CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Estimates of future product shipments are a necessary input to calculations of the national energy savings (NES) and net present value (NPV), as well as to the manufacturer impact analysis (MIA). This chapter describes the data and methods the U.S. Department of Energy (DOE) used to forecast annual product shipments and presents results for furnace fan product classes being considered in this analysis. The shipments model divides the population of appliance users into specific market segments and estimates the shipment of new equipment to each of these segments. The model starts from a historical base year and calculates, for each year of the analysis period, both shipments and retirements by market segment. This approach produces an estimate of the total equipment stock, broken down by age or vintage, in each year of the analysis period. The product stock distribution is calculated for the base case and for each efficiency level of each product class. The stock distribution is used in the national impact analysis (NIA) to estimate the total dollar and energy costs and benefits associated with each efficiency level.

The vast majority of furnace fans are shipped pre-installed in furnaces and other heating, ventilating, and air conditioning (HVAC) products, so DOE estimated furnace fan shipments by projecting shipments of those products.

The shipments model was developed as a Microsoft Excel spreadsheet that is accessible on DOE's Appliance and Commercial Equipment Standards website (http://www1.eere.energy.gov/buildings/appliance_standards/residential/central_ac_hp.html). Appendix 10-A discusses how to access and utilize the shipments model spreadsheet, which is integrated into the spreadsheet for the NIA. This chapter explains how the shipments model is constructed and provides some summary output. The rest of section 9.1 describes the methodological approach. The analysis incorporates a large number of components or market segments, describing different product classes, market sectors, and geographic regions; for simplicity, the methodology is explained in terms of a single product class for residential consumers for the country as a whole.

9.1.1 Definition of Market Segments for the Shipments Analysis

The furnace shipments model considers three product placement channels (hereafter referred to as "channels") as follows:

1. New housing: a certain fraction of new buildings are assumed to acquire furnaces in the year of construction. This fraction is defined as the new construction saturation, which varies by year, by region, and by product type.

2. Existing owners (replacements): these are defined as existing buildings with furnaces installed. This category receives new shipments when existing equipment is replaced.

3. New owners: these are defined as existing buildings that acquire furnaces for the first time during the analysis period. The new owners primarily consist of households that have central air conditioning alone or central air conditioning and electric heating and choose to install a gas furnace.

9.1.2 Fundamental Model Equations

The fundamental dependent variable in the shipments model is the equipment stock, which is represented as a function of analysis year (indexed by *j)*, and equipment vintage or age (the equipment age is noted as *a,* and is equal to the analysis year minus the vintage). The stock function is adjusted in each year of the analysis period by new shipments coming in and broken or demolished equipment being taken out.

For existing stock:

$$\boldsymbol{Stock_p(j,a) = Stock_p(j-1,a-1) - Rem_p(j,a)}$$

and for new units:

$$\boldsymbol{Stock_p(j,a=1) = Ship_p(j-1)}.$$

Where:

$Stock_p\ (j,\ a)$ = number of units of product class *p* and age *a* in analysis year *j,*
$Rem_p\ (j,\ a)$ = number of units of product class *p* and age *a* removed in analysis year *j,* and
$Ship_p(j)$ = number of units of product class *p* shipped in year *j*.

Shipments are directed to one of the three channels:

$$\boldsymbol{Ship_p(j) = Rpl_p(j) + NC_p(j) + NO_p(j)}$$

Where:

$Rpl_p(j)$ = number of units of product *p* replaced in year *j*, which depends on removals,
$NC_p(j)$ = number of units installed in new construction of product *p* in year *j*, and
$NO_p(j)$ = number of units shipped to “new owners” of product *p* in year *j*.

Removals due to equipment failure contains two terms. In the first, a survival function $f_p(a)$ is used to represent the probability that a unit of age *a* will survive in a given year; equivalently, the probability that this unit will fail is 1- $f_p(a)$. The second term is the extended repair stock that has been in use for six years following the repair date. Total removals in the base case are then:

$$Rem_p(j,a) = [1 - f_p(a)] \times Stock_p(j,a) + ER\_Stock_p(j, a2 = 6)$$

Where:

$a2$ =	number of years since the equipment was repaired[a], and
$ER\_Stock_p(j, a2)$ =	number of extended-repair units of product p replaced in year j.

