Savings Estimates for the United States Environmental Protection Agency's ENERGY STAR Voluntary Product Labeling Program

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ABSTRACT

ENERGY STAR is a voluntary energy efficiency-labeling program operated jointly by the United States Department of Energy and the United States Environmental Protection Agency (EPA). Since the program inception in 1992, ENERGY STAR has become a leading international brand for energy efficient products. ENERGY STAR's central role in the development of regional, national, and international energy programs necessitates an open process whereby its program achievements to date as well as projected future savings are shared with committed stakeholders. Through 2006, EPA'S ENERGY STAR labeled products saved 4.9 exajoules (EJ) of primary energy and avoided 85 terragrams (Tg) carbon (C) equivalent. We project that EPA'S ENERGY STAR labeled products will save 13.4 EJ and avoid 212 Tg C equivalent over the period 2007-2015. A sensitivity analysis examining two key inputs (carbon factor and ENERGY STAR unit sales) bounds the best estimate of carbon avoided (2007-2015) between 153 Tg C and 278 Tg C equivalent.

Introduction and Study Objectives

ENERGY STAR is a voluntary labeling program operated jointly by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). DOE and EPA enter into partnerships with manufacturers and key stakeholders to promote products that meet energy efficiency and performance criteria. The ENERGY STAR label assists consumers to identify and purchase energy efficient products. The ENERGY STAR label also provides a national energy efficiency platform for regional stakeholders such as utilities and energy partnerships. By transforming the market for high efficiency products, DOE and EPA reduce air pollution and greenhouse gases associated with the consumption of energy. For a more detailed description of the ENERGY STAR program, refer to McWhinney et al. (2005) and Brown et al. (2002).

Webber et al. (2000) first published an overview of savings for EPA's ENERGY STAR labeled products. Since the 2000 publication, EPA has added numerous new product types to its program and revised eligibility requirements for key product categories. Several important methodological changes to the savings analysis have been made to more accurately quantify program impacts. LBNL publishes an annual update to the Energy Star labling program savings and that publication includes additional detail on the methods and sources, in particular the criteria and methods specific to individual product types (LBNL-56380).

In this article, we address the following questions for the included EPA ENERGY STAR labeled products: 1) How are ENERGY STAR impacts quantified? 2) What are ENERGY STAR achievements? 3) What are the limitations to our method?

Study Scope

ENERGY STAR consists of four programmatic areas: 1) labeled products, 2) buildings and industrial plants, 3) home performance, and 4) new homes. Complete descriptions of these program areas can be found at www.energystar.gov. The present article deals only the labeled products that are administered by EPA. The methodologies used to quantify savings for buildings and industrial plants, home performance, new homes, and the labeled products administered by DOE differ from the methodology outlined here. See Horowitz (2001, 2004, 2007) for the program impacts for ENERGY STAR Buildings, and EPA (2006) for the program impacts of ENERGY STAR home performance, industrial plants, and new homes.

All product types included in this analysis are either new ENERGY STAR products or have had eligibility requirements revised since Webber et al. (2000). Since 2000 EPA developed ENERGY STAR criteria for the following new product types: battery charging systems, bottled water coolers, ceiling fans, commercial fryers, commercial hot food holding cabinets, commercial refrigerators and freezers, commercial steam cookers, dehumidifiers, digital TV adapters, external power supplies, light commercial heating ventilation and air-conditioning (HVAC), refrigerated beverage vending machines, room air cleaners, set-top boxes, telephony, traffic lights, and ventilation fans.

The following existing product specifications were revised since 2000: air source heat pumps, audio equipment and DVD, boilers, central air conditioners, computers, exit signs, furnaces, geothermal heat pumps, imaging equipment, residential light fixtures, roofing, televisions and videocassette recorders. ENERGY STAR specifications were suspended for programmable thermostats, set-top boxes, traffic signals, and transformers. With the exception of programmable thermostats, all product changes are included in this analysis[1]. Full eligibility requirements for each product can be found at www.energystar.gov.

Our study tracks the following program indicators for the analysis period 1993-2025: carbon savings, energy savings, monetary savings, net monetary savings (monetary savings minus the incremental investment cost of realized savings), and peak power reductions. We track these indicators on an annual basis and also generate cumulative results over several time periods. In this paper, we present analysis results for energy savings, carbon savings and monetary savings over the period 1993-2015.

