CHAPTER 6. SHIPMENTS ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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6.1 INTRODUCTION

Estimates of commercial boiler equipment (CBE) shipments are a necessary input to national energy savings (NES) and net present value (NPV) calculations. This chapter describes the U.S. Department of Energy's (DOE's) methodology for projecting annual shipments of CBE and presents results.

The Shipments Model results are driven primarily by base year (2007) shipment data for the 10 classes of commercial boiler equipment under consideration (see TSD chapter 4). The flow chart presented in Figure 6.1.1 outlines the structure of the Shipments Model, which assumes that, in each year, the existing commercial boiler equipment stock either ages by 1 year or breaks. Broken equipment is replaced and new equipment can be shipped into new commercial floor space.

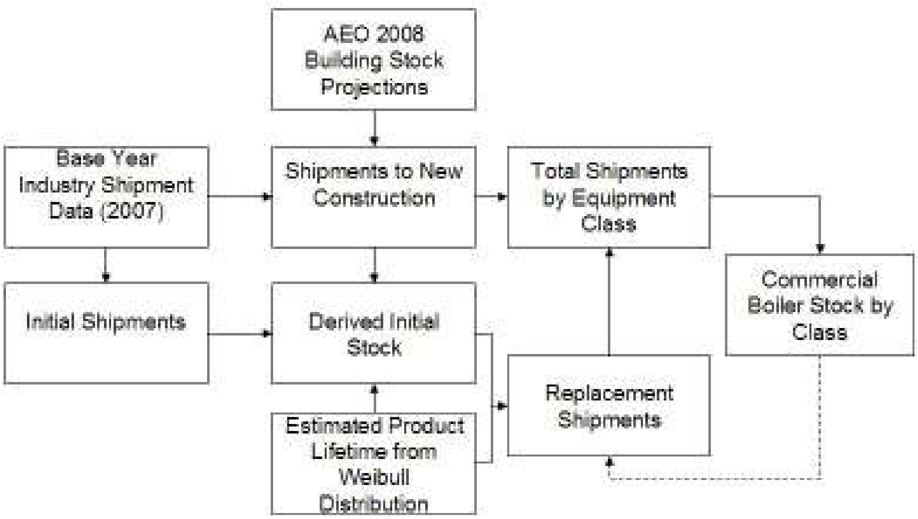

Figure 6.1.1 Flow Chart Showing Inputs to the Shipments Model

The Shipments Model is in a Microsoft Excel spreadsheet format embedded in the National Impacts Model spreadsheet that is accessible on the DOE website at http://www1.eere.energy.gov/buildings/appliance_standards/commercial/ashrae_products_docs_meeting.html.

This chapter explains the Shipments Model and its derivation in detail. Section 6.2 discusses the formulation of the model, section 6.3 describes the data input to the model, and section 6.4 presents the results for the base-case energy conservation standard level scenario and discusses the development of higher standard level scenarios. The energy conservation standards for commercial boiler equipment will set the maximum allowable rated energy consumption for all equipment within an equipment class.

Shipment forecasts were determined for the baseline level and all higher efficiency levels (reflecting potential higher standard levels) for which NES and NPV are required. DOE is considering up to four efficiency levels plus one baseline efficiency level for each of the 10 equipment classes.

6.2 FORMULATION OF SHIPMENTS MODEL

The Shipments Model is a description of commercial boiler equipment stock flows as a function of year and equipment age in the stock. While there are 10 equipment classes, no coupling is assumed between them, so the equations describe each type of equipment independently.

This section begins with a definition of the different commercial boiler equipment stock categories. DOE formulates the equations as updates of the distribution of stock in year *t* as a function of age *a* to year *t+1*.

