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Calendar Year 2007 Program Benefits for ENERGY STAR Labeled Products

Marla Sanchez, Gregory Homan, and Richard Brown

Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory
University of California
Berkeley, California 94720

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DISCLAIMER

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Executive Summary

ENERGY STAR is a voluntary energy efficiency-labeling program operated jointly by the United States Department of Energy and the United States Environmental Protection Agency (US EPA). Since the program inception in 1992, ENERGY STAR has become a leading international brand for energy efficient products. ENERGY STAR's central role in the development of regional, national, and international energy programs necessitates an open process whereby its program achievements to date as well as projected future savings are shared with committed stakeholders. Through 2007, the program saved 7.1 Quads of primary energy and avoided 128 MtC equivalent. The forecast shows that the program is expected to save 21.2 Quads of primary energy and avoid 375 MtC equivalent over the period 2008-2015. The sensitivity analysis bounds the best estimate of carbon avoided between 84 MtC and 172 MtC (1993 to 2007) and between 243 MtC and 519 MtC (2008 to 2015).

1. Introduction and Study Objectives

ENERGY STAR is a voluntary labeling program operated jointly by the Department of Energy (DOE) and the Environmental Protection Agency (EPA). DOE and EPA enter into partnerships with manufacturers and key stakeholders to promote products that meet energy efficiency and performance criteria established by the agencies. The ENERGY STAR label allows consumers to more easily identify and purchase energy efficient products. By transforming the market for high efficiency products, DOE and EPA reduce air pollution and greenhouse gases associated with the consumption of energy. For a more detailed description of the ENERGY STAR program, refer to McWhinney et al. (2005) and Brown et al. (2002). In this report, we address the following questions for ENERGY STAR labeled products:

- How are ENERGY STAR impacts quantified?
- What are ENERGY STAR achievements?
- What are the limitations to our method?

We begin by providing an overview of our methodology and then present a discussion of analysis results.

2. Study Scope

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 report focuses only on labeled products such as office equipment, appliances, and electronics. This report does not cover savings for buildings and industrial plants, home performance, or new homes. The methodologies for quantifying savings for these program segments are significantly different than the methodology outlined in this paper (for labeled products). We cannot address these additional methodologies and results with the necessary detail within the scope of this paper. See Horowitz (2001, 2004, 2007) for a complete summary of program impacts for ENERGY STAR Buildings. See US EPA (2007a) 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. Full eligibility requirements for each product can be found at www.energystar.gov.

Table 1. Summary of ENERGY STAR products

	Specification Effective Dates	
	Original Specification	Specification Revision Dates
Product types included in analysis		
Audio and DVD[1, 2]	1999	2003
Battery charging systems	2006	
Boilers	1996	2002
CAC/ASHP[2]	1995	2002, 2006, 2009
Ceiling fans	2002	2003, 2006
CFLs	1999	2001, 2004, 2008
Commercial dishwasher	2007	
Commercial fryers	2003	
Commercial hot food holding cabinets	2003	
Commercial solid door refrigerators and freezers	2001	2009 (proposed)
Commercial steam cookers	2003	
Computers	1992	1995, 1999, 2000, 2007, 2009 (proposed)
Copiers	1995	1997, 1999, 2007, 2009 (proposed)
Decorative light strands	2008	
Dehumidifiers	2001	2006, 2007, 2008
Digital TV Adapters	2007	
Exit signs[3]	1996	1999, 2004, 2008
External power adapters	2005	2008
Facsimile	1995	1995, 2000, 2001, 2007, 2009 (proposed)
Furnaces	1995	2006, 2009 (proposed)
Geothermal HP[2]	1995	2001
Ice machines	2008	
Light commercial HVAC[2]	2002	2004
Monitors	1992	1995, 1998, 1999, 2005, 2006
Multifunction devices	1997	1999, 2007, 2009 (proposed)
Printers	1993	1995, 2000, 2001, 2007, 2009 (proposed)
Programmable thermostats[3]	1995	*2008, 2009 (proposed)
Refrigerators and freezers	1996	2001, 2003, 2004, 2008
Residential clothes washers	1997	2001, 2004, 2007, 2009, 2011
Residential dishwashers	1996	2001, 2007
Residential light fixtures	1997	2001, 2002, 2003, 2005, 2008
Roof products	1999	2005, 2007
Room air cleaners	2004	
Room air conditioners	1996	2000, 2003, 2005
Scanners	1997	2007, 2009
Set-top boxes[3]	2001	*2005, 2009
Telephony	2002	2004, 2006, 2008
Televisions/VCRs[2]	1998	2002, 2004, 2005, 2008
Traffic signals[3]	2000	2003, *2007
Transformers[3]	1995	*2007
Vending machines	2004	2006, 2007
Ventilation fans	2001	2003
Water coolers	2000	2004
Product types not included in analysis[4, 5]		
Buildings and industrial plants[5]	1991	1995, 1999, 2000, 2001, 2002, 2004, 2006
Home performance	2000	2002
Insulation[6]	1995	*2002
New homes	1995	1997, 2006
Windows, doors, and skylight	1997	2003, 2005, 2009 (proposed)

Source: US EPA (2008a)

Notes to Table 1:
1) Audio includes CDs, mini-systems, audio separates, and home theater in a box.
2) 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, VCR=video cassette recorder.
3) Specification revisions that resulted in program suspension are indicated with an "*". Set-top boxes was suspended in 2004 and then re-launched in 2009. Programmable thermostats are scheduled for sunset pending the 2009 specification revision outcome.
4) 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.
5) Changes to ENERGY STAR buildings and industrial plants reflect building types or manufacturing sectors added to the program.
6) Insulation specification revised in 2002 and insulation incorporated into Home Performance with ENERGY STAR.

Our study tracks carbon savings, energy savings, monetary savings, net monetary savings (monetary savings minus the incremental investment cost of realized savings), and peak power reductions for the analysis period 1993-2025. We track these indicators on an annual basis and also generate cumulative results over several time periods. In this report, we present annual results for energy savings, peak load savings, carbon savings and monetary savings for calendar year 2007, 2008, and 2009. Although the model results extend through 2025, we present cumulative results for energy savings, carbon savings, and monetary savings over the period *1993-2015* to minimize uncertainty inherent in an extended forecast.

3. Program Attribution

Numerous supporting stakeholders including utilities, regional energy partnerships, energy consortiums, and non-profit organizations leverage the ENERGY STAR program nationally. All stakeholders work towards advancing ENERGY STAR goals, improving ENERGY STAR consumer awareness, and promoting the sales of ENERGY STAR products. This report provides a top-level summary of national savings achieved by ENERGY STAR voluntary product labeling and does not make an attempt to attribute the national savings across federal, regional, state and/or local efforts.

4. Technical Approach

4.1 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 EPA and DOE 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[1]. 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 DOE's Energy Information Administration (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.

4.2 Methodology Summary

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 EPA each calendar year[2]. In 2007, partners reported ENERGY STAR sales for all EPA labeled products except thermostats, PCs, facsimiles, scanners, printers, copiers, and MFDs due to specific Partner requirements found in their existing partnership agreements. Market shares for these products are LBNL estimates based on market research reports and industry estimates (Garter 2001). Manufacturers will begin reporting ENERGY STAR sales for PCs and imaging equipment for calendar year 2008.

