CHAPTER 9. SHIPMENTS

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CHAPTER 9: SHIPMENTS

9.1 INTRODUCTION

Furnace and boiler shipments estimates are a necessary input to national energy savings (NES) and net present value (NPV) calculations and the manufacturer impact analysis (MIA). To provide projections of shipments, DOE constructed a shipments forecasting model that accounts for equipment used to replace retired units, equipment shipped to new homes, and equipment installed through conversion from a different heating fuel. This chapter describes DOE's Shipments Model and presents the forecasts of future shipments in each product class.

The Shipments Model results are driven in part by historical shipments. Chapter 3, Market and Technology Assessment, shows past trends in shipments of each product class. The Shipments Model uses data from GAMA through 2003.[1] Shipments are increasing in general because the number of houses is increasing, more equipment is reaching retirement age, and the saturation of central heating in new homes is increasing.

DOE estimated the number of replacements based on past shipments, projected shipments to new housing, and expected retirement rates. Forecasting future replacements requires estimates of shipments to new housing, since new equipment will be needed 20–30 years from now to replace equipment shipped in the next few years. Consumers most commonly replace equipment with equipment in the same product class, although some households switch fuels if there are clear advantages for doing so.

DOE estimated the total number of shipments to new housing based on projections of new housing completions and mobile home placements. Market shares of heating equipment often reflect a choice that is influenced by relative fuel costs and equipment prices. For non-weatherized gas furnaces and mobile home furnaces, DOE developed a model to estimate market-shift effects due to standards.

DOE projected annual shipments through 2038, which is the end year used in the current rulemaking. The Shipments Model is in a Microsoft Excel spreadsheet format that is accessible on the Internet from DOE's Furnace and Boiler Rulemaking page: http:// www.eere.energy.gov/buildings/appliance_standards/residential/ furnaces_boilers.html. From that page, follow the links to the final rule and then to the Analytical Tools.

The Shipments Model is contained within a larger spreadsheet called the Shipments and NES Spreadsheet Model. The Shipments and NES Spreadsheet Model includes models for forecasting shipments and calculating NES as well as consumer NPV. Details and instructions for using the spreadsheet are discussed in Appendix S. The rest of this chapter explains the Shipments Model in more detail. Section 9.2 presents the mathematical formulation of the model, sections 9.3 through 9.5 describe the data inputs to the model, and section 9.6 presents the shipments projections for different energy efficiency standard levels.

9.2 SHIPMENTS MODEL EQUATION

The Shipments Model is a mathematical description of furnace and boiler stock flows as a function of year and age. Furnace and boiler shipments are in response to: (1) replacements of retired units with the same type ("in-kind replacements"), (2) conversions at retirement to another fuel type, and (3) installations in new homes. Total shipments for a product class are:

$$S(y)_{class} = R(y)_{class} + C(y)_{class} + NH(y)_{class}$$

where:

$S(y)_{class}$	=	total shipment per product class,
$R(y)_{class}$	=	replacements of retired equipment with the same type equipment ("in-kind replacements"),
$C(y)_{class}$	=	equipment conversions at retirement to another fuel type, and
$NH(y)_{class}$	=	equipment installations in new homes.

9.3 NEW HOUSING SHIPMENTS

Gas furnaces were installed in nearly 60 percent of homes built between 1995 and 1999, according to the U.S. Census Bureau's *American Housing Survey*.[2] Electric central heating systems (heat pumps and electric furnaces) accounted for about 30 percent of the heating systems installed. In the 2000–2003 period, however, the gas furnace share fell to 50 percent in response to high natural gas prices, and the electric share rose to 40 percent. Oil-fired furnaces and gas- or oil-fired boilers were installed in only about five percent of new homes in both periods.

9.3.1 Approach

In the Shipments Model, the number of annual shipments of each product class going to new housing units is equal to housing completions or mobile home placements for that year, multiplied by the estimated market share for each product class:

$$NH(y)_{class} = MS(y)_{class} \times HUC(y)$$

where *HUC(y)* is new housing completions. DOE used mobile home placements for *HUC(y)* to calculate shipments of mobile home gas furnaces. For all other product classes, *HUC(y)* is the sum of single-family and multi- family housing unit completions.

