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2008 Status Report
Savings Estimates for the ENERGY STAR Voluntary Labeling Program

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ABSTRACT

ENERGY STAR is a voluntary labeling program designed to identify and promote energy-efficient products, buildings and practices. Operated jointly by the Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), ENERGY STAR includes 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 ENERGY STAR labeled products. We present estimates of energy, dollar, and carbon savings achieved by the program in the year 2007, what we expect in 2008, and provide savings forecasts for the periods 2008 to 2015 and 2008 to 2025. The forecast represents our best estimate of future ENERGY STAR savings. It is based on realistic ENERGY STAR unit sales for each of the products.

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Introduction

This paper presents current and projected savings for ENERGY STAR labeled products. 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. This report details the status of the model as implemented in the July 2007 spreadsheets.

The ENERGY STAR Labeling Program

ENERGY STAR is a voluntary labeling program operated jointly by EPA and DOE. These 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. The ENERGY STAR label does not constitute an endorsement of the product by EPA or DOE.

ENERGY STAR consists of four programmatic areas: products, buildings and industrial plants, home performance, and new homes. Complete descriptions of these program areas can be found at www.energystar.gov. This article focuses only on labeled products such as office equipment, appliances, and electronics. This article does not cover savings for buildings and industrial plants, new homes, or home performance. The methodologies for quantifying savings for these program segments are significantly different than the methodology outlined in this report (for EPA labeled products). We cannot address these additional methodologies and results with the necessary detail within the scope of this report. See Horowitz (2001, 2004, 2007) for a complete summary of program impacts for ENERGY STAR Buildings. See US EPA (2006) for a summary of program impacts for ENERGY STAR home performance, industrial plants, and new homes. ENERGY STAR product types are shown in **Table 1**. For each product type, we list the program start year and the dates for subsequent specification revisions.

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. The sheer size of the federal market pushed manufacturers to participate in the program. In 1995, facsimile machines, copiers, residential heating and air conditioning equipment, thermostats, insulation, and transformers were added to the program.

In 1996, DOE agreed to work jointly with EPA to promote energy efficient products using the ENERGY STAR brand. Because energy efficiency involves both environmental protection and energy policy, the DOE/EPA partnership was an important step in developing and expanding ENERGY STAR.

In 1996, EPA introduced labels for exit signs and residential boilers and DOE introduced ENERGY STAR dishwashers, refrigerators/freezers, and room air conditioners. In 1997, scanners, multi-function devices[1] and residential lighting fixtures were added to EPA's labeled products, and clothes washers and windows, doors and skylights were added to DOE's suite of products. In 1998 EPA introduced ENERGY STAR TVs and VCRs. In 1999, EPA began labeling ENERGY STAR consumer audio, DVD players, and roof products and DOE began labeling 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, and reach-in refrigerators and freezers in 2001. Telephony and ceiling fans were added to ENERGY STAR 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; external power supplies were added to the program in 2005; battery chargers were added to ENERGY STAR in 2006. Digital TV adapters were added to the program in 2007.

[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.

Table 1. Summary of ENERGY STAR products

	Specification Effective Dates	
	Original Specification	Specification Revision Dates
Product types included in analysis		
Audio and DVD	1999	2003
Battery charging systems	2006	
Boilers	1996	1998, 2002
CAC/ASHP	1995	2002, 2006, 2009
Ceiling fans	2002	2003, 2006
CFLs	1999	2001, 2004
Clothes washers	1997	2001, 2004, 2007
Commercial fryers	2003	
Commercial hot food holding cabinets	2003	
Commercial solid door refrigerators and freezers	2001	
Commercial steam cookers	2003	
Computers	1992	1995, 1999, 2000, 2007, 2009
Copiers	1995	1997, 1999, 2007, 2009
Dehumidifiers	2001	2006, 2007, 2008
Digital TV Adapters	2007	
Dishwashers	1996	2001, 2007
Exit signs	1996	1999, 2004
External power adapters	2005	
Facsimile	1995	1995, 2000, 2001, 2007, 2009
Furnaces	1995	2006
Geothermal HP	1995	2001
Light commercial HVAC	2002	2004
Monitors	1992	1995, 1998, 1999, 2005, 2006
Multifunction devices	1997	1999, 2007, 2009
Printers	1993	1995, 2000, 2001, 2007, 2009
Programmable thermostats	1995	2008
Refrigerators and freezers	1996	2001, 2003, 2004, 2008
Residential light fixtures	1997	2001, 2002, 2003, 2005
Roof products	1999	2005
Room air cleaners	2004	
Room air conditioners	1996	2000, 2003, 2005
Scanners	1997	2007, 2009
Set-top boxes	2001	*2005
Telephony	2002	2004, 2006
Televisions/VCRs	1998	2002, 2004, 2005
Traffic signals	2000	2003, *2007
Transformers	1995	*2007
Vending machines	2004	2006, 2007
Ventilation fans	2001	2003
Water coolers	2004	2004
Product types not included in analysis		
Buildings and industrial plants	1991	1995, 1999, 2000, 2001, 2002, 2004, 2006
Home performance	2000	2002
Insulation	1995	*2002
New homes	1995	1997, 2006
Windows, doors, and skylight	1997	2003, 2005

a) Specification revisions that resulted in program suspension are indicated with an "*"
b) CFLs, clothes washers, dishwashers, refrigerators and freezers, room air conditioners are DOE products and are included in the analysis
c) Buildings and Industrial Plants, New Homes, and Home Performance programs are administered by EPA but are not included due to a different program benefits methodology. We also do not include windows, doors, and skylights, which are administered by DOE
d) Audio includes CDs, mini-systems, audio separates, and home theater in a box.
e) CAC =central air conditioning, ASHP = air source heat pump, HP = heat pump, DVD = digital versatile disc, CFL = compact fluorescent lamp, HVAC = heating ventilation and air conditioning.
f) Insulation specification revised in 2002 and insulation incorporated into Home Performance with ENERGY STAR.

g) Changes to ENERGY STAR buildings and industrial plants reflect building types or manufacturing sectors added to the program.

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 (McWhinney 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.

Technical Approach

General Overview

We employ a bottom-up methodology for quantifying savings for ENERGY STAR labeled products. Each ENERGY STAR product type is characterized by product-specific inputs that result in a product savings estimate. ENERGY STAR program impacts are the sum of the impacts for each individual ENERGY STAR product type. The bottom-up model allows us to separately evaluate the implementation process for each product type and quantify ENERGY STAR's impact within each market. Since ENERGY STAR specifications are often a key component of many regional energy efficiency efforts, the bottom-up model allows ENERGY STAR to distribute critical product data to facilitate the development of localized programs.

We implement the bottom-up model with awareness that uncertainty for each product type contributes to uncertainty in total ENERGY STAR impacts. This means that many small inaccuracies are additive overall and any one inaccuracy for a product type with large energy savings can significantly affect the overall results. To address uncertainty, we run sensitivity tests on key variables including ENERGY STAR unit sales, energy prices and carbon emission factors. While all aspects of the input data are regularly updated, we focus additional resources on the office equipment product category due to the large energy savings potential, as well as consumer electronics where usage patterns are more uncertain and new field data are becoming increasingly available (Porter et al. 2006; Nordman and McMahon, 2004; Roth and McKenny, 2007).

In cases where other organizations have collected market and engineering data pertaining to ENERGY STAR product types, we integrate the data as applicable. We also work with the US DOE's Energy Information Administration (US EIA) to harmonize inputs with the National Energy Modeling System (NEMS), which is used to generate national energy forecasts at both the sector and end-use level. In particular, we share data on product power consumption, usage, total energy, and ENERGY STAR market shares for product types that are individually treated in both models, including residential heating and cooling equipment, televisions and set-top boxes, home computers, commercial office equipment, and lighting.

