CHAPTER 12. NATIONAL ENERGY IMPACTS

TABLE OF CONTENTS

TABLES

FIGURES

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12.1 INTRODUCTION

In order for a proposed energy efficiency standard to be acceptable, it must be shown to present no net negative economic impact on consumers. The primary tool for judging the value of each proposed standard is a cost-benefit analysis on the scale of the nation as a whole. This chapter reports the details of the methodology of such an evaluation.

Each of the trial standard levels considered in this analysis has the effect of removing the least efficient, and generally least expensive, water heater models from the market. As new water heaters which conform to the standards are shipped, the efficiency of the stock improves. Therefore, the total energy consumption of the stock will decrease relative to the base case. At the same time, however, consumers will be faced with somewhat higher equipment costs. The National Energy Savings (NES) spreadsheet calculates operating and equipment costs to consumers associated with each of the trial standard levels. From these costs, we calculate a Net Present Value (NPV) for each trial standard level relative to the base case. NPV represents the net economic impact of a standard and includes the discounting of future savings and costs. The analysis considers cumulative savings through the year 2030.

The NES spreadsheet is largely dependent on the Shipments spreadsheet described in Chapter 11, which calculates average water heater efficiency, equipment cost, and total shipments by fuel type. National energy impacts are sensitive to water heater shipments for two reasons. First of all, total energy savings due to efficiency standards depend on the size of the water heater stock, and the rate at which older, less efficient water heaters are replaced with new, more efficient ones. Secondly, water heaters using different fuels have different operating and equipment costs associated with them and are affected differently by efficiency standards. Therefore, national energy impacts depend somewhat on the fuel type market shares modeled by the Shipments spreadsheet. All assumptions made about operating and equipment costs, as well as consumer purchasing behavior in reaction to efficiency standards, are contained within the Shipments spreadsheet. The National Energy Savings module makes no additional assumptions about the effects of proposed standards.

12.2 SITE ENERGY SAVINGS

As energy standards take effect in 2004, newly shipped water heaters will be more efficient on average. This will reduce the energy consumed by water heaters at the household level and, for electricity, the amount of energy that utilities need to generate. We distinguish these two types of energy consumption, defining *site* energy consumption as the amount of energy actually consumed in the home, and *source* energy as the amount of energy expended to produce and deliver site energy. In evaluating financial impacts to consumers, we are interested in site energy only, since this is the energy paid for by consumer energy bills.

National site energy savings is the difference between the total site energy consumed by the post-standards stock (Standards Case) and the energy which would have been consumed in the absence of standards (Base Case). Site energy savings are calculated for each year and each fuel type is treated separately. In any given year, the water heater stock is composed of appliances of different ages, or *vintages*. We assume that all vintages before the implementation of standards have the same "base case" average efficiency by fuel type, and that all vintages after standards have the same "standards" average efficiency. These efficiencies are determined by estimates of current efficiency market shares and its evolution due to standards (See Section 11.3.1). Site energy consumption in year j is therefore a function of how deeply high-efficiency units have penetrated the stock by that year.

Total site energy consumption in year j for all water heaters of fuel type n is given by:

$$AEC_{j,n} = \sum_{V=j-20}^{j} UEC_{V,n} * Stock_{V,j,n}$$

where:

$AEC_{j,n}$	= total annual site energy consumption of water heaters of fuel type n in year j
$UEC_{V,n}$	= average unit site energy consumption of water heaters of fuel type n shipped in vintage year V
$Stock_{V,j,n}$	= number of water heaters of vintage year V still in operation

The surviving stock of each vintage is tracked as part of the shipments module described in Chapter 11. For each year, the sum over the previous 24 years guarantees that all water heaters in operation are accounted for since the maximum expected lifetime of any unit is 21 years.[1]

Annual site energy savings for year j and fuel type n is the difference between $AEC_{j,n}$ for the Base Case and Standards Case:

$$Site\ \ Energy\ \ Savings = \Delta AEC_{j,n} = AEC^{0}_{j,n} - AEC_{j,n} \qquad \textbf{Eq. 12.1}$$

Energy savings technology, and therefore the efficiency improvement of a water heater varies by fuel type. For this reason, it makes sense to calculate site energy savings for each fuel type individually. While the *overall* water heater stock is not expected to be affected by standards, fuel type market shares *are* expected to change somewhat, causing an increase of the stock of one fuel type at the expense of the others. Thus, *site energy savings by fuel type depends on market share shifts*. This effect tends to enhance the energy savings for one fuel type while reducing (or even eliminating) savings for another.

The impacts on energy savings due to market share shifts can best be understood by dividing Eq. 12.1 into two components, one of which represents *efficiency*-related savings, the other *market-share-shift* related savings. We define efficiency-related savings as those effects resulting from increased average water heater efficiency. We define market savings as the effect on energy consumption due to an increase or decrease in stock of the fuel type in question. While the efficiency-related savings is always positive, the market component can be either positive or negative, thus enhancing or mitigating overall savings.