DOE used industry-provided data of base-year (2007) shipments to calculate current shipments by equipment class. It used the lifetime of the equipment and a corresponding survival function to estimate a replacement rate for existing stock. DOE then used this information combined with estimates from the DOE Energy Information Administration's (EIA's) *Annual Energy Outlook 2008*[1] (hereafter referred to as AEO 2008) for surviving and new commercial floor space in 2007, along with an assumption of constant boiler saturation rates across sin the stock and in new construction, to determine the percentage of shipments to existing buildings and to new construction. Then, DOE forecasted new sales as a function of new construction by multiplying new building floor space by the share of new shipments (1-replacement ratio). Sales of new and replacement equipment are recorded by the year sold, and each annual vintage is depreciated over the estimated life of the equipment. At the beginning of a new year, DOE determines the fraction of stock that has failed based on the survival function (see section 6.3.3) and uses an assumed replacement rate to find replacement sales for that year. Total sales for that year are replacement sales plus new stock. Sales in each year are allocated to the 10 equipment classes in proportion to their relative base-year shipments. DOE assumed that all units experience a normal rate of repairs and that this is included in the average lifetime of the equipment.

In view of industry practice, available information suggests that the average lifetime of a unit is 30 years (see TSD chapters 2 and 5). The age of base-year stock for each equipment class was developed by application of a survival function (based on a Weibull distribution with a mean life of 30 years) to an assumed constant level of shipments into the building population over a 45-year period. This results in a steady-state long-term distribution of the vintages of the equipment in the building population for 2007. The total stock of age *a* in a given year *t* is represented by

$$U(\mathrm{t,a}) = U_0(\mathrm{t,a}) \qquad \textbf{Eq. 6.1}$$

and the average age of the stock in year *y* is defined as

$$StockAge(\mathrm{t}) = \textstyle\sum_a U(\mathrm{t, a}) \times \mathrm{a} \;/\; \sum(U(\mathrm{t,a})) \qquad \textbf{Eq. 6.2}$$

where

a = age of stock,

t = year,
$U(t,a)$ = total stock of age a in a given year y,
$U_0(t,a)$ = stock of existing units.

The shipments of new stock in a given year are $Uship(t)$. By definition, the age of the equipment is zero in the year that it is shipped, so that $Uship(t) = U(t,0)$.

6.2.1 Stock Events

In the transition from year t to year $t+1$, two things could happen to the stock of commercial boiler equipment:

1. existing equipment could fail and be replaced, or
2. the stock could simply age by 1 year.

In the model, early replacements (*i.e.*, existing equipment that is replaced before the expected end of service life) are not considered, and all failed equipment is assumed to be replaced by a similar replacement boiler (*e.g.*, no change of equipment is assumed). The model is capable of forecasting total shipments with replacement rates different than 100 percent, but this was not implemented because of lack of data. The following sections present the equations used to represent each possible event.

6.2.1.1 Replacing Equipment

DOE determines the probability that commercial boiler equipment of age a from stock U_0 will break or will be replaced using a Weibull survival distribution function $PB_1(a)$, with a scale parameter of 33.1 and a shape parameter of 4 such that $PB_1(a)=W(4,33.1)$ results in a 30-year average lifetime with a minimum lifetime of about 8 years, and a maximum lifetime of about 50 years (consistent with industry comments). Similarly, the probability that equipment of age a from stock U_l will fail is given by the same function $PB_1(a)$. These probabilities do not depend on the model year t. DOE defines the quantities of replaced equipment as

$$UB(\text{t, a}) = PB_0(\text{a}) \times UB_0(\text{t,a})$$ **Eq. 6.3**

where

$UB_0(t,a)$ = stock of existing units,
$PB_0(a)$ = probability that stock of existing units will fail, or will be replaced,
$U_0(t,a)$ = stock of existing units,
a = age of stock,
t = year.

6.2.1.2 New Equipment

New commercial boiler equipment will be purchased to replace the units described above. Available information suggests that the purchase of new equipment that would go into new buildings is driven by total building floor space. DOE uses AEO 2008 projections through 2030 to create a building floor space index. DOE uses these floor space projections to create an index that is used to estimate future boiler sales by inflating base-year sales. The total of new equipment shipments is the estimated total shipments for 2007 multiplied by the index of new construction of square feet of buildings for each future year.

DOE has no information about the variation in the market saturation of commercial boiler equipment by building type or over time. Therefore, in the model, the purchase of new equipment is driven by the construction of new floor space and the replacement of broken or removed equipment on a one-for-one basis.