Methodology

We begin the analysis by segmenting sales of each product type into non-ENERGY STAR and ENERGY STAR units. Manufacturer partners report ENERGY STAR unit sales to the agencies each calendar year[2]. Non-ENERGY STAR unit sales are estimated as the difference between total US unit sales obtained from industry reports and ENERGY STAR unit sales.

Sales of ENERGY STAR 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 estimated sales of ENERGY STAR units not due to the program are a forecast based on our market share analysis of models that met the ENERGY STAR specification prior to implementation of the program for each product type. This analysis is based on energy consumption test results for individual product models that are submitted by manufacturers to EPA and DOE during the ENERGY STAR product development phase. We analyze the test data according to the applicable ENERGY STAR performance metric and calculate the business as usual (BAU) penetration rate as the total number of models in the dataset divided by the number of models that meet ENERGY STAR requirements. ENERGY STAR savings include only the savings for ENERGY STAR units directly attributable to the program. **Figure 1** illustrates the sales segmentation.

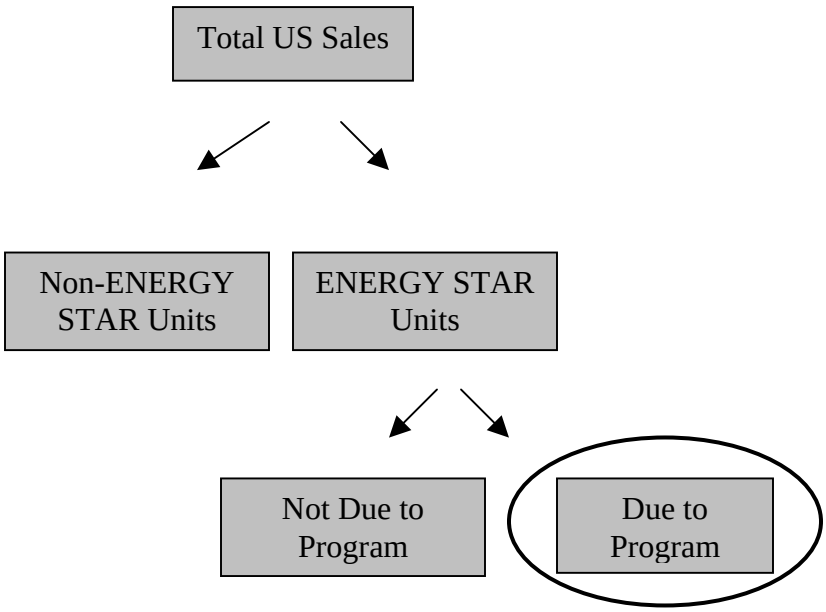
We next estimate unit energy consumptions (UEC) for both non-ENERGY STAR and ENERGY STAR units. Our BAU forecast is comprised of standard efficiency unit sales (representing units that do not meet the ENERGY STAR requirement) and high efficiency non-ENERGY STAR unit sales (representing units that meet or exceed ENERGY STAR requirement but are not attributable to the program). The BAU is characterized both by a UEC and a market share for each segment. BAU efficiency improvements can be modeled directly as a change in the UEC of either of these segments. We can also model BAU efficiency improvements as a shift over time from standard efficiency units to high efficiency non-ENERGY STAR units.

The ENERGY STAR UECs for office equipment and consumer electronics are estimated to be the average UEC of ENERGY STAR qualified products sold in the market in a given year based on manufacturer energy consumption test data for qualified products and independent field testing. For all other product types, the ENERGY STAR UEC is calculated based on the minimum program requirements.

Figure 1. Market segmentation of ENERGY STAR products [products in circle accrue savings

[2]ENERGY STAR unit sales data have been collected from manufacturer partners as part of the ENERGY STAR Program requirements for calendar years 2002-2006 (ICF 2003, 2004, 2006a, 2006b, 2007). ENERGY STAR sales data for earlier years and subsequent forecast years are based from industry and market data.

for the program]



The unit energy savings (UES) for each product type is the difference between the BAU UEC and the ENERGY STAR UEC in a given year. The UES for most product types changes over time due to specification revisions, usage pattern changes, and changes to the BAU efficiency. To account for this variation, we calculate the energy savings for each year's ENERGY STAR sales and then use a retirement function to add up the savings for all the equipment vintages in place in a given year. We assume that ENERGY STAR units remain in service and accrue savings for a period equal to the average product lifetime.

Aggregate energy bill savings are estimated using year-by-year energy prices from DOE shown in **Table 2**. Energy bill savings are discounted at a 4 percent real discount rate. Carbon emissions reductions are calculated from energy savings using year-by-year carbon emissions factors. For electricity, we use EPA's national average marginal carbon factor, which is derived from models used as part of the US government's reporting requirements under the U.N. Framework Convention on Climate Change and historical emissions data from US EPA's Emissions and Generation Resource Integrated Database (eGRID). Forecasted marginal carbon factors are derived from energy efficiency scenario runs of the integrated utility dispatch model (IPM®) (US EPA 2007). Carbon factors 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. **Equation 1** summarizes our calculation methodology for estimating ENERGY STAR savings for a single product type in year t:

Equation 1.

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

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

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

where;

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

UES_n = The unit energy savings of ENERGY STAR units sold in year *n* (in kWh or GJ)

L = product lifetime

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

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

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

Table 2. Best estimate energy prices and carbon factors by year (2006 dollars)[a]

Year	Cmcl. Elec Price $/kWh	Res. Electricity Price $/kWh	Cmcl. Gas Price $/MBtu	Res. Gas Price $/MBtu	Oil Price $/MBtu	Price Sources, US DOE [c]	Carbon Emissions Factor for Electricity kg C/kWh	Electric Heat Rate btukWh	Electric Heat Rate Source, US DOE [c]
1993	0.102	0.109	6.57	7.80	8.60	1996a	0.203	11,019	1996a
1994	0.101	0.109	6.88	8.05	8.18	1996b	0.203	10,948	1996b
1995	0.094	0.105	6.27	7.50	7.90	1997b	0.203	10,970	1997
1996	0.093	0.103	6.51	7.64	8.73	1998b	0.203	10,866	1998
1997	0.092	0.101	6.87	8.21	8.59	1999a	0.203	10,978	1999
1998	0.090	0.098	6.49	7.99	7.41	2000	0.203	10,891	2000
1999	0.085	0.096	6.20	7.72	7.41	2001	0.203	10,784	2001
2000	0.085	0.095	7.52	8.78	10.96	2003	0.203	11,181	2003
2001	0.089	0.097	9.40	10.61	10.12	2003	0.203	11,030	2003
2002	0.087	0.094	7.22	8.53	9.13	2005	0.203	11,008	2005
2003	0.086	0.095	8.76	10.00	10.44	2006a	0.203	10,997	2006
2004	0.086	0.095	9.68	11.03	13.27	2007	0.203	10,952	2007
2005	0.089	0.097	11.53	12.79	15.16	2007	0.203	10,851	2007
2010	0.086	0.095	9.61	11.30	15.31	2007	0.180	10,757	2007
2015	0.082	0.091	8.72	10.54	12.96	2007	0.180	10,601	2007

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 2006 dollars using implicit GDP deflators from the US Department of Commerce (2007a).
c) US DOE refers to US DOE Annual Energy Outlook (AEO) published by the Energy Information Administration. The publication year for the applicable AEO is listed in the table. Full citations are found in the references section.
d) Carbon emission factors (1993-2005) are from the Cadmus Group (1998), carbon emission factors 2010 and 2015 are from US EPA (2007).
e) Cmcl = commercial; Res = residential

ENERGY STAR has implemented over fifty specification revisions for product types included in this analysis. With each specification revision, ENERGY STAR unit sales typically decrease due to the tightened requirements until manufacturers institute product design changes to meet the revised requirements. The initial decline in ENERGY STAR unit sales results in a cohort of units that met the ENERGY STAR criteria under the previous specification but do not meet the revised ENERGY STAR requirements. We calculate the number of these "former" ENERGY STAR units as the difference between ENERGY STAR unit sales in the year preceding a specification change and the actual ENERGY STAR unit sales in subsequent years when the new specification is effective. **Table 3** illustrates a hypothetical application of this methodology. ENERGY STAR realizes savings

for the cohort of products until it is completely phased out by products meeting the revised ENERGY STAR criteria. This cohort realizes savings at a UES equivalent to the previous specification.

