# Residential Technology Scenario Analysis: Defining the Role of Efficiency Standards, DSM, and Market Forces

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Future end-use markets are being molded by the joint influences of technological change, efficiency standards, utility DSM programs, and market forces. Analysis of these factors requires a well-defined framework for constructing and analyzing consumer decisions within the context of dynamic technology scenarios. These scenarios must allow for the introduction of new equipment design options, restrictions imposed by efficiency standards, and incentives provided by utility DSM programs. It is also necessary to examine interactions among end uses, especially the relationship between improved appliance efficiency and heating and cooling loads.

This paper provides a discussion of technology issues for three major residential end-use categories: refrigerators, central air conditioners, and electric resistance water heaters. The analysis is carried out using the REEPS 2.0 framework. Conclusions are reached about the differential roles of standards, DSM programs, and market forces for each end use.

## Introduction

Residential energy analysis efforts are focusing increasingly on the construction of technology scenarios for the analysis of end-use efficiency. There are three driving forces behind this trend:

- First, changes in end-use technologies and appliance manufacturing methods have changed dramatically the spectrum of efficiency options available to consumers.
- Second, existing and proposed efficiency standards are limiting the efficiency range toward the high end of the efficiency spectrum.
- Finally, within this limited range, utility DSM programs are providing incentives for consumers to purchase the most efficient of the remaining options.

Because of the magnitude of the changes involved, direct analysis of appliance and thermal efficiency has become a planning imperative for utilities. The natural framework for this analysis has two key pieces: (a) a well-defined method for describing dynamic technology scenarios and (b) a robust approach for modeling consumer decisions within the context of these scenarios.

In the specification of technology scenarios, it is not enough to look at current technologies, current standards, and current DSM programs. Instead, it is necessary to construct a long-run technology scenario for each major end-use. In this construction, explicit assumptions are required about the development and introduction of future technology options. Also, explicit assumptions about future changes in efficiency standards are required. Finally, the magnitude and long-run focus of DSM programs must be specified.

This paper presents detailed results of residential technology analysis at the national level. End uses covered include air conditioning equipment, water heaters, and refrigerators. The analysis is carried out using the REEPS 2.0 framework, developed by EPRI. Conclusions are reached about the differential roles of standards, DSM programs and market forces for each product class.

## Framework

To evaluate the relative roles of standards and DSM programs, it is necessary to recognize four distinct types of analysis issues. These are:

- **Building Envelope Efficiency.** The thermal efficiency of the building envelope is an important factor for heating and cooling loads and for ventilation fan energy use. For the most part, thermal efficiency standards apply only to new construction, and must be considered jointly with DSM programs aimed at new construction. Efficiency standards do not typically play a role in the retrofit of existing homes, but DSM programs are often aimed at such changes.

- **Equipment efficiency.** Equipment efficiency standards apply at the time of equipment purchase. DSM programs related to equipment efficiency also apply to purchase decisions. The number of purchases is determined largely by new construction decisions, replacement decisions, and for some appliances, the rate of acquisition in existing homes.

- **Add-on measures.** This area covers measures or devices that alter energy use, given equipment efficiency. For some measures, it is appropriate to treat energy savings as a change in efficiency, for example with water heater blankets. For other measures, it is more natural to record the savings as a change in equipment usage, for example with time clocks or low-flow devices. Add-on measures typically do not involve major equipment expenditures, and they are often covered by DSM programs.

- **Interactions.** There are four main types of interactions that must be considered. These are (a) direct efficiency interactions, (b) internal gains, (c) usage interactions, (d) behavioral interactions.

  - An example of direct efficiency interactions is the multiplicative relationship between thermal efficiency and heating efficiency. A twenty percent improvement in both efficiency aspects will give 36% savings rather than 40%, because the actions compound.

  - All energy using devices give off heat. In many cases, such as inside lighting and first refrigerators, virtually all energy input ends up as "free heat" in conditioned space. This implies strong interactions with heating loads, cooling loads and fan energy requirements.

  - The main usage interactions are for water heating. The presence and features of clothes washers and dish washers directly impact the level of hot water usage, and therefore the value of equipment efficiency gains.

  - Behavioral interactions include rebound effects and any other changes in equipment usage that offset or amplify efficiency gains.

As the following analyses indicate, the relative importance of these analysis aspects differs strongly across end uses. The four analysis components are illustrated in Figure 1.

The analysis framework in REEPS 2.0 has two key parts for modeling of equipment efficiency decisions.

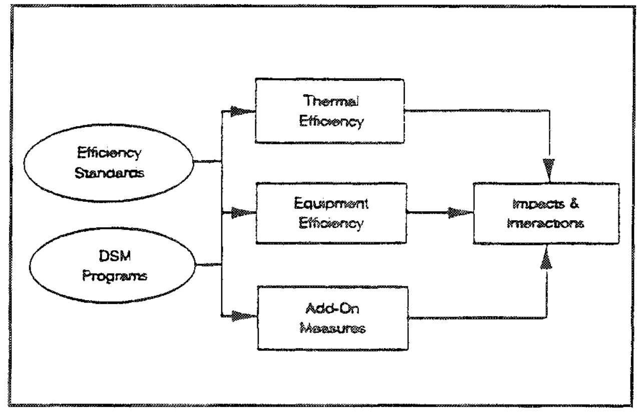


*Figure 1. Four Aspects of Efficiency Analysis*

- The first is a set of methods for describing the range of technology options, including variables for specifying the availability of these options.

  Availability variables include fuel availability, legal availability, and market availability.

- The second is a set of methods for modeling buyer awareness of the options and corresponding decision outcomes. The modeling approach combines decision maker segmentation with multinomial logit and nested logit decision models. Four types of decisions are modeled, including new home decisions, replacement decisions, non-owner acquisitions, and pre-failure conversions.

As appliance purchases are made, standard stock accounting methods are used to compute the gradual change in appliance stock average values.

Descriptions of technology options rely on direct application of a technology language for each end use. Components of the language are appliance size, appliance efficiency, and appliance usage. The concepts that are used for each end use are consistent with standard engineering terms and data reporting methods. For example, when talking about air conditioning, size is measured in kBtu per hour, efficiency is measured by an SEER (kBtu/kWh), and usage is measured in annual hours of use.

For all end uses, efficiency is measured in direct units, so that a larger efficiency value implies a more efficient appliance. Using this approach, Figure 2 depicts the general framework for describing efficiency options.