Efficiency and market components to energy savings can be made explicit by making the substitution $AEC = U\,N$, giving:

$$\Delta AEC = AEC^0 - AEC = N^0U^0 - NU \qquad \textbf{Eq. 12.2}$$

where

N^0	=	Total number of water heaters in stock in Base Case
N	=	Total number of water heaters in stock in Standards Case
U^0	=	Annual average unit energy consumption in Base Case
U	=	Annual average unit energy consumption in Standards Case

We have omitted the subscripts j and n for simplicity.

Next, we make the substitution $N=(N^0+\Delta N)$ and $U=(U^0-\Delta U)$, where ΔN is the increase in stock, and ΔU is the *decrease* in unit energy consumption due to standards:

$$\begin{aligned}\Delta AEC &= N^0U^0 - (N^0+\Delta N)(U^0-\Delta U) \\ &= N^0U^0 - N^0U^0 + N^0\Delta U - \Delta N\,U^0 + \Delta N\,\Delta U \\ &= N^0\Delta U - \Delta N\,U^0 + \Delta N\,\Delta U \\ &= N^0\Delta U - \Delta N\,(U^0 - \Delta U) \\ &= N^0\Delta U - U\Delta N \qquad \textbf{Eq. 12.3}\end{aligned}$$

In Eq. 12.3, the contribution to energy savings is explicitly split into a term $N^0\Delta U$, proportional to the unit decrease in energy consumption (efficiency savings), and a term $-U\,\Delta N$ proportional to the induced change in fuel type stock (market savings).

Site energy savings are shown for all four fuel types in Figure 12.1, for four standards levels.

12.3 OPERATING COST SAVINGS

The money saved by consumers as a result of efficiency standards can be calculated directly from site energy savings. Operating cost savings is the product of total site fuel savings and fuel price. Energy price projections are taken from the *Annual Energy Outlook 2000* (*AEO2000*).[2]

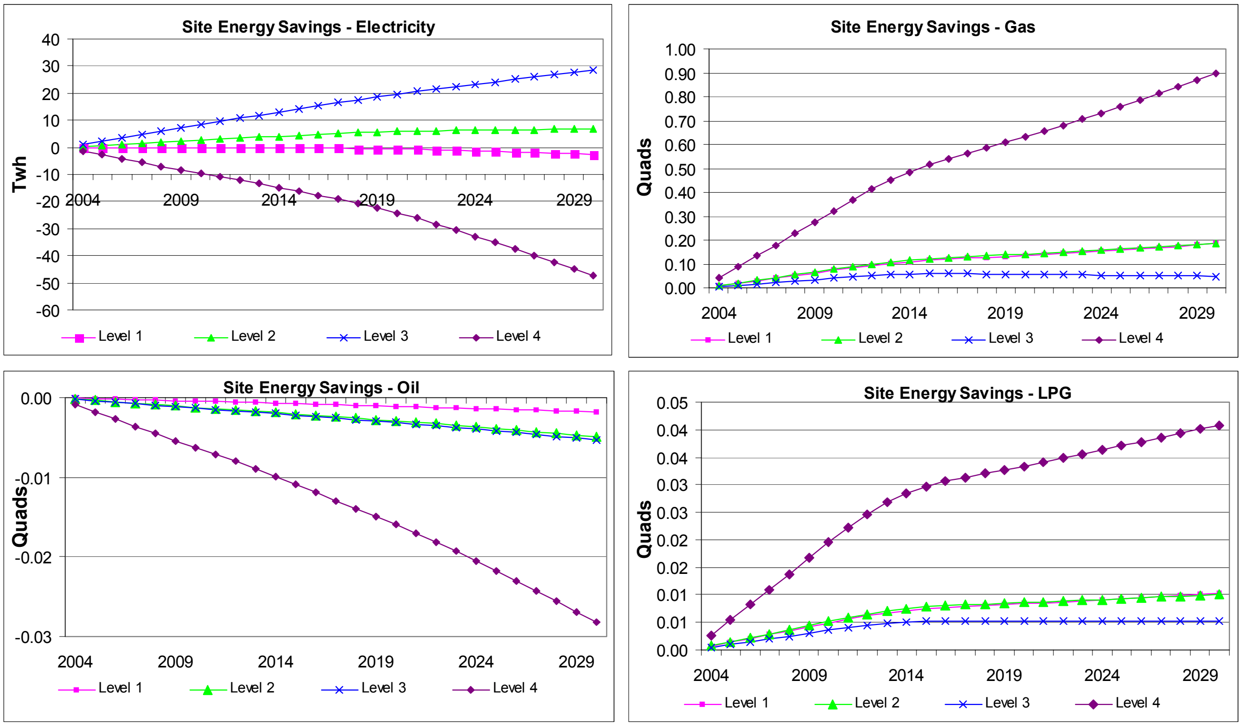

Figure 12.1 Incremental Site Energy Savings by Fuel Type

Operating cost savings, $\Delta OC_{j,n}$, is calculated for each year and fuel type:

$$\Delta OC_{j,n} = Energy\_Price_{j,n} * \Delta AEC_{j,n}$$

where

$\Delta OC_{j,n}$	=	Energy cost savings for fuel type *n* in year *j*
$Energy\_Price_{j,n}$	=	Marginal energy price for fuel type *n* in year *j*
$\Delta AEC_{j,n}$	=	Annual site energy savings for fuel type *n* in year *j*