Retail partners report ENERGY STAR unit sales to DOE each calendar year. Non-ENERGY STAR unit sales are estimated as the difference between total US unit sales obtained from industry reports and ENERGY STAR unit sales. **Table 2** shows actual ENERGY unit sales for 2007 and projected ENERGY STAR unit sales for 2008.

[1] The sensitivity analysis is in section 5.2 and includes varying carbon inputs. We do not present monetary or energy results for price and heat rate sensitivity.

[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.

Table 2. Actual ENERGY STAR Market Shares for 2007 and Projected ENERGY STAR Market Shares for 2008

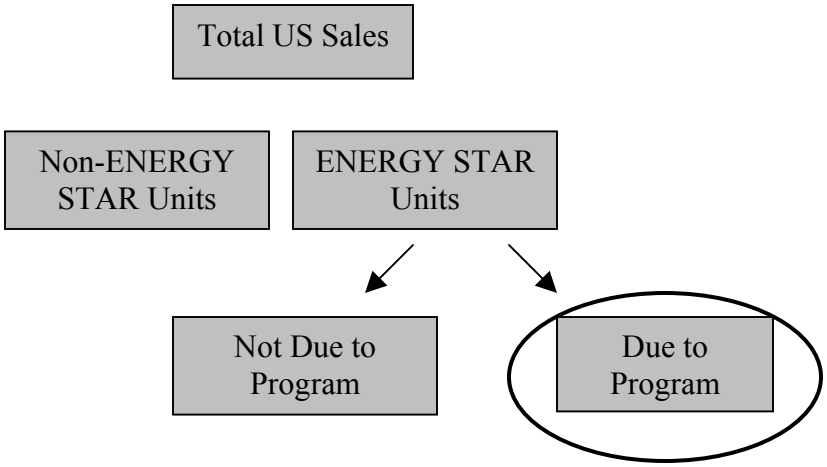
	Actual 2007			Projected 2008		
Equipment Type	Total ENERGY STAR Shipments	Total US Shipments	ENERGY STAR Market Share	Total ENERGY STAR Shipments	Total US Shipments	ENERGY STAR Market Share
	1000s	1000s	%	1000s	1000s	%
Office Equipment						
-Office Copiers	663	1,325	50	932	1,332	70
-Office Facsimile	141	281	50	184	263	70
-Office Printers	3,313	6,626	50	4,583	6,548	70
-Office Scanners	1,530	3,060	50	2,121	3,029	70
-Office Multi-function	8,647	17,299	50	12,647	18,153	70
-Office CRTs	78	727	11	50	353	14
-Office LCDs	23,380	24,640	95	23,581	24,852	95
-Office PCs	40,120	41,042	98	10,936	44,044	25
-Residential Copiers	0	0	NA	0	0	NA
-Residential Facsimile	415	830	50	546	779	70
-Residential Printers	3,066	6,132	50	3,892	5,560	70
-Residential Scanners	2,628	5,256	50	3,642	5,203	70
-Residential Multi-function	1,269	2,538	50	1,858	2,654	70
-Residential CRTs	53	499	11	75	251	30
-Residential LCDs	16,074	16,940	95	16,810	17,716	95
-Residential PCs	27,401	53,733	51	7,672	57,385	13
Consumer Electronics						
- TVs	16,649	31,680	53	19,177	32,670	59
-VCRs	0	751	0	0	744	0
-TV/VCR/DVD	802	6,578	12	814	6,536	12
-DVD Player	8,395	19,590	43	8,815	19,394	45
-Mini-Systems	351	3,905	9	368	3,903	9
-Home Theater	800	2,723	29	681	2,720	25
-Audio Separates	762	2,064	37	763	2,062	37
-Compact Disc Player	0	598	0	0	598	0
-Answering Machines	0	1,182	0	0	1,170	0
-Cordless Phones	1,850	13,620	14	1,841	13,483	14
-DSS Cordless Phones	412	3,032	14	750	3,001	25
-Combination Phones	4,192	12,307	34	4,171	12,431	34
-DSS Combination Phones	3,191	9,370	34	3,247	9,277	35
-Additional Handsets	160	1,224	13	159	1,211	13
-Digital TV Adapters	0	0	NA	0	0	NA
-Set-top Box	0	20,528	0	0	23,429	0
-External Power Supplies	312,041	554,710	56	315,335	565,704	56
-Battery charger	6,505	41,255	16	6,602	41,668	16
Heating and Cooling						
-Air Source Heat Pump	385	2,151	18	391	2,178	18
-Geothermal Heat Pump	99	108	92	100	161	62
-Central Air Conditioner	1,032	5,000	21	1,048	5,050	21
-Gas Furnace	1,031	3,248	32	1,046	3,300	32
-Oil Furnace	10	100	10	11	100	11
-Gas Boiler	76	196	39	77	196	40
-Oil Boiler	99	162	61	101	162	62
-Unitary HVAC (10^6 ft^2)	261	741	35	284	750	38
-Thermostats	2,432	6,538	37	2,549	6,610	39
Residential and Commercial Lighting						
- Indoor Fixtures	10,810	189,263	6	11,351	191,156	6
- Outdoor Fixtures	4,781	28,619	17	5,020	28,905	17
- Exit Signs	NA	NA	NA	NA	NA	NA
- CFLs	313,523	1,318,030	24	332,334	1,289,112	26
- DLSs	NA	NA	NA	37,700	125,668	30
- Traffic Signal	NA	NA	NA	NA	NA	NA
Residential Appliances						
-Clothes Washers	4,318	9,595	45	4,361	9,691	45
-Dishwashers	5,135	7,335	70	5,237	7,482	70
-Refrigerators	4,520	11,299	40	3,538	11,412	31
-RACs	4,263	10,659	40	4,304	11,192	38
-Dehumidifiers	1,151	2,000	58	933	2,034	46

-Air Cleaners	361	2,505	14	391	2,567	15
-Exhaust Fans	805	6,354	13	859	6,432	13
-Ceiling Fans Only	2,647	7,709	34	2,917	7,760	38
-Ceiling Fan with Light Kit	132	9,970	1	145	10,045	1
-Light Kit for Ceiling Fan	21	2,151	1	23	2,167	1
Commercial Appliances						
-Vending Machines	64	246	26	69	246	28
-Hot Food Holding Cabinet	20	114	17	23	116	19
-Steamers	5	41	12	7	42	17
-Fryers	6	85	7	7	86	8
-Commercial Refrigeration	147	240	61	149	242	62
-Water Coolers	624	1,201	52	633	1,264	50
-Ice Machines	NA	NA	NA	24	162	15
-Dishwashers	NA	NA	NA	6	38	15
Other						
- Utility Transformers	NA	NA	NA	NA	NA	NA
- C&I Transformers	NA	NA	NA	NA	NA	NA
- Residential Roofing (10^9 ft^2)	0	5	9	0	5	9
- Commercial Roofing (10^9 ft^2)	2	16	10	2	16	10

