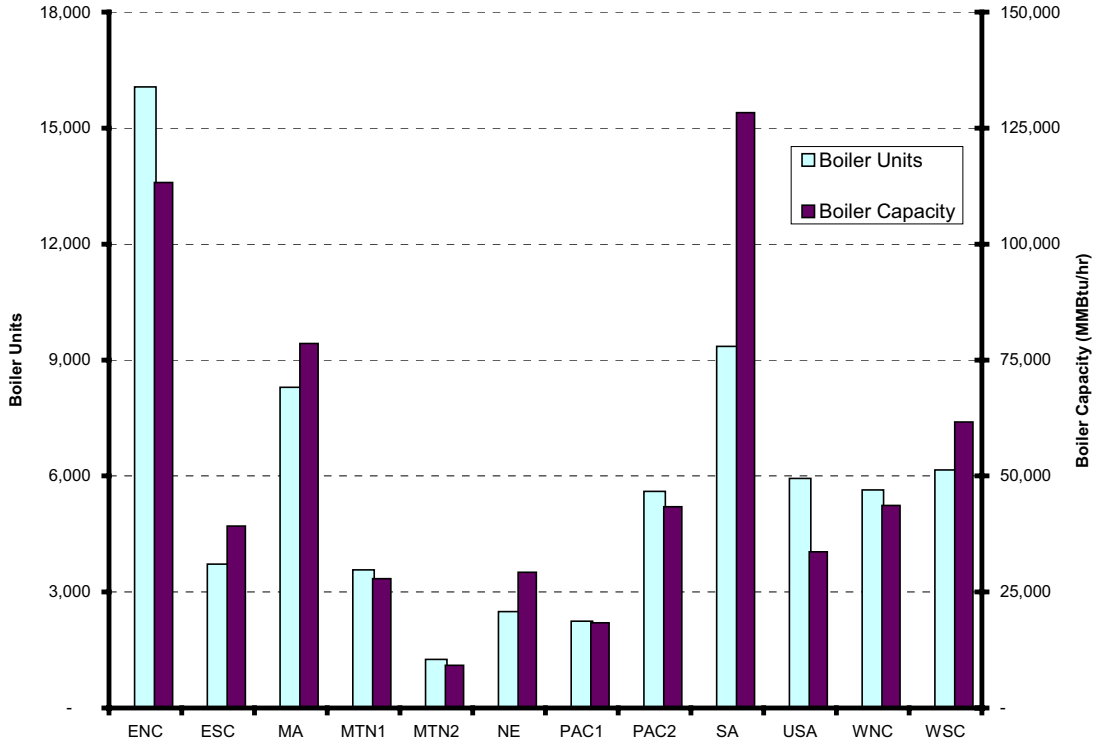


Table A-3 MECS Boiler Fuel Summary

	Residual Oil	Distillate Oil	Natural Gas	LPG	Coal,Coke, Breeze	Other Fuels	Electricity	Total
Boiler Fuel	245	38	2,141	24	770	3,249	-	6,467
Total Fuel Consumption	357	133	6,644	135	1,143	6,248	3,035	17,695

"Other" fuels include by-product fuels such as black liquor in the paper industry. Unlike purchased fuels, MECS does not estimate the end-use of "other" fuels and boiler fuel use for this analysis is based on EEA estimates. Boiler fuel consumption from the MECS is used in estimating boilers not captured in the other inventories, especially smaller units.

Table A-4 MECS Fuel Consumption in Boilers by Industry

	Residual Oil	Distillate Oil	Natural Gas	LPG	Coal,Coke, Breeze	Other Fuels	Total
Food	12	11	329	1	115	99	566
Paper	123	5	379	1	268	1,406	2,181
Chemicals	30	4	775	14	269	705	1,797
Refining	41	1	110	7	-	216	374
Primary Metals	10	-	134	-	30	294	468
Other Manufacturing	30	17	416	1	88	530	1,081
Total	**245**	**38**	**2,141**	**24**	**770**	**3,249**	**6,467**

A.3 EEA's 1996 Analysis of the Industrial Boiler Population

In 1996 EEA produced the Analysis of the Industrial Boiler Population for the Gas Research Institute (referred to as the 1996 Analysis). The 1996 Analysis estimated an industrial boiler population of 32,875 boilers larger than 10 MMBtu/hr and a total industrial boiler capacity of 2.1 million MMBtu/hr. Figure A-3 summarizes the 1996 Analysis.