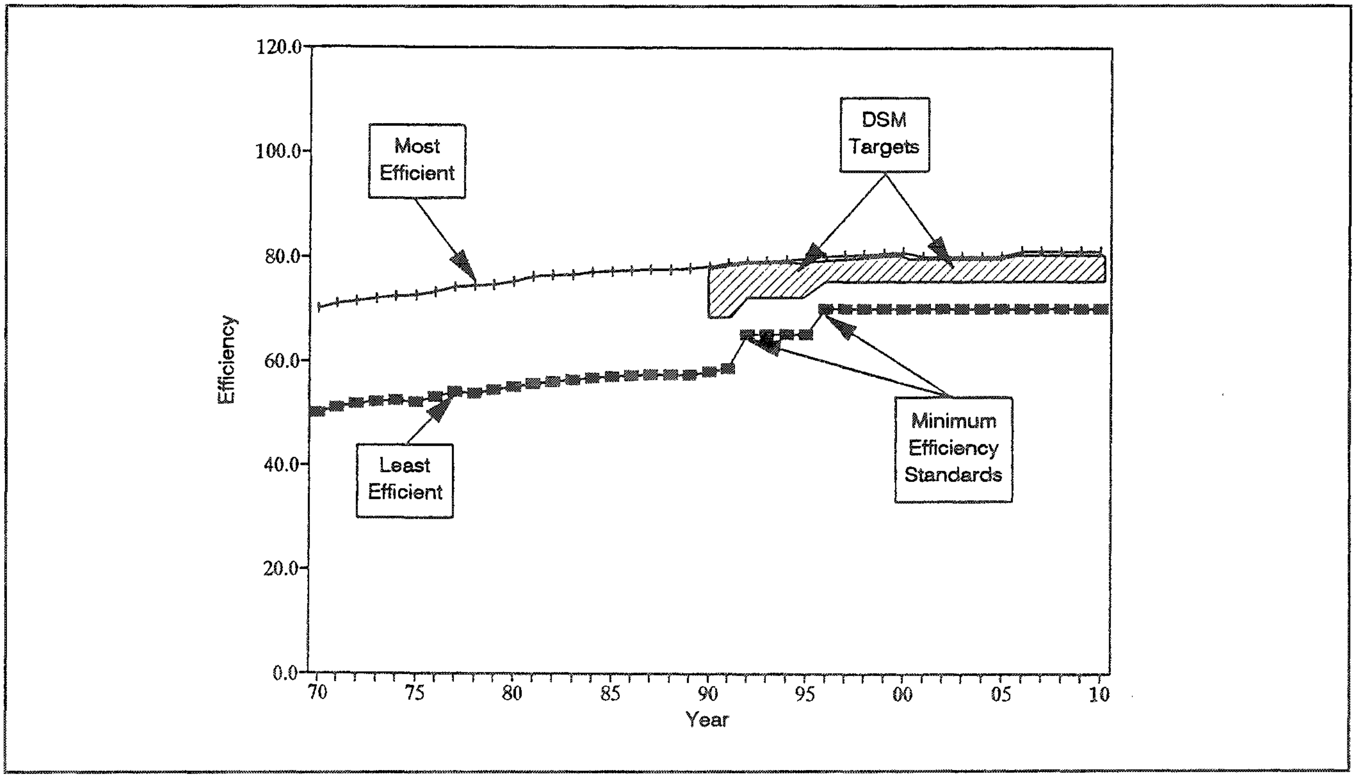


*Figure 2. Framework for Technology Scenarios*

- In any year, the height of the lowest line gives the bottom of the efficiency range, representing the least efficient options that are available in the market.
- The top line represents the high end of the efficiency spectrum, indicating the most efficient options that are available on the market.
- When efficiency standards are introduced, the bottom line will pull upward, as depicted in 1992 and 1996 in the figure.
- Typically, DSM programs target the upper portion of the efficiency range. The minimum required efficiency level for these programs will necessarily change over time, especially as the incidence of standards narrows the range of available options.

The number of specific appliance options actually available in the market is too large to be modeled in detail. For purposes of end-use analysis, similar models are grouped into a set of representative design options. The list of options must cover the entire efficiency spectrum over the forecast period. In the REEPS framework, when a standard is imposed, data for options that are impacted are migrated to the legal boundary. When a DSM incentive is introduced, cost multipliers are applied to the options that are available and that qualify for the incentive.

During the forecast, it may be necessary to introduce new efficiency options to represent upward expansion of the efficiency range due to technological innovation. The efficiency level, appliance cost, and the phasing of availability into the market must be specified for each of these options.

## Refrigerator Analysis

The two key analysis issues for refrigerators are equipment efficiency and thermal interactions with HVAC uses. Refrigerator efficiencies have changed dramatically over the past decade, and another decade of rapid change lies before us. Today, this appliance is in a complete state of technology disequilibrium; new units purchased in the next few years will be radically different from the units that they replace in the existing stock.

In the REEPS national data base (EPRI 1991), the forecast for first refrigerator unit energy consumption (UEC) values gives a decline from about 1250 kWh per year in 1990 to about 720 kWh in 2010. This decline is attributed mainly to the strong 1993 national efficiency standard. The associated loss of refrigerator heat will add almost 8 tWh to electric heating loads, but will reduce electric cooling loads by over 3 tWh. The impact on natural gas and fossil fuel use is an increase of about 130 tBtu, which corresponds to a 3.5% increase in heating energy use in 2010.

**Efficiency Definition.** Efficiency levels for refrigerators are measured by an energy factor (EF). This measure gives the number of cubic feet that can be supported under test conditions by one kWh per day. The units are therefore cubic feet per kWh per day or cft/kWh/day. In general, translation between energy factor and annual energy use under test conditions (UEC) is as follows:

$$UEC = \frac{Size}{EF} x\ Use$$

where Use = 365 test days. As this expression reveals, an efficient unit has a high EF value and therefore a low annual UEC.

The measure of size used in these computations is an adjusted volume, equal to the volume of refrigerator space plus 1.63 times the volume of freezer space. For example, if a unit an 18 cubic foot unit has 14 cubic feet of refrigerator space and 4 cubic feet of freezer space, the adjusted volume is about 20.5 cubic feet (computed as 14 + 1.63 x 4). If a unit with 20.5 cubic feet of adjusted volume uses 1400 kWh per year under test conditions, its energy factor is 5.3 cft/kWh/day (computed as 20.5 x 365 / 1400). If the same unit used 900 kWh, its energy factor would be 8.3.

**Technology Issues.** The basic function of a refrigerator is to create and maintain a temperature differential, with low temperatures inside the unit compared to the surrounding air. For a given type and size, the major factors that determine refrigerator energy use under test conditions are the levels of wall and door insulation, compressor efficiency, heat exchanger properties, fan efficiency, and use of defrost heaters. Actual energy consumption in the home will vary somewhat with household usage patterns, with temperature settings inside the unit, which are manually controlled, and with the ambient conditions surrounding the unit, which vary through the year and depend on the operation of HVAC systems.

Stand-by heat gains through the refrigerator shell far outweigh heat gains associated with usage. As a result insulation is a key aspect of refrigerator efficiency. Manufacturers are presently experimenting with a variety of evacuated or vacuum panels. This approach promises a substantial increase in unit efficiencies, although the level of success, production cost, and timing remain uncertain. If this technology succeeds and production costs are reasonable, it is possible that national standards will be adjusted upward by the turn of the century.

**Efficiency Standards.** National efficiency standards for refrigerators are established under the National Appliance Energy Conservation Act (NAECA 1987). These standards establish maximum allowable energy-use levels for seven classes of refrigerators. For each class, a formula based on size is used to set maximum allowable energy use. The 1990 standard is currently in place, and a more stringent standard has been established for 1993 (DOE, 1989). The next revision is currently expected in 1999.

Top-mount automatic defrost units are the most common type sold today, and in the analysis that follows, this type of unit is used as a prototype for evaluating the impact of standards. For this product class without through-the-door features, the formulas for maximum annual energy use (kWh/year) are as follows:

1990: 471 + 23.5 x Adjusted Volume

1993: 355 + 16.0 x Adjusted Volume

For an 18 cubic foot unit with 20.5 cubic foot adjusted volume, these formulas give the following values for maximum energy use levels and minimum allowable energy factors.

| | Maximum Energy Use (kWh/Year) | Minimum Energy Factor (cft/kWh/day) |
|---|---|---|
| 1990 | 953 | 7.85 |
| 1993 | 683 | 10.96 |

Because surface area is less than proportional to volume, energy factors for larger units will tend to be higher than for smaller units that are comparably equipped. As a result, minimum energy factor values must be computed for a specified adjusted volume.