Table 3. ENERGY STAR market transformation methodology

	2002	2003	2004	2005	2006	2007	2008
ENERGY STAR Sales - Tier 1	300	440	600	340	180	0	0
ENERGY STAR Sales - Tier 2				260	420	600	800
Total ENERGY STAR Sales	300	440	600	600	600	600	800
UES Tier 1 (kWh/yr)	50	50	50	50	50	50	50
UES Tier 2 (kWh/yr)				80	80	80	80
Yearly Energy Saved, 1 Years Sales (kWh/yr)	15,000	22,000	30,000	37,800	42,600	48,000	64,000
Total Yearly Energy Saved (kWh/yr)	15,000	37,000	67,000	104,800	147,400	195,400	259,400

a) We refer to specification versions as ENERGY STAR Tiers. Tier 1 corresponds to the original specification and Tier 2 corresponds to the revised specification.
b) In this example, there were 600 ENERGY STAR units sold in 2004 (the final year of the Tier I specification). In 2005, there were only 340 ENERGY STAR units sold that met the revised Tier II specification. We calculate that 260 units (600-340) were sold in 2005 that continued to meet Tier I levels. We assume that the 260 units accrue savings equivalent to 50 kWh/year (the UES for Tier 1). This methodology is applied until 2007 when ENERGY STAR units shipped under Tier II is equivalent to ENERGY STAR units shipped under Tier I (in 2004).

We refer to this component of our methodology as a market transformation effect. This methodology assumes that units that met previous ENERGY STAR levels continue to be in compliance with previous levels despite no longer being labeled ENERGY STAR (i.e., manufacturers do not change the design of these previously qualified products to be less efficient). To date, energy consumption test data for non-qualified models submitted by manufacturers to EPA and DOE during a subsequent specification revision support this assumption. In reference to our general program savings equation (Equation 1), when applicable the market transformation effect means that in any given year n, the number of units sold for a single product type that will accrue program savings (X) is equal to:

$$X_n = \sum_{r=1}^{t_n} X_r$$

and the average UES in any given year n, is equal to:

$$UES_n = \sum_{r=1}^{t_n} X_r * UES_r \div X_n$$

where t is the current Tier of the ENERGY STAR specification in year n.

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.

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).

Product Category Overview

Our analysis groups ENERGY STAR product types into the following categories: office equipment, consumer electronics, heating/ventilation/air conditioning (HVAC), lighting, residential appliances, commercial appliances, and other. We summarize our methodology for each product category below.

Office Equipment

Office equipment includes computers, copiers, facsimile machines, monitors, multifunction devices (MFD), printers, and scanners. ENERGY STAR computers and monitors incorporate a sleep mode in which a product enters a low power mode after a period of inactivity. ENERGY STAR computers and monitors must meet maximum power requirements in sleep mode, standby mode and on or idle mode. ENERGY STAR imaging equipment must meet either a maximum total energy consumption (TEC) requirement expressed as kWh/week or maximum operational mode power requirements (sleep and standby) depending on a product's marking technology and size format[3].

We model residential and office settings separately due to different usage patterns. Commercial operating patterns are derived from equipment audits at various locations that provide time spent in each operating mode, nighttime turn-off rates, and power management success rates (Piette et al. 1995; Nordman et al. 1998; Webber et al. 2001; Roberson et al. 2004). Operating patterns for residential computers are derived from hours-of-use monitoring for a large sample of residential computer users (Media Metrix 2001). Operating patterns for residential monitors, MFDs, printers, and scanners are from field measurement data for a sample of California homes (Porter et al. 2006).

We calculate the BAU and ENERGY STAR UEC by multiplying the time spent in each power mode by the power consumption in each mode, then summing over all power modes. Low power savings are only realized for ENERGY STAR products that are successfully power managing (Roberson et al. 2004).

Consumer Electronics

Consumer electronics include audio equipment and DVDs, battery charging systems, external power supplies, set-top boxes, telephony, TVs, and VCRs. ENERGY STAR for audio/DVD, set-top boxes,

3 US EPA defines the on/active mode for monitors as the state in which the unit is connected to the power source and producing an image. US EPA defines the idle mode for computers as the state in which the operating system and other software have completed loading, the machine is not asleep and activity is limited to those basic applications that the system starts by default. Standby mode refers to a product's lowest power state.

telephony, and TV/VCR products focuses on reducing the power consumption of a device in its standby mode. Savings are assumed to accrue in both active and standby mode since efficiency improvements to achieve standby savings (like remote control and memory) reduce power whether the device is in on or standby mode. We estimate BAU and ENERGY STAR UECs by multiplying the time spent in each power mode by the power consumption in each mode, then summing over all power modes. Power consumption and usage patterns are derived from Floyd and Webber (1998); Nordman and McMahon (2004); Horowitz et al. (2005); Roth and McKenney (2007); and Porter et al. (2006).

ENERGY STAR external power adapters must meet efficiency criteria in both active and no-load modes. ENERGY STAR battery charging system must meet a non-active energy ratio requirement, which is the non-active energy of a battery charging system divided by the energy deliverable by the battery under a known discharge condition. Calwell (2003) provides BAU and ENERGY STAR UECs for external power adapters. BAU and ENERGY STAR UECs for battery charging systems are derived from Webber et al. (2006).

Residential HVAC

The HVAC program covers air-source heat pumps (ASHP), boilers (gas and oil), central air conditioners (CAC), furnaces (gas and oil), geothermal heat pumps, and programmable thermostats. For heating and cooling equipment, ENERGY STAR eligibility is based solely on efficiency, measured by standard test procedures such as the average fuel utilization efficiency (AFUE) or the seasonal energy efficiency ratio (SEER). Programmable thermostats qualify for the ENERGY STAR label by automating the set back of thermostats at times determined by the building occupant. Savings for HVAC products with an applicable minimum federal efficiency standard (ASHP, CAC, furnaces, and boilers) are calculated by improving the unit efficiency from the federal minimum level to the ENERGY STAR level.

We derive the baseline UECs using household level data from the 1993 Residential Energy Consumption survey (US DOE 1995a) 4. We model the baseline UEC using equipment efficiency equal to the federal minimum efficiency standard where applicable. The UECs for ENERGY STAR equipment are similarly modeled but assume ENERGY STAR equipment efficiency levels. Regional UECs are then aggregated to a national average. Our savings estimates do not include improving the quality of equipment installation, appropriately sizing equipment, and/or air sealing within the home. These improvements are a part of the Home Performance with ENERGY STAR program and are accounted for separately by US EPA.

To avoid double counting savings, we analyze programmable thermostats in conjunction with HVAC equipment. For simplicity, we assume that HVAC equipment is chosen first and therefore ENERGY STAR HVAC receives its full measure of savings. Programmable thermostat savings are calculated from a forecast of HVAC energy use that takes into account the increasing market penetration of ENERGY STAR HVAC and any changes to the federal minimum efficiency standard.

