METHODOLOGY OF THE NATIONAL ENERGY SAVINGS ANALYSIS FOR RESIDENTIAL WATER HEATER EFFICIENCY STANDARDS AND PRELIMINARY BASE CASE RESULTS

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6.0 INTRODUCTION

The Energy Policy and Conservation Act, as amended, provides energy conservation standards for water heaters among other products and authorizes the Secretary of Energy to prescribe amended or new energy standards for each type of covered product. This is a preliminary National Energy Savings Analysis; it is part of the analyses the Department will conduct for the water heater rulemaking.

Request for Stakeholder Comments

The Department specifically requests comments from stakeholders and other interested parties regarding the following items:

1) water heater life expectancy
2) historical retail prices and installation costs for residential water heaters
3) historical consumer responsiveness to water heater prices (e.g., price elasticities of demand for water heaters)
4) historical consumer responsiveness to water heater operating expense (e.g., operating expense elasticity of demand for water heaters)
5) projections of future residential energy prices
6) voluntary programs affecting the distribution of energy efficiencies of new water heaters

Purpose of National Energy Savings Analysis

This report describes the method for estimating the quantity and value of future national energy savings (NES) from possible standards. The results of the analysis include:

- Annual shipments of residential water heaters by fuel
- National energy consumption for residential water heating by fuel type
- Consumer expenditures for the purchase of residential water heaters
- Consumer operating expenditures for residential water heaters
- Impacts of new standards on energy consumption and consumer expenditures

The discussion begins with a review of methodology and definitions in section 6.1. Key quantities and current assumptions used in the NES calculations are detailed in section 6.2 All calculations are performed on a series of Microsoft Excel™ spreadsheets which are accessible over the internet. Access to and basic instructions for the spreadsheets are discussed in section 6.3. Basic outputs from the spreadsheet calculations are discussed in section 6.4.

Connection to Remainder of Water Heater Standards Analysis

The National Energy Savings (NES) Analysis is one step in the analysis of water heater efficiency standards. Much of the input for this analysis regarding individual water heaters and households comes from the Life Cycle Cost Analysis[1]. The National Energy Savings Analysis estimates energy savings for the entire nation, and over a time period through the year 2030. The National Energy Savings Analysis will be used by the Department to help evaluate the impacts associated with trial standard levels in later stages of analysis and decision making. The outputs from the National Energy Savings Analysis will also be used by the Utility, Environmental, and Indirect Employment Impacts analyses. Shipments projections will be used by the Manufacturer Impacts Analysis.

6.1 METHODOLOGY AND DEFINITIONS

Shipments are estimated based upon two markets: construction of new housing and water heater replacements in existing housing. National energy consumption by residential water heaters is calculated as the product of annual shipments and unit energy consumption. Fuel types include electricity, natural gas (including LPG), and distillate oil. Annual consumer expenditures for purchasing water heaters by fuel type are calculated as the product of average purchase price and annual shipments. Annual consumer expenditures for energy consumed by water heaters are calculated as the product of average unit energy consumption by vintage times the price of energy in that year. These calculations are performed for each year from the present to the year 2030.

A base case is a projection assuming no new energy efficiency standards. Then a second scenario is examined in the same spreadsheet, after adjusting inputs to account for new energy efficiency standards for residential water heaters. National energy savings due to new energy efficiency standards are calculated as the difference in annual energy consumption between the base case and the standards case. Typically, less energy is consumed in the standards case, so values greater than zero represent savings. Cumulative energy savings are calculated as the sum over years of annual energy savings.

The changes in annual consumer expenditures due to new energy efficiency standards are calculated, comprised of change in purchase prices and changes in operating expenses. The net present value is calculated as the discounted sum over the forecast time horizon of these changes in expenditures. Net savings are expressed as greater than zero and net costs are expressed as less than zero.

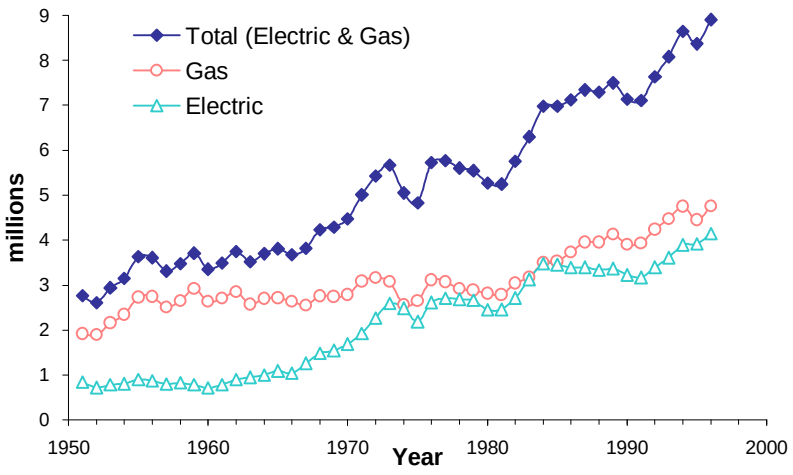
Section 6.1.1 describes how future shipments are estimated. Section 6.1.2 describes the methodology for calculating national energy savings. Section 6.1.3 describes the calculation of net present value.

6.1.1 Shipments

Figure 6.1 shows historical annual shipments of residential storage water heaters using electricity or natural gas (including LPG). (Oil-fired residential water heaters, representing <1%

of the total shipments, are not shown.[a]) Total annual shipments were about 8 million in the mid-1990s. This section describes: (1) segmentation of annual shipments into two markets - new housing construction (Section 6.1.1.1) and existing housing (Section 6.1.1.2); (2) the influence of life expectancy of water heaters on replacement shipments (Section 6.1.1.2); (3) fuel shares among competing fuels (Section 6.1.1.3); (4) fuel switching (Section 6.1.1.4); (5) consumer responsiveness to changes in purchase prices and operating expenses of water heaters (Section 6.1.1.5); (6) an accounting model is proposed for forecasting shipments (Section 6.1.1.6), and (7) preliminary base case projections are presented and compared to other projections (Section 6.1.1.7).

Figure 6.1
Annual Shipments of Residential Water Heaters

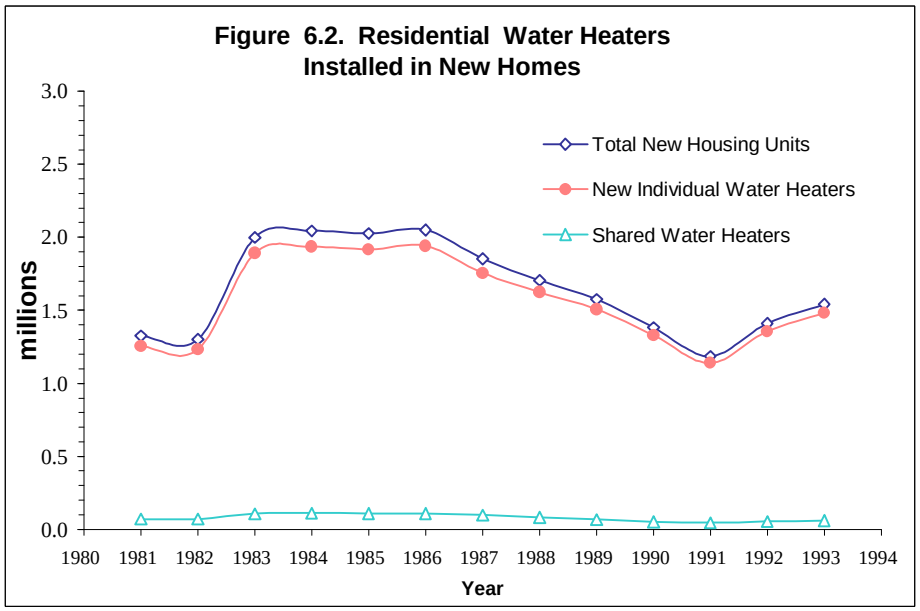


6.1.1.1 Shipments to new housing

Figure 6.2 shows about 1.3-2.1 million new housing units are completed each year. From 1980 to 1993, about 95- 96% of new housing units had residential storage water heaters of the type and size for which standards are under consideration here[2]. The remaining 4-5% of new housing units have water heaters that are shared among more than one housing unit, and are not of the type of interest here. So about 1.1-1.9 million residential storage water heaters are installed in new housing each year. Since 1989, these installations account for 16-20% of annual water heater shipments.

[a] Statistics for oil water heaters from 1969 to 1986 show shipments of 13,800 in 1969, increasing to a peak of 49,300 in 1977, then declining to 26,200 in 1981, and rising to 39,300 in 1986.

6.1.1.2 Water heater replacement market



After accounting for new housing construction, about 71-85% of shipments remain. Most shipments are replacements. With an average life around 10 years, a rough estimate of replacements would be equivalent to shipments 10 years ago, so about 7 million per year.

