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Savings Potential of ENERGY STAR® Voluntary Labeling Programs

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ABSTRACT

In 1993 the U.S. Environmental Protection Agency (EPA) introduced ENERGY STAR®, a voluntary labeling program designed to identify and promote energy-efficient products. Since then EPA, now in partnership with the U.S. Department of Energy (DOE), has introduced programs for more than twenty products, spanning office equipment, residential heating and cooling equipment, new homes, commercial and residential lighting, home electronics, and major appliances. We present potential energy, dollar and carbon savings forecasts for these programs for the period 1998 to 2010.

Our target market penetration case represents our best estimate of future ENERGY STAR savings. It is based on realistic market penetration goals for each of the products. We also provide results under the assumption of 100% market penetration; that is, we assume that all purchasers buy ENERGY STAR-compliant products instead of standard efficiency products throughout the analysis period. Finally, we assess the sensitivity of our target penetration case forecasts to greater or lesser marketing success by EPA and DOE, lower-than-expected future energy prices, and higher or lower rates of carbon emission by electricity generators.

The potential savings of introduced ENERGY STAR are substantial. If all purchasers chose ENERGY STAR-compliant products instead of standard efficiency products over the next 15 years, they would save more than $100 billion on their energy bills during those 15 years. (Bill savings are in 1995 dollars, discounted at a 4% real discount rate.)

Introduction

In the wake of the Kyoto summit on greenhouse gases, it has become even more important to assess the benefits of existing carbon reduction programs introduced ENERGY STAR® labeling programs, operated jointly by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), has received attention at the highest levels. In a speech on global climate change, President Clinton (1997) made the following statement:

> If over the next 15 years everyone were to buy only those energy-efficient products marked in stores with EPA's distinctive "ENERGY STAR" label, we could shrink our energy bills by a total of about $100 billion over the next 15 years and dramatically cut greenhouse gas emissions.

The purpose of this paper is to document the forecast of ENERGY STAR energy, energy bill and carbon savings that generated that $100 billion savings estimate. Since President Clinton made that speech, new ENERGY STAR programs have been introduced, and we now estimate that the present value of energy bill savings could reach $130 billion if ENERGY STAR devices were to achieve 100% market penetration.

This paper describes the methodology of the introduced ENERGY STAR savings forecasts. It provides results for both the 100% market penetration case and for a target market penetration case using the market share goals used by EPA and DOE. The paper also considers the impact on energy, energy bill and carbon savings if the programs fall short or exceed their market penetration goals, if energy prices fall, and for two alternative rates of carbon emissions from electricity generation.

The ENERGY STAR® Programs

ENERGY STAR is a group of voluntary product labeling programs operated jointly by EPA and DOE. Those agencies enter into agreements with manufacturers that allow the manufacturers to promote products meeting certain energy-efficiency and performance criteria through use of the ENERGY STAR label. EPA and DOE have focused their efforts in areas where efficiency improvements can be achieved while offering the same or improved level of service. However, the ENERGY STAR label does not constitute an endorsement of the product by EPA or DOE.

The EPA launched the ENERGY STAR program in 1993 with computers, monitors and printers. The goal was to take energy-saving features already in use for laptop computers and incorporate them into desktop devices. The program received a boost when President Clinton issued Executive Order 12845 requiring that microcomputers, monitors and printers purchased by federal agencies be ENERGY STAR-compliant. The sheer size of the federal market pushed manufacturers to participate in the program. Now we estimate that 95% of monitors, 80% of computers and 99% of printers sold are ENERGY STAR-compliant.

With the success of these programs, EPA looked for candidates for new programs. In 1995, programs for fax machines, copiers, residential heating and air conditioning equipment, thermostats, new homes and exit signs were introduced. In 1996, DOE agreed to work jointly with EPA to promote energy efficient products using the ENERGY STAR logo. Because energy efficiency is equal parts environmental protection and energy policy, the DOE/EPA partnership was an important step in developing and expanding ENERGY STAR. DOE introduced programs for refrigerators, room air conditioners, clothes washers and dishwashers. In 1997, scanners and multi-function devices were added to EPA's office equipment programs and the residential lighting fixtures program was introduced. EPA's TV and VCR program was launched in January of this year, followed quickly by DOE's windows program in March.[1]

EPA and DOE continue to research products and industries in search of new program opportunities. Factors evaluated include the potential for improvements in unit energy savings, the size of the stock, turnover rates and the structure of the industry.