4 The Residential Energy Consumption Survey (RECS) is a national multistage probability sample survey that the US EIA conducts every three years. RECS gathers data primarily by means of personal interviews with householders and a mail survey of those household's energy suppliers. The 1993 RECS sample included more than seven thousand households.

While ENERGY STAR New Homes are not covered in this analysis, the effects of ENERGY STAR New Homes are taken into account when estimating savings for ENERGY STAR HVAC equipment. Since ENERGY STAR HVAC equipment is typically part of an ENERGY STAR New Home and counted toward its savings, sales of ENERGY STAR HVAC equipment are first allocated to the New Homes program and the remaining ENERGY STAR equipment sales are accounted for in this analysis.

Lighting

Lighting includes CFLs, exit signs, residential fixtures (indoor and outdoor), and traffic signals. Savings for exit signs are calculated from a BAU UEC that is a market share weighted average across incandescent, CFL, and non-ENERGY STAR LED energy consumption (Suozzo and Nadel, 1998). ENERGY STAR assumes an average power of five Watts (W) and an annual operating time of 8,760 hours.

Savings for CFLs assume baseline incandescent lamp wattage of 65 W and a CFL replacement wattage of 16 W (KEMA 2005). We assume a three hour per day duty cycle (Vine et al. 2006).

Savings for residential indoor fixtures are based on KEMA (2005), which reports power savings from incandescent/CFL lamp replacement for a sample of monitored fixtures in California homes. We assume replacement of a 65 W incandescent lamp with a 16 W compact fluorescent lamp and a daily operating time of three hours (KEMA, 2005; Vine et al. 2006). Since ENERGY STAR fixtures require pin-based lamps, we assume savings accrue over the lifetime of the fixture (20 years). Savings for outdoor fixtures assume replacing a 109 W incandescent lamp with a 36 W fluorescent lamp (Vorsatz et al. 1997). We assume a daily operating time of five hours (Vine et al. 2006).

Savings for ENERGY STAR traffic signals are based on stock replacement rather than ENERGY STAR unit sales since retrofits are the primary market driver. Red and green traffic signals are modeled separately due to differences in cost effectiveness. Yellow (amber) signals are not analyzed because of their very short operating times. Suozzo (1998) and Caltrans (1999) provide UECs for each signal type analyzed.

Residential Appliances

Residential appliances include clothes washers, dishwashers, room air conditioners, refrigerators, ceiling fans, dehumidifiers, room air cleaners, and ventilation fans.

Refrigerators, freezers, clothes washers, dishwashers, and room air conditioners (RACs) are 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 in 2007.

To obtain energy use for these 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.[5] 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 (1999b). Unit energy consumption and savings for clothes washers and dishwashers included machine energy and weighted-average water heating energy for all fuels, expressed as primary energy.

Ceiling fans include fan only units, fans with lights, and light kit only. We separately model fans located in the southern region versus fans located elsewhere in the US due to the different operating times as summarized below (52% of installed stock in the south and 48% of installed stock elsewhere (US DOE 2004)). Ceiling fan UEC data are taken from Calwell and Horowitz (2001) and are based on a BAU 34 W fan with 180 W of lighting. The ENERGY STAR case assumes a 31 W fan with 60 W of lighting. We assume a daily operating time for the fan of 9 hours in the south and three hours elsewhere. We assume the lighting is operated three hours per day.

ENERGY STAR dehumidifiers must meet energy performance requirements specified in terms of kWh of energy used per liter of water removed from the air. The BAU UEC is derived from energy consumption test data collected by the Canadian Standards Association (CSA) in conjunction with Natural Resources Canada (McWhinney et al. 2005). The ENERGY STAR UEC represents the minimum efficiency requirements for an average equipment capacity. We assume annual operating

[5] 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.

time of 1,620 hours (Cadmus Group 1999).

ENERGY STAR room air cleaners must meet energy performance requirements that are specified in terms of volume of air cleaned per minute (defined as clean air delivery rate or CADR) per W. We analyze the following CADR bins (m^3/min): 1.4-2.8, 2.8-4.2, 4.2-5.7, 5.7-7.1, greater than 7.1. BAU wattage is derived from manufacturer power consumption test data for individual product models. ENERGY STAR wattages are extrapolated by dividing the average CADR per CADR bin by the ENERGY STAR efficiency criteria (2 CADR per watt). Our savings assume that room air cleaners are operated continuously.

ENERGY STAR ventilation fans include rangehood fans and bathroom and utility room fans. We assume a daily operating time of one hour. The BAU UECs are from Cadmus (2000a) and ENERGY STAR UECs reflect the minimum program requirements.

Commercial Appliances

Commercial appliances include bottled water coolers, commercial fryers, commercial hot food holding cabinets, commercial refrigerators and freezers, commercial steamers, and refrigerated beverage vending machines.

ENERGY STAR bottled water coolers include hot and cold units and cold only units. ENERGY STAR focuses on reducing a unit's standby energy consumption and specification requirements are expressed as a maximum standby energy consumption requirement per day. Our BAU and ENERGY STAR UECs are taken from engineering testing conducted by the Cadmus Group, Inc (2000b).

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. UECs for commercial cooking equipment are obtained from the Food Service Technology Center (FSTC 2007).

Data for commercial refrigerators and freezers are taken from FSTC (2007). Although the program covers refrigerators, freezers, and ice cream freezers, we only model solid door refrigerators and freezers due to insufficient data regarding ice cream freezers. Efficiencies are expressed as kWh per day.

Refrigerated beverage vending machines include both newly manufactured and refurbished units. Units are modeled by the following can capacities: less than 500, 500-600, 600-700, and greater than 800. Baseline UECs are taken from product energy consumption test data gathered by Horowitz (2002). ENERGY STAR UECs are calculated as the required percentage reduction in energy consumption from the current Canadian minimum efficiency standard. UECs also include a standby consumption and an enabling rate for ENERGY STAR units that enter a low power mode after a period of inactivity.

Other Products

Other ENERGY STAR products include transformers (commercial/industrial and utility) and roofing (residential and commercial). Commercial/industrial transformers assume a BAU UEC for a unit with a 45 kVA rating, a load factor of 35% and a 97.3% efficiency (Suozzo and Nadel, 1998). ENERGY STAR requires an efficiency of 98% based on the specification average of single phase and three phase transformers. Utility transformers assume a BAU UEC for a unit with a 25 kVA rating, a load factor of 30%, and an efficiency of 98.5%. ENERGY STAR requires an efficiency of 98.65% (ORNL 1996).

ENERGY STAR roofing has a higher reflectivity than standard roofing in order to reduce heat gains into the building and the resulting cooling load. UES for ENERGY STAR roofing are based on a US average derived from a study of 11 metropolitan areas including: Atlanta, Dallas, Chicago, Houston, Los Angeles, Miami, New Orleans, New York, Philadelphia, Phoenix, and Washington DC. Savings are expressed in primary energy and include cooling savings and increased energy use during the heating season (Konopacki et al. 1997).

Changes to the Model in the 2008 Status Report

Universal Inputs

We updated energy prices and electric heat rates to US DOE 2007. We also added a commercial natural gas price to the spreadsheets since the universal gas rate previously represented the rate for the residential sector. We also updated the GDP deflator to the Bureau of Economic Analysis 2007 and dollars are now expressed as 2006 dollars (US DOC 2007a). We also updated our marginal carbon factors (US EPA 2007).

The following shows marginal electric carbon factors (MMTC/billion kWh) used in this analysis.

