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Savings Estimates for the ENERGY STAR® Voluntary Labeling Program

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ABSTRACT

ENERGY STAR® is a voluntary labeling program designed to identify and promote energy-efficient products, buildings and practices. Operated jointly by the Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), ENERGY STAR labels exist for more than thirty products, spanning office equipment, residential heating and cooling equipment, commercial and residential lighting, home electronics, and major appliances. This report presents savings estimates for a subset of ENERGY STAR program activities, focused primarily on labeled products. We present estimates of the energy, dollar and carbon savings achieved by the program in the year 2001, what we expect in 2002, and provide savings forecasts for two market penetration scenarios for the period 2002 to 2020.

The target market penetration forecast represents our best estimate of future ENERGY STAR savings. It is based on realistic market penetration goals for each of the products. We also provide a forecast under the assumption of 100 percent market penetration; that is, we assume that all purchasers buy ENERGY STAR-compliant products instead of standard efficiency products throughout the analysis period.

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Introduction

In the wake of California's energy crisis of 2000 and continuing threats of energy shortages, it has become even more important to assess the impacts of energy conservation programs. This paper presents past and predicted savings for the ENERGY STAR® labeling program, operated jointly by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Since 1992, the ENERGY STAR label has been used to promote high efficiency office equipment, heating and cooling equipment, appliances, lighting, windows, transformers, buildings, and commercial kitchen equipment, among other product areas. The ENERGY STAR program also encompasses a new homes program and a home improvement program. This analysis focuses only on labeled products. Three labeled products were not included in the analysis: transformers, cool roofs, and windows. Table 1 shows EPA's product labels and related programs and indicates which are covered by this report.

Our forecast of future savings extends through 2020. We include both a 100 percent market penetration case and a target market penetration case using the market share goals used by EPA and DOE.

The ENERGY STAR® Labeling Program

ENERGY STAR is a voluntary labeling program operated jointly by EPA and DOE. Those agencies enter into agreements with manufacturers that allow the manufacturers to promote products meeting certain energy-efficiency and performance criteria through use of the ENERGY STAR label. EPA and DOE have focused their efforts in areas where efficiency improvements can be achieved while offering the same or improved level of service. However, the ENERGY STAR label does not constitute an endorsement of the product by EPA or DOE.

The EPA launched the ENERGY STAR program in 1992 with computers and monitors. In 1993, the program was extended to include printers. The goal was to promote energy-saving features already common in laptop computers for use in desktop devices. These labeled products soon dominated the market, largely due to President Clinton's issuance of Executive Order 12845 in 1993 requiring that microcomputers, monitors and printers purchased by federal agencies be ENERGY STAR-compliant. The sheer size of the federal market pushed manufacturers to participate in the program. Now we estimate that 95 percent of monitors and 98 percent of computers sold are ENERGY STAR-compliant. In 1994, fax machines were added to the labeling program, followed by copiers, residential heating and air conditioning equipment, thermostats, and transformers in 1995.

In 1996, DOE agreed to work jointly with EPA to promote energy efficient products using the ENERGY STAR logo. In 1996, DOE introduced ENERGY STAR labels for refrigerators, room air conditioners and dishwashers. Because energy efficiency involves both environmental protection and energy policy, the DOE/EPA partnership was an important step in developing and expanding ENERGY STAR.

Table 1. ENERGY STAR Products and Programs

	Covered in this report?	
	Yes	No
Computers	X	
Monitors	X	
Printers	X	
Fax Machines	X	
Scanners	X	
Copiers	X	
MFDs	X	
TVs	X	
VCRs	X	
TV-VCRs	X	
Audio Equipment	X	
Set-top Boxes	X	
Telephony	X	
Air-Source Heat Pumps	X	
Geothermal Heat Pumps	X	
Central Air Conditioning	X	
Gas-Fired Heat Pumps		X
Gas Furnaces	X	
Oil Furnaces	X	
Gas Boilers	X	
Oil Boilers	X	
Programmable Thermostats	X	
Exhaust Fans	X	
Ceiling Fans	X	
Residential Lighting Fixtures	X	
Exit Signs	X	
Traffic Signals	X	
CFLs	X	
Clothes Washers	X	
Dishwashers	X	
Room Air Conditioners	X	
Refrigerators	X	
Commercial Refrigerators and Freezers	X	
Dehumidifiers	X	
Bottled Water Coolers	X	
Windows		X
Cool Roofs		X
Transformers		X
New Homes		X
Commercial Buildings		X
Home Improvement Program		X

Also in 1996, EPA introduced labels for exit signs, insulation and residential boilers. The following year, scanners, multi-function devices[1] and residential lighting fixtures were added to EPA's labeled products, and clothes washers were added to DOE's suite of products. In 1998 EPA introduced ENERGY STAR TVs and VCRs and DOE introduced an ENERGY STAR label for windows. EPA began labeling ENERGY STAR consumer audio, DVD players, and roof products in 1999 while DOE took on screw-based compact fluorescent lamps. Water coolers and traffic signals were added to EPA's labeling program in 2000, followed by set-top boxes, dehumidifiers, ventilation fans, ceiling fans, and reach-in refrigerators and freezers in 2001 and telephony in 2002.

Several of these products are not included in this analysis (see Table 1). Two labeled products were omitted because they have been dropped from the program: gas-fired heat pumps in 2000 (the product was no longer commercially available) and insulation in 2001 (insulation was incorporated in EPA's Home Improvement Program and was dropped as an individual product label). Transformers, cool roofs, and windows have not yet been added to the analysis. The ENERGY STAR Homes, Buildings and Home Improvement programs, while part of the ENERGY STAR family of programs, are separate from ENERGY STAR labeled products and are not addressed in this report.

EPA and DOE continue to research products and industries in search of new program opportunities. Factors evaluated include the potential for improvements in unit energy savings, the size of the stock, turnover rates and the structure of the industry (Sanchez, et al. 2000).

Historically, the focus of the ENERGY STAR program has been on energy savings and carbon emissions reductions. During California's energy crisis in 2000, however, interest shifted to the impact of conservation programs on power grid reliability. The peak impacts of an ENERGY STAR label depend on the timing of the savings, which in turn depends on the daily usage pattern of the labeled product. The products with high peak savings may therefore be different from the products with high annual energy savings. The current interest in reliability has not changed how EPA and DOE choose products for labeling; however, it has added an additional dimension to evaluating the program.

Methodology

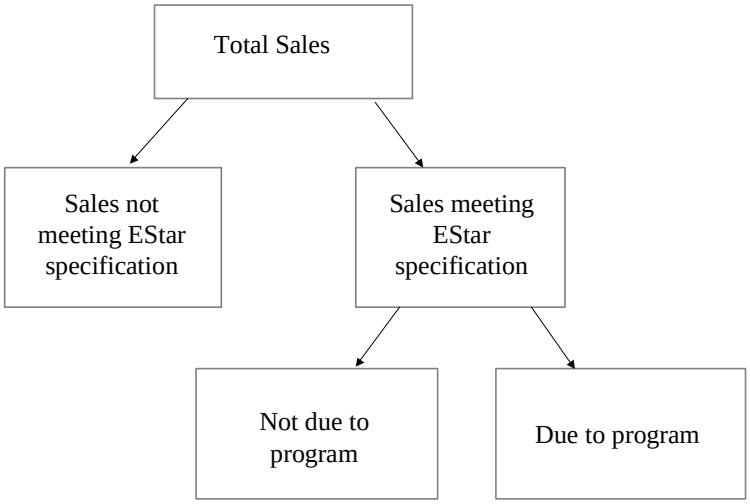
At the core of the ENERGY STAR savings calculations is a stock accounting that calculates the number of ENERGY STAR–compliant units in place each year that can be attributed to the ENERGY STAR program. We segment sales of each product first into non-ENERGY STAR and ENERGY STAR units. Sales of ENERGY STAR-qualifying units are further divided into those that would have been sold even without the program and those that can be attributed to the program. The ENERGY STAR savings forecast includes only the savings for ENERGY STAR units attributable to the program. Figure 1 illustrates the sales segmentation.

The market share of ENERGY STAR units not due to the program is a forecast based on historic

[1] The term multifunction device (in the context of office equipment) refers to a device that combines copying, printing, scanning and/or fax functions in a single device. Under the ENERGY STAR program the term refers to the subset of such devices that have copying as their primary function. Digital copiers that can be upgraded to have printing functions are also covered.

efficiency trends. "Business-as-usual" is represented by non-ENERGY STAR sales and ENERGY STAR sales not due to the program, and is characterized both by a unit energy consumption and a market share for each segment. Business-as-usual efficiency improvements can be modeled directly as a change in the UEC of either of these segments. We can also model business-as-usual efficiency improvements as a shift over time from non-ENERGY STAR units to ENERGY STAR units not due to the program.

