# CHAPTER 11. SHIPMENTS

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# CHAPTER 11. SHIPMENTS

## 11.1 INTRODUCTION

A forecast of water heater shipments supports the proposed rulemaking in two ways. First, it gives direct input to the Manufacturer Impact Analysis, which makes estimates of the business impacts of efficiency standards. Second, its results serve as input to the assessment of national energy savings described in Chapter 12.

Almost every U.S. household uses hot water and has a water heater that was originally installed during construction of the building. A new water heater is shipped every time an old one is replaced, or when a new housing unit is completed:

$$WH^{j}_{TOT} = WH^{j}_{Replaced} + HC^{j}$$

where $WH^{j}_{TOT}$ is total shipments in year $j$, and $HC^{j}$ is the number of housing completions for that year.

Since water heater lifetime, energy consumption, and equipment cost vary depending on the type of fuel used by a water heater, we forecast water heater shipments by fuel type. Shipments of fuel type $n$ in year $j$ are given by:

$$WH^{j}_{n} = WH^{j}_{n,Retired} + HC^{j} * MS^{j}_{n}$$

where $WH^{j}_{n,\,Retired}$ are retirements of fuel type $n$ in year $j$, and $MS^{j}_{n}$ is market share to new housing of that fuel type for that year. We assume that retired units are replaced by units of the same fuel type. Differences in retirements by fuel type therefore depend only on existing stock and the lifetime of the appliance. They will not be directly affected by energy efficiency standards. The decision of which type of water heater to install in a new home will depend on relative installed unit price and operating cost, both of which would be affected by energy efficiency standards. We forecast market share by fuel type of water heaters shipped to new housing using a detailed econometric model described in Section 11.3.2 and 11.3.3.

## 11.2 TOTAL SHIPMENTS

Water heater energy efficiency standards affect residential water heaters fueled by electricity, gas (or LPG), and oil. Our analysis excludes households which heat water with other fuels (such as wood or solar). In addition, we exclude households which share a water heater with one or more other households, since these water heaters are likely to be larger than those affected by the standard. According to the *Residential Energy Consumption Survey*,[1] about **2%** of households built in 1996

either do not use hot water, use a fuel other than the primary four, or share a water heater. Assuming this number remains constant over the forecast period, total water heater shipments in each forecast year will equal **98%** of housing completions plus the number of replacements for that year.

### 11.2.1 Shipments To New Housing

About 15-20% of water heater shipments from 1967 to 1997 are likely to have come from shipments to new housing. Statistics on housing completions come from the U.S Department of Commerce.[2] and include mobile homes,[3] which use residential water heaters covered by the same energy efficiency standards. The analysis used predictions of housing completions from *Annual Energy Outlook 2000* (*AEO2000*)[4] to project shipments to new housing from 1999 to 2020. From 2021 to 2030, we assume a constant annual housing completion rate at 2020 levels.

### 11.2.2 Replacements

Roughly 80-85% of water heater shipments are due to the replacement of retired water heaters. We assume that every retired water heater is replaced immediately with one of the same fuel type. The retirement model is an accounting procedure which keeps track of the total stock of water heaters by fuel type and vintage (year manufactured). Depending on the vintage, a certain percentage of each type will fail and be replaced each year. We also assume that consumers do not choose to convert from a water heater of one fuel type to one of another fuel type.

#### 11.2.2.1 Total Stock

The analysis calculates total stock of water heaters by integrating historical shipments[5] starting from 1951. As water heaters are added to the stock, some of the older ones are retired and therefore removed from stock, thus triggering the shipment of a new one. Because of the relationship between retirements and total stock, there is a strong correlation between past and future shipments by fuel type.