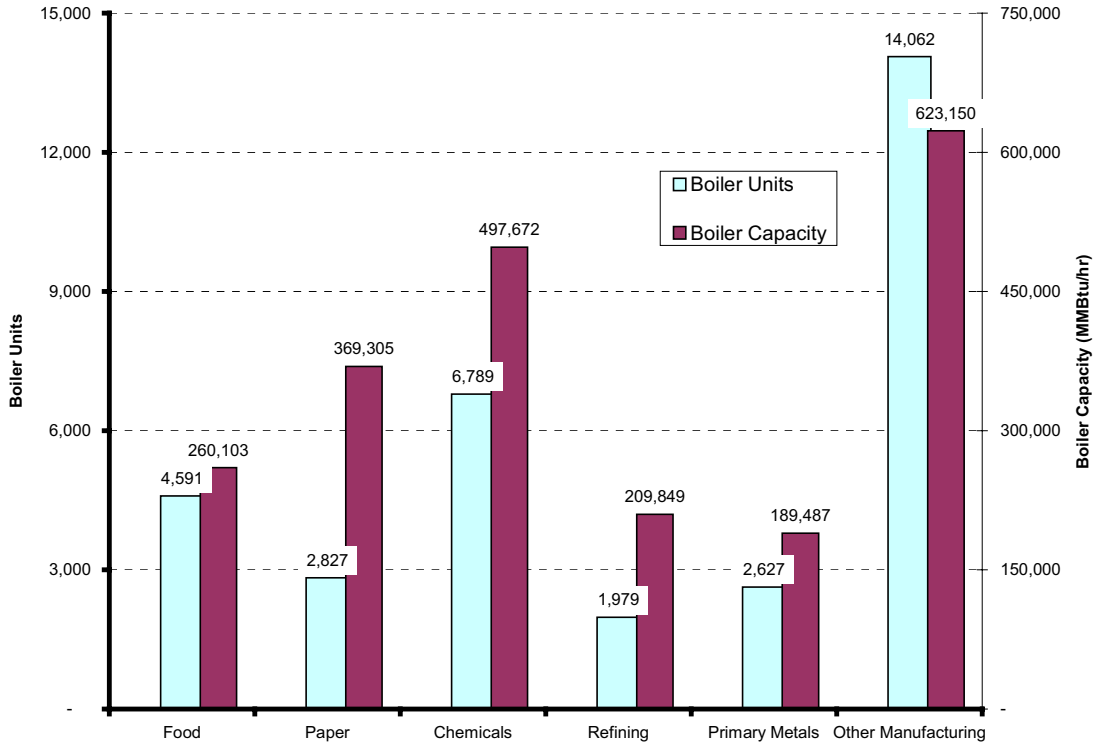
The 1996 Analysis was based largely on 1977-vintage EPA and DOE/EIA reports and could not simply be updated for the current analysis. Because the major data sources are now 25 years old, it was not reasonable to update the 1996 Analysis. Despite this limitation, it remains a useful benchmark for comparison.

The 1996 Analysis estimated that a majority of boilers (60 percent) and capacity (70 percent) were concentrated in the five major steam-consuming industries. In the 1996 Analysis the largest number of boilers were in the food and chemicals industries, which accounted for 35 percent of the units in the inventory. The paper and chemicals industries had the largest number of boilers larger than 250 MMBtu/hr. Other conclusions of the 1996 analysis were that:

- More than half of the boilers and capacity were located in the north central and south central regions.
- More than half of the capacity was fired by natural gas or by-product fuel.
- 80 percent of the boilers in place in 1993 were purchased prior to 1978.

The industrial boiler capacity in the 2005 study is 25 percent less than the total reported in the 1996 EEA analysis for units 10 MMBtu/hr and larger (the 1996 analysis excluded units below this threshold). The biggest differences are in primary metals (66 percent) and other manufacturing (32 percent). The primary metals industries, especially the production of iron and steel from ore, have experienced significant contraction in the last 20 years and this is reflected in the analysis.