A better estimate of replacements can be obtained by accounting for the difference in lifetimes between water heaters of different fuel types, and the range in those lifetimes. Life expectancy is estimated to range from 4 to 19 years (average 12 years) for electric water heaters, and to range from 3 to 15 years (average 9 years) for gas water heaters[3]. Applying these life expectancies to historical shipments produces estimates of annual retirements of water heaters. Combining calculated replacements with calculated shipments to new housing provides an estimate of total shipments, which can be compared with reported shipments.

Figure 6.3 shows estimated total electric and gas water heater shipments to new housing units, estimated replacements based upon life expectancies and total reported water heater shipments.

Figure 6.4 uses the same information as in Figure 6.3 expressed as percent of total shipments. The total calculated electric and gas water heater shipments agree within 9% of reported shipments.

Figure 6.3. Annual Water Heater Shipments: Actual and Estimates

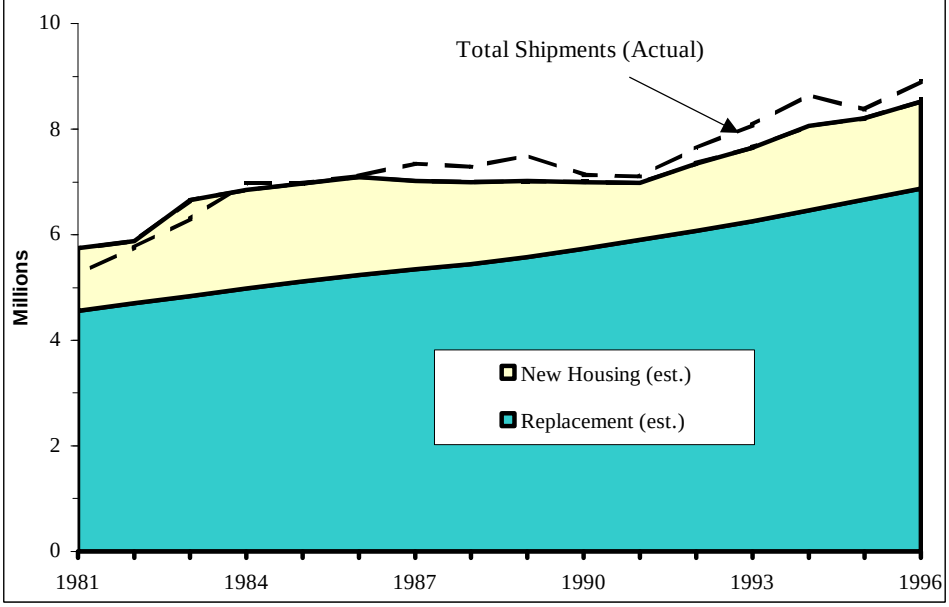
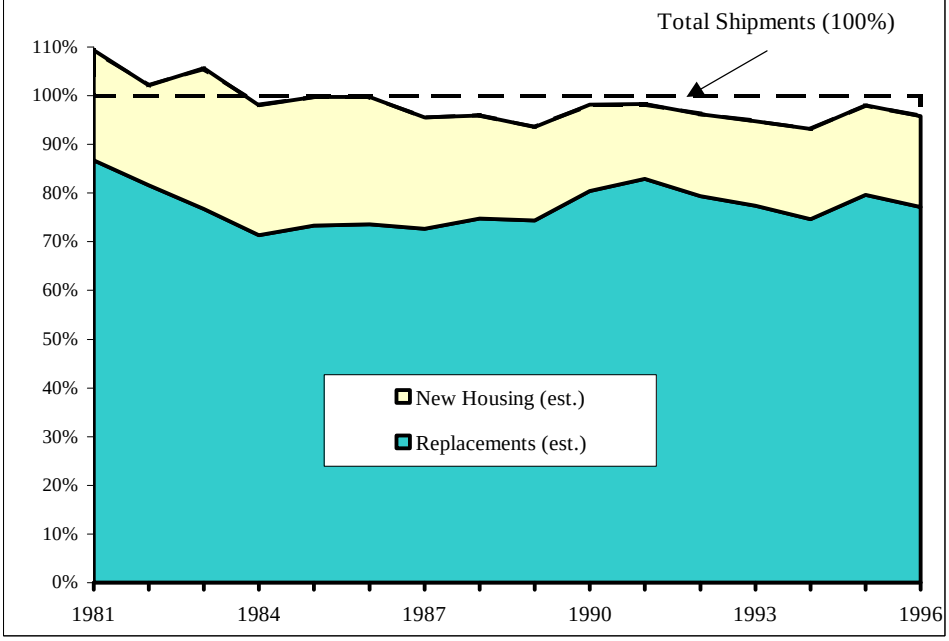


Figure 6.4. Percentage of Water Heater Shipments

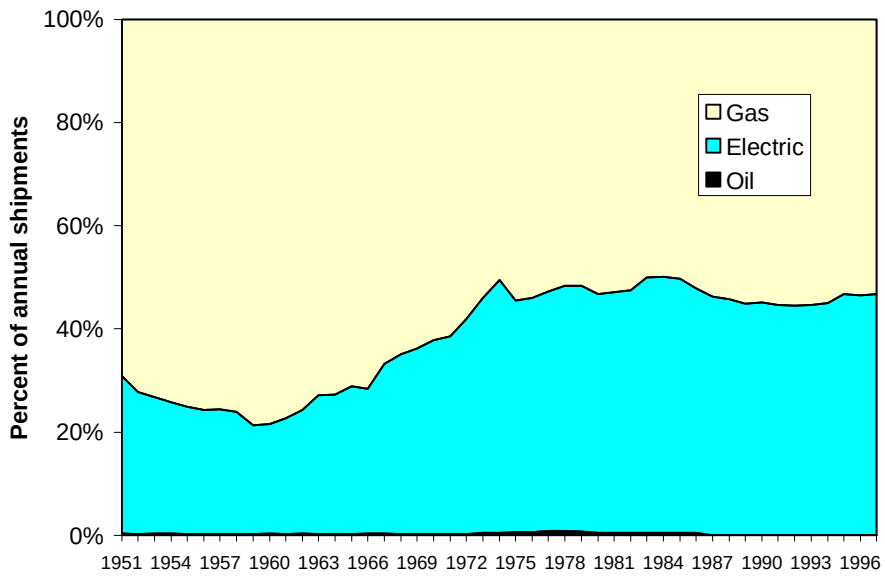


After accounting for new construction (15 to 29%) and estimated replacements (71 to 87%), a residual remains, equivalent to a range of under- or over-estimates from about -9% to 7% of total shipments that are not explained. These may represent additions of water heaters to existing homes that do not involve replacement of the previous water heater, non-residential applications, economic factors affecting shipments, or some other explanation.

6.1.1.3 Fuel shares

The major shares of shipments are captured by natural gas and electric water heaters. Figure 6.5 shows that market shares of electric water heaters increased in the 1960s and 1970s. Changes in fuel shares have decreased over time. Of the total, electric shares have been between 44 and 50% every year since 1973, with gas shares accounting for 50-56%. Oil shares (reported only for 1969-1986) are less than 1%. Since 1986, the range has narrowed further, with electric fuel shares between 44 and 47%. Natural gas (including LPG) water heaters have accounted for the remainder (53-56%). (No data are included for oil after 1986, but shipments are believed to remain low.)

Figure 6.5 Market shares of residential water heaters by fuel type



A national survey in 1993 indicated that 98% of existing homes have water heaters, composed of 38% electric, 53% have gas, 4% oil, and 3% LPG. These shares include common water heaters, that is, water heaters shared by more than one housing unit. For the 88% of homes with individual water heaters, the saturations are: electric 37%, gas 46%, oil 2% and LPG 3%.

There are regional differences in market share of water heaters in existing homes. The market share of gas water heaters for the total U.S. has been 52% from 1987 to 1995. However, the market share for gas water heaters in the Northeast has increased 3%, while the corresponding share in the South has decreased 3%[4]. Part of the decrease in gas market share in the South may be attributable to utility programs promoting electric water heaters[5].

Developers or builders make the decision about the original water heater installation in a home. That decision depends upon the local market, fuel availability and price, utility programs, and consumer preferences as perceived by the builder. Usually the choice of fuel for the heating system determines the fuel of the water heater.

6.1.1.4 Fuel switching

Fuel switching is defined here to include any activity which alters the market shares by fuel of residential storage water heaters. Such activities include replacements of retiring water heaters of one fuel with a different fuel. Fuel switching could be motivated by fuel availability (as when gas supplies were short in the 1970s), changes in relative energy costs, utility programs, or other factors.

