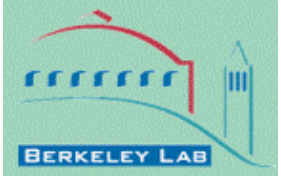

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Calendar Year 2009 Program Benefits for ENERGY STAR Labeled Products

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November 15, 2010

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Disclaimer

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Figures and Tables

Executive Summary

ENERGY STAR is a voluntary energy efficiency labeling program operated jointly by the Environmental Protection Agency (US EPA) and the U.S. Department of Energy (US DOE), designed to identify and promote energy-efficient products, buildings and practices. Since the program inception in 1992, ENERGY STAR has become a leading international brand for energy efficient products, and currently labels more than thirty products, spanning office equipment, heating, cooling and ventilation equipment, commercial and residential lighting, home electronics, and major appliances. 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 stakeholders. This report presents savings estimates from the use ENERGY STAR labeled products. We present estimates of energy, dollar, and carbon savings achieved by the program in the year 2009, annual forecasts for 2010 and 2011, and cumulative savings estimates for the period 1993 through 2009 and cumulative forecasts for the period 2010 through 2015. Through 2009 the program saved 9.5 Quads of primary energy and avoided the equivalent of 170 million metric tons carbon (MMTC). The forecast for the period 2009-2015 is 11.5 Quads or primary energy saved and 202 MMTC emissions avoided. The sensitivity analysis bounds the best estimate of carbon avoided between 110 MMTC and 231 MMTC (1993 to 2009) and between 130 MMTC and 285 MMTC (2010 to 2015).

1. Introduction

ENERGY STAR is a voluntary labeling program operated jointly by the US Environmental Protection Agency (US EPA) and US Department of Energy (US DOE). These agencies enter into partnership agreements with manufacturers and key stakeholders to promote products that meet certain energy-efficiency and performance criteria established by the agencies. By encouraging the adoption of high efficiency products and contributing to transformation of markets DOE and EPA reduce air pollution and greenhouse gases associated with the consumption of energy. Since its inception in 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. For a more detailed description of the ENERGY STAR program, refer to McWhinney et al. (2005) and Brown et al. (2002).

As part of its technical support to the Energy STAR program LBNL has compiled power, usage and market characteristics of the products covered by ENERGY STAR, and created a model which calculates measures of program impact, including energy savings, greenhouse gas reduction, fiscal impact, and measures of market penetration. In the present report we address the following questions:

- How are ENERGY STAR impacts quantified?
- What are the ENERGY STAR achievements?
- How do the current savings estimates compare to previous reports?
- What are the limitations to our method?

This paper presents current and projected savings for ENERGY STAR labeled products, and details the status of the model as implemented in the September 2009 spreadsheets.

2. Study Scope

ENERGY STAR consists of four programmatic areas: products, buildings (including 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, and does not cover savings for buildings and industrial plants, new homes, or home performance. The methodologies for quantifying savings for the buildings and homes program segments are significantly different than the methodology for EPA labeled products. We cannot address these additional methodologies and results with the necessary detail within the scope of this report. See Horowitz (Horowitz, M. 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. In the model products are added in the year the specification becomes effective, if the effective date is before July 1, otherwise in the first full year the specification is in force. The full eligibility requirements for each product can be found at www.energystar.gov.

Table 1. Summary of ENERGY STAR product specifications

Specification Effective Dates	Initial	Revisions
Product types included in analysis		
Audio and DVD [1,2]	1999	2003, 2009
Battery charging systems	2006	
Boilers	1996	2002
CAC/ASHP[2]	1995	2002, 2006, 2009
Ceiling fans	2002	2003, 2006
CFL	1999	2001, 2004, 2008
Commercial dishwasher	2007	
Commercial fryers	2003	
Commercial Griddles	2009	2011
Commercial hot food holding cabinets	2003	
Commercial Ovens	2009	
Commercial solid door refrigerators and freezers	2001	2009
Commercial steam cookers	2003	
Computers	1992	1995, 1999, 2000, 2007, 2009
Copiers	1995	1997, 1999, 2007, 2009
Decorative light strands	2008	
Dehumidifiers	2001	2006, 2007, 2008
Digital TV Adapters	2007	
Displays	1992	1995, 1998, 1999, 2005, 2006
Exit signs[3]	1996	1999, 2004
External power adapters	2005	
Facsimile	1995	
Furnaces	1995	2006, 2009
Geothermal HP[2]	1995	2001
Ice machines	2008	
Light commercial HVAC[2]	2002	2004
Multifunction devices	1997	1999, 2007, 2009
Printers	1993	1995, 2000, 2001, 2007, 2009
Programmable thermostats[3]	1995	*2008
Professional Displays	2009	
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
Servers	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		
Buildings and industrial plants	1991	1995, 1999, 2000, 2001, 2002, 2004, 2006
Home performance	2000	2002
Insulation[3]	1995	*2002
New homes	1995	1997, 2006
Windows, doors, and skylight	1997	2003, 2005, 2009

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 "*". In the case of Set-top boxes the specification was suspended in 2004 and then re-launched in 2009.
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 model 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. The model can report these indicators on an annual basis and can generate cumulative results over selectable time periods. In this report, we present annual results for energy savings, peak load savings, carbon savings and monetary savings for calendar year 2009, and forecasts for 2010, and 2011. We present cumulative results for energy savings, carbon savings, and monetary savings over the period 1993-2009. Although the model results extend through 2025, we present cumulative forecasts for energy savings, carbon savings, and monetary savings over the period 2009-2015 to minimize the 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 forecasts of national savings achieved by ENERGY STAR voluntary product labeling summarized at a high level but does not attempt to attribute the national savings to specific 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 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. The bottom-up model allows us to separately evaluate the implementation process for each product or equipment type and quantify to ENERGY STAR's impact within each market. In addition, ENERGY STAR specifications are often a key component of many regional energy efficiency efforts, and the bottom-up model allows ENERGY STAR to distribute product data that can be of use to 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 input data are regularly updated, we put extra effort into updating the inputs for two product categories: 1) office equipment, because of the large energy savings potential, and 2) consumer electronics, where usage patterns are more uncertain and new field data are emerging (Nordman and McMahon, 2004; Porter et al. 2006; Roth and McKenny, 2007).

Where other organizations have collected market or engineering data pertaining to ENERGY STAR product types, we integrate that data into our inputs as applicable. We also work with the US DOE's Energy Information Administration (US EIA) to harmonize inputs into our model with the National Energy Modeling System (NEMS), which is used to generate national energy forecasts at both the sector and end-use level. We also share with other organizations our 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 those that could meet the ENERGY STAR performance requirement criteria and those that do not. We obtain estimates of total U. S. sales for each product from industry reports and ENERGY STAR unit sales data are obtained from manufacturer and retail partners. Partners report ENERGY STAR unit sales to the respective program agencies[1] each calendar year[2] either directly or through trade organizations such as CEA or AHRI. Shipments of EPA labeled products are compiled annually for EPA by ICF Consulting (ICF 2003, 2004, 2006a, 2006b, 2007, 2008, 2009, 2010). EPA labeled products for which partners reported ENERGY STAR sales in 2008 are listed in T**able 2**.

Table 2. EPA ENERGY STAR Products with Partner Reported Shipment Data

• Audio/DVD Products	• Battery Charging Systems
• Boilers	• Ceiling Fans
• Central Air Conditioners and Air-Source Heat Pumps	• Commercial Dishwashers
• Commercial Fryers	• Commercial Griddles
• Commercial Hot Food Holding Cabinets	• Commercial Ice Machines
• Commercial Ovens	• Commercial Refrigerators and Freezers
• Commercial Steam Cookers	• Compact Florescent Lamps (CLFs)
• Computers	• Decorative Light Strings (DLS)
• Dehumidifiers	• Digital-to-Analog Converters (DTAs)
• External Power Supplies and End-Use Products with Qualified EPS	• Furnaces
• Geothermal Heat Pumps	• Imaging Equipment
• Light Commercial HVAC	• Monitors
• Residential Light Fixtures (RLF)	• Roof Products
• Room Air Cleaners	• Set-Top Boxes
• Solid State Luminaires (SSL)	• Telephony
• TVs/VCRs	• Vending Machines
• Ventilating Fans	• Water Coolers
• Water Heaters	

Source: ICF, 2009

Unit sales for any EPA labeled products not reported by partners are LBNL estimates based on market research reports and industry estimates.

Non-ENERGY STAR unit sales are estimated as the difference between total US unit sales and ENERGY STAR unit sales. **Table 3** shows actual ENERGY unit sales for 2009 and projected ENERGY STAR unit sales for 2010.

Table 3. ENERGY STAR Market Shares for 2009 and projections for 2010

Equipment Type	**Actual 2009**			**Projected 2010**		
	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	149	191	78%	42	170	25%
-Office Facsimile	65	945	7%	32	917	3%
-Office Printers	2,499	3,731	67%	835	3,341	25%
-Office Scanners	121	125	97%	42	97	43%
-Office Multi-function Devices	7,892	16,536	48%	4,118	16,473	25%
-Office CRTs	0	0	NA	0	0	NA
-Office LCDs	17,003	18,859	90%	4,648	18,591	25%
-Office PCs	14,166	29,618	48%	4,182	29,778	14%
-Servers	40	1,950	2%	41	1,985	2%

[1] Through 2008 labeled products were divided between US EPA and DOE. Starting in 2009 EPA will track all ENERGY STAR labeled products.

[2] ENERGY STAR unit sales data have been collected from manufacturer partners as part of the ENERGY STAR Program requirements for calendar years 2002-2009 (ICF 2003, 2004, 2006a, 2006b, 2007, 2008, 2009, 2010). ENERGY STAR sales data for earlier years and subsequent forecast years are based from industry and market data. The DOE-labeled product dishwashers, clothes washers, room A/C and CFLs have sales data complied by D&R International, and are available from ENERGY STAR. Starting in 2009 the DOE-labeled products are being transferred to EPA.