Figure A-3 1996 EEA Analysis of the Industrial Boiler Population



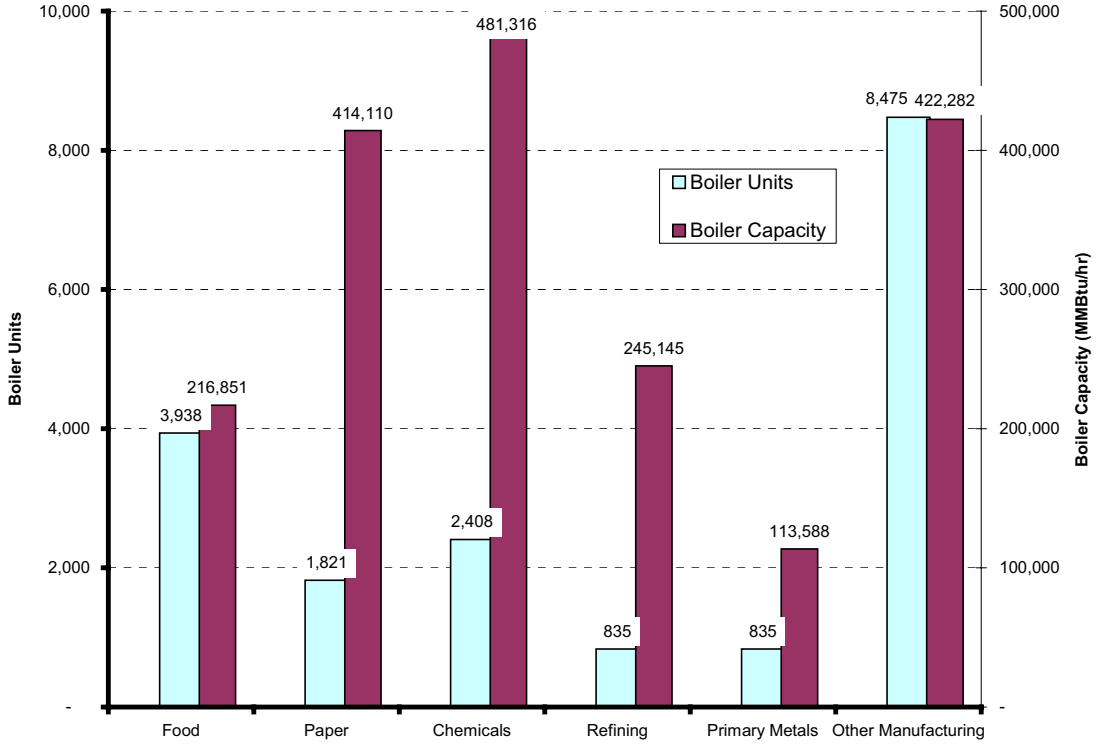
A.4 MIPD Database

IHS Energy produces the Major Industrial Plant Database (MIPD), which tracks energy consumption at more than 15,000 large industrial facilities. This sample is small compared to the total number of manufacturing facilities (approximately 363,000)[4] but captures about 68 percent of boiler fuel consumption due to its focus on large energy consuming facilities. The MIPD survey includes the number and capacity of boilers at each facility as well as the total amount of energy consumed in boilers. Figure A-4 summarizes the boiler inventory data from MIPD.

The MIPD is continuously updated and considered to be generally reliable. The primary limitation of the MIPD is that it is a limited survey and does not provide good coverage of smaller facilities and boilers, in particular.

[4] 1997 Economic Census, Bureau of the Census.

Figure A-4 Summary of Boilers in MIPD

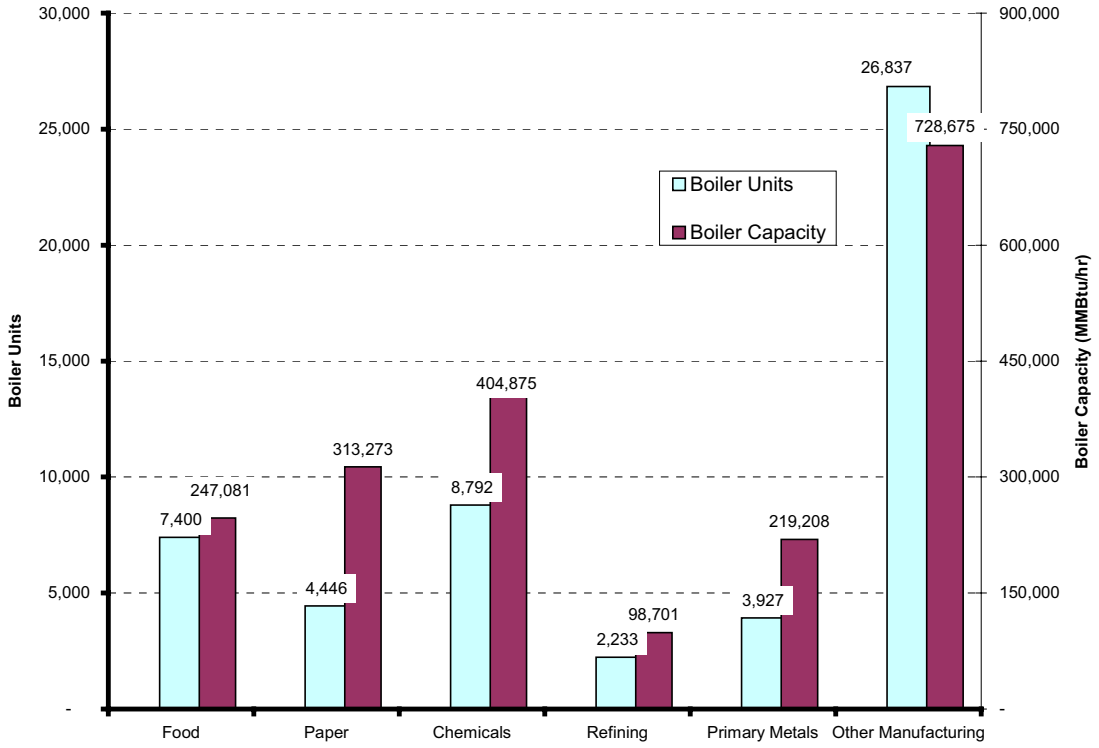


A.5 EPA's ICCR Database

EPA developed the ICCR database as part of the work of the Industrial Coordinated Combustion Rulemaking (ICCR) Federal Advisory Committee. The committee developed this database to provide a basis for the development of regulations for hazardous air pollutants from boilers. The database, last revised in November 2000, contains 70,000 boilers including 53,635 at industrial facilities. Although the data contain information on unit capacity, those data were determined to be incomplete or unreliable, limiting their usefulness. Also, a sampling of the inventory revealed several cases where the number of boilers reported at a facility was unreasonable (i.e., more than 200 boilers at a metal fabrication plant).

