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Savings Estimates for the ENERGY STAR® Voluntary Labeling Program 2001 Status Report

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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 2000, what we expect in 2001, and provide savings forecasts for two market penetration scenarios for the period 2001 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 this current era of rolling blackouts and 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. The following labeled products were not included in the analysis: transformers, windows, CFLs, ventilation fans, ceiling fans and commercial refrigeration.[1] Table 1 shows EPA's product labels 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 issuing 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, 90 percent of computers and almost 100 percent of printers sold are ENERGY STAR-compliant.

[1] Windows and commercial refrigerators and freezers have not yet been added to our forecasts. Screw-based compact fluorescent lamps, ventilation fans, and ceiling fans were not added in time to be included in this analysis.

Table 1. ENERGY STAR Products and Programs

	Covered in this report?
Computers	Y
Monitors	Y
Printers	Y
Fax Machines	Y
Scanners	Y
Copiers	Y
MFDs	Y
TVs	Y
VCRs	Y
TV-VCRs	Y
Audio Equipment	Y
Set-top Boxes	Y
Telephony	N
Air-Source Heat Pumps	Y
Geothermal Heat Pumps	Y
Central Air Conditioning	Y
Gas-Fired Heat Pumps	Y
Gas Furnaces	Y
Oil Furnaces	Y
Gas Boilers	Y
Oil Boilers	Y
Programmable Thermostats	Y
Ventilation Fans	N
Ceiling Fans	N
Residential Lighting Fixtures	Y
Exit Signs	Y
Traffic Signals	Y
CFLs	N
Clothes Washers	Y
Dishwashers	Y
Room Air Conditioners	Y
Refrigerators	Y
Commercial Refrigerators and Freezers	N
Dehumidifiers	Y
Bottled Water Coolers	Y
Windows	N
Cool Roofs	N
Transformers	N
Homes	N
Buildings	N
Home Improvement Program	N

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. Because energy efficiency involves both environmental protection and energy policy, the DOE/EPA partnership was an important step in developing and expanding ENERGY STAR. In 1996, DOE introduced ENERGY STAR labels for refrigerators, room air conditioners and dishwashers. EPA introduced labels for exit signs, insulation and residential boilers. Scanners, multi-function devices[2] and residential lighting fixtures were added to EPA's labeled products in 1997, 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. 1999 saw ENERGY STAR consumer audio, DVD players, and roof products introduced by EPA and a label for screw-based compact fluorescent lamps introduced by DOE.[3] 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.[4] Two labels have since 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 it was dropped as an individual product label).

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. As California's energy crisis developed in 2000, however, interest shifted to the impact of conservation programs on electrical system reliability. 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. Because the peak impacts of a particular product depend on the timing of the savings, a ranking of products by peak savings would be very different from a list ranked by energy or carbon savings. Although the current interest in reliability has not changed how EPA and DOE choose products for labeling, it has added an additional dimension to evaluating the program.

[2] 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.

[3] Windows and screw-based compact fluorescent lamps have not yet been added to our forecasts.

[4] Ventilation fans, ceiling fans, and commercial refrigerators and freezers were added in Summer 2001, too late to be included in this analysis.

Methodology

We begin by calculating the stock of ENERGY STAR units in place in each year of the analysis. To do this, we apply market penetrations to total annual product shipments to obtain annual shipments of ENERGY STAR devices. In order to correctly measure the effects of the ENERGY STAR program we explicitly account for the baseline penetration of high-efficiency units that would have met the ENERGY STAR requirement even if the program did not exist. Only shipments of ENERGY STAR units over and above this baseline (i.e. those that can be attributed to the program) are counted toward ENERGY STAR program savings.

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, we calculate the number of ENERGY STAR units in place in each year 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.

In general, reference-case annual unit energy savings are 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.[5] This assumption may overstate savings somewhat, since many products have achieved significant energy efficiency improvements even in the absence of efficiency programs. The way we account for baseline penetration of high efficiency (ENERGY STAR-qualifying) units captures a large portion of this reference-case efficiency improvement. However, potential improvements in the average efficiency of non-qualifying units is not taken into account. Energy savings estimates are national averages derived from monitored data (where possible) or engineering estimates.