The market shares of competing fuels for water heaters are highly dependent on the market shares of those fuels for space heating. Most homes use the same fuel for water heating as for space heating[2]. Subsequently, most replacements of water heaters are of the same fuel type as the original. From 1986 to 1996, between 148,000 and 311,000 housing units annually converted from another fuel to natural gas househeating. Since 1993, conversions to gas have declined, and are expected to continue to decline[6].

Over the long term, households that convert to gas househeating may switch to gas water heating as well, but the extent to which this occurs and the timing (simultaneously with conversion to gas househeating or later when the water heater reaches the end of its useful life) has not been documented. An estimate of the maximum impact on annual water heater shipments is obtained by assuming that homes that converted to gas househeating also convert simultaneously to gas water heaters. Hypothetically, if all conversions to gas househeating also converted simultaneously to gas water heating, these conversions would represent a maximum of 2 to 4% of total (electric + gas) water heater shipments each year, or 3 to 7% of gas water heater shipments. Fuel switching for residential water heaters has represented a small portion of the U.S. market compared to replacement and to new housing construction.

6.1.1.5 Consumer economic factors

This section discusses consumer economic factors that could affect shipments of water heaters, specifically:

- purchase prices
- operating expenses
- elasticities

Purchase Prices

Historical data on purchase prices for water heaters are not readily accessible, since most purchases are made through contractors. Typically, the consumer pays for a package of services, including the price of the water heater, delivery and installation. In the case of new housing, the builder makes the purchase and the consumer receives the water heater contained in the price of the property. Information on current (1998) retail prices has been gathered and is described in a separate LBNL report[7]. The National Energy Savings Analysis uses retail prices consistent with the Life-Cycle Cost Analysis.

Operating Expenses

The principal operating expense for residential water heaters is for energy. Most energy bills do not separate expenses by end use, so the energy bill for water heaters is contained in the energy bill for the household. Historical operating expenses have been estimated in national surveys. In 1993, the annual per household expenditures for water heating were estimated to be $203 for electric, $157 for gas, $159 for oil and $200 for LPG. The national total expenditures for residential water heating were estimated as $7.58 billion for electricity, $8.08 billion for natural gas, $0.73 billion for fuel oil and $0.58 billion for LPG[8].

In the National Energy Savings Analysis, national operating expenses are based upon the Life-Cycle Cost Analysis (LCC), and are not necessarily consistent with the EIA RECS results. The LCC characterizes energy consumption for individual households in much greater detail than the EIA RECS conditional demand approach, so that agreement is not expected.

Consumer Responsiveness to Prices: Elasticities

According to economic principles, increasing the price of water heaters is expected to decrease shipments. By the same principles, decreasing the operating expense may increase shipments. One way to express these economic responses is by means of elasticities. An elasticity is the percent change in one quantity in response to a percent change in a driving variable. The price elasticity of demand for water heaters is the change in annual shipments (expressed as a percent of baseline shipments) corresponding to a percent change in price. For example, if a 10% increase in price causes a 2% decrease in shipments, then the price elasticity is -0.2 (i.e.: -2%/10%). Price elasticities are expected to be negative; that is, an increase in the price of the water heater is expected to produce a decrease in shipments.

Similarly, the operating expense elasticity of demand for water heaters is the change in annual shipments (expressed as a percent of shipments) corresponding to a percent change in operating expense. Operating expense elasticities are expected to be negative, since an increase in the operating expense of the water heater is expected to produce a decrease in shipments.

In the case of water heaters, most of the variability in shipments can be explained with an accounting model (Figure 6.4 above), even ignoring the price and operating expense of water heaters. That is, water heaters are purchased as a necessity, and the range of price fluctuations in the past have not convinced many consumers to do without hot water. But relative purchase price and operating expense among water heaters utilizing competing fuels are expected to affect the market shares of those fuels.

To fully anticipate the potential impacts of new energy efficiency standards, this analysis proposes to include elasticities on purchase price and on operating expense. The elasticities are not well known. Complications include: (1) Factors other than price have strong influence on the purchase decision. In most cases, the initial purchase decision is made when the building is built, by someone other than the consumer who will pay the energy bills. (Also, see Section 6.1.1.3 above, regarding relationship between heating system and water heater fuel type.) (2) Publicly available information on actual prices paid for water heaters is lacking.[b]

Some research has been conducted, estimating operating cost elasticities, and the relationship between operating cost elasticities and equipment price elasticities[9]. That research also accounted for cross-elasticities, namely the influence of energy prices of one fuel on the purchases of a water heater using a different fuel. This analysis adopts the operating expense elasticities from that research, conducts sensitivities using original and more recent estimates of discount rates associated with efficiency choice, and derives purchase price elasticities.

Table 6.1 shows the operating expense elasticities currently in use in the National Energy Savings Analysis. (The equation in which elasticities of market shares are used is explained below in Section 6.2.1 "Shipments," under the subheading "Market Shares of New Installations.") The cells in Table 6.1 show the elasticities of market share by fuel type (columns) for residential water heaters as a function of the operating expense by fuel type (rows). For example, the market share for electric water heaters has an elasticity of -1.00 with respect to the operating expense of electric water heaters, and an elasticity of 0.40 with respect to the operating expense of gas water heaters. Negative values indicate that higher prices cause lower market shares for the same fuel type ("own elasticities"), while positive values indicate that higher prices of one fuel type cause higher market shares for a different fuel type ("cross-elasticities").

[b] Newell, 1998 refers to the Sears catalog as a source of transaction prices for 415 gas water heater models from 1982 through 1993.

Table 6.1 Operating Expense Elasticities of Water Heaters

MARKET SHARE:	Electric	Gas	Oil	LPG
OPERATING EXPENSE:				
Electric	-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

Table 6.2 shows the relationship between income and fuel type for water heaters, with high income associated with gas, and lower income associated with LPG. Over time, as incomes change, this affects the market shares of competing fuels.

Table 6.2 Income Elasticities of Water Heaters

	Electric	Gas	Oil	LPG
Income	0.00	0.35	0.00	-1.95

Source: ORNL, 1979[9]

The equipment price elasticities for purchase of new equipment are calculated from the operating expense elasticities using the following equation:

$$E_q = E_o \cdot \frac{Equipment\ Price}{(Operating\ Expense \cdot PWF)}$$

where E_q is the equipment price elasticity[c] and E_o is the operating expense elasticity. *PWF* is the present worth factor for a given discount rate *r* and lifetime *t*.

$$PWF = \frac{1}{r} \cdot \left(1 - (1+r)^{-1}\right)$$

Table 6.3 shows average lifetimes[3].

Table 6.3 Water Heater Average Lifetimes

	Electric	Gas	Oil	LPG
Lifetime	12	9	9	9

[c] Equipment price as used here includes installation cost.

Discount rates are a key assumption in deriving the equipment price elasticities.[d] Table 6.4 shows the original low discount rates assumed in the literature[9] and an alternative higher set, based upon recent purchases in the context of the current engineering analysis. Research has indicated that in the context of a life-cycle cost framework, the inability of higher energy efficiency products to capture larger market shares can be expressed as higher market discount rates.[10] This does not mean that water heater purchases are making decisions based upon an explicit calculation of life-cycle cost. Rather, a high discount rate is just one way to express the observation that equipment price is given more weight (discounted less) by the purchaser than is given to operating expense (discounted more). These higher discount rates were derived for each fuel type by determining the minimum discount rate necessary to make the baseline water heater have the same or lower life cycle cost as the next higher efficiency design option. (The higher discount rates for oil and LPG are taken to be the same as for gas. The discount rate for oil will be updated in future analysis.)

Table 6.4 Water Heater Discount Rates

	Electric	Gas	Oil	LPG
Low	12%	15%	15%	15%
High	191%	83%	83%	83%

To test the sensitivity of the National Energy Savings Analysis to the assumption about discount rates, Table 6.5a shows the equipment price elasticities associated with the "Low" discount rates, and Table 6.5b shows an alternative set of equipment price elasticities based upon a set of "High" discount rates.

Table 6.5a Equipment Price Elasticities of Water Heaters (Low Discount Rates)

MARKET SHARE:	Electric	Gas	Oil	LPG
EQUIPMENT PRICE:				
Electric	-0.16	0.06	0.04	0.04
Gas	0.19	-0.33	0.09	0.00
Oil	0.26	0.36	-0.66	0.13
LPG	0.06	0.00	0.04	-0.12

[d] The market discount rates used here with respect to how purchasers weigh equipment price compared to operating expense in deciding which water heater to purchase are not related to the discount rate used for calculating Net Present Value.