6.3 DATA INPUTS

6.3.1 Historical Shipments

Historical shipments are necessary to calibrate a shipments model to the existing market. DOE has no data for historical shipments of commercial boilers and therefore developed a model that relies on 2007 shipments to make its predictions. All remaining stock from historical shipments is assumed to be distributed across vintages based on the survival function and an assumption of constant boiler shipments over time into the building population.

6.3.2 Equipment Class Breakdown

DOE organized commercial boiler equipment into either gas- or oil-fired equipment classes according to the boiler's input capacity size, output, input, and draft type based on the ASHRAE 90.1-2007 equipment classes . Following these guidelines, DOE used the following 10 equipment classes:

- Small gas-fired hot water boilers;
- Small gas-fired steam, all except natural draft;
- Small gas-fired steam, natural draft boilers;
- Small oil-fired hot water boilers;
- Small oil-fired steam boilers;
- Large gas-fired hot water boilers;
- Large gas-fired steam all except natural draft boilers;
- Large gas-fired steam natural draft boilers;
- Large oil-fired hot water boilers; and
- Large oil-fired steam boilers.

6.3.3 Equipment Life and Survival Function

DOE determined the average lifetime for commercial boilers to be 30 years. DOE developed a survival function based on a Weibull distribution (see Figure 6.3.1) that generated a minimum lifetime of commercial boiler equipments of about 8 years, and a maximum lifetime of about 50 years. As commercial boiler equipment enters and ages through the total stock, each boiler has percentage chances of surviving to the next year or failing (1-survival probability) based on its failure rate for the general population according to its vintage.

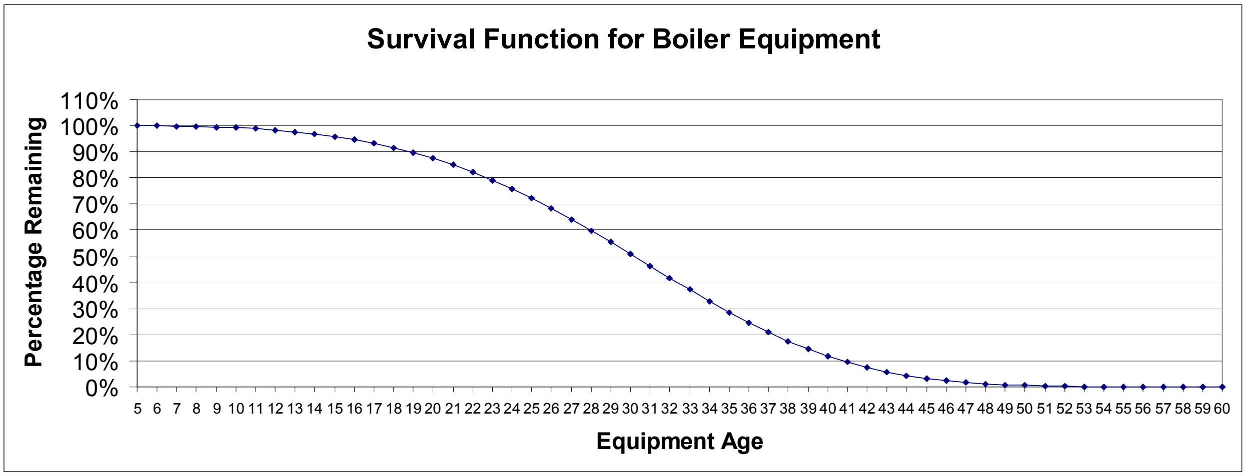

Figure 6.3.1 Survival Function for Commercial Packaged Boilers (Weibull-based)

6.3.3.1 Building Growth Forecasts

The amount of commercial floor space is the main driver for commercial boiler equipment shipments and is appropriately one of the basic inputs into the Shipments Model.