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[1] Multi-function devices and windows have not yet been added to our forecasts. We are currently collecting the data necessary for the multi-function device calculations. We expect to add both programs to our analysis within the coming year.

Methodology

We begin by calculating the stock of ENERGY STAR units in place in each year of the forecast. To do this, we apply target market penetrations to a forecast of total annual product shipments to obtain annual shipments of ENERGY STAR devices. The target market penetration we use is an incremental penetration above the forecasted baseline penetration of high efficiency units, so we avoid counting free riders. That is, we count only those ENERGY STAR product shipments that can be attributed to the program.[2]

Some products, particularly office equipment, do not accrue savings unless the ENERGY STAR features are enabled. In the past, manufacturers sometimes shipped devices with ENERGY STAR features disabled. Manufacturers are now required to ship units enabled, so no user action is required to achieve energy savings. However, users may disable features for various reasons, such as slow recovery times from low-power modes or incompatibility with computing networks. Research suggests that only half of all ENERGY STAR computers have the power-saving features enabled (Koomey et al. 1995). For products where this was a problem, we estimated an enabling rate in each year. We apply these enabling rates to the number of ENERGY STAR units shipped to get the number of new ENERGY STAR units that accrue savings.

Using annual installations of energy-saving units, we calculate the number of ENERGY STAR units in place in each year by applying a simple retirement model. Devices are assumed to remain in place and accrue savings for a period equal to the average lifetime of the product (see Table 1), then are retired.

Each of these units is assumed to save a fixed amount of energy in each year. These energy savings estimates are national averages derived from monitored data (where possible) or engineering estimates. The energy savings are constant throughout the lifetime of each device. In cases where the ENERGY STAR program requirements are planned to be tightened, we assume a higher level of savings for devices sold later in the analysis period. Unit energy savings are multiplied by the number of ENERGY STAR units in place in each year to get aggregate annual energy savings. Aggregate energy bills are estimated using energy prices that have been levelized over the analysis period using fuel price forecasts (US DOE 1996a, 1996b). Energy bill savings are discounted at a 4% real discount rate.

Forecasting Issues

Office Equipment. The ENERGY STAR office equipment program covers computers, monitors, fax machines, printers, copiers, scanners and multi-function devices (MFDs). The program focuses on reducing the power consumed by these devices when not in active use. ENERGY STAR devices automatically enter a low-power mode and/or turn themselves off after a period of inactivity. To qualify for the ENERGY STAR label, devices must incorporate low-power and/or auto-off modes, and must meet power consumption limits in those modes. In some cases, default power-saving settings are specified, such as the length of the idle period necessary to trigger a lower-power mode or a maximum recovery time from low power modes.

For our analysis, we used operating patterns derived from equipment audits at various locations (Piette et al. 1995; Nordman et al. 1998). These sources provide both the time spent in

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[2] Free ridership in the homes program is treated differently, and is discussed in the forecasting issues section.

each operating mode (e.g. active, standby, suspend and off), and the percent of ENERGY STAR devices that were actually enabled. Baseline unit energy consumptions were calculated by multiplying the time spent in each power mode by the power consumption in each mode, then summing over all power modes. The unit energy consumption for ENERGY STAR products is calculated essentially the same way, although some of these products have additional power modes. ENERGY STAR products also have different usage patterns than standard products (because of features like auto-off) and lower power levels in certain operating modes. Office equipment shipment data was obtained from Dataquest (1997a, 1997b), Infotrends Research Group (1998) and Lyra Research (1998). The unit energy savings are applied to forecasts of enabled, ENERGY STAR-compliant devices to obtain aggregate savings.

Because of different usage patterns, computers and monitors were modeled separately for homes and offices. We assume that sixty-four percent of shipments for these products are used in offices.

Residential Heating and Cooling (HVAC). The HVAC program covers air-source heat pumps, geothermal heat pumps, central air conditioners, gas and oil furnaces, gas-fired heat pumps, gas and oil boilers, and programmable thermostats. For heating and cooling equipment, ENERGY STAR eligibility is based solely on efficiency, measured by standard test procedures such as AFUE or SEER.[3] Programmable thermostats qualify for the ENERGY STAR label because they automate what people often fail to do manually: set back their thermostats at night or when they are out of the house. Several issues arose in analyzing heating and cooling equipment, including multiple fuel types, technology substitution and program interactions.

Energy bill and carbon savings both depend on the type of fuel used. In addition to their primary fuels, gas and oil furnaces and gas-fired heat pumps consume electricity to operate fans. Programmable thermostats save energy according to the type of HVAC installed in the home. For these products, it was necessary to divide the analysis by fuel type, then add the component savings together.