Table 6.5b Equipment Price Elasticities of Water Heaters (High Discount Rates)

MARKET SHARE:	Electric	Gas	Oil	LPG
EQUIPMENT PRICE:				
Electric	-1.59	0.63	0.40	0.40
Gas	0.71	-1.24	0.36	0.00
Oil	0.95	1.30	-2.37	0.47
LPG	0.23	0.00	0.14	-0.46

The cells in Tables 6.5a and 6.5b show the elasticities of market share by fuel type (columns) for residential water heaters as a function of the equipment price by fuel type (rows). For example, in Table 6.5a the market share for electric water heaters has an elasticity of -0.16 with respect to the equipment price of electric water heaters, and an elasticity of 0.19 with respect to the equipment price of gas water heaters. Negative values indicate that higher prices cause lower market shares for the same fuel type ("own elasticities"), while positive values indicate that higher prices of one fuel type cause higher market shares for a different fuel type ("cross-elasticities").

The choice of elasticities, combined with projections of future prices, will impact the projections of market shares by fuel type. The larger the price changes and the elasticities, the more will market shares change, particularly if the price changes differ by fuel type.

6.1.1.6 Model for projecting water heater shipments

This section presents: (1) major factors that have influenced shipments in the past, or new factors which are anticipated to influence shipments in the future; and (2) recent projections of shipments.

Major historical factors that may influence the number of residential water heaters shipped in future years include:

- number of existing water heaters retiring
- new households constructed

Factors that may influence the market shares of competing fuels include:

- fuel availability
- installed cost (equipment and installation)
- operating expense
- utility programs
- energy efficiency standards

New factors may include: (1) changes in pricing associated with mitigation of gas vapor ignition by gas-fired water heaters; (2) changes in future energy prices; and (3) the relative stringency of new energy efficiency standards on water heaters of different fuel types, as they

affect both pricing and operating expenses. These new factors may lie outside the range of historical experience.

An accounting model has been developed to project future national shipments of water heaters by fuel type. The model separates water heater purchases into two markets: new housing and replacement of water heaters in existing housing. If the elasticities are set to zero ("Accounting Only"), the model ignores economic factors, and provides a first estimate of shipments based upon numbers of housing units and percent of each house type that has residential storage water heaters by fuel type. Including purchase price and operating expense elasticities ("Accounting and Elasticity") provides a refinement to the estimate of shipments obtained in the accounting mode.

Table 6.6 shows the different variables impacting shipments that are included in the National Energy Savings Analysis. Results reported below include accounting and elasticities.

Table 6.6 Variables accounted for by forecasting approach

Mode	**Variables Accounted For:**				
	water heater replacements	number of new households	saturation	water heater lifetime	price & operating cost & elasticities
Accounting only	X	X	X	X	
Accounting and Elasticity	X	X	X	X	X

The accounting model seeks to forecast shipments by determining sales destined for new homes plus sales of replacement water heaters to existing houses meant to replace water heaters being retired from service. The accounting model is described by the equation:

$$Wh_{shipments} = [Sat_{new\ home} @ House_{starts}] + WH_{replacements}$$

where $WH_{shipments}$ = Water heater shipments
$Sat_{new\ home}$ = Saturation of water heaters in new housing starts
$House_{starts}$ = New housing starts
$WH_{replacements}$ = Water heaters retired from service

Water heater saturations in new housing starts are projected to remain around 96%, with the remaining 4% being shared systems, not of interest here. The number of water heaters retired are based on the number shipped in the past and a distribution of water heater life expectancies (Section 6.1.2). The life expectancy varies by fuel type.

6.1.1.7 Future shipments of residential water heaters

Two figures show historical shipments and projections of future shipments according to the "Accounting Only" and "Accounting and Elasticity" models for electric and gas (Figure 6.7) water heaters, respectively. In this case, the model provides projections starting in 1981, for comparison with the recent history of shipments. Including the elasticities improves the fit to historical shipments. In these figures, future equipment prices are assumed the same every year, so the effect of elasticities on shipments is from changes in operating expenses over time as energy prices change.