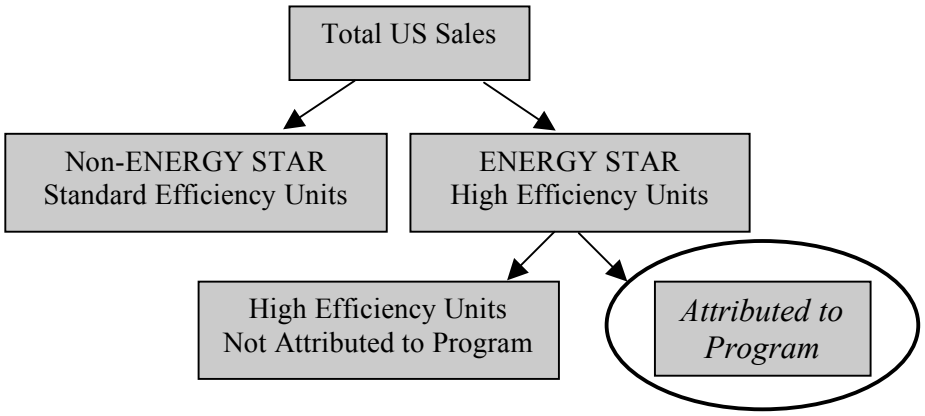
Equipment Type	Actual 2009			Projected 2010		
-Professional Displays PDP	0	614	0%	233	777	30%
-Professional Displays LCD	0	1,549	0%	1,458	2,916	50%
Home Office Equipment						
-Residential Copiers	0	0	NA	0	0	NA
-Residential Facsimile	191	2,755	7%	93	2,672	3%
-Residential Printers	1,964	2,932	67%	594	2,376	25%
-Residential Scanners	295	304	97%	103	237	43%
-Residential CRTs	0	0	NA	0	0	NA
-Residential LCDs	9,445	10,476	90%	2,403	9,613	25%
-Residential PCs	22,415	35,806	63%	10,438	39,579	26%
Home Electronics						
-DPFs	0	9,868	0%	1,498	13,618	11%
-TVs	43,316	45,316	96%	10,444	42,982	24%
-VCRs	0	460	0%	0	299	0%
-TV-VCRs	0	1,743	0%	0	1,736	0%
-DVD Players	22,576	28,114	80%	7,943	31,771	25%
-Mini-Systems	163	1,556	10%	40	1,603	3%
-Home Theater	1,815	3,143	58%	473	3,202	15%
-Audio Separates	1,126	2,048	55%	256	1,707	15%
-CD Players	131	175	75%	33	154	21%
-Answering Machines	0	0	NA	0	0	NA
-Cordless Phones	4,193	6,088	69%	4,172	6,027	69%
-DSS Cordless Phones	4,502	6,537	69%	4,547	6,570	69%
-Combo Phones	632	807	78%	629	802	78%
-DSS Combo Phones	11,391	14,530	78%	11,505	14,602	79%
-Additional Handsets	377	604	62%	374	598	62%
-DTAs	1,282	17,000	8%	0	1,500	0%
-Set-top Boxes	14,924	29,890	50%	16,073	31,116	52%
-External Power Supplies	394,429	670,150	59%	453,593	740,152	61%
-Battery Charging Systems	11,220	42,085	27%	11,388	42,506	27%
Residential Appliances						
-Clothes Washers	3,775	7,865	48%	2,000	8,000	25%
-Dishwashers	3,624	5,330	68%	2,692	5,383	50%
-Refrigerators	2,939	8,397	35%	2,983	8,481	35%
-RACs	2,083	5,786	36%	2,135	5,844	37%
-Dehumidifiers	1,346	1,642	82%	1,376	1,670	82%
-Air Cleaners	500	2,631	19%	540	2,697	20%
-Exhaust Fans	1,090	6,511	17%	1,125	6,588	17%
-Ceiling Fans Only	1,266	7,812	16%	1,279	7,864	16%
-Ceiling Fan with Light Kit	219	10,121	2%	241	10,198	2%
-Light Kit for Ceiling Fan	61	2,183	3%	68	2,199	3%
Commercial Appliances						
-Vending Machines	45	246	18%	46	246	19%
-Hot Food Holding Cabinet	22	30	75%	22	29	75%
-Steamers	6	22	28%	6	22	29%
-Fryers	11	91	12%	11	93	12%
-Commercial Refrigeration	155	292	53%	69	291	24%
-Water Coolers	575	1,328	43%	633	1,454	44%
-Ice Machines	60	142	42%	62	146	42%
-Dishwashers	29	37	78%	29	37	78%
-Ovens	15	221	7%	15	223	7%
-Griddles	1	15	5%	1	15	6%
HVAC						
-Air Source Heat Pump	519	1,642	32%	527	1,658	32%
-Geothermal Heat Pump	74	125	59%	75	129	59%
-Central Air Conditioner	614	3,516	17%	644	3,551	18%
-Gas Furnace	1,095	2,175	50%	1,111	2,209	50%
-Oil Furnace	13	56	24%	14	55	25%
-Gas Boiler	88	192	46%	89	192	46%
-Oil Boiler	76	122	62%	77	122	63%
-Unitary HVAC	279	759	37%	299	769	39%
-Thermostats	2,668	6,682	40%	2,791	6,756	41%
Lighting						
-Indoor Fixtures	12,934	165,566	8%	13,257	165,483	8%
-Outdoor Fixtures	7,868	29,194	27%	8,064	29,486	27%
-All Fixtures	20,801	194,759	11%	21,321	194,969	11%
-Exit Signs	0	4,115	0%	0	4,165	0%

Equipment Type	Actual 2009			Projected 2010		
-CFLs	252,137	1,703,000	15%	251,525	1,679,820	15%
-DLSs	23,549	106,662	22%	31,808	107,875	29%
-Traffic Signals	0	8,840	0%	0	8,840	0%
Other						
-Utility Transformers	0	1,465	0%	0	1,494	0%
-C&I Transformers	0	277	0%	0	280	0%
-Residential Roofing	1	5	15%	1	5	15%
-Commercial Roofing	4	16	26%	4	16	26%

Notes to Table 3:
1) 2009 ENERGY STAR units are from ICF (2009) with the exception of clothes washers, dishwashers, RAC, and refrigerators which are from D&R International.
2) ENERGY STAR exit signs, traffic signals, and transformers are discontinued; however, program savings continue to accrue due to units in the existing stock.
3) Residential PCs include desktops, laptops. and video games. The video game spec is current suspended so there are no current year savings.
4) Office PCs include desktops, laptops, workstations, thin clients and small servers. The last two currently have no shipments.
5) Unitary HVAC is expressed in million square feet
6) Roofing is expressed in billion square feet
7) Projected 2010 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

Having segmented the total shipments into units that meet the ENERGY STAR requirements and those that do not, the units meeting the ENERGY STAR criteria are further divided into those that would have been sold even without the program -"business as usual" (BAU) high efficiency units- and those that can be attributed to the program. The estimated sales of BAU high efficiency units are a forecast based on our market share analysis of models of each product type that met the performance requirements of the ENERGY STAR specification prior to the specification's effective date. This analysis is based on energy consumption test results for individual product models that are submitted by partner manufacturers to EPA and DOE during the ENERGY STAR product specification development process. Performance results in the test dataset are compared to the applicable ENERGY STAR performance metric and the BAU penetration rate is calculated as the ratio of the number of models in the test dataset that meet ENERGY STAR requirements and the total number of models in the dataset. ENERGY STAR savings include only the savings for ENERGY STAR units directly attributable to the program. Figure 1 illustrates the sales segmentation.

Figure 1. Market segmentation of ENERGY STAR products



The model also tracks that a portion of the BAU high efficiency units may be made by ENERGY STAR partners, and so carry the ENERGY STAR label. Since these "free rider" units do not contribute to the savings estimates, this part of the market segmentation is not described here in detail.

Unit energy consumption values (UEC) are developed for both non-ENERGY STAR (standard efficiency) and ENERGY STAR (high-efficiency) units. The method used to calculate the UEC for each product falls into one of three general categories: (1) mode-based, (2) duty cycle and (3) exogenous

annual UEC based. Mode-based products have multiple operational modes. The most common operational modes are active, idle, sleep or off. Each mode is characterized by a power level and a usage pattern: the amount of time the device spends in that mode. Total annual energy is the summation of the annual modal energy consumptions. Duty-cycle products typically do not have differentiated operational modes and their annual energy consumption is calculated from detailed power and usage inputs. Exogenous annual UEC products are those whose annual consumption is a single value (with no details on product power and usage) taken from a source outside the model, such as third party metering or other research. **Table 4** summarizes the UEC calculation method for the included products.

Table 4. Summary of UEC Methodology by Product

Program	Product	Electronic Modal	Duty Cycle	Exogenous Annual UEC
Office Equipment	Computers	**X**		**X**
	Servers	**X**		
	Displays	**X**		
	Imaging (Inkjet or Laser: printer fax, scanner, copier, MFD)	**X**		**X**
	Professional Displays	**X**		
Consumer Electronics	Digital Picture Frames	**X**		
	TVs	**X**		
	VCRs	**X**		
	TV/VCR/DVD	**X**		
	DVD Player	**X**		
	Audio Equipment (audio separates)			**X**
	Audio Equipment (mini-system, HTIB, CD)	**X**		
	Telephony	**X**		
	Digital TV Adapter	**X**		
	Set-top Box (cable, satellite, IP)			**X**
	External Power Supplies	**X**		**X**
	Battery Charging Systems	**X**		**X**
Heating & Cooling	Furnace, Boiler, CAC, AS & GeoHP, lt. Com. HVAC, Thermostat			**X**
Lighting	Fixtures, Exit sign, DLS, Traffic signal, CFL		**X**	
Residential Appliances	Room Air Conditioners		**X**	
	Dehumidifiers		**X**	
	Air Cleaners		**X**	
	Exhaust Fans			**X**
	Ceiling Fans			**X**
	Dishwashers		**X**	
	Refrigerators		**X**	
	Clothes Washers		**X**	
Commercial Appliances	Water Coolers			**X**
	Commercial Refrigeration (refrigerators, freezers)			**X**
	Hot Food Holding Cabinets		**X**	
	Fryers		**X**	
	Steamers		**X**	
	Ice Machines		**X**	
	Dishwashers		**X**	
	Vending Machines		**X**	
	Griddles		**X**	
	Ovens		**X**	
Other	C&I, Utility Transformers		**X**	
	Residential and Commercial Roofing			**X**

Notes to table 4:
1) External power supply and battery charger are categorized as electronic modal, duty-cycle, or exogenous annual UEC, depending on what equipment attaches to them.
2) Inkjet technology is electronic modal-based, and laser technology is exogenous annual UEC-based.
3) Set-top box cable and satellite used an electronic modal calculation from 2001 through 2005 when the program was suspended. The specification was revised in 2009, at which point the calculation became exogenous annual UEC-based. DTA is electronic modal-based.

Having estimated UECs for both standard and high efficiency units, we create BAU and ENERGY STAR forecasts. The BAU forecast is comprised of standard efficiency (units that do not meet the ENERGY STAR requirement) and high efficiency units (those that meet or exceed ENERGY STAR requirement but are not attributable to the program). The BAU forecast 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 due to changing rates in

the market share of standard efficiency or high efficiency non-ENERGY STAR units. The ENERGY STAR forecast is based on the specification criteria for the current year. We typically do not claim program savings beyond the criterion level for qualifying (and participating) units that exceed the specification.

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 change over time due to ENERGY STAR specification revisions, usage pattern changes, changes to the BAU efficiency or changes in the penetration rate of BAU high efficiency units. 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 5**. Energy bill savings are discounted at a four percent real discount rate. Carbon emissions reductions are calculated from energy savings using fuel specific carbon emissions factors. Carbon emission reductions for electricity are estimated using 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). Forecast marginal carbon factors for electricity are derived from energy efficiency scenario runs of the integrated utility dispatch model (IPM®) (US EPA 2007b). Carbon emission 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 5. Best estimate energy prices and carbon factors by year (2009 dollars)

Year	Cmcl. Elec Price	Res. Elec Price	Cmcl. Gas Price	Res. Gas Price	Oil Price	Price Sources	Elec. Carbon Emission Factor	Electric Heat Rate	Electric Heat Rate Sources
	$/kWh[2]	$/kWh[2]	$/MBtu	$/MBtu	$/MBtu	US DOE [3]	MMTC/ TWh[1]	Btu/kWh	US DOE [3]
1993	0.109	0.117	7.023	8.342	9.194	1996a	0.000	11,019	1996a
1994	0.108	0.116	7.351	8.603	8.737	1996b	0.203	10,948	1996b
1995	0.101	0.113	6.698	8.019	8.442	1997	0.203	10,970	1997
1996	0.100	0.110	6.945	8.153	9.321	1998	0.203	10,866	1998
1997	0.098	0.108	7.330	8.768	9.166	1999	0.203	10,978	1999
1998	0.096	0.105	6.920	8.527	7.907	2000	0.203	10,891	2000
1999	0.090	0.103	6.612	8.235	7.913	2000	0.203	10,784	2000
2000	0.090	0.101	8.041	9.385	11.710	2000	0.203	11,181	2000
2001	0.095	0.104	10.057	11.356	10.832	2000	0.203	11,030	2000
2002	0.093	0.100	7.722	9.120	9.764	2000	0.203	11,008	2000
2003	0.093	0.101	9.370	10.700	11.173	2000	0.203	10,997	2000
2004	0.092	0.101	10.321	11.769	14.153	2007	0.203	10,952	2007
2005	0.095	0.103	12.252	13.665	18.056	2008	0.203	10,861	2008
2006	0.100	0.110	12.294	14.159	19.083	2009	0.195	10,811	2009
2007	0.099	0.110	11.336	13.098	20.544	2010	0.190	10,802	2010
2008	0.105	0.115	12.086	13.642	24.756	2010	0.190	10,805	2010
2009	0.100	0.112	9.154	11.528	18.198	2010	0.190	10,876	2010
2010	0.094	0.107	8.775	11.019	17.780	2010	0.190	10,918	2010
2015	0.092	0.108	10.113	11.694	21.332	2010	0.190	10,727	2010
2020	0.094	0.110	10.477	12.095	24.381	2010	0.190	10,650	2010
2025	0.096	0.111	10.830	12.437	25.531	2010	0.190	10,543	2010

Notes to Table 4:

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 2009 dollars using implicit GDP deflators from the US Depart. of Commerce, Bureau of Economic Analysis.