#### 11.2.2.2 Retirement Function

We assume a triangular retirement function for water heaters. According to this model, no water heaters retire below the minimum age, and all have retired by the maximum age. Retirement rate reaches a maximum at the most likely retirement age. Mean, minimum, and average ages for retirement of electric and gas units come from *Appliance Magazine*.[6] For gas-fired water heaters, the distribution is symmetric, so the average and most likely retirement ages are the same. For electric water heaters, we chose a "most likely" retirement age such that the average age would equal that reported in *Appliance Magazine*. Due to similarity of design, we assume life expectancies for oil and LPG water heaters equal those of gas water heaters. The retirement functions are shown in Figure 11.1 below.

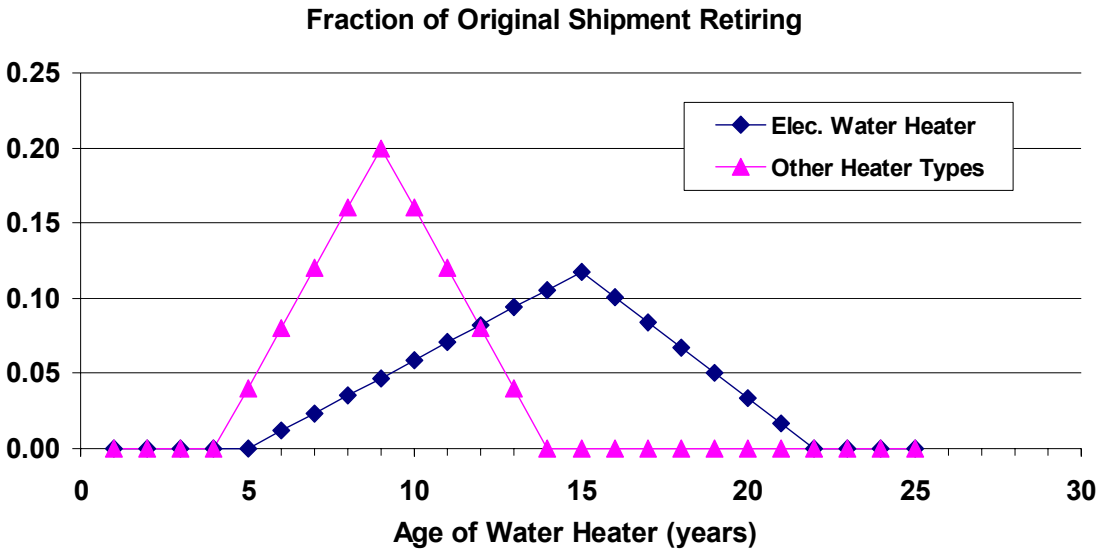


**Figure 11.1 Water Heater Retirement Function**

The longer lifetime of electric water heaters tends to reduce shipments of electric water heaters relative to the other fuel types, independent of efficiency standards.

### 11.2.3 Correction to Total Shipments

In general, the calculation of total shipments from replacements and new housing follows historical data quite well. We do observe, however, a small systematic disagreement between modeled and historical replacements. Our calculation is found to overestimate replacements before 1980 by about 5%, and to underestimate them in 1992 by about the same amount. To correct for this, we fit the difference between the model calculation and data to a straight line. The slope and intercept of this function are applied as a correction to total shipments in the forecast period. Figure 11.2 shows historical shipment data and results of the total shipment model. Figure 11.3 shows the difference between model and data, as well as the correction function applied.