Figure 1. Segmentation of product sales in the CCAP model



For each market segment, there is an associated annual unit energy consumption (UEC). In general, the annual unit energy consumption for non-ENERGY STAR units is assumed to be constant unless the ENERGY STAR requirement is tightened or (if applicable) the efficiency standard for the product changes during the forecast period.[2,3] (A change in the ENERGY STAR requirement changes the definition of a "non-ENERGY STAR" unit and therefore changes the UEC for this segment.) For most products there is insufficient data on historic efficiency trends to create a credible UEC forecast, so rather than model efficiency improvements directly, we rely on a forecast of increasing market share of ENERGY STAR units not due to the program to capture changes in business-as-usual efficiencies (see below).

"Business-as-usual" is represented by the combination of non-ENERGY STAR units and ENERGY STAR units not due to the program. Even though we do not fully model efficiency improvements in non-ENERGY STAR units, the average efficiency of "business-as-usual" units changes over time based on our forecast of the market share of ENERGY STAR units not due to the program. For example, from 1996 to 2000, the UEC for non-ENERGY STAR refrigerators was 744 kWh/year and the UEC for ENERGY STAR refrigerators was 595 kWh per year (note that both the minimum efficiency standard and the ENERGY STAR requirement changed in 2001). The business-as-usual market share of ENERGY STAR refrigerators was forecast to increase from 8 percent to 10 percent over this period. The weighted average business-as-usual energy consumption declined from 731 to 728 kWh/year over this period.

[2]While we do not speculate about future changes to standards, we do account for the effects of past, present, and finalized future standards. Standards are considered business-as-usual-case effects for the purpose of analyzing the effects of the ENERGY STAR Program.

[3] For VCRs and exit signs the average efficiency of non-ENERGY STAR units does change over time, because there is good data on historic efficiency trends and the market share of ENERGY STAR units not due to the program is a poor proxy for efficiency trends in these products.

There is one UEC for all ENERGY STAR units, both those due and not due to the program. For most products, this UEC is assumed to be constant unless the ENERGY STAR requirement is tightened.[4] Where compelling data is available showing trends in Energy Star product efficiency (as with manufacturer-reported data for consumer electronics), we do model a change in the UEC over time. In cases where both the non-ENERGY STAR and ENERGY STAR UECs are changing over time, it is possible for savings to increase, decrease or remain the same.

Some office equipment products do not accrue savings unless the ENERGY STAR features are enabled. In the past, manufacturers sometimes shipped devices with ENERGY STAR features disabled. Manufacturers are now required to ship units enabled, so no user action is required to achieve energy savings. However, users may disable features for various reasons, such as slow recovery times from low-power modes or incompatibility with computing networks. Metering of ENERGY STAR computers suggests that less than half have their power-saving features enabled (Roberson et al. 2000). For products where this occurs, we estimate an enabling rate in each year, which we apply to the number of ENERGY STAR units shipped to get the number of new ENERGY STAR units that accrue savings.

Using annual installations of energy-saving units due to the program, we calculate the number of ENERGY STAR units in place in each year (due to the program) by applying a simple retirement model. Devices are assumed to remain in place and accrue savings for a period equal to the average lifetime of the product (given in Table 4 below), then are retired.

Because the unit energy savings (UES) for some products changes over time, we cannot simply multiply the number of enabled ENERGY STAR units (due to the program) in place in each year by a single UES to get aggregate annual energy savings. Instead, we calculate the energy savings for each year's ENERGY STAR sales, then use our retirement function to add up the savings for all the equipment vintages in place in a given year. Aggregate energy bills are estimated using year-by-year energy prices from US DOE (1996a, 1996b, 1997b, 1998b, 1999, 2000, 2001), shown in Table 2. Energy bill savings are discounted at a 4 percent real discount rate. Carbon emissions reductions are calculated from energy savings using year-by-year carbon emissions factors. Electric heat rates (also US DOE) and carbon emissions factors for electricity (Cadmus 1998) are also shown in Table 2.

The following equations summarize our calculations for savings in year t.

$$\text{Annual Energy Savings in Year t} = \sum_{n=t-L+1}^{t} X_n UES_n$$

$$\text{Annual Energy Bill in Year t (Undiscounted)} = AES_t P_t$$

$$\text{Annual Carbon Savings in Year t} = AES_t C_t$$

[4] We do not speculate about possible future changes to existing ENERGY STAR specifications or possible additions to the program. We do, however, account for the effects of specification revisions that have already been agreed to by manufacturers and have a set start date.

Table 2. Best Estimate Energy Prices and Carbon Emissions Factors by Year[a]

Year	Commercial Electricity Price 2000$/kWh	Residential Electricity Price 2000$/kWh	Gas Price 2000$/ MBtu	Oil Price 2000$/ MBtu	Price Source[b]	Carbon Emissions Factor for Electricity kg C/kWh	Carbon Source	Electric Heat Rate Btu/kWh	Electric Heat Rate Source
1993	0.088	0.094	7.45	6.76	[c]	0.203	[k]	11,019	[c]
1994	0.088	0.094	6.97	7.07	[d]	0.203	[k]	10,948	[d]
1995	0.081	0.091	6.50	6.84	[e]	0.203	[k]	10,970	[e]
1996	0.081	0.089	6.61	7.56	[f]	0.203	[k]	10,866	[f]
1997	0.079	0.087	7.12	7.43	[g]	0.203	[k]	10,978	[g]
1998	0.078	0.085	6.91	6.41	[h]	0.203	[k]	10,891	[h]
1999	0.073	0.083	6.65	6.39	[i]	0.203	[k]	10,784	[h]
2000	0.075	0.083	7.64	9.42	[i]	0.203	[k]	10,776	[h]
2001	0.078	0.084	8.81	9.04	[i]	0.192	[l]	10,718	[h]
2005	0.070	0.076	6.85	7.68	[i]	0.148	[k]	10,589	[h]
2010	0.068	0.076	6.73	7.94	[i]	0.135	[k]	10,236	[h]
2015	0.068	0.076	6.84	8.43	[i]	0.135	[j]	10,008	[h]
2020	0.069	0.077	6.97	8.54	[i]	0.135	[j]	9,829	[h]
>2020	0.069	0.077	6.97	8.54	[j]	0.135	[j]	9,829	[j]

Notes to Table 2:

[a]Carbon coefficients for natural gas and oil are assumed to be constant throughout the period at 14.4 kg C/MBtu for natural gas and 19.75 kg C/MBtu for oil. Carbon emissions factors for electricity are marginal, not average.

[b]All prices have been converted to 2000 dollars using implicit GDP deflators from the Department of Commerce (2000).

[c]US DOE (1996a).

[d]US DOE (1996b).

[e]US DOE (1997b).

[f]US DOE (1998b).

[g]US DOE (1999a).

[h]US DOE (2000).

[i]US DOE (2001).

[j]The carbon coefficient for electricity is assumed to remain constant after 2010. Energy prices and heat rates are assumed to remain constant after 2020.

[k]Cadmus (1998)

[l]The carbon coefficient for electricity in 2001 was obtained by interpolation.

Where

X_n = The number of ENERGY STAR units sold in year n due to the program

UES_n = The unit energy savings of units sold in year n (in kWh or MBtu)

L = product lifetime

AES_t = The aggregate annual energy savings in year t (in kWh or MBtu)

P_t = The energy price in year t (in $/kWh or $/MBtu)

C_t = The carbon emissions factor in year t (in kg/kWh or kg/MBtu)

When looking at reliability, the savings that matter most are those that occur when the system is constrained, typically during periods of peak demand. In most parts of the country, peak demand is driven by high summer cooling loads. ENERGY STAR room air conditioner savings tend to occur on-

peak, while the auto-off feature of ENERGY STAR copiers tends to save energy off-peak. Other products, such as TVs, accrue fairly level savings through peak and off-peak periods.

Peak power reductions are estimated from aggregate energy savings using a conservation load factor (CLF) that relates average load savings to peak load savings for a conservation measure. CLFs for each ENERGY STAR product are shown in Table 5. Conservation load factors were obtained from previous research (when available), developed from time-of-day metered data or based on assumed time-of-day and seasonal operating patterns if no metered data were available. A CLF of one indicates that energy savings are distributed evenly across peak and off-peak periods (e.g. ENERGY STAR TVs). CLFs of less than one indicate that savings are greater during peak periods (e.g. central and room air conditioners), while CLFs of more than one indicate that savings occur mostly off-peak (e.g. copier low-power and auto-off modes). Conservation load factor methodology is detailed in Koomey et al. (1990).

Several ENERGY STAR specifications have been revised since their introduction to a more stringent efficiency level. After each specification changed it is assumed that unit energy savings increase, but fewer models qualify at the new level, at least until manufacturers have a chance to revamp their product line to meet the new specification. The question arose, what happens to the models that met the old specification but not the new one? There are three possibilities: they are replaced by models that are less efficient than the old specification (recidivism), they continue to be made or are replaced by models of similar efficiency (market transformation), or they are replaced by models meeting the new specification. If recidivism is widespread, saving may be lower under the new specification than the old. To address this issue, market transformation effects were incorporated into the model. Currently, we assume there is no recidivism, although it is possible to change this assumption in the model. There are currently no empirical data available that would resolve this question.