**Efficiency Analysis.** A depiction of historical and forecast data for energy factors of new refrigerator purchases is presented in Figure 3.

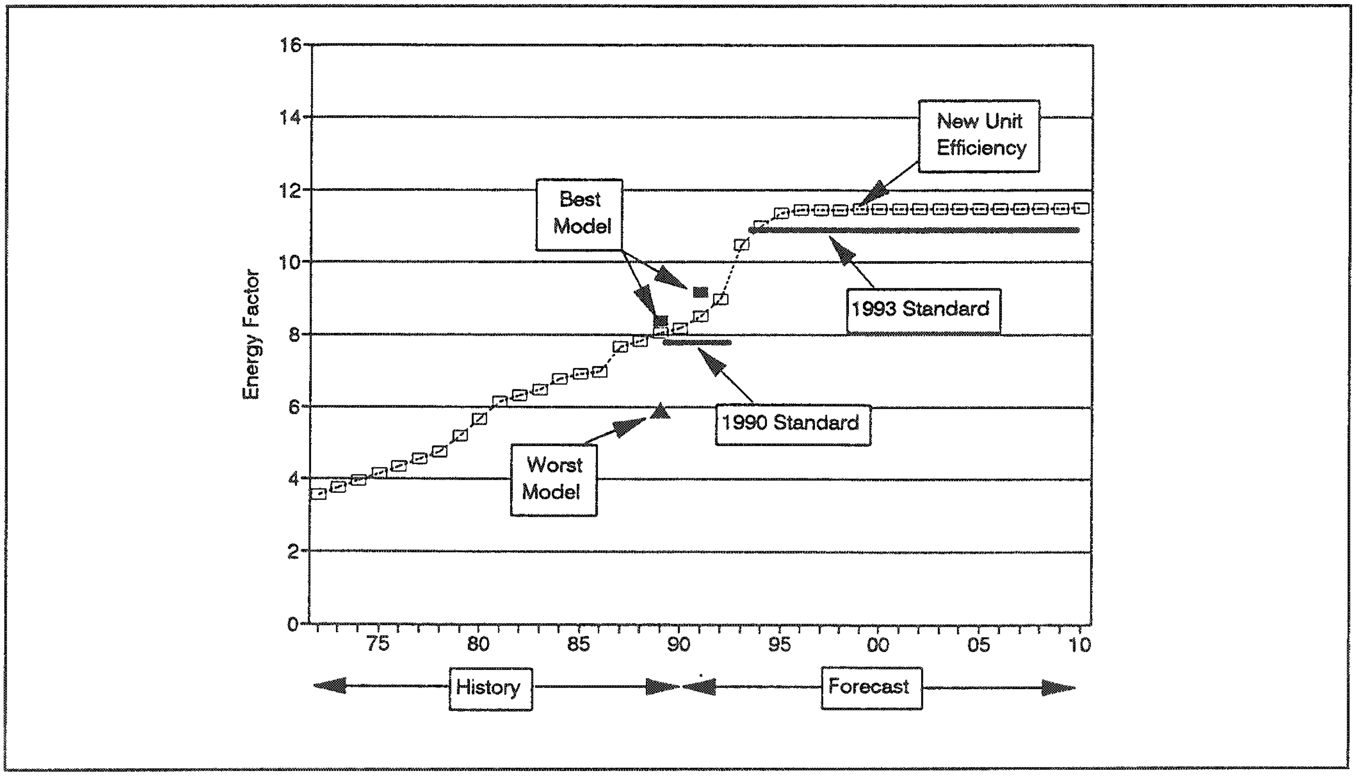


*Figure 3. Technology Data for Refrigerators*

- The historical data give the average efficiency of all new units shipped in each year. These data are provided by the Association of Home Appliance Manufacturers (AHAM).

- The best (most efficient) and worst (least efficient) points are for top-mount automatic defrost units in the 18 to 21 cubic foot range. These data come from the AHAM Directory of Certified Refrigerators and Freezers.

- The 1990 and 1993 standards are evaluated for a top mount unit with an adjusted volume of 20.5 cubic feet, and without "through-the-door" features.

- The forecasts are outputs of REEPS 2.0. These forecasts account explicitly for the 1990 and 1993 standards and include the introduction of new efficiency options with energy factors as high as 15 during the forecast period.

The state of technology disequilibrium is evident in these data and from the summary data presented below in Table 1. Units purchased in 1991 have an average energy factor above 8, which is about twice the efficiency level of older units being replaced. After introduction of the 1990 standard, the efficiency range is narrowed substantially. Finally, the 1993 standard demands a substantial improvement, requiring a minimum energy factor nearing 11. As of the June 1991 AHAM directory, there are no major brand refrigerators available that meet this standard.

Despite a 22% increase in the number of households, the forecast calls for a 30% decline in refrigerator energy use. This is caused by a near doubling of average efficiency. These savings are only partly offset by increases in average size and changes in appliance features related to rising household incomes and a continuation of existing trends.

**DSM Analysis.** From an efficiency perspective, the clear fact that emerges from Figure 3 is that refrigerators are in a rapid transition and the appliance stock is in a state of disequilibrium. The role of DSM programs in this fluid situation will necessarily fluctuate.

During the early 1990's, the role of efficiency incentives in new appliance purchases will be limited by the narrow and rapidly shifting efficiency band. For example in 1991, for the major product class, the efficiency range is from energy factor 8 to 9, leaving little room for DSM

*Table 1. Refrigerator Electricity Use Forecast*

| | Units (Millions) | Average Size (cft) | Average Efficiency (EF) | Electricity Use (tWh) | New Unit Efficiency (EF) |
|---|---|---|---|---|---|
| 1990 | 94.2 | 19.8 | 5.75 | 118 | 7.9 |
| 2000 | 105.9 | 21.0 | 8.77 | 92 | 11.5 |
| 2010 | 115.0 | 22.0 | 11.13 | 83 | 11.5 |

Notes: Data are for "first" refrigerators.
Units of EF are cubic feet per kWh per day.
Size includes adjustments for through-the-door features.

incentives. The 1993 standard forces the minimum efficiency level to about 11, and it is not now known what the range of design options will be in the mid 1990's.

Once the 1993 standards are in place, DSM programs aimed at early replacement of existing units can be expected to give some short-term energy savings. Also, second refrigerator buyback programs will remain as a source of DSM activity and energy savings. Beyond these types of programs, the future role of DSM programs will depend on further technology developments and the policy response to these developments.

In the forecast presented above, it is assumed that energy factor 15 refrigerators become available in the late 1990's. However, with no further tightening of national standards, and without aggressive DSM activity, the market share of these units is estimated to remain low, at about 12% of sales beyond 2000.

**Thermal Interactions.** Virtually all electricity input to refrigerator motors and fans ends up as heat within the home. As a result, an old relatively inefficient refrigerator can be thought of as a 2000 kWh per year (6.8 mmBtu) source of "free heat." When such a unit is replaced with a new unit using say 700 kWh per year, there is a 1300 kWh decline (4.4 mmBtu) in internal heat gains.