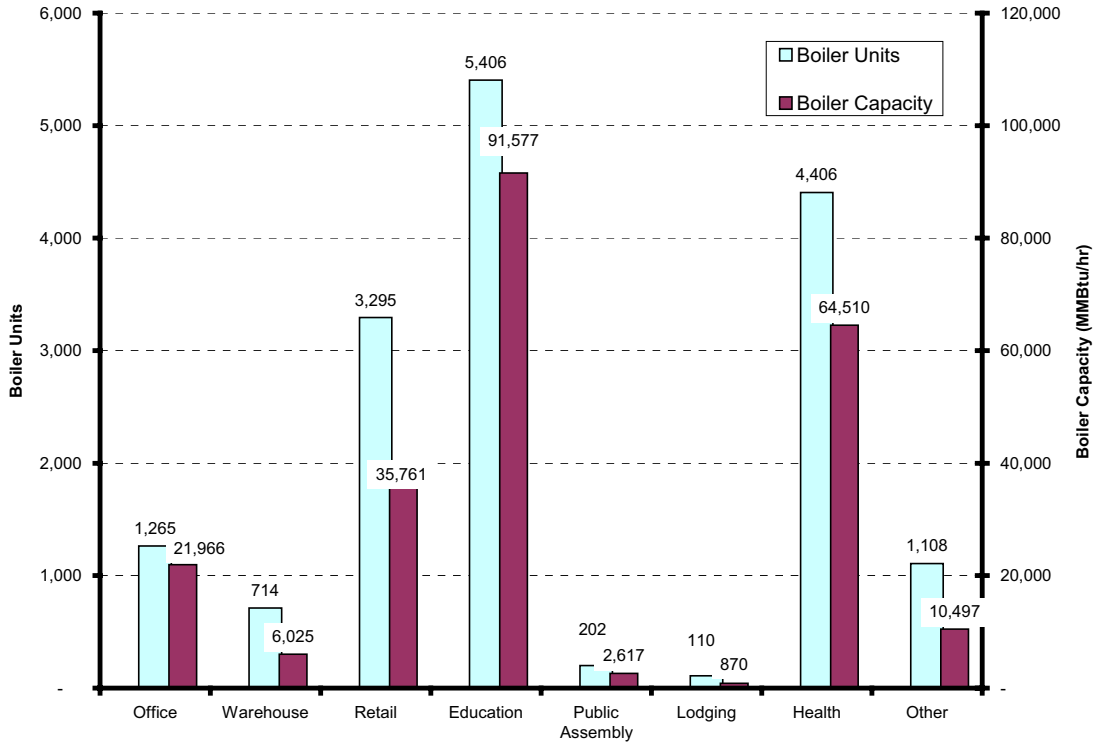
Figure A-5 shows a summary of the industrial boilers in the ICCR database. Consistent with other data sources, most of the boilers are in the food, chemicals and other manufacturing industries. Compared to the final EEA composite in this study, the ICCR database has a greater fraction of its boilers in the fabricated metals and transportation industries (i.e., car and truck production). The distributions of base fuels and regions are similar to the distributions in the final data set but the number of boilers is smaller in each category.

Figure A-5 Summary of Industrial Boilers in EPA's ICCR Database



The ICCR database includes 16,506 commercial boilers with an aggregate capacity of 234,000 MMBtu/hr. The distribution by building type is shown in Figure A-6. Slightly more than half of the boilers and boiler capacity are located at educational and health care facilities. One limitation of the ICCR database is that a large number of boilers are identified only by a capacity range (i.e., 10-100 MMBtu/hr) because the specific capacity values were missing or determined to be unreliable.

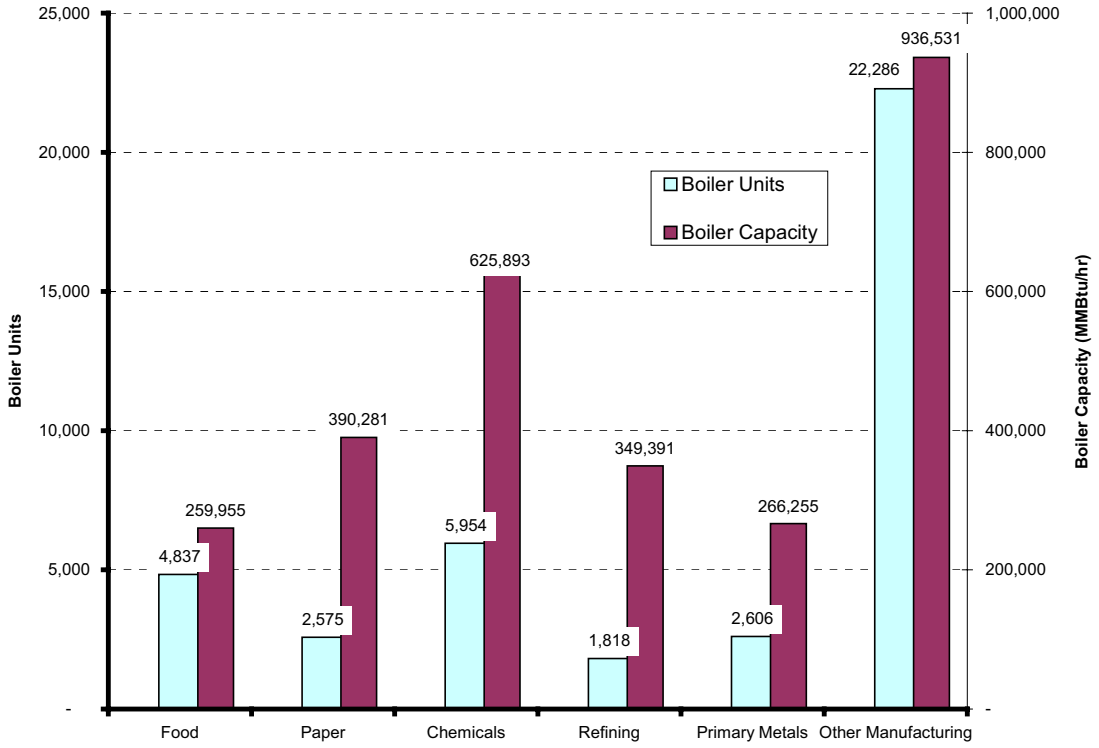
Figure A-6 Summary of Commercial Boilers in EPA's ICCR Database



