LBNL-56380 (2006)

2006 Status Report
Savings Estimates for the ENERGY STAR® Voluntary Labeling Program

Carrie A. Webber, Richard E. Brown, Marla Sanchez and Gregory K. Homan

Lawrence Berkeley National Laboratory
Mail Stop 90-4000
1 Cyclotron Road
Berkeley, CA 94720
(510) 486-5164
fax: (510) 486-4247

March 7, 2006

The work described in this paper was supported by the Office of Atmospheric Programs, Climate Protection Partnerships Division of the U.S. Environmental Protection Agency and prepared for the U.S. Department of Energy - Contract No. DE-AC02-05CH11231.

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 labeled products. We present estimates of the energy, dollar and carbon savings achieved by the program in the year 2005, what we expect in 2006, and provide savings forecasts for two market penetration scenarios for the periods 2006 to 2015 and 2006 to 2025.

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.

Acknowledgments

This work was supported by the U.S. Environmental Protection Agency, Climate Protection Division, Office of Air and Radiation, under Department of Energy contract No. DE-AC03-76SF00098. Several EPA staff have contributed to these forecasts over the years: Andrew Fanara, Craig Hershberg, Rachel Schmeltz, Steve Ryan, David Shiller, Robin Shudak, Glenn Chinery, Stephan Sylvan, Jeremy Symons, and Linda Latham. Ed Barbour (Arthur D. Little), Bill McNary (D&R International) and Sarah Bretz (LBNL) also contributed to the analysis.

Introduction

This paper presents past and predicted savings for the ENERGY STAR® labeling program, a 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, a home improvement program, and a commercial buildings program. This analysis focuses only on labeled products. Table 1 shows EPA's product labels and related programs and indicates which are covered by this report.

Our forecast of future savings now extends through 2025. 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. This report details the status of the model as implemented in the November 2005 and May 2006 spreadsheets.

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 that meet 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 Executive Order 12845 in 1993 which required 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. 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.

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

[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 multi-page copying as their primary function. Digital copiers that can be upgraded to have printing functions are also covered.

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. In 2003, EPA introduced commercial fryers, commercial hot food holding cabinets, and commercial steam cookers. Refrigerated beverage vending machines and air cleaners were added to the program in 2004, and in 2005 external power supplies and battery charging systems.

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). 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.

Table 1. ENERGY STAR Products and Programs

Product	Start/End Yr.	Product	Start/End Yr.
Computers……..	1992	TVs……..……	1998
Monitors……..	1992	VCRs……..…….	1998
Printers…….	1993	TV-VCRs……	1998
Fax machines……	1994	Audio Equipment……	1999
Copiers……	1995	DVD Players	1999
Air-Source Heat Pumps…….	1995	Roofs……..……..	1999
Geothermal Heat Pumps……	1995	CFLs……..……	1999[a]
Central Air Conditioning…….	1995	Traffic Signals……	2000
Gas Furnaces…….	1995	Bottled Water Coolers…….	2000
Oil Furnaces……	1995	Exhaust Fans……..……..	2001
Programmable Thermostats……	1995	Ceiling Fans……	2001
Transformers……..……	1995	Dehumidifiers…….	2001
Gas Boilers……..	1996	Commercial Refrigerators and Freezers	2001
Oil Boilers……..	1996	Set-top Boxes…….	2001-200X[b]
Exit Signs……	1996	Telephony……..	2002
Dishwashers……	1996[a]	Hot Food Holding Cabinets……	2003
Room Air Conditioners……..	1996 [a]	Commercial Steam Cookers……	2003
Residential Refrigerators……..……	1996 [a]	Commercial Fryers…….	2003
Clothes Washers……	1997 [a]	Cold Beverage Vending Machines…….	2004
Scanners……..	1997	Air Cleaners ……..	2004
MFDs…….	1997	External Power Adapters……	2005
Residential Lighting Fixtures……	1997	Battery Charging Systems …….	2005
Gas-Fired Heat Pumps……	1995-2000	Windows……..	1998[a]
Homes……..……	N	Buildings…….	N
Insulation……	1996-2001	Home Improvement Program...…….	N

[a]DOE Product

[b]With the exception of digital television adapters, set-top boxes have been dropped from the Energy Star Program. Set-top boxes are included in the analysis, but except for digital television adapters, sales of Energy Star products are zero after 2004.

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).

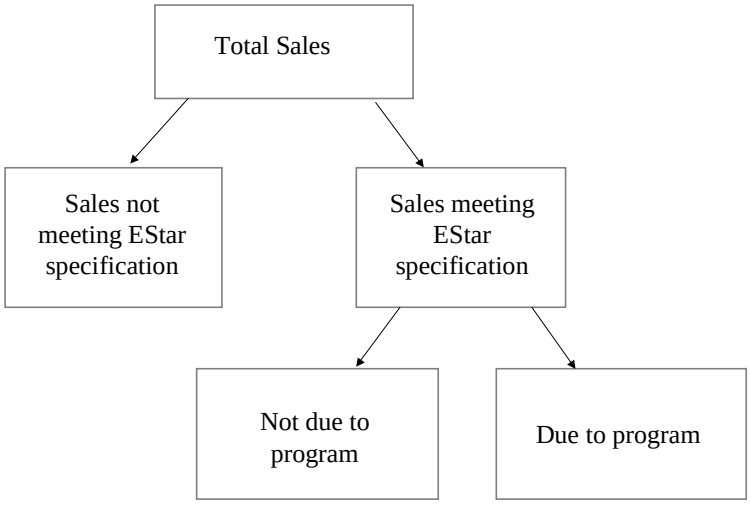
Historically, the focus of the ENERGY STAR program has been on energy savings and carbon emissions reductions. During California's energy crisis in 2000, however, interest shifted to the impact of conservation programs on electrical system reliability. The peak impacts of an ENERGY STAR label depend on the timing of the savings (do they occur on or off peak), 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 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 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 annual unit energy consumption (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



In general, 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). This is because for most

products there is insufficient data on historic efficiency trends to create a credible UEC forecast.[2] For most products 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.[3] In cases where both the non-ENERGY STAR UEC and the ENERGY STAR UEC are changing over time, it is possible for unit energy savings to increase, decrease or remain the same.

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.

Some products have ENERGY STAR features, such as low power modes when the device is idle, that do not accrue savings unless the feature is enabled.[4] 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 (for PCs) incompatibility with computing networks. Metering of ENERGY STAR computers suggests that less than ten percent have their power-saving features enabled (Roberson et al. 2004). To account for the enabling factor, we calculate separate UECs for products that are enabled and products that are not enabled and then calculate a weighted average UEC based on our estimate of the enabling rate.

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 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 and 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, 2003, 2005), shown in Table

[2] VCRs, telephony and exit signs are exceptions to this, and we do model the average efficiency of non-ENERGY STAR units does changing over time.

[3] 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 to be part of the reference case for the purpose of analyzing the effects of the ENERGY STAR Program.

[4] All of the savings for PCs, scanners, copiers, fax machines, and MFDs come from features that need to be enabled. Monitors and vending machines have low power modes that must be enabled, but also have active power savings. Programmable thermostats are assumed to save energy only if they are enabled (that is, programmed for automatic setback).

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. In this update the electric heat rate for the period 2021 to 2025 was revised, and energy prices were revised to be consistent with AEO 2005.

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

Year	Commercial Electricity Price 2003$/kWh	Residential Electricity Price 2003$/kWh	Gas Price 2003$/ MBtu	Oil Price 2003$/ MBtu	Price Source	Carbon Emissions Factor for Electricity kg C/kWh	Carbon Source	Electric Heat Rate Btu/kWh	Electric Heat Rate Source
1993	0.093	0.100	7.86	7.13	c	0.203	m	11019	c
1994	0.092	0.099	7.35	7.47	d	0.203	m	10948	d
1995	0.086	0.096	6.86	7.22	e	0.203	m	10970	e
1996	0.085	0.094	6.98	7.98	f	0.203	m	10866	f
1997	0.084	0.092	7.50	7.85	g	0.203	m	10978	g
1998	0.082	0.090	7.30	6.77	h	0.203	m	10891	h
1999	0.077	0.088	7.14	6.62	i	0.203	m	10784	i
2000	0.077	0.086	6.98	6.47	j	0.203	m	11181	j
2001	0.082	0.090	6.98	6.47	j	0.203	m	11030	j
2002	0.080	0.086	7.82	8.37	k	0.203	m	11008	k
2003	0.079	0.087	9.22	9.57	k	0.203	n	10997	k
2004	0.079	0.086	9.94	10.54	k	0.203	n	10957	k
2005	0.078	0.086	10.04	10.12	k	0.203	n	10938	k
2010	0.068	0.078	7.79	8.29	k	0.168	n	10754	k
2015	0.073	0.081	8.21	8.49	k	0.141	n	10538	k
2020	0.075	0.082	8.66	8.85	k	0.135	n	10349	k
2025	0.076	0.083	9.07	9.12	k	0.135	n	10349	k

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 (1999)
[h]US DOE (2000)
[i]US DOE (2001)
[j]US DOE (2003)
[k]US DOE (2005)
[m]Cadmus (1998)
[n]EPA (2003).

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 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 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).