To the extent that this decline is coincident with the heat losses leading to the operation of heating equipment, heating energy use and, if present, fan energy use will rise. This offset will be largest in cold climates, where homes will be in heating mode well over 50% of the time. If the home is electrically heated, this implies that more than half of the energy savings will be offset by an increase in heating loads for a resistance system, with a lesser offset of about 25% for a heat-pump. If the home has natural gas or fuel oil heating, the offset will come in the form of increased fuel use and a proportional increase in fan energy for central systems.

To the extent that the decline in refrigerator energy use is coincident with the operating period of cooling equipment, cooling loads will decline, giving a further savings. In most climates, this impact will be relatively small for two reasons. First, the cooling season is relatively short, giving an annual coincidence factor of 15% to 20%. Second, cooling equipment typically has a mechanical efficiency of 2.0 or greater, which reduces the value of the interaction proportionally. As residential cooling equipment efficiencies increase, the importance of this interaction will diminish.

Results from the REEPS national data base are displayed in Figures 4 and 5. For electricity, it is estimated that the increase in refrigerator efficiency will lead to an increase of about 7.7 tWh (5.1%) in electric heating energy in the year 2010. This is amplified by a .6 tWh increase in fan

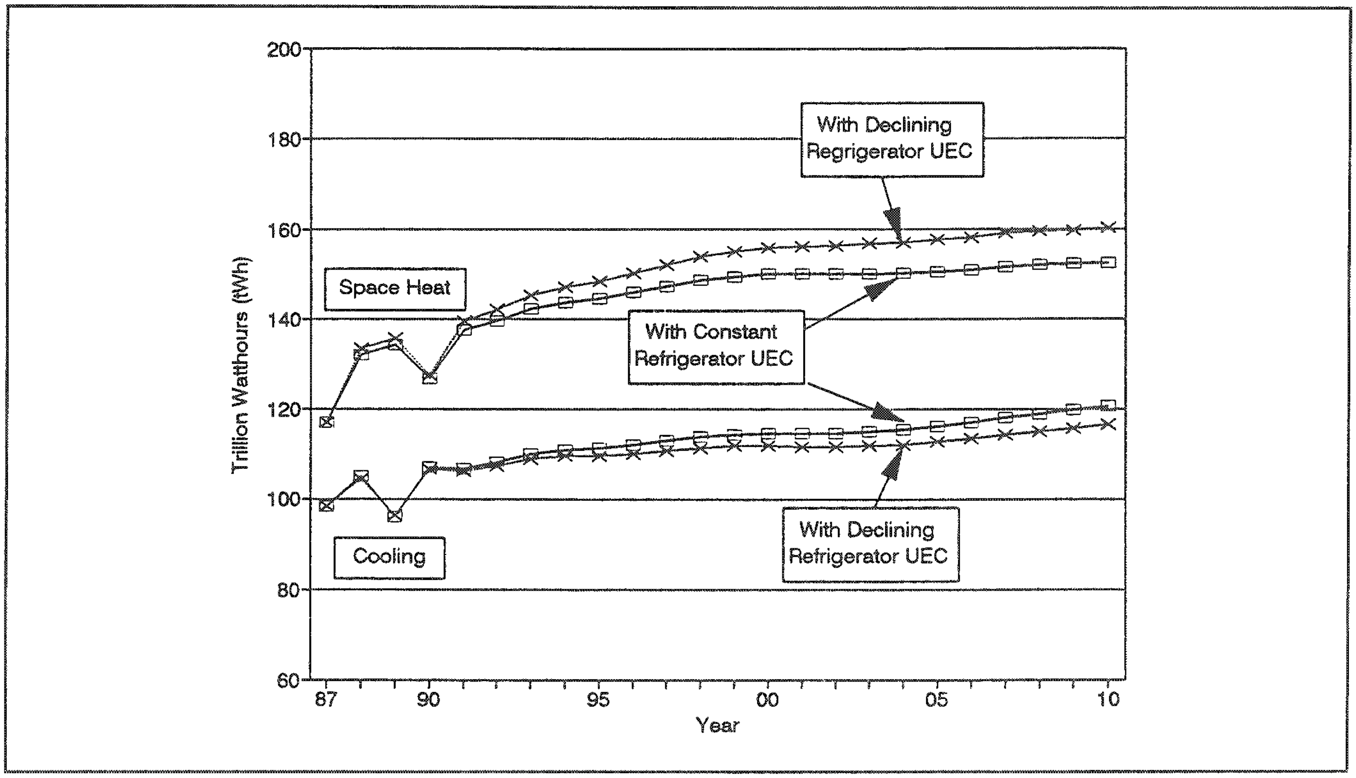


*Figure 4. Impact of Refrigerator Efficiency on Electric Heating and Cooling Loads*