A.6 EPA's ICI Database

ICF Consulting produced the Industrial/Commercial/Institutional (ICI) database to support EPA's rulemaking process for new air pollution control regulations. The most recent available version was last updated in 1999. The ICI database, summarized in Figure A-7, includes 40,000 industrial boilers with an aggregate capacity of 2.8 million MMBtu/hr. Like the ICCR database, the ICI database is skewed toward larger units, with lesser coverage of smaller boilers. The average unit size is 71 MMBtu/hr compared to 31 MMBtu/hr for the final composite inventory of industrial boilers. The distribution of boilers is similar to the ICCR database with most of the boilers in the food, chemicals and other manufacturing industries. Although the ICI database contains more than 90 percent of the number of boilers larger than 250 MMBtu/hr in the final inventory, it contains only 42 percent of the number smaller than 50 MMBtu/hr.

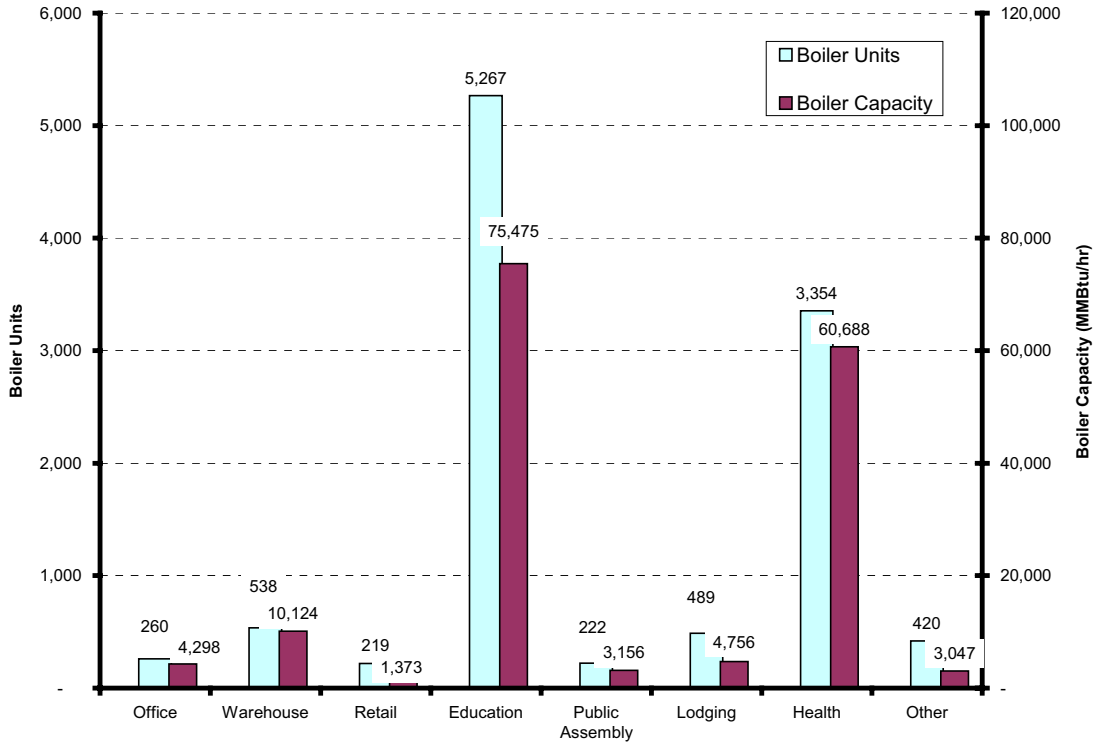
Figure A-7 Summary of Industrial Boilers in ICF's ICI Database



The ICI database includes 10,769 commercial boilers, summarized in Figure A-8. Almost 95 percent of the commercial boilers in the ICI database are in the 1 to 50 MMBtu/hr size range, although units larger than 50 MMBtu/hr account for 38 percent of the capacity in the database. Oil and gas-fired boilers represent more than 90 percent of the units and capacity.

Almost half of the commercial ICI boilers and boiler capacity are located at educational facilities with health care facilities representing the next largest concentration in the inventory. Created to support air pollution rulemaking, the ICI database captures a sample of the boilers at commercial facilities with better coverage of larger boilers than smaller units. However, because it includes less than 11,000 commercial boilers, it includes only a small fraction of the estimated 460,000 commercial facilities that have boilers.