Technology substitution was an issue for new technologies that are not yet in widespread use. As geothermal heat pumps and gas-fired heat pumps increase in market share, they will displace shipments of established technologies. In our forecast, we assumed that geothermal heat pumps would displace air-source heat pumps, and gas-fired heat pumps would displace gas furnaces and central air conditioning.

Programmable thermostats also interact with other equipment. Because these devices reduce overall usage of heating and cooling equipment, they must be analyzed in conjunction with HVAC equipment to avoid double-counting savings from thermostats and efficient equipment. Thermostat savings are calculated as a percentage of total heating and cooling energy, so the savings will be lower if one assumes ENERGY STAR-compliant HVAC is in place. Conversely, if there is a programmable thermostat in place, replacing old equipment with an ENERGY STAR model will save less than if the thermostat was a standard one. So the question arose: Which measure is instituted first? We assumed that the programmable thermostat was installed first because it was the less expensive measure. Once in place, the programmable thermostat automatically decreases temperatures during specified hours (e.g., at night and during the workday when no one is home), reducing the hours of operation for HVAC equipment. This has the effect of reducing the savings attributed to heating and cooling equipment compared to a

[3] AFUE is average fuel utilization efficiency and SEER is seasonal equipment efficiency ratio.

situation in which no programmable thermostat was installed or if we had assumed the equipment was installed first.

One additional interaction we accounted for was the promotion of ENERGY STAR HVAC equipment through the ENERGY STAR homes program. In order to avoid double counting, savings due to ENERGY STAR HVAC equipment installed in ENERGY STAR homes were attributed to the homes program. We made a simple assumption that 2/3 ENERGY STAR homes have ENERGY STAR-compliant HVAC equipment.

Consumer Electronics. Launched at the beginning of 1998, the TV/VCR program focuses on reducing the standby power of these devices. Savings are assumed to accrue in both active and standby mode, since functions like remote control and memory are powered whether the device is on or off. The power savings from the TV/VCR program are only a few watts per unit, but the number of units is large. There are about 190 million TVs and almost 140 million VCRs in the United States (Sanchez 1997).

The biggest difficulty in forecasting TV and VCR power consumption was obtaining unit power consumption data. When EPA began to develop the program, the most recent data available were over ten years old. New metered data collected by researchers at LBNL and the Florida Solar Energy Center provided the basis for developing the program. Once the program was in place these values were updated using shipment-weighted power consumption values provided by industry representatives (Isaacs 1998). Our shipments forecast was developed using historic shipment data from Appliance (1995).

Residential Lighting. The ENERGY STAR residential lighting fixtures program promotes energy-efficient lighting fixtures. These include fixtures designed for compact fluorescent lamps (CFLs), electronically-ballasted tube fluorescent fixtures, and outdoor fixtures that incorporate motion sensors and photocells.

We analyzed residential lighting fixtures by fixture type (portable, recessed, etc.), although only aggregate results are reported here. Very little reliable data are available on wattage and usage by fixture type. We used the results of a metering study by Tacoma Public Utilities which provided detailed data about a fairly large sample of fixtures, including wattage, hours of use, location and type. The shortcoming of these data is that they were only collected from the Pacific Northwest and they were collected over a period shorter than one year. We nevertheless believe they are the best data available for an analysis such as this. Shipment data are from U.S. Department of Commerce (1997).

Because CFLs are usually not cost-effective in low-use fixtures, we assumed that the target market was fixtures used more than three hours per day. Although these high-use fixtures are less than 20% of the fixture stock, they use more than 60% of household lighting energy. We calculate savings based on the UEC for high-use fixtures, so per-unit savings are higher than if we targeted all fixtures. In reality, some high-efficiency fixtures will probably end up in low-use applications, but we assumed this would be in addition to the high-use applications and chose to ignore this. The 100% penetration scenario we provide assumes that 100% of high-use fixtures are replaced. Low-use fixtures are not replaced in the 100% scenario.

Commercial Lighting. Although exit signs may seem like a small niche in the commercial lighting market, they were an ideal target for an ENERGY STAR program. Exit signs must be lit 24 hours a day. Most signs use incandescent lamps for illumination, which consume about 30 watts, or about 263 kWh per year. ENERGY STAR exit signs must consume less than five watts. Because of the importance of visibility during emergencies, the program also requires that products meet visibility and luminance requirements.