	2006	2007	2008	2010	2015	2020	2025
Current	0.190	0.180	0.180	0.180	0.180	0.180	0.180
12/2006	0.196	0.189	0.182	0.168	0.141	0.135	0.135

Shipments Revisions

We updated 2006 ENERGY STAR sales as reported in ICF (2007). Imaging equipment ENERGY STAR sales also changed since we obtained new US shipments and our methodology for estimating ENERGY STAR sales is still a market share approach.

To most accurately estimate ENERGY STAR market penetrations, we updated total US sales for VCRs, TV/VCR combination units, DVDs, audio mini-systems, geothermal and air source heat pumps, CAC, furnaces, boilers, scanners, printers, copiers, MFDs, clothes washers, dishwashers, room air conditioners, refrigerators, dehumidifiers, room air cleaners, and ceiling fans.

Table 4 summarizes ENERGY STAR market shares as reported for calendar year 2006. ENERGY STAR products with at least a 50% market share are imaging equipment, computers, televisions,

geothermal heat pumps, oil boilers, dishwashers, dehumidifiers, and commercial and industrial transformers.

Office Equipment

We incorporated power and usage data obtained from Roth and McKenney (2007) and Porter et al. (2006). Updates included adjusting monitor usage patterns by type, adjusting usage times and baseline power data for video games, and adjusting baseline power estimates for scanners, inkjets, and inkjet MFDs.

Consumer Electronics

We updated usage patterns by technology type for televisions; we updated VCRs to include VCR/DVDs; we updated VCR usage patterns based on Roth and McKenney (2007); we updated DVDs to include record and play only units. We also updated usage patterns for DVD, mini-systems, home theater, audio separates and CDs. We also adjusted baseline efficiency improvements to account for business-as-usual efficiency improvements by product category (Roth and McKenney 2007).

We included digital TV adapters.

HVAC

We included the relaxed oil furnace specification beginning in 2007.

Lighting

We discontinued ENERGY STAR traffic signals beginning in 2007.

Our previous methodology for calculating savings for indoor fixtures was based on the assumption that 75% of ENERGY STAR sales went to high usage fixtures with a run time of over 6 hours per day. The collection of CFL metering data shows that while there is a modest difference in duty cycles of CFL lamps and incandescent lamps, CFLs are only used an average of three hours per day. We now have only one usage bin (3 hours per day) for indoor fixtures (Vine et al. 2006). We used a household weighted average for CFL replacements that shows an incandescent wattage (65 W) and CFL replacement 16 W (KEMA 2005).

We also modified our outdoor fixtures assumptions. Previously, our usage assumption assumed a duty cycle of over 7 hours per day. Based on a CFL metering study report, we have reduced our usage assumption to a duty cycle of 5 hours per day and a base line incandescent fixture-wattage of 109 W (Vine et al. 2006; Vorsatz 1997). We were also assuming both a 2/3 reduction in power for ENERGY STAR units as well as the reduction in run time from 7 hours per day to only 1 hour per day. Since ENERGY STAR outdoor fixtures can meet *either* a reduced run time specification or an improved lighting efficiency specification, we are now only applying one method to achieving our savings. We've chosen to apply a 2/3 reduction in power to ENERGY STAR outdoor fixtures.

Previously, our CFL model was based on a stock accounting framework where incandescent lamps were retired and replaced by either a CFL or incandescent lamp. Since we were able to obtain CFL and incandescent sales data from 1998 to 2006, we determined that the stock replacement model was obsolete and inconsistent with our current shipment-based approach for other products. As such, the CFL model is now based on CFL sales (US DOC 2007b).

Residential Appliances

No significant changes.

Commercial Appliances

We updated our UES and incremental costs for hot food holding cabinets, fryers, and steamers to FSTC 2007.

Other Products

We discontinued transformers beginning in 2007.

Table 4. ENERGY STAR Market Shares for 2006

Equipment Type	Total Energy Star Shipments	Source Code	Total US Shipments	Source Code	Energy Star Market Share
	1000s	See notes	1000s	See notes	%
Office Equipment					
-Office Copiers	1,222	a	1,358	f	90
-Office Facsimile	304	a	307	f	99
-Office Printers	6,781	a	6,821	f	99
-Office Scanners	2,627	a	3,091	f	85
-Office Multi-function	15,905	a	16,277	f	98
-Office CRTs	0	b	1,605	g	0
-Office LCDs	8,334	b	22,451	g	37
-Office PCs	38,646	a	39,562	h	98
-Residential Copiers	0	a	0	f	NA
-Residential Facsimile	890	a	900	f	99
-Residential Printers	7,108	a	7,118	f	100
-Residential Scanners	4,513	a	5,309	f	85
-Residential Multi-function	2,396	a	2,403	f	100
-Residential CRTs	0	b	1,064	g	0
-Residential LCDs	5,525	b	14,882	g	37
-Residential PCs	25,457	a	34,652	h	73
Consumer Electronics					
- TVs	17,363	b	27,112	i	64
-VCRs	201	b	10,877	j	2
-TV/VCR/DVD	121	b	6,778	j	2
-DVD Player	729	b	8,734	k	8
-Mini-Systems	1,706	b	5,917	k	29
-Home Theater	801	b	3,062	l	26
-Audio Separates	336	b	2,066	j	16
-Compact Disc Player	0	b	598	k	0
-Answering Machines	0	b	4,343	m	0
-Cordless Phones	360	b	23,706	m	2
-DSS Cordless Phones	1,901	b	9,954	m	19
-Combination Phones	212	b	7,502	m	3
-DSS Combination Phones	4,290	b	14,785	m	29
-Additional Handsets	1,111	b	3,364	m	33
-Set-top Box	0	b	42,152	c	0
-External Power Supplies	148,388	b	472,696	c	31
-Battery charger	72	b	40,847	c	0
Heating and Cooling					
-Air Source Heat Pump	482	b	2,210	k	22
-Geothermal Heat Pump	51	b	59	n	86
-Central Air Conditioner	1,019	b	5,600	k	18
-Gas Furnace	1,167	b	3,314	k	35
-Oil Furnace	6	b	100	k	6
-Gas Boiler	68	b	200	k	34
-Oil Boiler	109	b	162	k	67
-Unitary HVAC	213	b	703	c	30
-Thermostats	2,318	c	6,467	o	36
Residential and Commercial Lighting					
- Indoor Fixtures	8,135	b	220,242	d	4
- Outdoor Fixtures	3,227	b	28,335	d	11
- Exit Signs	1,426	b	3,971	p	36
- CFLs	145,808	d	1,302,068	d	11
- Traffic Signal	605	b	8,840	q	7
Residential Appliances					
-Clothes Washers	3,603	e	9,500	k	38
-Dishwashers	6,822	e	7,394	k	92
-Refrigerators	3,678	e	11,802	k	31
-RACs	3,253	e	9,000	k	36
-Dehumidifiers	1,203	b	2,011	k	60
-Air Cleaners	287	b	2,037	r	14
-Exhaust Fans	773	b	6,285	k	12
-Ceiling Fans Only	1,845	b	7,819	k	24

-Ceiling Fan with Light Kit	117	b	10,132	k	1
-Light Kit for Ceiling Fan	12	b	2,185	k	1
Commercial Appliances					
-Vending Machines	77	b	246	s	31
-Hot Food Holding Cabinet	17	b	112	t	15
-Steamers	3	b	41	t	8
-Fryers	9	b	83	t	11
-Commercial Refrigeration	83	b	238	u	35
-Water Coolers	499	b	1,138	v	44
Other					
- Utility Transformers	0	b	1,380	w	0
- C&I Transformers	173	b	267	w	65
- Residential Roofing (1000 sq ft)	0	b	4	x	10
- Commercial Roofing (1000 sq ft)	4	b	16	x	26