Figure A-8 Summary of Commercial Boilers in ICF's ICI Database



A.7 EPA's Boiler MACT Database

In February 2004 EPA published the Maximum Achievable Control Technology (MACT) floor development documents for industrial, commercial, and institutional boilers and process heaters. The MACT floor refers to the emission control requirement that all affected sources must meet to control the emission of hazardous air pollutants (HAPs). The documents confirm that the MACT rule proposed in November 2002 likely will become the final rule. EPA estimates that the rule will affect 42,000 boilers, including solid-fuel boilers larger than 10 MMBtu/hr and those located at major sources (i.e., facilities emitting 10 tons per year of any one HAP or 25 tons per year of any combination of HAPs).

The MACT floor development documents identify the ICCR database as an important reference but EPA reports that the data were adjusted to determine the number of affected units. Unfortunately, EPA did not produce a final, corrected database of affected boilers. It is difficult to confirm EPA's estimates of affected boilers without complete HAP emissions data, but EPA's estimate of the number of affected solid-fuel boilers is consistent with the values in the final boiler inventory.

A.8 Economic Census

The Bureau of the Census performs the Economic Census every 5 years with 1997 providing the most recent data. EEA used the 1997 Economic Census (EC97) to project the size distribution of boilers that are not captured in existing inventories. The EC97 estimates that there are 363,000 manufacturing facilities. Although the EC97 does not track boilers or boiler fuels, it does provide a breakdown of the number of establishments by the North American Industrial Classification System (NAICS) code and number of employees and the summary of this data is shown in Table A-5.

Table A-5 Percentage of Facilities by Number of Employees

	Distribution of Facilities by Number of Employees									
Industry	**<5**	**5-9**	**10-19**	**20-49**	**50-99**	**100-249**	**250-499**	**500-999**	**1000-2499**	**>=2500**
Food	24%	14%	15%	18%	10%	10%	4%	3%	2%	0%
Paper	6%	5%	10%	24%	20%	25%	4%	3%	2%	0%
Chemicals	16%	10%	12%	21%	15%	15%	5%	3%	2%	0%
Refining	7%	5%	7%	17%	10%	21%	16%	11%	7%	0%
Metals	11%	5%	6%	11%	7%	18%	20%	10%	6%	6%
Other Manufacturing	24%	13%	14%	18%	11%	11%	5%	2%	1%	0%
Total	**22%**	**13%**	**14%**	**19%**	**12%**	**12%**	**5%**	**2%**	**1%**	**0%**

A.9 CBECS

Approximately every four years EIA performs the Commercial Buildings Energy Consumption Survey (CBECS), with the most recent survey completed for 1999. EIA completed interviews for 5,430 buildings and used the results to estimate fuel consumption for the 4.66 million commercial building in the U.S. EIA estimates that boilers serve 581,000 buildings.

Figure A-9 shows the distribution of floor space in commercial buildings by building size and building age. The largest amount of floor space served by boilers is in buildings constructed in the 1960s, which is fairly consistent with the vintage analysis in Chapter 4. Commercial floor space served by boilers decreased in the 1970s, 1980s and 1990s, although boilers remained a common technology for facilities larger than 200,000 square feet.