Forecasting Issues

Office Equipment. ENERGY STAR-labeled office equipment includes computers, monitors, fax machines, printers, copiers, scanners and multi-function devices (MFDs). The program focuses on reducing the power consumed by these devices when not in active use. ENERGY STAR devices automatically enter a low-power mode and/or turn themselves off after a period of inactivity. To qualify for the ENERGY STAR label, devices must incorporate low-power and/or auto-off modes, and must meet power consumption limits in those modes. In some cases, default power-saving settings are specified, such as the length of the idle period necessary to trigger a lower-power mode or a maximum recovery time from low power modes.

Because of different usage patterns, computers and monitors were modeled separately for homes and offices. For our analysis of commercial office equipment, we used operating patterns derived from equipment audits at various locations (Piette et al. 1995; Nordman et al. 1998). These sources provided both the time spent in each operating mode (e.g. active, standby, suspend and off), and the percent of ENERGY STAR devices that were actually enabled. Another key input was the percent of units left on after working hours. Nighttime audits of office buildings found that 56 percent of computers, 68 percent of monitors, 75 percent of printers and 82 percent of copiers and MFDs were

left on at night (Webber et al. 2001). For residential computers and monitors, we used data from Media Metrix (2001) describing average usage of a large sample of residential computer users.

Baseline unit energy consumptions were calculated by multiplying the time spent in each power mode by the power consumption in each mode, then summing over all power modes. The unit energy consumption for ENERGY STAR products was calculated essentially the same way, although some of these products have additional power modes. ENERGY STAR products may also have different usage patterns than standard products (because of features like auto-off) and lower power levels in certain operating modes. Office equipment shipment data were obtained from Gartner (2001), IDC (2001), and Guo et al. (1998). The unit energy savings were applied to forecasts of enabled, ENERGY STAR-compliant devices to obtain aggregate savings.

As noted above, taking account of enabling rates was particularly important for office equipment. A significant number of ENERGY STAR devices, particularly computers, fail to save energy because either their power management features are not enabled or external factors (such as computer network connections) keep the device from entering low power modes. Although success rates have improved significantly since the program began, we are unlikely to see 100 percent success rates in the foreseeable future given variations in computing environments, networking issues and the rate of technological change. Table 3 shows the office equipment enabling rates assumed in the analysis.

Table 3. Enabling Rates for ENERGY STAR Office Equipment (Percent)

Product	**1993**	**1994**	**1995**	**1996**	**1997**	**2000**	**2005**	**2010**
Copiers	NA	NA	34	37	90	90	90	90
Facsimile	NA	NA	90	90	90	90	90	90
Printers	80	90	96	96	96	96	96	96
Scanners	NA	NA	NA	NA	90	90	90	90
Multi-Function Devices	NA	NA	NA	NA	100	100	100	100
Office Monitors	10	15	15	59	59	59	59	59
Office PCs	10	15	15	20	20	25	35	35
Residential Monitors	10	15	15	59	59	59	59	59
Residential PCs	10	15	15	20	20	20	20	20

Notes to Table 3:
a) Enabling rates represent the percent of ENERGY STAR-compliant devices assumed to be correctly configured for power management and successfully saving energy.

Residential Heating and Cooling (HVAC). The HVAC program covers air-source heat pumps, geothermal heat pumps, central air conditioners, gas and oil furnaces, gas and oil boilers, and programmable thermostats. For heating and cooling equipment, ENERGY STAR eligibility is based solely on efficiency, measured by standard test procedures such as AFUE or SEER.[5] Programmable thermostats qualify for the ENERGY STAR label because they automate what people often fail to do manually: set back their thermostats at night or when they are out of the house. Several issues arose in analyzing heating and cooling equipment, including multiple fuel types, technology substitution and program interactions.

[5] AFUE is average fuel utilization efficiency and SEER is seasonal energy efficiency ratio.

New federal minimum efficiency standards for central air conditioners and air-source heat pumps begin in 2006. In response to the announcement of the new standard, EPA tightened the ENERGY STAR requirement for split systems from 12 SEER[6] to 13 SEER, beginning in 2002.

The market shares for ENERGY STAR central air conditioners and air-source heat pumps from 1996 to 2000 are from ARI (2001). Shipments of programmable thermostats are estimated based on stocks reported in the 1997 Residential Energy Consumption Survey (RECS; US DOE 1999c). The market share forecast for geothermal heat pumps is an LBNL estimate, although 1995 and 1996 shipments were taken from US DOE (2000). Geothermal heat pumps are an intrinsically efficient technology, and all units are assumed to meet the ENERGY STAR efficiency level. Because of this, and because geothermal heat pumps are not yet in widespread use, increased sales of this products are modeled as displacing shipments of established products. For our model we assume they displace air-source heat pumps.

Energy bill and carbon savings both depend on the type of fuel used. In addition to their primary fuels, gas and oil furnaces consume electricity to operate fans. Programmable thermostats save energy according to the type of HVAC installed in the home. For these products, we segmented the analysis by fuel type, then added the component savings together.

Because programmable thermostats reduce the operating hours of heating and cooling equipment, they must be analyzed in conjunction with HVAC equipment to avoid double-counting savings from thermostats and efficient equipment. Because we calculate thermostat savings as a percentage of total heating and cooling energy, thermostat savings should be lower if ENERGY STAR-compliant HVAC equipment is in place. Conversely, if there is a programmable thermostat in place, replacing old equipment with an ENERGY STAR model will save less than if the thermostat was a standard one. For simplicity, we assumed that HVAC equipment is chosen first and therefore ENERGY STAR HVAC receives its full measure of savings. Programmable thermostat savings were calculated from a forecast of HVAC energy use that took into account the increasing market penetration of ENERGY STAR HVAC (we assumed the choice of a programmable thermostat was independent of the choice of ENERGY STAR HVAC). Programmable thermostat savings are therefore net of ENERGY STAR HVAC equipment savings.

Consumer Electronics. For TVs, VCRs, audio equipment, and set-top boxes[7], ENERGY STAR focuses on reducing devices' standby power. Savings are typically assumed to accrue in both active and standby mode, since standby functions like remote control and memory are powered whether the device is on or off. The power savings are only a few watts per unit, but the number of units is large. There are approximately 200 million TVs, 120 million VCRs, and 10 million TV/VCR combination units in U.S. homes (Rosen and Meier 1999). This does not include the many TVs and VCRs that are used in the U.S. commercial sector, about which we have little data of any kind. We estimate that some 54 million audio devices are sold each year, including amplifiers, receivers, tuners, CD players, cassette players, equalizers, radios, mini-systems, rack systems, DVDs and laserdiscs. Car audio and portable audio products are not included in this total, since they are not covered under the program.

[6] SEER = seasonal energy efficiency ratio, a measure of efficiency.

[7] Set-top boxes are devices intended for use with a TV, including satellite receivers, cable boxes, digital converters, internet devices, videogames, videophones, digital (hard-drive) video recorders, and combination devices.

At the present time, CD players, DVD players and mini-systems make up the vast majority of ENERGY STAR audio savings. We currently include only these three products in our reported savings; others may be added as ENERGY STAR participation increases among other types of audio products.

The biggest difficulty in forecasting TV and VCR power consumption was obtaining unit power consumption data. When EPA began to develop the program, the most recent data available on television energy use were over ten years old, and virtually no data were available for VCRs or audio equipment. New metered data collected by researchers at LBNL and the Florida Solar Energy Center provided the basis for developing the product label (Floyd & Webber 1998). Once the TV/VCR agreement was in place these values were updated using shipment-weighted power consumption values provided by industry representatives (Isaacs 1998). Our TV and VCR shipment forecasts were developed using historic shipment data from *Appliance* (1995).

During the course of this analysis, EPA was in the process of revising the TV and VCR specification. EPA and the consumer electronics manufacturers agreed on a new specification in January 2002, and that specification was incorporated into the model at that time. That specification reduced allowable standby power levels to one watt in mid-2002. A change in EPA's policy regarding grandfathering[8] threw the specification back into negotiation, and a new agreement was reached that delayed the change to a one-watt specification for most products. However, this final agreement came too late to be incorporated in this analysis. This analysis therefore assumes a more aggressive specification than the final agreement.

An Energy Star label for telephony products was launched in January of 2002. While this label does not affect 2001 savings, it does contribute toward savings in our 2002 savings forecast and our cumulative savings forecasts for 2002-2010 and 2002-2020.

Residential Lighting. The ENERGY STAR program promotes energy-efficient residential lighting fixtures and compact fluorescent lamps (CFLs). ENERGY STAR fixtures include fixtures designed to take only pin-based CFLs, electronically-ballasted tube fluorescent fixtures, and outdoor fixtures that incorporate motion sensors and photocells.