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. There are currently no empirical data available that would resolve this question. We incorporated market transformation effects into the model, working under the assumption that there is no recidivism. If future program evaluations determine that recidivism occurs, partial or total recidivism could be analyzed using the same modeling framework.

Forecasting Issues

Office Equipment. 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. Based on data presented in Gartner (2001) we estimate that 98 percent of computers currently sold are ENERGY STAR-compliant, and that —prior to the addition of the active power requirement to the Energy Star monitor specification— a similarly large fraction (95 percent) of monitors were compliant.

ENERGY STAR-labeled office equipment includes computers, monitors, fax machines, printers, copiers, scanners and multi-function devices (MFDs). The program has historically focused 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.

Beginning in January 2005 EPA recently added a requirement that monitors meet an active power specification in addition to the existing low power requirement. This new active power specification was included in this forecast.

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, Webber et al. 2001, Roberson et. al 2004). 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. Recent nighttime audits of office buildings found that 64 percent of computers, 68 percent of CRT monitors, 82 percent of LCD monitors, 85 percent of laser printers (77 percent of all printers), 52 percent of copiers and 80 percent of MFDs were left on at night (Roberson et al. 2004). Three years earlier a similar study 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 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. Enabling rates (or, more accurately, power management "success rates"[5]) were obtained from the nighttime audits mentioned above. Only 6 percent of computers were observed to be in low-power mode (Roberson et al. 2004). 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 Gartner (2001).

In the present version of CCAP the unit lifetimes for residential computers and monitors was reduced from 8 to 5 years. The 8-year lifetime was originally chosen to reconcile conflicting shipment and stock data; essentially, shorter lifetime assumptions produced stock estimates that were inconsistent with published data, using the best shipment data we had available. It was time to review this assumption, and a comparison of current shipment and stock data confirmed that the 8-year life was too high. A 5-year life produced stock estimates consistent with RECS. This did not effect shipments but did affect energy and carbon savings estimates because a shorter lifetime means the stock of Energy Star units in place is smaller.

Unit energy consumption calculations for copiers were revised and the new calculation resulted in a decline in savings for the device type. Because copiers have largely been supplanted by MFDs, this effect becomes insignificant around 2003. This version of CCAP also revised the night-time turn-off rate for color copiers, based on the results of the 2003 night audit (Roberson et al 2004). Because this change was not made when the audit data was incorporated for other products the result was higher unit energy savings.

Table 3. Enabling Rates for ENERGY STAR Office Equipment

Product	1993	1994	1995	1996	1997	2000	2005	2010	2015	2020	2025
Copiers	NA	NA	76%	76%	76%	76%	29%	29%	29%	29%	29%
Facsimile	NA	NA	90%	90%	90%	90%	90%	90%	90%	90%	90%
Printers	80%	90%	96%	96%	96%	96%	95%	95%	95%	95%	95%
Scanners	NA	NA	NA	NA	90%	90%	60%	60%	60%	60%	60%
Office Multifunction	NA	NA	NA	NA	67%	77%	55%	59%	61%	61%	61%
Office CRT Monitors	10%	15%	15%	59%	59%	59%	76%	77%	76%	76%	75%
Office LCD Monitors	10%	15%	15%	59%	59%	59%	80%	81%	80%	80%	79%
Office PCs	10%	15%	15%	10%	5%	5%	7%	8%	10%	11%	13%
Residential Multifunction	NA	NA	NA	NA	NA	97%	94%	96%	96%	97%	97%
Residential CRT Monitors	10%	15%	15%	59%	59%	59%	71%	71%	71%	71%	71%
Residential LCD Monitors	10%	15%	15%	59%	59%	59%	75%	75%	75%	75%	75%
Residential PCs	10%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%

Notes to Table 3:

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

b) Enabling rates for 1997 to 2002 are from Webber et al. (2001); rates for 2003 are from Roberson et al. (2004). For all products except office PCs and office monitors, enabling rates are expected to remain flat after 2003. Office PC

[5] A device is said to be enabled if its power management settings indicate that the device has been programmed to go into a low-power state. Since, as discussed, some of these devices will nevertheless fail to enter a low-power state, the term "success rate" more accurately describes the share of devices that succeed in entering a low-power state. Because this distinction is not widely understood, we use the term "enabling" throughout the paper to mean the share of devices that are successfully power managing.

and monitor enabling rates are expected to increase over time due to outreach efforts by EPA. Enabling for multifunction devices changes over time due to the changing mix of products (speed and imaging technology).

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 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 1999). 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. We first received shipment data for gas and oil fired furnaces in 2003 (ICF, 2003) and the present report is the first in the series to reflect this new data. The estimated incremental market penetration for Energy Star units based on this shipment data was considerably greater that the estimates previously used, so the savings estimates for these products are considerably higher than in past reports.

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 and then added the component savings together (electricity was converted to primary energy).

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.

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

While Energy Star Homes are not covered by this report, the effects of that program are taken into account when estimating savings for Energy Star HVAC equipment. Since Energy Star HVAC equipment is often part of an Energy Star home and counted toward its savings. Sales of Energy Star HVAC that are attributed to the Homes program are not included in this report (which is concerned specifically with sales due to Energy Star's product labeling program).

Consumer Electronics. For TVs, VCRs, and audio equipment, 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 260 million TVs (NRDC 2005), 120 million VCRs, and 10 million TV/VCR combination units in U.S. homes (Rosen and Meier 1999). In addition, 41 percent of US homes had a DVD player as of 2003 (*Appliance* 2004). 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 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 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 TV forecast has been revised to take into account new screen technologies. The analysis was divided into the following product classes: CRT, projection, LCD and plasma TVs. Digital cable ready TVs with Point of Deployment (POD) slots are not currently included in the analysis because no baseline power data or US shipment data is readily available for these products. TV monitors are also excluded from the model due to a limited availability of data. The incorporation of TV product classes was necessitated in part by the changing market for television, and in part by the upcoming specification revision. To support the new analysis, we found new data sources for energy use by technology and usage per television set from a variety of sources including CNET, ECOS consulting, and NRDC. New TV shipment data by product class (from Isupply) was incorporated into the model. The new data, due to higher baseline standby consumption for the newer television technologies, led to sharply higher overall energy saving from 2003 onward (when the new technologies began appearing in significant numbers).

DVD savings were revised sharply downward based on the 2004 manufacturer-reported shipment data, which was not incorporated into CCAP until January 2006. DVD savings only reflect stand-alone products since DVD/VCRs are included under the VCR category.

The biggest difficulty in modeling the TV/VCR and audio category is the limited information available for certain product classes defined by the Energy Star specification. Since there is no baseline power data available for digital ready TVs or TV monitors, these classes have been excluded from analysis despite the fact that existing models within these classes are qualifying under the Energy Star program. Additionally, DVD/VCRs are theoretically included under the VCR category even though power estimates for the category have not been updated to reflect DVD/VCRs (all baseline wattages represent only VCR units). To incorporate these technologies, metering data needs to be collected to quantify program effects for these new product classes. Recent data also suggests that the Energy Star impact on audio products extends well beyond just DVDs, CDs, and

mini-systems. Although we have baseline metering data available for a variety of audio products not included in the existing spreadsheets, we do not have any US shipment data. Specifically, shipment data for RACK audio systems, amplifiers and receivers need to be collected from CEA sources so that we can fully update our audio model.

The set-top box specification was discontinued after 2005 for all but digital to analog converters (DTA). DTA shipments are assumed to decrease to 0 after 2012 (because the market will have fully transitioned to digital and those needing adapters for older sets will have already purchased them). The free rider market penetration for all set-top box products was reduced to zero.

Telephony. Telephony equipment consists of answering machines plus cordless telephones and telephone combination units, either of which may include digital spread spectrum (DSS) functionality. Initial sales estimates came from *Appliance* (May 2002). Sales estimates for 2001, which reflect the disaggregation by technology come from CEA. The energy use by non-Energy Star units is calculated from Rosen et al. 2001. The estimate of the number of units meeting the Energy Star criterion came from LBNL metering. Growth in the unit sales of answering machines is from CEA (2002).

External Power Supplies. Battery Chargers were added to the CCAP model in this version. Battery chargers can be either an independent device ("universal battery chargers) or an accessory specific to some other appliance. We modeled, in addition to free-standing or "universal" types, battery chargers for floor care, kitchen appliances, personal care, and power tools. These are the categories analyzed in the Cadmus metering dataset and those are the reported shipment category breakdowns in ICFs market summary report. Because no unit shipment data is yet available, we are still estimating Energy Star sales based on an estimated market penetration. Once shipment data becomes available for calendar year 2006, we will adjust the model to be consistent with the shipment-based approach. The baseline and energy star unit energy consumption estimates are from test data compiled by Cadmus for each of the five categories. Total unit shipments are from ICFs Battery Charger Market Report.

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 two segments, indoor fixtures and outdoor fixtures.[7] Initial shipment data for indoor fixtures and outdoor fixtures were from the U.S. Department of Commerce (1997). Energy Star shipments are from EPA's tracking data (ICF 2003).

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

[7] Formerly, torchieres were split out from indoor fixtures because of the rapid growth of high-wattage halogen fixtures using 300 to 500 watts. That market trend seems to have run its course, however, and sales of halogen torchieres have declined somewhat. We therefore no longer split out torchieres.