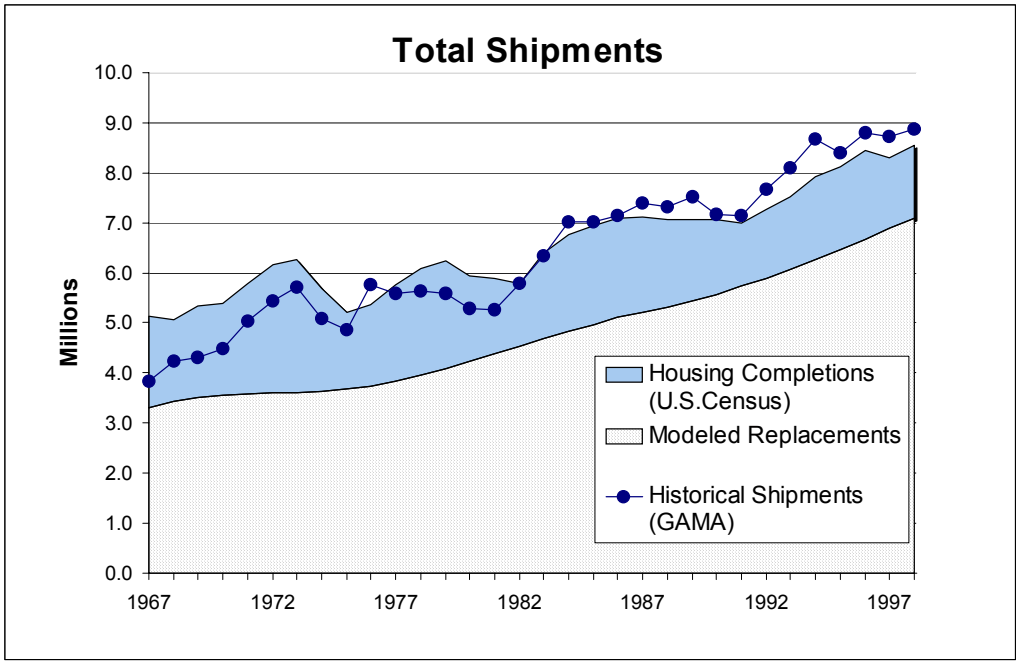


**Figure 11.2 Total Water Heater Shipments**

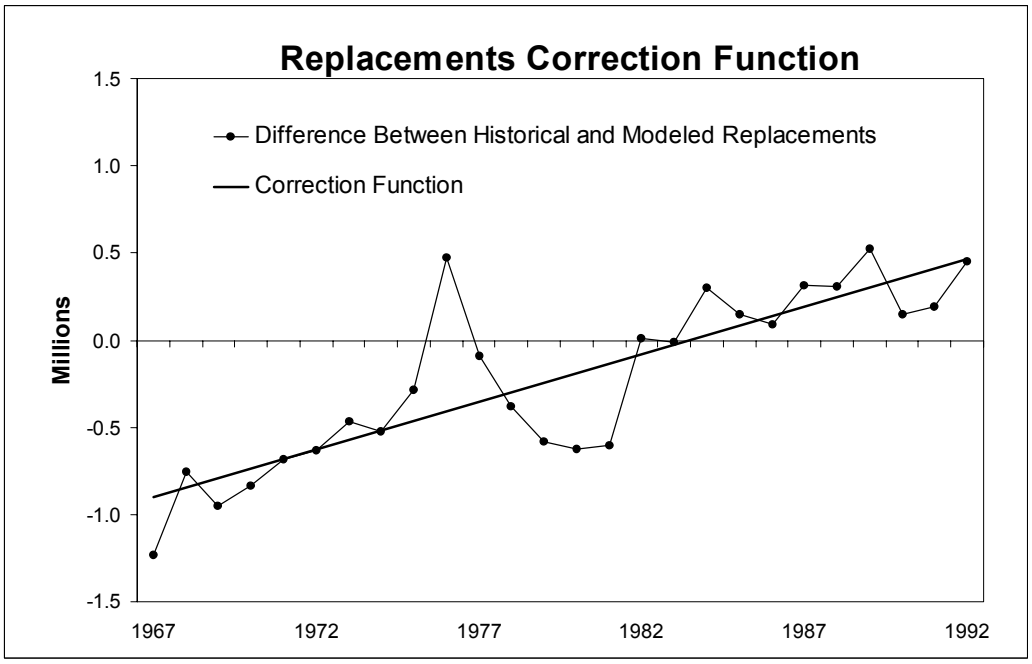


**Figure 11.3 Correction Function Applied to Total Water Heater Replacements**

## 11.3 MARKET SHARE IN NEW HOUSING

The relative number of each fuel type water heater shipped to new homes in a given year depends on contractors' choice in installing water heaters. This decision depends in part on fuel prices over time, but will also be affected by increases in equipment costs as energy efficiency standards take effect. By this mechanism, energy efficiency standards have a direct impact on market share by fuel in new housing.