We analyze the residential lighting fixture market in three segments: torchieres, other indoor fixtures, and outdoor fixtures. Torchieres were split out because the market is dominated by high-wattage halogen fixtures using 300 to 500 watts. ENERGY STAR CFL replacements for these fixtures have proven to be a great success, and market penetrations for these products are higher than for other ENERGY STAR fixtures. Torchiere energy savings are calculated using data from Calwell (1999) and Calwell and Granda (1999). Shipment data for other indoor fixtures and outdoor fixtures were from the U.S. Department of Commerce (1997).

Even though prices of CFLs have fallen significantly in recent years, they are still not cost-effective in low-use fixtures. However, we recognize that some CFLs do end up in low-use applications (for example, if the consumer needs a long-life lamp for a hard-to-reach socket). We therefore split

[8] Previously, once a model earned the Energy Star label, it could continue to carry the label until the model was discontinued, even after EPA changed the specification. Under the new rule, units must meet the current specification to be sold with the label.

indoor fixtures into three usage bins (less than one hour per day, one to three hours per day, and more than three hours per day) for this analysis. We assume a high market penetration among high-use fixtures, since CFLs are generally cost effective at that level of use, but lower penetrations for medium- and low-use fixtures. Unit energy consumption for high-use indoor fixtures was taken from the Baseline Residential Lighting Energy Use Study (described in Vorsatz et al 1997). For the 100 percent penetration scenario, we assumed that 100 percent of high-use fixtures were replaced, 50 percent of medium-use fixtures and 10 percent of low-use fixtures.

Our analysis of outdoor fixtures focused on motion sensor- and photocell-equipped fixtures. Baseline energy consumption was again taken from the Baseline Residential Lighting Energy Use Study. As with indoor fixtures, we focused on high-use fixtures, although for different reasons. Outdoor fixtures, especially around entryways, are often left on all night for security. Motion sensor fixtures are particularly suited for this type of application. A motion sensor was assumed to reduce usage to one hour per day.

Compact fluorescent lamps were added to the analysis this year. Like indoor fixtures, they were analyzed by usage bin. The analysis was complicated by the fact that CFLs have a significantly longer lifetime (10,000 hours) than incandescent lamps (usually estimated at 750 to 1,500 hours, we use 1,500 hours for this analysis). Because a CFL lasts longer, one CFL replaces one current plus several future incandescent lamp purchases. The larger the market share of CFLs, the fewer total lamps will be sold (because they need to be replaced less often). This problem required a more elaborate stock accounting than had been done for the other products.

Commercial Lighting. Commercial lighting products covered by ENERGY STAR labels include exit signs and traffic signals. Both of these products have ample opportunity for efficiency improvements, particularly through the use of LEDs. The advantage of LEDs go beyond energy efficiency. Since LEDs last many times longer than incandescent lamps, maintenance costs can be sharply reduced.

Although exit signs may seem like a small niche in the commercial lighting market, they were an ideal target for an ENERGY STAR program. Exit signs must be lit 24 hours a day. Most signs use incandescent lamps for illumination, which consume about 40 watts. ENERGY STAR exit signs must consume less than five watts. Because of the importance of visibility during emergencies, the program also includes visibility and luminance requirements.

Calculating energy savings for exit signs was fairly straightforward. However, there is some uncertainty associated with the size of the stock, shipments and lifetime. The lifetime for some light sources (LED and electroluminescent) are reported to be 20 years or more, but because efficacy may degrade over time we use a more conservative ten year lifetime.

Because retrofits are the primary driver of LED traffic signal sales, we based our analysis for these products on stock replacement rather than estimating the ENERGY STAR share of units shipped, as we did with other products. Red and green traffic signals were modeled separately because of differences in cost effectiveness. Green signals have shorter duty cycles and green LEDs are more expensive than red LEDs, making it less cost effective to replace a green incandescent signal with an LED signal.

Appliances. ENERGY STAR appliances for the home include refrigerators, clothes washers, dishwashers, room air conditioners (RACs), dehumidifiers, ceiling fans and exhaust fans. Bottled water coolers (cold only and hot/cold) and commercial refrigerators and freezers are also covered.

After HVAC and water heating, large appliances constitute the largest energy end-uses in a typical home. Like some of the HVAC products, refrigerators, clothes washers, dishwashers, and room air conditioners (RACs) are already subject to federal minimum efficiency standards. The ENERGY STAR program is intended to expand the market for products that significantly exceed the minimum standard. To earn an ENERGY STAR label refrigerators must be 10 percent more efficient than standards, dishwashers must be 25 percent more efficient and RACs must be 10 percent more efficient than standards. The clothes washer specification is set so that the devices must be horizontal axis or equivalent efficiency to qualify. The minimum efficiency standard for clothes washers will be tightened in 2004 and again in 2007.

To obtain energy use for these ENERGY STAR devices, we first calculated unit energy consumption for units just meeting the federal minimum efficiency standards. The average energy consumptions for refrigerators and RACs (under both existing and new efficiency standards) were weighted according to the distribution of products by product class and capacity (Wenzel et al. 1997, US DOE 1995b, US DOE 1997a). In the case of dishwashers and clothes washers a prototypical model was used to calculate energy consumption. Where ENERGY STAR criteria were specified in terms of percent efficiency improvement over standards, the appropriate percentages were then applied to obtain ENERGY STAR energy consumption.

A large share of the energy consumption by clothes washers and dishwashers is due to the use of household hot water, which may be heated using gas, oil, LPG or electricity. (Because oil and LPG water heaters represent only a small fraction of water heaters, they were treated together with gas water heaters for this analysis). The test procedures for these products include both the electricity used by the device itself (motor, controls, etc.) and energy (fuel or electric) used for water heating. The test procedure for clothes washers also includes dryer energy, since remaining moisture content in the load at the end of a wash cycle varies by washer and affects the amount of energy required to dry the load.[9] Dryers may also be gas or electric. We therefore analyzed dishwasher energy savings in three parts: machine energy, which accrued to all devices, electric water heating energy, which accrued to devices installed in electric water heating homes, and gas water heating energy, which accrued to devices installed in gas water heating homes (oil and LPG water heating homes were also included here). Similarly, clothes washer saving are analyzed in five parts: machine, electric water heating, gas water heating, electric drying and gas drying. The shares of water heating by fuel type were taken from US DOE (1999b). Unit energy consumption and savings for clothes washers and dishwashers included machine energy and weighted-average water heating energy for all fuels, expressed as primary energy.

[9] The Department of Energy changed the test procedure for clothes washers several years ago. The current standard is based on energy factors that measure energy per wash cycle for machine and water heating energy. The 2004 and 2007 standards are based on modified energy factors (MEF), which include dryer energy. The current ENERGY STAR specification is expressed in terms of MEF.

Dehumidifiers are not covered by appliance standards. For these, the ENERGY STAR requirement was specified in terms of kWh of energy used per liter of water removed from the air. Baseline efficiencies were obtained from Cadmus (1999).

Ceiling fans and exhaust fans arguably could have been grouped with HVAC equipment. However, because these products are not covered by minimum efficiency standards, they are instead included with appliances. Ceiling fan UEC data was taken from Calwell and Horowitz (2001). Information on exhaust fan usage was unavailable; usage was simply assumed to be one hour per day for the types of fans covered by the program (rangehood fans and bathroom and utility room exhaust fans). Exhaust fan power levels were obtained from product literature from manufacturers.

Energy Star also covers two commercial appliances. Water coolers were added in 2000 and commercial refrigeration in 2001. Water cooler efficiencies are specified in terms of kWh per day. Baseline efficiencies were obtained from Cadmus (2000). Data for commercial refrigerators and freezers was taken from A. D. Little (1996) and Cadmus (2001).

Recent Changes to the Model

The results of this model have been presented in two earlier reports (Webber et al. 1999, Webber et al. 2002). Several important changes have been made to the program and the model between the 2001 status report and this one, which we will highlight here. Some of these items have been mentioned elsewhere, and are repeated here for ease of reference.

Several products were added to the analysis since the previous update (Webber et al. 2002). CFLs, telephony products, commercial refrigerators and freezers, residential spot ventilation fans and ceiling fans are all new additions to this year's analysis. In addition, LCD monitors were split out as a separate product class. Because LCD monitors have a lower active power consumption than CRTs, our monitor savings estimate declined as a result. New ENERGY STAR specifications for TVs, VCRs, central air conditioners and air-source heat pumps were introduced and incorporated into the model (although as noted above, the TV and VCR specifications were revised again after this update).

Market transformation effects were added to the model, as discussed above in the methodology section.

Detailed shipment data were purchased for office equipment products and incorporated into the model. Central air conditioner and air-source heat pump shipment data by efficiency level was used to update shipments and market share for those products.