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. Torchieres have been eliminated as separate product and rolled into the indoor fixture analysis.

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.

In addition to dedicated CFL fixtures, compact fluorescent lamps themselves are covered by an ENERGY STAR specification. Like indoor fixtures, CFLs 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 advantages 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 used incandescent lamps for illumination, which consumed 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. Yellow (amber) signals are not analyzed because of their very short duty cycles, although LED signals do have a small share of the yellow signal market.

Residential Appliances. ENERGY STAR appliances for the home include refrigerators, freezers, clothes washers, dishwashers, room air conditioners (RACs), dehumidifiers, ceiling fans and exhaust fans.

After HVAC and water heating, large appliances constitute the largest energy end-uses in a typical home. Like some of the HVAC products, refrigerators, freezers, 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 and freezers 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 was tightened in 2004 and will be 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.[8] 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 savings 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 (1999). Unit energy consumption and savings for clothes washers and

[8] The Department of Energy changed the test procedure for clothes washers several years ago. Through 2003 the standard was based on energy factors which 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.

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). The new dehumidifier specification was incorporated into the model. The new specification involves additional product classes and new worksheets were added to CCAP reflecting these. Due to the reorganization of product classes and capacity bins, we reallocated both total US shipments and Energy Star unit sales. Since both shipments and Energy Star sales were reallocated, it is impossible to reproduce last year's results under the new approach. We revised 2002 shipment data.

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.

The exhaust fan analysis was revised. The new approach more closely parallels the analysis of other products in that the shipment model replaced the market penetration approach. The basic efficiency assumptions are unchanged; the base effiecy is from Cadmus (2000). Previously exhaust fans were divided into low vs. high use and intermittent vs. continuous (4 types) plus exhaust fan lighting, range hood fans and range hood lighting, whereas in the new version the separation of intermittent vs. continuous was eliminated. The net effect of these changes is a modest increase in the estimated savings.

Air Cleaners are being included in this report for the first time starting with this version. The analysis is based on the unit capacity expressed as clean air delivery rate (CADR). Units are divided into bins of 51-100, 101-150, 150-200, 200-250 and over 250 CADR. The modeling start year is 2004. Shipment data is taken from ICF (2002). Baseline product wattage is from a manufacturer test dataset submitted during the specification development process through AHAM. Energy Star wattages are extrapolated from the efficiency criteria (CADR per watt) for each CADR category. Our savings assume an 8,760 hr/yr duty cycle. Unit lifetime is form *Appliance* (1998).

Commercial Appliances. Since 2000, Energy Star has expanded significantly into commercial appliances. In 2003, bottled water coolers and commercial refrigerators and freezers were joined by hot food holding cabinets, gas and electric steamers, and gas and electric fryers as Energy Star labeled products. Cold beverage vending machines were added in 2004.

The program covers cold-only and hot/cold bottled water coolers. 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). Only solid door refrigerators and freezers are covered. The program covers refrigerator/freezers and ice cream freezers under separate specifications, but due to insufficient

data, these product classes are not modeled separately. Efficiencies are again expressed as kWh per day.

The specifications for fryers and steamers include a cooking efficiency (the quantity of energy input into the food expressed as a percent of the energy input to the appliance) and an idle rate, expressed in Btu/hr (gas appliances) or watts (electric). Hot food holding cabinets have only an idle energy rate requirement, expressed in watts per cubic foot. Data for commercial cooking equipment was obtained from the Food Service Technology Center (Fisher 2003).

There were only minor changes in the modeling of commercial appliances in this iteration of CCAP; We reduced the free rider forecast for freezers from 2001-2002. Ice cream freezers were added to 2004 freezer shipments, and free ridership for gas fryers was reduced to 0 based on Energy Star participation. We added high-efficiency non-Energy Star units to the baseline, which reduced unit savings.

Recent Changes to the Model

The results of this model have been presented in five earlier reports (Webber et al. 1999, 2002, 2003, 2004, and 2005). Several important changes have been made to the program and the model since the 2005 status report.

Past versions of CCAP have used incremental market penetrations due to the Energy Star program as the primary metric for modeling program achievements. Now that we have been receiving ENERGY STAR shipment data from manufacturers for several years, it makes sense to take a more direct approach. This change was started in the last CCAP update, in which we had begun to revise the CCAP spreadsheets to include separate input lines for ENERGY STAR unit shipments and total market penetration. In the last version the shipment data was used as an input to the calculation of market penetration, which in turn, informed the final estimate of units, shipped. In this version we have adopted the method of using the shipment data as a direct input wherever possible. This revised approach makes it much easier to incorporate and to be consistent with manufacturer-reported shipment data. It also had the desirable side-effect of reducing the size and complexity of the CCAP model.

Another effect of the change from the market penetration to the shipment model is that we no longer attempt to model mid-year program start dates. Such mid-year effective dates for new specifications have always been somewhat problematic for CCAP, however the shipment data, being itself annual made the methods we had developed to deal with these problems unworkable. At present all specifications are modeled as starting at the beginning of the year: January through June start dates are modeled as starting in January, July through December start dates are modeled as starting the following January.

The change in model also had implications for the treatment of market transformation effects. The CCAP model presumes that there is no recidivism. That is to say, when a new specification is introduced, manufacturers do not replace the previously qualifying units with lower-efficiency ones. In the past when a new specification was introduced the combined market penetration of the previous tier and the new was held constant; in the new the combined shipments for the two tiers are

taken to be constant. The result of this change in the model is that the estimated number of previously qualifying (i.e. tier 1) units declines more rapidly than before, as is shown in Figure 2.

Figure 2. Sample Market Transformation Calculation under New and Old Methods

	2002	2003	2004	2005	2006	2007	2008	2009
Old Method								
Total Shipments	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700
Market Penetration-Tier 1	30%	40%	50%	30%	20%	10%	0%	0%
Market Penetration-Tier 2	-	-	-	20%	30%	40%	50%	60%
Total Market Penetration	30%	40%	50%	50%	50%	50%	50%	60%
E* Shipments--Tier 1	300	440	600	390	280	150	0	0
E* Shipments-Tier 2	-	-	-	260	420	600	800	1,020
Total Tier 1 & 2 Shipments	300	440	600	650	700	750	800	1,020
New Method								
E* Shipments--Tier 1	300	440	600	340	180	0	0	0
E* Shipments-Tier 2	-	-	-	260	420	600	800	1,020
Total Tier 1 & 2 Shipments	300	440	600	600	600	600	800	1,020

Although the effect of the new market transformation calculation was relatively small for any given product, this change affected most of the products analyzed.

Baseline high-efficiency units are now explicitly divided into free riders, which get the ENERGY STAR label, and non-qualifying (or non-participating) high efficiency shipments.

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 commercial steam cookers have the highest absolute per unit savings; followed by geothermal heat pumps, hot food holding cabinets, air source heat pumps, commercial refrigeration, and fryers. Ranked by percentage savings, however, traffic signals take the lead at 89 percent savings. Other products with at least 50 percent savings are office CRT and LCD monitors, residential lighting fixtures, CFLs, copiers, office PCs, exhaust fans, ceiling fans, audio equipment, TV/VCR/DVD combination units, DVD players, and commercial steamers.

Table 4. Annual and Lifetime Savings per Unit for ENERGY STAR® Devices Sold in 2004