In this equation, the *marginal* price for each fuel is used. The marginal price represents the cost of the 'last' unit of energy used. In other words, it is the dollar savings on a consumer's energy bill that reflects the consumption of one less unit of energy. Marginal prices are provided by a study performed at LBNL.[3, 4] In addition to the *AEO2000* base case predictions, energy savings can be calculated based on prices in Low and High Economic Growth scenarios, also provided by *AEO2000*. We also include forecasts from the Gas Research Institute for comparison.[5]

Due to its dependence on site energy savings, consumer energy cost savings can be affected significantly by shifts in fuel type market share. Additionally, each of the fuel types has a different cost savings associated with energy savings, since the price of each fuel is different. Specifically, electric water heaters cost roughly twice as much to operate as gas-fired water heaters. Therefore, increases in the market share of electric water heaters will, in general, negatively affect overall consumer energy cost.

12.4 EQUIPMENT COST

In assessing financial benefits of energy standards to consumers we must account for increases in equipment costs. Equipment costs for a given year equal average retail price plus installation cost, multiplied by shipments for that year. Average equipment cost for each design option comes from the Life-Cycle Cost Analysis (see Chapter 9). The shipments module weighs pricing of each design option by the expected market share of each (see Chapter 11).

The differential equipment cost is the difference between equipment costs in the Standards and the Base Case, given by:

$$\Delta EC = EC - EC^0 = SC - S^0C^0$$

where

EC	=	Total equipment cost in Standards Case
EC^0	=	Total equipment cost in Base Case
C	=	Unit equipment cost in Standards Case
C^0	=	Unit equipment cost in Base Case
S	=	Annual shipments in Standards Case
S^0	=	Annual shipments in Base Case

As in Eq. 12.2, the year and fuel type subscripts j and n are implicit. Making the substitution $S=(S^0+\Delta S)$ and $C=(C^0+\Delta C)$ gives:

$$\begin{aligned}\Delta EC &= (S^0+\Delta S)\ (C^0+\Delta C) - S^0C^0 \\ &= S^0C^0 + S^0\Delta C + \Delta S\, C^0 + \Delta S\, \Delta C - S^0C^0 \\ &= S^0\Delta C + \Delta S C^0 + \Delta S\, \Delta C \\ &= S^0\Delta C + \Delta S\, (C^0 + \Delta C) \\ &= S^0\Delta C + C\, \Delta S \qquad \textbf{Eq. 12.4}\end{aligned}$$

As in Eq. 12.3, the first term in Eq. 12.4 is the efficiency term, equal in this case to the average unit differential cost of a water heater, multiplied by total Base Case shipments. The market term here is the average per unit cost of a water heater multiplied by the difference in shipments of that water heater fuel type between the Standard and Base Cases. In general, most of the differential equipment cost comes from the efficiency term. The market term represents the differential cost due to the increase or decrease in shipments of a particular water heater fuel type in response to a standard. As in the case of energy savings, a market differential cost for one fuel type is compensated roughly by an opposite market differential cost for the other fuel types.

It is important to note that equipment prices for gas and LPG units rise significantly in 2003 due to implementation of a flammable-vapor ignition-resistant design, independent of efficiency standards. The 2003 baseline case for equipment costs includes these cost increases and therefore is used for comparison with efficiency trial standards.

The evolution of operating cost savings and the compensating effect of incremental equipment cost over time is shown in Figure 12.2. Positive net savings in Trial Standard Level 3 are significantly greater than in Levels 1 or 2.