Calculating energy savings for exit signs was fairly straightforward. However, there is some uncertainty associated with the size of the stock, shipments and lifetime. Estimates of the stock of exit signs in the U.S. range vary widely. Sign lifetime is estimated to be ten years, which may be low considering that the lifetime for some light sources (LED and electroluminescent) are reported to be 20 years or more.

Appliances. After HVAC and water heating, large appliances constitute the largest energy end-uses in a typical home. Refrigerators, clothes washers, dishwashers, and room air conditioners (RACs) became eligible for ENERGY STAR labels in 1997. Like some of the HVAC products, these appliances are already subject to the National Appliance Energy Conservation Act (NAECA). The ENERGY STAR program is intended to expand the market for products that significantly exceed the minimum standard. The requirements are 20% more efficient than NAECA for refrigerators, 15% for RACs, 13% for dishwashers and 50% for clothes washers.

To obtain energy use for ENERGY STAR devices, we first calculated unit energy consumption for units just meeting the minimum efficiency requirements under NAECA. The average energy consumptions for refrigerators and RACs were weighted according to the distribution of products by product class and capacity. In the case of dishwashers and clothes washers a prototypical model was used to calculate energy consumption. Since these ENERGY STAR criteria are specified in terms of percent efficiency improvement over NAECA, the appropriate percentages were then applied to obtain ENERGY STAR energy consumption.

The analysis of clothes washers and dishwashers is complicated by multiple fuel types. Most of the energy savings is due to the use of household hot water, which may be heated using gas, electricity or oil. The remaining energy savings may be attributed to the motor, controls, or, in the case of dishwashers, internal water heating, all of which use electricity. Since carbon emissions vary by fuel type, it was necessary to attribute the energy consumption of each device to each fuel type and analyze each fuel type separately. Totaling energy consumption and savings and carbon savings over the three fuel types yields an estimate of the totals for the average device.

Homes. The ENERGY STAR homes program works with builders to encourage the construction of energy-efficient homes. The goal is to construct homes that consume 30% less energy for heating, cooling, and hot water than equivalent homes meeting the national Model Energy Code. To meet the ENERGY STAR guidelines, a home must receive a Home Energy Rating System (HERS) rating of at least 86 using the national HERS guidelines. To achieve such a rating, homes typically have a variety of upgrades, such as increased insulation, reduced infiltration, high-performance windows, high-efficiency heating and cooling equipment, and reduced losses in ducts.

Average new single-family home energy consumption for heating, cooling and hot water were estimated by census division from the 1990 RECS data set. These estimates were aggregated using 1993 housing permits as the weighting factor. Single-family housing completions (the equivalent of shipments for the other products) were assumed to be a constant one million units per year over the forecast period. Savings were reduced by 25% to account for free-ridership among program participants.

Forecast Results

We provide results for two cases: a target market penetration case, using EPA's and DOE's market penetration goals for ENERGY STAR devices, and a 100% market penetration case, assuming that all shipments are ENERGY STAR -compliant from 1998 onward. We also consider the effect of deviations from target market penetrations, falling energy prices, and two alternative estimates of the carbon emissions factor for electricity. Each scenario is based on the same set of underlying assumptions about unit energy consumption and savings. Table 1 shows annual and lifetime savings per unit.

Target Market Penetration Case. This case represents the best estimate of the long-term aggregate savings achievable by ENERGY STAR programs given the market penetration goals and unit energy savings estimates of the individual programs. The target market penetration case uses unit savings estimates and year-by-year penetration targets with the best available estimates of inputs such as energy prices and carbon emission factors. The target market penetrations are based, in part, on the price premium for ENERGY STAR units. Because ENERGY STAR computers and monitors are no more expensive than non- ENERGY STAR devices, they are expected to represent a large share of the market (85 to 95 percent) by 2010. In contrast, high efficiency heating and cooling equipment is significantly more expensive than standard equipment. The target market penetrations (in addition to high-efficiency shipments not due to ENERGY STAR programs) range from only 10 percent for boilers to about 40 percent for gas furnaces in 2010.

Table 2 shows the cumulative savings through 2010 under target market penetrations. Computers result in the biggest savings primarily due to the large market share of ENERGY STAR devices. Residential lighting fixtures are also big savers; this is largely because there are so many light fixtures in the housing stock. Even assuming a relatively slow growth in shipments, the number of ENERGY STAR fixtures in place by 2010 is huge — about 230 million fixtures, or about two ENERGY STAR fixtures per household. Although geothermal and gas-fired heat pumps have high per unit savings, their aggregate savings are quite low due to low projected market penetrations. Because of the higher cost of these devices, we expect them to gain market share slowly.