Equipment Type	Annual Energy Savings	Annual Unit Primary Energy Savings	Annual Bill Saving due to Energy Star	Product Lifetime	Lifetime Primary Energy Savings	Lifetime Energy Bill Savings, undiscounted
	%	Million Btu	2004$/yr	Years	Million Btu	2004$
Office Equipment						
- Office PC	76%	3.10	$24.64	4	12.35	$94.75
- Office CRT Monitor	84%	4.40	$34.96	4	17.53	$134.47
- Office LCD Monitor	81%	2.60	$20.70	4	10.38	$79.59
- Home PC	41%	0.69	$6.19	5	3.43	$28.61
- Home CRT Monitor	51%	0.98	$8.81	5	4.89	$40.74
- Home LCD Monitor	43%	0.48	$4.31	5	2.39	$19.92
- Fax	40%	1.41	$11.19	4	5.61	$43.03
- Copier (1)	70%	2.04	$16.20	6	12.14	$90.93
-Multifunction Device	25%	6.48	$51.52	6	38.61	$289.21
- Scanner	49%	0.83	$6.57	4	3.30	$25.28
- Printer	26%	2.21	$17.58	5	11.00	$83.31
Consumer Electronics						
- TVs	28%	0.70	$4.22	9	6.18	$33.93
-VCRs	23%	0.14	$1.25	7	0.96	$7.90
-TV/VCR/DVD	88%	0.73	$6.56	7	5.08	$41.61
-DVD Player	59%	0.34	$3.09	7	2.39	$19.61
-Audio Equipment	77%	0.76	$6.79	8	5.99	$54.16
-Telephony	33%	0.11	$1.40	7	0.78	$8.87
-Set-top Box	23%	0.33	$3.39	7.	2.31	$21.51
-External Power Supplies	35%	0.14	$1.43	5	0.57	$7.10
-Battery Charging Systems	0%	0.00	$0.00	7	0.00	$0.00
Heating and Cooling						
- Furnace (Gas or Oil)	15%	12.86	$149.62	18	230.08	$2,295.54
- Central Air Conditioner	24%	8.52	$76.42	14	116.61	$937.83
- Air-Source Heat Pump	17%	23.40	$158.97	12	275.45	$1,682.31
- Geothermal Heat Pump	30%	57.04	$511.38	15	834.50	$6,711.85
- Boiler (Gas or Oil)	06%	6.06	$74.50	20	121.18	$1,266.17
- Programmable Thermostat	20%	21.51	$235.15	15	319.09	$3,062.91
Residential and Commercial Lighting						
- Fixtures	73%	0.67	$6.21	20	13.05	$108.06
- CFLs	66%	0.94	$8.53	(4)	5.67	$44.30
- Exit Sign	9%	0.30	$23.68	10	2.99	$214.12
- Traffic Signal	89%	4.75	$37.79	10	46.82	$341.65
Residential Appliances						
- Room Air Conditioners	10%	0.69	$6.17	13	8.77	$70.55
- Dehumidifiers	6%	0.68	$6.08	12	7.98	$64.35
- Air Cleaners	46%	3.99	$35.79	9	35.45	$287.91
- Exhaust Fans	73%	0.64	$5.70	10	6.26	$50.72
- Ceiling Fans	47%	1.07	$9.58	10	10.53	$85.26
- Dishwashers	21%	0.89	$8.80	13	11.57	$99.67
- Refrigerators	15%	0.86	$7.74	19	15.89	$128.02
- Clothes Washers	31%	2.74	$26.65	14	38.39	$324.58
Commercial Appliances						
- Water Coolers	45%	2.58	$20.50	10	25.40	$185.37
- Commercial Refrigeration	37%	19.04	$151.39	10	187.57	$1,368.68
- Hot Food Holding Cabinets	59%	45.03	$357.98	15	658.82	$4,766.03
- Fryers	16%	17.90	$309.53	11	199.85	$2,785.45
- Steamers	55%	78.31	$763.17	10	783.13	$6,809.45
- Vending Machines	36%	14.26	$113.34	14	195.05	$1,410.94
Other						
- Utility Transformers	5%	0.53	$4.71	32	16.31	$133.24
- C&I Transformers	26%	10.72	$85.18	32	327.55	$2,407.97
- Residential Roofing (1000 sq ft)	n/a	1.02	$7.72	20	19.51	$136.34
- Commercial Roofing (1000 sq ft)	n/a	2.05	$14.38	7	14.22	$94.08

Notes next page

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. For HVAC, the standard energy bills are derived from 1990 RECS consumption data. All savings are for specifications that apply in 2003.

b) Electricity is converted to primary energy using a conversion factor of 10,938 Btu/kWh (US DOE 2000).

c) Yearly U.S. average energy prices are given 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, VCR, DVD, and audio product lifetimes are from *Appliance* (1996); telephony and dehumidifier lifetimes are from *Appliance* (1998); settop box lifetimes are assumed to be similar to other electronics products; 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; lifetimes for residential lighting fixtures are based on a ballast life of 40,000 hours and 2,000 hours of use per year; traffic signal life is from Suozzo and Nadel (1998); exit sign life is from National Lighting Product Information (1994); clothes washer, dishwasher, refrigerator, and room air conditioner lifetimes are from Wenzel et al (1997); commercial refrigeration lifetimes are from A.D. Little (1996); water coolers lifetimes are assumed to be the same as commercial refrigeration; exhaust fans and ceiling fan lifetimes are taken from Cadmus (1999); hot food holding cabinet life is from Zabrowski (2003); steamer, fryer and vending machine lifetimes are from ICF (2002a, b, and c, respectively); commercial and industrial transformer life is from Thomas et al. (2002).

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

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

Tables 5 shows the annual energy, dollar, and carbon savings for 2005 as well as 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 2005 were 981 trillion Btu and 8.6 billion dollars (undiscounted). These figures represent increases of 180 TBtu and 3.1 billion dollars over the 2004 energy savings. The also represent an increase of 101 TBtu and 2.5 billion dollars over the 2005 forecast in the last status report. The peak demand reduction due to the ENERGY STAR labeling program was 9.8 gigawatts in 2005 up from 7.9 GW in 2004.

There were increased savings in most program areas. The largest increase occurred in Heating and Cooling, where the large increase in savings was due to the shipment data showing many more Energy Star units than had been previously estimated. Office Equipment savings were also up, despite lowered savings estimates for computers and monitors. This increase is mostly due to the large increase in savings attributed to printers, and to a lesser degree, multifunction devices. Consumer electronics savings were also increased, due in large part to the higher savings attributed to TV's. There were also two new device types in this area; external power supplies and battery charging systems. Savings for residential appliances were essentially the same as in last version with exception of a large increase in savings attributed to clothes washers.

Table 6 shows the forecast for saving expected in 2006. By 2006, energy savings are expected to reach 1098 trillion Btu and 9.5 billion dollars. Peak demand reduction is modeled as increasing to 11.12 gigawatts in 2006.

Market Penetration scenarios.

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 2005 onward. These estimates cannot be directly compared to those from previous status reports because the scenarios have been extended to 2025, whereas they ended in 2015 in previous versions.

Table 5. Annual Savings in 2005

Program	Equipment Type	Primary Savings	Energy Bill Savings, Undiscounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2004	MtC		GW
Office Equipment	- Computers & Monitors	231.25	$1,873	4.292	1.19	1.247
	- Fax	9.10	$79	0.169	1.03	0.092
	- Copier	4.51	$36	0.084	5.81	0.008
	-Multifunction Device	39.73	$316	0.737	0.88	0.471
	- Scanner	20.66	$181	0.383	0.32	0.683
	- Printer	172.61	$1,414	3.203	7.44	0.527
	Subtotal	477.9	$3,899	8.869	1.34	3.027
Consumer Electronics	- TVs	43.89	$393	0.815	1.00	0.458
	-VCRs	15.63	$140	0.290	1.00	0.163
	-TV/VCR/DVD	11.50	$103	0.213	1.00	0.120
	-DVD Player	11.14	$100	0.207	1.00	0.116
	-Audio Equipment	10.19	$91	0.189	1.00	0.106
	-Telephony	6.52	$58	0.121	1.00	0.068
	-Set-top Box	0.84	$7.5	0.016	0.72	0.027
	-External Power Supplies	1.21	$10.7	0.022	1.00	0.013
	-Battery Charging Systems	0.00	$0	0.000	0.00	0.000
	Subtotal	100.9	$905	1.873	0.98	1.071
Heating & Cooling	- Furnace (Gas or Oil)	49.65	$578	0.757	-	-
	- Central Air Conditioner	5.83	$52	0.108	0.15	0.406
	- Air-Source Heat Pump	2.54	$23	0.047	0.15	0.065
	- Geothermal Heat Pump	1.98	$18	0.037	0.15	0.016
	- Boiler (Gas or Oil)	4.02	$53	0.068	-	-
	- Programmable Thermostat	46.71	$512	0.778	0.15	0.694
	- Unitary HVAC	1.72	$14	0.032	0.15	0.120
	Subtotal	112.5	$1,250	1.827	0.16	1.301
Res and Com Lighting	- Fixtures	76.78	$688	1.425	1.02	0.782
	- CFLs	96.50	$865	1.791	1.02	0.983
	- Exit Sign	5.39	$43	0.100	1.00	0.056
	- Traffic Signal	11.12	$88	0.206	1.00	0.116
	Subtotal	189.8	$1,685	3.522	1.02	1.937
Residential Appliances	- Room Air Conditioners	10.27	$92	0.191	0.15	0.715
	- Dehumidifiers	2.21	$20	0.041	0.42	0.055
	- Air Cleaners	2.56	$23	0.048	1.00	0.027
	- Exhaust Fans	0.68	$6.1	0.013	1.02	0.006
	- Ceiling Fans	0.95	$8.5	0.018	1.02	0.001
	- Dishwashers	17.57	$174	0.306	1.02	0.003
	- Refrigerators	15.43	$138	0.286	1.02	0.005
	- Clothes Washers	34.39	$342	0.597	0.77	0.171
	Subtotal	84.1	$804	1.499	0.95	0.169
Commercial Appliances	- Water Coolers	5.17	$41	0.096	0.70	0.081
	- Commercial Refrigeration	2.62	$21	0.049	0.95	0.029
	- Hot Food Holding Cabinets	0.25	$2.0	0.005	0.95	0.003
	- Fryers	0.26	$3.1	0.004	0.95	0.000
	- Steamers	0.10	$0.8	0.002	0.95	0.001
	- Vending Machines	1.86	$15	0.034	0.95	0.020
	Subtotal	10.27	$83	0.190	0.78	0.134
Other	- Utility Transformers	0.06	$0.50	0.001	1.00	0.001
	- C&I Transformers	0.70	$5.6	0.013	0.77	0.010
	- Residential Roofing	0.49	$3.7	0.010	0.15	0.063
	- Commercial Roofing	7.36	$51	0.143	0.15	0.744
	Subtotal	8.61	$61	0.167	0.16	0.817
TOTAL		981.4	$8,663	17.90	0.84	9.826

Notes on next page

Notes to Table 5

a) Columns may not total due to rounding.

b) Electricity is converted to primary energy using a conversion factor of 10,938 Btu/kWh (US DOE).

c) Energy bills are calculated using yearly U.S. average energy prices. 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 refrigeration equipment are taken from Koomey et al. (1990). Roofs are assumed to have the same CLF as cooling technologies. Commercial cooking equipment is assumed to have the same CLF as commercial refrigeration. 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). Ceiling fans are assumed to have the same CLF as residential lighting. Exhaust fans encompass several products. The CLF represents a weighted average of intermittent fans (assumed the same as lighting), continuously operated fans (CLF of 1), and rangehood fans (assumed the same as cooking equipment, Ruderman et al., 1989).