Unit energy savings are multiplied by the number of enabled ENERGY STAR units in place in each year to get aggregate annual energy savings. Aggregate energy bills are estimated using year-by-year energy prices from US DOE (1996a, 1996b, 1997b, 1998b, 1999), shown in Table 2. Energy bill savings are discounted at a 4 percent real discount rate. Carbon emissions reductions

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

[5]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 reference-case effects for the purpose of analyzing the effects of the ENERGY STAR Program.

Year	Commercial Electricity Price 1998$/kWh	Residential Electricity Price 1998$/kWh	Gas Price 1998$/ MMBtu	Oil Price 1998$/ MMBtu	Price Source	Carbon Emissions Factor for Electricity kg C/kWh	Carbon Source
1993	0.085	0.091	7.158	6.495	US DOE (1996a)[b]	0.203	Cadmus (1998)
1994	0.084	0.09	6.694	6.799	US DOE (1996b)[b]	0.203	Cadmus (1998)
1995	0.078	0.088	6.244	6.573	US DOE (1997b)[b]	0.203	Cadmus (1998)
1996	0.078	0.086	6.354	7.265	US DOE (1998b)[b]	0.203	Cadmus (1998)
1997	0.076	0.084	6.830	7.140	US DOE (1999)	0.203	Cadmus (1998)
1998	0.074	0.080	6.600	6.120	US DOE (1999)	0.203	Cadmus (1998)
1999	0.073	0.080	6.603	6.324	[c]	0.203	Cadmus (1998)
2000	0.072	0.079	6.606	6.529	[c]	0.203	Cadmus (1998)
2005	0.066	0.075	6.620	7.550	US DOE (1999)	0.148	Cadmus (1998)
2010	0.064	0.074	6.570	7.740	US DOE (1999)	0.135	Cadmus (1998)
2015	0.063	0.073	6.430	7.820	US DOE (1999)	0.135	[c]
2020	0.062	0.073	6.360	7.880	US DOE (1999)	0.135	[c]
>2020	0.062	0.073	6.360	7.880	[c]	0.135	[c]

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 1998 dollars using implicit GDP deflators from the Department of Commerce (2000).

[c]Where there were gaps in the forecast, missing values were filled in using linear interpolation. The carbon coefficient for electricity is assumed to remain constant after 2010. Energy prices are assumed to remain constant after 2020.

are calculated from energy savings using year-by-year carbon emissions factors. Carbon emissions factors for electricity (Cadmus 1998) are also shown in Table 2.

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

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

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

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

Where

X_n = The number of units sold in year n

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)

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 where no metered data were available. A CLF of one indicates that energy savings are distributed evenly across peak an 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).

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.

For our analysis, 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).

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 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 Dataquest (1997a, 1997b, 1999), Guo et al. (1998) and Lyra Research (1998, 1999). The unit energy savings were applied to forecasts of enabled, ENERGY STAR-compliant devices to obtain aggregate savings.

Table 3. Enabling Rates for ENERGY STAR Office Equipment

Product	1993	1994	1995	1996	1997	2000	2005	2010
Copiers	NA	NA	90%	90%	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%	35%	50%	50%
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.

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 powermodes. 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.

Because of different usage patterns, computers and monitors were modeled separately for homes and offices. Shipments to homes were obtained from Dataquest (1999).

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.[6] 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.

The shipment forecasts for ENERGY STAR HVAC equipment (excluding thermostats) are based on EPA's sales training activities. EPA provided estimates of the expected increase in annual sales for each salesperson trained, which was used to forecast total increased sales due to the trainings. By focusing on EPA HVAC promotional activities rather than attempting to count ENERGY STAR device sales directly, we avoided the need to account for ENERGY STAR HVAC installed due to other programs, particularly the ENERGY STAR Homes program.

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

Energy bill and carbon savings both depend on the type of fuel used. In addition to their primary fuels, gas and oil furnaces and gas-fired heat pumps 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.