Notes to Table 2:
1) Columns may not equal due to rounding
2) 2007 ENERGY STAR units are from ICF (2008) with the exception of the following products: residential and office copiers, fax, printers, scanners, MFDs, and PCs are extrapolated from Gartner (2001). Residential clothes washers, dishwashers, RAC, and refrigerators are from email communication with Bill McNary (D&R International) on July 17, 2008. Thermostat market shares are an industry estimate provided by Honeywell
3) ENERGY STAR exit signs, traffic signals, and transformers are discontinued. (program savings continue to accrue due to existing stock)
4) Residential PCs include desktops, laptops, and video games
5) Office PCs include desktops, laptops, and workstations
6) Unitary HVAC is expressed in million square feet
7) Roofing is expressed in billion square feet
8) PC market shares in 2008 reflect the revised computer specification
9) Digital TV adapters are modeled as sales in 2009
10) Projected 2008 market shares are LBNL best estimates taking into consideration past ENERGY STAR unit sales, new product launches, ENERGY STAR specification revisions, and trends in total US sales
11) New specifications for DLSs, commercial ice machines and dishwashers are effective in 2008

Sales of ENERGY STAR units are further divided into ENERGY STAR unit sales attributed to program efforts and ENERGY STAR unit sales not attributed to program efforts. At each product launch, we set the ENERGY STAR units not attributed to the program equal to the market share of products that meet the final ENERGY STAR performance level at the time of the agency's initial product development/market transformation efforts. This initial ENERGY STAR program penetration is calculated using the energy consumption test data collected by the agency at the start of its product development effort. To estimate the initial ENERGY STAR market share, we divide the total number of models in the dataset by the number of models in the dataset that meet the final ENERGY STAR performance levels. ENERGY STAR unit sales attributed to the program are calculated as the total ENERGY STAR unit sales in any given year minus ENERGY STAR unit sales not attributed to the program. ENERGY STAR savings include only the savings for ENERGY STAR units directly attributed to the program. **Figure 1** illustrates the sales segmentation.

Figure 1. Market segmentation of ENERGY STAR products [products in circle accrue savings for the program]



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.

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 3**. 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 2007b). 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. Heat rates are average rates and not marginal.

Table 3. Best Estimate Energy Prices and Carbon Factors by Year (2007 dollars)

Year	Cmcl. Elec Price $/kWh[2]	Res. Electricity Price $/kWh[2]	Cmcl. Gas Price $/MBtu	Res. Gas Price $/ MBtu	Oil Price $/MBtu	Price Sources, US DOE [3]	Carbon Emissions Factor for Electricity MMTC / TWh[1, 4]	Electric Heat Rate Btu/kWh	Electric Heat Rate Source, US DOE [3]
1993	0.105	0.113	6.78	8.05	8.87	1996a	0.203	11,019	1996a
1994	0.104	0.112	7.09	8.30	8.43	1996b	0.203	10,948	1996b
1995	0.097	0.109	6.46	7.74	8.15	1997	0.203	10,970	1997
1996	0.096	0.107	6.71	7.88	9.01	1998	0.203	10,866	1998
1997	0.094	0.104	7.08	8.47	8.86	1999	0.203	10,978	1999
1998	0.092	0.101	6.69	8.24	7.64	2000	0.203	10,891	2000
1999	0.087	0.099	6.39	7.96	7.65	2001	0.203	10,784	2001
2000	0.087	0.098	7.76	9.06	11.30	2003	0.203	11,181	2003
2001	0.092	0.100	9.69	1095	10.44	2003	0.203	11,030	2003
2002	0.090	0.097	7.45	8.79	9.41	2005	0.203	11,008	2005
2003	0.089	0.097	9.03	10.31	10.77	2006	0.203	10,997	2006
2004	0.089	0.098	9.96	11.35	13.65	2007	0.203	10,952	2007
2005	0.091	0.100	11.83	13.20	17.44	2008	0.203	10,861	2008
2010	0.098	0.110	10.88	12.48	17.66	2008	0.190	10,717	2008
2015	0.089	0.105	9.93	11.50	14.65	2008	0.190	10,623	2008
2020	0.090	0.106	10.17	11.70	14.66	2008	0.190	10,609	2008
2025	0.090	0.106	10.75	12.25	15.54	2008	.0190	10,552	2008

Notes to Table 3:
1) 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.
2) All prices have been converted to 2006 dollars using implicit GDP deflators from the US Department of Commerce (2007).
3) 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 Section 7.0.
4) Carbon emission factors (1993-2005) are from the Cadmus Group (1998), carbon emission factors 2010 and 2025 are from US EPA (2007b).
5) Cmcl = commercial; Res = residential
6) Heat rates are average heat rates

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)

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 4** 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.

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 the agency during a subsequent specification revision support this assumption. In reference to our general program savings equation, 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.

Table 4. 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 Savings for Current Year Sales Only (kWh/yr)	15,000	22,000	30,000	37,800	42,600	48,000	64,000
Annual Energy Saved for ENERGY STAR stock in Current Year (kWh/yr)	15,000	37,000	67,000	104,800	147,400	195,400	259,400

Notes to Table 4:
1) We refer to specification versions as ENERGY STAR Tiers. Tier 1 corresponds to the original specification and Tier 2 corresponds to the revised specification.
2) 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
3) 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).

4.3 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.

4.3.1 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).

[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.

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).

4.3.2 Consumer Electronics

Consumer electronics include audio equipment and DVDs, battery charging systems, external power supplies, digital TV adapters, set-top boxes, telephony, TVs, and VCRs. ENERGY STAR for audio/DVD and telephony 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); Roth and McKenney (2007); and Porter et al. (2006).

ENERGY STAR for set-top boxes focuses on reducing the TEC of the product measured in annual kWh. ENERGY STAR for set-top boxes also includes power allowance adders to account for product functionality such as DVDs, tuners, and advanced video processing. Power consumption and usage patterns are derived from Cadmus (2007). The set-top box specification was reinstated with an effective data of 2009.

In 2008, ENERGY STAR for televisions incorporated criteria for both active and standby modes. ENERGY STAR for digital TV adapters also includes both active and standby eligibility criteria. We estimate BAU and ENERGY STAR UECs for these two product types by multiplying the time spent in each power mode by the power consumption in each mode, then summing over all power modes. Television power consumption and usage patterns are derived from Rosen et al. (1999); CNET (2005); US EPA (2008b); Horowitz et al. (2005); and Porter et al. (2006). Digital TV adapter power consumption and usage patterns are from Amann (2003) and NYSERDA (2006). The baseline standby power consumption for digital TV adapters is equivalent to the National Telecommunications and Information Administration (NTIA) standard of 2 watts.

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. Beginning in 2009, the BAU for external power adapters is set equal to the federal minimum efficiency level. BAU and ENERGY STAR UECs for battery charging systems are derived from Webber et al. (2006).

4.3.3 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 1995) [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. 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.