Figure A-9 CBECS Distribution of Floor Space by Building Size and Vintage

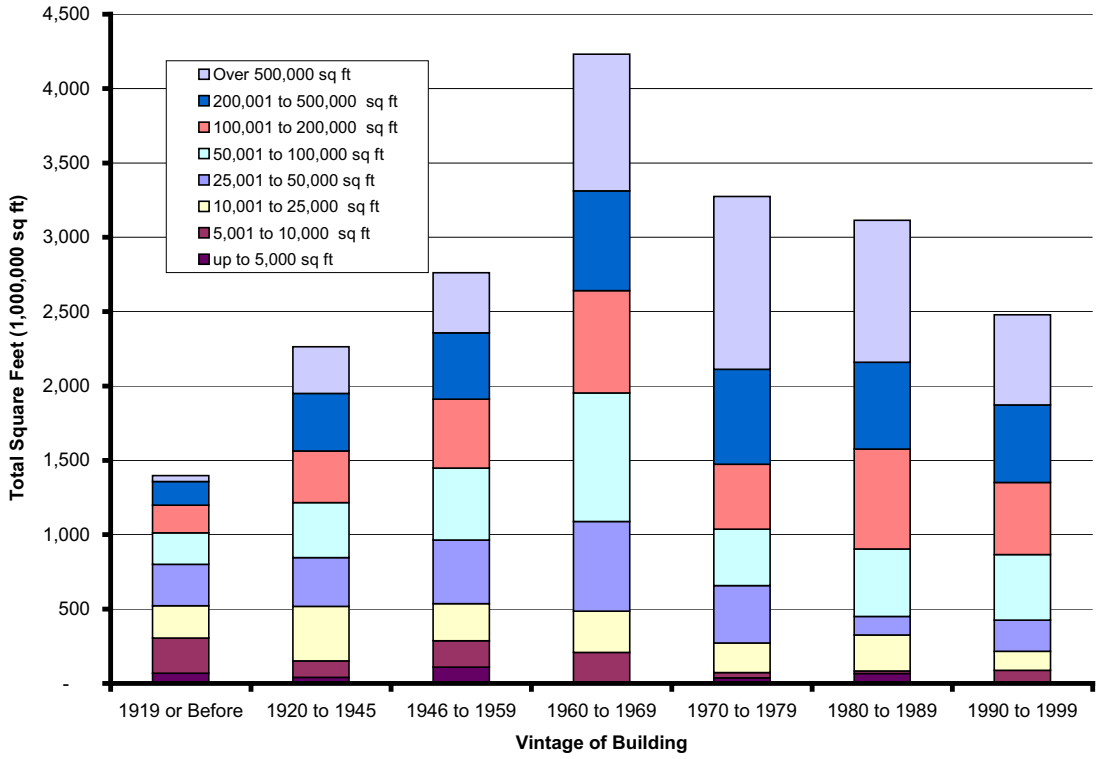


Table A-6 lists space heating technology data for commercial buildings by period of construction. Although not the dominant choice for all buildings, boilers provide space heat for more than a third of floor space in buildings constructed before 1970. Packaged heating units now provide heating for more than half of commercial building floor space but boilers heat 22 percent of floor space constructed in the 1990s.

Table A-6 CBECS Space Heating Technologies by Building Vintage

Year Constructed	Number of Buildings with boilers	1,000,000 Square footage served by boilers	% Square Footage served by boilers	Dominant Technology for Period
1919 or Before	99,828	1,397	35%	Boilers 35%
1920 to 1945	82,857	2,264	35%	Boilers 35%
1946 to 1959	120,792	2,762	30%	Packaged Heating Units 32%
1960 to 1969	97,832	4,231	39%	Boilers 39%
1970 to 1979	62,892	3,275	28%	Packaged Heating Units 41%
1980 to 1989	64,888	3,114	22%	Packaged Heating Units 46%
1990 to 1999	51,911	2,479	22%	Packaged Heating Units 51%

APPENDIX B
METHODOLOGY FOR CALCULATING THE BOILER INVENTORY

B.1 Methodology for Calculating the Industrial Boiler Inventory

Many reports and studies have been produced on the subject of industrial boilers, but most are not comprehensive or are out of date. This analysis relies on EEA's 1996 Analysis of the Industrial Boiler Population, IHS Energy's MIPD, EPA's ICCR database, ICF's ICI database, ABMA sales data, EIA's MECS and the 1997 Economic Census. Two other comprehensive reports, EPA's Population and Characteristics of Industrial/Commercial Boilers in the U.S. and DOE/EIA's Report on the 1980 Manufacturing Industries Energy Consumption Study and Survey of Large Combustors are based on 1977 data and were determined to be too out-of-date to be useful.

The MIPD, 1996 EEA Analysis and MECS were the primary elements in constructing the industrial boiler population estimate. Data selected from the MIPD and 1996 EEA Analysis were the starting point for the inventory. These were augmented with data from the ICCR and ICF data bases. These sources were judged to represent a good estimate of larger industrial boilers but were known to be lacking most of the smaller boilers, particularly those below 50 MMBtu/hr.

The MECS energy consumption is used to estimate the additional boilers to complete the inventory. ABMA sales databases were used for comparison and to fill in portions of the inventory where the other sources were incomplete. These "missing" smaller boilers were referred to as the "incremental" boilers.

The incremental boilers are calculated in three steps: estimating the fuel consumption for the incremental boilers, calculating the boiler size distribution and capacity factors for each industry and calculating the size and number of incremental boilers for each industry. Table B-1 lists the fuel consumption, number of units and capacity of the incremental boilers.

Table B-1 Incremental Industrial Boilers

Incremental Boiler Fuel (TBtu/year)							
	Food	Paper	Chemicals	Refining	Metals	Other Manufacturing	**Total**
TBtu/yr fuel consumption	196	361	548	85	204	115	**1,510**

Incremental Boiler Units							
	Food	Paper	Chemicals	Refining	Metals	Other Manufacturing	**Total**
< 10 MMBtu/hr	4,786	474	6,179	178	1,473	2,670	**15,761**
10-50 MMBtu/hr	1,623	632	2,711	88	689	1,127	**6,870**
50-100 MMBtu/hr	193	314	486	55	254	133	**1,435**
100-250 MMBtu/hr	61	146	149	24	50	32	**463**
>250 MMBtu/hr	5	62	40	16	31	2	**156**
Total	**6,667**	**1,628**	**9,564**	**362**	**2,498**	**3,965**	**24,685**

Incremental Boiler Capacity (MMBtu/hr)							
	Food	Paper	Chemicals	Refining	Metals	Other Manufacturing	**Total**
< 10 MMBtu/hr	22,948	2,437	26,446	860	5,990	11,243	**69,924**
10-50 MMBtu/hr	34,633	14,768	65,818	2,376	14,317	25,109	**157,021**
50-100 MMBtu/hr	13,136	21,873	34,118	4,236	17,517	9,012	**99,891**
100-250 MMBtu/hr	8,860	22,525	21,993	4,150	8,045	4,449	**70,022**
>250 MMBtu/hr	1,894	27,339	16,824	8,363	11,175	975	**66,569**
Total	**81,471**	**88,942**	**165,198**	**19,985**	**57,043**	**50,788**	**463,427**

The estimated fuel for the incremental boilers in each industry is equal to the fuel for the known boilers (e.g., 1996 Analysis, MIPD, ICCR and ICI databases) subtracted from the total estimated fuel consumption for boilers. One complicating factor is that the MECS category "Indirect Uses-Boiler Fuel" includes fuel consumption for non-boiler CHP, such as combustion turbines, in addition to fuel for boilers. EEA analyzed historic CHP reports and current EIA Form 906 reports to quantify the amount of fuel that should be allocated to non-boilers. The non-boiler portion of the MECS "boiler" fuel is estimated to be 243 TBtu in 1991, 354 TBtu in 1994 and 437 TBtu in 1998. The major consumers of this fuel were chemicals (223 TBtu) and refining (156 TBtu) for non-boilers in 1998. The data in this report reflect this correction. EEA estimates that fuel consumption for the incremental boilers is 1,510 TBtu/year equals 23 percent of the MECS total.