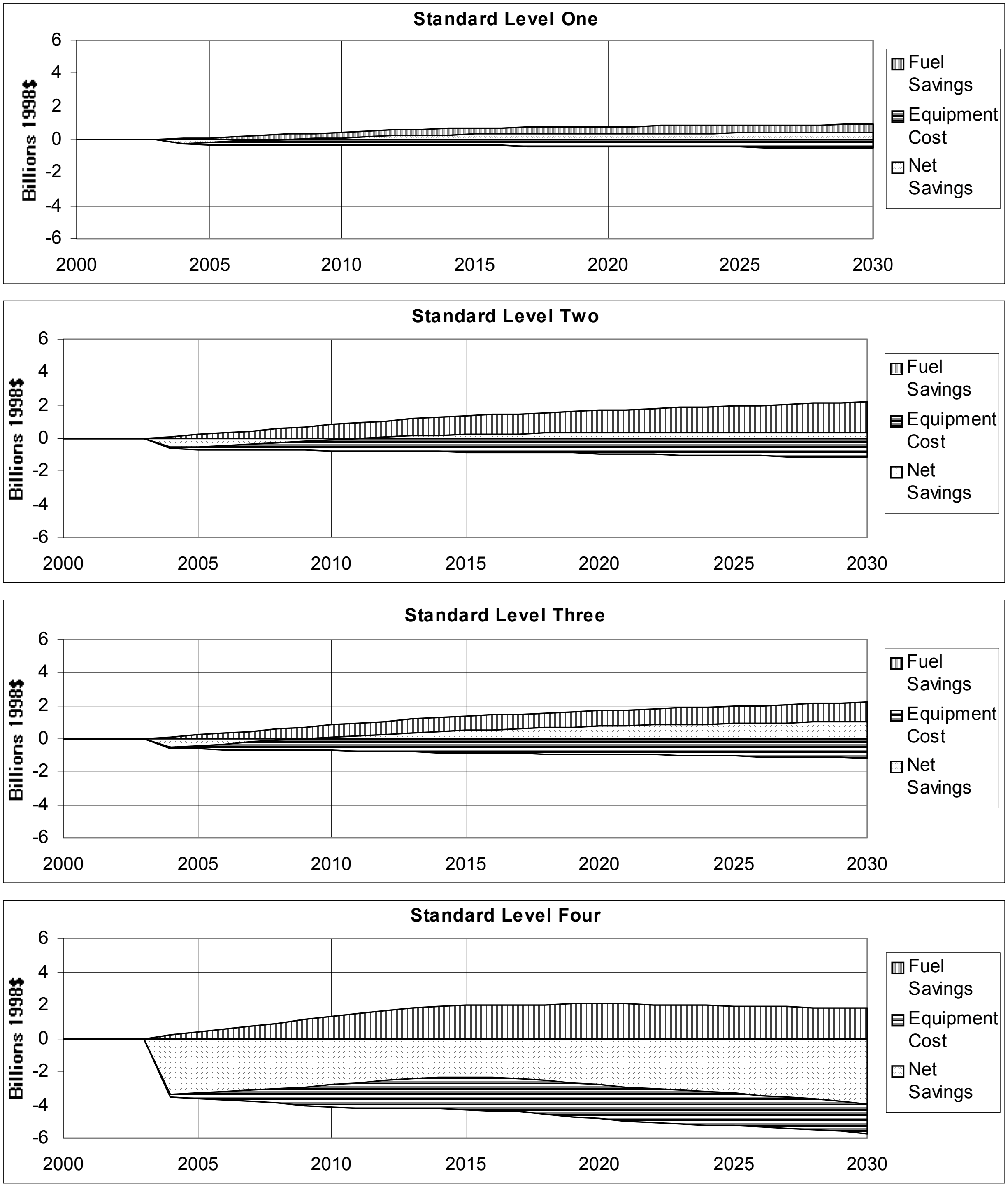

Figure 12.2 Fuel Savings, Equipment Cost, Net Savings

12.5 NET PRESENT VALUE

The NES spreadsheet calculates a cost-benefit figure of merit in terms of NPV. NPV for fuel type n is given by:

$$NPV_n = \sum_{j=2004}^{2030} Discount\ Factor_j * (\Delta OC_{j,n} + \Delta EC_{j,n}) \qquad \textbf{Eq. 12.5}$$

where equipment cost savings are generally negative. Present values account for the fact that a savings (or loss) experienced in the future is not as significant as one experienced today. This downscaling of future financial gains and losses is achieved through the use of discount rates. The discount factor for year j is given by:

$$Discount\ Factor_j = (1 + r)^{-(j - j_0)}$$

where r is the real discount rate, and j_0 is the present year. By default, the analysis assumes a real discount rate of 7% and the present year is taken to be 1998. We apply the appropriate discount factor to arrive at net present value of energy and equipment savings for each year, by fuel type. The total cost-benefit of a given trial standard is the sum of net present value of all fuel types. The NES spreadsheet also provides cost-benefit ratios for comparison of standard levels.

Table 12.1 Net Present Value

Net Present Value (2004-2030) *billion 1998$*					
Standard	**Electricity**	**Gas**	**Oil**	**LPG**	**Total**
Level 1	-1.01	1.91	-0.08	0.39	1.20
Level 2	-0.34	0.22	-0.23	0.22	-0.13
Level 3	3.97	-1.80	-0.25	0.10	2.02
Level 4	-21.93	-1.62	-1.26	-0.13	-24.94

12.5.1 Relative Effects of Efficiency and Fuel Choice

Due to operating cost savings, consumers receive a direct economic benefit from energy efficiency standards. However, efficient appliances are generally more expensive than more energy-intensive ones. Therefore, a standard also imposes a direct efficiency-related equipment cost arising from the factor DC in the first term in Eq. 12.4. Efficiency-related fuel savings and equipment costs are the “direct” savings and costs one expects from an efficiency standard.