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) 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. ENERGY STAR annual energy savings

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

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

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

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 MBtu)

L = product lifetime

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

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

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

LBNL has produced an expanded methodology description (Sanchez et al, 2009) which provides a higher level of detail regarding the shipment estimates, energy consumption and savings calculations, as well as detailed descriptions of the assumptions and data sources for each covered product.

A major change in the savings estimation method in this year's model is the removal of the "market transformation effect." In the past it had been assumed that units meeting previous ENERGY STAR levels continued to be in compliance with those previous levels despite no longer being labeled ENERGY STAR; that manufacturers did not change the design of these previously qualified products to be less efficient, therefore the ENERGY STAR program was attributed savings at a UES equivalent to the previous specification for that cohort of products until they were completely phased out by products meeting the revised ENERGY STAR criteria. As part of the ongoing review of the project it was decided that this attribution combined very different conceptions of "savings" and for that reason was unclear and could lead to over-estimation of program savings.

For power system reliability, the electricity savings that matter most are those that occur when the power system is constrained, during periods of peak demand. In most parts of the country, peak demand is driven by high summer cooling loads. ENERGY STAR central 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 1.0 indicates that energy savings are distributed evenly across peak and off-peak periods (e.g., ENERGY STAR TVs). Conservation load factors of less than 1.0 indicate that savings are greater during peak periods (e.g., CLF of central air conditioners), while CLFs of more than 1.0 indicate that savings occur mostly off-peak (e.g., CLF of copier low-power and auto-off modes). Conservation load factor methodology is detailed in Koomey et al. (1990).

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, servers, computer monitors, professional displays[3], and imaging equipment.

ENERGY STAR computers incorporate a sleep mode in which a product enters a low power mode after a period of inactivity[4]. The UEC for notebook computers reflects five power consuming modes: charging, active, idle, sleep and off. Servers may qualify as ENERGY STAR by meeting power supply efficiency requirements. In addition servers with up to two processor sockets must meet an idle power maximum. ENERGY STAR displays must meet maximum power requirements in on, sleep and off 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[5]. All these products have UECs calculated using the modal approach using with the exception of workstation class computers, and TEC imaging equipment. Workstation class computers have exogenous UECs based on the manufacturer's test data set submitted to EPA. The ENERGY STAR UECs for TEC based imaging equipment are set to the criterion annual kWh rather than being a calculated UEC based on time in mode.

We model office equipment differently for residential and for commercial settings due to different usage or operating patterns between the two sectors, market shares for sectors and for speed/capacity bins are based on Gartner Research's special report the the EPA (Gartner 2001). 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) and turn off rates from Tiax LCC (Roth and McKenney 2007). Operating patterns for residential displays, MFDs, printers, and scanners are from field measurement data for a sample of California homes (Porter et al. 2006). Low power savings are only realized for ENERGY STAR products that are successfully doing power management. Turn-off and enabling rates are taken from Webber et al. (2001) and Roberson et al. (2004).

Office equipment power consumption in operating modes is based on Nordman et al. (1998), Lee (1999), ECOS Consulting (Calwell 2000), LBNL metering (Lee et al. 2000), Roberson et al. (2002), the Star database January 2004 (Webber 2004), and U.S. EPA (2007c). Starting in 2005 the BAU UECs for devices with external power supplies, primarily notebook computers, and inkjet imaging equipment, declined due to the impact of the ENERGY STAR external power supply specification, this effect is removed in 2010 due to the federal standard for external power supplies becoming effective.

The ENERGY STAR specification for enterprise servers became effective May 2009 and servers accrued savings in the model for the first time in this report. The UECs for one and two socket servers are based on the improvement in idle power consumption. The EPA report to congress (Brown et. al. 2007), showed

[3] The ENERGY STAR specification for "displays" covers computer monitors, digital picture frames (DPF), and professional signage. Displays are categorized as "office equipment", with the exception of DPFs which are reported with consumer electronics.

[4] Starting in 2009 the requirements for computers is expressed as total energy consumption, annual kWh based on standardized assumptions regarding operational mode power and weighting for time in mode, however the savings estimates continue to use time and power in mode..

[5] US EPA defines the on/active mode for displays 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.

servers having low average utilization, so most of the time they are in idle or near idle states, and because published SPEC benchmark data indicated a high (.95 or better) correlation between idle mode and all other load levels (Brown, 2008), so the savings in idle mode are presumed to accrue even at higher load levels. In addition configuration of servers is more individualized than commodity computers making it difficult to obtain accurate data on time at load-level, and therefore to do a full modal accounting. The UEC for three or four socket servers is based on the improvement of the power supply efficiency, the operational modes are therefore power supply load levels, the power levels are taken from analysis of the test set submitted to EPA. Servers with one and two processor sockets are required to ship with processor level power management enabled, but this is not accounted for in the savings estimates as we have insufficient data on either the power management enabling rate for BAU units or rate at which ENERGY STAR units have power management disabled after shipment.

4.3.2 Consumer Electronics

Consumer electronics include audio/video equipment, telephony, set-top boxes, battery charging systems, external power supplies, digital picture frames, TVs, and VCRs.

The ENERGY STAR specification for audio/video products focuses on reducing the power consumption of a device in its standby mode. Savings are assumed to accrue in both active and standby modes since efficiency improvements to achieve standby savings (like remote control and memory) reduce power whether the device is in "on" or "standby" mode. The UECs are calculated using the electronic modal method, except for "audio separates" (amplifiers, receivers, and powered speakers systems) and set-top boxes (STB) all of which have exogenous UECs. Power consumption data are derived from Floyd and Webber (1998); Nordman and McMahon (2004); Horowitz et al. (Horowitz, N. 2005); and usage patterns from Porter et al. (2006) and Roth and McKenney (2007). The UEC for audio separates is taken from field metering by LBNL. Professional audio equipment is not currently modeled due to limited data regarding energy and usage patterns.

The UEC for telephony equipment reflects four power-consuming modes: active, charge (empty battery), charge (full battery), and standby. BAU power consumption is measured data taken from Rosen et al. (2001) and from FSEC, LBNL, and UC Berkeley (Webber 2003). The ENERGY STAR standby power consumption is set to the maximum allowable consumption. Savings for charge mode and active mode reflect power reductions due to an improved power supply efficiency that is required by the ENERGY STAR specification. Usage patterns are estimates taken from Rosen et al. (2001).

The ENERGY STAR requirements for set-top boxes focus on reducing the TEC of the product, measured in annual kWh. The specification for set-top boxes also include power allowances above the base unit to account for enhanced product functionality such as DVRs, extra tuners, and advanced video processing. An exogenous UEC is used for both the BAU and ENERGY STAR cases, using power consumption and usage patterns developed by Cadmus (Beavers, 2007), based on their analysis of data originally developed by Roth (2007).

ENERGY STAR external power adapters are required to 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). The calculation methodology for external power adapters reflects the devices that they are used to power. Because a federal standard has been established with levels equal to the ENERGY STAR criteria, the external power supply program is being phased out in the model beginning in 2009, with no ENERGY STAR unit shipments claimed starting in 2011, the first full year of the new standard.

ENERGY STAR digital picture frames must meet criteria for maximum power consumption in operational modes and has a standby mode requirement. The UECs are based on the power levels in the manufacturer's test set submitted to EPA, and time in mode estimates, which are LBNL assumptions.

ENERGY STAR televisions originally were required to meet only standby mode criteria. Starting in 2008 ENERGY STAR added criteria for active mode as well, based on the unit's screen size and resolution. ENERGY STAR for digital TV adapters also includes both active and standby eligibility criteria. The UECs for these products are calculated using the electronic modal method. Television initial power consumptions are derived from CNET (2005) and Horowitz et al. (Horowitz, N. 2005). After 2008 power consumption is based on the test dataset for the television specification version three (US EPA, 2008b). The usage pattern is from Roth and McKenney (2007). 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 two watts.

4.3.3 HVAC

ENERGY STAR labels both residential and light commercial heating, ventilation and air conditioning (HVAC) equipment. The residential HVAC program covers air-source heat pumps (ASHP), boilers (gas and oil), central air conditioners (CAC), furnaces (gas and oil), and geothermal heat pumps. The specification for programmable thermostats was suspended effective December 31, 2009, and savings for thermostats, both achieved and forecast, have been removed from the model.

Light commercial HVAC covers central air conditioners and heat pumps with up to 250,000 Btu/hr capacity. Gas/electric package units may also qualify under the light commercial HVAC specification, if they meet the requirements for air conditioners. 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) Heating Seasonal Performance Factor (HSPF), energy efficiency ratio or seasonal energy efficiency ratio (EER, SEER), Integrated Part-Load Value (IPLV) or coefficient of performance (COP). The UEC calculation method is that of an exogenous UEC. Savings for HVAC products with an applicable minimum federal efficiency standard (ASHP, CAC, furnaces, and boilers) are calculated by modeling improvement of the unit efficiency from the federal minimum level to the ENERGY STAR level, that is, we assume that the efficiency of new units are equal to the standard efficiency. This has the effect of raising the business as usual efficiency and reducing the estimated savings for upgrading to the ENERGY STAR level.

For residential Furnaces and Boilers we derive the baseline and ENERGY STAR UECs from the DOE Technical Support Document (US DOE 2009) and the associated LCC spreadsheets. The TSD contains estimated energy consumption by efficiency level and distribution of shipments by efficiency. Using these estimates we calculate annual estimates of the ENERGY STAR and non-ENERGY STAR efficiencies. In years where federal standards apply the non-ENERGY STAR efficiency is based only on the proportion of shipments that exceed the standard level. We apply these annual efficiency estimates to the TSD consumption estimates to calculate separate ENERGY STAR and non-ENERGY STAR annual consumption estimates. This method replaces the fixed baseline method described in previous CCAP status reports. The 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.

For residential Heat Pumps and Central Air Conditioning we derive the baseline UECs using household level data from the 1993 Residential Energy Consumption survey (US DOE 1995)[6]. We model the

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

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.

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.

The UECs for light commercial HVAC products are taken from an LBNL analysis of the EIA Commercial Building Energy Consumption Survey (CBECS). The BAU UEC is based on the amount of conditioned floor area, and the distribution of product types among the CBECS building types and the annual average new energy use for the equipment type. The ENERGY STAR UEC is based on the percent of improvement between the stock average and the ENERGY STAR criterion. The energy use and saving by light commercial HVAC units is expressed in kWh/sqft/year. In 2010 a new federal standard mandating energy efficiency levels equal to ENERGY STAR comes into effect, therefore the BAU UEC is set equal to ENERGY STAR and no further savings accrue to the program.