The results of a metering study of PCs and monitors (Roberson et al., 2002) were used to update active and standby power levels for these products. The metering showed that PC had significantly higher power levels than in the past, with the Pentium 4 and Athlon computers using 100 watts or more, compared to the 55 watts we had previously used in the model, reflective of earlier, cooler-running chips. The monitor metering, on the other hand, found that the model had significantly overstated monitor active power levels. We had previously assumed an 85-watt active power level based on the information reported by manufacturers to EPA on their qualifying models. When the

metering found an average power of only 65 watts for 17 inch CRTs,[10] an investigation into the manufacturer-reported data ensued. We found that for a variety of reasons, manufacturers tended to report worst-case power consumption.[11] Since our savings calculations should reflect average monitor settings and average user behavior, we revised the model using the metered data, which resulted in a significant decline in our estimate of monitor savings for the program.

We switched to year-by-year electric heat rates (previously we had assumed a constant heat rate of 10,500 Btu per kWh). This methodology is consistent with our use of year-by-year carbon factors for electricity. Both carbon factors and heat rates depend on the mix of electricity generation technologies, which have been moving away from coal toward cleaner generation technologies.

Market penetrations for HVAC equipment were significantly revised. Previously, market penetrations were based on EPA forecasts of their sales training activity. This methodology has been dropped. New central air conditioner and air-source heat pump market penetrations were based on recent ARI sales data (which showed significantly lower market penetrations than anticipated), and reasonable expectations of the effect of the 2006 standards. In the absence of comparable sales data, the furnace and boiler forecasts were revised to be much more conservative, based on the air conditioner and heat pump experience. Programmable thermostat shipments were increased to be consistent with stocks reported in RECS (US DOE 1999c).

The lighting analysis was split by usage bins. Previously, it was assumed that all ENERGY STAR fixtures would go to high-use applications. The 100 percent market penetrations scenario also targeted only high-use fixtures. We now assume a low level of penetration in medium- and low-use applications, with maximum penetrations of 50 percent and 10 percent, respectively, in the 100 percent market penetration case.

[10] The average monitor size has been increasing over time, and average active power along with it. The average monitor size in 2002 is slightly larger than 17 inches. However, monitor size differences do not account for the discrepancy between manufacturer-reported and metered data.

[11] The manufacturers that were interviewed reported that they measured monitor active power use at maximum resolution, brightness and contrast, displaying a white screen. Safety concerns require that they know the maximum power that the device will draw, and they used the same power measurements for both safety testing and to report to ENERGY STAR.

Table 4. Annual and Lifetime Savings per Unit for ENERGY STAR® Devices Sold in 2001

Equipment Type	% Annual Energy Savings[a]	Annual Unit Primary Energy Savings[b] MBtu/yr	Annual Bill Savings Due to ENERGY STAR[c] 2000$/unit	Product Lifetime[d] years	Lifetime Energy Savings[e] (million Btu)	Lifetime Energy Bill Savings, Undiscounted[c] 2000$/unit
Office Equipment						
-Office Computer and Monitor	54%	6.2	$45	4	25	$170
-Home Computer and Monitor[f]	28%	1.4	$11	8	11	$81
-Fax	40%	1.4	$10	4	5.5	$38
-Copier	41%	3.9	$28	6	23	$160
-Multifunction Devices	42%	5.6	$41	6	34	$230
-Scanner	49%	0.91	$6.5	4	3.6	$25
-Printer	27%	1.8	$13	5	9.0	$61
Consumer Electronics						
-TV	24%	0.39	$3.0	11	4.2	$25
-VCR	19%	0.13	$1.0	11	1.4	$6.6
-TV/VCR	23%	0.41	$3.2	11	4.4	$21
-Audio Equipment	64%	0.49	$3.9	7	3.4	$30
-Set-top Boxes	16%	0.23	$1.8	7	1.6	$12
Residential Heating and Cooling						
-Furnace (Gas or Oil)	15%	13	$110	18	230	$1,600
-Central Air Conditioner	19%	6.4	$50	14	87	$650
-Air-Source Heat Pump	13%	17	$140	12	200	$1,500
-Geothermal Heat Pump	30%	56	$440	15	810	$6,000
-Boiler (Gas or Oil)	7%	7.0	$62	20	140	$970
-Programmable Thermostat	20%	21	$180	15	310	$2,300
Lighting						
-Fixture	78%	0.82	$6.4	20	16	$120
-CFL	67%	0.93	$7.3	[i]	5.6	$14
-Exit Sign	76%	1.5	$11	10	15	$98
-Traffic Signal	90%	5.9	$43	10	58	$390
Appliances						
-Room Air Conditioner	10%	0.67	$5.3	13	8.5	$63
-Dehumidifier	10%	1.2	$9.6	12	14	$110
-Water Coolers	45%	1.5	$12	10	15	$110
-Exhaust Fan	65%	0.58	$4.6	10	5.7	$42
-Ceiling Fan	52%	1.6	$13	10	16	$95
-Dishwasher[g]	25%	1.1	$8.6	13	13	$98
-Refrigerator[h]	16%	1.1	$8.4	19	20	$150
-Commercial Refrigeration	43%	20	$150	10	200	$1,300
-Clothes Washer[g,h]	38%	3.3	$46	14	44	$330

Notes to Table 4:

a) Annual savings are relative to standard new unit, with the following qualifications: Geothermal heat pump is compared to air-source heat pump and electric water heater. Residential lighting fixtures are compared to a standard incandescent fixture. Copier and multifunction device savings are for models meeting the Tier 2 requirements, effective in 1998 for copiers and in 2000 for MFDs. Exit sign savings are compared to standard incandescent fixtures. For HVAC, the standard energy bills are derived from 1990 RECS consumption data.

b) Electricity is converted to primary energy using a conversion factor of 10,500 Btu/kWh (US DOE 1995a).

(Continued on next page.)

Results

Table 4 shows annual unit energy and energy bill savings, average product lifetime, and lifetime energy and energy bill savings for each product. These estimates form the basis of the calculation of savings to date and the forecasts of future savings. ENERGY STAR geothermal heat pumps have the highest absolute per unit savings, followed by programmable thermostats and commercial refrigeration. Ranked by percentage savings, however, traffic signals take the lead at 90 percent savings. Other products with at least 50 percent savings are exit signs, residential lighting fixtures, CFLs, computers, exhaust fans, ceiling fans, and audio equipment.

Tables 5 and 6 show annual energy, dollar, and carbon savings for 2001 and 2002, respectively. Also shown is the peak demand reduction due to the program. The addition of new products combined with increased market penetration for existing products is increasing annual savings at a rapid rate. Annual savings in 2001 were 550 trillion Btu and $4.1 billion, an increase of more than 30% over 2000 savings. By 2002, energy savings are expected to reach 700 trillion Btu and $4.9 billion. The peak demand reduction due to the ENERGY STAR labeling program was 5.7 gigawatts in 2001 and is expected to increase to 7.0 gigawatts in 2002.

We provide savings forecasts for two cases: a target market penetration case, using EPA's and DOE's market penetration goals for ENERGY STAR devices, and a 100 percent market penetration case, assuming that all shipments are ENERGY STAR-compliant (but not necessarily enabled, see below) from 2002 onward.

Notes to Table 4 (continued):

c) Yearly U.S. average energy prices are from US DOE (1996a, 1996b, 1997b, 1998b, 1999a), and are shown in Table 2. Lifetime energy bill savings are calculated using the stream of future energy prices.

d) Lifetimes are the average lifetime for each product. Computer, monitor, copier, printer and fax lifetimes are from Koomey et al. (1995) (the short lifetimes for computers reflects rapid obsolescence for those products); scanner lifetimes are assumed to be the same as those of fax machines; TV and VCR lifetimes are from *Appliance* (1996); gas furnace, central air conditioner, air-source heat pump and boiler lifetimes are from Lewis and Clarke (1990); geothermal heat pump lifetime is an LBNL estimate; thermostat lifetime is the weighted average of HVAC lifetimes; exit sign life is from National Lighting Product Information (1994); new home life is based on a typical 30 year mortgage; appliance lifetimes are from Wenzel et al (1997).

e) Lifetime energy savings may not equal the product of annual energy savings and product lifetime due to rounding.

f) Usage assumptions for home computers and monitors differ from office computers and monitors, resulting in different unit savings.

g) Dishwashers energy savings include machine energy and water heating energy. Clothes washer savings include machine, water heating and dryer energy. Water heating and dryer energy are a weighted average of gas and electric equipment energy.

h) The savings for refrigerators and clothes washers given here are lower than the percent savings over efficiency standards specified by the ENERGY STAR program (20 percent and 50 percent, respectively) because here we are comparing to standard new units, which are more efficient than the minimum standard. Refrigerator savings are from US DOE (1995b). Clothes washer savings are from US DOE (1998a).

i) CFL lifetime is assumed to be 10,000 hours.