Technology substitution is an issue in the analysis of new technologies that are not yet in widespread use, such as geothermal heat pumps. As new technologies increase in market share, they will displace shipments of established products. In our forecast, we assumed that geothermal heat pumps would displace air-source heat pumps

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 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 about 190 million TVs and almost 140 million VCRs in the United States (Sanchez et al. 1998). 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. 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 savingn; 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

[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.

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. 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).

Residential Lighting. The ENERGY STAR residential lighting fixtures program promotes energy-efficient lighting fixtures. These include fixtures designed for compact fluorescent lamps (CFLs), electronically-ballasted tube fluorescent fixtures, and outdoor fixtures that incorporate motion sensors and photocells. DOE's screw-based CFL program was not treated in this analysis.

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).

For indoor fixtures, we assumed that the target market was fixtures operated more than three hours per day. Higher cost CFLs are often not cost-effective in low-use fixtures. Although these fixtures used more than three hours per day represent less than 20 percent of the fixture stock, they use more than 60 percent of household lighting energy (Wenzel et al. 1997). By focusing only on high-use fixtures we increase the expected per-unit savings but limit the maximum penetration that can be achieved. Unit energy consumption for high-use indoor fixtures was taken from the Baseline Residential Lighting Energy Use Study (described in Vorsatz et al 1997). In reality, some high-efficiency fixtures will probably end up in low-use applications, but we assumed this would be in addition to the high-use applications and did not account for this effect. For the 100 percent penetration scenario, we assumed that 100 percent of high-use fixtures were replaced (about 17 percent of all fixtures). Low-use fixtures were not replaced in the 100 percent scenario.

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.

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 requires that products meet 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) and dehumidifiers. Water coolers (cold only and hot/cold), used predominantly in commercial buildings, 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.

Table 4. Annual and Lifetime Savings per Unit for ENERGY STAR® Devices Sold in 2000

Equipment Type	% Annual Energy Savings[a]	Annual Unit Primary Energy Savings[b] MMBtu/yr	Annual Bill Savings due to ENERGY STAR[c] 1998$/unit	Product Lifetime[d] years	Lifetime Energy Savings[e] (million Btu)	Lifetime Energy Bill Savings, Undiscounted[c] 1998$/unit
Office Equipment						
-Office Computer and Monitor	70%	6.5	$44	4	26	$170
-Home Computer and Monitor[f]	53%	0.95	$7.1	4	3.8	$28
-Fax	40%	1.4	$9.2	4	5.4	$36
-Copier	33%	3.0	$21	6	18	$120
-Multifunction Devices	43%	6.5	$45	6	39	$260
-Scanner	51%	1.2	$7.9	4	4.6	$31
-Printer	10%	0.56	$3.8	5	2.8	$18
Consumer Electronics						
-TV	19%	0.36	$2.7	11	4.0	$29
-VCR	33%	0.21	$1.6	11	2.3	$17
-TV/VCR	21%	0.37	$2.8	11	4.1	$29
-Audio Equipment	65%	0.52	$3.9	7	3.6	$32
-Set-top Boxes	13%	0.17	$1.3	7	1.2	$8.8
Residential Heating and Cooling						
-Furnace (Gas or Oil)	15%	13	$86	18	230	$1,500
-Central Air Conditioner	19%	6.3	$47	14	88	$630
-Air-Source Heat Pump	13%	17	$130	12	200	$1,500
-Geothermal Heat Pump	30%	55	$410	15	820	$5,900
-Gas-Fired Heat Pump	34%	43	$320	15	650	$4,600
-Boiler (Gas or Oil)	7%	7.0	$46	20	140	$910
-Programmable Thermostat	20%	21	$150	15	320	$2,200
Lighting						
-Fixture	73%	2.0	$15	20	40	$280
-Exit Sign	77%	1.5	$10	10	30	$97
-Traffic Signal	90%	6.0	$41	10	120	$380
Appliances						
-Room Air Conditioner	14%	0.66	$7.3	13	13	$90
-Dehumidifiers	10%	1.2	$9.0	12	14	$100
-Water Coolers	45%	1.5	$11	10	15	$110
-Dishwasher[g]	13%	0.54	$3.9	13	7.0	$49
-Refrigerator[h]	20%	1.6	$12	19	30	$210
-Clothes Washer[g,h]	48%	4.1	$36	14	57	$400

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. Gas-fired heat pump is compared to gas furnace and central air conditioner. 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).