Technical Approach

Overview

We employ a bottom-up methodology for quantifying savings for EPA ENERGY STAR labeled products. Each ENERGY STAR product type is apprached individually and is characterized by its own product-specific inputs that result in a product savings estimate. These inputs include product characteristics, and usage data. Where there are optional energy saving features, enabling rates are included in the inputs. Where a product type varys widely in perforamce unit energy use and savings are analyzed by capacity bins in increase specificity.

[1] Programmable thermostat requirements are suspended beginning in May 2008. Currently, EPA is engaged with industry as well as the National Electrical Manufacturers Association in support of a new industry consensus-based quality standard for programmable thermostats. We are planning to reevaluate savings for this product type based on the outcome of the EPA and Industry programmable thermostat work group.

Overall, the ENERGY STAR program impacts are the sum of the impacts for each individual ENERGY STAR product type.

The development of a new specification includes analysis of the device from an engineering perspective and of the market for the device and these analyses are a major source of the inputs to the savings estimates. Where other organizations have collected relevant market and engineering data, we work to obtain and integrate that information. In particular, we work with the DOE's Energy Information Administration (US EIA) to harmonize inputs with the National Energy Modeling System (NEMS)[2]. We share data with EIA on product power consumption, usage, total energy, and ENERGY STAR market shares for product types including residential HVAC equipment, televisions and set-top boxes, home computers, commercial office equipment, and lighting.

There are a number of advantages to this bottom-up model: It allows us to separately evaluate the implementation process for each product type and to quantify EPA's impact within each market. In addition, ENERGY STAR specifications are often a component regional energy efficiency efforts, and the bottom-up model allows EPA to distribute product data for the development of localized programs.

We implement the bottom-up model with awareness that uncertainty for each product type contributes to uncertainty in total ENERGY STAR impacts. This means that many small inaccuracies are additive and inaccuracy for a product type with large energy savings can significantly affect the overall results. Sources of inaccuracy include uncertainty about the baseline comparision case, differences between tested and "real world" performance, and variability in usage.

To address uncertainty, we run sensitivity tests on key variables including ENERGY STAR unit sales, energy prices and carbon emission factors. While all aspects of the input data are regularly updated, we focus additional resources on the office equipment product category due to the large energy savings potential, as well as consumer electronics where usage patterns are less certain and new field data are becoming available.

Methodology Summary

We begin the analysis by segmenting sales of each product type into non-ENERGY STAR and ENERGY STAR units. Manufacturer partners report ENERGY STAR unit sales to EPA each calendar year[3] as part of their participation in the program. Non-ENERGY STAR unit sales are estimated as the difference between total US unit sales obtained from industry reports and ENERGY STAR unit sales.

Sales of ENERGY STAR units are further divided into those that would have been sold even without the program and those that can be attributed to the program. The estimated sales of ENERGY STAR units not due to the program are a forecast based on our market share analysis of models that met the ENERGY STAR specification prior to implementation of the program for each product type. Test results for individual product models are submitted by manufacturers during the ENERGY STAR product development phase. Each model is compared to the ENERGY STAR performance metrics and the business as usual (BAU) penetration rate is

[2] NEMS is a system which is used to generate national energy forecasts at both the sector and end-use level.

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

calculated as the number of existing models that meet ENERGY STAR requirements divided by the total number of models in the dataset. This market share is considered to represent "naturally occuring" improvement, not specificlly due to the program. ENERGY STAR program savings include only the savings for units directly attributable to the program, that is, shipments of qualifying units in excess of the pre-existing market share.

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

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

The unit energy savings (UES) for each product type is the difference between the BAU and the ENERGY STAR UEC's in a given year. The UES for most product types changes over time due to specification revisions, usage pattern changes, and changes to the BAU efficiency. To account for this variation, we calculate the energy savings for each year's ENERGY STAR sales and then use a retirement function to add up the savings for all the equipment vintages in place in a given year. We assume that ENERGY STAR units remain in service and accrue savings for a period equal to the average product lifetime. Other than including BAU high efficiency units direct replacement of ENERGY STAR units is not explicity accounted for.