Target Market Penetration Case. This case represents the best estimate of the long-term aggregate savings achievable by ENERGY STAR programs given the market penetration goals and unit energy savings estimates of the individual programs. The target market penetration case uses unit savings estimates and year-by-year penetration targets with the best available estimates of inputs such as energy prices and carbon emission factors. The target market penetrations are based, in part, on the price premium for ENERGY STAR units. Because ENERGY STAR computers and monitors are no more expensive than non-ENERGY STAR devices, they are expected to represent a large share of the market (95 percent or more) by 2010. In contrast, high efficiency heating and cooling equipment is significantly more expensive than standard equipment.

Table 7 and Table 8 show the cumulative savings under target market penetrations for the periods 2002-2010 and 2002-2020, respectively. All the products together are expected to save 11 quadrillion Btu (quads) by 2010, growing to 31 quads by 2020. Through 2010, computers (CPUs and monitors) account for the largest share of savings, primarily due to the large market share of ENERGY STAR devices and steep growth in the number of units in place. Residential lighting fixtures have the second highest savings. By 2020, those positions are reversed and residential fixtures have the largest savings. Although residential fixtures have only a moderate penetration, the number of units shipped each year is large, resulting in a large number of ENERGY STAR units in place, each with a high unit savings. In both periods, printers and CFLs take the number three and four spots, respectively.

100 Percent Market Penetration. Our 100 percent market penetration scenario shows the savings that could be achieved if everyone bought ENERGY STAR equipment instead of standard equipment from 2001 to 2010. Because geothermal heat pumps are a new technology without a defined baseline market share, they are modeled as seizing a share of the markets for more traditional technologies. Geothermal heat pumps are assumed to displace half of non-ENERGY STAR air-source heat pumps. The 100 percent penetration forecast for air-source heat pumps takes into account this loss of market to geothermal heat pumps. As noted above, among residential lighting fixtures only high-use fixtures are assumed to achieve 100 percent market penetration in this scenario. Medium- and low-use fixtures are assumed to have maximum market penetrations of 50 percent and 10 percent, respectively. Similarly, for CFLs we assume a maximum penetration of 50 percent for medium-use fixtures and 25 percent for low-use fixtures.

The 100 percent market penetration scenario should not be interpreted as a technical potential, because although we assume that all units sold are ENERGY STAR, we do not assume that all units sold are properly enabled. Studies have noted less than 100 percent enabling rates of ENERGY STAR features in office equipment, particularly copiers, computers and monitors (see Table 3).

The cumulative savings for the 100 percent market penetration scenario are also shown in Tables 7 and 8. Together the programs could save 36 quads from 2001 to 2010, growing to 70 quads by 2020. These correspond to a total energy bill savings of $190 billion through 2010 and $440 billion through 2020 (present value, discounted at a 4 percent real discount rate). These totals are about three times the savings in the target market penetration case. By far the largest savings in the 100 percent market penetration case is due to CFLs, followed by residential lighting fixtures and computers. By 2020, fixtures and CFLs remain in the number one and two spots, but programmable thermostats have overtaken computers.

Table 5. Annual Savings in 2001

Program	Equipment Type	Primary Savings[b] (trillion Btu)	Energy Bill Savings Undiscounted[c] (millions of 2000$)	Carbon Emissions Avoided[d] (MtC)	Conser-vation Load Factor[e]	Peak Load Savings (GW)
Office Equipment	- Computers and Monitors	250	$1,800	4.4	1.2	2.3
	- Faxes	32	$230	0.57	1.0	0.33
	- Copiers	9.6	$70	0.17	9.8	0.011
	- Multifunction Devices	17	$130	0.31	2.7	0.065
	- Scanners	11	$80	0.20	0.32	0.37
	- Printers	58	$420	1.0	7.3	0.23
	Subtotal	370	$2,700	6.7	1.2	3.3
Consumer Electronics	- TVs	14	$110	0.26	1.0	0.15
	- VCRs	10	$79	0.18	1.0	0.11
	- TV/VCRs	4.6	$36	0.083	1.0	0.049
	- Audio Equipment	1.5	$12	0.027	1.0	0.016
	- Set-top Boxes[f]	0.50	$3.9	0.0089	1.0	0.0051
	Subtotal	31	$240	0.56	1.0	0.33
Residential Heating & Cooling	- Furnaces (Gas or Oil)	3.3	$28	0.050	NA	NA
	- Central Air Conditioners	2.8	$22	0.050	0.15	0.20
	- Air-Source Heat Pumps	2.1	$16	0.038	0.15	0.055
	- Geothermal Heat Pumps	1.1	$8.7	0.020	0.15	0.0091
	- Boilers (Gas or Oil)	0.12	$1.1	0.0021	NA	NA
	- Programmable Thermostats	39	$330	0.64	0.15	0.58
	Subtotal	48	$400	0.80	0.15	0.84
Res and Com Lighting	- Fixtures	34	$270	0.61	1.0	0.36
	- CFLs	18	$140	0.33	1.0	0.19
	- Exit Signs	26	$190	0.46	1.0	0.28
	- Traffic Signals[f]	1.3	$9.3	0.023	1.0	0.014
	Subtotal	80	$610	1.4	1.0	0.83
Appliances	- Room Air Conditioners	2.4	$18	0.042	0.15	0.17
	- Dehumidifiers[f]	0.12	$0.96	0.0022	0.42	0.0031
	- Water Coolers	0.075	$0.59	0.0013	0.66	0.0012
	- Exhaust Fans	0.021	$0.17	0.00038	0.61	0.00037
	- Ceiling Fans	0.00	$0.0	0.0	1.0	0.0
	- Dishwashers	2.4	$19	0.040	0.76	0.024
	- Refrigerators	7.0	$55	0.13	0.95	0.078
	- Commercial Refrigeration	0.17	$1.2	0.0030	0.94	0.0019
	- Clothes Washers	7.7	$62	0.13	0.66	0.086
	Subtotal	20	$160	0.34	0.50	0.36
TOTAL		550	$4,100	9.8	0.96	5.7

Notes to Table 5:

a) Columns may not total due to rounding.

b) Electricity is converted to primary energy using a conversion factor of 10,500 Btu/kWh (US DOE 1995a).

c) Energy bills are calculated using yearly U.S. average energy prices from US DOE (1996a, 1996b, 1997b, 1998b, 1999a). See Table 2.

d) Carbon emissions for electricity are from Cadmus (1998). See Table 2.

e) CLFs for clothes washers and dishwashers are derived from PG&E and SCE summer load shape from Ruderman et al. (1989, Table D-1 to D-5 and D-7 to D-11, p. D-1 to D-12). Dehumidifier CLF take from usage patterns from AD Little (1998). Water cooler CLF derived from metered load data from Rovi (2001). CLFs for cooling technologies and refrigerators taken from Koomey et al. (1990). Residential lighting CLFs are based on load profiles taken from an October 1979 report by the CEC. CLFs for exit signs and traffic signals equal one because they operate 24 hours a day. CLFs for consumer electronics equal one because savings are assumed to accrue whether the device is on or off. Office equipment CLFs are derived from assumed operating patterns (Piette et al. 1995, Nordman et al. 1998, and recent printer and scanner metered data).

f) ENERGY STAR traffic signals were not introduced until the end of 2000 and did not achieve any savings that year. ENERGY STAR set-top boxes and dehumidifiers were not introduced until 2001.

Table 6. Expected Annual Savings in 2002

Program	Equipment Type	Primary Savings[b] (trillion Btu)	Energy Bill Savings Undiscounted[c] (millions of 1998$)	Carbon Emissions Avoided[d] (MtC)	Peak Load Savings (GW)[e]
Office Equipment	- Computers and Monitors	280	$1,900	4.7	2.5
	- Faxes	35	$240	0.59	0.36
	- Copiers	7.6	$52	0.13	0.0078
	- Multifunction Devices	27	$180	0.45	0.10
	- Scanners	15	$100	0.26	0.52
	- Printers	83	$570	1.4	0.29
	Subtotal	450	$3,100	7.5	3.8
Consumer Electronics	- TVs	20	$150	0.34	0.21
	- VCRs	13	$93	0.21	0.13
	- TV/VCRs	6.5	$49	0.11	0.069
	- Audio Equipment	3.0	$22	0.051	0.032
	- Telephony	0.063	$0.47	0.0011	0.00068
	- Set-top Boxes	1.3	$9.6	0.022	0.013
	Subtotal	43	$320	0.73	0.46
Residential Heating & Cooling	- Furnaces (Gas or Oil)	4.8	$32	0.072	NA
	- Central Air Conditioners	3.5	$26	0.058	0.25
	- Air-Source Heat Pumps	2.2	$16	0.037	0.058
	- Geothermal Heat Pumps	1.6	$12	0.027	0.013
	- Boilers (Gas or Oil)	0.17	$1.3	0.0030	NA
	- Programmable Thermostats	46	$320	0.73	0.68
	- Unitary HVAC	0.17	$1.1	0.0028	0.012
	Subtotal	58	$410	0.93	1.00
Res and Com Lighting	- Fixtures	53	$390	0.89	0.55
	- CFLs	35	$260	0.59	0.36
	- Exit Signs	32	$220	0.55	0.34
	- Traffic Signals	2.5	$17	0.042	0.026
	Subtotal	120	$890	2.1	1.3
Appliances	- Room Air Conditioners	2.4	$18	0.041	0.17
	- Dehumidifiers	0.37	$2.7	0.0062	0.0094
	- Water Coolers	0.15	$1.1	0.0025	0.0023
	- Exhaust Fans	0.13	$0.96	0.0022	0.0020
	- Ceiling Fans	3.4	$26	0.058	0.072
	- Dishwashers	2.9	$21	0.047	0.029
	- Refrigerators	7.1	$53	0.12	0.079
	- Commercial Refrigeration	0.39	$2.7	0.0067	0.0044
	- Clothes Washers	11	$77	0.17	0.12
	Subtotal	28	$200	0.46	0.49
TOTAL		700	$4,900	12	7.0