Homebuilders tend to be sensitive to the initial installed cost of heating equipment. Market share data (presented below) suggest that changes in equipment cost and fuel costs have had an effect in the past on the choice of installing either a gas furnace or an electric central

heating system in new homes. Thus, for non-weatherized gas furnaces and mobile home gas furnaces, DOE accounted for possible market-shift effects from changes in equipment prices related to efficiency standards. DOE believes that there would be little if any market shift away from gas for weatherized gas furnaces, since there are very few packaged units with electric heating. For the other product classes, the current market shares in new housing are small, and DOE assumed that their shares remain unchanged in the future.

9.3.2 New Housing Projections

New housing includes single- and multi-family units, referred to as new housing completions, and mobile home placements. For new housing completions and mobile home placements, DOE adopted the data and projections from the Energy Information Administration (EIA)'s *Annual Energy Outlook 2007* (*AEO*2007) for the 2004–2030 period.[3] This forecast shows housing completions staying between 1.8 million and 1.9 million in the 2015–2030 period. DOE assumed that completions grow at 0.5-percent rate until 2030. For mobile homes, DOE assumed a constant rate of placements in the 2031-2038 period.

9.3.3 Market Shift Effects in New Housing

DOE estimated the future market shares of non-weatherized gas furnaces and mobile home gas furnaces in alternative standards cases using historical relationships between gas and electricity prices, gas and electric heating equipment prices, and gas furnace market shares, combined with estimated increases in installed equipment cost associated with higher efficiency. For the years 2004–2014, DOE's model predicts changes in gas furnace market share relative to 2003 produced by relative changes in gas and electricity prices. The 2003 shares are from U.S. Census data.[2] The forecast for 2004–2014 also includes the impact on market share of the Federal efficiency standard on heat pumps effective in 2006. DOE expects this standard to increase heat pump prices, which induces a slight shift to gas furnaces in the model.

For 2015 and after, the model uses market-shift elasticity parameters to estimate changes in market share produced by shifts in equipment prices due to furnace standards, as well as shifts in energy prices. DOE developed a model within the Shipments Model to estimate the degree to which an increase in gas furnace equipment cost due to standards will induce a shift in the market toward electric heating. This market share model uses historical trends in residential gas and electricity prices and heating equipment prices, and data on the gas furnace market share in new housing. These data indicate equipment preference and its dependence on relative equipment and energy prices.

In colder regions, electric heating is relatively expensive to operate. In the southern region and in mobile homes, however, electric heating is often attractive, so more sensitivity to a higher cost of gas furnaces is likely. Therefore, DOE independently estimated market shift effects for three groups: single-family and multi-family (SF+MF) homes within the southern census region, SF+MF homes in regions other than the southern census region, and mobile

homes. For consistency, DOE developed separate indices of gas-to-electricity price for the south and non-south regions.

DOE obtained index data for gas furnace prices from the Bureau of Labor Statistics.[4] Historical time-series data on heat pump prices are not available, so DOE used retail price data on residential central air conditioners[5] as a proxy for retail heat pump prices. Historical time-series data on retail electric furnace prices are also not available, so DOE used the price index data on residential gas furnaces as a proxy for retail electric furnace prices. It then derived a weighted-average index for electric heating equipment using the heat pump and electric furnace indices. The last year for which the necessary data are available is 1995. While the inflation-adjusted price of gas furnaces has declined over time, the estimated inflation-adjusted price of electric heating equipment has dropped more rapidly, so the ratio of gas furnace price to electric heating equipment price increased considerably from the early 1980s to 1995.

The gas furnace market shares in new housing are from data for different vintage groups (which indicate the year of home construction) in the *American Housing Survey*.[6] Gas furnaces not in mobile homes include both non-weatherized and weatherized furnaces.

The market share of gas furnaces in each of the three groups is described by the following equation:

$$MS_y = MS_0 \times \left[1 + \varepsilon_F \left(\frac{\Delta F}{F_0} \right)_y + \varepsilon_E \left(\frac{\Delta E}{E_0} \right)_y \right]$$

where:

MS_0	=	market share in the reference year,
F	=	an index (ratio) of gas-to-electricity price,
E	=	an index (ratio) of gas-to-electric equipment price, and
e_F and e_E	=	"elasticities" that measure the change in market share that occurred in response to changes in the gas-to-electricity price ratio and the gas-to-electric equipment price ratio.

The terms $\Delta F/F_0$ and $\Delta E/E_0$ represent percentage increases in prices in a given year relative to the reference period, which is 1960–1969.