Figure 6.6 Shipments of Electric Water Heaters

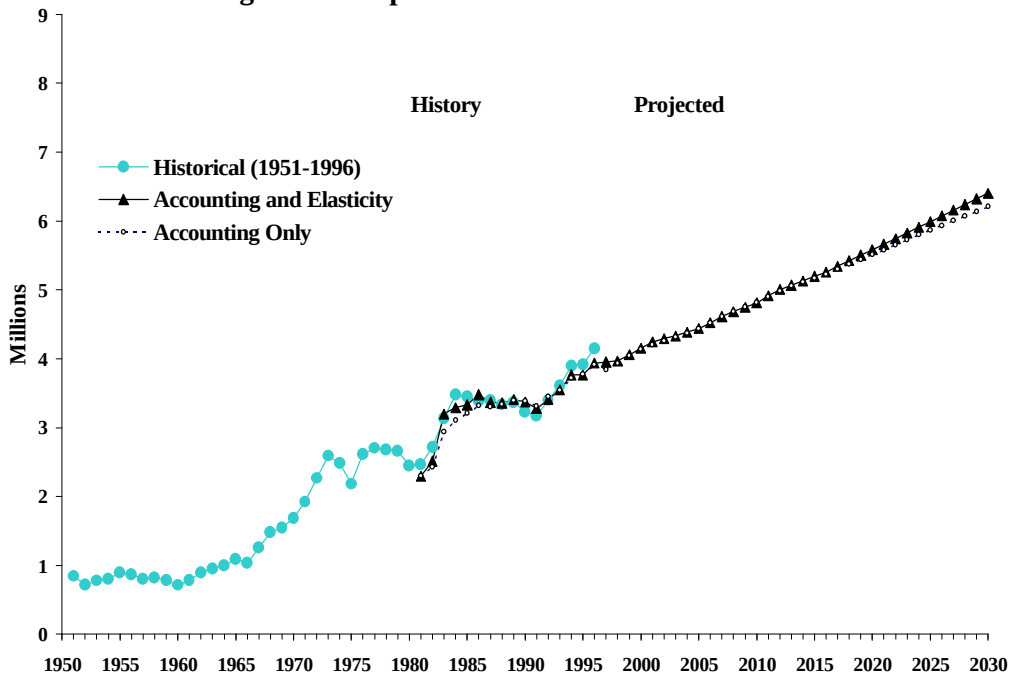


Figure 6.7 Shipments of Gas Water Heaters

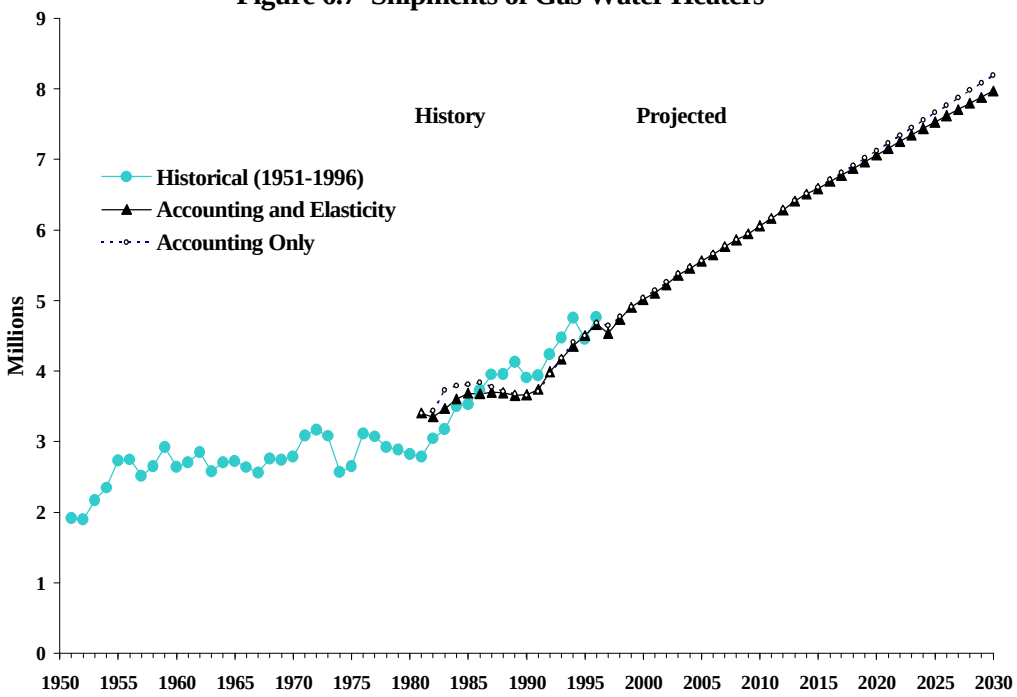
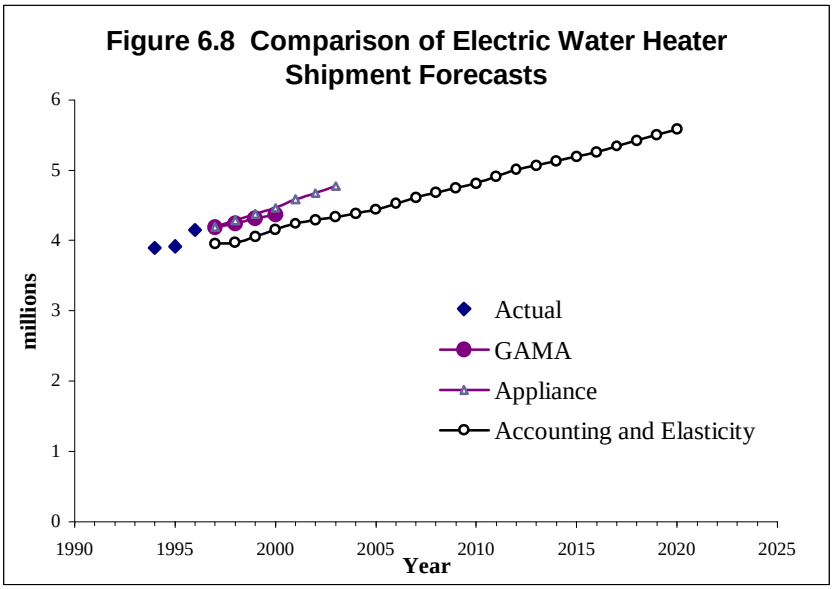
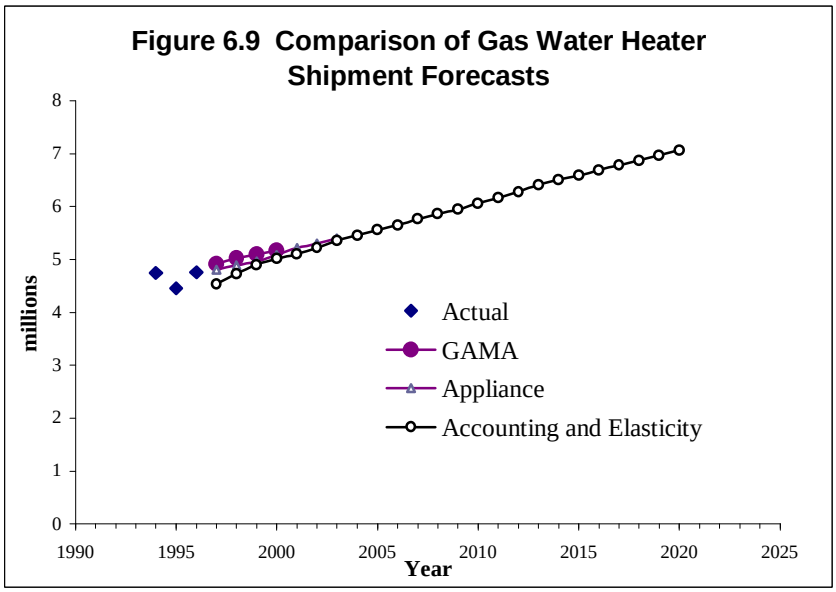


Figure 6.8 and Figure 6.9 compare the results of the "Accounting and Elasticity" model with other forecasts. The sources of other projections are: "GAMA"[11] and "Appliance"[12].

Figure 6.8 Comparison of Electric Water Heater Shipment Forecasts





6.1.2 National Energy Savings

This section provides the definition of national energy savings. The following section (6.2 Quantities and Assumptions) discusses inputs.

6.1.2.1 Method

National annual energy savings are calculated as the difference between two projections: a base case (without new standards) and a standards case. Positive values of NES correspond to energy savings, that is, energy consumption with standards is less than energy consumption in the base case.

$$NES_y = AEC_{base} - AEC_{standard}$$

Cumulative energy savings are the sum over some period (e.g., 2000-2030) of the annual national energy savings.

$$NES_{cum} = \sum NES_y$$

The national annual energy consumption is calculated according to the following equation:

$$AEC = \sum STOCK_v * UEC_v$$

For the above expressions, the quantities are:

AEC	=	Annual energy consumption each year (Quads), summed over vintages of water heater stocks, V.
NES	=	Annual national energy savings (Quads)
$STOCK_V$	=	Stock of water heaters (millions of units) of vintage V surviving in the year for which annual energy consumption is being calculated. Vintages range from 0 (new)- to 19-years old.
UEC_V	=	Annual energy consumption per water heater (kWh electricity, MMBtu gas or oil). [NOTE: electricity consumption is converted from site energy (kWh or MMBtu) to source energy (Quads) by applying a time dependent conversion factor. See quantity "src_conv" below in discussion of AEC.]
V	=	Year in which the water heater was purchased as a new unit.
y	=	year in the forecast (e.g., 2000-2030)

6.1.2.2 Voluntary programs

The U.S. Department of Energy is conducting research on electric heat pump water heaters and hopes to increase their market penetration. The Federal Energy Management Program provides government purchasers with information about higher energy efficiency models available and their life-cycle costs. The extent to which these and other programs are expected to alter the current mix of energy efficiencies in the absence of new standards will be included in future analysis.

6.1.3 Net Present Value

Net present value (NPV) is the value today of a future stream of savings less expenditures.

In the NES spreadsheet table labeled "Cost and Net Present Value," "Total Fuel Savings" is the present value of the savings. "Total Equipment Cost" is the present value of increased purchase prices. "Net Present Benefit" is the difference between "Total Fuel Savings" and "Total Equipment Cost." "Benefit/Cost Ratio" is the ratio of "Total Fuel Savings" to "Total Equipment Cost."

6.2 QUANTITIES AND CURRENT ASSUMPTIONS

This section provides information about the quantities and assumptions used to calculate shipments, national energy savings, and net present values for water heater standards. For each quantity, the discussion includes:

- definition
- approach
- current assumption

Section 6.2.1 describes quantities and assumptions used to calculate shipments. Section 6.2.2 describes quantities and assumptions used to calculate energy savings. Quantities and assumptions used to calculate net present value are described in section 6.2.3.

6.2.1 Shipments

This section provides information about the quantities and assumptions used to calculate shipments of residential water heaters.

Table 6.7 shows the quantities and their locations in the SHIPMENT spreadsheet (SHIPWH01.XLS). For example, the electric water heater shipments, historical and projection to 2030, are in sheet "Elec WH".

Table 6.7 Water Heater Shipments Forecast and Their Locations in the SHIPMENT Spreadsheet

QUANTITY	SHEET
Electric Water Heater Shipments	Elec WH
Gas Water Heater Shipments	Gas WH
Oil Water Heater Shipments	Oil WH
New Houses Projection	Elec WH, Gas WH and Oil WH
Energy Price Projection	Energy Price
Retirement Function of Water Heaters	retirement function
Market Shares by Fuel for Replacements	Market Share (Repl)
Market Shares by Fuel for New Installations	Market Share (New)

Water Heater Shipments

Definition. Annual shipments of residential water heaters by fuel type.

Approach. The following discussion applies to the forecast of shipments for electric, gas and oil water heaters. Annual water heater shipments by fuel type are calculated as the sum of water heater installations in new housing and replacement units. Water heater installations in new housing are calculated as the product of the number of new housing units and the market share by fuel type of new water heaters. For each year, the total number of water heaters of all fuel types

are summed together to obtain total water heater shipments. See also *Market Shares of New Installations* below. Replacement water heaters by fuel type are allocated according to the market shares calculated for replacements; see *Market Share of Replacements* section.

New Housing Unit Projection

Definition. Number of new housing units completed by year.

Approach. A projection of new housing construction by year is an input[13].

Current Assumption. The new housing units projection is obtained from Annual Energy Outlook 1998[11].

*Energy Price Projection*s

Definition. National residential energy prices by fuel by year.

Approach. Projected average residential energy prices are input by fuel type by year. (In future analyses, marginal energy prices are expected to be used.) Eight projections have been collected, five of which are in the current National Energy Savings spreadsheet, and one in the shipments spreadsheet. In future analysis, we expect to offer a menu of at least three alternative energy price projections. Discussion about the appropriate set of scenarios to include in future analysis is expected.

Current Assumption. Residential energy price projections for shipments are currently obtained from Annual Energy Outlook 1998[11]. For the National Energy Savings, the current menu includes five scenarios: three scenarios from the Annual Energy Outlook 1998 (reference, low economic and high economic), one from the Gas Research Institute 1998 Baseline Projection, and constant energy prices.

Retirement Functions

Definition. Fraction of units shipped that remain in service, as a function of years since purchase.

Approach. The minimum, maximum and average life times of electric and gas water heaters are represented as triangular distributions, which are then used to calculate the fraction of units retiring by age. The life expectancy for oil water heaters is assumed to be the same as that of gas water heaters.