Table 1. Annual and Lifetime Savings per Unit for ENERGY STAR® Devices

Equipment Type	% Annual Energy Saving (1)	Annual Primary Energy Saving (2) (million Btu/yr)	Annual Bill Savings due to ENERGY STAR	Product Lifetime (3) (yrs)	Lifetime Energy Saving (million Btu)	Lifetime Energy Bill Savings of Unit Live (undiscounted)
Office Equipment						
Computer (CPU & Monitor)	56%	3.0	$21	4	12	$82
Fax	55%	1.8	$12	4	7.1	$49
Copier	35%	3.1	$22	6	19	$130
Scanner	69%	2.7	$19	4	11	$74
Laser Printing	62%	2.1	$14	5	10	$72
Consumer Electronics						
TV	16%	0.31	$2.4	11	3.4	$27
VCR	23%	0.15	$1.1	11	1.6	$12
TV/VCR	17%	0.29	$2.2	11	3.1	$24
Residential Heating & Cooling						
Furnace (Gas or Oil)	15%	13	$76	18	230	$1400
Central Air Conditioner	20%	6.3	$49	14	88	$680
Air-Source Heat Pump	15-20%	17	$130	12	200	$1600
Geothermal Heat Pump	30-40%	55	$420	15	820	$6400
Gas-Fired Heat Pump	20-40%	43	$320	15	650	$4900
Broiler (Gas or Oil)	10%	7.0	$39	20	140	$780
Programmable Thermostat	20-30%	17	$110	15	250	$1700
Residential Lighting						
Fixture	57%	1.6	$12	11	18	$140
Commercial Lighting						
Exit Sign	83%	2.3	$16	10	23	$160
New Home	30%	63	$240	30	1900	$7170
Appliances						
Room Air Conditioner	15%	1.0	$7.89	12	12	$94
Dishwasher	13%	0.51	$3.7	15	7.7	$56
Refrigerator	16%	1.2	$8.9	20	23	$180
Clothes Washer	53%	2.9	$20	13	38	$260

Notes to Table 1:

1) Annual savings are relative to standard new unit, with the following qualifications: Geothermal heat pump is compared to air-source heat pump and electric water heater. Gas-fired heat pump is compared to gas furnace and central air conditioner. Residential lighting fixtures are compared to high use fixtures (those used 3 or more hours per day), since this is the targeted portion of the market (it is not generally cost effective to use CFLs in fixtures used less than 3 hours per day.) Copier savings are for models meeting the Tier 2 requirements, in effect beginning in 1998. Exit sign savings are compared to standard incandescent fixtures. For HVAC and New Homes, the standard energy bills are based on 1990 RECS consumption data. Office equipment savings assume average commercial usage and electricity price.

2) Electricity is converted to primary Btus at a heat rate of 10,500 Btu/kWh (US DOE 1995).

3) Lifetimes are the average lifetime for each product. Computer, monitor, copier, printer and fax lifetimes are from Koomey et al. (1995) (the short lifetimes for computers reflects rapid obsolescence for those products); scanners are assumed to be the same as fax machines; TV and VCR lifetimes are from Appliance (1996); gas furnace, central air conditioner, air-source heat pump and boiler lifetimes are from Lewis and Clarke (1990); geothermal and gas-fired heat pumps are LBNL estimates; thermostat lifetime is the weighted average of HVAC lifetimes; exit sign life is from National Lighting Product Information (1994); new home life is based on a typical 30 year mortgage; appliance lifetimes are from DOE.

4) U.S. average energy prices (levelized over the period 1995-2010): Commercial electricity = $0.073/kWh, residential electricity = $0.081/kWh, natural gas = $5.54/MMBtu, oil = $7.70/MMBtu.

100% Market Penetration. Our 100% market penetration scenario shows the savings that could be achieved if everyone bought ENERGY STAR equipment instead of standard equipment from 1998 to 2010. For geothermal heat pumps and gas-fired heat pumps, which are new technologies without a defined baseline market share, this scenario assumed that geothermal heat pumps would take half of the heat pump market (using the air-source heat pump baseline) and gas-fired heat pumps would take a third of the gas furnace market. The 100% penetration forecasts for air-source heat pump and gas furnace take into account this loss of market to the new technologies.