Market shifts are influenced by: (1) unit equipment cost, (2) unit operating cost, and (3) household income. Of these, the unit equipment cost is expected to cause the most significant shift in fuel type market share when standards are imposed. Even in the Base Case, some price increase is expected, due to new insulation blowing agents and redesign of gas-fired water heaters to meet requirements for resistance to flammable vapors. After standards are imposed, we assume unit equipment prices (in constant dollars) remain unchanged.

Less important to fuel type market shifts are the effects of operating cost and household income. Operating costs shift abruptly with the onset of efficiency standards. In addition to this effect, however, operating costs are also dependent on fuel prices, which evolve over time. Finally, income also influences fuel type market shares somewhat. The effects of fuel prices and income are slight and gradual, and affect the Base Case as well as the Standards scenarios.

In analyses of standard proposals for other products, there was a deliberate exclusion of part of the contribution to savings associated with market shifts. This was done to avoid overstating savings associated with the standard in an unsaturated appliance market. Freezers are an example of such an appliance. If imposing an efficiency standard significantly raises freezer equipment prices, some consumers may be priced out of the market, resulting in a drop of shipments. While the first term in Eq. 12.3 and Eq. 12.4 correctly accounts for the savings associated with having *more efficient* freezers, the second term counts equipment cost and energy savings associated with having *fewer* freezers. Part of the second term was deliberately excluded from the calculation of NPV for other products, because a reduction in consumer utility should not be counted as an economic benefit.

The case of water heaters is different from that of freezers. Water heaters are treated as a necessity, not as a luxury item. No reasonable standard will affect the percentage of households using a water heater. However, price increases due to standards *may* affect the fuel type mix of the water heater market. In calculating NPV for gas-fired water heaters, for example, the first terms of Eq. 12.3 and Eq. 12.4 represent the fuel savings and operating costs associated with having more efficient and more expensive gas-fired water heaters on the market. The second terms represent the changes in expenditures because gas-fired water heaters have lost or gained market share. Since a shift to or from one fuel type must be compensated by an equal and opposite flow to another fuel type, inclusion of the market term for water heaters does not represent a spurious claim to savings, but correctly accounts for the effects of market shifts.

As an aside, it should be noted that there are some second-order effects of standards on savings by fuel type. Because equipment and operating costs are not identical across fuel types, national savings in one fuel will not exactly compensate for additional national expenses in the others. In addition, the share of shipments of gas-fired water heaters will always be higher than the percent of gas-fired water heaters in the existing housing stock because, on average, gas-fired water heater lifetimes are shorter than electric water heater lifetimes. This difference in lifetimes has a small "compounding" effect that over the years slightly amplifies any changes in market share to gas-fired water heaters.

The relative benefit of trial standard levels, when expressed for a particular fuel type, is significantly influenced by the market shift effects described above. A striking example appears in the NPV for gas water heaters. In this case, the design option for Trial Standard Level 3 was chosen to be identical to that of Trial Standard Level 1. However, NPV for Trial Standard Level 1 is $1.91 billion, while for Trial Standard Level 3 it is -$1.80 billion. Per-unit equipment costs and operating cost savings for gas water heaters are, of course, identical in each of these cases. The large discrepancy in NPV therefore originates entirely from market effects.

The fuel type market share difference between Trial Standard Level 1 and Trial Standard Level 3 arises primarily from the difference in design options for *electric* water heaters. This shift in fuel choices is due to the fact that the average retail price of an electric water heater under Trial Standard Level 3 is $69 more expensive than under Trial Standard Level 1 (see Table 11.2). As a result, electric water heater market shares decrease in Trial Standard Level 3 relative to Trial Standard Level 1. In the period between 2004 and 2030, the shipment model forecasts about ten million fewer electric water heater shipments in Trial Standard Level 3 than in Trial Standard Level 1. This loss in shipments of electric units is compensated by a roughly equivalent gain in gas-fired unit shipments, leading to greater expenditure on gas water heaters.

Exactly how this market shift affects fuel type NPV and the magnitude of the effects can be clarified by examining the calculation of total expenditures and net savings. Total expenditures for fuel and equipment for electric and gas-fired water heaters are shown in Figure 12.3. Total discounted expenditures are shown for the base case, and each of four trial standard levels. The expenditures are summed over the 27 years of the forecast period, and a discount factor is applied to the expenditures.