Current Assumptions. Minimum, maximum and average life expectancy of electric and gas water heaters are from *Appliance, 1998*[3]. For electric water heaters, lifetimes range from 4 to

19 years, with an average of 12 years. For gas water heaters, lifetimes range from 3 to 15 years, with an average of 9 years[3]. Triangle distributions use minimum, average, and maximum lifetimes for each fuel type to define the retirement rates of the water heaters. All retired units in each year are assumed to be replaced.

Market Shares of New Installations

Definition. Fraction of new housing units having water heaters of each fuel type, by year.

Approach. Market shares from 1981 to 1993 for new houses are taken from the Residential Energy Consumption Survey (RECS), 1993[2]. The spreadsheet starts forecasting the market shares of new installations from 1994 onwards based on the following equation

$$\ln\left(\frac{MS_j}{1-MS_j}\right) = a_j + \sum_{all\ i} b_{ij} * \frac{OC_n^j}{OC_0^j} + \sum_{all\ i} c_{ij} * \frac{P_n^j}{P_0^j} + d_j * \frac{HI_n}{HI_0}$$

where MS_j = Market share for fuel type j in year n, where j can be electric, gas or oil
a_j = a constant term calibrated to the latest historical market shares in 1993.
b_{ij} = Operating cost coefficients derived from operating cost elasticities. i is a fuel types index like j.
c_{ij} = Equipment price coefficients derived from equipment price elasticities.
d_j = Income coefficients derived from income elasticities.
OC^j_n = Per unit operating cost in year n for water heaters of fuel type j.
OC^j_0 = Per unit operating cost in year 1993 for water heaters of fuel type j.
P^j_n = Equipment price for water heaters of fuel type j in year n.
P^j_0 = Equipment price for water heaters of fuel type j in year 1993.
HI_n = Income per household in year n.
HI_0 = Income per household in year *1993*.

The operating cost coefficients b_{ij}, equipment price coefficients c_{ij} and income coefficients d_j are all derived by dividing the corresponding elasticities (see Tables 6.3, 6.4, 6.6a and 6.6b) by some constants. *Note: i represents the rows and j represents the columns in those tables.* The constants are 1 minus the stock saturation in 1981 for water heaters of each fuel type j. For example, the operating cost elasticity of electric water heaters is -1.0 and the saturation of electric water heaters in 1981 is 0.31, then the operating cost coefficient = -1.0 / (1 - 0.31) = -1.45.

The constant term a_j in the above equation is calibrated to satisfy the initial market shares in 1993. The market shares that are calculated are normalized (scaled so the sum over all fuels equals all housing units), and then multiplied by the total number of new houses in a year to obtain the shipments for new installations.

Current Assumptions. The fraction of new housing units with shared water heaters remains constant over time. Market shares change over time as a function of changes in equipment prices, energy prices, and water heater energy consumption. Annual unit energy

consumption and equipment price of water heaters remain constant over time in the baseline case, but will change due to new standards. The annual operating costs of water heaters in the base case vary only from changing energy prices in the energy price projections.

Market Shares of Replacements

Definition. Fraction of retiring water heaters that are replaced, by fuel type.

Approach. The equation to calculate the market shares of replacement units is identical to that for new installations (see above section). The equation is, however, calibrated to the replacement market shares in 1981 and the spreadsheet starts forecasting replacements from 1982.

The set of retired water heaters, to which the derived market shares will be applied, has a different mix of fuels in each year. This is a result of the difference in both the lifetimes among fuel types and shipment growth rates. If all the conditions regarding operating cost, equipment price and household income are kept constant over time, the market shares calculated from the equation would remain the same for all years. Therefore, the equation, by itself, is not sufficient to derive the market shares because it does not take into account the variation in the mix of retiring water heaters.

To overcome this problem, the percentage of each fuel type in the pool of all retiring water heater is noted for each year. These percentages are compared to those in 1981 and the ratio is used to scale the market shares calculated from the equation.

For example, in 1981, the initial market shares for water heater replacements are assumed to be 36% electric and 64% gas, based on the percentages of electric and gas water heaters in the set of retired water heaters. The percentage of gas water heater retirements (64%) is higher than that of electric (36%) because of larger shipments of gas water heaters prior to 1974 (see Figure 6.1). With parameters calibrated to the initial market shares in 1981, the equation yields market shares (after normalization) of 37% electric and 63% gas in 1997. However, the percentages of electric and gas water heater retirements in 1997 are estimated to be 46% and 54%, respectively. The percentage of electric water heater retirements has risen from 36% in 1981 to 46% in 1997 as electric water heater shipments increased after 1974. To adjust for this shift in fuel shares of retired water heaters, the calculated market share for electric water heaters (37%) is scaled by the relative change in retirement percentages (46%/36%) to become 47%. Similarly, the calculated market shares for gas water heaters (63%) is scaled by 54%/64% to become 53%. The adjusted market shares are then applied to the entire set of retired water heaters to obtain the replacement shipments for electric and gas water heaters.

Current Assumptions. Market shares change over time as a function of changes in equipment prices, energy prices, and water heater energy consumption. Market shares also change because the fuel shares of retiring water heaters vary from year to year.

6.2.2 National Energy Savings

This section provides information about the quantities and assumptions used to calculate national energy savings for water heater standards.

Table 6.8 shows the quantities and their locations in the NES spreadsheet (NES_WH01.XLS). For example, NES occurs in sheets "EWH Stds" and "GWH Stds".

Table 6.8 National Energy Saving Quantities and their Locations in the NES Spreadsheet

QUANTITY	SHEET
National Annual Energy Consumption (AEC)	EWH Base, EWH Stds, GWH Base, GWH Stds
National Annual Energy Savings (NES)	EWH Stds and GWH Stds
Source conversion factor	Elec Conversion
Energy Price Projection	Energy Price
Retirement Function of water heaters	retirement function
Stock of water heaters ($STOCK_v$)	EWH Base, EWH Stds, GWH Base, GWH Stds
Unit energy consumption per Year (UEC)	Engr Data

Note: Sheets "EWH Base" and "EWH Stds" contain calculations for the electric water heater Base Case, and Standards Case respectively. Similar calculations for gas water heaters are contained in sheets "GWH Base" and "GWH Stds".

Annual Energy Consumption (AEC)

Definition. National energy consumption associated with residential water heaters.

Approach. National energy consumption is the product of energy consumption per water heater times the number of water heaters of each vintage. This approach accounts for differences in unit energy consumption from year to year. Average annual energy consumption per water heater by fuel type, from the Life-Cycle Cost Analysis, is an input for the baseline and each of the design options.

$$AEC = \sum STOCK_v * UEC_v$$

Current Assumptions. Energy consumption is calculated at the site (e.g., electricity in kWh consumed in the household, natural gas and oil in MMBtu). Primary energy consumption is calculated from site energy consumption by applying a conversion factor to account for losses, such as losses in generation, transmission and distribution of electricity, or distribution losses for natural gas. See *Source Conversion Factor*, below.

National Energy Savings (NES)

Definition. Energy savings attributable to the new standards.

Approach. Energy savings are calculated as the difference between projected energy consumption in the Base Case (having no new standards) and the projected energy consumption in the Standards Case.

Current Assumptions. Simple subtraction between two projections.

Source Conversion Factor

Definition. For electricity, this is the factor by which site kWh is multiplied to obtain primary (source) Btu. The source conversion factor for electricity accounts for losses in generation, transmission and distribution.

For natural gas, this is the factor by which site MMBtu (million British thermal units) is converted to primary (source) Btu.

Approach. After calculating energy savings at the site, multiply those site energy savings by a conversion factor to obtain primary energy consumption, usually expressed in Quads (quadrillion Btu). This conversion permits comparison across fuels by taking account of the heat content of different fuels and the efficiency of different energy conversion processes.

Current Assumptions. A source conversion factor is applied to site electricity, to convert from site kWh to source Btu. This analysis assumes that the source conversion factor changes over time, and applies annual values. The annual values are the U.S. average conversion factors, calculated from AEO 98[14], Table A4, (DOE/EIA 1997).

A source conversion factor is applied to site natural gas consumption to convert from site MMBtu to source MMBtu. The source energy is defined as site energy divided by 0.9 (AGA, 1998).[15]

Stock of Water heaters by Vintage ($STOCK_v$)

Definition. Number of water heaters purchased in a particular year that survive in a later year. The vintage is the age of the water heater.

Approach. The NES spreadsheet keeps track of the number of water heaters purchased each year. Water heaters are assumed to have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is the survival function. The lifetime was obtained from a trade publication, and verified by comparing historical and recent shipments.

Example: In sheet "EWH Base", cell Z57 shows 4.14 million electric water heaters purchased as new units in year 2000. Cell N69 shows 1.5 million of these will still be in use in year 2012. The vintage of these units in year 2012 is 12 years old (Cell N6).