The 100% market penetration scenario should not be interpreted as a technical potential, because although we assume that all units sold are ENERGY STAR, we do not assume that all units sold are properly enabled. Studies have noted low enabling rates of ENERGY STAR features in office equipment, particularly copiers, computers and monitors.

The cumulative savings for the 100% market penetration scenario are also shown in Table 2. Together the programs could save 27 quads through 2010--for a total of $200 billion savings (undiscounted). These totals are more than 2.5 times the savings in the target market penetration case. The largest savings are due to residential lighting, even though we assumed that 100% penetration only applied to high-use fixtures. If we had modeled 100% of all fixture shipments, the total savings would have been several times higher. Gas-fired heat pumps and geothermal heat pumps do better in this scenario due to their high per unit savings.

Sensitivity Analysis. The market penetration achieved is one of many factors that influences the savings that will be realized. As noted above, simply getting the product to market does not guarantee savings. User behavior may differ from what we have modeled, which could impact savings either positively or negatively. Changes in energy prices will affect dollar savings and changes in carbon emissions from electrical generation will affect carbon dioxide savings. We used an electricity carbon emissions factor of 0.185 kg carbon per kWh for this analysis. It is possible to make an argument that the "correct" factor is either higher or lower than that. First, the electricity carbon emissions factor changes over time with changes in the generation mix. The trend has been toward cleaner generation technologies, which would suggest a lower number should be used for our long-term forecast. On the other hand, our current factor represents average emissions, and it can be argued that a marginal emissions factor is more appropriate. A recent analysis by the Cadmus Group (1998) suggests that the current marginal emissions factor is 0.2 kg per kWh.

Table 2. Cumulative Savings 1998-2010

Program	Equipment type	Target Market Penetration Case: Primary Energy Savings (2) (trillion Btu)	Target: Energy Bill Savings (3,4) (millions of 1995 dollars) Undiscounted	Target: Energy Bill Savings (3,4) (millions of 1995 dollars) Discounted	Target: CO2 Emissions Avoided (5) (MMT CO2)	100% Market Penetraton Case: Primary Energy Savings (2) (Trillion Btu)	100%: Energy Bill Savings (3,4) (millions of 1995 dollars) Undiscounted	100%: Energy Bill Savings (3,4) (millions of 1995 dollars) Discounted	100%: CO2 Emissions Avoided (5) (MMT CO2)
Office Equipment	Computer	2500	$18,000	$12,000	160	2700	$19,000	$13,000	170
	Faxes	30	$230	$180	2.1	30	$240	$190	2.2
	Copiers	230	$1600	$1100	15	270	$1800	$1300	17
	Scanners	1000	$6600	$4300	61	3100	$21,800	$14,200	203
	Printers	670	$4600	$3200	43	670	$4700	$3200	43
	Subtotal	4400	$31,000	$21,000	280	6800	$48,000	$32,000	440
Consumer Electronics	TVs	520	$4000	$2600	34	810	$6300	$4100	52
	VCRs	69	$530	$340	4.4	180	$1400	$890	11
	TV/VCRs	33	$260	$160	2.1	79	$610	$390	5.1
	Subtotal	620	$4800	$3100	40	1100	$8200	$5400	69
Residential Heating & Cooling	Furnaces (Gas or Oil)	890	$5400	$3400	50	1600	$10,000	$6300	89
	Central Air Conditioners	450	$3500	$2200	29	1100	48900	$5800	74
	Air-Source Heat Pumps	270	$2100	$1300	17	210	$1600	$1100	13
	Geothermal Heat Pumps	80	$700	$350	5.5	1700	$13,000	$8700	110
	Gas-Fired Heat Pumps	27	$210	$130	1.7	2400	$18,000	$12,000	150
	Boilers (Gas or Oil)	17	$120	$77	1.1	130	$860	$560	8.1
	Programmable Thermostats	350	$2400	$1600	21	1500	$10,000	$6600	88
	Subtotal	2100	$14,000	49000	130	8600	$62,000	$41,000	530
New Homes	New Homes (6)	750	$4100	$3300	45	750	$5100	$3300	45
Res. Lighting	Fixtures	1200	$9500	$6000	21.7	5800	$45,000	$29,000	3809
Comm. Lighting	Exit Signs	230	$1600	$1100	14.8	370	$2600	$1700	24
Appliances	Room Air Conditioners	77	$600	$400	5	420	$3300	$2100	27
	Dishwashers	56	$410	$270	3	220	$1600	$1000	14
	Refrigerators	240	$1900	$1300	16	990	$7600	$5000	64
	Clothes Washers	370	$2600	$1800	20	2000	$14,000	$9000	120
	Subtotal	700	$5000	$4000	50	3600	$27,000	$18,000	230
TOTAL		10,000	$71,000	$47,000	580	27,000	$200,000	$130,000	1700

Notes to Table 2:

1) Base case market penetrations represent EPA's best estimate of the percent of equipment shipped that is Energy Star. These estimates are based on past market penetrations, manufacturer commitments, and EPA's long-term goals. 100% market share scenario assumes all equipment shipped from 1998 onward is Energy Star-compliant.