To account for savings uncertainty related to programmable thermostats, we make a conservative estimate of the number of ENERGY STAR programmable thermostat units that successfully realize savings. We adjust our total ENERGY STAR programmable thermostat unit sales to account for the following factors: sales represent manual thermostat replacements only (70% of total ENERGY STAR unit sales), we assume EPA is credited with only 40% of ENERGY STAR units that replace manual thermostats, we assume that only 44% of sales credited to US EPA are installed in homes that did not previously setback the thermostat manually (US DOE, 2004), and we assume that only 70% of unit sales to homes that did not previously setback manually are properly programmed and successfully achieving energy savings (US DOE, 2004). Once the four adjustment factors are applied, we credit US EPA savings to less than 10% of total ENERGY STAR programmable thermostat unit sales. We assume a 14% reduction in

[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.

household heating consumption[5]. We do not assume any cooling savings due to the limited data available to support verified savings. Beginning in 2011, we assume no additional sales of ENERGY STAR units due to the discontinuation of the ENERGY STAR programmable thermostat specification.

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.

4.3.4 Lighting

Lighting includes decorative light strands, exit signs, residential fixtures (indoor and outdoor), traffic signals, and compact fluorescent lamps (CFLs). Decorative light strands include mini lamps (100 lamps per strand) and regular lamps (25 lamps per strand). Our baseline for mini strands is 0.42 W/lamp and 5 W/lamp for regular strands. ENERGY STAR power levels are set equal to minimum program requirements (0.2 W/lamp). We assume an operating time of 10 hours per day and 45 days per year. Power and usage data are from Navigant Consulting (2005).

Through 2005, 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). From 2006 onward, the BAU UEC is set equivalent to the federal minimum efficiency standard. ENERGY STAR assumes an average power of five Watts (W) and an annual operating time of 8,760 hours.

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. 2005). 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. 2005).

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. The ENERGY

[5] Based on RLW Analytics (2007), which showed a household energy savings of approximately 8% per thermostat for homes in New England (RLW 2007). We adjusted the per household savings by the fraction of household energy consumption due to heating for New England (58%) and arrive at a 14% reduction in heating consumption.

STAR specification for traffic signals was suspended in 2007 due to a new federal minimum efficiency standard and we assume no additional savings throughout the forecast period.

Savings for CFLs are consistent with assumptions for residential light fixtures. 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. 2005). We assume a lamp lifetime of 6,000 hours, which at 3 hours per day usage equates to five years.

4.3.5 Residential Appliances

Residential appliances include ceiling fans, dehumidifiers, room air cleaners, ventilation fans, dishwashers, clothes washers, refrigerators, and room air conditioners. 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 incandescent lighting. Beginning in 2007, our BAU lighting consumption is reduced to 60 W to account for the federal mandate that ceiling fans with integral lights or ceiling fan light kits are required to be shipped with CFL lamps enclosed. 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. Through 2007, 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). From 2008 onward, the BAU UEC is equivalent to the applicable federal minimum efficiency standard. The ENERGY STAR UEC represents the minimum efficiency program requirements for an average equipment capacity. We assume annual operating 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.

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 obtain energy use for these appliances, we first calculated unit energy consumption for units just meeting the federal minimum efficiency standards. The average energy consumption 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.[6] 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.

3.3.6 Commercial Appliances

Commercial appliances include bottled water coolers, commercial fryers, commercial hot food holding cabinets, commercial refrigerators and freezers, commercial steamers, commercial ice machines, commercial dishwashers, 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

[6] 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.

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 2008).

Data for commercial refrigerators and freezers are taken from FSTC (2008). 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. From 2010 onward, the BAU UEC is set equal to the federal minimum efficiency standard.

Commercial ice machines include self-contained units, ice maker heads, and remote condenser units. Each product category is divided into low capacity units and high capacity units as denoted by the ENERGY STAR specification. Power consumption test data is from ARI and usage patterns assume a 75% duty cycle.

Commercial dishwashers include under-the-counter, door, single tank conveyor, and multi-tank conveyor. Each product category is divided into low temperature and high temperature units. ENERGY STAR criteria include a water-per-cycle requirement as well as an idle energy rate requirement. Relevant water consumption, idle energy, and duty cycles are from FSTC (2008).

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.

4.3.7 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). The ENERGY STAR specification for transformers was suspended in 2007 due to a new

federal minimum efficiency standard and we do not assume any additional savings throughout the forecast period.

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).

5.0 Results

5.1 Savings for ENERGY STAR labeled products

In 2007, ENERGY STAR labeled products saved 1.4 Quadrillion Btu (Quads) of primary energy, $14 billion in energy bills, and avoided 25 million metric tons carbon equivalent (MtC eq.) through its voluntary program efforts. For reference, these carbon savings represent 4.0% of residential and commercial building sector carbon emissions in 2007 (US DOE 2008). ENERGY STAR also saved 21 GW of peak power. The following are the top five ENERGY STAR products in terms of carbon savings achieved in 2007 (**Table 5**):

- CFLs: 6.5 MtC (26% of total)
- Monitors: 4.6 MtC (18% of total)
- Printers: 1.8 MtC (7% of total)
- Residential Light Fixtures: 1.3 MtC (5% of total)
- Televisions: 1.2 MtC (5% of total)

These five products accounted for over 60% of ENERGY STAR product labeling savings. Projected savings for 2008 and 2009 are shown in **Table 6**and **Table 7** respectively. We project that carbon savings will increase to 31.3 MtC in 2008 and 36.5 MtC in 2009.