9.2 DATA INPUTS AND SUPPORTING CALCULATIONS

9.2.1 Historical Shipments and Calculation of Replacement Shipments

9.2.1.1 Historical Shipments

DOE used historical shipments data (i.e., domestic shipments and imports) to populate its shipments model for furnace fan equipment. As part of its data submittal to DOE's 2011 furnace standards rulemaking, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) provided historical shipments data over the 2005-2009 time period disaggregated into three categories: (1) non-weatherized gas and mobile home gas furnaces, (2) oil-fired furnaces, and (3) weatherized gas furnaces.[2] Historical shipments for 1972-2005, except for weatherized gas furnace shipments, were also provided by the Gas Appliance Manufacturers Association (GAMA) from previous data submittals to the Lawrence Berkeley National Laboratory (LBNL).[2] DOE disaggregated mobile home gas furnace shipments from the gas furnace total by using a combination of data from the U.S. Census [3] and American Housing Survey (AHS).[4] DOE used a similar method to determine mobile home electric furnace shipments. For electric furnaces, DOE used the historical estimates calculated in DOE's 2011 furnace standards rulemaking. For weatherized gas furnaces, DOE used the 2005-2009 data provided by AHRI together with historical packaged central air conditioner shipments. For hydronic air handlers, DOE estimated that they represented less than 1% of the total furnace market and estimated historical shipments keeping this market share constant.

Disaggregated condensing and non-condensing shipments by region were available from 1992 to 2009, and these data were used to estimate shipments before 1992.

Figure 9.2.1 summarizes the historical shipments data that DOE assembled.

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[a] Based on data available from Decision Analyst consumer survey of central heating and cooling equipment owners, DOE was able to estimate that consumers expect a major repair to extend the lifetime of the equipment by around 6 years.[1]