4.3.4 Lighting

Lighting includes residential fixtures (indoor and outdoor), compact fluorescent lamps (CFL), exit signs, traffic signals, and decorative light strands. Lighting equipment is treated using the duty cycle methodology. The specification for traffic signals was suspended in 2007 and the specification for exit signs in 2008 because federal standards were set equal to the ENERGY STAR criteria. The UECs for fixtures and CFLs were revised in the current version of the model. Previously these all had static baselines, however in the current version the baseline UECs decline over time, reflecting new information regarding lamp power consumption and usage. A specification for Light emitting diode (LED) lamps became effective in 2010, but has not been incorporated into the model at present.

For residential indoor fixtures the initial UECs are calculated using an operating time of three hours from Vine (2006) and replacement of 65 watts of incandescent lighting with a 16 watt CFL based on the CFL metering study by KEMA (2005). The UEC in 2009 is based on 72 watts being replaced with 30 watts, 1.5 lamps per fixture and an operating time of 1.9 hours from the final upstream lighting report (KEMA, 2010), with intervening years interpolated. UEC after 2009 uses the 2009 power values but operating time is assumed to decline by 3% per year. Since ENERGY STAR fixtures require pin-based lamps, we assume savings accrue over the lifetime of the fixture (20 years).

For outdoor fixtures the initial UEC is based on the average of the Tacoma Public Utility dataset (TPU 1996), with a 36 watt fluorescent lamp (Vorsatz et al. 1997) assumed to replace the equivalent of 109 watt incandescent lamp, with a daily operating time of five hours (Vine et al. 2006). 2008 is based on power and usage figures from the upstream lighting study (Kema 2010), with intervening years interpolated.

The initial UECs for compact fluorescent lamps is based on replacement of a 65 watts incandescent lamp with a 16 watt compact fluorescent lamp (KEMA, 2005), and a daily operating time of three hours (Vine et al. 2005), and 1.6 lamps per fixture based on the TPU dataset (Vorsatz 1997). The 2008 UEC is based on estimates from the final upstream lighting report (KEMA 2010), with a 62 W per unit being replaced by a 17 W per unit and 1.5 lamps per fixture. Operating time in 2008 is 1.9 hours per day, with values between 1999 and 2007 interpolated. After 2008 operating time is assumed to decline the same amount, 4% per year. 2009 is the first year that partner-reported shipment data of ENERGY STAR units has been available and the aggregate savings reflect that change.

A federal standard for residential lighting exists in legislation and will be phased in 2012-2014, but is not accounted for in the model at this time, largely due to lack of data, or a forecast of the effect of the standard on shipments. The intent of the standard is to raise the baseline efficiency 25%; since that would decrease the UES. All else being equal a reduction in the UES would lead to reduction in the program savings estimate. However the standard could also change the market share between BAU and ENERGY STAR units. For example if the cost of units conforming to the new standard is higher than present BAU, it might make ENERGY STAR units relatively more attractive to consumers, and a higher ENERGY STAR market share would tend to increase the program savings estimates. Because of the degree of uncertainty regarding the impact of this standard new data will have to be developed before it can be incorporated into the model. A possible source for this sort of data would be DOE rulemaking.

There is also a specification for ENERGY STAR solid state lighting which became effective in September 2008, and shipments for qualifying units were reported for the first time in 2009. These products have yet to be integrated into the +model; however at present the shipment volume is small enough that these units would have minimal impact on either the annual or cumulative program savings.

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). The UEC is calculated using an operating time of ten 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, Updyke 2003). From 2006 onward, the BAU UEC is set equivalent to the federal minimum efficiency standard, which is an average power of five Watts (W) and an annual operating time of 8,760 hours, and there are no further ENERGY STAR savings.

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. There are no ENERGY STAR savings claimed after 2006 due to the establishment of the federal standard.

4.3.5 Residential Appliances

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

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 UECs are based on the duty cycle. 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 watt. The UECs are based on the duty cycle. We analyze the following CADR bins (square meters/min): 1.4-2.8, 2.8-4.2, 4.2-5.7, 5.7-7.1, and 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/W). Our estimate of savings assumes that room air cleaners are operated continuously.

Ceiling and ventilation fans can qualify as ENERGY STAR by meeting efficiency requirements expressed as cubic feet per minute per watt. For both ceiling and ventilation fans the UECs are exogenous. 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 nine hours in the south and three hours elsewhere. We assume the lighting is operated three hours per day. ENERGY STAR ventilation fans include range hood fans and bathroom and utility room fans. The reference case UEC is from LBNL analysis (Roberson 2001). In the UEC calculation, usage is modeled as one hour a day, 350 days per year. The airflow and efficiency varies between the two airflow capacity types. The reference case UECs for exhaust fan and range hood lighting are averages from the Tacoma Public Utility dataset (TPU 1996). The ENERGY STAR UECs are calculated from the reference cases, assuming a 67% improvement in lighting efficiency.

Refrigerators, freezers, clothes washers, dishwashers, and room air conditioners (RAC) are all 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 UECs 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 1995, US DOE 1997). In the case of dishwashers and clothes washers a prototypical model was used to calculate energy consumption, based on the DOE Technical Support Document (US DOE, 2000b) and the associated LCC spreadsheets. 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 the electricity used by the device itself (motor, controls, etc.) and the 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[7]. 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 homes with electric water heating, and fuel water heating energy, which accrued to devices installed in home using natural gas, LPG or fuel oil water heating. Similarly, clothes washer savings are analyzed in five parts: machine, electric water heating, fuel water heating, electric drying and fuel drying. 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. For clothes washers the ENERGY STAR and non-ENERGY STAR machine energy and energy for water heating, as well as the shares of water heating by fuel type are based on the DOE Technical Support Document (US DOE 2000b). For dishwashers the non-ENERGY STAR UEC is based on Wenzel et al (1997), and assumed

[7] 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.

229 loads per year, machine energy of 0.58 kWh/load and water heating energy of 1.60 kWh/load. The ENERGY STAR UEC is calculated based on the ratio of the ENERGY STAR and BAU efficiencies, which are expressed as modified energy factor (MEF).

4.3.6 Commercial Appliances

Commercial appliances include commercial refrigeration applications: bottled water coolers, refrigerated beverage vending machines, icemakers, refrigerators and freezers; commercial cooking: fryers, hot food holding cabinets, steamers, ovens, and griddles; and commercial dishwashers. The UEC calculation methodology is duty cycle except for water coolers, refrigerators and freezers, which have exogenous UECs.

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 (2000).

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 NRDC (Horowitz, N. 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. A federal standard will come into effect in 2013 making the standard requirement equal to the current ENERGY STAR requirement. Since the minimum standard requirement will be equal to the ENERGY STAR requirement we assume no savings accrue to vending machines starting in 2013.

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 is based on test data submitted to EPA and usage patterns assume that machines are operated 75% of the time (273 days/yr).

UECs for commercial refrigerators and freezers are taken from A. D. Little (1996), adjusted by LBNL to a volume of 30 cubic feet. Although the program covers refrigerators, freezers, and ice cream freezers, we model only solid door refrigerators and freezers due to insufficient data regarding ice cream freezers.

The specifications for fryers, steamers, oven and griddles 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, 2009).

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).

4.3.7 Other Products

Other ENERGY STAR products include transformers (commercial/industrial and utility) and roofing (residential and commercial). Transformers have UECs calculated from a duty cycle, the UECs for roofing are of the exogenous type. 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 the institution of a federal minimum efficiency standard. Transformers are included here because they contribute to the cumulative achieved savings. We do not assume any additional savings from new product shipments 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 values 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. Results

5.1 Savings for ENERGY STAR labeled products

Table 7 presents the estimated savings of energy, energy bills, carbon emissions and peak load along with the conservation load factor for each included product for the year 2009. In 2009, ENERGY STAR labeled products are estimated to have saved 1.65 Quadrillion Btu (Quads) of primary energy, $16.3 billion in energy bills, and avoided 28.7 million metric tons carbon (MMTC) equivalent. For reference, these carbon savings represent 4.7% of the combined residential and commercial building sector carbon emissions in 2009, from Annual Energy Outlook, table aeotab18 (US DOE 2010). ENERGY STAR also saved 26.3 GW of peak power. The following are the top five ENERGY STAR products in terms of carbon savings achieved in 2009:

- CFLs: 6.5 MMTC (23% of total)
- Displays: 5.4 MMTC (19% of total)
- Televisions: 2.3 MMTC (8% of total)
- Residential Light Fixtures: 1.7 MMTC (5% of total)
- Printers: 1.4 MMTC (5% of total)

These five products accounted for over 60% of ENERGY STAR product labeling savings. Projected savings for 2010 and 2011 are shown in Table 7 and Table 8 respectively. We project that carbon savings will increase to 29.9 MMTC in 2010 and 31.3 MMTC in 2011.

Table 6. Achieved 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 $2008	MMTC		GW
Office Equipment	Computers	40	390	0.7	0.0089	29
	Servers	0.2	1.9	0.0035	1	2.8
	Displays (Monitors)	310	2900	5.4	1.4	2.8
	Fax	2.3	23	0.04	1	0.018
	Copier	23	210	0.4	4.6	0.071
	Multifunction Device	38	350	0.66	1.1	0.36
	Scanner	1.2	12	0.021	0.76	0.011
	Printer	77	730	1.4	4	0.25
	Professional Displays	0	0	0	0.42	0
	Subtotal	490	4600	8.5	1.5	3.7
Consumer Electronics	Digital Picture Frames	0	0	0	1	0
	TVs	130	1300	2.3	1	1.4
	VCRs	4.2	43	0.074	1	0.044
	TV/VCR/DVD	8	82	0.14	1	0.084
	DVD Player	8.7	89	0.15	1	0.091
	Audio Equipment	9	92	0.16	1	0.094
	Telephony	22	220	0.38	1	0.23
	Digital TV Adapter	5.8	60	0.1	0.69	0.089
	Set-top Box	12	120	0.21	1	0.13
	External Power Supplies	68	660	1.2	1	0.72
	Battery Charging Systems	1.6	16	0.028	1	0.017
	Subtotal	270	2700	4.7	0.99	2.8
Heating & Cooling	Furnace (Gas or Oil)	49	550	0.75	-	-
	Central Air Conditioner	32	320	0.55	0.15	2.2
	Air-Source Heat Pump	30	310	0.52	0.15	0.78
	Geothermal Heat Pump	13	130	0.22	0.15	0.1
	Boiler (Gas or Oil)	4.4	64	0.074	-	-
	Programmable Thermostat	0	0	0	0.15	0
	Unitary HVAC	54	490	0.94	0.15	3.7
	Subtotal	180	1900	3.1	0.18	6.8
Residential and Commercial Lighting	Fixtures	98	1000	1.7	1	1
	CFLs	370	3800	6.5	1	3.8
	Exit Sign	4.1	38	0.072	1	0.043
	Decorative Light Strands	0.66	6.8	0.012	1	0.0068
	Traffic Signal	9.9	91	0.17	1	0.1
	Subtotal	490	5000	8.5	1	5
Residential Appliances	Room Air Conditioners	20	210	0.36	0.15	1.4
	Dehumidifiers	9.3	96	0.16	0.38	0.26
	Air Cleaners	4.6	47	0.081	1	0.048
	Exhaust Fans	1.9	20	0.034	1	0.02
	Ceiling Fans	1.5	16	0.026	1	0.016
	Dishwashers	39	410	0.65	0.77	0.38
	Refrigerators	27	280	0.47	0.95	0.3
	Clothes Washers	44	460	0.73	0.65	0.52
	Subtotal	150	1500	2.5	0.44	3
Commercial Appliances	Water Coolers	14	130	0.24	0.7	0.22
	Commercial Refrigeration	8.9	82	0.16	0.95	0.099
	Hot Food Holding Cabinets	4.3	39	0.075	0.95	0.047
	Fryers	0.17	1.6	0.003	0.95	0.0019
	Steamers	0.089	0.81	0.0013	0.95	0.0002
	Ice Machines	1.2	11	0.021	0.95	0.014
	Dishwashers	3.9	36	0.063	0.95	0.024
	Vending Machines	3.5	32	0.062	0.95	0.039
	Griddles	0	0	0	0.95	0
	Ovens	0	0	0	0.95	0
	Subtotal	36	330	0.63	0.76	0.44
Other	Utility Transformers	0.063	0.58	0.0011	1	0.00066
	C&I Transformers	1.1	9.9	0.019	0.77	0.015
	Residential Roofing	2.3	23	0.044	0.15	0.31
	Commercial Roofing	42	380	0.76	0.15	4.2
	Subtotal	45	420	0.82	0.15	4.6
TOTAL		1700	16000	29	0.65	26

Notes to Table 7,8.9:

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 range hood fans (assumed the same as cooking equipment, Ruderman et al., 1989).