Table 5. Achieved Annual savings in 2007

Program	Equipment Type	Primary Savings	Energy Bill Savings, Discounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2007	MtC		GW
Office Equipment	- Computers	47.2	440	0.8	1.31	0.392
	- Monitors	259.6	2,335	4.6	1.75	2.422
	- Faxes	3.2	31	0.1	1.00	0.024
	- Copiers	32.1	284	0.6	4.61	0.098
	-Multifunction Devices	15.3	135	0.3	1.00	0.162
	- Scanners	10.4	96	0.2	0.76	0.145
	- Printers	100.4	912	1.8	3.45	0.323
	Subtotal	**468.2**	**4,233**	**8.2**	**1.53**	**3.566**
Consumer Electronics	- TVs	70.1	691	1.2	1.00	0.742
	-VCRs	8.4	83	0.1	1.00	0.089
	-TV/VCR/DVD	15.3	151	0.3	1.00	0.162
	-DVD Player	13.5	133	0.2	1.00	0.142
	-Audio Equipment	11.9	117	0.2	1.00	0.126
	-Telephony	12.8	127	0.2	1.00	0.136
	-Digital TV Adapter	0.0	0	0.0	0.69	0.000
	-Set-top Box	0.0	0	0.0	1.00	0.000
	-External Power Supplies	26.2	245	0.5	1.00	0.277
	-Battery Charging Systems	0.4	4	0.0	1.00	0.005
	Subtotal	**158.7**	**1,550**	**2.8**	**1.00**	**1.674**
Heating & Cooling	- Furnace (Gas or Oil)	53.5	658	0.8	-	-
	- Central Air Conditioner	31.6	312	0.6	0.15	2.231
	- Air-Source Heat Pump	25.8	254	0.5	0.15	0.659
	- Geothermal Heat Pump	7.8	77	0.1	0.15	0.064
	- Boiler (Gas or Oil)	10.0	181	0.2	-	-
	- Programmable Thermostat	28.6	363	0.5	0.15	0.000
	- Unitary HVAC	35.9	318	0.6	0.15	2.530
	Subtotal	**193.2**	**2,164**	**3.2**	**0.18**	**5.484**
Res and Com Lighting	- Fixtures	76.4	753	1.3	1.02	0.789
	- CFLs	367.6	3,622	6.5	1.02	3.794
	- Exit Sign	5.0	44	0.1	1.00	0.053
	- Decorative Light Strands	0.0	0	0.0	1.02	0.000
	- Traffic Signal	9.8	87	0.2	1.00	0.104
	Subtotal	**458.8**	**4,506**	**8.1**	**1.02**	**4.740**
Residential Appliances	- Room Air Conditioners	16.9	166	0.3	0.15	1.191
	- Dehumidifiers	4.9	48	0.1	0.48	0.107
	- Air Cleaners	3.3	32	0.1	1.00	0.035
	- Exhaust Fans	1.3	13	0.0	1.02	0.014
	- Ceiling Fans	1.4	13	0.0	1.02	0.014
	- Dishwashers	31.1	333	0.5	0.77	0.306
	- Refrigerators	20.0	198	0.4	0.95	0.243
	- Clothes Washers	41.5	442	0.7	0.66	0.493
	Subtotal	**120.4**	**1,245**	**2.1**	**0.45**	**2.381**
Commercial Appliances	- Water Coolers	9.7	86	0.2	0.70	0.154
	- Commercial Refrigeration	3.4	31	0.1	0.95	0.038
	- Hot Food Holding Cabinets	0.0	0	0.0	0.95	0.000
	- Fryers	0.1	1	0.0	0.95	0.001
	- Steamers	0.0	0	0.0	0.95	0.000
	- Ice Machines	0.0	0	0.0	0.95	0.000
	- Dishwashers	0.0	0	0.0	0.95	0.000
	- Vending Machines	1.6	14	0.0	0.95	0.018
	Subtotal	**14.9**	**132**	**0.3**	**0.74**	**0.211**
Other	- Utility Transformers	0.1	1	0.0	1.00	0.001
	- C&I Transformers	1.0	9	0.0	0.77	0.013
	- Residential Roofing	1.3	11	0.0	0.15	0.166
	- Commercial Roofing	31.7	265	0.6	0.15	3.255
	Subtotal	**34.0**	**285**	**0.6**	**0.15**	**3.435**
TOTAL		**1,448.0**	**14,116**	**25.3**	**0.68**	**21.490**

Notes to Table 5:
1) Columns may not total due to rounding.
2) Electricity is converted to primary energy using electricity heat rates as shown in Table 3.
3) Energy bills are calculated using yearly U.S. average energy prices. See Table 3.
4) Carbon emissions for electricity are from US EPA (2007). See Table 3.
5) 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 is based on usage patterns from AD Little (1998). Water cooler CLF is 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. Projected Annual savings in 2008

Program	Equipment Type	Primary Savings	Energy Bill Savings, Discounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2007	MtC		GW
Office Equipment	- Computers	60.5	550	1.1	1.19	0.575
	- Monitors	307.7	2,715	5.4	1.75	2.775
	- Faxes	3.6	34	0.1	1.00	0.028
	- Copiers	37.9	330	0.7	4.61	0.114
	-Multifunction Devices	19.5	170	0.3	0.98	0.209
	- Scanners	10.6	95	0.2	0.76	0.147
	- Printers	114.6	1,019	2.0	3.57	0.382
	Subtotal	**554.4**	**4,913**	**9.8**	1.57	4.230
Consumer Electronics	- TVs	80.1	769	1.4	1.00	0.850
	-VCRs	6.2	59	0.1	1.00	0.066
	-TV/VCR/DVD	15.7	151	0.3	1.00	0.167
	-DVD Player	13.8	133	0.2	1.00	0.147
	-Audio Equipment	12.5	120	0.2	1.00	0.133
	-Telephony	16.7	160	0.3	1.00	0.177
	-Digital TV Adapter	0.0	0	0.0	0.69	0.000
	-Set-top Box	0.0	0	0.0	1.00	0.000
	-External Power Supplies	52.6	481	0.9	1.00	0.558
	-Battery Charging Systems	0.9	8	0.0	1.00	0.009
	Subtotal	**198.4**	**1,883**	**3.5**	**1.00**	**2.097**
Heating & Cooling	- Furnace (Gas or Oil)	56.3	675	0.8	-	-
	- Central Air Conditioner	33.9	326	0.6	0.15	2.398
	- Air-Source Heat Pump	27.9	268	0.5	0.15	0.714
	- Geothermal Heat Pump	11.1	107	0.2	0.15	0.091
	- Boiler (Gas or Oil)	11.0	213	0.2	-	-
	- Programmable Thermostat	30.9	390	0.5	0.15	0.000
	- Unitary HVAC	44.2	385	0.8	0.15	3.127
	Subtotal	**215.3**	**2,362**	**3.6**	**0.18**	**6.330**
Res and Com Lighting	- Fixtures	93.0	894	1.6	1.02	0.963
	- CFLs	509.3	4,893	9.0	1.02	5.275
	- Exit Sign	4.6	40	0.1	1.00	0.049
	- Decorative Light Strands	0.9	9	0.0	1.02	0.010
	- Traffic Signal	9.8	85	0.2	1.00	0.104
	Subtotal	**617.6**	**5,921**	**10.9**	**1.02**	**6.400**
Residential Appliances	- Room Air Conditioners	19.7	190	0.3	0.15	1.397
	- Dehumidifiers	6.3	61	0.1	0.50	0.134
	- Air Cleaners	4.8	46	0.1	1.00	0.051
	- Exhaust Fans	1.6	15	0.0	1.02	0.016
	- Ceiling Fans	1.4	14	0.0	1.02	0.015
	- Dishwashers	38.3	400	0.6	0.77	0.378
	- Refrigerators	25.3	243	0.4	0.95	0.282
	- Clothes Washers	45.2	467	0.8	0.65	0.548
	Subtotal	**142.7**	**1,435**	**2.4**	**0.45**	**2.820**
Commercial Appliances	- Water Coolers	12.0	104	0.2	0.70	0.190
	- Commercial Refrigeration	5.0	43	0.1	0.95	0.056
	- Hot Food Holding Cabinets	0.0	0	0.0	0.95	0.000
	- Fryers	0.1	1	0.0	0.95	0.001
	- Steamers	0.0	0	0.0	0.95	0.000
	- Ice Machines	0.1	1	0.0	0.95	0.001
	- Dishwashers	0.2	2	0.0	0.95	0.001
	- Vending Machines	2.8	24	0.0	0.95	0.031
	Subtotal	**20.1**	**175**	**0.4**	**0.75**	**0.281**
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	1.6	13	0.0	0.15	0.215
	- Commercial Roofing	34.7	285	0.6	0.15	3.583
	Subtotal	**37.4**	**307**	**0.7**	**0.15**	**3.812**
TOTAL		**1,785.9**	**16,997**	**31.3**	**0.71**	**25.960**

Notes to Table 6:
1) Columns may not total due to rounding.
2) Electricity is converted to primary energy using electricity heat rates as shown in Table 3.
3) Energy bills are calculated using yearly U.S. average energy prices. See Table 3.
4) Carbon emissions for electricity are from US EPA (2007). See Table 3.
5) 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 is based on usage patterns from AD Little (1998). Water cooler CLF is 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. Projected Annual savings in 2009