Table 6. Expected Annual Savings in 2006

Program	Equipment Type	Primary Savings	Energy Bill Savings, Undiscounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2004	MtC		GW
Office Equipment	- Computers and Monitors	220.71	1,768	4.292	1.06	1.005
	- Fax	7.74	$66	0.139	1.03	0.078
	- Copier	2.82	$22	0.051	5.81	0.005
	-Multifunction Device	38.65	$305	0.694	0.88	0.457
	- Scanner	21.29	$182	0.382	0.32	0.706
	- Printer	204.10	$1,649	3.666	7.48	0.627
	Subtotal	495.3	$3,992	8.896	1.37	2.88
Consumer Electronics	- TVs	55.25	$481	0.992	1.00	0.578
	-VCRs	12.39	$108	0.223	1.00	0.130
	-TV/VCR/DVD	12.47	$109	0.224	1.00	0.130
	-DVD Player	13.38	$117	0.240	1.00	0.140
	-Audio Equipment	12.71	$111	0.228	1.00	0.133
	-Telephony	7.66	$67	0.138	1.00	0.080
	-Set-top Box	1.06	$9.3	0.019	0.76	0.034
	-External Power Supplies	2.74	$23.4	0.049	1.00	0.029
	-Battery Charging Systems	0.03	$0	0.001	1.00	0.00032
	Subtotal	117.7	$1,025	2.113	0.98	1.25
Heating & Cooling	- Furnace (Gas or Oil)	62.33	$696	0.943	-	-
	- Central Air Conditioner	5.84	$51	0.105	0.15	0.407
	- Air-Source Heat Pump	2.71	$24	0.049	0.15	0.070
	- Geothermal Heat Pump	2.81	$24	0.050	0.15	0.023
	- Boiler (Gas or Oil)	5.08	$68	0.085	-	-
	- Programmable Thermostat	51.18	$547	0.838	0.15	0.757
	- Unitary HVAC	2.54	$20	0.046	0.15	0.177
	Subtotal	132.5	$1,430	2.117	0.16	1.43
Res and Com Lighting	- Fixtures	92.81	$809	1.667	1.02	0.947
	- CFLs	115.28	$1,005	2.071	1.02	1.177
	- Exit Sign	5.98	$47	0.107	1.00	0.063
	- Traffic Signal	13.33	$105	0.239	1.00	0.139
	Subtotal	227.4	$1,965	4.084	1.02	2.33
Residential Appliances	- Room Air Conditioners	12.12	$106	0.218	0.15	0.845
	- Dehumidifiers	2.97	$26	0.053	0.42	0.074
	- Air Cleaners	3.89	$34	0.070	1.00	0.041
	- Exhaust Fans	0.98	$8.5	0.018	1.02	0.009
	- Ceiling Fans	1.61	$14.1	0.029	0.95	0.001
	- Dishwashers	22.47	$215	0.381	1.02	0.004
	- Refrigerators	18.50	$161	0.332	1.02	0.009
	- Clothes Washers	40.21	$385	0.681	0.77	0.219
	Subtotal	102.7	$949	1.782	0.95	0.20
Commercial Appliances	- Water Coolers	7.02	$55	0.126	0.70	0.110
	- Commercial Refrigeration	3.69	$29	0.066	0.95	0.041
	- Hot Food Holding Cabinets	0.52	$4.1	0.009	0.95	0.006
	- Fryers	0.42	$4.7	0.006	0.95	0.001
	- Steamers	0.19	$1.6	0.003	0.95	0.002
	- Vending Machines	2.81	$22	0.051	0.95	0.031
	Subtotal	14.65	$117	0.262	0.79	0.19
Other	- Utility Transformers	0.06	$0.50	0.001	1.00	0.001
	- C&I Transformers	0.70	$5.5	0.013	0.77	0.010
	- Residential Roofing	0.76	$5.6	0.015	0.15	0.097
	- Commercial Roofing	10.50	$74	0.197	0.15	1.065
	Subtotal	12.02	$85	0.225	0.16	1.17
TOTAL		1098.4	$9,530	19.41	0.81	11.12

Notes next page.

Notes to Table 6:
a) Columns may not total due to rounding.
b) Electricity is converted to primary energy using a conversion factor of 10,938 Btu/kWh (US DOE).
c) Energy bills are calculated using yearly U.S. average energy prices. 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.

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 are no more expensive than non-ENERGY STAR devices, they are expected to represent a large share of the market (90 percent or more) by 2015. 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 2005-2015 and 2005-2025, respectively. All the products together are expected to save 16.5 quadrillion Btu (quads) by 2015, growing to 42 quads by 2025. Through 2015, Printer are forecast to to be the largest source of savings, with computers (the sum of CPUs and monitors) close behind. In both cases, primarily due to the large market share of ENERGY STAR devices and steep growth in the number of units in place. CFLs and residential lighting fixtures are neck and neck for the third highest savings.

By 2025, the same four products take the top four slots, but with residential fixtures having taken over first place, followed by computers, printers, and CFLs, in that order. Although residential fixtures and CFLs 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.

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 2005 to 2015. Because geothermal heat pumps are a new technology without a defined baseline market share, they are modeled as replacing 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 applications.

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 shown in Tables 9 and 10. Together the programs could save 46 quads from 2006 to 2015, growing to 118 quads by 2025. These correspond to a total energy bill savings of $236 billion through 2015 and $497 billion through 2025 (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 2015 case is due to CFL's, followed by residential lighting fixtures, computers and printers. By 2025 the largest share of savings are attributed to residential lighting fixtures, followed by CFLs, furnaces (gas and oil fired) and computers.

Figure 3 compares annual carbon savings under the 100 percent market share scenario and the target market penetration scenario through 2025.

Table 7. Cumulative Savings 2006-2015, Target Market Penetrations

Program	-Equipment	Primary Energy Savings Trillion Btu	Energy Bill Savings Million $2004 Undiscounted	Energy Bill Savings Million $2004 Discounted	Carbon Avoided MMTC
Office Equipment	- Computers and Monitors	2518	$18,391	$12,150	38.70
	- Fax	53	$418	$285	0.84
	- Copier	8	$60	$43	0.13
	-Multifunction Device	326	$2,351	$1,581	5.08
	- Scanner	280	$2,188	$1,445	4.30
	- Printer	2582	$19,015	$12,573	39.73
	Subtotal	5766	$42,423	$28,079	88.8
Consumer Electronics	- TVs	1480	$11,711	$7,459	22.12
	-VCRs	39	$320	$236	0.66
	-TV/VCR/DVD	146	$1,165	$771	2.25
	-DVD Player	169	$1,344	$888	2.60
	-Audio Equipment	203	$1,611	$1,052	3.09
	-Telephony	152	$1,203	$771	2.28
	-Set-top Box	15	$120	$65	0.23
	-External Power Supplies	128	$979	$617	1.89
	-Battery Charging Systems	12	$95	$58	0.17
	Subtotal	2204	$17,475	$11,242	35.1
Heating & Cooling	- Furnace (Gas or Oil)	1242	$12,261	$7,909	18.09
	- Central Air Conditioner	54	$436	$294	0.85
	- Air-Source Heat Pump	51	$402	$255	0.76
	- Geothermal Heat Pump	72	$569	$362	1.07
	- Boiler (Gas or Oil)	99	$1,141	$738	1.65
	- Programmable Thermostat	640	$6,118	$4,059	9.76
	- Unitary HVAC	82	$580	$366	1.21
	Subtotal	2239	$21,506	$13,983	33.4
Res and Com Lighting	- Fixtures	1793	$14,214	$9,146	27.00
	- CFLs	1848	$14,678	$9,560	28.11
	- Exit Sign	60	$433	$292	0.94
	- Traffic Signal	131	$946	$643	2.06
	Subtotal	3832	$30,271	$19,641	58.1
Residential Appliances	- Room Air Conditioners	198	$1,573	$1,024	3.01
	- Dehumidifiers	119	$939	$592	1.76
	- Air Cleaners	96	$763	$490	1.45
	- Exhaust Fans	27	$212	$135	0.40
	- Ceiling Fans	61	$485	$305	0.91
	- Dishwashers	480	$4,129	$2,656	7.13
	- Refrigerators	324	$2,569	$1,663	4.90
	- Clothes Washers	610	$5,267	$3,450	9.17
	Subtotal	1915	$15,936	$10,317	28.7
Commercial Appliances	- Water Coolers	162	$1,150	$739	2.43
	- Commercial Refrigeration	90	$639	$409	1.35
	- Hot Food Holding Cabinets	33	$231	$143	0.48
	- Fryers	13	$132	$83	0.19
	- Steamers	19	$149	$90	0.27
	- Vending Machines	80	$566	$347	1.19
	Subtotal	396	$2,867	$1,812	5.91
Other	- Utility Transformers	1	$4	$3	0.010
	- C&I Transformers	7	$50	$33	0.11
	- Residential Roofing (per 1000 sq ft)	23	$160	$101	0.35
	- Commercial Roofing (per 1000 sq ft)	223	$1,428	$924	3.41
	Subtotal	254	$1,642	$1,062	3.87
TOTAL		16510	$131,356	$85,645	252.48

See notes after Table 10.