Table 7. Expected Annual Savings in 2010

Program	Equipment Type	Primary Savings	Energy Bill Savings, Discounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2008	MMTC		GW
Office Equipment	Computers	34	300	0.59	0.0073	29
	Servers	0.4	3.4	0.007	1	2.4
	Displays (Monitors)	270	2300	4.7	1.5	2.4
	Fax	1.1	10	0.019	1	0.0084
	Copier	17	140	0.29	4.6	0.051
	Multifunction Device	44	370	0.76	1.1	0.41
	Scanner	0.66	5.9	0.011	0.76	0.006
	Printer	62	530	1.1	4.2	0.2
	Professional Displays	0.0012	0.0096	0.00002	0.42	0.023
	Subtotal	430	3600	7.5	1.5	3.3
Consumer Electronics	Digital Picture Frames	0	0	0	1	0
	TVs	150	1400	2.6	1	1.6
	VCRs	1.4	13	0.024	1	0.014
	TV/VCR/DVD	6.2	58	0.11	1	0.064
	DVD Player	6.4	60	0.11	1	0.067
	Audio Equipment	8.3	78	0.14	1	0.086
	Telephony	23	220	0.41	1	0.25
	Digital TV Adapters	5.8	55	0.1	0.69	0.089
	Set-top Box	25	230	0.43	1	0.26
	External Power Supplies	83	730	1.4	1	0.87
	Battery Charging Systems	2.3	21	0.039	1	0.024
	Subtotal	310	2900	5.4	0.99	3.2
Heating & Cooling	Furnace (Gas or Oil)	54	550	0.82	-	-
	Central Air Conditioner	34	320	0.59	0.15	2.3
	Air-Source Heat Pump	33	310	0.58	0.15	0.89
	Geothermal Heat Pump	15	140	0.26	0.15	0.12
	Boiler (Gas or Oil)	4.8	65	0.081	-	-
	Programmable Thermostat	0	0	0	0.15	0
	Unitary HVAC	54	450	0.94	0.15	3.7
	Subtotal	190	1800	3.3	0.18	7.1
Res and Com Lighting	Fixtures	120	1100	2	1	1.2
	CFLs	410	3900	7.1	1	4.2
	Exit Sign	3.4	29	0.06	1	0.036
	Decorative Light Strand	1.5	14	0.027	1	0.016
	Traffic Signal	9.1	76	0.16	1	0.095
	Subtotal	540	5100	9.4	1	5.5
Residential Appliances	Room Air Conditioners	22	200	0.37	0.15	1.5
	Dehumidifiers	12	110	0.21	0.38	0.33
	Air Cleaners	6.2	58	0.11	1	0.064
	Exhaust Fans	2.4	22	0.041	1	0.024
	Ceiling Fans	1.5	14	0.027	1	0.016
	Dishwashers	40	390	0.65	0.77	0.39
	Refrigerators	31	290	0.54	0.95	0.34
	Clothes Washers	45	440	0.75	0.65	0.54
	Subtotal	160	1500	2.7	0.45	3.2
Commercial Appliances	Water Coolers	16	140	0.29	0.7	0.26
	Commercial Refrigeration	9.5	79	0.17	0.95	0.1
	Hot Food Holding Cabinets	5.4	45	0.093	0.95	0.059
	Fryers	0.22	1.8	0.0038	0.95	0.0024
	Steamers	0.2	1.7	0.003	0.95	0.00059
	Ice Machines	1.9	16	0.033	0.95	0.021
	Dishwashers	6	50	0.096	0.95	0.036
	Vending Machines	4.3	36	0.075	0.95	0.047
	Griddles	0	0	0	0.95	0
	Ovens	0	0	0	0.95	0
	Subtotal	44	370	0.76	0.75	0.53
Other	Utility Transformers	0.063	0.52	0.0011	1	0.00066
	C&I Transformers	1.1	9	0.019	0.77	0.015
	Residential Roofing	3	27	0.057	0.15	0.39
	Commercial Roofing	49	400	0.88	0.15	4.9
	Subtotal	53	440	0.96	0.15	5.4
TOTAL		1700	16000	30	0.63	28

Table 8. Expected Annual Savings in 2011

Program	Equipment Type	Primary Savings	Energy Bill Savings, Discounted	Carbon Emissions Avoided	Conservation Load Factor	Peak Load Savings
		Trillion Btu	Million $2008	MMTC		GW
Office Equipment	Computers	36	290	0.63	0.0079	29
	Servers	0.6	4.6	0.011	1	2
	Displays (Monitors)	220	1700	3.8	1.5	2
	Fax	1.7	14	0.03	1	0.013
	Copier	11	83	0.19	4.6	0.032
	Multifunction Device	51	390	0.88	1.1	0.48
	Scanner	0.51	4.2	0.0089	0.76	0.0046
	Printer	45	350	0.79	4.3	0.14
	Professional Displays	0.0	0.0	0.0	0.42	0.057
	Subtotal	370	2800	6.4	1.5	3
Consumer Electronics	Digital Picture Frames	0.23	2	0.004	1	0.0024
	TVs	190	1700	3.4	1	2
	VCRs	0.47	4.1	0.01	1	0.0049
	TV/VCR/DVD	3.6	31	0.062	1	0.037
	DVD Player	5.4	48	0.095	1	0.057
	Audio Equipment	7.5	66	0.13	1	0.079
	Telephony	26	230	0.46	1	0.28
	Digital TV Adapters	5.8	51	0.1	0.69	0.089
	Set-top Box	37	320	0.65	1	0.39
	External Power Supplies	81	660	1.4	1	0.85
	Battery Charging Systems	2.9	26	0.052	1	0.031
	Subtotal	360	3100	6.4	0.99	3.8
Heating & Cooling	Furnace (Gas or Oil)	59	610	0.9	-	-
	Central Air Conditioner	35	310	0.62	0.15	2.5
	Air-Source Heat Pump	37	320	0.64	0.15	1
	Geothermal Heat Pump	18	160	0.31	0.15	0.14
	Boiler (Gas or Oil)	5.3	70	0.088	-	-
	Programmable Thermostat	0	0	0	0.15	0
	Unitary HVAC	54	400	0.94	0.15	3.7
	Subtotal	210	1900	3.5	0.18	7.4
Res and Com Lighting	Fixtures	130	1200	2.3	1	1.4
	CFLs	440	3800	7.7	1	4.5
	Exit Sign	2.7	21	0.048	1	0.029
	Decorative Light Strand	2.7	24	0.048	1	0.028
	Traffic Signal	8.2	62	0.14	1	0.086
	Subtotal	590	5100	10	1	6
Residential Appliances	Room Air Conditioners	22	200	0.39	0.15	1.6
	Dehumidifiers	14	120	0.25	0.38	0.4
	Air Cleaners	7.8	68	0.14	1	0.082
	Exhaust Fans	2.8	24	0.048	1	0.028
	Ceiling Fans	1.5	13	0.027	1	0.016
	Dishwashers	40	370	0.66	0.77	0.39
	Refrigerators	35	310	0.61	0.95	0.39
	Clothes Washers	46	430	0.77	0.65	0.56
	Subtotal	170	1500	2.9	0.45	3.4
Commercial Appliances	Water Coolers	19	140	0.33	0.7	0.3
	Commercial Refrigeration	10	77	0.18	0.95	0.11
	Hot Food Holding Cabinets	6.4	48	0.11	0.95	0.07
	Fryers	0.27	2	0.005	0.95	0.003
	Steamers	0.32	2.8	0.005	0.95	0.0012
	Ice Machines	2.6	20	0.045	0.95	0.029
	Dishwashers	8.1	67	0.13	0.95	0.049
	Vending Machines	5.1	39	0.09	0.95	0.057
	Griddles	0	0	0	0.95	0
	Ovens	0	0	0	0.95	0
	Subtotal	52	400	0.89	0.74	0.62
Other	Utility Transformers	0.063	0.47	0.0011	1	0.00066
	C&I Transformers	1.1	8.1	0.019	0.77	0.015
	Residential Roofing	3.7	29	0.069	0.15	0.48
	Commercial Roofing	55	400	1	0.15	5.6
	Subtotal	60	440	1.1	0.15	6.1
TOTAL		1800	15000	31	0.61	30

Estimates of cumulative savings 1993-2009 and 2010-2015 are summarized in **Table 9**. Through 2009, ENERGY STAR labeled products saved 9.49 Quads of primary energy, $91 billion dollars in energy bills, and avoided 170 MMTC. Although ENERGY STAR labeled products encompass over forty product types, only five of those product types accounted for 58% of all ENERGY STAR carbon reductions achieved to date. Those product types are as follows (ranked by total carbon avoided through 2009):

- Displays: 47.07 MMTC (28% of total)
- CFLs: 28.3 MMTC (17% of total)
- Printers: 14.6 MMTC (8% of total)
- Residential light fixtures: 8.26 MMTC (5% of total)
- TVs: 8.02 MMTC (5% of total)

Over the period 2010 to 2015, ENERGY STAR labeled products are projected to save 11.5 Quads of primary energy, $95.6 billion dollars in energy bills (4% discount rate), and avoid 202 MMTC. For reference, these carbon savings represent 5.7% of the projected U.S. carbon emissions for the combined residential and commercial building sectors over this period based on Annual Energy Outlook, table aeotab18 (US DOE 2010). The following five product types account for 57% of future carbon avoided:

- CFLs: 42.9 MMTC (21% of total)
- Displays: 26.1 MMTC (12% of total)
- Televisions: 20.3 MMTC (10% of total)
- Residential light fixtures: 16.7 MMTC (8% of total)
- Computers: 8.9 MMTC (4% of total)