2) Electricity is converted to primary Btus at a heat rate of 10,500 Btu/kWh (US DOE 1995).

3) Cumulative bill savings do not take into account increased investment costs. Cumulative bill savings are discounted using a 4% real discount rate.

4) U.S. average energy prices (levelized over the period 1995-2010): Commercial electricity = $0.073/kWh, residential electricity = $0.081/kWh, natural gas = $5.54/MMBtu, oil = $7.70/MMBtu

5) CO_2 emissions for electricity are based on the average US power plant mix, 0.185 kg/kWh. Units are million metric tonnes of CO_2 ($MMTCO_2$).

6) New Homes Program impacts have been reduced by 25% to account for free ridership among program participants.

Table 3. Cumulative Energy, Dollar and CO_2 Savings Under Different Sets of Assumptions

	Market Penetration		
	Low	**Target**	**High**
Cumulative Primary Energy Savings in 2010 (trillion Btu)	8300	10,000	11,300
Cumulative CO_2 Savings in 2010 (million metric tonnes CO_2)			
Low Carbon Emissions Factor	400	480	540
Baseline Carbon Emissions Factor	480	580	650
High Carbon Emissions Factor	510	620	690
Cumulative Dollar Savings in 2010 (millions of 1995$, not discounted)			
Baseline Energy Price Scenario	459,000	471,000	$81,000
Low Energy Price Scenario	$53,000	$64,000	$72,000

In light of these uncertainties, we analyzed the sensitivity of our target penetration case result to the following changes of assumption that could affect energy, dollar or carbon savings:

(1) Energy prices are 10% lower than expected
(2) The carbon emissions factor for electricity is 0.15 kg/kWh
(3) The carbon emissions factor for electricity is 0.2 kg/kWh
(4) Market penetrations are 20% lower than the target penetration case from 1998 onward
(5) Market penetrations are 20% higher than the target penetration case from 1998 on (up to 100%)

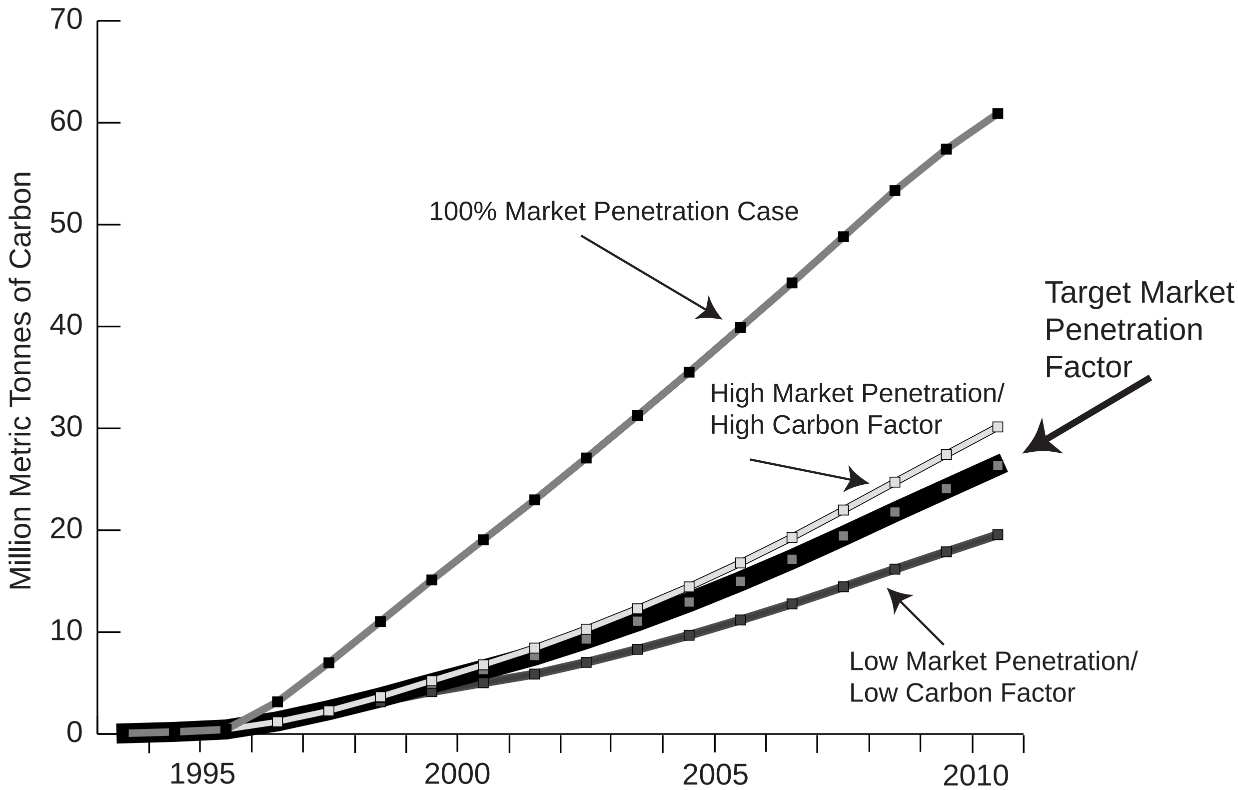
Our target penetration case and 100% market penetration forecasts already factor in a decline in energy prices (based on EIA forecasts). The 10% reduction would be on top of that decrease. We do not model high/low enabling rates as a separate case, since this has the same effect as a change in market penetrations: it decreases the number of activated units in place.