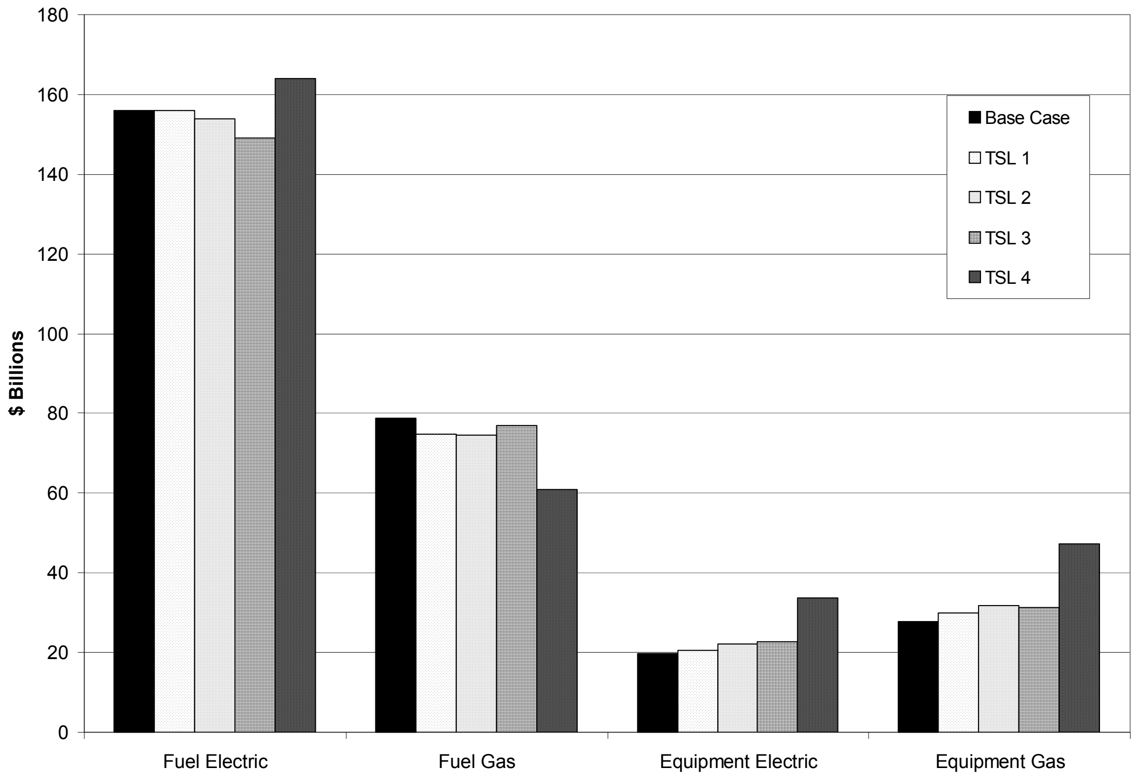

Figure 12.3 Total Fuel and Equipment Expenditures: Electric and Gas-Fired Water Heaters

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Generally, as standards become more stringent (from Trial Standard Level 1 to Trial Standard Level 4), fuel expenditures decrease and equipment costs increase for both electric and gas. One *exception* to the trend of decreasing fuel expenditures and is gas-fired water heaters when moving from Trial Standard Level 1 to Trial Standard Level 3. Both fuel and equipment expenditures actually *increase* slightly between these two standard levels for gas-fired water heaters. Under Trial Standard Level 3, a market shift has occurred so shipments of gas-fired water heaters are about 6% higher between 2004 and 2030 (almost twelve million more units) than for Trial Standard Level 1. This results in an increase in equipment cost of about $1.5 billion compared with Trial Standard Level 1. While the average efficiency of the units are the same for Trial Standard Level 1 and 3, because of the increased shipments under Trial Standard Level 3, there is an increase in natural gas fuel expenditure of about 3%, or about $2 billion.

Because of this market shift, the decrease in fuel expenditures for electric water heaters is larger than can be attributed to efficiency changes alone. Likewise, the increase in electric water heater equipment costs is smaller than would be expected from the change in unit equipment costs alone.

NPV is determined by subtracting incremental equipment costs from fuel savings for each fuel type. The results are shown in Figure 12.4. Here, the NPV for gas is significantly lower for Trial Standard Level 3 compared with Trial Standard Level 1. This is due to the $2.2 billion increase in fuel expenditure of gas water heaters as well as about $ 1.5 billion in increased equipment costs from higher shipments. The result is a gas NPV that is $3.7 billion less for Trial Standard Level 3 than Trial Standard Level 1.

The NPV for electric water heaters for Trial Standard Level 3 is considerably higher than it would be without market shift effects. The combined NPV is therefore much higher in Level 3 than Level 1.

NPV combined across fuel types includes the effect of market share changes induced by revised efficiency standards. Considering NPV separately by fuel type can be misleading because changes in shipments among fuel types (market effects due to price increases) can obscure the expected fuel savings due to improved efficiency (efficiency effects).