Table 9.3.1 shows the estimated energy and equipment price elasticities for each group. The elasticities are negative, since an increase in relative natural gas or gas furnace prices tends to lower the gas furnace market share. As expected, the south shows a stronger response to change in the equipment price index than non-south regions, and mobile homes show the greatest response. In all three cases, the response to change in the energy price index is greater than the response to change in the equipment price index.

Table 9.3.1 Estimated Elasticity of Gas Furnace Market Share in New Housing in Response to Change in Energy and Equipment Price Indices

South Region		Regions Outside South		Mobile Homes	
Energy Price	Equipment Price	Energy Price	Equipment Price	Energy Price	Equipment Price
-0.84	-0.37	-0.34	-0.13	-1.06	-0.50

The base case forecast in the shipments analysis estimates the gas furnace market share separately for each of the three groups using the energy price elasticities and the forecast national natural gas and electricity prices from *AEO*2007 (see Chapter 10, section 10.3.2).[a] DOE calculated the national gas furnace market share (excluding mobile homes) according to the estimated shares in the south and non-south regions, weighted by the fraction of new homes in each region, as given in the *AEO*2007 forecast.

DOE used the equipment price elasticities to estimate market share shifts due to increases in total installed cost estimated for various efficiency levels in the engineering analysis (Chapter 6). In the south, for example, an efficiency level that raises the gas furnace installed cost by 10 percent causes a projected gas furnace market share change of 10 percent times -0.37, or -3.7 percent.

The model estimates the combined market share of non-weatherized and weatherized gas furnaces in new housing completions. Based on data for the 1990s (see Chapter 3, section 3.4.1), DOE used a market share of 10 percent for weatherized gas furnaces for all years in the forecast. In the base case, DOE calculated the shipments of non-weatherized gas furnaces alone by subtracting the estimated share of weatherized gas furnaces in the combined shipments. In the higher-efficiency cases, the estimated market shift is attributed entirely to non-weatherized gas furnaces, since a shift away from weatherized gas furnaces is unlikely (see section 9.4.1).

In the model, shifts from gas furnaces result in installation of electric heating equipment (heat pumps and electric furnaces). For non-weatherized gas furnaces, DOE estimated that heat pumps account for 54 percent of the additional electric heating equipment purchased due to market shift, and electric resistance furnaces account for 46 percent. For mobile home gas furnaces, the estimated shares of additional electric heating equipment purchased due to the market shift are 41 percent for heat pumps and 59 percent for electric resistance furnaces. DOE based these values on equipment shares in homes built in the 1999–2003 period with electric space heating, as provided by the Residential Energy Consumption Survey (RECS) 2001. DOE reviewed the projections of new heating equipment market shares in *AEO*2007 and found that they show little change in the national market shares of heat pumps and electric resistance

[a] DOE used national energy prices from *AEO*2007 rather than separate price forecasts for South and Non-South regions.

furnaces until 2030. Therefore, DOE assumed that the market shares given above remain constant over the analysis period.

9.3.4 Market Shares of Other Product Classes in New Housing

DOE estimated the future market shares of oil-fired furnaces and gas- and oil-fired boilers in total new housing completions based on their respective average shares in homes built in the 1999–2003 period (Table 9.3.2). For new homes that use oil-fired equipment, gas is generally not available, so DOE assumed that the market shares are independent of changes in equipment price due to standards implementation. Gas boilers in new homes are associated with specific types of heating systems, such as hydronic radiators or radiant floors, and substitution of alternative equipment is unlikely, so here too DOE estimated that the market share is independent of changes in equipment price due to standards.

Table 9.3.2 Shares of Other Product Classes in Shipments to New Housing (million)

Product Class	Market Share (% of new housing)
Oil-fired furnaces	0.5
Gas boilers	4.1
Oil-fired boilers	1.8

9.4 REPLACEMENTS

9.4.1 Approach

Historical shipments of each product class influence the number of replacement units entering the housing stock in each year. For each year, the Shipments Model estimates what fraction of the historically shipped units are still in service, and how many will be replaced. The model uses estimates of how long each type of equipment is expected to operate before it is replaced. Depending on the age (vintage) of a piece of heating equipment, there is a certain probability of its being replaced.

The model uses a replacement probability distribution based on minimum, mean, and maximum expected equipment lifetimes (Table 9.4.1). Two basic assumptions influence the probability distribution. First, DOE expects equipment to have a maximum probability of being replaced at the mean lifetime. Second, replacement probability goes to zero in the minimum and maximum lifetime years. Assuming a linear slope in probability produces a triangular distribution.