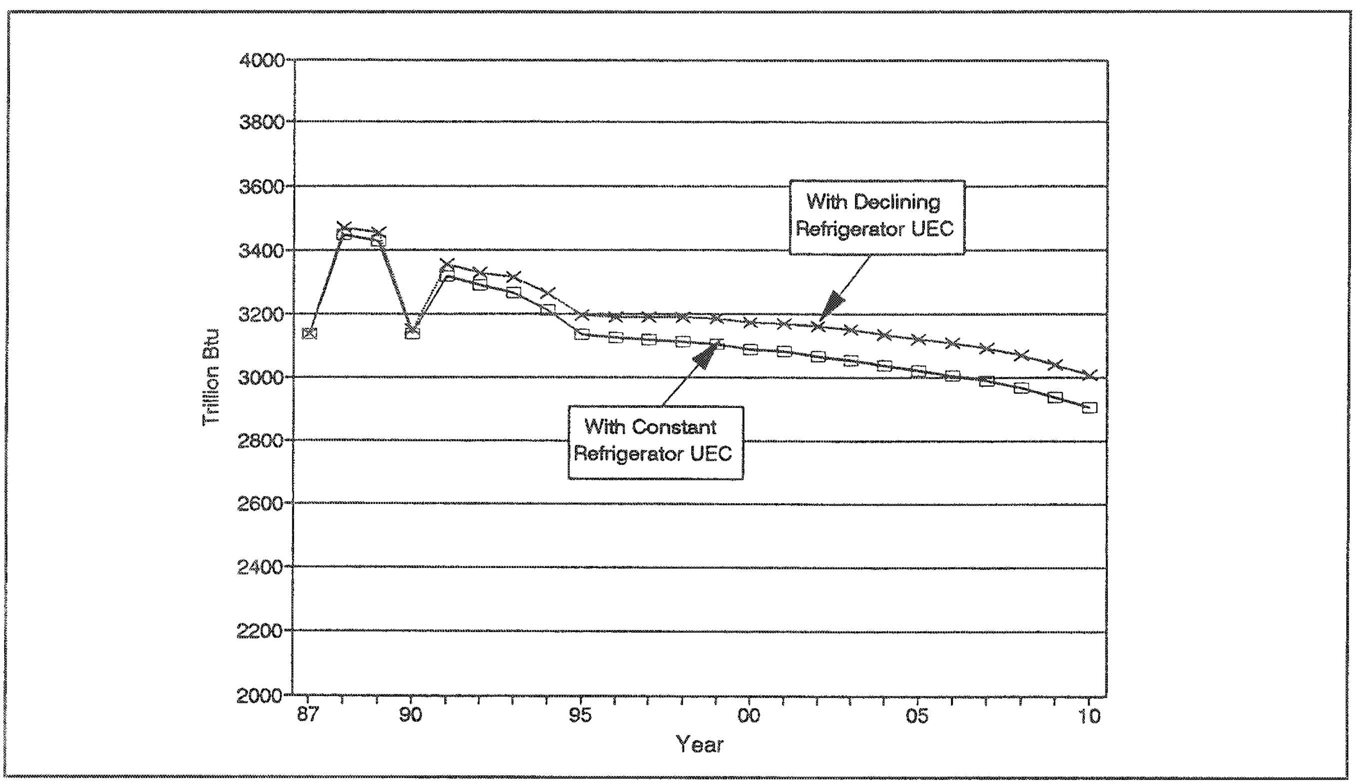


*Figure 5. Impact of Refrigerator Efficiency on Gas Heating Loads*

energy use for central systems. These increases are partially offset by an estimated savings of about 4.1 tWh (3.4%) for cooling. Overall, the net impact is positive, and averages about 8% of the initial impact. That is, for each 100 kWh in refrigerator energy savings, there is about an 8 kWh offset in increased electric HVAC loads.

For natural gas, the increase in heating loads is about 100 tBtu, with an additional 30 tBtu for other fossil fuels. This is an increase of about 3.5% over what heating energy use would be with constant refrigerator average efficiency. Looked at differently, for each kWh of electricity saved in reduced refrigerator energy consumption, there is about 2.4 kBtu increase in fossil energy use for heating. This occurs despite significant improvements in the efficiency of fossil heating equipment.

## Central Air Conditioner Analysis

The two key analysis issues for central air conditioners are saturation and equipment efficiency changes related to DSM programs and future standards. Secondary issues are the thermal efficiency of homes, and thermal interactions with other uses. The importance of these issues varies strongly with climate.

The efficiency of central air conditioners, like refrigerators, has increased significantly over the last 20 years. However, unlike refrigerators, existing national standards do not approach the upper part of the efficiency range. In absence of a strong national standard, there is significant room for DSM programs aimed at equipment efficiency. This is especially true in warm climates, where frequent operation implies relatively quick payback on efficiency investments.

**Efficiency Definition.** Efficiency levels for central air conditioners are measured by a seasonal energy efficiency ratio (SEER). This gives the ratio of Btu of heat removed per Watthour of electricity input averaged across the range of conditions occurring during the cooling season. The SEER is a direct efficiency measure, and a larger value implies a more efficient appliance. As an example, the average SEER value for units sold in 1987 was about 9.0 Btu/Watthour. This is below the minimum value of 10, which is set by the 1992 standard.

**Technology Issues.** The major factors that determine the efficiency of air conditioning equipment are compressor efficiency, size and efficiency of heat exchange surfaces, and fan efficiency. Seasonal efficiencies are also sensitive to weather conditions, with better average efficiencies in cooler climates. As indicated in the analysis, these programs could produce savings as large as 20 tWh by the year 2000.

Additional factors that impact energy use are home size, occupancy patterns, thermostat settings, consumer income levels, energy prices, the thermal efficiency of the building envelope, and climatic factors including temperature, humidity, and solar radiation.

Many manufacturers are beginning to introduce two-speed and variable speed compressors. By reducing cycling inefficiencies, these technologies improve SEER values, although COP values at rated capacity are not necessarily improved.

Estimates of the tradeoff between efficiency and capital costs have been prepared by Lawrence Berkeley Laboratories as part of economic analyses performed for DOE. For central air conditioners, these tradeoff data are presented in Figure 6. Each point on the curve represents a specific design option in the LBL analysis. With the exception of the two labelled points, the gradations in efficiency are achieved through improved heat-exchange surfaces on the condenser and evaporator coils. The labelled points indicate changes in compressor design and controls. This type of tradeoff or design-option data provides useful background for constructing long-run technology scenarios.

**Efficiency Standards.** The national appliance efficiency standards establish minimum allowable SEER levels for classes of central air conditioning equipment. Efficiency standards are in place for 1992 for split systems (which dominate the central air market) and 1993 for single package equipment. A revision to these standards is expected in 1999.

The minimum SEER values allowed by the national standards for central air conditioning equipment are as follows:

- SEER 10.0 in 1992 for split systems
- SEER 9.7 in 1993 for single package units.

**Efficiency Analysis.** Figure 7 presents a depiction of historical and forecast data for SEER values of central air conditioning equipment purchased each year.