Table 8. Cumulative Savings 2006-2025, Target Market Penetrations

Program	-Equipment	Primary Energy Savings Trillion Btu	Energy Bill Savings Million $2004 Undiscounted	Energy Bill Savings Million $2004 Discounted	Carbon Avoided MMTC
Office Equipment	- Computers and Monitors	5758	$42,412	$22,878	81.34
	- Fax	93	$730	$426	1.36
	- Copier	10	$76	$51	0.16
	-Multifunction Device	660	$4,780	$2,670	9.47
	- Scanner	595	$4,694	$2,571	8.45
	- Printer	5647	$41,916	$22,842	80.06
	Subtotal	12763	$94,607	$51,438	180.9
Consumer Electronics	- TVs	4019	$32,199	$16,668	55.53
	-VCRs	39	$323	$237	0.66
	-TV/VCR/DVD	302	$2,420	$1,336	4.30
	-DVD Player	424	$3,411	$1,804	5.96
	-Audio Equipment	495	$3,968	$2,105	6.93
	-Telephony	501	$4,027	$2,025	6.87
	-Set-top Box	30	$242	$111	0.43
	-External Power Supplies	271	$2,086	$1,160	3.78
	-Battery Charging Systems	35	$275	$146	0.47
	Subtotal	5811	$46,591	$24,285	84.5
Heating & Cooling	- Furnace (Gas or Oil)	3775	$37,280	$19,017	54.04
	- Central Air Conditioner	93	$745	$431	1.36
	- Air-Source Heat Pump	264	$2,127	$1,006	3.56
	- Geothermal Heat Pump	252	$2,027	$1,006	3.45
	- Boiler (Gas or Oil)	290	$3,385	$1,734	4.85
	- Programmable Thermostat	1342	$12,850	$7,071	19.79
	- Unitary HVAC	335	$2,430	$1,178	4.54
	Subtotal	6351	$60,843	$31,444	91.6
Res and Com Lighting	- Fixtures	5775	$46,407	$23,388	79.38
	- CFLs	4716	$37,838	$19,889	65.84
	- Exit Sign	108	$782	$449	1.57
	- Traffic Signal	197	$1,423	$862	2.93
	Subtotal	10795	$86,450	$44,587	149.7
Residential Appliances	- Room Air Conditioners	485	$3,887	$2,060	6.78
	- Dehumidifiers	378	$3,032	$1,527	5.17
	- Air Cleaners	250	$2,004	$1,044	3.47
	- Exhaust Fans	74	$596	$307	1.03
	- Ceiling Fans	229	$1,841	$904	3.11
	- Dishwashers	1271	$11,017	$5,744	17.83
	- Refrigerators	882	$7,082	$3,673	12.25
	- Clothes Washers	1182	$10,209	$5,715	16.89
	Subtotal	4752	$39,668	$20,973	66.5
Commercial Appliances	- Water Coolers	425	$3,070	$1,597	5.90
	- Commercial Refrigeration	255	$1,840	$943	3.52
	- Hot Food Holding Cabinets	152	$1,099	$525	2.04
	- Fryers	47	$466	$231	0.67
	- Steamers	101	$845	$397	1.40
	- Vending Machines	249	$1,798	$875	3.41
	Subtotal	1229	$9,118	$4,569	16.9
Other	- Utility Transformers	1	$9	$5	0.017
	- C&I Transformers	14	$98	$55	0.19
	- Residential Roofing (per 1000 sq ft)	96	$676	$327	1.26
	- Commercial Roofing (per 1000 sq ft)	614	$4,005	$2,067	8.44
	Subtotal	725	$4,788	$2,454	9.92
TOTAL		42176	$340,063	$178,708	596.55

See notes after Table 10.

Table 9. Cumulative Savings 2006-2015, 100% Market Penetration

Program	-Equipment	Primary Energy Savings Trillion Btu	Energy Bill Savings Million $2004 Undiscounted	Energy Bill Savings Million $2004 Discounted	Carbon Avoided MMTC
Office Equipment	- Computers and Monitors	3478	$25,368	$16,733	53.41
	- Fax	54	$422	$288	0.85
	- Copier	8	$61	$45	0.14
	-Multifunction Device	350	$2,522	$1,691	5.44
	- Scanner	309	$2,416	$1,593	4.74
	- Printer	2604	$19,173	$12,675	40.06
	Subtotal	6759	$49,626	$32,767	103.9
Consumer Electronics	- TVs	2001	$15,820	$10,036	29.80
	-VCRs	39	$320	$236	0.66
	-TV/VCR/DVD	146	$1,165	$771	2.25
	-DVD Player	474	$3,753	$2,423	7.16
	-Audio Equipment	532	$4,206	$2,691	7.97
	-Telephony	818	$6,463	$4,113	12.22
	-Set-top Box	552	$4,353	$2,266	8.20
	-External Power Supplies	1242	$9,511	$6,082	18.62
	-Battery Charging Systems	129	$1,016	$644	1.92
	Subtotal	4561	$36,081	$22,535	86.9
Heating & Cooling	- Furnace (Gas or Oil)	2340	$23,158	$14,761	34.34
	- Central Air Conditioner	1344	$10,607	$6,658	19.85
	- Air-Source Heat Pump	901	$7,113	$4,469	13.32
	- Geothermal Heat Pump	127	$1,001	$633	1.88
	- Boiler (Gas or Oil)	118	$1,342	$864	1.94
	- Programmable Thermostat	2098	$19,947	$12,775	31.64
	- Unitary HVAC	1340	$9,490	$5,993	19.87
	Subtotal	8268	$72,659	$46,153	122.8
Res and Com Lighting	- Fixtures	8989	$71,007	$44,835	133.4
	- CFLs	10175	$81,433	$55,412	160.4
	- Exit Sign	77	$556	$370	1.20
	- Traffic Signal	131	$946	$643	2.06
	Subtotal	19372	$153,942	$101,261	297.04
Residential Appliances	- Room Air Conditioners	406	$3,212	$2,051	6.08
	- Dehumidifiers	143	$1,131	$712	2.12
	- Air Cleaners	356	$2,814	$1,777	5.29
	- Exhaust Fans	222	$1,756	$1,105	3.29
	- Ceiling Fans	1121	$8,846	$5,560	16.57
	- Dishwashers	616	$5,294	$3,385	9.13
	- Refrigerators	672	$5,315	$3,388	10.04
	- Clothes Washers	753	$6,433	$4,230	11.34
	Subtotal	4289	$34,802	$22,208	63.9
Commercial Appliances	- Water Coolers	223	$1,586	$1,013	3.34
	- Commercial Refrigeration	245	$1,740	$1,103	3.65
	- Hot Food Holding Cabinets	236	$1,673	$1,054	3.50
	- Fryers	85	$846	$533	1.22
	- Steamers	145	$1,161	$731	2.12
	- Vending Machines	183	$1,297	$784	2.71
	Subtotal	1118	$8,302	$5,219	16.5
Other	- Utility Transformers	1	$4	$3	0.01
	- C&I Transformers	7	$50	$33	0.11
	- Residential Roofing (per 1000 sq ft)	254	$1,742	$1,094	3.80
	- Commercial Roofing (per 1000 sq ft)	1632	$10,405	$6,626	24.57
	Subtotal	1893	$12,201	$7,756	28.48
TOTAL		45904	$364,798	$236,122	714.2

See notes after Table 10.

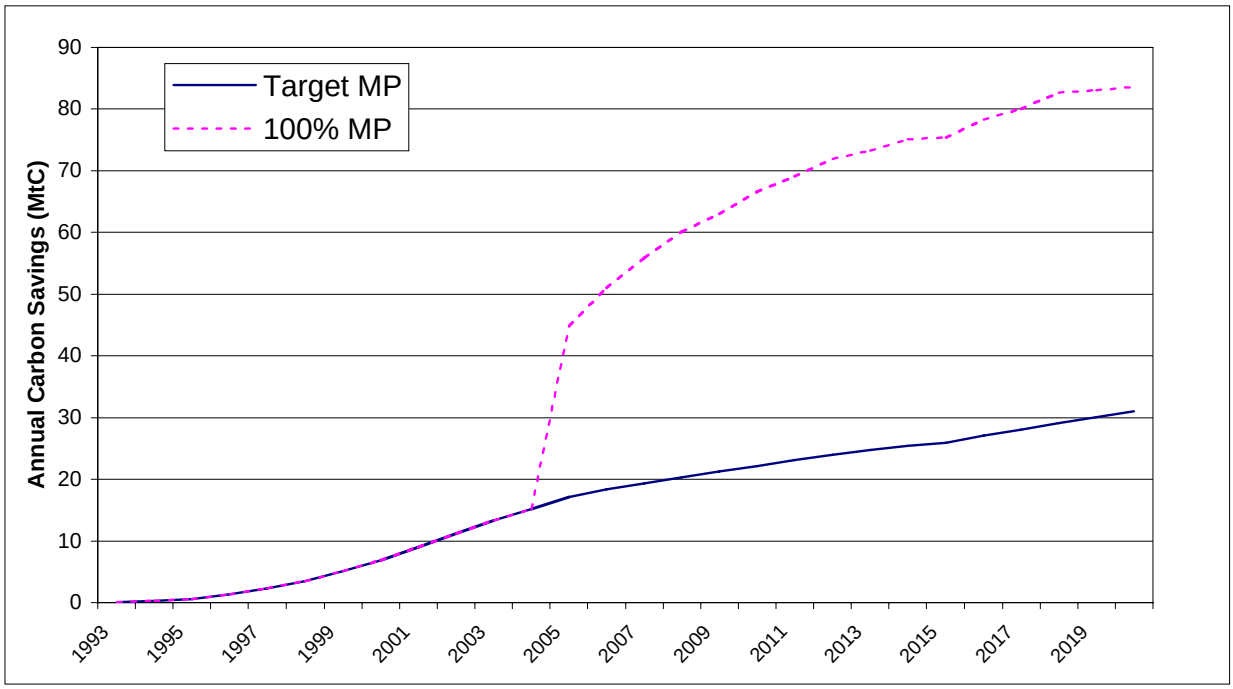
Table 10. Cumulative Savings 2006-2025, 100% Market Penetration