Table 9.4.1 Equipment Lifetime Values (years)

Product Class	Minimum	Mean	Maximum
Non-Weatherized Gas Furnace	10	20	30
Weatherized Gas Furnace	12	18	24
Mobile Home Furnace	14	19	23
Oil-Fired Furnace	10	15	20
Hot-Water Gas Boiler	20	25	30
Hot-Water Oil-Fired Boiler	20	25	30
Heat Pump	6	14	21
Electric Furnace	11	17	23

Sources: see Chapter 8, Table 8.2.3

Given the probability of replacement as a function of equipment vintage, the calculation of expected replacements in any given year follows from past shipments. In a given year, the number of replacements is equal to the portion of the previous year's shipments expected to retire, plus the number of shipments from other past years expected to retire. The majority are replacements-in-kind—consumers replace existing equipment with equipment of the same product class.

Mathematically, the replacements in each year for each product class are given by

$$R_{y,class} = \sum_{v=L\min}^{L\max} FR_{class}(v) \times S(y-v)_{class}$$

where:

$R_{y,class}$ = replacements,
v = equipment vintage,
$S(y\text{-}v)$ = shipments in the year $y\text{-}v$, and
$FR_{class}(v)$ = fraction of each cohort that will be replaced at each vintage.

The summation runs from the minimum to the maximum lifetime given in Table 9.4.1. This replacement fraction has the property

$$\sum_{v=L\min}^{L\max} FR_{class}(v) = 1$$

where *v* runs from the *Lmin* and *Lmax*, indicating that the entire cohort will be replaced by the maximum lifetime.

9.4.2 Market Shift Effects in the Replacement Market

In most cases, a building owner will replace a retired unit with the same type of equipment. However, building owners are somewhat sensitive to changes in relative fuel and equipment prices between competing heating equipment choices. Thus, as it did for new housing installations, DOE considered the impact on replacement fuel choice from increases in first costs for non-weatherized gas furnaces and mobile home gas furnaces. The approach DOE took to estimate replacement market shifts was similar to its approach for new housing. Unfortunately, historical data tracking fuel share choice in the replacement market were not accessible, so a parameterization of equipment price elasticities for replacements was not possible. Instead, DOE used the same elasticities for the new construction and replacement market segments.

For the years 2015–2038, DOE adjusted the shipments to reflect market shift effects for non-weatherized gas furnaces and mobile home gas furnaces. This adjustment was equal to the base case replacements in each region multiplied by the appropriate elasticity for the region, multiplied by the percentage increase in installed costs relative to the base case. For example, the increase in installed cost for a condensing furnace results in some fraction of building owners switching from gas to electric heating. Thus, gas furnace shipments in the replacement market are lower in the case of a standard at the condensing level than in the base case.

9.4.3 Conversions to Gas Heating

Data from utility surveys conducted by the American Gas Association (AGA) report the numbers of households that converted to natural gas space heating from another fuel in various years.[7] DOE estimated the annual conversions to natural gas as a percentage of projected replacements using the AGA data from the 1985–1995 period. These data indicate an average rate of conversion at retirement of 35 percent for oil-fired equipment and 32 percent for electric furnaces. DOE applied these percentages to retirements of oil-fired equipment and electric furnaces for all years in the forecast. Since this period covers a range of variation in relative energy prices, DOE believes its projection of conversions is consistent with projected future energy prices.

DOE assumed that these conversions generally occur at the time of retirement; i.e., a homeowner will opt to install gas heating equipment only when the installed oil or electric equipment has reached the end of its lifetime. All conversions are to non-weatherized gas furnaces.

9.5 MODEL CALIBRATION WITH ADDITIONAL SHIPMENTS CATEGORIES

In the analysis for the advance notice of proposed rulemaking (ANOPR), DOE estimated retirements based solely on past shipments and the assumed equipment lifetimes. For gas furnaces (all three product classes together), the resulting total shipments in the 1993–2001 period were less than reported by GAMA. In the analysis for the notice of proposed rulemaking (NOPR), DOE added two additional sources of gas furnace shipments in this period. This addition brought the shipments estimated by the model into closer agreement with the GAMA data.