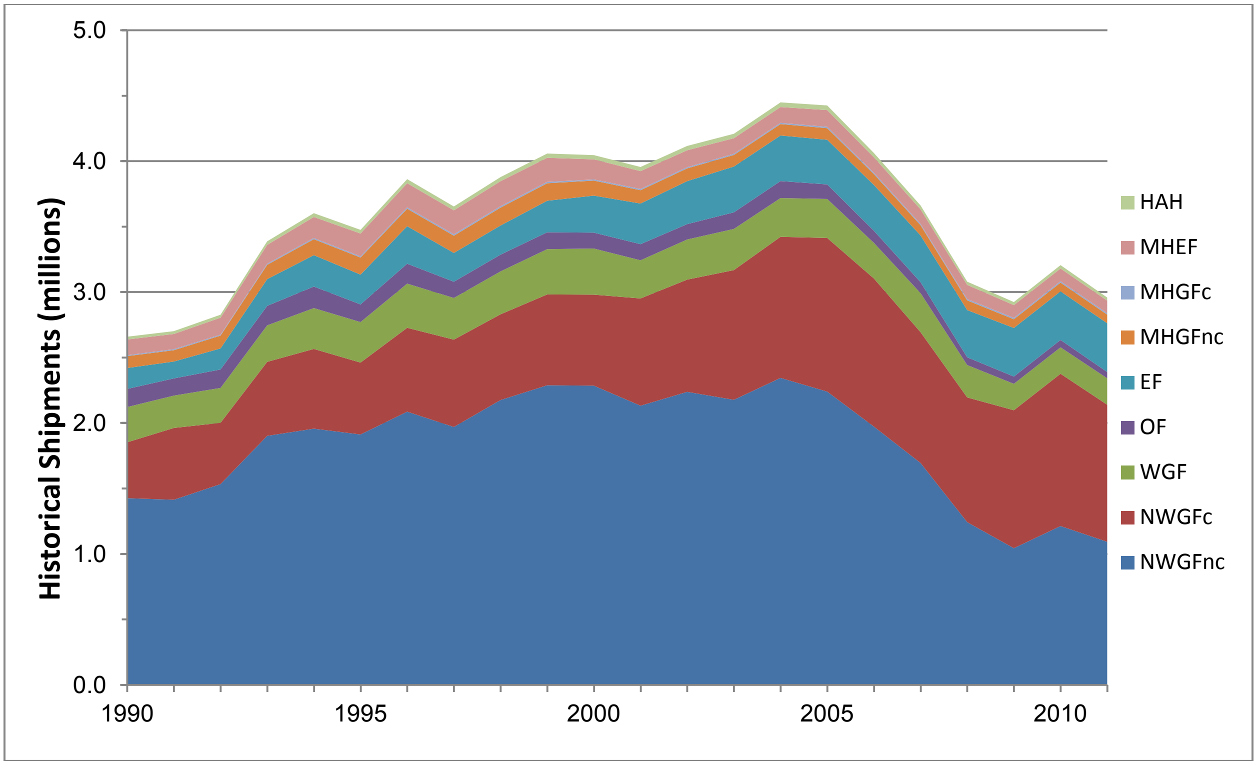

Figure 9.2.1 Historical Shipments of HVAC Products with Furnace Fans

9.2.1.2 Replacement Shipments

When an equipment unit fails, it is removed from the stock. The following retirement function $r_p(a)$ is used to represent the probability that a unit will be broken at age a.

$$\boldsymbol{Rem_p(j) = \sum_a r_a(a) \times Stock_p(j,a)}$$

Retirement functions and product lifetimes are discussed in more detail in chapter 8.

In each year, equipment is removed from demolished buildings. As represented by the following expression, the shipments model assumes that the saturation of the equipment in the demolished buildings is the same as that of the overall population.

$$\boldsymbol{D(j) = H\_Stock(j-1) + H\_Starts(j) - H\_Stock(j)}$$

$$Dem(j) = D(j) \times sat(p, j-1)$$

Where:

$H\_Stock(j)$ = number of housing units in analysis year j,
$H\_Starts(j)$ = number of new housing units in year j,
$D(j)$ = number of demolished buildings,

Dem (j) = number of equipment units demolished in analysis year *j,* and
sat(p,j) = saturation of equipment of product class p for all buildings in year j.

The shipments model assumes that units that are taken from demolished buildings, *Dem(j*), are included in the mix of broken units $Rem_p(j)$. As the demolished units do not need to be replaced, they are deducted from $Rem_p(j)$ when calculating the required replacements, as represented by the following expression.

$$Rpl_p(j) = Rem_p(j) - Dem(j)$$

9.2.2 Shipments to New Housing

DOE multiplied new construction market saturations by forecasts of new housing units to estimate shipments to the new construction channel. On a product class basis, the determination of shipments to new construction is represented by the following expression:

$$NC_p(j) = NC\_Starts(j) \times NC\_Sat_p(j)$$

Where:

NC_Starts (j) = number of new housing starts in year *j,* and
NC_Sat(j) = new housing saturation for product class p and year *j*.

DOE determined new construction starts to the residential market segment, otherwise referred to as housing starts, by using recorded data through 2008 and projections from the DOE-Energy Information Administration (EIA)'s *Annual Energy Outlook 2011* (*AEO2011*) for the period 2010–2035.[8]

DOE developed new housing market saturations from *Characteristics of New Housing* data from the U.S. Census Bureau. DOE used historical new housing saturations for each furnace product class to project future saturations for each class. DOE used a 10-year average (2000-2009) to estimate future saturations for non-weatherized gas (43.9%) and mobile home gas furnaces (30.7%), and a 5-year average from 2005-2009 to estimate future saturations for oil furnaces (0.4%).

9.2.3 Shipments to New Owners and Adjustment for Switching

The third market segment consists of new owners of products in a given product class, and also includes an adjustment for switching to a different product class. In most cases, new owners consist of households that have central air conditioning alone, or central air conditioning and electric heating, and choose to install a gas furnace to augment or replace their existing equipment.

DOE estimated historical shipments to this market segment using the following equation:

$$A(j) = Shipment(j) - (RU(j) + NU(j))$$

Where:
j = year where historical shipment data is available
$A(j)$ = new owners (if positive) or adjustment for switching (if negative) for year j,
$Shipment(j)$ = historical shipment in year j,
$RU(j)$ = estimated replacement units in year j,
$NU(j)$ = new units for new homes in year j,

To estimate future shipments to this market segment, DOE calculated the average shipments for this market segment in the past 3-4 years, and projected this quantity into the future.

9.2.4 Forecasting Condensing and Non-Condensing Market Shares

For non-weatherized gas and mobile home gas furnaces, the future market shares will be affected by the regional furnace standards that require compliance starting in 2013. The standards require that non-weatherized gas and mobile home gas furnaces sold in the North region must have a minimum annual fuel utilization efficiency (AFUE) of 90 percent, which requires them to be condensing furnaces. Therefore, all non-weatherized gas and mobile home gas furnaces shipments in the north from 2013 onward are assumed to be condensing furnaces.