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

(Continued on next page.)

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 savings for 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 remaining energy savings may be attributed to the motor, controls, or, in the case of dishwashers, internal water heating, all of which use electricity. We therefore analyzed clothes washer and 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). The shares of water heating by fuel type were taken from Wenzel et al (1997). 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.

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).Water coolers are currently the only commercial appliance covered under the ENERGY STAR program. Efficiencies are specified in terms of kWh per day. Baseline efficiencies were obtained from Cadmus (2000).

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

Notes to Table 4 (continued):

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 and gas-fired heat pumps are LBNL estimates; 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) For clothes washers and dishwashers energy savings is the sum of machine energy, water heating energy and dryer energy for all fuel types.

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).

geothermal heat pumps have the highest absolute per unit savings, followed by gas-fired heat pumps. 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, computers, and audio equipment.

Tables 5 and 6 show annual energy, dollar, and carbon savings for 2000 and 2001, 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 2000 were 470 trillion Btu and $3.3 billion, an increase of almost 30% over 1999 savings. By 2001, energy savings are expected to reach 570 trillion Btu and $3.7 billion. The peak demand reduction due to the ENERGY STAR labeling program was 4.5 gigawatts in 2000 and is expected to increase to 5.5 gigawatts in 2001.

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 2001 onward.

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) by 2010. In contrast, high efficiency heating and cooling equipment is significantly more expensive than standard equipment. The total target market penetrations for HVAC equipment (including baseline high efficiency shipments) range from 34 percent for oil furnaces to 81 percent for oil boilers.

Table 7 and Table 8 show the cumulative savings under target market penetrations for the periods 2001-2010 and 2001-2020, respectively. All the products together are expected to save 11 quads by 2010, growing to 38 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 scanners take the number three and four spots, respectively.

Table 5. Annual Savings in 2000

Program	Equipment Type	Primary Savings[b] (trillion Btu)	Energy Bill Savings Undiscounted[c] (millions of 1998$)	Carbon Emissions Avoided[d] (MtC)	Conser-vation Load Factor[e]	Peak Load Savings (GW)
Office Equipment	- Computers and Monitors	260	$1,800	5.0	1.1	2.6
	- Faxes	24	$170	0.47	1.0	0.25
	- Copiers	11	$75	0.21	4.7	0.025
	- Multifunction Devices	1.0	$7.0	0.020	1.9	0.0060
	- Scanners	10	$70	0.20	1.0	0.11
	- Printers	63	$430	1.2	2.6	0.26
	Subtotal	370	$2,500	7.1	1.2	3.3
Consumer Electronics	- TVs	9.4	$71	0.18	1.0	0.10
	- VCRs	9.3	$69	0.18	1.0	0.10
	- TV/VCRs	2.7	$20	0.053	1.0	0.030
	- Audio Equipment	0.52	3.9	0.010	1.0	0.0057
	- Set-top Boxes[f]	-	-	-	1.0	-
	Subtotal	22	$160	0.42	1.0	0.24
Residential Heating & Cooling	- Furnaces (Gas or Oil)	2.3	$16	0.036	NA	NA
	- Central Air Conditioners	1.4	$11	0.028	0.15	0.10
	- Air-Source Heat Pumps	0.91	$6.8	0.018	0.15	0.024
	- Geothermal Heat Pumps	0.26	$1.9	0.0050	0.15	0.0022
	- Gas-Fired Heat Pumps	0.00017	$.0013	0.0000032	NA	NA
	- Boilers (Gas or Oil)	0.12	$0.77	0.0020	NA	NA
	- Programmable	18	$130	0.31	0.60	0.068
	Subtotal	23	$160	0.40	0.26	0.20
Res and Com Lighting	- Fixtures	22	$170	0.43	1.0	0.24
	- Exit Signs	19	$130	0.36	1.0	0.20
	- Traffic Signals[f]	-	-	-	1.0	-
	Subtotal	41	$290	0.79	1.0	0.44
Appliances	- Room Air Conditioners	2.3	$17	0.044	0.15	0.16
	- Dehumidifiers[f]	-	-	-	0.42	-
	- Water Coolers	0.012	$0.092	0.00024	0.71	0.00019
	- Dishwashers	1.9	$14	0.034	0.77	0.019
	- Refrigerators	6.4	$48	0.12	0.86	0.081
	- Clothes Washers	6.0	$43	0.11	0.67	0.070
	Subtotal	17	$120	0.31	0.49	0.33
TOTAL		470	$3,300	9.0	1.1	4.5