The first additional source of gas furnace shipments is early retirement of non-condensing furnaces and replacement with more-efficient condensing furnaces. Evidence for this trend can be seen in the GAMA data, which show a large increase in condensing furnace shipments in response to rising natural gas prices (see Chapter 10, section 10.2.3).

The second additional source of gas furnace shipments is conversion from non-central gas heating (e.g., room heaters) to central heating with a gas furnace. There is evidence for this conversion in data from the RECS, which show a large increase between 1993 and 2001 in homes with central gas heat that were built before 1990.[8] Since this increase is greater than can be accounted for by conversions to gas heat from oil or electric heating, the data suggest there were many conversions from non-central gas heating to central heating with a gas furnace. There is also discussion of this phenomenon in the trade literature.[9]

DOE assumed that shipments from these additional sources follow a normal distribution, rising gradually from 1993, reaching a maximum value, and then decreasing again. DOE chose the size, peak year, and width of this distribution that minimized the discrepancy between modeled shipments and the GAMA data. This calibration revealed that the additional shipment sources result in a maximum of 603,000 units in 2005. DOE assumed that two-thirds of these were due to early retirement of non-condensing furnaces and one-third were due to conversions to central heating. DOE assumed that shipments from these additional sources gradually taper off due to a smaller number of eligible homes with non-central heating equipment and a lessening of the incentive for early retirement of non-condensing furnaces.

Figure 9.5.1 shows the components of the base case projection for all gas furnaces, including the shipments from the sources discussed here. The shipments from these additional sources are most likely to be non-weatherized gas furnaces, so DOE allocated them to this product class.

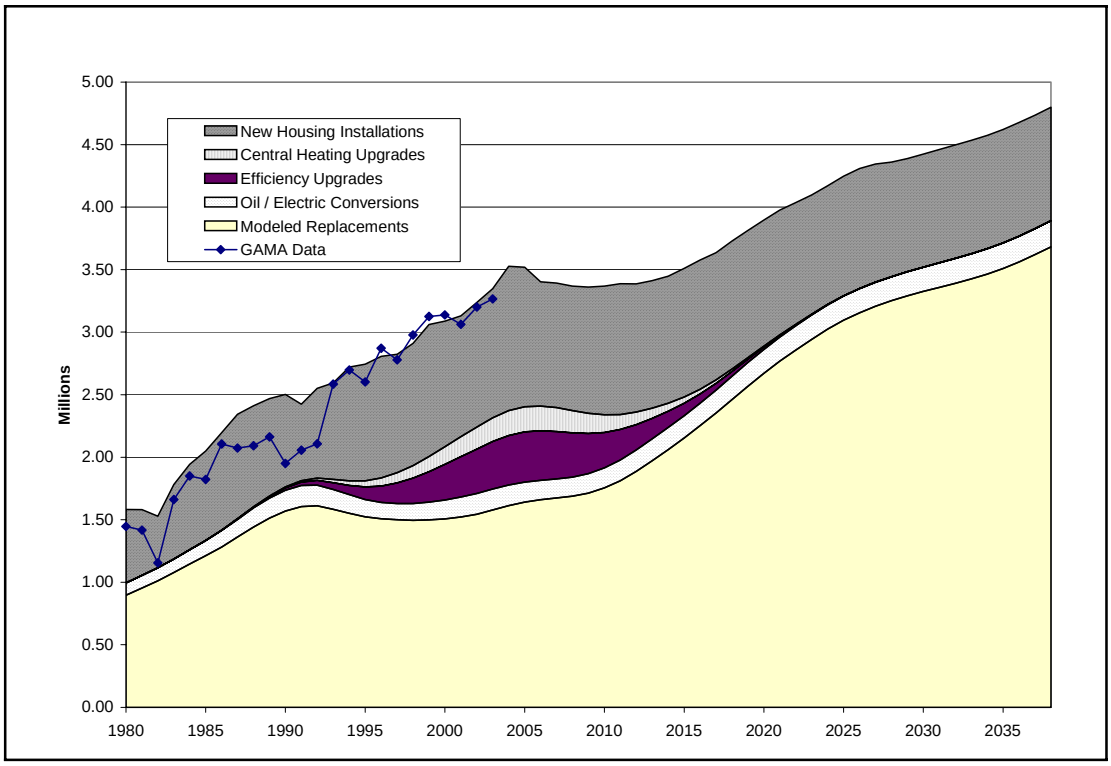

Figure 9.5.1 Components of the Base Case Projection for Gas Furnaces

9.6 PROJECTED SHIPMENTS

DOE calculated total shipments in each product class by adding new housing shipments in each year to replacements and conversions. For non-weatherized gas furnaces, DOE added estimated shipments for early retirement/upgrades to condensing furnaces, and upgrades from non-central gas heating to gas furnaces.