### 11.3.1 Market Share by Efficiency

Several models of each fuel type of water heater are available to consumers. Generally, high-efficiency models are more expensive and installation costs may also be higher. Our market analysis assumes that consumers of appliances make purchase decisions based on the trade-off between equipment price and energy costs over the lifetime of the unit. Our consultant provided an estimate of the relative market share by efficiency level. We mapped these efficiency levels onto the design options being considered in this analysis. From this mapping, weighted average annual base case energy consumption and equipment costs are calculated. The effect of standards is to eliminate market share of the most inefficient models of each fuel type, thus lowering average annual water heater energy consumption while increasing average equipment cost. We assume that the market share of below-standard models will be transferred to the model which just meets the standard. All consequences of proposed standards and the variation between trial standard levels are from this shift in market shares and choice of water heater fuel in response to changing operating and installation costs.

#### 11.3.1.1 Base Case Market Share by Efficiency

The market share of different efficiency water heater models is not well known. In general, most contractors buy baseline models, that is, those which meet or barely exceed current standards. Data provided by our consultant indicate that low-efficiency (at or near baseline) units account for 80% of electric water heaters and 70% of gas water heaters bought.

Once the market share for the low efficiency units is assigned, we allocate remaining market share to reflect our understanding of shipments by efficiency level in the current market. The resulting estimates for what the base case would be in 2004 are shown in Table 11.1 below.

**Table 11.1 Estimated Base Case Market Share Assigned to Design Options by Fuel Type**

| | Design Option | EF Above Minimum | Market Share |
|---|---|---|---|
| Electricity | 2003 Baseline | .00 | 0.40 |
| | Heat Traps | .01 | 0.40 |
| | Tank Bottom Ins. | .02 | 0.00 |
| | 2" Insulation | .03 | 0.00 |
| | 2.5" Insulation | .04 | 0.00 |
| | Plastic Tank | .04 | 0.20 |
| | 3" Insulation | .05 | 0.00 |
| Natural Gas, LPG | 2003 Baseline | .00 | 0.35 |
| | Heat Traps | .01 | 0.35 |
| | 78% RE | .02 | 0.12 |
| | 78% RE 2" Ins | .05 | 0.12 |
| | 78% RE 2.5" Ins | .05 | 0.06 |
| | 80% RE 2" Ins | .06 | 0.00 |
| | 80% RE 2.5" Ins | .07 | 0.00 |
| | 80% RE 3" Ins | .07 | 0.00 |
| | Side Arm | .17 | 0.00 |
| Oil | 2003 Baseline | .00 | 0.40 |
| | Heat Traps | .01 | 0.40 |
| | 2" Insulation | .02 | 0.10 |
| | 2.5" Insulation | .03 | 0.05 |
| | 3" Insulation | .03 | 0.00 |
| | 78% RE | .05 | 0.00 |
| | Interrupt. Ign. | .05 | 0.00 |
| | Incr. HX Area | .08 | 0.05 |

### 11.3.2 Operating and Equipment Costs

#### 11.3.2.1 Operating Cost

The annual operating cost of a water heater is the product of its unit energy consumption (UEC) and the price of fuel. For each design option combination for a given fuel type, UEC is the average annual energy consumption from the Life-Cycle Cost Analysis. As energy efficiency standards become effective, market share of low-efficiency models is shifted to models that just meet the new standard. Therefore, the average efficiency (and thus UEC) of shipments will experience a step increase in the year of standard implementation. The analysis uses fuel price forecasts from EIA *(AEO2000)*[4] and a forecast provided by GRI.[7]

#### 11.3.2.2 Equipment and Installation Cost

The Engineering Analysis described in Chapter 8 provides detailed estimates of production and installation costs of each set of proposed design options. The Life-Cycle Cost module takes these costs and estimates the variety of retail prices and installation fees to U.S. consumers through the use of a Monte Carlo-style analysis. The averages of resulting values are a key input to the shipments spreadsheet. The shipments spreadsheet weighs design option costs by the market shares shown in Table 11.1 in order to arrive at average costs for each trial standard level. As in the case of operating costs, the average equipment cost of a water heater may change abruptly upon removal of low-efficiency units from the market. The results of this calculation are shown in Table 11.2.