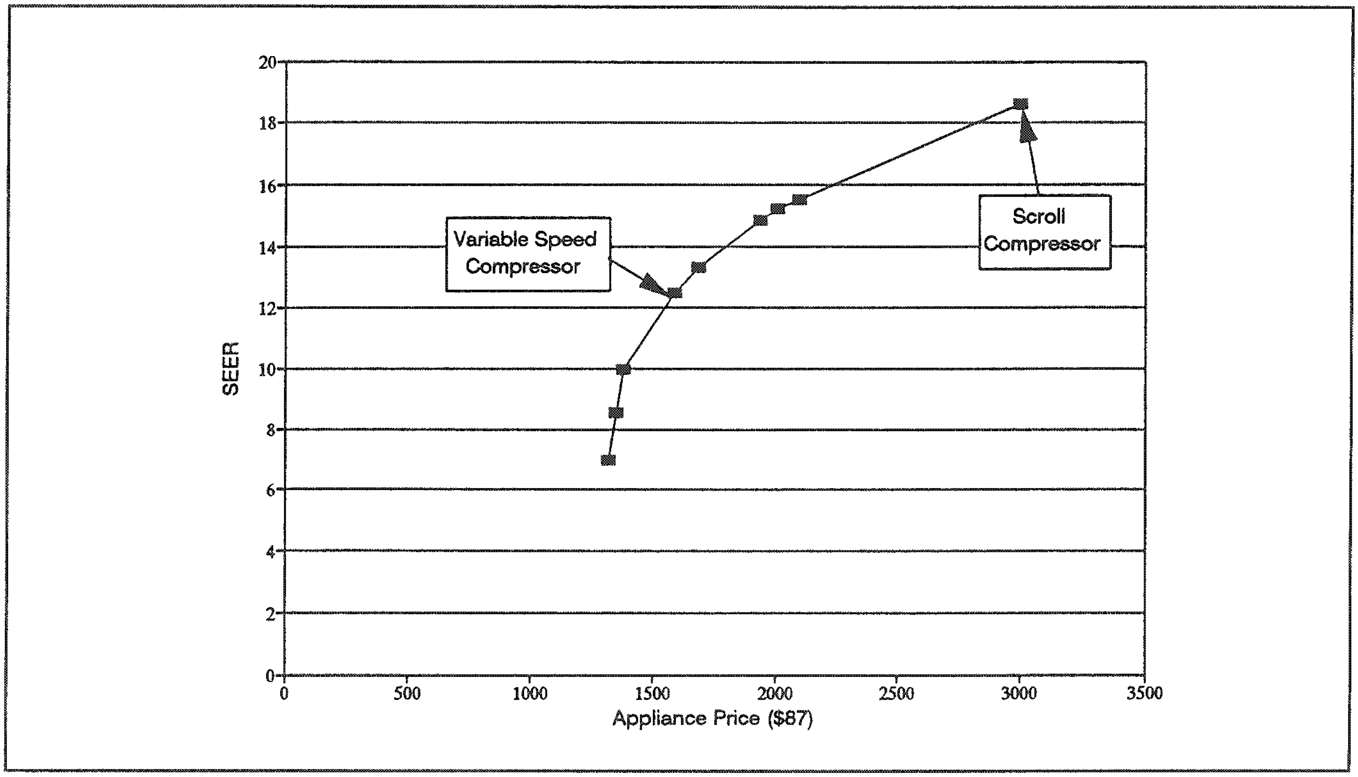


*Figure 6. Central Air Conditioner Technology Design Options*

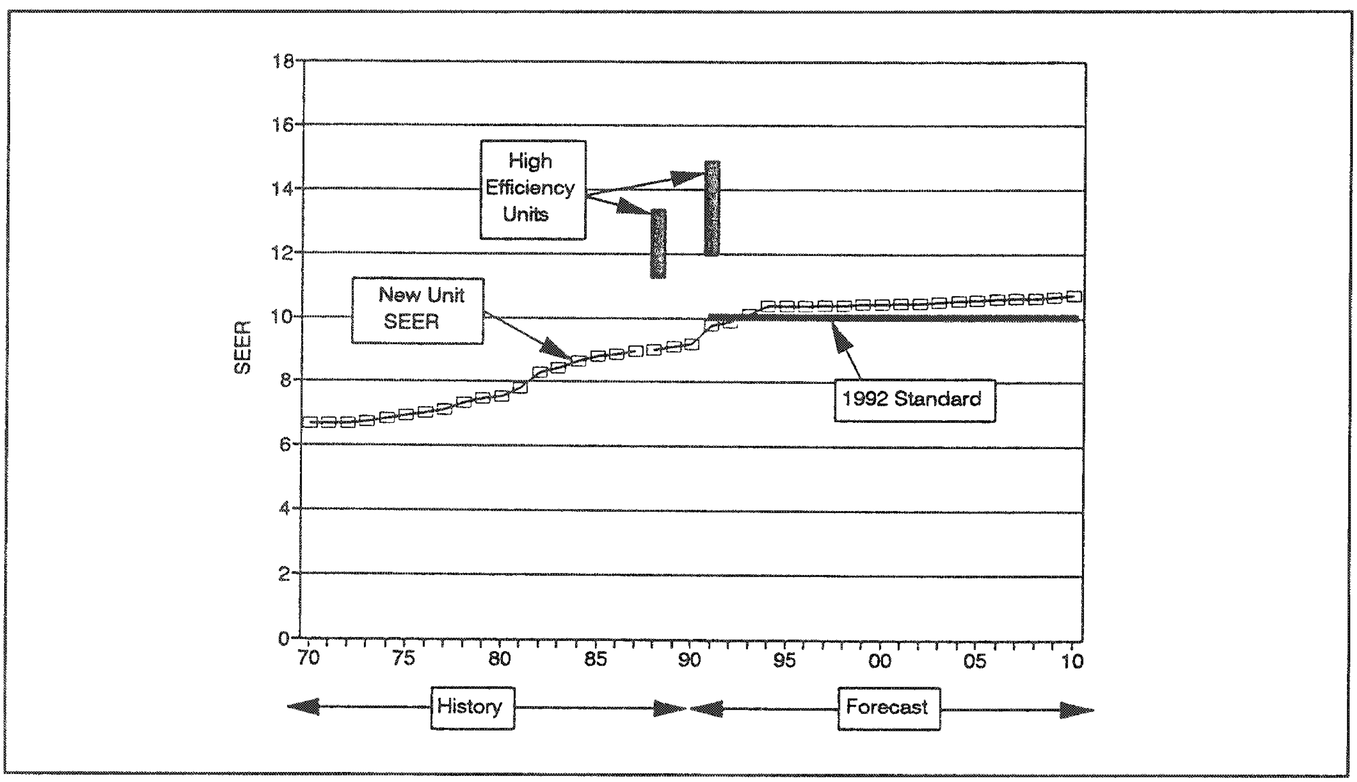


*Figure 7. Central Air Conditioner Marginal Efficiency (SEER)*

- The historical data on average efficiency of new units are from the Air Conditioning and Refrigeration Institute (ARI).

The range for the high efficiency units comes from the ARI. Directory of Certified Unitary Air Conditioners.

- The forecasts are outputs of REEPS 2.0. These forecasts assume imposition of the 1992 standard, but assume that no further standard is imposed.

According to the analysis, the 1992 standards will lead to a modest increase in average efficiency of new units, from the existing level of about 9 to a level between 10 and 11. However, as discussed above, these standards are not pressing against the high-efficiency end of the technology spectrum. In fact, a large number of units with SEER values above 12 are currently available. In the analysis, these high efficiency units are not projected to capture a large market share, reflecting higher purchase costs of the equipment.

**DSM Analysis.** Even in the presence of the 1992 standards, DSM programs can play a significant role in the air conditioning market. The analysis presented below shows the cumulative impact of a DSM scenario that adds about 2 to the average SEER of new purchases beginning in 1990. The results are depicted in Figure 8.

In the base case, central air conditioning energy use (including heat pumps in cooling mode) grows substantially from under 80 tWh to over 110 tWh. This growth reflects a growing housing stock, high central cooling shares in new construction, and conversion activity in existing homes. In the DSM scenario, electricity use is reduced by 19 tWh in 2010, which is a 17% reduction in annual power requirements for this end use.

The magnitude of the long-run DSM program impact depends on several factors. Energy prices play a role, as well as thermal efficiency and appliance efficiency standards. For example, in Figure 8, a second base forecast is shown, assuming imposition of a 1999 standard at a SEER level of 12. In this case, the DSM program impact in the year 2010 is greatly reduced, reflecting the reduced role of DSM in a technology scenario with more stringent efficiency standards.

The potential for DSM will vary across regions, reflecting differences in climate. These differences imply wide variation in annual operating hours and air conditioning loads, which in turn impact the economics of efficiency options.

**Interactions.** The main factors that interact with air conditioning equipment efficiency are thermal efficiency and internal gains from other end uses. Without DSM programs or national standards, the thermal efficiency of homes is forecast to improve by about 5% over the next 20 years. Any additional improvement will lower the forecast and reduce the incremental value of standards and DSM impacts for equipment efficiency.

As discussed above in the section on refrigerators, the interaction between internal gains and HVAC loads is of primary importance on the heating side. However, the interaction with cooling are significant. Any DSM programs that increase the efficiency of non-HVAC equipment will imply lower internal gains from these sources. This in turn will lower cooling loads and the potential savings from cooling equipment efficiency gains.

## Water Heater Analysis

Unlike refrigerators and central air conditioners, the efficiency range for electric resistance water heaters is limited. As a result, the key forecasting issues focus on market share more than on efficiency. With the imposition of standards in 1990, the efficiency range is narrowed further, implying a limited role for DSM programs that involve the heating unit directly. However, there are several utility programs promoting add-on measures that have large potential savings. The measures fall into four classes.

- **Reduce Stand-by Losses.** Measures that reduce stand-by losses include increased tank efficiency, water heater tank wrap, use of heat traps, and pipe wrap near the heater unit.