For non-weatherized gas furnaces and mobile home gas furnaces, the projected shipments are affected by the installed cost of a furnace, which varies with efficiency. This section reports the projected shipments at each trial standard level (TSL) considered for the Final Rule. The subsection below describes the TSLs.

9.6.1 Trial Standard Levels

The criteria DOE used to develop TSLs in the furnace and boiler rulemaking approximately match the following:

- TSL 1: Efficiency levels that are most common (highest level of shipments) in the current market.
- TSL A: Efficiency levels that are representative of the maximum NPV using a seven-percent discount rate. TSL A is the same as TSL 2 with the efficiency level for

non-weatherized, gas-fired furnaces and gas-fired boilers reduced to eliminate safety concerns.

- TSL 2: Efficiency levels that are representative of the maximum NPV using a seven-percent discount rate.
- TSL B: Efficiency levels that are representative of the maximum NPV using a three-percent discount rate. TSL B is the same as TSL 4 with levels for gas boilers and oil-fired furnaces reduced to eliminate safety concerns.
- TSL 4: Efficiency levels that are representative of the maximum NPV using a three-percent discount rate.
- TSL 5: Efficiency levels that correspond to the most energy efficient combination of design options available on the market.

Table 9.6.1 shows the annual fuel utilization efficiency (AFUE) levels for the six product classes at each TSL.

Table 9.6.1 Trial Standard Levels for Furnaces and Boilers

Trial Standard Levels	NWGF	WGF	MHF	OF	GB	OB
	AFUE %	AFUE %	AFUE %	AFUE %	AFUE %	AFUE %
TSL 1	80	80	80	80	82	83
TSL A	80	81	80	82	82	83
TSL 2	81	81	80	82	84	83
TSL B	90	81	90	82	82	84
TSL 4	90	81	90	84	84	84
TSL 5	96	83	90	85	99	95

The current AFUE standard levels for the product classes are as follows:

- Non-weatherized gas furnace (NWGF) = 78 percent
- Weatherized gas furnace (WGF) = 78 percent
- Mobile home gas furnace (MHF) = 75 percent
- Oil-fired furnace (OF) = 78 percent
- Gas boiler (GB) = 80 percent
- Oil-fired boiler (OB) = 80 percent

9.6.2 Non-Weatherized Gas Furnaces

Figure 9.6.1 shows the projections for non-weatherized gas furnaces for the base case and each TSL. The higher equipment prices associated with furnace standards have a sizeable effect

at TSLs 4and B, which include a standard at 90 percent AFUE. Compared to the base case, shipments in 2015 are 3.1 percent (90,000 units) lower at TSL 4 and TSL B.