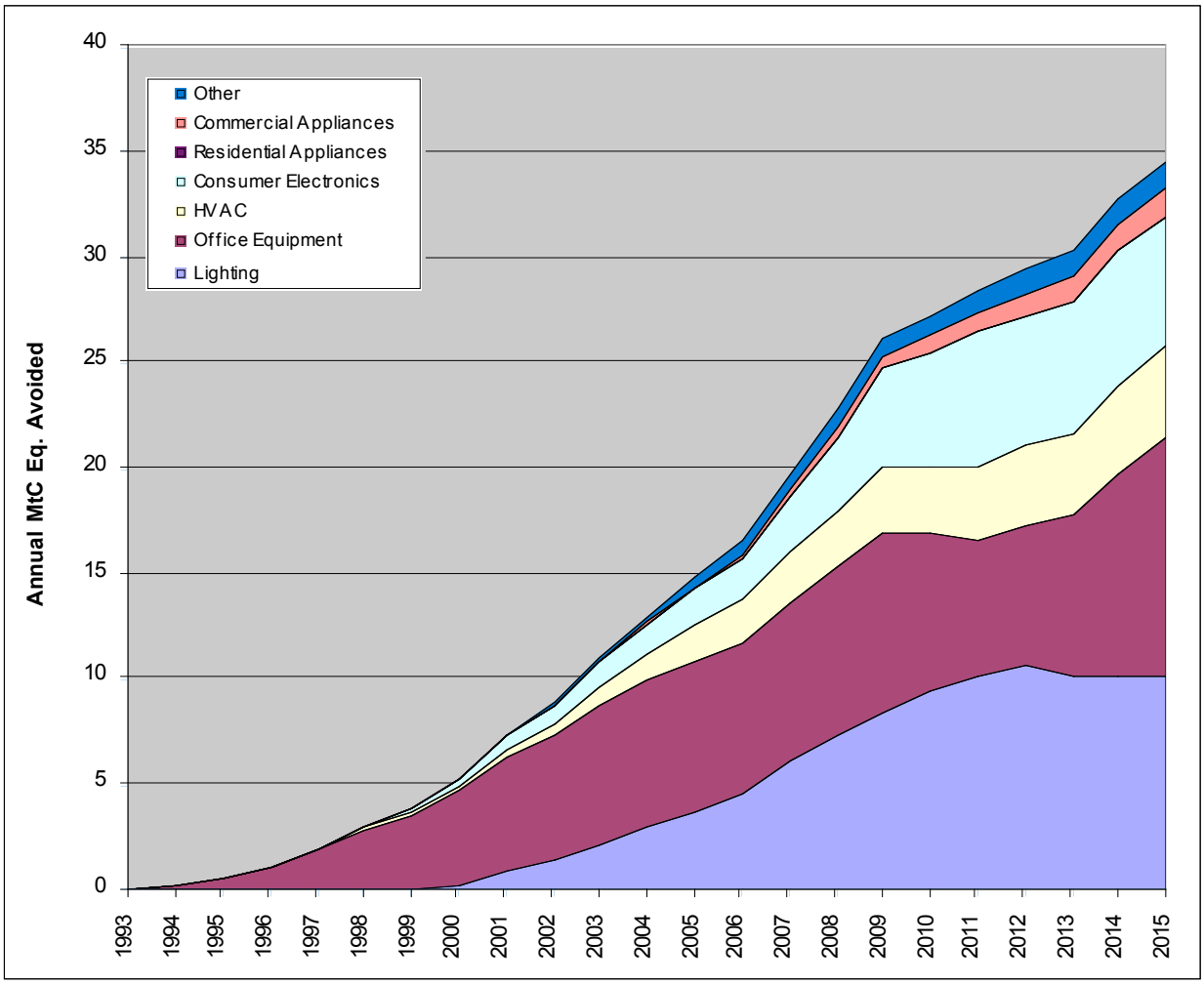
Table 9. Cumulative ENERGY STAR Savings (1993-2015)

Savings Analysis Period		Achieved Savings (1993 through 2009)			Projected Savings (2010-2015)		
Program	Product	Primary Energy Trillion Btu	Discounted Energy Bill Million $2008	Carbon Avoided MMTC	Primary Energy Trillion Btu	Discounted Energy Bill Million $2008	Carbon Avoided MMTC
Office Equipment	Computers	294	$2,743	5.30	506	$3,820	8.92
	Servers	0	$2	0.00	5	$35	0.09
	Displays (Monitors)	2,593	$23,261	47.07	1,487	$11,198	26.11
	Fax	104	$959	1.90	19	$157	0.34
	Copier	220	$1,959	3.98	46	$351	0.80
	Multifunction Device	228	$2,022	4.13	362	$2,682	6.36
	Scanner	42	$382	0.77	2	$19	0.04
	Printer	803	$7,271	14.60	297	$2,265	5.21
	Professional Display	0.0	$0	0.0	55.5	$394	1.0
	Subtotal	4,282	$38,600	78	2,779	$20,922	49
Consumer Electronics	Digital Picture Frames	0	$0	0.0000	7	$56	0.1195
	TVs	462	$4,627	8.2623	1,157	$9,959	20.3264
	VCRs	101	$969	1.8506	2	$18	0.0333
	TV/VCR/DVD	95	$924	1.7200	13	$122	0.2355
	DVD Player	64	$636	1.16	30	$261	0.53
	Audio Equipment	77	$759	1.40	35	$305	0.61
	Telephony	74	$750	1.31	159	$1,370	2.78
	Digital TV Adapters	11	$123	0.19	12	$111	0.21
	Set-top Box	12	$123	0.21	332	$2,813	5.83
	External Power Supplies	161	$1,585	2.82	328	$2,693	5.74
	Battery Charging Systems	3	$30	0.05	23	$195	0.40
	Subtotal	1,060	10,525	19.0	2,097	17,902	36.8
Heating & Cooling	Furnace (Gas or Oil)	314	$3,639	4.85	394	$3,822	6.05
	Central Air Conditioner	194	$1,931	3.50	231	$1,986	4.05
	Air-Source Heat Pump	156	$1,557	2.80	250	$2,152	4.40
	Geothermal Heat Pump	39	$397	0.69	132	$1,127	2.32
	Boiler (Gas or Oil)	26	$378	0.44	35	$451	0.58
	Programmable Thermostat	0	$0	0.00	0	$0	0.00
	Light commercial HVAC	191	$1,767	3.41	320	$2,374	5.62
	Subtotal	920	9,669	15.7	1,362	11,912	23.0
Lighting	Fixtures	447	$4,467	8.02	952	$8,155	16.73
	CFLs	1,583	$15,929	28.30	2,448	$21,211	42.97
	Exit Sign	41	$368	0.75	10	$78	0.18
	Decorative Light Strands	1	$7	0.01	32	$269	0.56
	Traffic Signal	69	$618	1.24	30	$232	0.53
	Subtotal	2,141	$21,389	38.3	3,472	$29,945	61.0
Residential Appliances	Room Air Conditioners	109	$1,083	1.95	141	$1,217	2.48
	Dehumidifiers	28	$288	0.50	93	$803	1.64
	Air Cleaners	12	$124	0.21	62	$529	1.09
	Exhaust Fans	7	$72	0.13	19	$163	0.33
	Ceiling Fans	8	$77	0.14	7	$65	0.13
	Dishwashers	180	$1,934	3.04	240	$2,181	4.01
	Refrigerators	154	$1,524	2.78	247	$2,116	4.34
	Clothes washers	273	$2,884	4.64	272	$2,450	4.57
	Subtotal	770	$7,987	13.39	1,082	$9,524	18.59
Commercial Appliances	Water Coolers	54	$492	0.95	125	$920	2.19
	Commercial Refrigeration	26	$241	0.46	71	$521	1.24
	Hot Food Holding Cabinets	12	$109	0.21	47	$346	0.83
	Fryers	1	$5	0.01	2	$15	0.04
	Steamers	0	$1	0.00	3	$27	0.05
	Ice Machines	2	$17	0.03	22	$157	0.38
	Dishwashers	6	$56	0.09	68	$529	1.09
	Vending Machines	9	$82	0.15	33	$245	0.58
	Griddles	0	0	0	0	0	0
	Ovens	0	0	0	0	0	0
	Subtotal	108	$1,003	1.91	371	$2,759	6.41
Other	Utility Transformers	1	$6	0.01	0	$3	0.01
	C&I Transformers	6	$59	0.12	6	$48	0.11
	Residential Roofing	7	$63	0.13	28	$223	0.54
	Commercial Roofing	202	$1,764	3.76	343	$2,444	6.27
	Subtotal	216	$1,892	4.03	378	$2,718	6.93
TOTAL		9,497	$91,065	170	11,542	$95,683	202

Notes to Table 10:
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. The estimates of achieved annual savings are estimated to increase from less than 0.1 MMTC in 1993 to 29 MMTC in 2009. We project annual savings will increase to 37.6 MMTC in 2015. The results show the critical importance of the office equipment and lighting product categories to overall ENERGY STAR product savings. In 2009, ENERGY STAR office equipment and lighting together avoided 17 MMTC, approximately 58% of the total annual carbon reductions for ENERGY STAR labeled products. We expect carbon reductions for ENERGY STAR office equipment and lighting to grow to 21.1 MMTC in 2015, representing 56% 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. Estimated Carbon Savings for ENERGY STAR Labeled Products (1993-2015)



5.2 Sensitivity Analysis

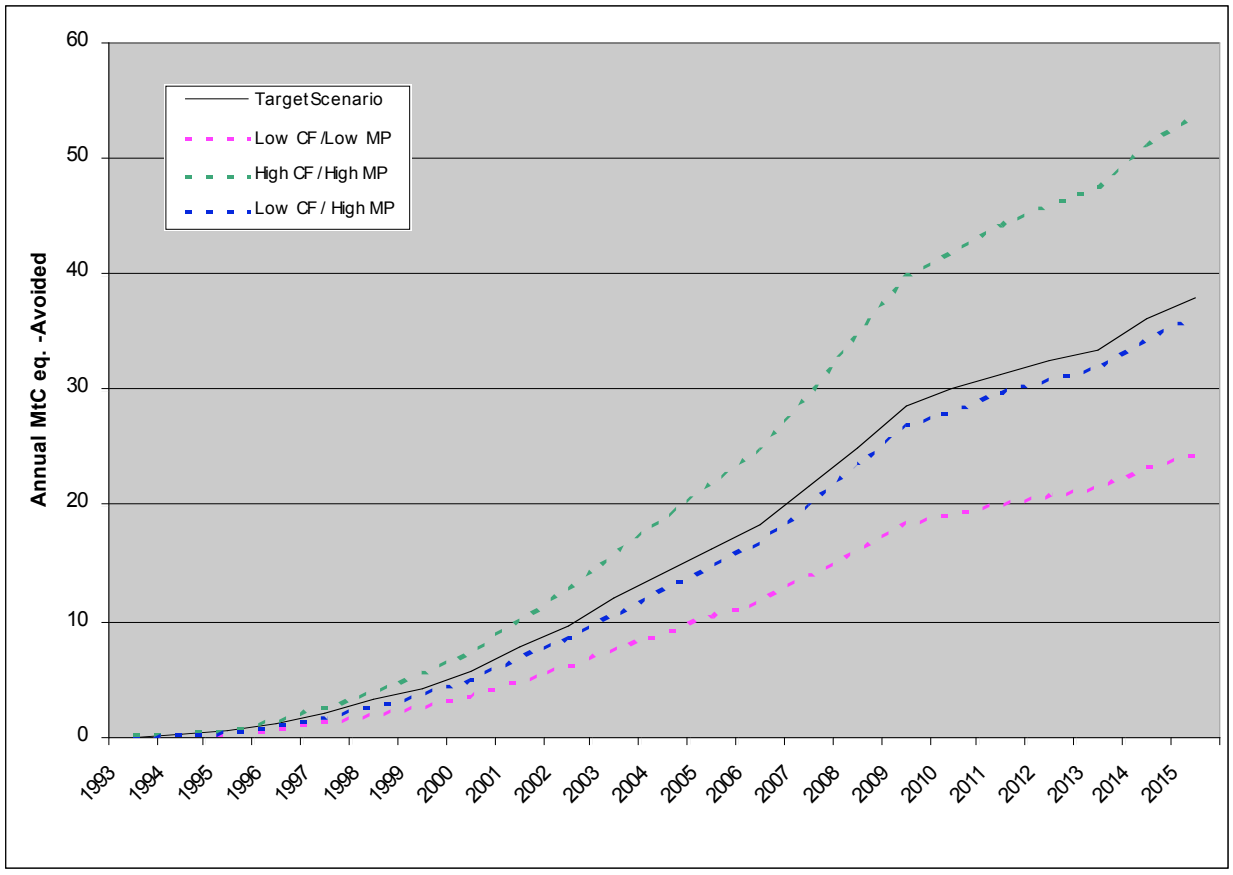
One method of addressing the uncertainty inherent in the model is to bracket the projected "best estimate" savings by varying key inputs that globally affect the model results. We examined the sensitivity of the

best-estimate carbon reductions under the following scenarios for the periods 1993 to 2008 and 2009 to 2015:

- The marginal carbon factor (CF) for electricity was reduced by 20%, the ENERGY STAR Market Penetration (MP) was reduced by lowering ENERGY STAR unit sales 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) [8]

Figure 3 illustrates the results of this sensitivity analysis. These results bound the best estimate of carbon avoided between 110 MMTC and 232 MMTC for the period 1993-2009 and between MMTC 130 and 285 MMTC for the period 2010-2015. 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



[8] A "High CF/low" MP scenario was also run; those results are not presented here as they are so similar to the high CF/low MP as to be indistinguishable.