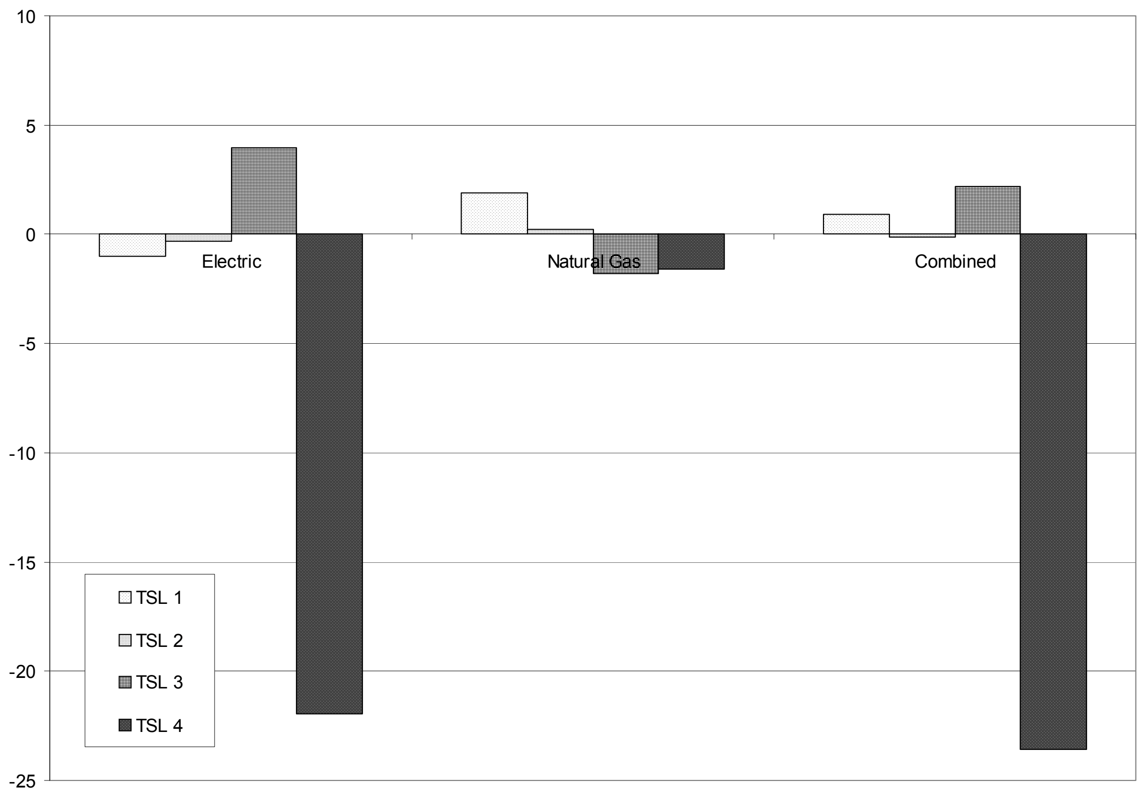

Figure 12.4 NPV for Electric and Gas-Fired Water Heaters and Combined NPV

12.6 SOURCE ENERGY CONSUMPTION

In addition to the site energy savings discussed in Section 12.2, the NES spreadsheet also calculates source energy consumption. Source energy consumption is larger than site consumption because it includes all energy used in energy production and transmission. In the case of electricity, site energy consumption in kWh is multiplied by a time-dependent conversion factor to arrive at source consumption in Btu. Conversion factor data from 1995 through 2030 come from *AEO2000* forecasts.[2] Natural gas losses include pipeline leakage, pumping energy, and transportation fuel. *AEO2000* uses a conversion factor of 1.11, assumed to be constant over time, to calculate source from site energy. For oil-fired and LPG water heaters, source energy accounts for the small amount of electricity they use during operation. Source energy savings are summarized in Table 12.2.

Table 12.2 Cumulative Source Energy Savings for the Period 2004 to 2030

	Level 1	**Level 2**	**Level 3**	**Level 4**
Total Quads Saved Relative to Base Case	3.33	4.47	4.61	11.46

In calculating source energy savings, *marginal* conversion factors are used. These conversion factors take into account the types of power plants that are used at the margin.[a]

Source energy savings, together with NPV, form the basic criterion for assessing the desirability of a particular trial standard level. The optimum standard is the one which maximizes energy savings while providing no net negative economic impact on the consumer. The relative merits of the trial standard levels can be seen in Figure 12.5 below.

Source energy savings increases with each successive trial standard level to Trial Standard Level 4, which represents the maximum *technically* feasible option. This option is associated with a large negative NPV,however.

[a] These marginal conversion factors are based on a computer model run that simulates the behavoir of primary energy consumption under a water heater standard (see the Utility Impacts Analysis, Chapter 14).