Program	Equipment Type	Primary Savings	Energy Bill Savings, Discounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2007	MtC		GW
Office Equipment	- Computers	80.0	718	1.4	1.19	0.772
	- Monitors	324.4	2,825	5.7	1.75	2.878
	- Faxes	4.3	40	0.1	1.00	0.033
	- Copiers	39.5	339	0.7	4.61	0.116
	-Multifunction Devices	29.8	257	0.5	0.97	0.318
	- Scanners	10.2	91	0.2	0.76	0.142
	- Printers	131.3	1,151	2.3	3.69	0.452
	Subtotal	**619.6**	**5,422**	**11.0**	**1.57**	**4.711**
Consumer Electronics	- TVs	90.9	869	1.6	1.00	0.965
	-VCRs	4.7	45	0.1	1.00	0.050
	-TV/VCR/DVD	16.0	153	0.3	1.00	0.170
	-DVD Player	13.2	126	0.2	1.00	0.140
	-Audio Equipment	12.8	122	0.2	1.00	0.135
	-Telephony	17.7	169	0.3	1.00	0.187
	-Digital TV Adapter	2.2	21	0.0	0.69	0.034
	-Set-top Box	4.5	43	0.1	1.00	0.048
	-External Power Supplies	53.0	480	0.9	1.00	0.563
	-Battery Charging Systems	1.3	12	0.0	1.00	0.014
	Subtotal	**216.1**	**2,041**	**3.8**	**1.00**	**2.292**
Heating & Cooling	- Furnace (Gas or Oil)	59.1	684	0.9	-	-
	- Central Air Conditioner	37.1	355	0.7	0.15	2.626
	- Air-Source Heat Pump	30.6	293	0.5	0.15	0.792
	- Geothermal Heat Pump	14.6	140	0.3	0.15	0.119
	- Boiler (Gas or Oil)	12.1	189	0.2	-	-
	- Programmable Thermostat	33.3	393	0.5	0.15	0.000
	- Unitary HVAC	53.1	455	0.9	0.15	3.758
	Subtotal	**239.9**	**2,508**	**4.0**	**0.18**	**7.295**
Res and Com Lighting	- Fixtures	110.6	1,058	2.0	1.02	1.147
	- CFLs	655.4	6,269	11.6	1.02	6.793
	- Exit Sign	4.1	35	0.1	1.00	0.043
	- Decorative Light Strands	3.6	34	0.1	1.02	0.037
	- Traffic Signal	9.8	84	0.2	1.00	0.104
	Subtotal	**783.5**	**7,480**	**13.8**	**1.02**	**8.124**
Residential Appliances	- Room Air Conditioners	22.4	214	0.4	0.15	1.583
	- Dehumidifiers	7.8	75	0.1	0.51	0.163
	- Air Cleaners	6.4	62	0.1	1.00	0.068
	- Exhaust Fans	1.9	18	0.0	1.02	0.019
	- Ceiling Fans	1.5	15	0.0	1.02	0.016
	- Dishwashers	45.4	466	0.8	0.77	0.448
	- Refrigerators	30.7	294	0.5	0.95	0.342
	- Clothes Washers	48.9	497	0.8	0.65	0.603
	Subtotal	**165.1**	**1,640**	**2.8**	**0.46**	**3.242**
Commercial Appliances	- Water Coolers	14.2	122	0.3	0.70	0.227
	- Commercial Refrigeration	6.6	57	0.1	0.95	0.073
	- Hot Food Holding Cabinets	0.0	0	0.0	0.95	0.000
	- Fryers	0.1	1	0.0	0.95	0.002
	- Steamers	0.0	0	0.0	0.95	0.000
	- Ice Machines	0.3	3	0.0	0.95	0.003
	- Dishwashers	0.5	5	0.0	0.95	0.004
	- Vending Machines	4.1	35	0.1	0.95	0.046
	Subtotal	**25.9**	**223**	**0.5**	**0.76**	**0.355**
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	2.0	17	0.0	0.15	0.265
	- Commercial Roofing	29.0	236	0.5	0.15	2.999
	Subtotal	**32.0**	**262**	**0.6**	**0.15**	**3.278**
TOTAL		**2,082.2**	**19,575**	**36.5**	**0.74**	**29.260**

Notes to Table 7:
1) Columns may not total due to rounding.
2) Electricity is converted to primary energy using electricity heat rates as shown in Table 3.
3) Energy bills are calculated using yearly U.S. average energy prices. See Table 3.
4) Carbon emissions for electricity are from US EPA (2007). See Table 3.
5) 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 is based on usage patterns from AD Little (1998). Water cooler CLF is 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).

Through 2007, ENERGY STAR labeled products saved 7.1 Quads of primary energy, $65 billion dollars in energy bills, and avoided 128 MtC through its voluntary program efforts (**Table 8**). Although ENERGY STAR labeled products encompass over forty product types, only five of those product types accounted for 60% of all ENERGY STAR carbon reductions achieved to date. Those product types are as follows (ranked by total carbon avoided through 2007):

- Monitors: 38.4 MtC (30% of total)
- CFLs: 19.9 MtC (16% of total)
- Printers: 12.3 MtC (10% of total)
- Residential light fixtures: 5.4 MtC (4% of total)
- TVs: 4.9 MtC (4% of total)

Over the period 2008 to 2015[7], ENERGY STAR labeled products are projected to save 21.2 Quads of primary energy, $172 billion dollars in energy bills (4% discount rate), and avoid 375 MtC. For reference, these carbon savings represent 6.4% of the projected U.S. carbon emissions for the residential and commercial building sectors over this period (US DOE 2008). The following five product types account for 66% of future carbon avoided:

- CFLs: 135.6 MtC (36% of total)
- Monitors: 42.8 MtC (11% of total)
- Printers: 23.8 MtC (6% of total)
- Residential light fixtures: 22.9 MtC (6% of total)
- Computers: 21.7 MtC (6% of total)

[7] We chose to present results for the period 2008 to 2015 even though the model results extend through 2025. We decided on this projected time frame to minimize the uncertainty associated with such a long forecast period.