Notes to Table 6:

a) Columns may not total due to rounding.

b) Electricity is converted to primary energy using a conversion factor of 10,500 Btu/kWh (US DOE 1995a).

c) Energy bills are calculated using yearly U.S. average energy prices from US DOE (1996a, 1996b, 1997b, 1998b, 1999a). See Table 2.

d) Carbon emissions for electricity are from Cadmus (1998). See Table 2.

e) Peak load savings are calculated using the CLFs shown in Table 5.

Table 7. Cumulative Savings 2002-2010

		Target Market Penetrations				100% Market Penetration Case			
		Primary Energy Savings[c]	Energy Bill Savings[d,e] (millions of 1998 dollars)		Carbon Avoided[f]	Primary Savings[c]	Energy Bill Savings[d,e] (millions of 1998 dollars)		Carbon Avoided[f]
Program	Equipment Type	(trillion Btu)	Undiscounted	Discounted	(MtC)	(trillion Btu)	Undiscounted	Discounted	(MtC)
Office	- Computers and Monitors	2,800	$19,000	$15,000	40	2,900	$20,000	$16,000	42
Equipment	- Faxes	340	$2,200	$1,800	4.8	340	$2,200	$1,800	4.9
	- Copiers	22	$150	$130	0.34	22	$150	$130	0.34
	- Multifunction Devices	460	$3,000	$2,400	6.5	510	$3,300	$2,600	7.1
	- Scanners	290	$1,900	$1,500	4.1	360	$2,400	$1,800	5.1
	- Printers	1,400	$10,000	$7,900	20	1,500	$10,000	$8,100	21
	Subtotal	5,400	$37,000	$29,000	76	5,600	$38,000	$30,000	80
Consumer	- TVs	390	$2,900	$2,200	5.5	670	$4,900	$3,800	9.4
Electronics	-VCRs	110	$830	$670	1.6	160	$1,100	$910	2.2
	-TV/VCRs	120	$850	$660	1.6	140	$990	$770	1.9
	- Audio Equipment	110	$780	$590	1.5	520	$3,900	$2,900	7.2
	- Telephony	140	$1,000	$750	1.9	360	$2,700	$2,000	4.9
	- Set-top Boxes	80	$590	$360	1.1	340	$2,500	$1,500	4.6
	Subtotal	950	$7,000	$5,200	13	2,200	$16,000	$12,000	30
Residential	- Furnaces (Gas or Oil)	120	$820	$620	1.7	1,400	$9,900	$7,500	21
Heating &	- Central Air Conditioners	53	$0.39	$0.30	0.00074	1,300	$9.9	$7.5	0.019
Cooling	- Air-Source Heat Pumps	18	$130	$110	0.26	480	$3,500	$2,700	6.6
	- Geothermal Heat Pumps	45	$330	$250	0.63	1,400	$10,000	$7,700	19
	- Boilers (Gas or Oil)	4.1	$30	$23	0.073	70	$500	$380	1.1
	- Programmable Thermostats	640	$4,500	$3,500	9.4	2,200	$16,000	$12,000	32
	- Unitary HVAC	26	$170	$120	0.35	1,200	$7,600	$5,800	16
	Subtotal	910	$6,000	$4,700	12	8,100	$48,000	$36,000	96
Res and	- Fixtures	1,500	$11,000	$8,200	21	3,800	$28,000	$21,000	52
	- CFLs	980	$7,200	$5,500	14	12,000	$90,000	$72,000	180
Comm. Lighting	- Exit Signs	420	$2,800	$2,200	5.9	460	$3,000	$2,400	6.5
Lighting	- Traffic Signals	53	$350	$270	0.74	53	$350	$270	0.74
	Subtotal	2,900	$21,000	$16,000	41	17,000	$120,000	$95,000	240
Appliances	- Room Air Conditioners	24	$180	$140	0.34	160	$1,200	$870	2.2
	- Dehumidifiers	12	$87	$66	0.16	41	$300	$230	0.57
	- Water Coolers	6.3	$46	$35	0.087	71	$520	$390	0.97
	- Exhaust Fans	15	$110	$83	0.21	150	$1,100	$820	2.1
	- Ceiling Fans	230	$1,700	$1,300	3.1	1,000	$7,500	$5,700	14
	- Dishwashers	52	$370	$280	0.73	240	$1,700	$1,300	3.4
	- Refrigerators	74	$540	$420	1.0	360	$2,600	$2,000	4.9
	- Commercial Refrigeration	18	$120	$90	0.25	180	$1,200	$870	2.4
	- Clothes Washers	170	$1,200	$940	2.4	740	$5,300	$4,100	10
	Subtotal	600	$4,300	$3,300	8.4	3,000	$21,000	$16,000	41
TOTAL		11,000	$76,000	$58,000	151	36,000	$240,000	$190,000	480

See notes after Table 8.

Table 8. Cumulative Savings 2002-2020

		Target Market Penetrations				100% Market Penetration Case			
		Primary Energy Savings[c]	Energy Bill Savings[d,e] (millions of 2000 dollars)		Carbon Avoided[f]	Primary Savings[c]	Energy Bill Savings[d,e] (millions of 2000 dollars)		Carbon Avoided[f]
Program	Equipment Type	(trillion Btu)	Undiscounted	Discounted	(MtC)	(trillion Btu)	Undiscounted	Discounted	(MtC)
Office	- Computers and Monitors	6,100	$42,000	$28,000	85	6,400	$44,000	$29,000	88
Equipment	- Faxes	750	$5,000	$3,300	10	760	$5,100	$3,300	11
	- Copiers	24	$160	$140	0.37	25	$160	$140	0.38
	- Multifunction Devices	1,100	$7,200	$4,600	15	1,200	$8,000	$5,100	16
	- Scanners	790	$5,300	$3,300	11	910	$6,100	$3,900	12
	- Printers	3,700	$30,000	$19,000	51	3,800	$30,000	$19,000	52
	Subtotal	12,000	$90,000	$58,000	170	13,000	$93,000	$60,000	220
Consumer	- TVs	1,000	$7,800	$4,900	14	1,900	$14,000	$8,800	26
Electronics	- VCRs	140	$1,000	$790	2.0	180	$1,400	$1,000	2.6
	- TV/VCRs	230	$1,700	$1,200	3.2	260	$1,900	$1,300	3.5
	- Audio Equipment	370	$2,800	$1,700	5.0	1,500	$11,000	$6,900	20
	- Telephony	590	$4,500	$2,600	8.0	1,300	$9,700	$5,800	17
	- Set-top Boxes	410	$3,100	$1,500	5.6	1,200	$9,300	$4,500	17
	Subtotal	2,800	$21,000	$13,000	38	6,300	$48,000	$28,000	86
Residential	- Furnaces (Gas or Oil)	520	$3,700	$2,100	7.5	6,200	$44,000	$26,000	90
Heating &	- Central Air Conditioners	130	$0.98	$0.62	0.0018	5,000	$38	$23	0.068
Cooling	- Air-Source Heat Pumps	20	$150	$120	0.29	1,500	$11,000	$6,900	20
	- Geothermal Heat Pumps	280	$2,100	$1,200	3.8	5,300	$40,000	$24,000	72
	- Boilers (Gas or Oil)	19	$150	$86	0.34	300	$2,200	$1,300	4.8
	- Programmable Thermostats	1,600	$12,000	$7,500	24	7,500	$54,000	$33,000	110
	- Unitary HVAC	180	$1,200	$680	2.4	4,200	$28,000	$17,000	57
	Subtotal	2,800	$19,000	$12,000	38	30,000	$180,000	$110,000	350
Res and	- Fixtures	7,200	$55,000	$32,000	99	15,000	$120,000	$68,000	210
	- CFLs	3.400	$26,000	$15,000	46	25,000	$190,000	$130,000	350
Comm. Lighting	- Exit Signs	660	$4,400	$3,100	9.2	800	$5,300	$3,700	11
Lighting	- Traffic Signals	150	$1,000	$640	2.1	150	$1,000	$640	2.1
	Subtotal	11,000	$86,000	$51,000	160	41,000	$310,000	$200,000	570
Appliances	- Room Air Conditioners	46	$340	$230	0.64	540	$4,100	$2,500	7.4
	- Dehumidifiers	39	$290	$180	0.53	140	$1,100	$650	1.9
	- Water Coolers	41	$320	$180	0.56	270	$2,000	$1,200	3.6
	- Exhaust Fans	98	$740	$420	1.3	490	$3,700	$2,200	6.6
	- Ceiling Fans	900	$6,800	$4,000	12	3,200	$24,000	$15,000	44
	- Dishwashers	170	$1,300	$770	2.4	870	$6,400	$3,800	12
	- Refrigerators	190	$1,500	$920	2.7	1,400	$11,000	$6,400	20
	- Commercial Refrigeration	92	$620	$360	1.2	560	$3,800	$2,300	7.7
	- Clothes Washers	310	$2,300	$1,600	4.4	1,500	$11,000	$7,300	21
	Subtotal	1,900	$14,000	$8,600	26	9,000	$67,000	$41,000	120
TOTAL		31,000	$230,000	$140,000	430	70,000	$700,000	$440,000	1,300

See notes next page.