Aggregate energy bill savings are estimated using year-by-year energy prices from DOE (USDOE 1996-2007), see LBNL 56380 for the specific figures. Energy bill savings are discounted at a 4 percent real discount rate. Carbon emissions reductions are calculated from energy savings using year-by-year carbon emissions factors. For electricity, we use EPA's national average marginal carbon factor, which is derived from models used as part of the US government's reporting requirements under the U.N. Framework Convention on Climate Change and historical emissions data from EPA's Emissions and Generation Resource Integrated Database (eGRID). Forecast marginal carbon factors are derived from energy efficiency scenario runs of the integrated utility dispatch model (IPM®) (USEPA 2007). Carbon factors for natural gas and oil are assumed to be constant throughout the period at 13.65 kg C/GJ for natural gas and 18.72 kg C/GJ for oil. **Equation 1** summarizes our calculation methodology for estimating ENERGY STAR savings for a single product type in year t:

Equation 1.

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

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

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

where:

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

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

L = product lifetime

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

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

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

EPA has implemented over fifty specification revisions for labeled products. With each specification revision, ENERGY STAR unit sales typically decrease due to the tightened requirements until manufacturers institute product design changes to meet the revised requirements. The initial decline in ENERGY STAR unit sales results in a cohort of units that met the ENERGY STAR criteria under the previous specification but do not meet the revised requirements. We calculate the number of these "former" ENERGY STAR units as the difference between ENERGY STAR unit sales in the year preceding a specification change and the actual ENERGY STAR unit sales in subsequent years when the new specification is effective. Table 1 illustrates a hypothetical application of this methodology.

Table 1. ENERGY STAR Market Transformation Methodology

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

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

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

transformation effect means that in any given year n, the number of units sold for a single product type that will accrue program savings (X) is equal to: $X_n = \sum_{r=1}^{t_n} X_r$ and the average UES in any given year n, is equal to: $UES_n = \sum_{r=1}^{t_n} X_r * UES_r \div X_n$ where t is the current Tier of the ENERGY STAR specification in year n.

Space constraints make this discription of the methology is somewhat compressed. Those interested in a more detailed description are referred to the full publication, LBNL 56380 (Sanchez 2007).

Results

Savings for EPA ENERGY STAR Labeled Products

Through 2006, EPA's ENERGY STAR labeled products saved 4.9 EJ of primary energy, $49 billion dollars in energy bills (discounted at 4%), and avoided 85 Tg C equivalent (eq.) through its voluntary program efforts, as shown in Table 2.

Table 2. Savings for US EPA ENERGY STAR Labeled Products (1993-2015)

Savings Analysis Period		Achieved Savings through 2006			Projected Savings 2007-2015		
Program		Primary Energy Savings	Disc Energy Bill Savings	Carbon Avoided	Primary Energy Savings	Disc Energy Bill Savings	Carbon Avoided
		PJ	Million $2006	Tg C eq.	PJ	Million $2006	Tg C eq.
Office Equipment	Computers	185	$1,759	3.20	1,362	$8,923	21.76
	Monitors	1,915	$18,681	33.41	2,101	$14,227	33.47
	Fax	47	$494	0.82	45	$319	0.71
	Copier	149	$1,408	2.60	397	$2,640	6.33
	Multifunction Device	167	$1,532	2.90	440	$2,803	7.03
	Scanner	53	$508	0.92	45	$310	0.71
	Printer	606	$6,106	10.56	1,559	$10,395	24.87
	Subtotal	**3,122**	**$30,488**	**54.41**	**5,948**	**$39,617**	**94.89**
Consumer Electronics	TVs	227	$2,222	3.92	1,126	$8,171	17.97
	VCRs	91	$914	1.58	77	$577	1.22
	V/VCR/DVD	76	$749	1.32	148	$1,108	2.36
	DVD Player	44	$425	0.76	144	$1,062	2.29
	Audio Equipment	49	$480	0.85	101	$755	1.60
	Telephony	29	$279	0.50	150	$1,087	2.39
	Set-top Box	0	$3	0.00	37	$261	0.59
	External Power Supplies	8	$75	0.14	319	$2,173	5.09
	Battery Charging Systems	0	$0	0.00	0	$2	0.00
	Subtotal	**525**	**$5,147**	**9.09**	**2,102**	**$15,194**	**33.51**
Heating & Cooling	Furnace (Gas or Oil)	243	$2,923	3.51	607	$5,459	8.57
	Central Air Conditioner	114	$1,113	1.98	421	$3,067	6.71
	Air-Source Heat Pump	82	$802	1.41	391	$2,831	6.23
	Geothermal Heat Pump	10	$92	0.16	88	$626	1.40
	Boiler (Gas or Oil)	13	$174	0.20	49	$495	0.74
	Programmable Thermostat	174	$2,055	2.68	286	$2,649	4.25
	Light commercial HVAC	58	$508	1.01	432	$2,875	6.88