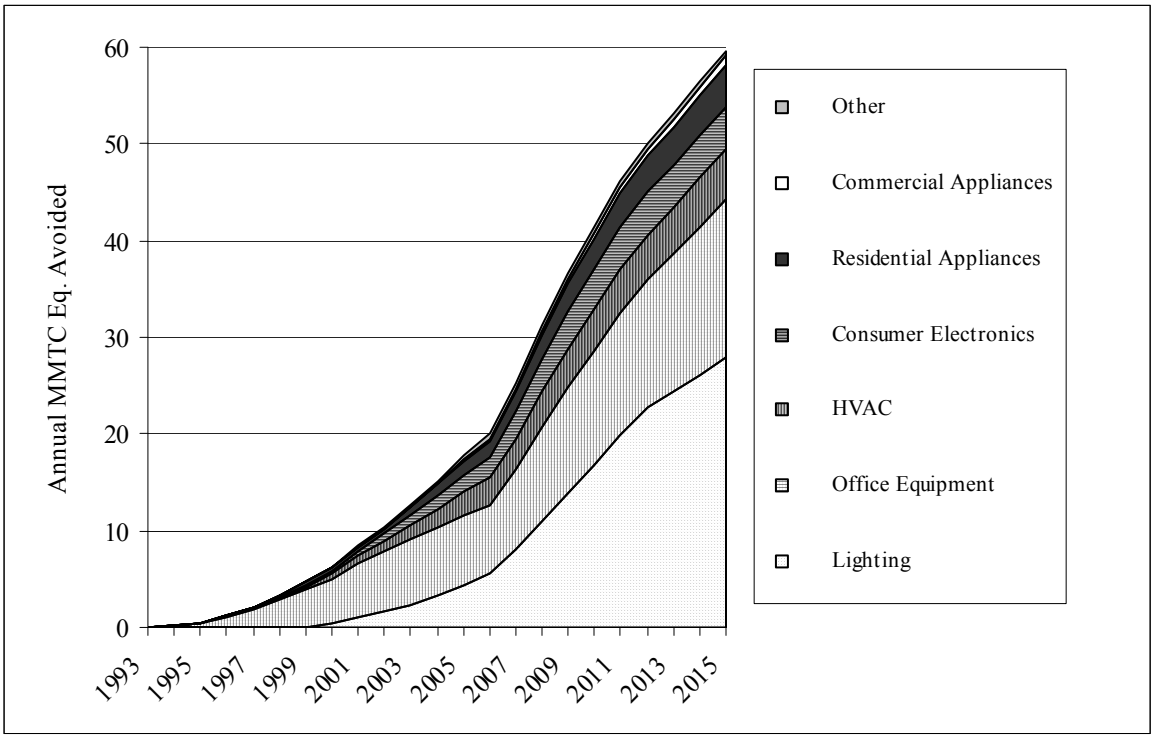
Table 8. Cumulative Savings (1993-2015)

Savings Analysis Period		Achieved Savings through 2007[1]			Projected Savings 2008-2015[1]		
Program		Primary Energy Savings[2]	Disc Energy Bill Savings[3]	Carbon Avoided[4]	Primary Energy Savings[2]	Disc Energy Bill Savings[3]	Carbon Avoided[4]
		Trillion Btu	Million $2007	MtC eq.	Trillion Btu	Million $2007	MtC eq.
Office Equipment	- Computers	2222	1,968	4.0	1,220	9,062	21.7
	- Monitors	2,101	17,835	38.4	2,407	18,352	42.8
	- Fax	48	425	0.9	39	320	0.7
	- Copier	174	1,469	3.2	344	2,539	6.1
	-Multifunction Device	173	1,442	3.2	428	3,052	7.6
	- Scanner	76	656	1.4	76	599	1.4
	- Printer	675	5,818	12.3	1,336	9,966	23.8
	Subtotal	**3,468**	**29,613**	**63.4**	**5,850**	**43,889**	**104.1**
Consumer Electronics	- TVs	269	2,532	4.9	845	7,084	15.0
	-VCRs	93	852	1.7	14	132	0.2
	-TV/VCR/DVD	84	777	1.5	137	1,155	2.4
	-DVD Player	55	520	1.0	105	890	1.9
	-Audio Equipment	56	526	1.0	96	818	1.7
	-Telephony	33	317	0.6	145	1,228	2.6
	-Digital TV Adapters	0	0	0.0	9	78	0.2
	-Set-top Box	0	1	0.0	192	1,506	3.4
	-External Power Supplies	32	303	0.6	323	2,653	5.7
	-Battery Charging Systems	0	4	0.0	17	141	0.3
	Subtotal	**624**	**5,832**	**11.3**	**1,883**	**15,684**	**33.5**
Heating & Cooling	- Furnace (Gas or Oil)	285	3,225	4.3	530	5,218	8.0
	- Central Air Conditioner	139	1,305	2.5	357	2,979	6.4
	- Air-Source Heat Pump	102	965	1.8	291	2,429	5.2
	- Geothermal Heat Pump	16	158	0.3	194	1,581	3.4
	- Boiler (Gas or Oil)	56	778	1.0	114	1,479	2.1
	- Programmable Thermostat	188	2,056	3.0	241	2,497	3.9
	- Light commercial HVAC	95	824	1.7	413	3,064	7.3
	Subtotal	**881**	**9,311**	**14.8**	**2,140**	**19,247**	**36.2**
Lighting	- Fixtures	298	2,800	5.4	1,285	10,572	22.9
	- CFLs	1,105	10,471	19.9	7,630	62,916	135.8
	- Exit Sign	33	275	0.6	19	149	0.3
	- Decorative Light Strand	0	0	0.0	160	1,256	2.9
	- Traffic Signal	49	417	0.9	49	390	0.9
	Subtotal	**1,485**	**13,963**	**26.8**	**9,142**	**75,284**	**162.7**
Residential Appliances	- Room Air Conditioners	75	701	1.4	224	1,863	4.0
	- Dehumidifiers	12	111	0.2	85	703	1.5
	- Air Cleaners	6	62	0.1	90	737	1.6
	- Exhaust Fans	4	35	0.1	21	170	0.4
	- Ceiling Fans	4	42	0.1	13	107	0.2
	- Dishwashers	107	1,097	1.8	366	3,277	6.2
	- Refrigerators	106	983	1.9	352	2,903	6.3
	- Clothes Washers	197	1,981	3.4	446	3,919	7.6
	Subtotal	**510**	**5,013**	**8.9**	**1,596**	**13,678**	**27.7**
Commercial Appliances	- Water Coolers	28	242	0.5	152	1,105	2.7
	- Commercial Refrigeration	6	55	0.1	50	371	0.9
	- Hot Food Holding Cabinets	0	0	0.0	1	6	0.0
	- Fryers	0	2	0.0	2	12	0.0
	- Steamers	0	0	0.0	1	4	0.0
	- Ice Machines	0	0	0.0	13	89	0.2
	- Dishwashers	0	0	0.0	22	162	0.4
	- Vending Machines	3	23	0.0	70	490	1.2
	Subtotal	**37**	**322**	**0.7**	**311**	**2,238**	**5.5**
Other	- Utility Transformers	1	5	0.0	0	4	0.0
	- C&I Transformers	4	34	0.1	8	57	0.1
	- Residential Roofing	3	24	0.1	24	177	0.5
	- Commercial Roofing	114	929	2.2	224	1,612	4.2
	Subtotal	**122**	**991**	**2.3**	**256**	**1,851**	**4.8**
TOTAL		**7,128**	**65,043**	**128.1**	**21,179**	**$171,870**	**374.5**

Notes to Table 8:
1) Columns may not total due to rounding.
2) Electricity is converted to primary energy using a conversion factor listed in Table 3
3) Disc = discounted, energy bills are calculated using yearly U.S. average energy prices (Table 3) and are discounted at 4%
4) Carbon emissions for electricity are listed in Table 2.

Figure 2 shows the allocation of ENERGY STAR labeled product savings across the seven categories. Annual savings are estimated to increase from 0.1 MtC in 1993 to 31.3 MtC in 2008. We project annual savings will increase to 59.6 MtC in 2015. The results show the critical importance of the office equipment and lighting product categories to overall ENERGY STAR product savings. In 2007, ENERGY STAR office equipment and lighting together avoided 16.3 MtC or 65% of total annual carbon reductions for ENERGY STAR labeled products. We expect carbon reductions for ENERGY STAR office equipment and lighting to grow to 44.2 MtC in 2015, representing 74% of total annual carbon reductions. Maintaining the relevance of the ENERGY STAR brand for office equipment and lighting will likely be a key indicator of program impact in the future.