6. Discussion

6.1 Changes in this Status Report

The cumulative savings presented above are considerably different from those reported in the CCAP status report for calendar year 2008 (CCAP-090807). During 2008 the cumulative savings estimate for the forecast period was 316 MMTC, which compares unfavorably with the 202 MMTC reported here. The forecast period is different in each CCAP version: in CCAP-090807 the cumulative forecast was for 2009-2015, whereas in the current version (CCAP-100930) it is 2010-2015, and since the cumulative results are summed over a different number of years making a direct comparison of different versions of the cumulative savings something less than "apples-to-apples". When the 2010-2015 forecast period is used with the CCAP090807 workbooks at total carbon saving forecast of 281 MMTC is achieved, which is still quite discrepant from the current year's estimate, and this discrepancy is the focus of the discussion. Because this year's CCAP version incorporates a global methodology change - the removal of the market transformation effect, that change will also be considered in some detail.

We used the CCAP-090807 spreadsheets to generate cumulative savings by equipment type for the same forecast period used in this status report, and those estimates are presented in **Table 10**.

Table 10. Comparison of 2010-2015 Cumulative Carbon Savings Estimates

Equipment Type	MMTC Saved CCAP-090807	MMTC Saved CCAP-100930	Change
Lighting	124.21	61.0	- 63.25
Office Equipment	64	49	- 15.46
Consumer Electronics	31.18	36.8	5.65
HVAC	28	23	- 4.99
Residential Appliances	20.93	18.59	- 2.34
Commercial Appliances	6.74	6.41	- 0.33
Other	5.72	6.93	1.21
EPA Labeled Products	169	143	- 25.62
Total ENERGY STAR	281	202	-79.52

There are 55 individual products within the categories listed in Table 10; of these 43 showed declines in carbon saved between CCAP versions, while only 12 showed increases, but for 40 products the magnitude of the change was less than 1 MMTC, thus there are a lot of relatively small declines. Total cumulative carbon savings are 124 MMTC less than what was reported in the last CCAP Status Report.

By far the largest change is the change in the Lighting type. Lighting accounts for 63 MMTC of the total difference of 124 MMTC. Of the 63 MMTC decline in cumulative carbon saved for this category, 52 MMTC was due to change in the savings estimate for CFLs. The cumulative savings estimate for CFLs for 2010-2015 using CCAP-090807 would have been almost 95 MMTC, using 100930 it is 43). Lighting equipment has only one tier so the change is not due to the removal of the market transformation effect. Rather it is due to a combination of the revised baseline methodology and a sharply reduced shipment forecast. In previous versions lighting was modeled with static UECs, the current version has declining baseline UEC and the ENERGY STAR UEC rises. Because of the very large number of units for lighting (particularly for CFLs) seemingly modest changes in the UECs have large cumulative impacts. This is the first ENERGY STAR Status Report in which the savings for CFL's is based on partner-reported shipment data. In previous versions ENERGY STAR shipments of CLFs was an estimate based on an assumed market penetration rate of 75%, that is, the ENERGY STAR unit shipments were set to 75% of the total shipments of CFLs. In CCAP 090807 the shipment forecast for CFLs was 299 million in 2010 increasing to 400 million in 2015, in the current version the corresponding figures are 251 million in 2009, declining very slighting to 250 million in 2015. Interestingly, changed estimates of total shipments resulted in the ENERGY STAR market penetration being higher than what had been previously assumed. In order to assess the relative importance of the effect of the revised UECs compared to the new shipment data, we used the ENERGY STAR shipment figures from CCAP-090807 in this year's workbooks. This yielded a cumulative savings estimate of about 52 MMTC, leading to the conclusion that the majority of the effect

is due to the revised UEC estimates. Within the lighting category, another decline of 11 MMTC was due to changes in the savings estimate for fixtures. The UECs for fixtures were revised along the same lines as CLF, and with the same data sources. The shipment estimate for ENERGY STAR fixtures also declined from the previous forecast. Unlike CLFs the ENERGY STAR shipments have been based on partner-reported data, and the shipment decline for these products does not a change in estimation method.

As noted in the discussion of the savings methodology for lighting, there is an upcoming federal standard for residential lighting which may impact the savings estimates for ENERGY STAR fixtures and CFLs. A side-analysis was performed using the current year's workbook for lighting to obtain a preliminary estimate of the magnitude of this effect. In this analysis the BAU UEC was decreased to 25% better than the existing estimates over the period 2012-2014, modeling the gradual phase of the standard, and kept at 25% better thereafter. Since we do not have forecasts of expected shipments or costs of the new standard units all other data was retained. In this scenario the implementation of the standard reduced the estimated savings for lighting equipment by another 4 MMTC, or about another 5%, over the cumulative reporting period. There is a very large element of uncertainty in this estimate and about how implementation of the lighting standard will play out in the market and the impact on ENERGY STAR savings estimates. We believe it unlikely that introduction of a minimum efficiency standard will increase the market share of BAU units; a small decline in the BAU market share might result in a smaller impact than our estimate above as the lower unit savings are somewhat offset by higher market penetration of ENERGY STAR units[9]. If, on the other hand, the market share of BAU units were to become very small, it could create a problem of having a meaningful base case from which to claim savings, as high efficiency CFLs or fixtures would increasingly replace units of similar efficiency.

The other equipment type with very large changes to savings is Office Equipment, which declined by almost 16 MMTC. Here the largest changes are declines in the savings estimates for displays and printers. Much of this decline is due to removal of market transformation effect; both displays and printers had more than one tier in market transformation.

The savings estimate for HVAC equipment declined by 5 MMTC. The removal of programmable thermostats from the models accounted for approximately 2.8 MMTC of this change. In addition the baseline UEC for furnaces and boilers was revised to model improvement in the BAU case resulting in moderately lower UES. Like lighting, HVAC equipment has only one tier in effect so removal of the market transformation effect is not a factor.

There were relatively modest declines in the Residential Appliances category most which are due to room A/C, dishwashers and clothes washers all having lower than previously forecast shipments; none of these products had more than one specification tier, so here to the removal of the market transformation effect is not causative. The savings estimates for Commercial Appliances are not dramatically different from those in the last CCAP status update. Many of the small declines in carbon savings are due to lower than previously forecast shipments, and are not entirely unexpected due to general economic conditions.

Consumer Electronics showed increased carbon savings between the two versions, amounting to 5.6 MMTC. The increased carbon savings for consumer electronic are due to higher savings estimates for TVs, Set-top boxes and external power adapters. In all three cases the increase is due to higher than forecast shipments. In the case of power supplies this increase was large enough to offset the discontinuation of the specification in the later years of the forecast period. In CCAP 090807 many products in the Electronics category (e.g. telephony, TV, VCR) had shipments in more than one tier during the forecast period so the removal of the market transformation likely made the carbon savings in this category lower than they would otherwise have been.

[9] In the side-analysis a 5% increase in the ENERGY STAR shipments balanced out the reduced savings due to the improved baseline UEC, at about 10% increase in shipments the carbon savings for CFLs increased by about 1 ½ MMTC.

There was also a very modest increase in the Other Equipment category, about 1.2 MMTC, the bulk of which was due to increase savings forecast for commercial roofing products.

6.2 Limitations of 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 11**.

Table 11. Limitation to the 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. 5. The model conceptualizes savings as the difference between standard efficiency and high efficiency at the unit level and does not control for possible effects such rebound, takeback or additional energy use attributable to the monetary savings.

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 has been successful in reducing carbon emissions through its voluntary product labeling efforts. Through 2009, the program saved 9.49 Quads of primary energy and avoided 170 MMTC equivalent. The forecast shows that the program is expected to save 11.5 Quads of primary energy and avoid 202 MMTC equivalent over the period 2008-2015. The sensitivity analysis bounds the best estimate of carbon

avoided between 109 MMTC and 231 MMTC (1993 to 2009) and between 130 MMTC and 284 MMTC (2010 to 2015).

The cumulative carbon savings are considerably lower in this status report than those previously reported. There are several factors that account for the decline, including removal of the market transformation effect, improved estimation of UECs for key products, new data source for and estimates of product shipments and removal of products from the model. By far the bulk of the change is due to the revision of UEC and shipment estimates; the impact of discontinued products and the market transformation effect are secondary. Because much of the change in the estimated cumulative savings is due to changes in method it should not be assumed that the decline is a direct reflection of program effectiveness. As noted previously the bottom-up analysis can be sensitive to changes in key inputs, and that appears to have been the case in this revision.

A large share for the program savings 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.

References

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

Amann, Jennifer Thorne. 2003. Set-top boxes: Opportunities and issues in setting efficiency standards: Report AO41. American Council for an Energy Efficient Economy, Washington, DC.

Beavers, D. 2007. Energy Star Projected Shipments of Set-top Boxes Version 2.0 Specification. (spreadsheet). Waltham, Massachusetts: The Cadmus Group, Inc.

Brown, R., C. Webber, J. Koomey. 2002. "Status and Future Directions of the ENERGY STAR Program." Energy--The International Journal. volume. 27, number. 5. (also published as LBNL-50859; Lawrence Berkeley National Laboratory, Berkeley CA). May. pp. 505-520.

Brown, Richard, Eric Masanet, Bruce Nordman, Bill Tschudi, Arman Shehabi, John Stanley, Jonathan Koomey, Dale Sartor, Peter Chan, Joe Loper, Steve Capana, Bruce Hedman, Rebecca Duff, Evan Haines, Danielle Sass, and Andrew Fanara. 2007. *Report to Congress on Server and Data Center Energy Efficiency: Public Law 109-431*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-363E. August.

The Cadmus Group, Inc. (Cadmus Group) and Energy Systems Consulting, Inc., 1998. Regional electricity emissions factors: final report. Prepared for the U.S. Environmental Protection Agency, Atmospheric Pollution Prevention Division under contract 68-W6-0050. Washington, DC. November.

Cadmus Group. 1999. Preliminary market background report for residential dehumidifiers. Prepared for the U.S. Environmental Protection Agency, Climate Protection Division under contract 68-W6-0050. Washington, DC. September.

Cadmus (the Cadmus Group, Inc.). 2000. Product testing and analysis of water dispensers. Prepared for the U.S. Environmental Protection Agency, Climate Protection Division, ENERGY STAR program under contract 68-W6-0050. Washington, DC. February.

Calwell, C. and N. Horowitz. 2001. "Ceiling fans: fulfilling the energy efficiency promise." Home Energy Magazine. January/February. pp 24-29.

Calwell, C. 2003. The European Code of Conduct: How can you lead a global effort to improve power supply efficiency? Presented to the European Commission- Directorate General JRC, Joint Research Center, Institute for Environment and Sustainability, Renewable Energies Unit. Ispra, Italy. April.

Caltrans. 1999. A Caltrans Alternative Traffic Signal Illumination Draft Final Report. Published by the State of California, Department of Transportation.

CNET. 2005. Power consumption results for twenty televisions tested.

D& R International. 2009, 2008, 2007 ENERGY STAR Qualified Appliance Retail Sales Data - National – Final. July. Excel workbook. Source: http://www.energystar.gov/index.cfm?c=manuf_res.pt_appliances

Floyd, D. and C. Webber. 1998. Leaking electricity: individual field measurements of consumer electronics. In Proceedings of the 1998 Summer Study on Energy Efficiency in Buildings. Washington DC: American Council for an Energy Efficient Economy. August.