Program	-Equipment	Primary Energy Savings	Energy Bill Savings Million $2004		Carbon Avoided
		Trillion Btu	Undiscounted	Discounted	MMTC
Office Equipment	- Computers and Monitors	7911	$58,218	$31,408	111.74
	- Fax	94	$738	$431	1.38
	- Copier	11	$79	$53	0.17
	-Multifunction Device	718	$5,198	$2,890	10.28
	- Scanner	659	$5,200	$2,844	9.36
	- Printer	5700	$42,304	$23,047	80.8
	Subtotal	15049	$111,401	$60,415	213.0
Consumer Electronics	- TVs	5604	$44,898	$23,084	77.21
	-VCRs	39	$323	$237	0.66
	-TV/VCR/DVD	302	$2,420	$1,336	4.30
	-DVD Player	1072	$8,575	$4,593	15.03
	-Audio Equipment	1288	$10,309	$5,439	17.93
	-Telephony	2067	$16,545	$8,636	28.66
	-Set-top Box	1498	$11,996	$5,067	20.66
	-External Power Supplies	2114	$16,252	$9,411	30.11
	-Battery Charging Systems	227	$1,800	$1,032	3.21
	Subtotal	11870	$95,066	$48,392	194.5
Heating & Cooling	- Furnace (Gas or Oil)	8038	$80,058	$39,903	116.1
	- Central Air Conditioner	4795	$38,492	$19,067	65.2
	- Air-Source Heat Pump	2941	$23,578	$11,840	40.2
	- Geothermal Heat Pump	478	$3,845	$1,887	6.51
	- Boiler (Gas or Oil)	364	$4,154	$2,110	5.93
	- Programmable Thermostat	6222	$59,713	$30,534	90.7
	- Unitary HVAC	4425	$31,964	$16,015	60.5
	Subtotal	27263	$241,805	$121,356	385.1
Res and Com Lighting	- Fixtures	33014	$265,332	$130,471	449.4
	- CFLs	10740	$85,630	$58,575	167.9
	- Exit Sign	141	$1,016	$579	2.03
	- Traffic Signal	197	$1,423	$862	2.93
	Subtotal	s	$353,401	$190,487	622.3
Residential Appliances	- Room Air Conditioners	1207	$9,684	$4,943	16.62
	- Dehumidifiers	455	$3,645	$1,837	6.22
	- Air Cleaners	1038	$8,323	$4,233	14.26
	- Exhaust Fans	629	$5,040	$2,580	8.65
	- Ceiling Fans	3192	$25,557	$13,063	43.82
	- Dishwashers	1769	$15,340	$7,876	24.72
	- Refrigerators	2220	$17,836	$8,923	30.41
	- Clothes Washers	1446	$12,277	$6,910	20.63
	Subtotal	11957	$97,703	$50,364	165.3
Commercial Appliances	- Water Coolers	593	$4,280	$2,220	8.21
	- Commercial Refrigeration	662	$4,769	$2,463	9.13
	- Hot Food Holding Cabinets	828	$5,984	$2,970	11.28
	- Fryers	256	$2,547	$1,292	3.66
	- Steamers	421	$3,416	$1,740	5.86
	- Vending Machines	651	$4,704	$2,240	8.86
	Subtotal	3411	$25,699	$12,926	47.0
Other	- Utility Transformers	1	$9	$5	0.017
	- C&I Transformers	14	$98	$55	0.19
	- Residential Roofing (per 1000 sq ft)	960	$6,722	$3,290	12.67
	- Commercial Roofing (per 1000 sq ft)	4109	$26,709	$13,930	56.44
	Subtotal	5083	$33,538	$17,279	69.33
TOTAL		117686	$950,291	$496,987	1682.3

See notes next page.

Notes to Tables 7-10:
a) Columns values may not add up to 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 2004 onward is ENERGY STAR-compliant.
c) Electricity is converted to primary energy using conversion factors given in Table 2.
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, 2000, and 2001). See Table 2.
f) Carbon emissions for electricity are from Cadmus (1998) and EPA (2003). See Table 2.

Figure 3. 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. New information may change our estimates significantly. 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.

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 rapid adoption of new television technologies (e.g. plasma, LCD and DLP) is undoubtedly changing TV power consumption. DVD players are rapidly supplanting VCRs in the market. 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. While we try to capture the effects of existing trends, the future of many technologies is too nebulous to predict in a way that could be incorporated into this analysis.

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 2025, 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, by our estimates, more than 981 trillion Btus of energy and prevented carbon emissions of 17.9 million metric tonnes in 2003 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. 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, $236 billion could be saved from estimated energy bills through 2015 (present value, at a 4 percent real discount rate).

References

A.D. Little, 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.* Prepared for US DOE Office of Building Technology. June.

AD Little, 1998. *Electricity Consumption by Small End Uses in Residential Buildings.* Prepared for the US DOE Office of Building Technology. August.

AHAM. 2002. Excel Spreadsheet: "Appliance_Shipment_Trends_1991-2001.xls". Air Cleaners

Appliance, 1995. "Statistical Review." April, pp 45-48.

Appliance, 1996. "A Portrait of the U.S. Appliance Industry 1996." September, pp 85-91.

Appliance, 1998. "A Portrait of the U.S. Appliance Industry 1998." September, pp 67-73.

Appliance, 2003. "50th Annual Report: Statistical Review." May, pp 47-50.

Appliance, 2004. "27th Annual Portrait of the U.S. Appliance Industry." September, pp P1-P7.

Cadmus (the Cadmus Group, Inc.) and Energy Systems Consulting, Inc., 1998. *Regional Electricity Emissions Factors.* Prepared for the U.S. Environmental Protection Agency. May.

Cadmus (the Cadmus Group, Inc.). 1999. *Preliminary Market Background Report for Residential Ventilation Fans.* Prepared for the U.S. Environmental Protection Agency. June.

Cadmus (the Cadmus Group, Inc.). 1999. *Preliminary Market Background Report for Residential Dehumidifiers*. Prepared for the U.S. Environmental Protection Agency. September.

Cadmus (the Cadmus Group, Inc.). 2000. *Product Testing and Analysis of Water Dispensers*. Prepared for the U.S. Environmental Protection Agency. February.

Cadmus (the Cadmus Group, Inc.). 2001. *Preliminary Market Background Report for Commercial Reach-In Refrigerators and Freezers*. Prepared for the U.S. Environmental Protection Agency. March.

Calwell, C., 1999. "Customers Turn Out for Torchiere Trade-In." *Home Energy*, 16(2), pp 32-35.

Calwell, C. and C. Granda, 1999. *Halogen Torchiere Market Transformation: A Look at Progress to Date and Future Strategies.* Natural Resources Defense Council. September.

Calwell, C. and N. Horowitz. 2001. "Ceiling Fans: Fulfilling the Energy Efficiency Promise." *Home Energy*, January/February 2001, pp 24-29.

CEA Market Research. 2004. *U.S. Consumer Electronics Sales & Forecasts, 1999-2004*. January.

Fisher, Don. 2003. Personal communication: email exchange, March-June 2003.

Floyd, D. and C. Webber. 1998. “Leaking Electricity: Individual Field Measurements of Consumer Electronics.” In *Proceedings of the 1998 Summer Study on Energy Efficiency in Buildings*. Washington DC: American Council for an Energy Efficient Economy.

Gartner. 2001. Special Report on PCs. Prepared for the Environmental Protection Agency Energy Star Program. November.

Guo, J. L., L. H. Lapera, A. Manning, P. Nappakaokeskui, M. Wyche, 1998. *Fall 1998 Report Forecasts: The Computer Hardware Industry*. Syracuse University Press. http://istweb.syr.edu/~ist775/spring98/hardware/profile_98.html.

ICF. 2002a. *Steamer Engineering Analysis*. Prepared for the Environmental Protection Agency Energy Star Program.