In addition to the energy efficiency standards proposed by the Department of Energy, an initiative by the Consumer Product Safety Commission (CPSC) will affect future gas-fired water heater design. In response to this initiative, water heater manufacturers have agreed to voluntarily implement flammable-vapor ignition-resistant designs for gas-fired and LPG water heaters by 2003. In addition, by 2003 the current insulation blowing agent, HCFC-141b, will have been phased out according to U.S. Environmental Protection Agency (EPA) requirements. The average incremental water heater retail price increases associated with these changes are $60.31 and $82.67 for natural gas and LPG, respectively. Incremental prices for electric and oil-fired water heaters, which are affected only by the new blowing agent, are $ 4.13 and $4.02, respectively. Only units conforming to the CPSC and blowing agent standards are included in the 2003 base case, which is used as the basis of comparison in the national energy impacts analysis described in Chapter 12.

For comparison, the average retail price and installation costs of water heaters sold before 2003 are also listed in Table 11.2 and under the “2002 Base Case” label.

**Table 11.2 Average Retail and Installation Costs by Fuel Type**

| Trial Standard Level | Electricity | | Gas | | Oil | | LPG | |
|---|---|---|---|---|---|---|---|---|
| | Retail $ | Install. $ | Retail $ | Install. $ | Retail $ | Install. $ | Retail $ | Install. $ |
| 2002 Base Case | 228 | 153 | 217 | 167 | 582 | 542 | 330 | 166 |
| 2003 Base Case | 232 | 153 | 277 | 167 | 586 | 542 | 412 | 166 |
| 1 | 247 | 153 | 320 | 182 | 586 | 542 | 471 | 182 |
| 2 | 292 | 153 | 339 | 192 | 586 | 542 | 497 | 195 |
| 3 | 316 | 170 | 320 | 182 | 586 | 542 | 471 | 182 |
| 4 | 395 | 220 | 589 | 335 | 586 | 542 | 840 | 352 |

### 11.3.2 Market Share by Fuel Type

Average costs are used to forecast market shares in new construction by fuel types. Increasing the price of a given type of water heater will tend to decrease its shipments, just as lowering operating expenses may increase shipments. One way to express these economic responses is by means of an elasticity. An elasticity is the percent change in one quantity in response to a percent change in a driving variable. For example, the price elasticity for water heaters is the change in market share resulting from a 1% change in price. For example, if a 1% increase in price causes a 2% decrease in market share, then the price elasticity is -2.0 (i.e., -2%/1%).

An increase in costs for one fuel type is expected to decrease market share relative to other fuel types, rather than result in a decrease of overall water heater sales. The market share forecast uses elasticities to produce relative market shares, which are then normalized to a total water heater market penetration of 98%. For this reason, relative, rather than absolute, values of elasticity affect fuel type market shares.

#### 11.3.2.1 Impact of Operating Cost on Fuel Type Market Share

Data on the impact of operating cost on fuel type market share come from an analysis performed by Oak Ridge National Laboratory[8] and are shown in Table 11.3. Diagonal elements are self-elasticities. For example, the element in the first row, first column, represents the decrease (negative increase) in electric water heater market share in response to increases in operating cost. Off-diagonal elements are cross-elasticities, which determine the effect on water heater sales of one fuel type due to operating cost increases in the other fuel types.