Current Assumption. The current stock of water heaters is calculated each year, based upon historical shipments and a retirement function (see *Retirement function* in Section 6.2.1 above). For electric water heaters, lifetimes range up to 19 years. For gas water heaters, lifetimes range up to 15 years.

Unit Energy Consumption per Year (UEC)

Definition. Average energy consumed per year for a water heater, by fuel type.

Approach. Energy used by the water heater to provide hot water is simulated for individual households in the life cycle cost analysis. The national average unit energy consumption per water heater by design option is taken from the life cycle cost analysis and used in the national energy savings calculation.

Current Assumptions. A weighted average unit energy consumption for new water heaters is calculated and applied to each year of the projection, based upon the results of the life cycle cost calculations for individual households.

6.2.3 Net Present Value

This section provides information about the quantities and assumptions used to calculate net present value for water heater standards. For each quantity, the discussion includes:

- definition
- approach
- current assumption

Table 6.9 shows the quantities and their locations in the national energy savings spreadsheet

Table 6.9 Net Present Value Quantities and their Locations in the NES Spreadsheet

QUANTITY	SHEET
Discount factor	EWH Stds, GWH Stds
Net Present Value (NPV)[e]	EWH Stds, GWH Stds
Present Value of Costs (PVC)[f]	EWH Stds, GWH Stds
Present Value of Savings (PVS)[g]	EWH Stds, GWH Stds
Total Equipment $Cost_y$	EWH Stds, GWH Stds
Total Operating Cost $Savings_y$	EWH Stds, GWH Stds

Discount Factor

Definition. The factor by which to multiply monetary values in one year, in order to determine the present value in a different year. The Discount Factor for year *t* using a discount rate *r* is described by the equation:

$$\text{Discount Factor} = 1 / (1 + r)^{(t - \text{present year})}$$

Approach. The discount factor depends upon the discount rate and the time period. For example, to discount monetary values in the year 2000 to the value in year 1998, assuming a discount rate of 7%, the discount factor is $1/(1.07)^2$ or 0.816.

Current Assumptions. The discount rate is assumed to be 7% real. The present year is defined to be 1998, for consistency with the year in which the manufacturing cost data was collected.

Net Present Value (NPV)

Definition. The value in the present time of a time series of costs and savings.

Approach. Net present value is described by the equation:

$$NPV = PVS - PVC$$

[e] Referred to in the spreadsheet as "net present benefit."

[f] Referred to in the spreadsheet as "total equipment cost" (discounted).

[g] Referred to in the spreadsheet as "total energy savings" (discounted).

where: PVS = present value of savings ("Total Fuel Savings")

$$= \sum TotalOperatingCostSavings_y * DiscountFactor_y$$

PVC = present value of costs ("Total Equipment Cost")

$$' \; \mathbf{j} \; TotalEquipmentCost_y (\; DiscountFactor_y$$

y = Years (from start date of standards to the year when units purchased in 2030 retire)

The net present value is calculated from the projections of national expenditures for appliances, including purchase price and operating costs. Costs and savings are calculated as the difference between a new standards case and a base case without those new standards. Future costs and savings are discounted to the present.

A discount factor is calculated from the discount rate and the number of years between the "present" (year to which the sum is being discounted) and the year in which the costs and savings occur. The net present value is the sum over time of the discounted net savings.

Current Assumptions. The assumptions are contained in the terms PVC and PVS, which are discussed below.

Present Value of Costs (PVC)

Definition. Total equipment cost, discounted to the present, and summed over the time period (from start of standards to year 2030). Total equipment cost includes the price of the water heater plus installation cost.

Approach. Costs are typically increases in purchase price (including installation) in the standards case compared to the base case. Costs are calculated as the difference in installed purchase price for new appliances purchased each year. ("del Unit Price"), multiplied by the shipments in the standards case[h] ("Total Equipment Costs").

[h] Counting the reduction in energy consumption from a reduction in shipments as a savings would be incorrect. If standards cause a decrease in shipments, then using the lower shipments in the standards case reduces the NPV appropriately. To illustrate with an extreme example, if standards cause shipments to be zero, then NPV is zero, no matter what the shipments were in the base case. Using the shipments from the standards case avoids miscounting any reduction in shipments due to standards as a savings.

Current Assumptions. The chief assumption made in calculating PVC lies in determining the discount factor to be applied. Here the discount factor is taken to be 7% (see *also Discount Factor*, above).

Present Value of Savings, PVS

Definition. Annual operating cost savings (difference between base case and standards case) discounted to the present, and summed.

Approach. Savings ("del Unit Op. Cost") are typically decreases in operating costs associated with the higher energy efficiency of appliances purchased in the standards case compared to the base case. "Total Operating Cost Savings" is the product of savings per unit times number of units of each vintage surviving in a particular year. Appliances consume energy over their entire lifetime, in some cases including energy consumed after year 2030.

Net savings each year are calculated as the difference between Total Operating Cost Savings and Total Equipment Costs.[i] The savings are calculated over the life of the appliance, accounting for the energy prices each year.

Current Assumptions. As with PVC, the chief assumptions made in calculating PVS are the unit energy consumption in the standards case (i.e, the standard level), energy price projections, and the discount factor to be applied. For related topics, see *Energy Price Projections* and *Discount Factor*, above, and see *Total Operating Cost Savings*, below.

Total Equipment Cost

Definition. Annual change in purchase price (difference between base case and standards case), multiplied by shipments in the standards case. Purchase price includes installation cost.

Approach. Purchase price per water heater in the standards case is subtracted from purchase price per water heater in the base case for each year. The result is multiplied by the projected shipments in that year.

Current Assumptions. Retail prices of the baseline design and of design options for higher energy efficiency are from the Engineering Analysis**.** See section 6.1.2.1 for a discussion of shipments.

[i] In the spreadsheet, Total Equipment Costs are expressed as a negative number (when standards cause an increase in equipment costs, the difference between the base case and the standards case is negative) then summed with Total Operating Cost Savings (when standards cause a decrease in operating cost, the difference between base case and the standards case is positive).

Total Operating Cost Savings

Definition. Annual national operating cost savings, calculated as the difference between total operating cost in the base case minus total operating cost in the standards case.

Approach. Operating expense per water heater in the standards case is subtracted from operating expense per water heater in the base case for one year. The result is multiplied by the projected shipments in that year. Positive values are savings (e.g., operating costs in the standards case are lower than in the base case).

Current Assumptions. See *Energy per Year* and *Energy Price Projections* in section 6.2.1.

6.3 USER INSTRUCTIONS FOR SPREADSHEETS

The spreadsheets used to obtain these results are available on the U.S. Department of Energy Office of Codes and Standards website at: www.eren.doe.gov/buildings/codes_standards/. There are two spreadsheets, one for shipments and one for national energy savings and net present value.

The spreadsheets posted on the Web represent the latest versions of the applicable models, and have been tested with both EXCEL97 and EXCEL95. At present, in the national energy savings calculation, the user can choose any one of five energy price projections by changing the index in sheet "Setup". The discount rate and the year to which future values are discounted can also be changed by updating certain cells in that sheet. The sheet "Setup" contains a note to the user on how to proceed with any change to those parameters.

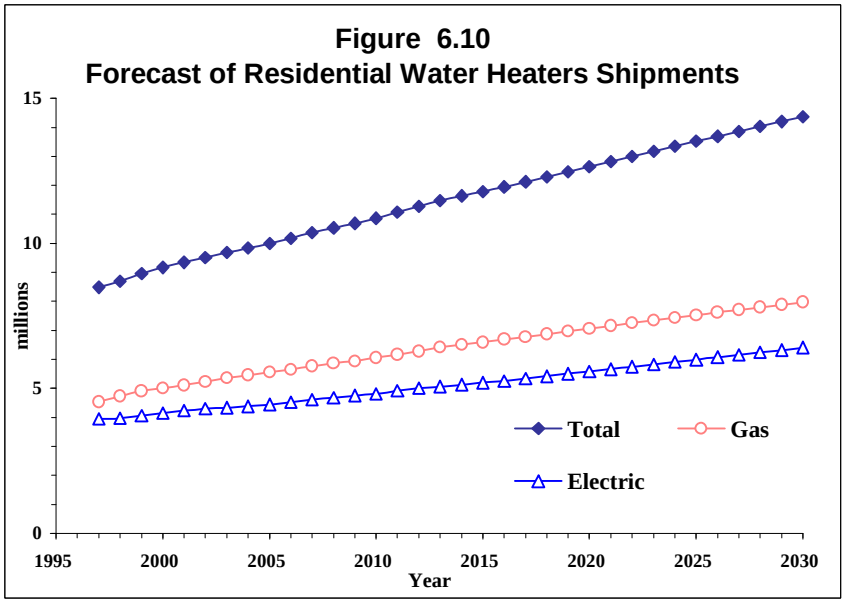
Updates to user instructions will be posted on the Department web site.