Changing the market penetration affects aggregate energy savings and therefore bill savings and carbon savings as well. A decrease in energy prices, however, affects only energy bill savings.[4] The electric carbon factor affects only carbon dioxide savings, not energy or bill savings. Table 3 shows total ENERGY STAR program savings under different combinations of these assumptions.

Figure 1 compares annual carbon savings under the 100% market share scenario, the target market penetration scenario, the low carbon factor/low market share case and the high carbon factor/high market share case. Although the most pessimistic case represents a significant reduction over the target penetration case, it nonetheless achieves significant carbon savings.

[4] Although falling energy prices might also have the effect of reducing market penetrations (by reducing the benefits of conservation), we do not model this indirect effect.

Figure 1. Annual Carbon Savings



Limitations of the Analysis

Our estimates of unit energy consumptions for office equipment and consumer electronics are calculated from underlying usage patterns and power consumption estimates. We face limitations on two fronts: First, there has been limited data collected for many of these products. As more information has become available, we have updated our forecasts, and we will continue to do so in the future. This can change our estimates significantly. In the case of high-speed copiers, recent research into copier energy use significantly reduced our estimates of baseline unit energy consumption and therefore reduced estimated savings. Second, there is great diversity in power consumption within each product category, and we lack the data to create a precise shipment-weighted average energy consumption.

We did not account for the possibility of improvements in baseline efficiency over the analysis period. For many products, notably HVAC and large appliances, there has been a trend toward increasing efficiency, even in the absence of conservation programs. Accounting for this effect would certainly reduce estimated program savings, but a complete analysis would be necessary to estimate the size of the effect.

Technological developments already on the horizon will likely force us to revise our forecast in the not-to-distant future. This issue is particularly striking in consumer electronics.

The advent of high-definition television will undoubtedly affect TV power consumption, and recordable DVDs could supplant VCRs in the near future. We believe that EPA and DOE will try to leverage their existing partnerships with manufacturers to extend the ENERGY STAR label to new technologies. Because of the uncertainties associated with this type of technological change, we made no attempt to model these changes.

Our analysis extends only to 2010, and we made no attempt to account for savings, which might accrue after that time.

Conclusions

ENERGY STAR has already proven successful in its established programs, such as computers and laser printers. Based on our analysis here, the continuation of those programs and the addition of new programs in appliances and home electronics have the potential to greatly reduce carbon emissions over the next 12 years. Our sensitivity analysis bounds our expectation of cumulative energy bill savings estimates between $53 billion and $81 billion (undiscounted) through 2010. However, as EPA and DOE continue to work to improve savings through consumer education, partnerships with manufacturers, new programs, and tightening requirements for existing programs, ENERGY STAR programs may be able to achieve even higher savings in the future. If ENERGY STAR programs could achieve 100% market penetration, $200 billion (undiscounted) could be saved.

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