**Table 11.3 Fuel Type Operating Cost Elasticity**

| | Electricity | Gas | Oil | LPG |
|---|---|---|---|---|
| **Electricity** | -1.00 | 0.40 | 0.25 | 0.25 |
| **Gas** | 0.40 | -0.70 | 0.20 | 0.00 |
| **Oil** | 0.40 | 0.55 | -1.00 | 0.20 |
| **LPG** | 0.25 | 0.00 | 0.15 | -0.50 |

#### 11.3.2.2 Impact of Equipment Cost on Fuel Type Market Share

Equipment costs affect purchase decisions in a similar way as operating costs and can be related to market share through elasticities. In practice, a simple relationship between operating and equipment cost elasticities expresses the degree to which purchasers prefer to save equipment costs at purchase time rather than save on operating costs over the life of the appliance. This relationship is given by:

$$E_q = E_o * \frac{EquipmentPrice}{(OperatingExpense * PWF)}$$

where $E_q$ and $E_o$ are equipment and operating cost elasticity, respectively. The present worth factor (PWF) represents a discounted sum over the lifetime of the appliance, and is given by:

$$PWF = \sum_{j=1}^{t} (1+r)^{-j} = \frac{1}{r} * (1 - (1+r)^{-t})$$

for implicit discount rate $r$ and average appliance lifetime $t$.

***Implicit Discount Rate.*** The implicit discount rate in the equation above indicates that future energy cost savings are devalued in the mind of purchasers. In using a high implicit discount rate, we assume that consumers are highly influenced by equipment costs. We define implicit discount rate as the minimum discount rate at which the life-cycle cost of the baseline model equals the life-cycle cost of the next most efficient model. In other words, it is the effective discount rate which captures the consumers' tendency to buy the cheapest appliance on the market. The analysis uses discount rates contained in App B[a] of the 1993 *Technical Support Document,*[9] as shown in Table 11.4.

[a]The implicit discount rate for gas-fired water heaters was revised using data available only after publication of the 1993 *Technical Support Document.*

**Table 11.4 Implicit Discount Rates by Fuel Type**

| Electricity | Gas | Oil | LPG |
|---|---|---|---|
| 191% | 83% | 124% | 83% |

#### 11.3.2.3 Household Income

The Oak Ridge model also contains a component related to household income. ORNL reports a household income elasticity of +0.35 for gas and zero for other fuel types, indicating a slight preference for more expensive and more efficient gas units among higher-income households. We use household income projections through 2020 from *AEO2000*. Income projections from 2021 through 2030 are extrapolated from 2020 assuming a constant average household income growth rate.

#### 11.3.2.4 Model Summary

The fuel choice market share model extrapolates from 1996 values, which are the most recent data available from the 1997 RECS survey.[1] These data are shown in Table 11.5. Households sharing water heaters with other units are excluded.

**Table 11.5 Market Share by Fuel Type for New Housing in 1996**

| Electricity | Gas | Oil | LPG |
|---|---|---|---|
| 39% | 52% | 4% | 3% |

Market shares have been updated to represent the 1997 survey data, which indicates a rise in the natural gas water heater market share in recent years. According to the American Gas Association's (AGA) *1998 Residential Natural Gas Market Survey,*[10] natural gas space heating market share was 70%. In order to reconcile this number with RECS survey data, several factors must be accounted for . The number quoted by AGA includes LPG with natural gas, and is for single family homes only. Inclusion of other building types (particularly mobile homes) results in a 15% reduction in gas market share, according to RECS. The AGA figure is for space heating, not water heating (RECS shows that over the past 20 years or so, gas water heater market share has been smaller than gas space heating market share by 7%). With these adjustments, we find that AGA's number implies a gas water heater market share of 52%, including all building types, but not including LPG. Therefore, we determine the two data sources to be consistent.