	Subtotal	**694**	**$7,667**	**10.95**	**2,272**	**$18,003**	**34.78**
Lighting	Fixtures	233	$2,273	4.04	1,209	$8,656	19.29
	Exit Sign	29	$267	0.51	25	$181	0.40
	Traffic Signal	47	$415	0.81	70	503	1.12
	Subtotal	**309**	**$2,955**	**5.36**	**1,304**	**$9,340**	**20.80**
Residential Appliances	Dehumidifiers	7	$68	0.12	81	$777	1.76
	Air Cleaners	3	$29	0.05	69	$519	1.17
	Exhaust Fans	2	$23	0.04	24	$179	0.40
	Ceiling Fans	3	$30	0.05	20	$148	0.33
	Subtotal	**15**	**$149**	**0.27**	**194**	**$1,382**	**3.09**
Commercial Appliances	Water Coolers	19	$169	0.33	166	$1,078	2.65
	Commercial Refrigeration	10	$87	0.17	71	$476	1.13
	Hot Food Holding Cabinet	2	$22	0.04	49	$312	0.78
	Fryers	1	$15	0.02	21	$157	0.30
	Steamers	0	$2	0.00	9	$57	0.15
	Vending Machines	3	$24	0.05	82	$518	1.31
	Subtotal	**36**	**$318**	**0.62**	**399**	**$2,598**	**6.32**
Other	Utility Transformers	1	$5	0.01	1	$4	0.01
	C&I Transformers	3	$28	0.05	9	$62	0.15
	Residential Roofing	2	$13	0.03	30	$188	0.51
	Commercial Roofing	87	$720	1.58	517	$3,259	8.51
	Subtotal	**93**	**$766**	**1.67**	**557**	**$3,512**	**9.17**
TOTAL		**4,795**	**$47,490**	**82.37**	**12,774**	**$89,646**	**202.57**

Note: Disc = "discounted"; energy bills are calculated using yearly U.S. average energy prices and are discounted at 4%

Although EPA ENERGY STAR labeled products encompass over forty product types, only seven of those product types accounted for 75% of all ENERGY STAR carbon reductions achieved to date. Those product types are as follows (ranked by total carbon avoided through 2006):

- Monitors: 33.4 Tg C (41% of total)
- Printers: 10.6 Tg C (13% of total)
- Residential light fixtures: 4.0 Tg C (5% of total)
- TVs: 3.9 Tg C (4% of total)
- Furnaces: 3.5 Tg C (4% of total)
- Computers: 3.2 Tg C (4% of total

Over the period 2007 to 2015, EPA's ENERGY STAR labeled products are projected to save 12.8 EJ of primary energy, $90 billion dollars in energy bills (4% discount rate), and avoid 203 Tg C eq. For reference, these carbon savings represent 3.3% of the projected US carbon emissions for the residential and commercial sectors over this period (DOE 2007). The savings forecast is based on a best projection of future ENERGY STAR sales, which is estimated using past ENERGY STAR sales and an understanding of the product market and technology trends. The following product types account for approximately 70% of future carbon avoided:

- Monitors: 33.5 Tg C (17% of total)
- Printers: 24.9 Tg C (12% of total)
- Computers: 21.8 Tg C (11% of total)
- Residential light fixtures: 19.3 Tg C (10% of total)

- TVs: 18.0 Tg C (9% of total)
- Furnaces: 8.6 Tg C (4% of total)
- Commercial roofing: 8.5 Tg C (4% of total)
- MFDs: 7.0 Tg C (3% of total)

Growth in savings due to EPA's ENERGY STAR labeled products can be attributed to any of the following factors: 1) addition of new product types to the ENERGY STAR brand; 2) BAU technology trends and/or market changes that result in higher per unit savings for existing ENERGY STAR product types; 3) increasing ENERGY STAR sales for existing ENERGY STAR product types; 4) future specification changes resulting in higher per unit savings for existing ENERGY STAR product types.