Notes to Table 11:
* Columns values may not add up to total due to rounding. Unitary HVAC expressed as million sq. ft.
a) Gartner (2001)
b) ICF (2007)
c) LBNL estimate
d) US DOC (2007b)
e) D&R Energy Star sales data 2007
f) IDC (2006a,b, c): Worldwide Printer Forecast and Analysis 2006-2011; Worldwide Multifunction Peripherals Forecast and Analysis 2006-2011; Worldwide Copier Forecast and Analysis 2006-2011
g) IDC (2006d) Worldwide PC Forecast 2006-2010
h) IDC (2003) Worldwide PC Monitor Forecast and Analysis 2002-2007
i) iSuppli (2005)
j) CEA ENERGY STAR and US Sales Report (2006a)
k) Appliance Magazine (2006), 55th Appliance Industry Forecast
l) CEA US Consumer Electronics Forecast 2002-2007 July (2006b)
m) CEA 2005. Domestic Sales of Corded and Cordless Telephones and Answering Machines. Report 530
n) Based off of Survey of Geothermal HP Manufacturers (US DOE 2006b)
o) Based off of RECS 2001 programmable thermostat stock (US DOE 2004)
p) Based off of exit sign stock as reported in Conway, K., P. Boyce, Andrew Bierman, Josepgh Ceterski and Burr Ruttledge. 1996. Exit Signs. Prepared for BPA, NYSERDA and EPA. May.
q) Strategies Unlimited 2004
r) ICF Draft Air Cleaner Industry and Market Research Analysis. 2001.
s) Vending Market and Industry reports. ICF 2002.
t) NAFEM (the North American Association of Food Equipment Manufacturers), "Size and Shape of the Industry Study: Primary Cooking Equipment."
u) The Cadmus Group, "Preliminary Market Background Report for Commercial Reach-In Refrigerators and Freezers." March 1, 2001
v) Cadmus 1999. Preliminary Market Background Report for Water Coolers. September.
w) Based off of ORNL. 1996. Determination Analysis of Energy Conservation Standards for Distribution Transformers. ORNL-6847.
x) Based off of 2002 sales from The National Roof Contractors Association

Results

Table 5 shows annual unit energy and energy bill savings, average product lifetime, and lifetime energy and energy bill savings for each product. These estimates form the basis of the calculation of savings to date and the forecasts of future savings. ENERGY STAR geothermal heat pumps have the highest absolute per unit savings; followed by commercial steamers, hot food holding cabinets, and commercial fryers. Ranked by percentage savings, however, traffic signals have the highest percent savings followed by CFLs, exhaust fans, fixtures, and hot food holding cabinets. Other products with at least 50 percent savings are VCRs, telephony, and commercial steamers.

Table 5. Annual and lifetime savings per unit for ENERGY STAR devices sold in 2008

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	2006$/yr	Years	Million Btu	2006$
Office Equipment						
- Office PC	20	0.22	1.82	4	0.88	7
- Laptop	16	0.04	0.33	4	0.16	1
- Workstation	27	3.66	30.13	4	14.61	117
- Office CRT Monitor	47	0.35	2.89	4	1.40	11
- Office LCD Monitor	44	0.23	1.93	4	0.94	8
- Home PC	19	0.26	2.28	4	1.02	9
- Home Laptop	16	0.05	0.44	4	0.20	2
- Video Game	6	0.03	0.24	7	0.19	2
- Home CRT Monitor	44	0.23	2.08	5	1.16	10
- Home LCD Monitor	41	0.29	2.62	5	1.46	13
- Fax	39	1.10	9.03	4	4.38	35
- Copier (1)	20	1.74	14.36	6	10.41	83
-Multifunction Device	22	2.63	21.69	6	15.73	125
- Scanner	10	0.02	0.16	4	0.08	1
- Printer	13	0.50	4.14	5	2.51	20
Consumer Electronics						
- TVs	21	0.84	7.45	9	7.45	65
-VCRs	55	0.26	2.34	7	1.82	16
-TV/VCR/DVD	38	0.73	6.52	7	5.08	44
-DVD Player	39	0.19	1.68	7	1.31	11
-Audio Equipment	34	0.26	2.34	8	1.82	16
-Telephony	54	0.18	1.63	7	1.27	11
-Set-top Box	23	0.38	3.41	7	2.66	23
-External Power Supplies	24	0.12	1.09	5	0.61	5
-Battery Charging Systems	32	0.07	0.58	7	0.46	4
Heating and Cooling						
- Furnace (Gas or Oil)	13	12.82	146.98	18	229.98	2,428
- Central Air Conditioner	14	4.05	36.12	14	55.94	489
- Air-Source Heat Pump	9	10.28	91.64	12	121.91	1,064
- Geothermal Heat Pump	30	56.20	501.18	15	830.88	7,267
- Boiler (Gas or Oil)	6	6.06	73.22	20	121.18	1,336
- Programmable Thermostat	15	14.51	162.47	15	216.37	2,224
- Unitary HVAC	5	NA	NA	15	NA	4
Residential and Commercial Lighting						
- Fixtures	73	0.99	8.83	20	19.40	171
- CFLs	75	0.58	5.14	9	5.14	45
- Exit Sign	34	0.24	2.01	10	2.41	19
- Traffic Signal	89	4.78	39.37	10	47.36	373
Residential Appliances						
- Room Air Conditioners	10	0.68	6.05	13	8.71	76
- Dehumidifiers	19	2.24	19.98	12	26.59	232
- Air Cleaners	48	3.93	35.07	9	35.09	306
- Exhaust Fans	75	0.63	5.58	10	6.19	54
- Ceiling Fans	47	1.01	9.02	10	10.02	87
- Dishwashers	29	1.17	11.45	13	15.03	141
- Refrigerators	15	0.85	7.59	19	15.86	139
- Clothes Washers	20	1.32	12.23	14	18.22	164
Commercial Appliances						
- Water Coolers	45	2.54	20.92	10	25.17	198
- Commercial Refrigeration	37	18.76	154.49	10	185.85	1,464
- Hot Food Holding Cabinets	65	50.97	419.68	12	604.71	4,772
- Fryers	20	29.50	305.21	12	353.85	3,222
- Steamers	50	56.19	479.26	10	560.2	4,491
- Vending Machines	42	16.50	135.88	14	227.96	1,803
Other						
- Utility Transformers	0%	0.00	0.00	32	0.00	0
- C&I Transformers	0%	0.00	0.00	32	0.00	0
- Residential Roofing (1000 sq ft)	n/a	1.00	7.55	20	19.46	152
- Commercial Roofing (1000 sq ft)	n/a	2.02	15.61	7	14.02	106

Notes next page

Notes to Table 5:

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 1993 RECS consumption data. All savings are for specifications that apply in 2008.

b) Yearly U.S. average energy prices and electric heat rates are given in Table 2. Lifetime energy bill savings are calculated using the stream of future energy prices.

c) 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).

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

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

f) 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.

g) Clothes washer savings are from US DOE (1998a).

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

i) Office equipment savings are calculated assuming both Energy Star and non-Energy Star units have power management features enabled.

j) Unitary HVAC given as NA because savings are not calculated as per unit (we calculate per square foot savings instead)

Table 6 shows the annual energy, dollar, and carbon savings for 2007 as well as the peak demand reduction due to the program. Annual savings in 2007 were 1.4 quadrillion Btu, 22.4 MMTC, and $12 billion dollars (undiscounted). These figures represent an increase in primary savings of 17.7 trillion Btu over the 2007 forecast in the last status report. Although primary energy savings increased overall, carbon savings for 2007 decreased over the 2007 estimates in the last status report due to the lowering of the electricity marginal carbon factor in this update.