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, 1999). 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 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 2001

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	300	$2,000	5.4	3.0
	- Faxes	28	$190	0.51	0.29
	- Copiers	12	$83	0.22	0.028
	- Multifunction Devices	1.6	$11	0.030	0.0095
	- Scanners	14	$94	0.26	0.15
	- Printers	61	$410	1.1	0.26
	Subtotal	410	$2,800	7.6	3.7
Consumer Electronics	- TVs	15	$110	0.27	0.16
	- VCRs	14	$100	0.25	0.15
	- TV/VCRs	4.3	$32	0.078	0.047
	- Audio Equipment	1.4	10	0.026	0.015
	- Set-top Boxes	0.48	3.5	0.0087	0.0050
	Subtotal	35	$260	0.63	0.38
Residential Heating & Cooling	- Furnaces (Gas or Oil)	4.5	$30	0.069	NA
	- Central Air Conditioners	2.8	$21	0.050	0.20
	- Air-Source Heat Pumps	1.7	$13	0.032	0.047
	- Geothermal Heat Pumps	0.53	$3.9	0.0097	0.0044
	- Gas-Fired Heat Pumps	0.00017	$.0012	0.0000030	NA
	- Boilers (Gas or Oil)	0.23	$1.5	0.0038	NA
	- Programmable	22	$150	0.36	0.081
	Subtotal	32	$220	0.53	0.33
Res and Com Lighting	- Fixtures	36	$270	0.66	0.38
	- Exit Signs	25	$170	0.46	0.28
	- Traffic Signals	1.3	$8.5	0.023	0.014
	Subtotal	63	$450	1.1	0.67
Appliances	- Room Air Conditioners	2.3	$17	0.042	0.17
	- Dehumidifiers	0.12	$0.89	0.0022	0.0031
	- Water Coolers	0.073	$0.54	0.0013	0.0011
	- Dishwashers	2.4	$17	0.040	0.024
	- Refrigerators	7.1	$53	0.13	0.090
	- Clothes Washers	8.8	$63	0.15	0.10
	Subtotal	21	$150	0.37	0.39
TOTAL		570	$3,900	10	5.5

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, 1999). 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 2001-2010