In terms of incremental carbon avoided in the forecast period (2007-2015) above the achieved carbon avoided to date (1993-2006), the following are the top five growing ENERGY STAR product types. These product types account for 55% of the net increase in carbon avoided during the forecast period:

Computers (delta 18.6 Tg C): growth in savings is primarily due to the addition of idle power energy requirements to the ENERGY STAR specification as well as tighter requirements for sleep and off mode. Idle mode savings are important because of low enabling rates (only 6% of desktop computers in the commercial sector power manage successfully even though 95% of office computers are equipped with power management capabilities). Office computers spend approximately 70% of the annual operating time in idle mode compared to only 4% of the annual operating time in sleep mode; residential computers spend 31% of the annual operating time in idle mode compared to only 6% of the annual operating time in sleep mode.

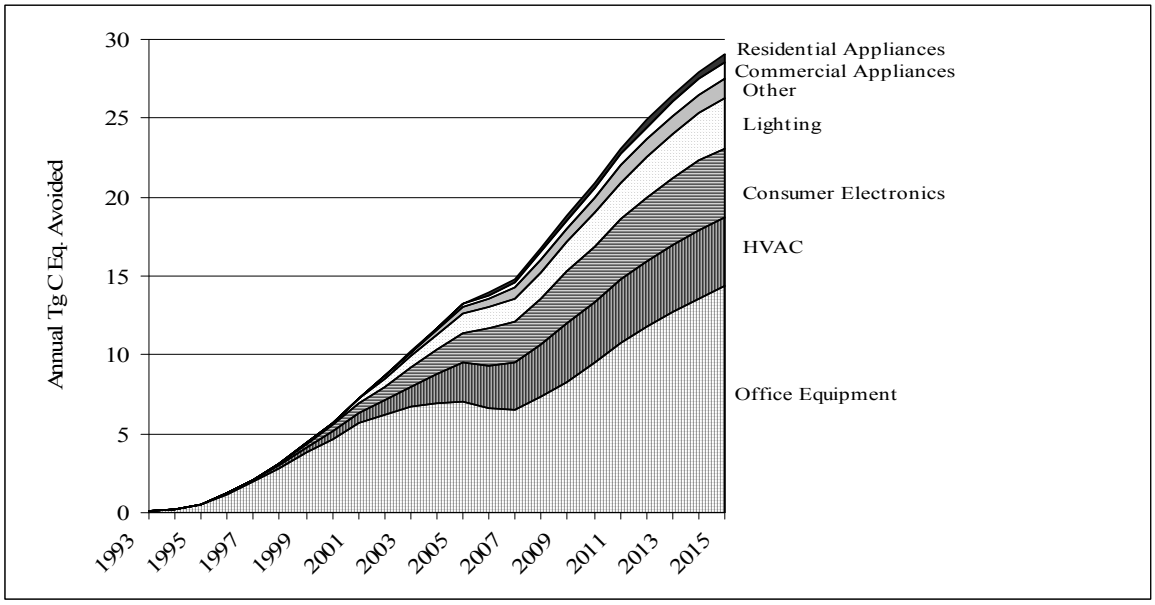
Residential light fixtures (delta 15.3 Tg C): growth in savings is primarily due to the increase in ENERGY STAR unit sales. We project that the ENERGY STAR market share will increase from 4.6% in 2006 to 6.5% by 2015. Because the US sales volume is large, topping 200 million units each year, this program growth translates into an increase in ENERGY STAR unit sales from 11 million in 2006 to 18 million in 2015. The installed stock of ENERGY STAR units similarly climbs due to a 20-year average product lifetime.

Printers (delta 14.3 Tg C): growth in savings is primarily due to the revision of the ENERGY STAR specification to reflect a TEC approach that targets all modes of operation in addition to just sleep and off mode. We estimate that printers are in active or job mode 20% of the annual operating time, in sleep mode 70% of the annual operating time, and in off mode 10% of the annual operating time.