6.4 PRELIMINARY RESULTS

Using these assumptions, we highlight preliminary results for the base case in key areas as shown in figures 6.10 to 6.14 below.

6.4.1 Base Case Shipments

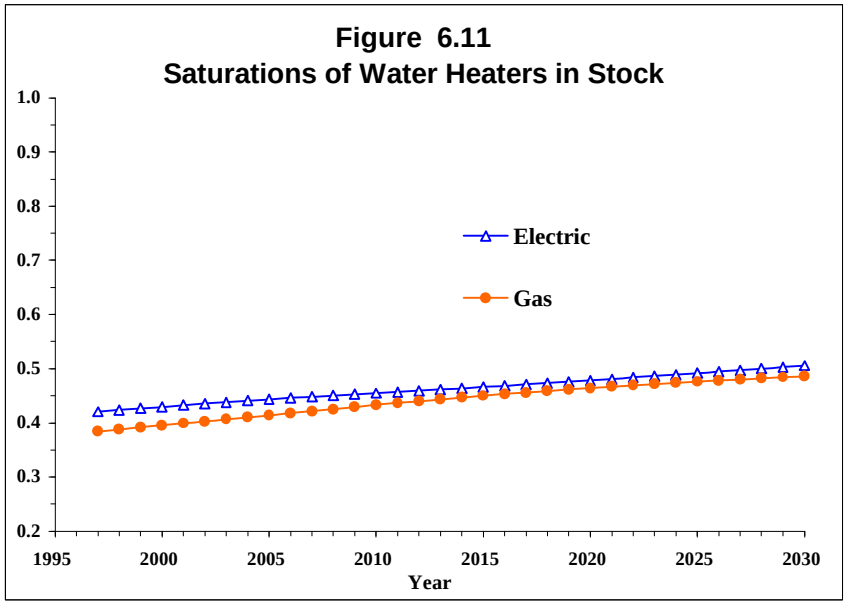
As discussed in section 6.1.2.1 above, the results of the Accounting model are used to establish a base case shipment forecast. The base case forecast is shown in Figure 6.10.



The projected shipments agree well with recent history. On the other hand, Figure 6.11 shows projected saturations that do not agree with the American Gas Association surveys (52% gas) or DOE/EIA 1993 Residential Energy Consumption Survey (38% electric, 53% gas). In particular, the model's saturations of electric water heaters appears high, while saturations of gas water heaters appear low.

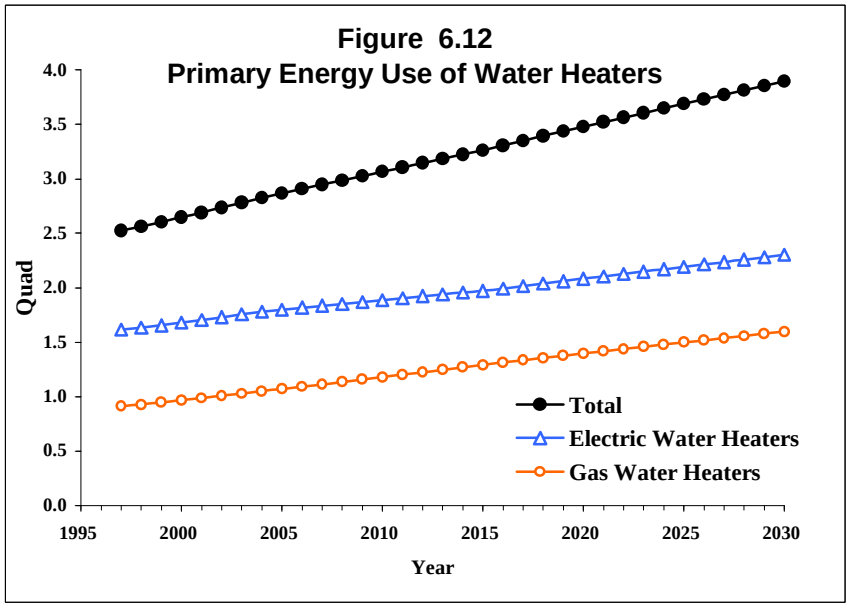
Much of the discrepancy comes from a broader definition for water heaters in the surveys, namely that the surveys include shared water heaters, such as a central water heater serving multiple housing units in a multifamily dwelling. This distinction can be made in the 1993 RECS survey, with the result that residential water heaters serving single housing units have saturations of 37% electric, 46% gas. While there is some uncertainty in those survey results, it appears that some discrepancy remains between modeled saturations and surveys.

Calibrating the model saturations to those other surveys would require different assumptions about either historical shipments or distribution of lifetimes. Assuming that historical shipments accurately represent the residential market, since the shipments projections are in good agreement with recent history, one possibility remains. Further calibration would presumably involve developing new estimates of the distribution of water heater lifetimes for each fuel type consistent with historical shipments, or some other explanation.



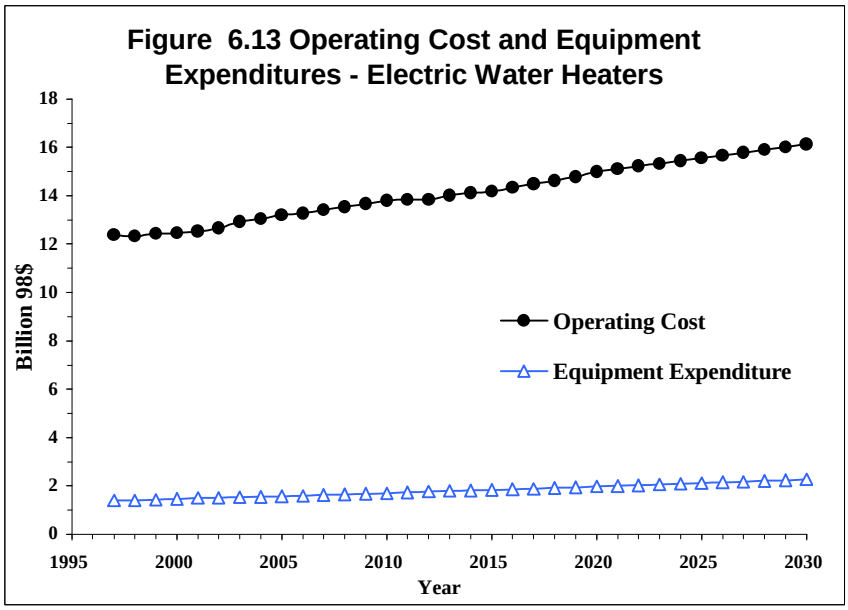
6.4.2 National Energy consumption

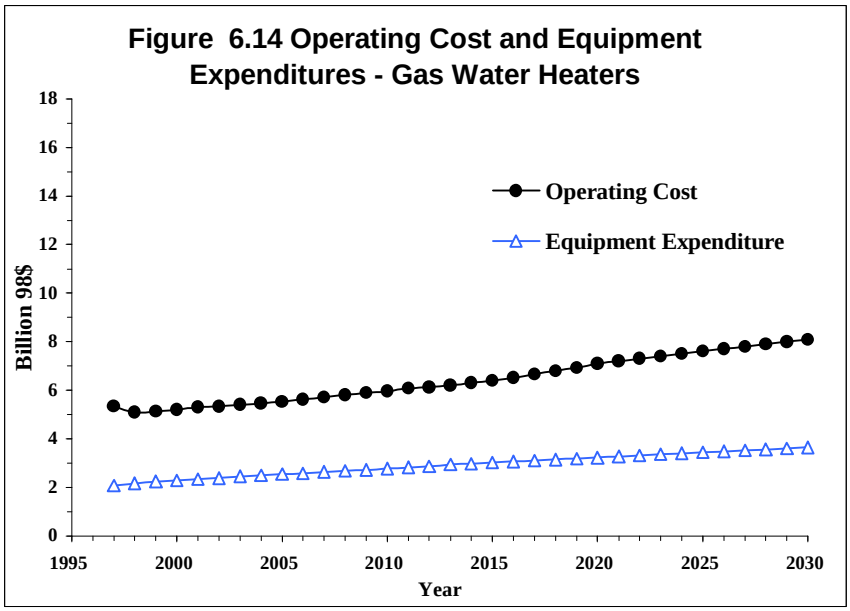
Figure 6.12 shows primary energy consumption of residential water heaters (including primary energy conversion factors).



6.4.3 National Consumer Expenditures

Figures 6.13 and 6.14 show annual operating and equipment expenditures (including installation) for electric and gas water heaters, respectively.





6.4.2 National Energy Savings and Net Present Value from Possible Standards

Future analysis will estimate energy savings from possible standards and associated expenditures.

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