ICF. 2002b. *Fryer Engineering Analysis*. Prepared for the Environmental Protection Agency Energy Star Program.

ICF. 2002c. *ENERGY STAR® Product Development for Refrigerated Beverage Vending Machines Industry & Market Research and Analysis*. Prepared for the Environmental Protection Agency Energy Star Program.

ICF Consulting. 2003. Energy Star Market Penetration Report Calender Year 2002. April.

ENERGY STAR® Product Development for
Refrigerated Beverage Vending Machines
Industry & Market Research and Analysis

IDC, 2003. *Worldwide PC Monitor Forecast and Analysis 2003-2007: It’s a Flat-out Success*. December.

Isaacs, David (EIA/CEMA), 1998. Personal communication, discussion with Stephan Sylvan of EPA, September 3, 1997.

Koomey, Jonathan, Arthur H. Rosenfeld, and Ashok K. Gadgil. 1990. "Conservation Screening Curves to Compare Efficiency Investments to Power Plants." *Energy Policy*. vol. 18, no. 8. October. p. 774-782.

Koomey, Jonathan, Michael Cramer, Mary Ann Piette and Joseph Eto, 1995. *Efficiency Improvements in U.S. Office Equipment: Expected Policy Impacts and Uncertainties*. Lawrence Berkeley Laboratory. LBL-37383. December.

Lewis, J. E. and A. Clarke, 1990. *Replacement Market for Selected Commercial Energy Service Equipment* (Topical Report: Phase 1B--Commercial). Gas Research Institute. GRI-89/0204.02. June.

Lyra Research, Inc., 1998. *Single-Function Fax Machine Forecast*. Prepared exclusively for Environmental Protection Agency. March.

Media Metrix. 2001. *Softscan 3Q2001*.

National Lighting Product Information, 1994. Specifier Reports: Exit Signs. Volume 2, Number 2. Troy, NY: Lighting Research Center, Rensselaer Polytechnic Institute. March.

Nordman, B., M.A. Piette, B. Pon and K. Kinney, 1998. *It's Midnight...Is Your Copier On?: Energy Star Copier Performance*. Lawrence Berkeley National Laboratory. LBNL-41332, February.

NRDC. 2005. "Tuning into Energy Efficiecy: Prospects for Saving Energy in Televisions." Natural Resources Defense Council. January.

Piette, M.A., M. Cramer, J. Eto and J. Koomey, 1995. *Office Technology Energy Use and Savings Potential in New York*. Completed for the New York State Energy Research and Development Authority and Consolidated Edison by Lawrence Berkeley Laboratory. Contract #1955-EEED-BES-93, also LBL-36752. January.

Roberson, J., B. Nordman, R. Brown, C. Webber, J. Koomey. 2000. *Measured Low Power Levels in Personal Computers, Vintage 1990-2000*. Memo to Andrew Fanara and Marla Sanchez of EPA, July 14.

Roberson, J., G. Homan, A. Mahajan, B. Nordman, C. Webber, R. Brown, M. McWhinney, and J. Koomey. 2002. *Energy Use and Power Management in New Personal Computers and Monitors*. Lawrence Berkeley National Laboratory, LBNL-48581. July.

Roberson, J. A., C. Webber, M. McWhinney, R. Brown, M. Pinckard, Busch, J. 2004. *After-hours power status of office equipment and energy use of miscellaneous plug-load equipment*. Lawrence Berkeley National Laboratory, LBNL-53729 Rev. May

Rovi, J. 2001. *Personal Communication*. Excel file containing metered water cooler data received 5/14/01 via Email.

Rosen, K. and A. Meier. 1999. *Energy Use of Televisions and Videocassette Recorders in the U.S.* Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-42393. March.

Ruderman, H., J. Eto, K. Heinemier, A. Golan, and D. Wood. 1989. *Residential End-Use Load Shape Data Analysis: Final Report.* Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-27114. April.

Sanchez, M., J. Koomey, M. Moezzi, A. Meier, and W. Huber, 1998. *Miscellaneous Electricity Use in the U.S. Residential Sector*. Lawrence Berkeley National Laboratory. LBNL-40295, April.

Sanchez, M., A. Fanara, and R. Schmeltz, 2000. "New Product Development: The Pipeline for Future ENERGY STAR® Growth." In Proceedings of the 2000 ACEEE Summer Study on Energy

Efficiency in Buildings, 6:343-354. American Council for an Energy Efficient Economy, Washington, DC.

Suozzo, M. and S. Nadel. 1998. *Selecting Targets for Market Transformation Programs: A National Analysis*. American Council for an Energy Effici cient Economy, Washington, DC. August.

Thomas, A., M. Shincovich, S. Ryan, D. Korn, J. Shugars. 2002. "Replacing Distribution Transformers: A Hidden Opportunity for Energy Savings." In *Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings*. American Council for an Energy Effici cient Economy, Washington, DC.

U.S. Department of Commerce, 1997. *Electric Lighting Fixtures--1996*. Current Industrial Reports MA36L(96)-1. Bureau of the Census. September.

U.S. Department of Commerce, 2000. Implicit GDP Deflator. Bureau of Economic Analysis, http://www.bea.doc.gov/bea/dn1.htm. March 6.

US DOE, U.S. Department of Energy, 1995a. *Monthly Energy Review*. DOE/EIA-0035(95/05). Energy Information Administration. May.

US DOE, U.S. Department of Energy, 1995b. *Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator/Freezers and Freezers*. Washington, DC.: US Department of Energy, Energy Efficiency and Renewable Energy, Office of Codes and Standards. DOE/EE-0064. July.

US DOE, U.S. Department of Energy, 1996a. *Annual Energy Outlook 1996 with Projections to 2015*. DOE/EIA-0383(96). Energy Information Administration. January.

US DOE, U.S. Department of Energy, 1996b. *Annual Energy Outlook 1997 with Projections to 2015*. DOE/EIA-0383(97). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 1997a. *Technical Support Document for Energy Conservation Standards for Room Air Conditioners*. US Department of Energy, Energy Efficiency and Renewable Energy, Office of Codes and Standards. http://www.eren.doe.gov/buildings/codes_standards/reports/index.htm. September.

US DOE, U.S. Department of Energy, 1997b. *Annual Energy Outlook 1998 with Projections to 2020*. DOE/EIA-0383(98). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 1998a. *Preliminary Technical Support Document: Energy Efficiency Standards for Consumer Products: Clothes Washers (TSD)*. Washington, DC: US Department of Energy, Energy Efficiency and Renewable Energy, Office of Codes and Standards. October.

US DOE, U.S. Department of Energy, 1998b. *Annual Energy Outlook 1999 with Projections to 2020*. DOE/EIA-0383(99). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 1999. *Annual Energy Outlook 2000 with Projections to 2020*. DOE/EIA-0383(2000). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 1999. *Life Cycle Cost of Clothes Washers*. Excel Spreadsheet lcccw_10_0001.xls created by Peter Biermeyer of LBNL. Downloaded from http://www.eren.doe.gov/buildings/codes_standards/applbrf/clwasher.html. March.

US DOE, U.S. Department of Energy, 1999. *A Look at Residential Energy Consumption in 1997*. DOE/EIA-0632(1997). Energy Information Administration. November.

US DOE, U.S. Department of Energy, 2004. *Residential Energy Consumption Survey 2001: Housing Characteristics Data Tables*. Energy Information Administration. http://www.eia.doe.gov/emeu/recs/recs2001/detail_tables.html.

US DOE, U.S. Department of Energy, 2000. *Annual Energy Outlook 2001 with Projections to 2020*. DOE/EIA-0383(2001). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 2001. *Annual Energy Outlook 2002 with Projections to 2020*. DOE/EIA-0383(2002). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 2003. *Annual Energy Outlook 2003 with Projections to 2025*. DOE/EIA-0383(2003). Energy Information Administration. December.

US DOE, U.S. Department of Energy, 2005. *Annual Energy Outlook 2005 with Projections to 2025*. DOE/EIA-0383(2005). Energy Information Administration. http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html. December.

Vorsatz, D., L. Shown, J. Koomey, M. Moezzi, A. Denver, and B. Atkinson, 1997. *Lighting Market Sourcebook for the U.S.* Lawrence Berkeley National Laboratory, LBNL-39102. December.

Webber, C., J. Roberson, R. Brown, C. Payne, B. Nordman, J. Koomey. 2001. *Field Surveys of Office Equipment Operating Patterns*. Lawrence Berkeley National Laboratory, LBNL-46930. September.

Webber, C., R. Brown, J. Koomey. 1999. "Savings Estimates for the ENERGY STAR® Voluntary Labeling Program." *Energy Policy* 28(2000)1137-1149.

Webber, C., R. Brown, A. Mahajan and J. Koomey. 2002. *2002 Status Report. Savings Estimates for the ENERGY STAR® Voluntary Labeling Program*. Lawrence Berkeley National Laboratory, LBNL-48496. February.

Wenzel, T., J. Koomey, G. Rosenquist, M. Sanchez and J. Hanford, 1997. *Energy Data Sourcebook for the U.S. Residential Sector*. Lawrence Berkeley National Laboratory, LBNL-40297. September.

Zabrowski, D. 2003. *Personal Communication.* Excel spreadsheet "HFHC Data Needs Assessment"

received via email 6/2/2003.