TVs (delta 14.1 Tg C): growth in savings is primarily due to the market shift away from CRT technology towards LCD technology. At the start of ENERGY STAR TVs in 1998, CRT technology was 100% of the market. By 2015, the market share for CRT TVs is projected to be only 2% and the market share for LCD TVs is over 60%. The UES for CRTs is only 46 kWh/yr whereas the UES for LCDs is 89 kWh/yr. The difference in UES is due to a higher standby power for LCDs in our BAU (11 W LCD vs. 6 W CRT).

Light commercial HVAC (delta 8.9 Tg C): growth in savings is primarily due to the increasing penetration of ENERGY STAR light commercial HVAC. We estimate an increase in ENERGY STAR unit sales from 92,000 in 2006 to 147,000 in 2015. **Figure 1** shows the allocation of EPA ENERGY STAR labeled product savings across the seven categories.

Figure 1. Carbon Savings for EPA ENERGY STAR Labeled Products (1993-2015)



Annual savings are estimated to increase from 0.1 Tg C eq. in 1993 to 13.9 Tg C eq. in 2006. We project annual savings will increase to 29.0 Tg C eq. in 2015[4]. The results show the critical importance of the office equipment product category to overall ENERGY STAR product savings. In 2006, ENERGY STAR office equipment avoided 6.6 Tg C or 46% of total annual carbon reductions for EPA labeled products. We expect carbon reductions for ENERGY STAR office equipment to grow to 14.4 Tg C in 2015, again representing 49% of total annual carbon reductions. Maintaining the relevance of the ENERGY STAR brand for office equipment will likely be a key indicator of program impact in the future.

Program strategies can include continuing to ensure relevance for the consumer market by recognizing and promoting only the most efficient subset of the office equipment market through tightened specifications (targeting the top quartile of energy performing models), continuing to find innovative ways to increase the energy performance of individual product types, continuing to aggressively target new product technologies and consumer usage/market trends that may offer additional savings opportunities (examples are digital networking and possible product convergence for televisions/monitors/personal computers and set-top boxes), and broadening the ENERGY STAR office equipment portfolio to include product types not historically targeted by the program (such as including wide-screen commercial displays/monitors, servers, and data centers).

[4] For reference, 2006 ENERGY STAR labeled product carbon savings represents 2% of US carbon emissions for the residential and commercial sector. 2015 ENERGY STAR labeled product carbon savings represents 4% of carbon emissions for the residential and commercial sector (DOE 2007).

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 (212 Tg C eq.) under the following scenarios for the period 2007 to 2015:

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

The results of this sensitivity analysis bound the best estimate of carbon avoided between 54 Tg C and 107 Tg C for the period 1993-2006 (-34% and +31% from best estimate 82 Tg C) and 132 Tg C and 278 Tg C for the period 2007-2015 (-35% and +37% from best estimate 203 Tg C). The fluctuation in ENERGY STAR unit sales, fuel supply, fuel demand, and fuel mix are highly difficult to predict over the nine year forecast period. However, even in a "worst case" scenario, the forecast shows substantial reductions in carbon achieved by EPA ENERGY STAR labeled products.

Limitations to the Analysis

The analysis is based on a bottom-up model for quantifying 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 3.

Table 3. Limitation to Analysis

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

Conclusions

EPA's ENERGY STAR labeled products has been successful in reducing carbon emissions through its voluntary labeling efforts. Through 2006, the program saved 4.9 EJ of primary energy and avoided 85 Tg C equivalent. The forecast shows that the program will save 13.4 EJ and avoid 212 Tg C equivalent over the period 2007-2015. The sensitivity analysis bounds the best estimate of carbon avoided between 153 Tg C and 278 Tg C (2007-2015).

Much of the program's success to date is attributable to ENERGY STAR office equipment products including monitors, computers, and imaging equipment. The analysis demonstrates the continued importance of this product category toward realizing future ENERGY STAR program goals. Strategies for continued success include maintaining program relevance through tightened specifications, exploring new approaches to improving a product's energy performance including new technologies and market trends, and broadening the portfolio of office equipment products covered by the ENERGY STAR program.

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