In the South region, condensing furnaces are not required, but some consumers may choose to purchase them anyway. DOE used the historical trend to estimate that condensing furnace shipments in the south increase from 28 percent in 2018 to 41 percent in 2047. This projection is similar to that used in DOE's 2011 furnace standards rulemaking.

9.3 IMPACT OF STANDARDS ON SHIPMENTS

For replacements, consumer purchase decisions are influenced by the purchase price and operating cost of equipment, and therefore will likely be different in the base case and under different candidate standard levels (CSLs). These decisions are modeled by estimating the purchase price elasticity for furnaces. The purchase price elasticity is defined as the change in the percentage of consumers acquiring a furnace divided by a change in the *relative price* (defined below) for that equipment. This elasticity and information obtained from the life-cycle cost (LCC) and payback period (PBP) analysis on the change in purchase price and operating costs under different CSLs are used in the shipments model to estimate the resulting change in shipments.

9.3.1 Purchase Price Elasticity

DOE conducted a literature review and an analysis of appliance price and efficiency data to estimate the combined effects on product shipments from increases in product purchase price, decreases in product operating costs, and changes to household income. Appendix 9-A provides a detailed explanation of the methodology DOE used to quantify the impacts from these variables.

Existing studies of appliance markets suggest that the demand for appliances is price-inelastic. Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for appliances, and that consumer behavior reflects relatively high implicit discount rates[b] when comparing appliance prices and appliance operating costs.

DOE used the available data for the period 1980-2002 on large appliance purchases to evaluate broad market trends and conduct simple regression analyses. These data indicate that there has been a rise in appliance shipments and a decline in appliance purchase price and operating costs over the time period. Household income has also risen during this time. Because purchase decisions are sensitive to income, as well as to potential savings in the operating cost of the appliance, DOE combined the available economic information into one variable, termed the *relative price*. This variable was used in a regression analysis to parameterize historical market trends. The relative price is defined with the following expression:

$$RP = \frac{TP}{Income} = \frac{PP + PVOC}{Income}$$

Where:

RP =	relative price,
TP =	total price,
Income =	household income,
PP =	appliance purchase price, and
PVOC =	present value of operating cost.

In the above equation, DOE used real prices, as opposed to nominal, and an implicit discount rate of 37 percent to estimate the present value of operating costs. The rate of 37 percent is based on a survey of several studies of different appliances suggests that the consumer implicit discount rate has a broad range and averages about 37 percent.[5]

DOE's regression analysis suggests that the relative price elasticity of demand, averaged over the three appliances, is -0.34. This implies that a relative price increase of 10 percent results in a 3.4 percent decrease in shipments. Note that the relative price elasticity incorporates the impacts from purchase price, operating cost, and household income, so the impact from any single effect can be mitigated by changes in the other two effects.

The relative price elasticity of -0.34 is consistent with estimates in the literature. Nevertheless, DOE stresses that the measure is based on a small data set, using simple statistical

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[b] A high implicit discount rate with regard to operating costs suggests that consumers put a low economic value on the operating cost savings realized from more-efficient appliances. In other words, consumers are much more concerned with higher purchase prices.

analysis. More importantly, the measure is based on an assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States since 1980. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE did not account for them in this analysis. Despite these uncertainties, DOE believes that its estimate of the relative price elasticity of demand provides a reasonable assessment of the impact that purchase price, operating cost, and household income have on product shipments.

Because DOE's forecasts of shipments and national impacts attributable to standards is calculated for a lengthy time period, it needed to consider how the *relative price* elasticity is affected after a new standard takes effect. DOE considered the *relative price* elasticity, described above, to be a short-term value. It was unable to identify sources specific to household durable goods, such as appliances, to indicate how short-run and long-run price elasticities differ. Therefore, to estimate how the *relative price* elasticity changes over time, DOE relied on a study pertaining to automobiles.[6] This study shows that the automobile price elasticity of demand changes in the years following a purchase price change, becoming smaller (more inelastic) until it reaches a terminal value around the tenth year after the price change. Table 9.3.1 shows the relative change in the price elasticity of demand for automobiles over time. DOE developed a time series of relative price elasticities based on the relative change in the automobile price elasticity of demand. For years not shown in Table 9.3.1, DOE performed a linear interpolation to obtain the relative price elasticity.