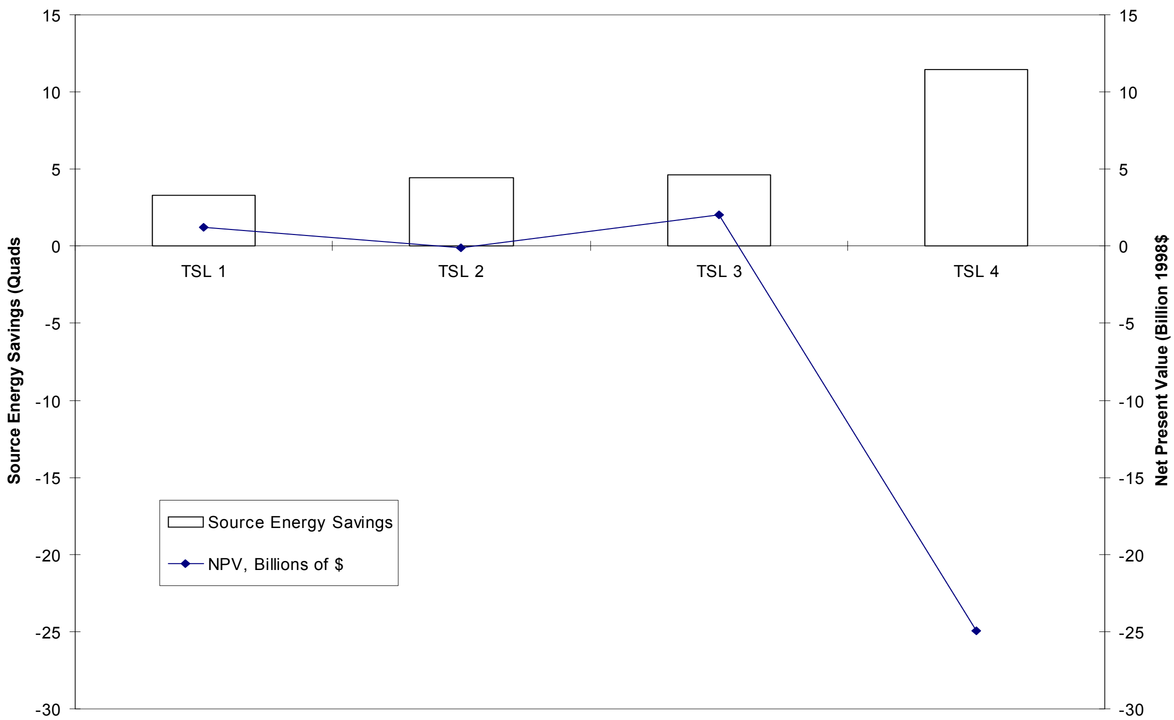

Figure 12.5 Source Savings and Net Present Value

12.5 MODEL SENSITIVITY

As in the case of NPV, source energy savings are affected by shifts in fuel type market shares. Because source energy savings are critical to the Department's choice of policy, we carefully investigated market share effects. In particular, we were concerned about possible inaccuracies in the component of the shipments model that influences fuel type market share. As described in Section 11.3, our estimate of fuel type market shares to new housing is based on an econometric relationship between costs and consumer purchase behavior. Parameters within this model (elasticities) determine the degree of consumer reaction, and therefore the post-standards market configuration.

The effect on source energy savings from new construction market shares is small, since shipments to new construction constitute only 15-20% of total shipments. The majority of water heater shipments are replacements. Most consumers replace their worn-out water heaters with a new one of the same fuel type. We believe it is very unlikely that the price increases which may accompany standards will alter this basic behavior. Market share effects are therefore limited to the small portion of shipments going to new housing. Thus, we can conclude that our estimate of energy savings benefit from standards is not severely impacted, even in the most extreme market scenarios, which we believe to be highly unlikely.

Next, we consider the issue of a dependency to the *relative* benefit of trial standard levels due to an inaccuracy in elasticities in the new housing market share model. Trial Standard Level 3 is very well separated from Trial Standard Level 1. It saves only 0.14 quads more than Trial Standard Level 2, however. Therefore, we consider carefully whether the parameters of the econometric model could influence the relative order of these levels. In other words, is it possible that another, more correct set of elasticities would reveal that Trial Standard Level 2 saves more energy than Trial Standard Level 3, due to the effect of market share shifts?

Without additional analysis, we can reject this possibility based on the composition of the design option combinations used to construct the two trial standard levels. Electric water heater efficiency (hence retail equipment price) in Trial Standard Level 3 is somewhat higher than of Trial Standard Level 2. On the other hand, gas water heater efficiency in Trial Standard Level 3 is lower than that of Trial Standard Level 2 (and equipment prices are lower). Trial Standard Level 3 will therefore induce a higher gas market share *independently of the model parameters*.

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