The model uses a logit equation, which is a modified version of a simple linear regression. This equation assumes a linear relationship between each economic variable and the probability that a consumer will choose a particular fuel type,[a] resulting in a market share constrained to be between 0 and 1. Input variables are the ratio of costs and income in the forecast year to those in the reference year 1996. The elasticities described in the previous section serve as constants of proportionality. The following relationship results:

$$\ln \frac{MS^j_n}{1 - MS^j_n} = a_n + \sum_i b_{in} * \frac{OC^j_n}{OC^0_n} + \sum_i c_{in} * \frac{EC^j_n}{EC^0_n} + d_n * \frac{HI^j}{HI^0}$$

where $MS^j_n$ is the market share of fuel type $n$ in year $j$. Input variables to the model are

$OC^j_n$ = Operating cost for water heaters of fuel type $n$ in year $j$
$OC^0_n$ = Operating cost for water heaters of fuel type $n$ in 1996
$EC^j_n$ = Equipment cost for water heaters of fuel type $n$ in year $j$
$EC^0_n$ = Equipment cost for water heaters of fuel type $n$ in 1996
$HI^j$ = Average household income in year $j$
$HI^0$ = Average household income in 1996

Constants $b_{in}$, $c_{in}$ and $d_n$ are operating cost, equipment cost, and household income elasticities, respectively. The sum over fuel type index, $i$, includes cross-elasticities. Finally, the constant $a_j$ scales resulting market shares to their values in the reference year. Resulting fuel type market shares are normalized to sum to 98%, the percentage of new housing units expected to be affected by energy efficiency standards.

## 11.4 RESULTS

There are two primary results of the shipments forecast. The first of these is the total number of water heaters shipped in each year from 2004 till 2030. Total shipments depend on assumptions made about the lifetime of the appliance and on the rate of new construction. No direct effect is expected on total shipments from energy efficiency standards. There may be a slight, indirect effect on total shipments because of different lifetimes, as the share by fuel type of total stock changes. In addition to the *AEO2000* reference economic forecast, low- and high-growth scenarios are also modeled. The low- and high-growth forecasts result in lower and higher total shipments, respectively, due to the difference in housing completions. Total baseline shipments for all three *AEO2000* scenarios are shown in Table 11.6.

[a] Detailed discussion of the logit formalism can be found in standard econometrics texts such as Pindyck and Rubinfeld, 1998.[11]

**Table 11.6 Total Shipments in 2004 and Integrated over Forecast Period, 2004-2030**

| 2004 Shipments *Millions* | Baseline Total Shipments 2004 - 2030 *Millions* | | |
|---|---|---|---|
| | Reference | Low-Growth | High-Growth |
| 10.7 | 393.7 | 379.0 | 402.5 |

The second component of the shipments forecast is the prediction of market share among fuel types. Here, we expect some dependence on the efficiency standards, which will raise average equipment prices and lower operating costs. Since pricing changes may not affect different fuel types uniformly, there may be a step increase in the market share of one fuel type at the expense of the others. In addition, other regulations mentioned in Section 11.3.1.3 are likely to cause some shift in market share. Table 11.7 summarizes the effects on fuel type market share due to these factors.

Total source energy savings of a given standard will depend not only on the average water heater efficiency, but also the mix of fuel types used. Therefore, a central output of the shipments analysis used by the national energy impacts analysis (described in Chapter 12) is total shipments over the forecast period, by fuel type, for each trial standard level. These results are presented in Table 11.8. The effect on shipments due to efficiency standards are summarized in Figure 11.4, in terms of incremental shipments (relative to the baseline) for each trial standard level. The most significant result is that with Trial Standard Level 3 incremental shipments of electric water heaters decrease, while those of natural gas water heaters increase.