Table 9.3.1 Change in Relative Price Elasticity Following a Purchase Price Change

	Years Following Price Change					
	1	2	3	5	10	20
Relative Change in Elasticity to 1st year	1.00	0.78	0.63	0.46	0.35	0.33
Relative Price Elasticity	-0.34	-0.26	-0.21	-0.16	-0.12	-0.11

9.3.2 Impact from Increase in Relative Price

Using the relative price elasticity, DOE was able to estimate the impact of the increase in relative price from a particular CSL. The impact, as shown in the equation below, is expressed as a percentage drop in market share for each year, dMS^p_j, which is applied in the decision for replacement versus extended repair.

$$dMS_j^p = \left[1 - \left(\frac{RP\_std_p(j)}{RP\_base_p(j)}\right)\right] \times e_{RP}(j)$$

Where:

$dMS^p_j =$ percentage market share drop for class *p,* year *j*,
$RP\_std_p(j) =$ relative price in the standards case for product class *p,* year *j*,
$RP_p(j) =$ relative price in the base case for product class *p,* year *j*, and

$e_{RP}(j)$ = relative price elasticity in year *j*.

Because the percentage change in the cost of furnaces due to potential furnace fan standards is relatively small, DOE assumed that the new construction market is unaffected by changes in either the total installed cost or operating costs of the equipment. That is, home builders are not likely to choose to not install a furnace if the installed cost rises by a small amount.

To model the impact of the increase in relative price from a particular CSL on furnace shipments, DOE assumed consumers affected by an increase in total installed cost would repair their equipment rather than replace it, extending the life of the product by six years. When the extended repaired units fail after six more years, they will be replaced with new ones.

The model calculates, for each year after the standard, the relative percentage market drop, dMS^p_j, due to the equipment price increase. The extended repair is only applicable to failed equipment that is purchased before 2018.

The number of failed furnaces that will be repaired instead of being replaced is calculated as follows:

$$XR_i = \sum_a \mathrm{Re}\,m(j,a) \times dMS_i^p \qquad for\,(j-a) < 2018$$

$$Rpl(j) = \sum_a Re\,m(j,a) - XR_i + XR_{j-6} - Dem(j)$$

Where:

dMS^p_j =	percentage market share drop for class *p,* year *j*,
a =	age of equipment,
j =	year,
Rem(j,a) =	retiring units in year *j* of age *a*,
XR_j =	extended repair units, year *j*,
Rpl(j) =	replacement units in year *j*, and
Dem (j) =	number of units gone with demolished buildings in analysis year *j*.

9.4 RESULTS

Figure 9.4.1 shows the historic and projected shipments of HVAC products with furnace fans by product class.

Figure 9.4.2 shows total projected shipments of HVAC products with furnace fans in the base case and under each standards case. Because the elasticity is modeled as a delayed replacement of a furnace, the forecast for the CSLs shows a decline in the early years, but an increase in later years once the delayed replacements are finally made. Recall that the elasticity parameter decreases over time, so the impact of the standards on shipments diminishes.