- **Install Flow Limiting Devices.** The main devices are low-flow shower heads and faucet aerators.

- **Install Water Efficient Appliances.** The main appliances using hot water are clothes washers and dish washers.

- **Reduce Tank Temperature.** This action reduces stand-by losses and also reduces the amount of energy required for appliance-related uses.

**Efficiency Definition.** Efficiency levels for water heaters are measured by an energy factor (EF) that gives the ratio of delivered heat to the full heat content of fuel input. These energy factors are measured under test conditions assuming a usage level of 64 gallons of hot water per day. Under the old test procedure, a temperature difference of 90 degrees was used for equipment rating, but this was

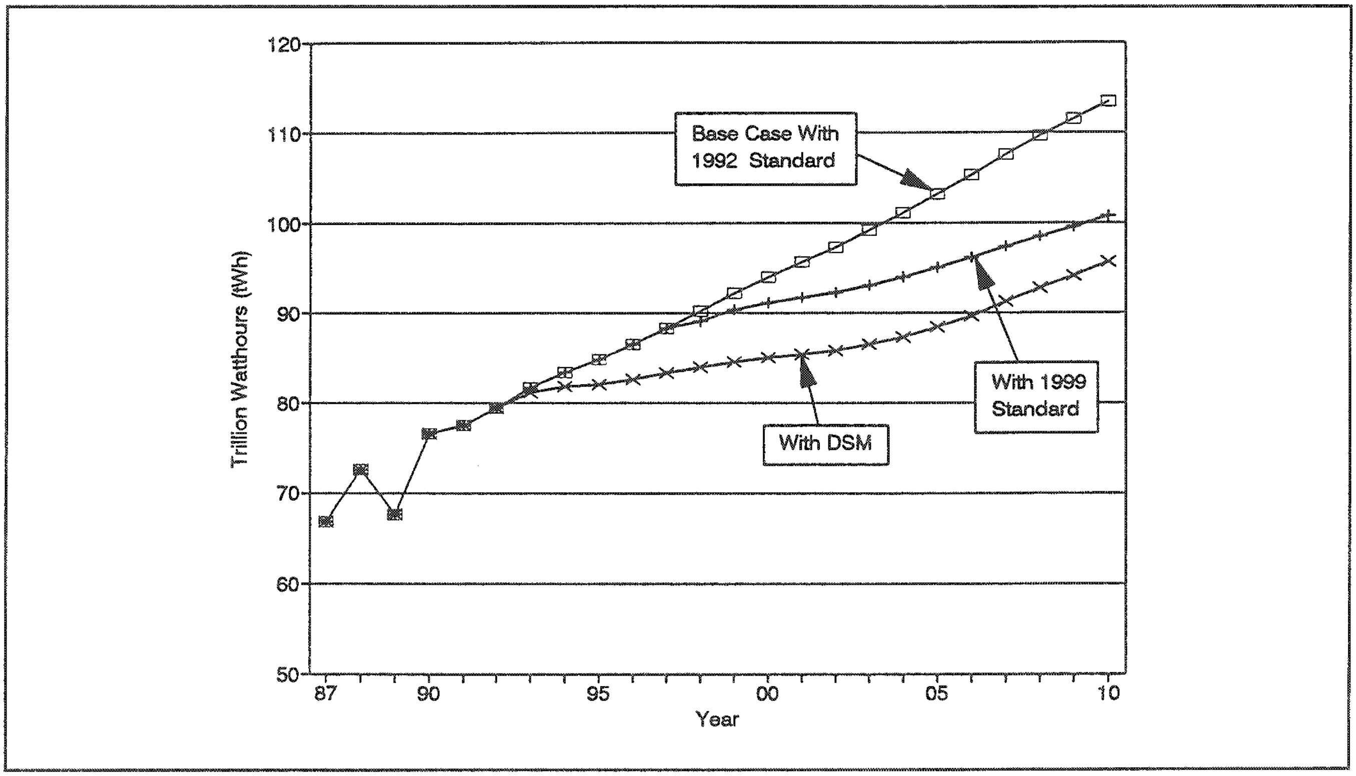


*Figure 8. Central Air Forecast Scenarios*

changed to 70 degrees in 1990. Since most historical efficiency data are recorded with the old test procedure, all values discussed here use this procedure as a reference point.

For electric resistance water heaters, energy factors for units of about 50 gallons in size that were sold in 1989 ranged from a low energy factor of .74 to a high value of .96.

**Technology Issues.** The basic function of a water heater is to add heat to supply water and maintain a temperature differential, with high temperatures inside the storage tank compared to the surrounding air. The main factor that determines the efficiency of electric water heaters is the type and level of tank insulation. A second factor is the presence or absence of heat traps, which minimize mixing between water pipes and the tank.

Water heater energy usage will vary with household usage patterns, with temperature level settings, which are manually controlled, and with unit location and climate. Also important are the presence of low-flow devices, hot water pipe wrap, and other appliances that use hot water, such as dish washers and clothes washers.

Other technologies that have small market shares today may become increasingly popular during the forecast. These include heat pump water heaters, instantaneous water heaters, point-of-use units, and integrated systems combined with HVAC equipment. Analysis of these technologies is not covered here.

**Efficiency Standards.** The efficiency standards establish minimum allowable energy factors. A 1990 standard is currently in place, and a revision is expected in 1996. For electric units, the most common water heaters have tank sizes of about 50 gallons. For units of this size, the 1990 standard requires a minimum energy factor of .88. (This limit applies under the old test procedure. Under the new procedure, the limit is .86.)

**Efficiency Analysis.** A depiction of historical and forecast data for water heater energy factors is presented in Figure 9. The historical data are derived from manufacturer surveys conducted irregularl by DOE. They indicate that the average efficiency of new units in the 1970's was about 80%. This drifted upward during the 1980's, reflecting a transition to higher levels of insulation and the use of foam rather than fiberglass insulation. The

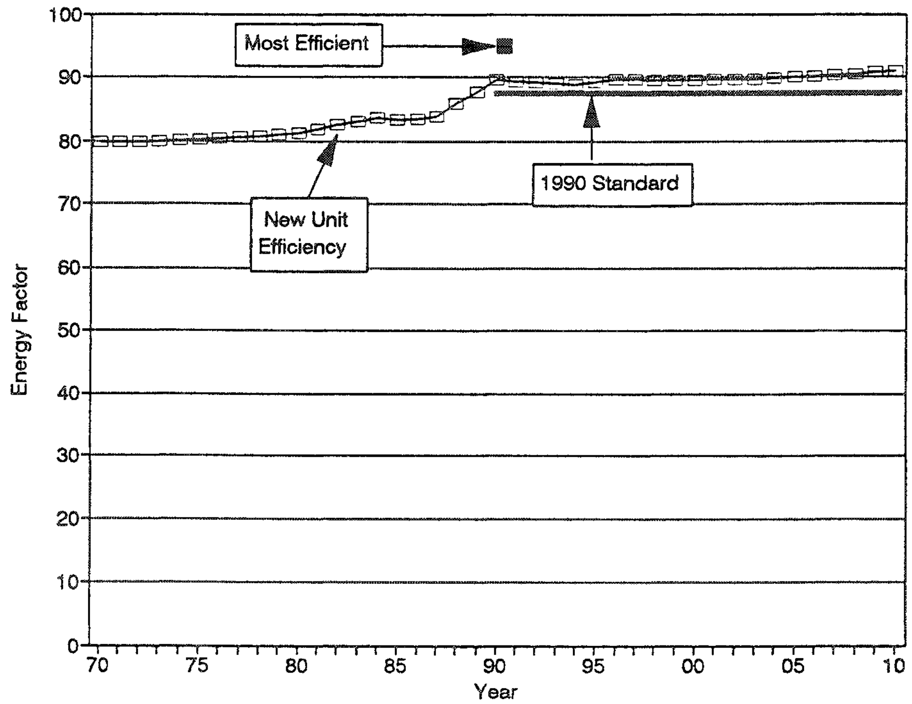


*Figure 9. Technology Data for Electric Water Heaters*

1990 standard, in essence, takes units with less than the equivalent of 3 inches of fiberglass insulation off the market.