DOE took the projected floor space construction after the year 2003 from the National Energy Modeling System (NEMS) projection published in the AEO 2008. AEO 2008 lists the projections for years 2004 to 2030. Beyond 2030, DOE extrapolated a 10-year trend of AEO-projected data between 2020 and 2030 to estimate future growth in commercial building stock from 2030 through 2042.

The total of new floor space is the estimated total floor space for 2007 multiplied by an index of new construction of floor space for buildings for each future year (see Table 6.3.1). The index is based on the estimated growth in each year from 2012 through 2042, divided by the 2007 estimated growth value.

Table 6.3.1 AEO 2008 Forecast of Total Building Floor Space

Year	Total Building Floor Space (Million Square Feet)	Floor Space Index (2007 Base Year)
2009	77,807	1.026
2010	78,799	1.039
2015	83,913	1.107
2020	89,250	1.177
2025	94,832	1.251
2030	100,756	1.329
Annual Growth Factor, 2030 through 2042	1.013%	

6.4 RESULTS

Table 6.4.1 shows the forecasted shipments for new and replacement commercial packaged boilers from 2012 through 2042 as calculated with the Shipments Model.

Table 6.4.1 Forecasted Shipments of New and Replacement Commercial Boiler Equipment, 2012 Through 2042 (Base Case)

Equipment Class	Units Shipped by Year by Equipment Class								
	2012	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2042**	**Cumulative**
Small, Gas-fFired, Hot Water	6,853	7,112	7,494	7,922	8,848	10,343	12,239	12,984	276,874
Small, Gas-Fired, Steam, All Except Natural Draft	2,322	2,410	2,539	2,684	2,998	3,505	4,147	4,399	93,817
Small, Gas-Fired, Steam, Natural Draft	3,568	3,703	3,902	4,125	4,607	5,385	6,372	6760	144,158
Small, Oil-Fired, Hot Water	1,926	1,999	2,106	2,226	2,486	2,906	3,439	3,648	77,799
Small, Oil-Fired, Steam	3,228	3,350	3,530	3,732	4,168	4,872	5,765	6,116	130,428
Large, Gas-Fired, Hot Water	1,104	1,146	1,208	1,277	1,426	1,667	1,972	2092	44,620
Large, Gas-Fired, Steam, All Except Natural Draft	2,011	2,087	2,199	2,324	2,596	3,034	3,591	3,809	81,232
Large, Gas-Fired, Steam, Natural Draft	2577	2,674	2,818	2,979	3,327	3,889	4,602	4,882	104,114
Large, Oil-Fired, Hot Water	538	558	588	622	695	812	961	1,019	21,738
Large, Oil-Fired, Steam	4,248	4,408	4,645	4,910	5,485	6,411	7,586	8,048	171,616
Total	28,376	29,449	31,030	32,801	36,637	42,824	50,675	53,758	1,146,397

As equipment purchase price increases with lower energy consumption levels, a drop in shipments could be expected relative to the base case. Although there is a provision in the spreadsheet for a change in shipments as the efficiency level increases (or energy consumption level decreases), DOE has no information with which to calibrate such a relationship. Therefore, for the Notice of Proposed Rulemaking analysis, DOE presumes that the shipments do not change in response to higher efficiency levels being considered as possible standard levels.

Results from this model provide an indication of future stock growth for the years 2012 through 2042, but, because of the nature of the model and the lack of shipments data, the model does not retroactively match the shipments in 2007 (approximately 36,000 units, reported in TSD chapter 2). However, over the period for which shipments were analyzed the average shipments per year were 36,980 boilers per year. The average shipments over the period from 2012 through 2042 was 2-percent higher than the 2007 shipment estimates.

REFERENCES

1. U.S. Department of Energy/Energy Information Administration. 2008. *Annual Energy Outlook 2008*. DOE/EIA-0383(2008), DOE/EIA, Washington, D.C.

ACRONYMS AND ABBREVIATIONS

AEO	Annual Energy Outlook
CRE	commercial boiler equipment
DOE	U.S. Department of Energy
EIA	Energy Information Administration
NEMS	National Energy Modeling System
NES	national energy savings
NOPR	Notice of Proposed Rulemaking
NPV	net present value