The next step was to characterize the incremental units. Using the Economic Census data, EEA selected the NAICS codes that are steam-intensive and used the distribution of establishments by number of employees to compile a distribution for each of the major steam-consuming industries. The EC97 distribution was matched to distributions from MIPD, which also includes employment data. The difference between the EC97 and MIPD employment distributions produced a profile of the distribution of facilities not captured in MIPD. Also, the comparison of the EC97 and MIPD distributions produced a boiler size distribution for each industry to go with the employment data. Combining these two data sets produced a boiler-size distribution for each industry to be used when adding incremental boilers.

The incremental boiler fuel is allocated by industry and region and is converted to boiler capacity by using the capacity factors from the known boilers in the same industry and size range. The MIPD and ICI datasets were used to characterize these boilers. The

incremental boiler capacity was then converted to boiler units using the average boiler size within each SIC and size range category.

B.2 Methodology for Calculating the Commercial Boiler Inventory

No comprehensive survey of boilers at commercial facilities has been performed, although partial surveys and energy analysis by DOE provide an adequate basis for estimating the boiler population. This analysis relies on partial surveys and a projection based on an energy consumption survey. The partial surveys are the EPA ICCR and ICF ICI databases, which were compiled to support air pollution rulemaking. Although incomplete, these databases include many of the largest commercial boilers in service. The energy survey is EIA's Commercial Buildings Energy Consumption Survey (CBECS), which includes boiler fuel consumption for space heating and hot water.

The CBECS data provides boiler fuel consumption by building type, building size and region. The number and size of buildings in each category is matched to similar commercial buildings in the ICCR and ICI databases. EEA used the CBECS data to estimate boiler fuel consumption and the number of buildings served by boilers in each category.

The 1999 CBECS does not provide specific end-use data, however the 1995 CBECS provides more specific breakdowns. Also, the 1999 CBECS public use data files provided an essential reference for performing the cross tabulations (i.e., floor space by facility type and building vintage). In commercial buildings, about twice as much energy is used for space heating as for water heating. It is impossible to break down how much of the boiler inventory is for space heating versus water heating but the split is probably about the same. Space heating and water heating may be provided by the same system (i.e., the same boiler) at many of these facilities.

Although many facilities are rather small (almost half of all commercial buildings are smaller than 5,000 square feet), the larger facilities are served by multiple boilers and EEA projects the number of building complexes served by boilers to be 462,000 and the final boiler count to be 529,642 units. Boiler capacity was calculated using the boiler energy consumption and model capacity factors for each building type and region. The resulting values for number of boilers and boiler capacity were compared to the ICI and ICCR databases and the ABMA sales to confirm reasonableness.

Once the total number of boilers and total capacity had been calculated the remainder of the analysis required reallocating the boilers to facilities based on the 1995 end-use tables and the 1999 public-use files.

Using the CBECS data presented two problems for the analysis. First, CBECS did not include coal as a fuel. Individual coal boilers were added to the inventory from the ICCR and ICI databases and these were subtracted from the natural gas boiler numbers. Another challenge was district heat. If a building is served by a boiler that is not inside the building, then it is determined by CBECS to be served by district heat, although this

does not fit the typical definition of the term. In these cases, EEA compared the CBECS energy use numbers to the National Energy Review values for commercial buildings and allocated the difference to the district heat boilers. In general, this meant the addition of natural gas boilers to the inventory.

APPENDIX C
ACRONYMS

ABMA	American Boiler Manufacturers Association
Btu	British Thermal Units
CBECS	Commercial Building Energy Consumption Survey
CHP	Combined Heat and Power
DG	Distributed Generation
DOE	U.S. Department of Energy
EEA	Energy and Environmental Analysis, Inc.
EIA	Energy Information Administration of the U.S. Department of Energy
ENC	East North Central Region
ESC	East South Central Region
FBC	Fluidized Bed Combustors
HAP	Hazardous Air Pollutants
ICCR	Industrial Coordinated Combustion Rulemaking
ICI	Industrial/Commercial/Institutional
MA	Mid Atlantic Region
MACT	Maximum Achievable Control Technology
MECS	Manufacturing Energy Consumption Survey
MIPD	Major Industrial Plant Database

MMBtu	Million British Thermal Units
MTN	Mountain Region
NAICS	North American Industrial Classification System
NE	New England Region
PAC	Pacific Region
SA	South Atlantic Region
SIC	Standard Industrial Code
TBtu	Trillion British Thermal Units
WNC	West North Central Region
WSC	West South Central Region

APPENDIX D
MAP OF U.S. CENSUS REGIONS