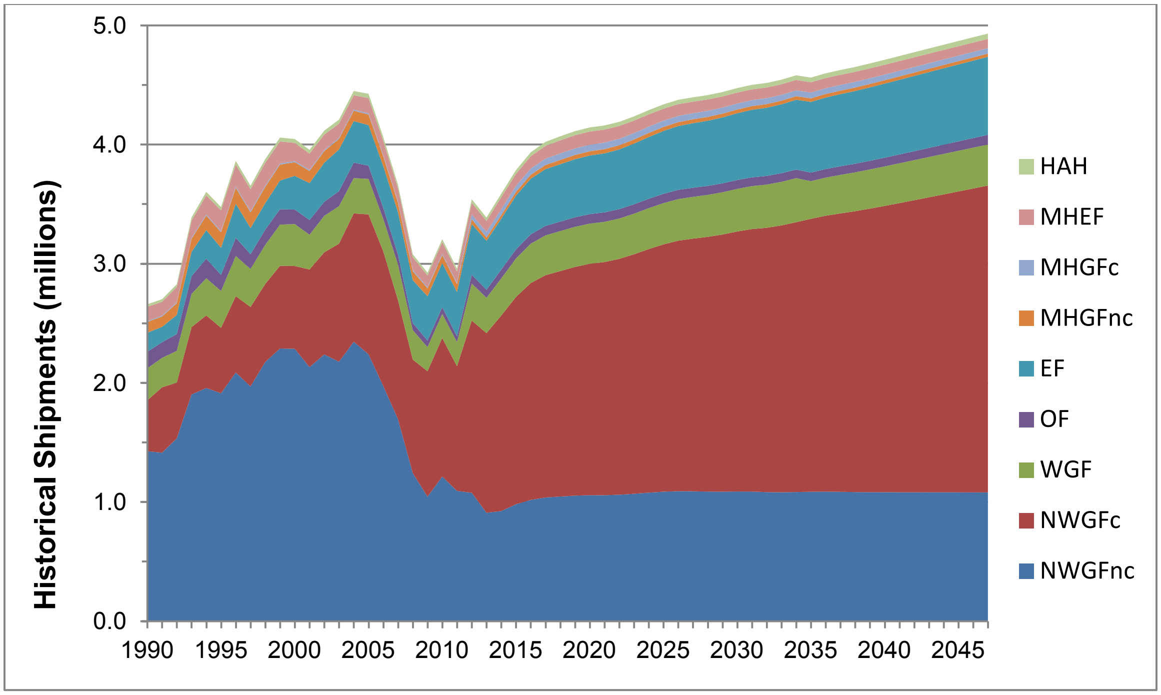

Figure 9.4.1 **Historic and Forecast Base Case Shipments of HVAC Products With Furnaces Fans by Product Class**

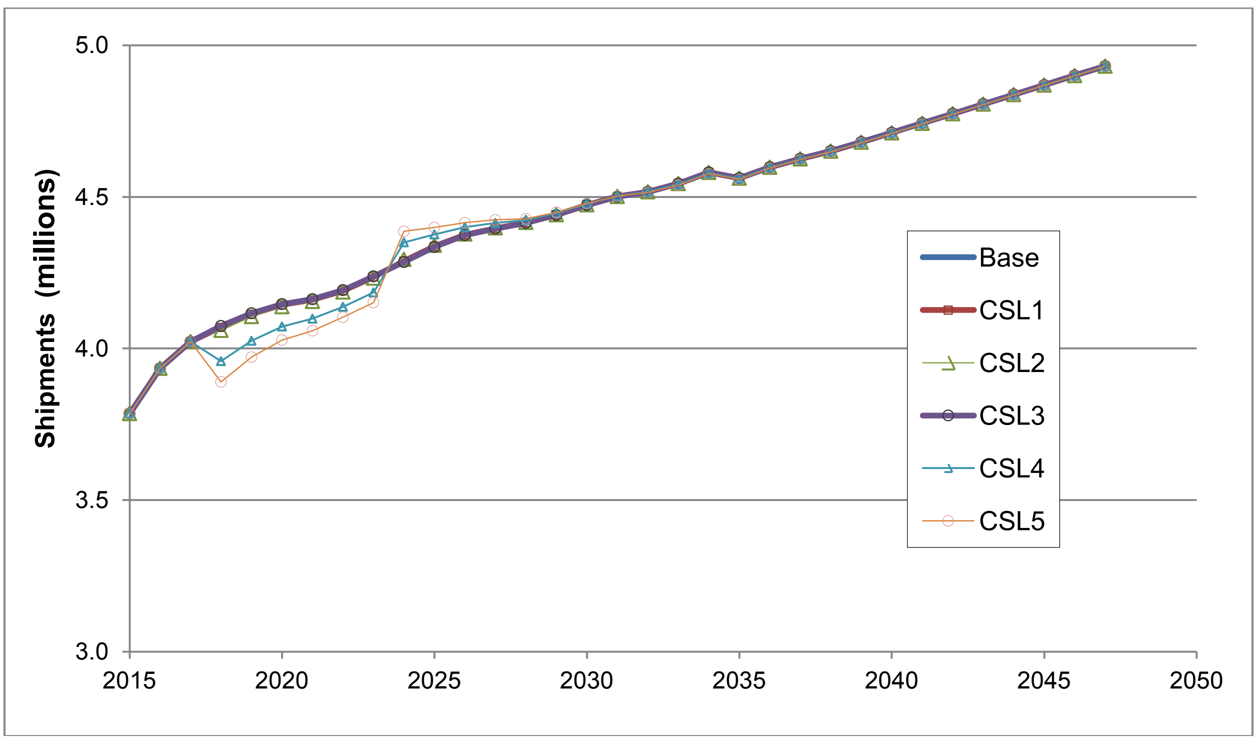

Figure 9.4.2 **Total Projected Shipments of HVAC Products With Furnaces Fans in the Base Case and Each Standards Case**

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