There were decreased savings in many product areas including the following: reduced savings for imaging equipment due to lower overall ENERGY STAR sales, reduced computer monitor savings for 2007 through 2008 due to updated usage pattern assumptions, lower savings for fixtures due to the duty cycle change to three hours per day, and reduced savings for gas furnaces based on 2006 ENERGY STAR sales. These reductions were balanced due to the increase in CFL savings based on the new sales data.

Table 7 shows the forecast for saving expected in 2008. By 2008, energy savings are expected to reach 1.5 quadrillion Btu and $14 billion dollars and carbon savings reach 25.9 MMTC. Peak demand reduction increases to 25.4 gigawatts.

Forecasted ENERGY STAR Savings (2008 through 2025)

Our forecast represents our best estimate of future ENERGY STAR unit sales. We provide savings forecasts for two forecasts: 2008 through 2015 and 2008 through 2025.

Table 8 shows the cumulative savings under target market penetrations for the periods 2008-2015 and 2008-2025, respectively. All the products together are expected to save 18 quadrillion Btu, $133 billion dollars in energy bills, and 302 MMTC by 2015. BY 2025, ENERGY STAR labeled products are projected to save 51 quadrillion Btu, $312 billion dollars in energy bills, and 874 MMTC. In terms of future savings, CFL has the highest overall cumulative product savings followed by the office equipment product category and televisions. Increased future savings for office equipment is due to the 2007 specification revisions, which target on mode/active power consumption in addition to sleep and off mode power consumption. Televisions achieve increased future savings due to the adoption of new technologies such as LCD and plasma with higher energy savings opportunities (compared to CRT).

These cumulative figures represent an increase in of 53 MMTC (2008 to 2015) and 206 MMTC (2007-2025) compared to estimates from our last update. Growth in CFL savings accounts for 90% of the increase in savings. This CFL increase is based on the new sales data as discussed earlier.

Table 6. Annual savings in 2007

Program	Equipment Type	Primary Savings	Energy Bill Savings, Undiscounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2006	MtC		GW
Office Equipment	- Computers	47.4	405	0.8	0.96	0.454
	- Monitors	190.2	1,581	3.2	0.96	1.800
	- Faxes	3.2	28	0.1	1.56	0.022
	- Copiers	32.2	264	0.5	5.81	0.067
	-Multifunction Devices	15.3	126	0.3	0.73	0.220
	- Scanners	4.6	39	0.1	0.32	0.164
	- Printers	101.1	846	1.7	6.74	0.336
	Subtotal	394.0	3,289	6.5	1.46	3.063
Consumer Electronics	- TVs	78.4	699	1.3	1.00	0.826
	-VCRs	10.6	94	0.2	1.00	0.112
	-TV/VCR/DVD	16.9	150	0.3	1.00	0.178
	-DVD Player	14.2	127	0.2	1.00	0.150
	-Audio Equipment	11.6	103	0.2	1.00	0.122
	-Telephony	10.9	97	0.2	1.00	0.114
	-Set-top Box	0.1	1	0.0	0.66	0.002
	-External Power Supplies	13.6	117	0.2	1.00	0.143
	-Battery Charging Systems	0.0	0	0.0	1.00	0.000
	Subtotal	156.2	1,388	2.6	1.00	1.648
Heating & Cooling	- Furnace (Gas or Oil)	53.6	620	0.8	-	-
	- Central Air Conditioner	33.6	299	0.6	0.15	2.360
	- Air-Source Heat Pump	28.2	252	0.5	0.15	0.729
	- Geothermal Heat Pump	5.0	44	0.1	0.15	0.040
	- Boiler (Gas or Oil)	3.8	53	0.1	-	-
	- Programmable Thermostat	55.4	620	0.9	0.15	0.804
	- Unitary HVAC	32.5	267	0.5	0.15	2.283
	Subtotal	212.1	2,156	3.4	0.18	6.217
Res and Com Lighting	- Fixtures	72.0	642	1.2	1.02	0.741
	- CFLs	320.4	2,856	5.3	1.02	3.296
	- Exit Sign	5.6	46	0.1	1.00	0.059
	- Traffic Signal	13.4	110	0.2	1.00	0.142
	Subtotal	411.4	3,655	6.8	1.02	4.237
Residential Appliances	- Room Air Conditioners	16.4	147	0.3	0.15	1.155
	- Dehumidifiers	4.4	39	0.1	0.43	0.107
	- Air Cleaners	2.8	25	0.0	1.00	0.030
	- Exhaust Fans	1.4	12	0.0	1.02	0.014
	- Ceiling Fans	1.4	12	0.0	1.02	0.014
	- Dishwashers	31.2	307	0.5	0.77	0.306
	- Refrigerators	22.0	197	0.4	0.95	0.244
	- Clothes Washers	45.3	444	0.7	0.66	0.527
	Subtotal	124.9	1,182	2.0	0.46	2.396
Commercial Appliances	- Water Coolers	9.5	78	0.2	0.70	0.150
	- Commercial Refrigeration	5.6	46	0.1	0.95	0.062
	- Hot Food Holding Cabinets	1.9	15	0.0	0.95	0.021
	- Fryers	0.9	9	0.0	0.95	0.001
	- Steamers	0.1	1	0.0	0.95	0.001
	- Vending Machines	2.4	19	0.0	0.95	0.026
	Subtotal	20.3	169	0.3	0.79	0.261
Other	- Utility Transformers	0.1	1	0.0	1.00	0.001
	- C&I Transformers	1.0	8	0.0	0.77	0.013
	- Residential Roofing	1.3	10	0.0	0.15	0.169
	- Commercial Roofing	36.9	284	0.6	0.15	3.781
	Subtotal	39.3	303	0.7	0.15	3.964
TOTAL		1,358.1	12,142	22.4	0.62	21.786

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Notes to Table 6
a) Columns may not total due to rounding.
b) Electricity is converted to primary energy using electricity heat rates as shown in Table 2.
c) Energy bills are calculated using yearly U.S. average energy prices. See Table 2.
d) Carbon emissions for electricity are from US EPA (2007). 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 7. Expected annual savings in 2008