Food Service Technology Center. 2007, 2008, 2009. Life cycle and energy cost calculators for food service equipment. Published by Fisher Nickel, Inc. San Francisco, CA. Data available at http://www.fishnick.com/

Gartner Research. 2001. Special report prepared for the United States Environmental Protection Agency: ENERGY STAR Market Share of computers, monitors, printers, copiers, facsimile, and MFDs. Washington, DC.

Horowitz, Marvin. 2001. "Economic indicators of market transformation: energy efficient lighting and EPA's Green Lights." The Energy Journal: volume 22, number 4. pp. 95-122.

Horowitz, Marvin. 2004. "Electricity intensity in the commercial Sector: market and public program effects." The Energy Journal: volume 25, number 2. pp. 115-137.

Horowitz, Marvin J. 2007. "Changes in electricity demand in the United States from the 1970s to 2003." The Energy Journal: volume 28, number 3.

Horowitz, Noah. 2002. Recommendations for beverage vending machine performance specifications. Prepared for the US Environmental Protection Agency, Climate Protection Division, ENERGY STAR program by the Natural Resources Defense Council. Washington DC. October.

Horowitz, Noah, P. Ostendorp, S. Foster, and C. Calwell. 2005. Televisions – active mode energy use and opportunities for energy savings. Issued by Natural Resources Defense Council (NRDC). San Francisco, CA. March.

ICF Consulting. 2003. Energy Star Market Penetration Report Calendar Year 2002. Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. June.

ICF Consulting. 2004. Energy Star Market Penetration Report Calendar Year 2003. Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. September.

ICF Consulting. 2006a. Energy Star Unit Shipment Data Report Calendar Year 2004. Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. January.

ICF Consulting. 2006b. Energy Star Unit Shipment Data Report Calendar Year 2005 (Final Draft). Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. August.

ICF Consulting. 2007. Energy Star Unit Shipment Data Report Calendar Year 2006 (Final Draft). Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. May.

ICF Consulting. 2008. Energy Star Unit Shipment Data Report Calendar Year 2007 (Final). Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. July.

ICF Consulting. 2009. Energy Star Unit Shipment Data Report Calendar Year 2008. Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. August

ICF Consulting. 2010. Energy Star Unit Shipment Data Report Calendar Year 2009. Prepared for the US Environmental Protection Agency, Climate Protection Partnership Division, ENERGY STAR Program. Washington, DC. September.

KEMA Inc. 2005. CFL metering study final report. Prepared for Pacific Gas and Electric (San Francisco, CA), San Diego Gas and Electric (San Diego, CA), and Southern California Edison (Rosemead, CA). Oakland, CA. February.

KEMA Inc. 2010. Final Evaluation Report: Upstream Lighting Program. Prepared for Pacific Gas and Electric (San Francisco, CA), San Diego Gas and Electric (San Diego, CA), and Southern California Edison (Rosemead, CA). Oakland, CA. February.

Konopacki, S., H. Akbari, M. Pomerantz, S. Gabersek, and L. Gartland. 1997. Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 US metropolitan Areas. LBNL-39433. Berkeley, CA. Lawrence Berkeley National Laboratory, May.

Koomey, Jonathan, Arthur H. Rosenfeld, and Ashok K. Gadgil. 1990. "Conservation Screening Curves to Compare Efficiency Investments to Power Plants". Energy Policy 18(8) October: 774–782.

Lee, J. 1999. Energy Star Office Equipment Program. Lawrence Berkeley National Laboratory. Excel workbook. October.

Lee, J., R. Brown, and B. Nordman. 2000. Power Consumption of Commercial Printers, Draft, Lawrence Berkeley National Laboratory. Spreadsheet. February.

McWhinney, M., A. Fanara, R. Clark, C. Hershberg, R. Schmeltz, and J. Roberson. 2005. "ENERGY STAR product specification development framework: using data and analysis to make program decisions". Energy Policy 33 (2005) 1613-1625.

Media Metrix. 2001. Hard Scan Volume 1 and Softscan (Third Quarter). Released as electronic data. New, York, New York.

Navigant Consulting. 2006. Decorative Light String Market Assessment Report. Prepared for Natural Resources Canada. September.

Nordman, B., M.A. Piette, B. Pon and K. Kinney, 1998. It's midnight...is your copier on: Energy Star copier performance. LBNL-41332. Berkeley, CA. Lawrence Berkeley National Laboratory, February.

Nordman, B and J. McMahon. 2004. Developing and testing low power mode measurement methods. Prepared for the California Energy Commission Public Interest Research Program (PIER) by Lawrence Berkeley National Laboratory under contract 500-99-013-TA20-5. CEC paper 500-04-057. Berkeley, CA. September.

NYSERDA. 2006. Workbook Documenting Calculations. Appliance Standards and Advisory Committee: Consumer Audio and Video Products – DTAs. June.

Oak Ridge National Laboratory (ORNL). 1996. Determination analysis of energy conservation standards for distribution transformers. ORNL-6847. Oak Ridge National Laboratory, Oak Ridge, TN.

Piette, M.A., M. Cramer, J. Eto and J. Koomey, 1995. Office technology energy use and savings potential in New York. Completed for the New York State Energy Research and Development Authority and Consolidated Edison by Lawrence Berkeley Laboratory. Contract #1955-EEED-BES-93, also published as LBL-36752. Berkeley, CA. January.

Porter, S., L. Moorefield and P. May-Ostendorp. 2006. Final field research report. Prepared for the California Energy Commission Public Interest Research Program (PIER) by Ecos Consulting under contract 500-04-030. Durango, CO. October.

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

Roberson, J. 2001. Ventilation fan energy analysis. (Spreadsheet Ventfans1.xls). Lawrence Berkeley National Laboratory.

Rosen, Karen, Alan Meier, and Stephan Zandelin. 2001. Energy Use of Settop Boxes and Telephony Products in the US. LBNL-45305. Lawrence Berkeley National Laboratory. June.

Roth, K. and K. McKenney. 2007. Residential consumer electronics electricity consumption in the United States. Published in the proceedings from the 2007 European Council for an Energy Efficient Economy (ECEEE) Summer Study. La Colle sur Loup, France, June 4-9.

Sanchez, M. C., G. Homan, J. Lai, R. Brown, 2009. Calendar Year 2007 Program Benefits for U.S. EPA Energy Star Labeled Products: Expanded Methodology. Lawrence Berkeley Laboratory. Contract # DE-AC02-05CH11231. Berkeley, CA. September.

Suozzo, M. and S. Nadel. 1998. Selecting targets for market transformation programs: A national analysis. Published by the American Council for an Energy Efficient Economy, Washington, DC. August.

Suozzo, Margaret. 1998. A Market Transformation Opportunity Assessment for LED Traffic Signals. Published by the American Council for an Energy Efficient Economy. Washington, DC. April.

TPU (Tacoma Public Utility). 1996. Measured Loads of Residential Lighting. Unpublished spreadsheet analysis of indoor and outdoor fixtures.

Updyke, C. 2003. U.S. Shipments of Exit Signs by Technology. Washington D.C.: National Electrical Manufacturers Association.

US DOC, United States Department of Commerce. 2007. Bureau of Economic Analysis, National Economic Accounts. Current dollar and real gross domestic product. January.

US DOE, United States Department of Energy. 1995. Residential energy consumption survey 1993: Housing Characteristics. DOE/EIA-0314(93). Energy Information Administration, Office of Energy Markets and End Use. Washington, DC. June.

US DOE, United States Department of Energy. 1996a. Annual energy outlook 1996 with projections to 2015. DOE/EIA-0383(96). Energy Information Administration. Washington, DC. January.

US DOE, United States Department of Energy. 1996b. Annual energy outlook 1997 with projections to 2015. DOE/EIA-0383(97). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 1997. Annual energy outlook 1998 with projections to 2020. DOE/EIA-0383(98). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 1998. Annual energy outlook 1999 with projections to 2020. DOE/EIA-0383(99). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 1999. Annual energy outlook 2000 with projections to 2020. DOE/EIA-0383(2000). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 2000. Annual energy outlook 2001 with projections to 2020. DOE/EIA-0383(2001). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 2000b. Preliminary Technical Support Document: Energy Efficiency Program for Consumer Products: Clothes Washers. Office of Energy Efficiency and Renewable Energy. Washington, D. C. December.

US DOE, United States Department of Energy. 2001. Annual energy outlook 2002 with projections to 2020. DOE/EIA-0383(2002). Energy Information Administration. Washington, DC. December.

US DOE, United States Department of Energy. 2003. Annual energy outlook 2003 with projections to 2025. DOE/EIA-0383(2003). Energy Information Administration. Washington, DC. January.

US DOE, United States Department of Energy. 2004. Residential Energy Consumption Survey 2001: Housing Characteristics. DOE/EIA-0314(01). Energy Information Administration, Office of Energy Markets and End Use. Washington, DC.

US DOE, United States Department of Energy. 2005. Annual Energy Outlook 2005 with Projections to 2025. DOE/EIA-0383(2005). Energy Information Administration. Washington, DC. February.

US DOE, United States Department of Energy. 2006. Annual Energy Outlook 2006 with Projections to 2025. DOE/EIA-0383(2006). Energy Information Administration. Washington, DC. February.

US DOE, United States Department of Energy. 2007. Annual Energy Outlook 2007 with Projections to 2030. DOE/EIA-0383(2007). Energy Information Administration. Washington, DC. February.

US DOE, United States Department of Energy. 2008. Annual Energy Outlook 2008 with Projections to 2030. DOE/EIA-0383(2008). Energy Information Administration. Washington, DC. June.

US DOE, United States Department of Energy. 2009. Annual Energy Outlook 2009 with Projections to 2030. DOE/EIA-0383(2009). Energy Information Administration. Washington, DC. June.

US DOE, United States Department of Energy. 2009. Preliminary Technical Support Document: Energy Efficiency Program for Consumer Products: Energy Conservation Standards for Heating Equipment. Office of Energy Efficiency and Renewable Energy. Washington, D. C. January.

US EPA, United States Environmental Protection Agency. 2007a. ENERGY STAR and other climate protection partnerships 2006 annual report. United States Environmental Protection Agency, Washington, DC. October.

US EPA, United States Environmental Protection Agency. 2007b. Estimating Avoided Carbon Emissions from US Environmental Protection Agency, Climate Protection Partnership Programs. Prepared by Ashley King, Environmental Scientist (US EPA). Washington DC. July 26.

US DOE, United States Department of Energy. 2008. Annual Energy Outlook 2008 with Projections to 2030. DOE/EIA-0383(2008). Energy Information Administration. Washington, DC. June.

US EPA, United States Environmental Protection Agency. 2008a. Maintaining the value of ENERGY STAR 2007 Report. United States Environmental Protection Agency, Washington, DC.

US EPA, United States Environmental Protection Agency. 2008b. Dataset used to determine Draft Final Version 3.0 Levels. Available online at: http://www.energystar.gov/index.cfm?c=revisions.tv_vcr_spec

Vine, E. and D. Fielding. An evaluation of residential CFL hours-of-use methodologies and estimates: Recommendations for evaluators and program managers. Energy and Buildings 38 (2006) 1388-1394.

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

Webber, C., D. Korn, M. Sanchez. 2006. Savings Potential of ENERGY STAR External Power Adapters and Battery Chargers. LBNL-62399. Lawrence Berkeley National Laboratory, Berkeley CA. also published in Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings. Asilomar, CA. August. 15 pgs.

Webber, C. 2003. Compilation of FSEC, LBNL, UCB Telephony Field Power Measurements. Lawrence Berkeley National Laboratory.

Webber, C. A. 2004. List of qualifying Energy Star MFDs from the Star Database. (Spreadsheet, Star_DB_Copier_and_MFD_040120_5.xls).

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

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

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