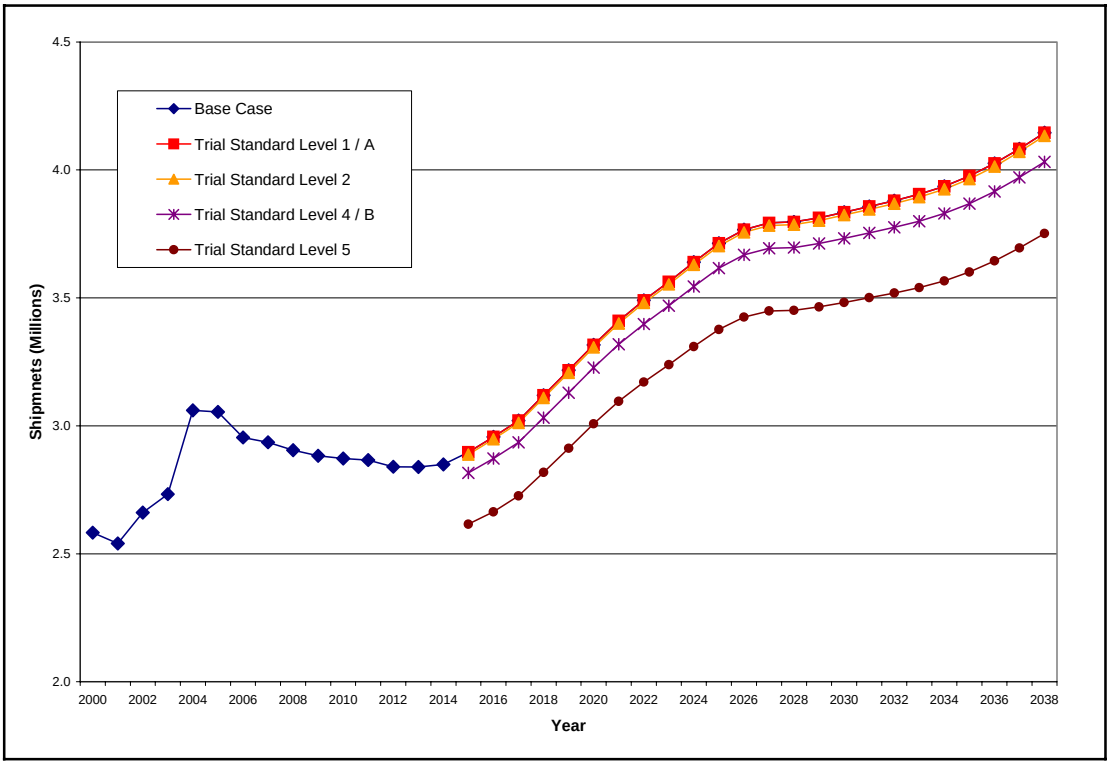

Figure 9.6.1 Shipment Projections for Non-Weatherized Gas Furnaces for the Base Case and Each Trial Standard Level

9.6.3 Mobile Home Gas Furnaces

Figure 9.6.2 shows the projections for mobile home gas furnaces for the base case and each TSL. The higher equipment prices associated with furnace standards at TSL 4/B, which include a standard at 90 percent AFUE, have a substantial effect on the shipments. Compared to the base case, shipments in 2015 are 17 percent (33,000 units) lower at TSL 4 and TSL B. For mobile home gas furnaces, the impact of higher equipment cost associated with furnace standards is greater than the effect on non-weatherized gas furnaces because the estimated equipment price elasticity is higher (see Table 9.3.1).

The downward trend after 2015 can be explained by mobile home placement patterns and declining gas furnace market share. Mobile home placements peaked in 1996–1999 and then dropped dramatically. This sharp decline leads to a low level of replacement shipments after 2020. The *AEO*2007 forecast DOE used shows total placements flat after 2015, but the projected share of gas furnaces declines due to rising natural gas prices. Based on the estimated energy price elasticity for mobile home furnaces (see Table 9.3.1), the projected gas furnace share is very

sensitive to relative energy prices. Since the *AEO*2007 forecast shows gas prices rising more than electricity prices, the projected gas furnace market share in new mobile homes declines.