		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	3,900	$ 25,000	$ 20,000	56	4,100	$ 26,000	$ 21,000	60
Equipment	- Faxes	480	$ 3,000	$ 2,300	6.8	500	$ 3,100	$ 2,500	7.1
	- Copiers	110	$ 690	$ 570	1.6	120	$ 740	$ 610	1.7
	- Multifunction Devices	62	$ 390	$ 300	0.87	130	$ 800	$ 610	1.8
	- Scanners	560	$ 3,500	$ 2,600	7.7	690	$ 4,300	$ 3,300	9.7
	- Printers	800	$ 5,500	$ 4,300	12	880	$ 6,000	$ 4,700	13
	Subtotal	5,900	$ 38,000	$ 30,000	85	6,400	$ 41,000	$ 33,000	93
Consumer	- TVs	560	$ 4,000	$ 3,000	7.7	670	$ 4,800	$ 3,700	9.4
Electronics	-VCRs	320	$ 2,300	$ 1,800	4.6	340	$ 2,400	$ 1,900	4.8
	-TV/VCRs	120	$ 880	$ 680	1.7	150	$ 1,100	$ 810	2.1
	- Audio Equipment	98	$ 700	$ 530	1.4	580	$ 4,100	$ 3,200	8.1
	- Set-top Boxes	100	$ 740	$ 450	1.4	300	$ 2,100	$ 1,300	4.1
	Subtotal	1,200	$ 8,600	$ 6,500	17	2,000	$ 14,000	$ 11,000	28
Residential	- Furnaces (Gas or Oil)	330	$ 2,200	$ 1,700	4.8	1,700	$ 12,000	$ 8,900	25
Heating &	- Central Air Conditioners	210	$ 1,500	$ 1,100	2.9	1,100	$ 7,800	$ 6,000	15
Cooling	- Air-Source Heat Pumps	120	$ 850	$ 640	1.6	300	$ 2,100	$ 1,600	4.2
	- Geothermal Heat Pumps	59	$ 420	$ 310	0.80	940	$ 6,700	$ 5,100	13
	- Gas-Fired Heat Pumps[g]	0.0017	$ 0.012	$ 0.0098	0.000025	0.0017	$ 0.012	$ 0.0098	0.000025
	- Boilers (Gas or Oil)	16	$ 120	$ 86	0.28	85	$ 590	$ 450	1.4
	- Programmable Thermostats	340	$ 2,300	$ 1,800	5.0	1,400	$ 9,600	$ 7,400	21
	Subtotal	1,100	$ 7,400	$ 5,600	15	5,500	$ 38,000	$ 29,000	79
Res and	- Fixtures	1,500	$ 11,000	$ 8,200	21	4,300	$ 30,000	$ 23,000	60
Comm. Lighting	- Exit Signs	420	$ 2,800	$ 2,200	6.4	500	$ 3,100	$ 2,500	7.1
Lighting	- Traffic Signals	54	$ 340	$ 260	0.76	54	$ 340	$ 260	0.76
	Subtotal	2,000	$ 14,000	$ 11,000	28	4,800	$ 34,000	$ 26,000	68
Appliances	- Room Air Conditioners	26	$ 190	$ 150	0.39	190	$ 1,300	$ 1,000	2.6
	- Dehumidifiers	12	$ 85	$ 65	0.17	50	$ 350	$ 270	0.69
	- Water Coolers	6.4	$ 46	$ 34	0.088	83	$ 590	$ 450	1.1
	- Dishwashers	54	$ 380	$ 290	0.77	290	$ 2,000	$ 1,500	4.0
	- Refrigerators	83	$ 600	$ 480	1.2	500	$ 3,600	$ 2,800	7.1
	- Clothes Washers	210	$ 1,500	$ 1,100	3.0	1,200	$ 8,100	$ 6,300	16
	Subtotal	390	$ 2,800	$ 2,200	5.6	2,300	$ 16,000	$ 12,000	32
TOTAL		11,000	$ 70,000	$ 55,000	150	21,000	$ 140,000	$ 110,000	300

See notes after Table 8.