Figure 2. Annual carbon savings relative to the business-as-usual case

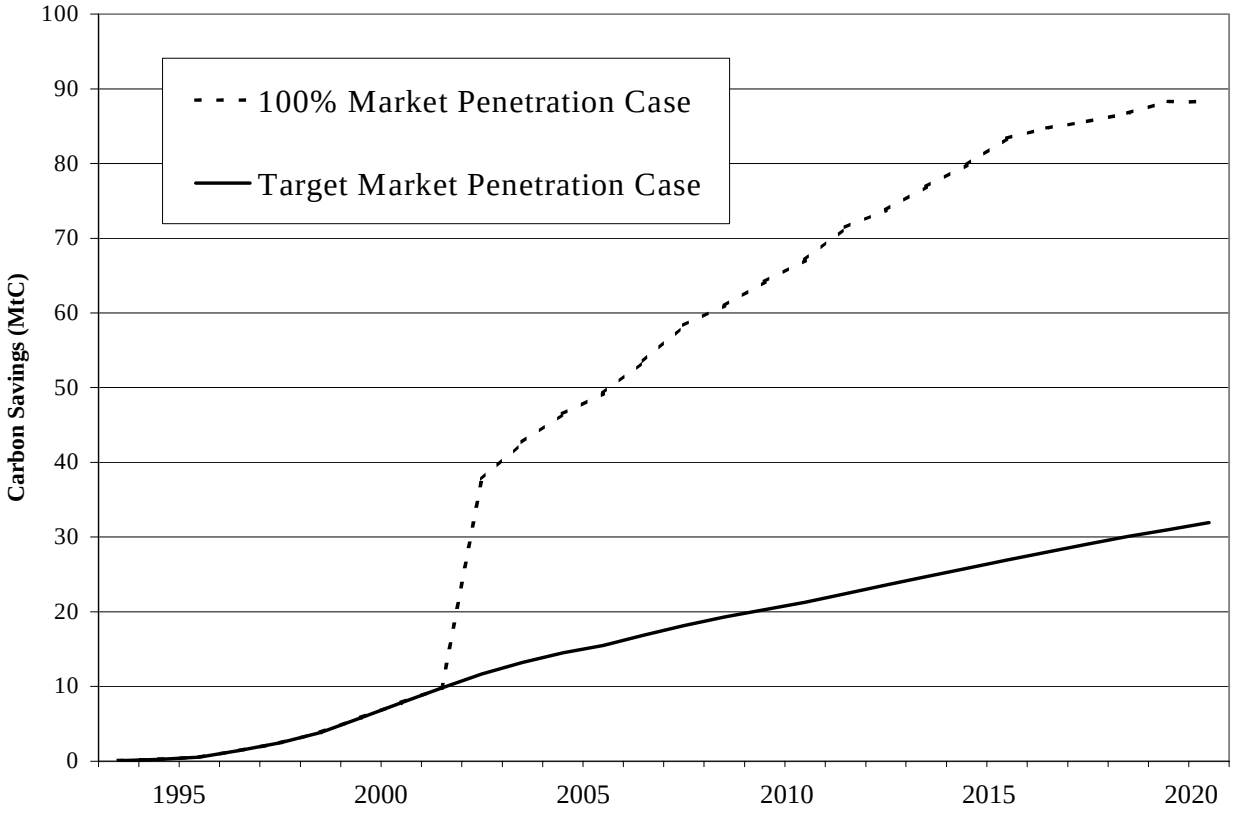


Figure 1 compares annual carbon savings under the 100 percent market share scenario and the target market penetration scenario through 2020.

Limitations of the Analysis

Our estimates of unit energy consumptions for office equipment and consumer electronics are calculated from underlying usage patterns and power consumption estimates. We face limitations on three fronts: First, there have been limited data collected for many of these products. As more information has become available, we have updated our forecasts, and we will continue to do so in the future. Such data can change our estimates significantly. In the case of monitors, recent product

Notes to Table 7 and 8:

a) Columns may not total due to rounding.

b) Target market penetrations represent EPA's and DOE's best estimates of the percent of equipment shipped that is ENERGY STAR. These estimates are based on past market penetrations, manufacturer commitments, and EPA's and DOE's long-term goals. The 100 percent market penetration scenario assumes all equipment shipped from 1998 onward is ENERGY STAR-compliant.

c) Electricity is converted to primary energy using a conversion factor of 10,500 Btu/kWh (US DOE 1995a).

d) Cumulative bill savings do not take into account increased investment costs. Cumulative bill savings are discounted using a 4 percent real discount rate.

e) Yearly U.S. average energy prices are from US DOE (1996a, 1996b, 1997b, 1998b, 1999a). See Table 2.

f) Carbon emissions for electricity are from Cadmus (1998). See Table 2.

metering found lower monitor active power than previously assumed (Roberson et al., 2002), which caused our unit energy consumption and savings estimates to drop. Second, there is great diversity in power consumption within each product category, and we lack the data to create a precise shipment-weighted average energy consumption. Third, we lack metered data on unit energy consumption; instead metered power use is paired with an assumed usage pattern to estimate consumption.

Our analysis focuses exclusively on the ENERGY STAR Program and does not attempt to rigorously reconcile the projected effects of the program with the existence of other overlapping efficiency programs.

Procurement programs and utility rebate programs now often use the ENERGY STAR label to identify qualifying products, reducing the costs of designing and operating these programs while helping to boost the market share of ENERGY STAR products. This analysis does not attempt to account for these interactions, and therefore the savings presented here include savings that might legitimately be claimed by other energy conservation programs. Sorting through the universe of efficiency programs to assess all potential interactions was beyond the scope of this analysis. Care should be taken, therefore, in combining these savings forecasts with those of other programs.

Although our analysis takes into account existing and finalized future federal minimum efficiency standards, we chose not to speculate about possible future standards and how they might affect the savings due to the various ENERGY STAR labels in the future. Such standards would probably trigger a tightening in the ENERGY STAR requirement, which would reduce the number of products qualifying for a label. A stringent enough standard could even eliminate the need for an ENERGY STAR label. The products affected by federal minimum efficiency standards include central air conditioners, heat pumps, room air conditioners, furnaces, boilers, refrigerators, clothes washers and dishwashers.

Technological developments already on the horizon will likely force us to revise our forecast in the not-too-distant future. The price of LCD monitors has dropped to the point where they are beginning to replace CRT monitors in significant numbers. The advent of high-definition television will undoubtedly affect TV power consumption, and recordable DVDs could supplant VCRs in the near future. We believe that EPA and DOE will try to leverage their existing partnerships with manufacturers to extend the ENERGY STAR label to new technologies. The face of office equipment is also changing as portable devices and wireless communication technologies take hold. Because of the uncertainties associated with this type of technological change, we made no attempt to model these changes.

The savings presented here are for the U.S. only. Since many of the ENERGY STAR products, notably office equipment, are marketed internationally, the global effects of the program may be significantly higher.

Our analysis extends only to 2020, and we made no attempt to account for savings that might accrue after that time.

Conclusions

ENERGY STAR has already proven successful in its established programs, having saved more than 500 trillion Btus of energy and prevented carbon emissions of 9.8 million metric tonnes in 2001 alone. Based on our analysis here, the continuation of those programs and the addition of new programs in appliances and home electronics have the potential to greatly reduce carbon emissions over the next 20 years. However, as EPA and DOE continue to work to improve savings through consumer education, partnerships with manufacturers, new product labels, and tightening requirements for existing products, the ENERGY STAR program may be able to achieve even higher savings in the future. If ENERGY STAR-labeled products could achieve 100 percent market penetration, $190 billion could be saved from estimated energy bills over the through 2010 (present value, at a 4 percent real discount rate).

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