Figure 2. Carbon Savings for ENERGY STAR labeled products (1993-2015)



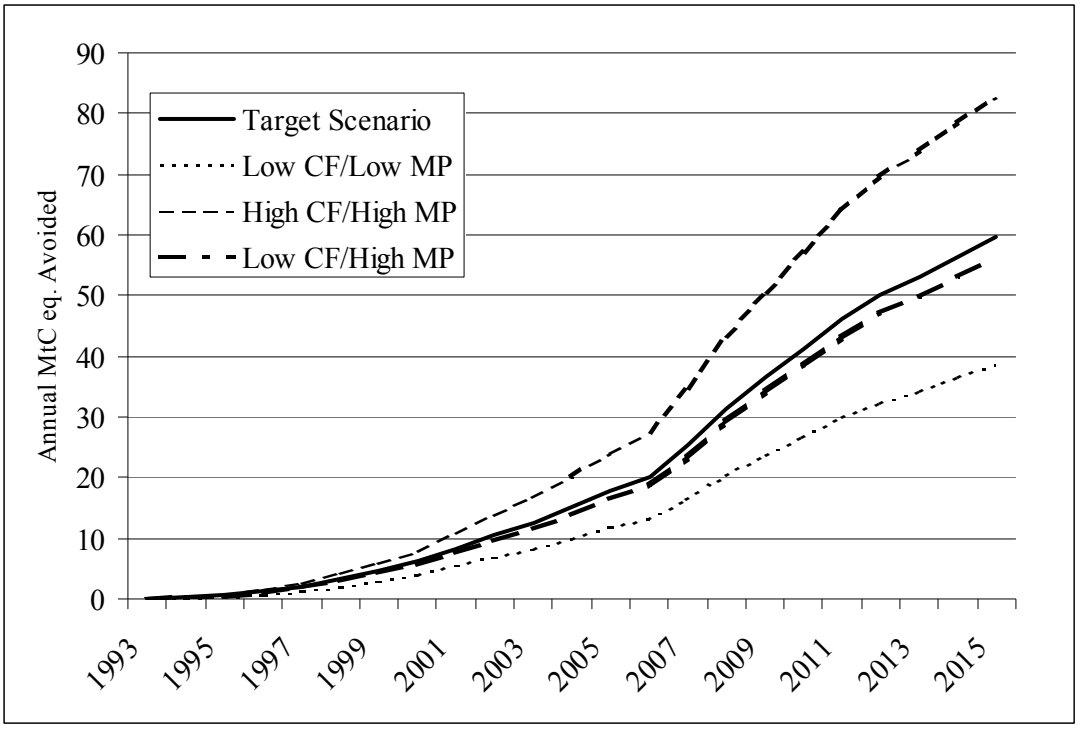
5.2 Sensitivity Analysis

One method of addressing the uncertainty inherent in the model is to bracket the projected "best estimate" savings by varying key inputs that globally affect the model results. We examined the sensitivity of the best-estimate carbon reductions under the following scenarios for the periods 1993 to 2007 and 2008 to 2015:

- the marginal carbon factor for electricity was reduced by 20%, ENERGY STAR sales were reduced by 20% (low CF/low MP)
- the marginal carbon factor for electricity was increased by 20%, ENERGY STAR sales were increased by 20% (high CF/high MP)
- the marginal carbon factor for electricity was reduced by 20% and ENERGY STAR sales were increased by 20% (low CF/high MP)

Figure 3 illustrates the results of this sensitivity analysis. These results bound the best estimate of carbon avoided between 84 MtC and 172 MtC for the period 1993-2007 and between 243 MtC and 519 MtC for the period 2008-2015. The fluctuation in ENERGY STAR unit sales, fuel supply, fuel demand, and fuel mix are highly difficult to predict and model over the twenty-three year analysis period. However, even in a "worst case" scenario, the analysis shows substantial reductions in carbon achieved by ENERGY STAR labeled products.

Figure 3. Sensitivity Analysis of Carbon Savings (1993-2025)



6. Limitations to the Analysis

The analysis is based on a bottom-up model for quantifying US EPA ENERGY STAR labeled product savings. General limitations to a bottom-up approach occur in two main areas: 1) the model requires numerous detailed inputs to generate the end result and; 2) uncertainty in those inputs are additive through the process. These limitations mean that

collecting and documenting high-quality inputs is essential, which can be a labor-intensive and expensive process. As a result, identifying areas of critical uncertainty and sensitivity and then targeting data collection and verification activities at those areas is key to successful results. We generalize specific limitations to three main areas: forecasting, inputs, and model structure as shown in **Table 9**.

Table 9. Limitation to Analysis

Forecasting	Inputs	Model Structure
1. Projecting future ENERGY STAR unit sales 2. Projecting key global inputs (energy prices, electricity heat rates, carbon emission factors) 3. Projecting changes in business as usual efficiency 4. Identifying and incorporating emerging or new technologies	1. UECs based on underlying power and usage patterns that can vary within a product type or at the consumer, organization, or regional level 2. UECs represent a national average only 3. Power and usage data often based on a smaller and regionally based sample (particularly in the case of office equipment and consumer electronics) 4. Power and usage change over time and need to be tracked consistently	1. Only includes finalized ENERGY STAR specifications and national energy efficiency standards 2. Attributes all savings to US EPA and does not reconcile ENERGY STAR savings with supporting utility and procurement programs 3. Does not rigorously capture new/emerging technologies and its effect on baseline efficiency and ENERGY STAR savings 4. Model is reactive rather than active, meaning that the model is updated subsequent to a technology market changing

7. Conclusions

Since the program inception in 1992, ENERGY STAR has become a leading international brand for energy efficient products. As such, ENERGY STAR achievements to date and projected savings have a critical impact on the success of both US and international energy efficiency programs. This report summarizes energy, carbon, and monetary impacts from US EPA's ENERGY STAR voluntary product labeling program. Regional, national and international stakeholders can use these results to evaluate energy efficiency opportunities associated with the ENERGY STAR program. US EPA's ENERGY STAR labeled products has been successful in reducing carbon emissions through its voluntary labeling efforts. Through 2007, the program saved 7.1 Quads of primary energy and avoided 128 MtC equivalent. The forecast shows that the program is expected to save 21.2 Quads of primary energy and avoid 375 MtC equivalent over the period 2008-2015. The sensitivity analysis bounds the best estimate of carbon avoided between 84 MtC and 172 MtC (1993 to 2007) and between 243 MtC and 519 MtC (2008 to 2015).

Much of the program's success to date is attributable to ENERGY STAR office equipment and lighting. The analysis demonstrates the continued importance of these product categories toward realizing future ENERGY STAR program goals. Strategies for continued success include maintaining program relevance through tightened

specifications, exploring new approaches to improving a product's energy performance including new technologies and market trends, and broadening the portfolio of office equipment products covered by the ENERGY STAR program.

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