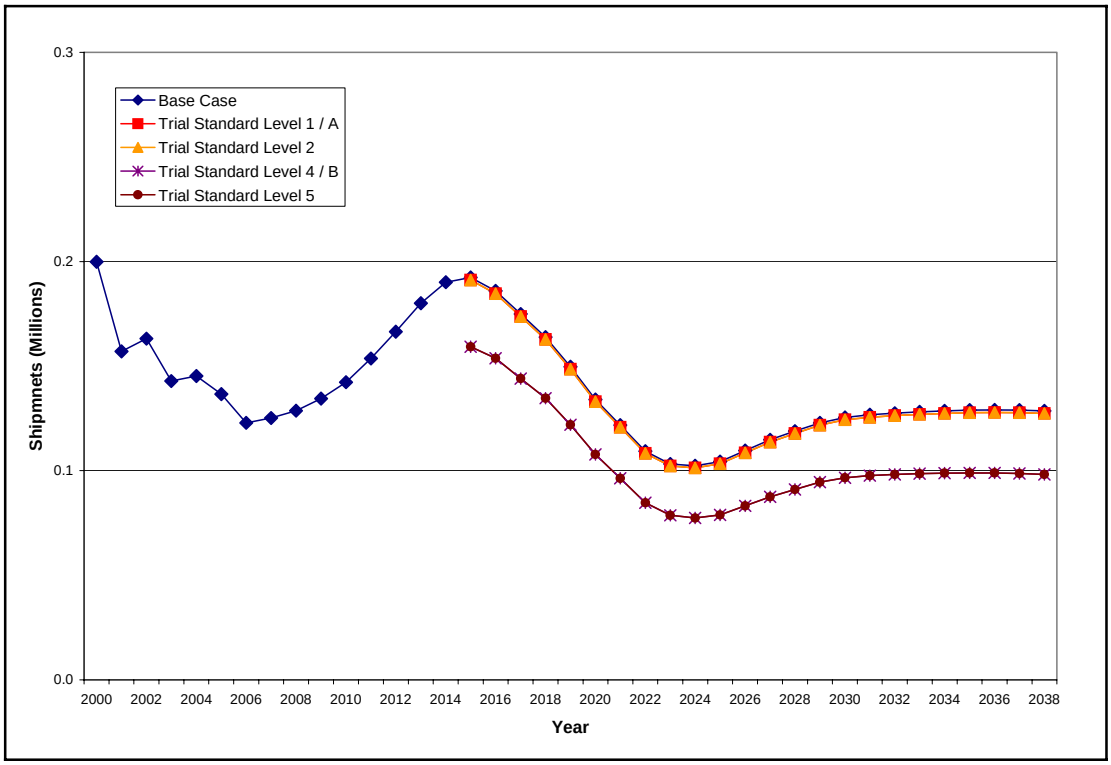

Figure 9.6.2 Shipments Projections for Mobile Home Furnaces for the Base Case and Each Trial Standard Level

9.6.4 Other Product Classes

Figure 9.6.3 shows the projections for the other product classes. Since DOE did not estimate any change in shipments due to standards, the projections are the same for the base case and each TSL.

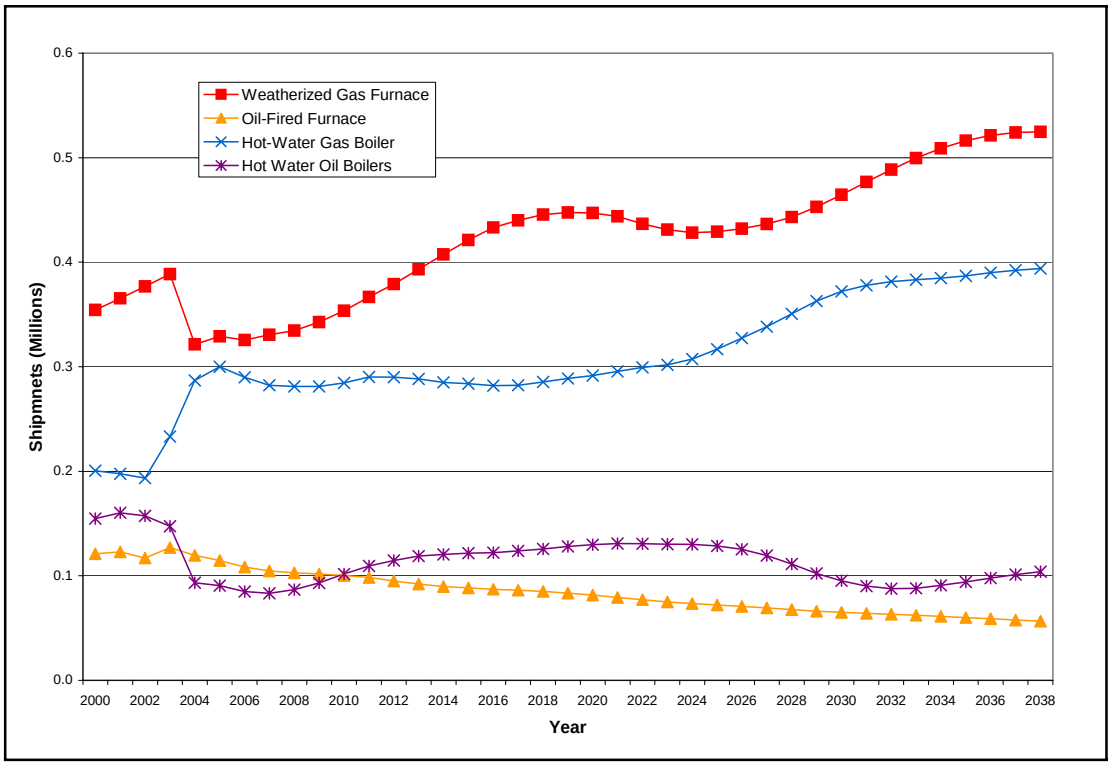

Figure 9.6.3 Shipment Projections for Other Product Classes

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