**Table 11.7 Fuel Type Market Share in New Housing by Trial Standard Level**

| Scenario | New Housing Market Share in 2004 | | | |
|---|---|---|---|---|
| | Electricity % | Gas % | Oil % | LPG % |
| 2003 Baseline | 46 | 46 | 4 | 3 |
| Trial Standard Level 1 | 50 | 42 | 4 | 3 |
| Trial Standard Level 2 | 48 | 44 | 4 | 3 |
| Trial Standard Level 3 | 37 | 54 | 4 | 3 |
| Trial Standard Level 4 | 80 | 11 | 6 | 2 |

**Table 11.8 Total Shipments During 2004-2030 by Fuel Type and Trial Standard Level**

| Total Shipments 2004-2030<br>*Millions* | | | | |
|---|---|---|---|---|
| **Scenario** | **Electricity** | **Gas** | **Oil** | **LPG** |
| 2003 Baseline | 161.8 | 210.5 | 5.8 | 15.5 |
| Trial Standard Level 1 | 164.5 | 206.9 | 6.0 | 15.5 |
| Trial Standard Level 2 | 162.8 | 208.7 | 6.2 | 15.7 |
| Trial Standard Level 3 | 154.7 | 218.7 | 6.2 | 16.0 |
| Trial Standard Level 4 | 189.1 | 183.7 | 7.9 | 15.4 |

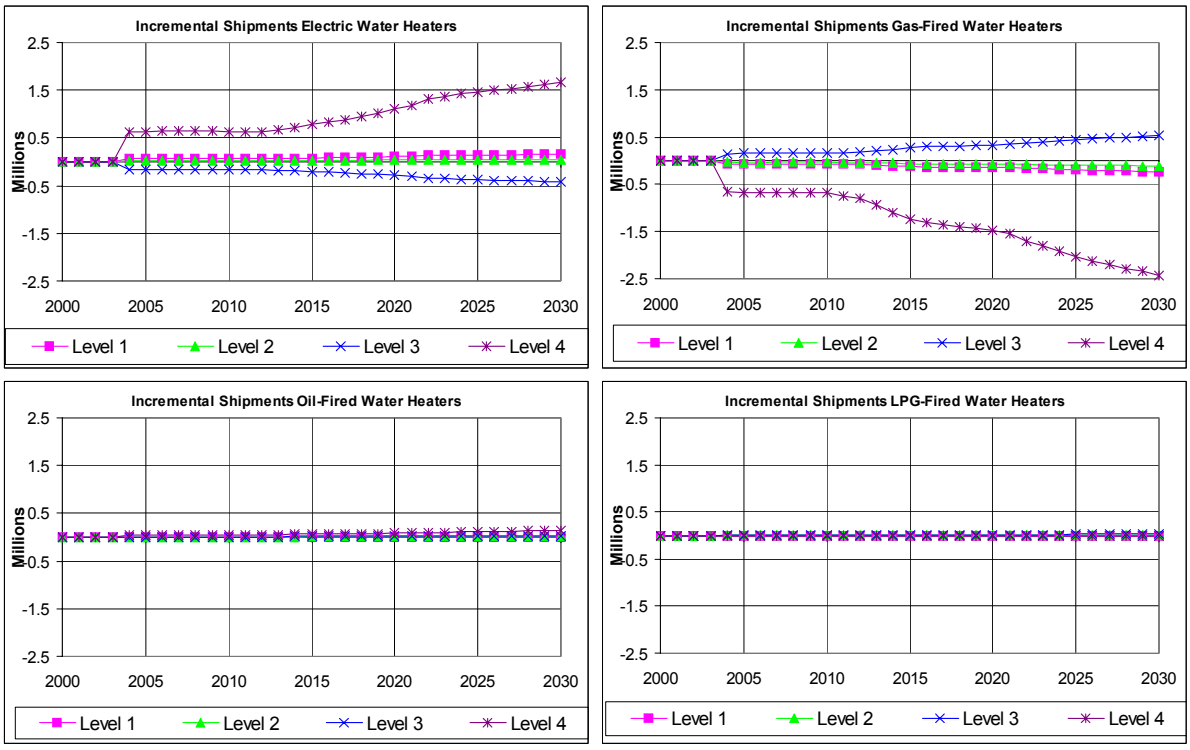


**Figure 11.4 Incremental Shipments (Relative to Baseline) by Fuel Type**

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