Table 8. Cumulative Savings 2001-2020

		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 Equipment	- Computers and Monitors	8,200	$ 51,000	$ 34,000	110	8,700	$ 54,000	$ 36,000	120
	- Faxes	1,600	$ 10,000	$ 6,100	22	1,700	$ 10,000	$ 6,400	23
	- Copiers	160	$ 980	$ 730	2.3	170	$ 1,100	$ 790	2.4
	- Multifunction Devices	220	$ 1,300	$ 800	2.9	430	$ 2,600	$ 1,600	5.7
	- Scanners	2,100	$ 13,000	$ 7,600	27	2,400	$ 14,000	$ 8,800	32
	- Printers	3,100	$ 24,000	$ 14,000	42	3,200	$ 25,000	$ 15,000	43
	Subtotal	15,000	$ 100,000	$ 64,000	210	16,000	$ 110,000	$ 69,000	220
Consumer Electronics	- TVs	1,800	$ 13,000	$ 7,900	24	2,100	$ 15,000	$ 9,100	28
	- VCRs	660	$ 4,800	$ 3,200	9.1	710	$ 5,000	$ 3,300	9.6
	- TV/VCRs	290	$ 2,000	$ 1,300	3.8	350	$ 2,500	$ 1,600	4.7
	- Audio Equipment	360	$ 2,600	$ 1,500	4.8	1,600	$ 11,000	$ 6,900	21
	- Set-top Boxes	580	$ 4,100	$ 1,900	7.6	1,100	$ 7,800	$ 3,800	15
	Subtotal	3,700	$ 26,000	$ 16,000	49	5,800	$ 41,000	$ 25,000	77
Residential Heating & Cooling	- Furnaces (Gas or Oil)	2,100	$ 14,000	$ 7,700	29	6,800	$ 45,000	$ 27,000	98
	- Central Air Conditioners	1,300	$ 9,200	$ 5,200	17	4,100	$ 29,000	$ 17,000	54
	- Air-Source Heat Pumps	640	$ 4,500	$ 2,600	8.4	940	$ 6,600	$ 4,100	12
	- Geothermal Heat Pumps	460	$ 3,200	$ 1,800	6.0	3,400	$ 24,000	$ 14,000	44
	- Gas-Fired Heat Pumps[g]	0.0020	$ 0.014	$ 0.011	0.000029	0.0020	$ 0.014	$ 0.011	0.000029
	- Boilers (Gas or Oil)	98	$ 700	$ 390	1.7	330	$ 2,300	$ 1,400	5.3
	- Programmable Thermostats	550	$ 3,800	$ 2,700	8.0	4,400	$ 30,000	$ 19,000	63
	Subtotal	5,100	$ 35,000	$ 20,000	70	20,000	$ 140,000	$ 82,000	280
Res and Comm. Lighting Lighting	- Fixtures	8,700	$ 61,000	$ 35,000	110	16,000	$ 120,000	$ 69,000	220
	- Exit Signs	700	$ 4,300	$ 3,100	9.7	850	$ 5,200	$ 3,700	12
	- Traffic Signals	160	$ 960	$ 600	2.1	160	$ 960	$ 600	2.1
	Subtotal	9,600	$ 66,000	$ 38,000	130	17,000	$ 120,000	$ 73,000	230
Appliances	- Room Air Conditioners	49	$ 350	$ 240	0.68	600	$ 4,200	$ 2,600	7.9
	- Dehumidifiers	40	$ 280	$ 170	0.53	160	$ 1,100	$ 680	2.1
	- Water Coolers	43	$ 300	$ 170	0.56	290	$ 2,000	$ 1,200	3.8
	- Dishwashers	180	$ 1,200	$ 760	2.4	950	$ 6,500	$ 4,000	13
	- Refrigerators	210	$ 1,500	$ 970	2.9	1,800	$ 12,000	$ 7,500	23
	- Clothes Washers	530	$ 3,700	$ 2,400	7.1	3,300	$ 23,000	$ 14,000	44
	Subtotal	1,100	$ 7,300	$ 4,700	14	7,000	$ 49,000	$ 30,000	94
TOTAL		35,000	$ 230,000	$ 140,000	470	67,000	$ 460,000	$ 280,000	900

See notes next page.

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 and gas-fired heat pumps are new technologies without a defined baseline market share, these technologies 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. Because the gas-fired heat pump program has been discontinued, assumptions are the same as in the target market penetration case (some savings accrue on products shipped prior to the end of the program, but no additional gas-fired heat pumps are shipped from 1999 onward). As noted above, the "100 percent penetration" forecast for residential lighting fixtures applies to only high-use fixtures, about 17 percent of all fixtures sold.

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 23 quads from 2001 to 2010, growing to 72 quads by 2020. These correspond to a total energy bill savings of $120 billion through 2010 and $300 billion through 2020 (present value, discounted at a 4 percent real discount rate). These totals are about twice the savings in the target market penetration case. The largest savings in the 100 percent market penetration case are again due to computers and residential lighting fixtures. Computer savings were only slightly higher than fixture savings from 2001 to 2010, and by 2020 fixtures had the most savings by a wide margin, even though we assumed that only high-use fixtures are replaced in the 100 percent penetration case. Furnaces and programmable thermostats also have high savings in the 100 percent market penetration case.

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

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).