Data for the most efficient units are derived from the Gas Appliance Manufacturers Association (GAMA) Directory of Certified Efficiency Ratings. Data for 1990 indicate a narrow range between the standard at 88% and the most efficient electric option at 96%.

The REEPS national forecast assumes that the 1990 standard remains in place, and that there is no further standard. Through the influence of real energy prices and other factors, there is a modest efficiency improvement above the standard, with energy factors for new units increasing to about 91% by 2010.

DSM Analysis. The long-run technology scenario presented in Figure 9 indicates the limited role for DSM programs aimed at equipment efficiency for electric resistance water heater units, especially after imposition of the 1990 standard. Still there is substantial room for DSM impacts that relate to usage levels, cycling programs, and programs involving advanced technologies.

To illustrate the interaction between DSM potential and equipment efficiency standards, the following analysis was conducted for water heater blankets. The three design options used in the analysis have energy factors of .80, .89, and .94. Reference data for these units are provided below, with and without addition of an R6 blanket.

| | Usage Energy (kWh) | Stand-by Loss (kWh) | With Wrap (kWh) | kWh Savings (kWh) |
|---|---|---|---|---|
| EF .80 | 4000 | 1000 | 600 | 400 |
| EF .89 | 4000 | 500 | 320 | 180 |
| EF .94 | 4000 | 250 | 150 | 100 |

In all cases, the economics of water heater blankets remain acceptable. For example, with blanket cost set at about $18, and with electricity at $.07 per kWh, the payback period is about 8 months for the .80 EF unit, and about 2.5 years with the .94 EF unit.

The market shares for the design options depend on assumptions about the costs of these options, consumer decision rules, and national efficiency standards. In the first scenario, the 1990 standard eliminates the .80 efficiency factor option. In the second scenario, an additional standard is introduced in 1996 that eliminates the .89 energy factor option. The technical potential for savings from water heater blankets under these two scenarios are presented in Figure 10.

As the data in Figure 10 indicate, the initial technical potential from water heater blankets is a little over 8 tWh. In the first case, with no further standard, the technical potential declines to a about 6 tWh by the year 2010. In the second case, with a introduction of a strong standard in 1996, technical potential declines to about 4 tWh in 2010. This occurs despite a strong increase in the number of electric water heaters from about 32 million in 1987 to almost 50 million in 2010.

## Conclusion

The three analysis examples presented above show clearly the value of long-run technology scenarios. These types of scenarios provide necessary background for the analysis of efficiency standard impacts and DSM program potential. In the presence of strong and evolving national appliance efficiency standards, the role of DSM programs will necessarily be limited to actions beyond the standards. For long-run program planning, for integrated resource planning, and for long-run forecasting, it is important to understand these interactions and the limits they place on DSM potential.

In addition to the direct technology scenarios, an understanding of interactions between appliance efficiency and HVAC loads is also important. These interactions are significant for both heating and cooling, and can be especially large on the heating side in cold climates. An understanding of these interactions is important from the perspective of short-term impact evaluation, and also for anticipating the full long-run impact of standards and DSM programs as part of the long-run forecast.

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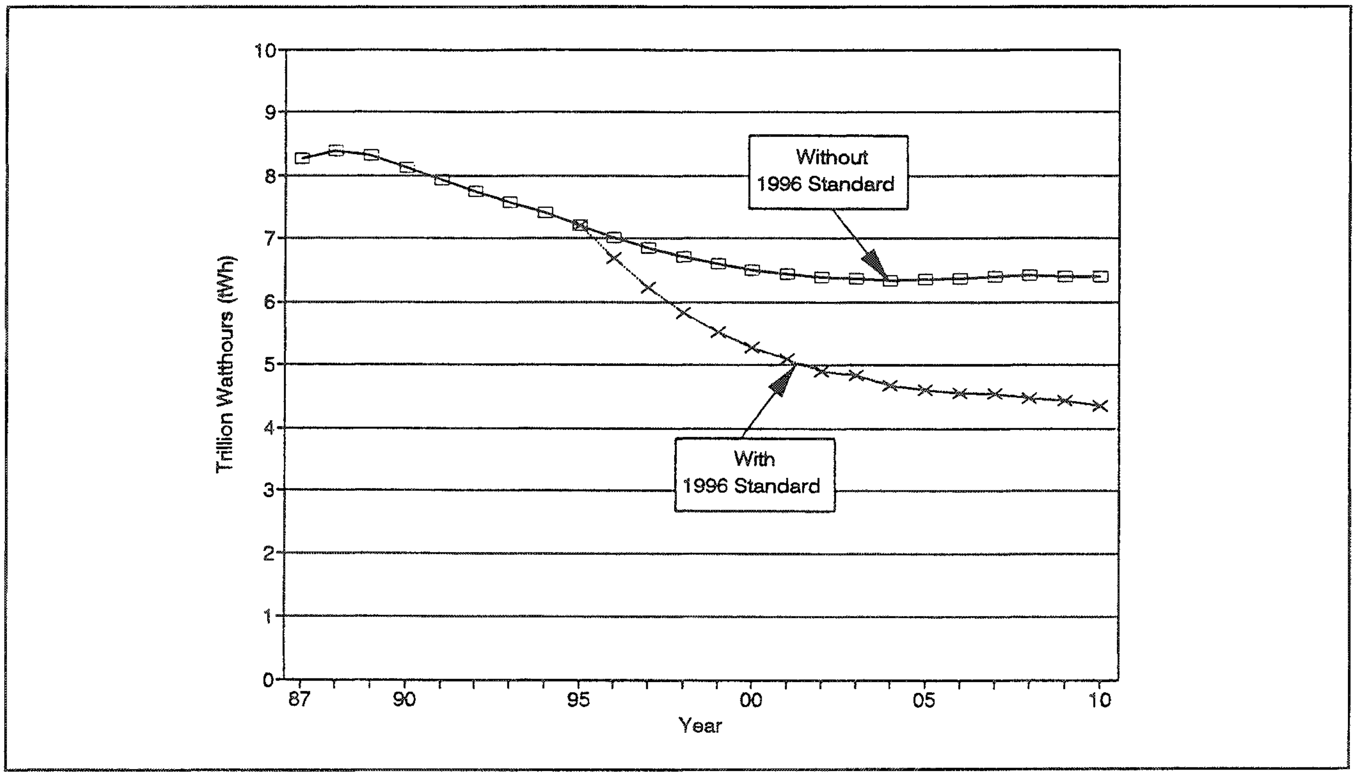


*Figure 10. Water Heater Tank Wrap Technical Potential*