Program	Equipment Type	Primary Savings	Energy Bill Savings, Undiscounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2006	MtC		GW
Office Equipment	- Computers	60.7	518	1.0	0.95	0.605
	- Monitors	196.9	1,640	3.3	0.91	1.825
	- Fax	3.6	32	0.1	1.56	0.025
	- Copier	38.0	313	0.6	5.81	0.081
	-Multifunction Device	19.1	157	0.3	0.79	0.252
	- Scanner	4.4	38	0.1	0.32	0.158
	- Printer	115.9	971	1.9	6.57	0.397
	Subtotal	438.7	3,668	7.3	1.52	3.349
Consumer Electronics	- TVs	90.2	804	1.5	1.00	0.955
	-VCRs	9.4	84	0.2	1.00	0.100
	-TV/VCR/DVD	17.1	153	0.3	1.00	0.181
	-DVD Player	15.2	135	0.3	1.00	0.161
	-Audio Equipment	11.9	106	0.2	1.00	0.126
	-Telephony	13.0	116	0.2	1.00	0.138
	-Set-top Box	0.1	1	0.0	0.66	0.002
	-External Power Supplies	19.3	166	0.3	1.00	0.204
	-Battery Charging Systems	0.0	0	0.0	1.00	0.000
	Subtotal	176.2	1,566	2.9	1.00	1.868
Heating & Cooling	- Furnace (Gas or Oil)	56.9	654	0.8	-	-
	- Central Air Conditioner	36.6	327	0.6	0.15	2.588
	- Air-Source Heat Pump	31.4	280	0.5	0.15	0.818
	- Geothermal Heat Pump	5.9	53	0.1	0.15	0.048
	- Boiler (Gas or Oil)	4.1	56	0.1	-	-
	- Programmable Thermostat	59.8	664	0.9	0.15	0.862
	- Unitary HVAC	40.3	332	0.7	0.15	2.846
	Subtotal	234.9	2,365	3.8	0.18	7.162
Res and Com Lighting	- Fixtures	84.2	751	1.4	1.02	0.870
	- CFLs	391.7	3,493	6.5	1.02	4.048
	- Exit Sign	5.5	45	0.1	1.00	0.058
	- Traffic Signal	13.4	110	0.2	1.00	0.142
	Subtotal	494.7	4,399	8.3	1.02	5.118
Residential Appliances	- Room Air Conditioners	19.0	170	0.3	0.15	1.345
	- Dehumidifiers	6.1	54	0.1	0.43	0.148
	- Air Cleaners	3.9	35	0.1	1.00	0.041
	- Exhaust Fans	1.7	15	0.0	1.02	0.018
	- Ceiling Fans	1.6	14	0.0	1.02	0.016
	- Dishwashers	38.2	375	0.6	0.77	0.376
	- Refrigerators	25.1	224	0.4	0.95	0.279
	- Clothes Washers	49.6	485	0.8	0.66	0.586
	Subtotal	145.2	1,371	2.4	0.46	2.809
Commercial Appliances	- Water Coolers	11.5	95	0.2	0.70	0.182
	- Commercial Refrigeration	7.1	58	0.1	0.95	0.078
	- Hot Food Holding Cabinets	2.6	21	0.0	0.95	0.029
	- Fryers	1.1	12	0.0	0.95	0.001
	- Steamers	0.2	2	0.0	0.95	0.002
	- Vending Machines	3.6	30	0.1	0.95	0.040
	Subtotal	26.1	217	0.4	0.80	0.333
Other	- Utility Transformers	0.1	1	0.0	1.00	0.001
	- C&I Transformers	1.0	8	0.0	0.77	0.013
	- Residential Roofing	1.7	13	0.0	0.15	0.227
	- Commercial Roofing	45.3	351	0.8	0.15	4.664
	Subtotal	48.1	372	0.8	0.15	4.905
TOTAL		1,563.9	$13,957	25.9	0.62	25.544

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Notes to Table 7:
a) Columns may not total due to rounding.
b) Electricity is converted to primary energy using conversion factors in Table 2.
c) Energy bills are calculated using yearly U.S. average energy prices. See Table 2.
d) Carbon emissions for electricity are from US EPA (2007). See Table 2.
e) Peak load savings are calculated using the CLFs shown in Table 5.

Table 8. Projected cumulative ENERGY STAR savings (2008-2015 and 2008-2025)

Savings Analysis Period		Projected Savings (2008-2015)			Projected Savings (2008-2025)		
Program		Primary Energy Savings	Disc Energy Bill Savings	Carbon Avoided	Primary Energy Savings	Disc Energy Bill Savings	Carbon Avoided
		Trillion Btu	Million $2006	MtC	Trillion Btu	Million $2006	MtC
Office Equipment	- Computers	1,243	8,502	21.0	5,044	27,729	86.2
	- Monitors	1,801	12,583	30.3	4,026	23,763	68.5
	- Fax	39	290	0.7	86	540	1.5
	- Copier	345	2,365	5.8	804	4,631	13.7
	-Multifunction Device	402	2,672	6.8	1,176	6,494	20.0
	- Scanner	38	269	0.6	88	527	1.5
	- Printer	1,376	9,515	23.2	3,848	23,896	65.6
	Subtotal	5,244	36,196	88.3	15,072	87,581	256.9
Consumer Electronics	- TVs	990	7,444	16.7	2,494	15,593	42.5
	-VCRs	62	479	1.0	133	862	2.3
	-TV/VCR/DVD	124	951	2.1	264	1,718	4.5
	-DVD Player	122	930	2.1	270	1,737	4.6
	-Audio Equipment	84	647	1.4	191	1,223	3.2
	-Telephony	131	986	2.2	360	2,226	6.1
	-Set-top Box	35	260	0.6	35	261	0.6
	-External Power Supplies	289	2,051	4.9	790	4,659	13.5
	-Battery Charging Systems	0	2	0.0	1	4	0.0
	Subtotal	1,836	13,750	30.9	4,538	28,283	77.3
Heating & Cooling	- Furnace (Gas or Oil)	522	4,813	7.8	1,055	8,356	15.8
	- Central Air Conditioner	365	2,755	6.1	795	5,111	13.5
	- Air-Source Heat Pump	342	2,570	5.8	797	5,045	13.6
	- Geothermal Heat Pump	78	580	1.3	279	1,658	4.8
	- Boiler (Gas or Oil)	44	453	0.7	122	1,015	1.9
	- Programmable Thermostat	533	4,805	8.4	1,245	9,292	19.8
	- Light commercial HVAC	556	3,728	9.4	1,804	9,848	30.8
	Subtotal	2,440	19,705	39.5	6,097	40,325	100.1
Lighting	- Fixtures	1,074	7,988	18.1	3,964	23,423	67.7
	- CFLs	4,801	35,870	80.9	14,568	88,392	248.5
	- Exit Sign	32	226	0.5	52	327	0.9
	- Traffic Signal	74	534	1.2	74	534	1.2
	Subtotal	5,980	44,619	100.8	18,657	112,676	318.3
Residential Appliances	- Room Air Conditioners	213	1,596	3.6	586	3,618	10.0
	- Dehumidifiers	100	736	1.7	337	2,015	5.7
	- Air Cleaners	67	492	1.1	242	1,430	4.1
	- Exhaust Fans	22	166	0.4	61	379	1.0
	- Ceiling Fans	18	135	0.3	55	335	0.9
	- Dishwashers	498	3,980	8.0	1,443	9,462	23.5
	- Refrigerators	288	2,157	4.9	858	5,229	14.6
	- Clothes washers	463	3,742	7.5	968	6,610	16.0
	Subtotal	1,669	13,006	27.5	4,551	29,078	76.0
Commercial Appliances	- Water Coolers	148	997	2.5	409	2,281	7.0
	- Commercial Refrigeration	96	645	1.6	282	1,554	4.8
	- Hot Food Holding Cabinets	45	296	0.8	188	990	3.2
	- Fryers	19	148	0.3	79	469	1.2
	- Steamers	9	56	0.1	53	272	0.9
	- Vending Machines	76	498	1.3	289	1,539	4.9
	Subtotal	392	2,640	6.6	1,300	7,104	22.0
Other	- Utility Transformers	0	3	0.0	1	6	0.0
	- C&I Transformers	8	53	0.1	17	100	0.3
	- Residential Roofing	27	177	0.5	108	563	2.0
	- Commercial Roofing	453	2,964	7.9	1,190	6,475	21.0
	Subtotal	488	3,198	8.5	1,316	7,144	23.3
TOTAL		**18,050**	**133,113**	**302.1**	**51,532**	**$312,191**	**873.8**

Notes to Table 7:
a) Columns may not total due to rounding.
b) Electricity is converted to primary energy using conversion factors in Table 2.
c) Energy bills are calculated using yearly U.S. average energy prices. See Table 2.
d) Carbon emissions for electricity listed in Table 2.

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 1,358 trillion Btus of energy and prevented carbon emissions of 22.4 million metric tons in 2007 alone. Based on our analysis, the continuation of these programs and the addition of new programs in appliances and home electronics have the potential to greatly reduce carbon emissions over the next 18 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.

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