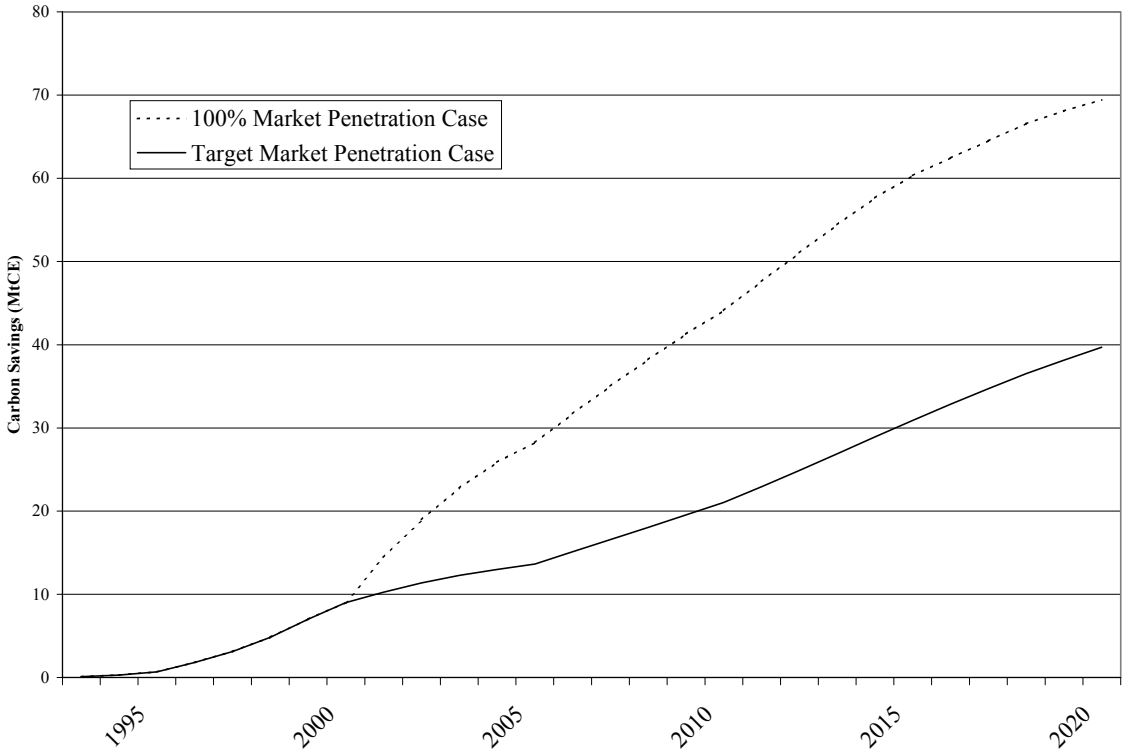
d) Cumulative bill savings do not take into account increased investment costs. Cumulative bill savings are discounted using a 4 percent real discount rate.

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

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

g) All savings for gas-fired heat pumps in the target market penetration case are for units shipped before 1999.

Figure 1. Annual carbon savings relative to the business-as-usual case



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 two 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 PCs and monitors, recent research into nighttime turn-off behavior found a much higher percent of devices left on at night than previously assumed (Webber et al, 2001), which caused our unit energy consumption and savings estimates to jump. 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.

We did not account for the possibility of improvements in the efficiency of non-ENERGY STAR units over the analysis period, although we do include increases in the number of ENERGY STAR units not attributable to the program. As an example, our analysis takes into consideration increases in the number of horizontal axis (ENERGY STAR-qualifying) clothes washers that might have occurred in the absence of the program, but it does not take into account efficiency improvements that might be occurring in non-qualifying vertical-axis washers. Since we calculate savings relative to non-ENERGY STAR units (vertical axis washers, in this case), we may be crediting the program with savings that should be attributed to a general trend toward increasing energy efficiency. Accounting for this effect would certainly reduce estimated program savings, but was beyond the scope of this study.

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 LCD monitors has dropped to the point where they may begin 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 the popular media heralds the advent of the "post-PC" era (Galarza and Clark, 2000). 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 4.7 quads of energy and prevented carbon emissions of 9 million metric tonnes in 2000 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, $110 billion could be saved from estimated energy bills over the next ten years (present value, at a 4 percent real discount rate).

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