Efficiency Improvements In U.S. Office Equipment: Pollution Prevention at a Profit

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Office equipment is a rapidly growing end use that accounts for about 7% of the electricity used in the U.S. commercial sector. We use a detailed end-use forecasting model to explore the likely impacts of the U.S. Environmental Protection Agency's ENERGY STAR office equipment program and the potential impacts of advanced technologies. This program encourages manufacturers to incorporate power-saving features into personal computers, monitors, printers, copiers, and fax machines in exchange for allowing them to use the EPA ENERGY STAR logo in their advertising campaigns. The Advanced Technology scenario assumes that the most energy-efficient current technologies are implemented regardless of cost.

We create a Business-as-Usual scenario from industry forecasts of equipment sales, surveys of equipment densities by building type, measured data on wattage and usage by equipment type, and projected lifetimes for equipment. We then calculate electricity use by building type and equipment type for ENERGY STAR and Advanced Technology scenarios, and explore the sensitivity of these results to variations in key input parameters.

According to our analysis, the ENERGY STAR program will save the U.S. more than $1 billion annually starting in the year 2000, with minimal expenditure of public funds. It is one of a growing number of public policies that both prevents pollution and saves society money. The Advanced Technology scenario promises substantial additional reductions in office equipment energy use if the costs of advanced technologies decline from current levels.

INTRODUCTION

In spite of the recent activity to promote energy efficiency in office equipment, assessments of the potential impacts of these actions on energy use have, with few exceptions, been ad hoc and relatively crude. This report describes a detailed end-use forecast of office equipment energy use for the U.S. commercial sector. This forecast builds upon earlier work for the state of New York (Piette et al. 1995) and revises that work to reflect conditions for the U.S. as a whole. The forecasting methodology is used first to establish a baseline scenario and then to assess the projected effects of, and uncertainties surrounding, the U.S. Environmental Protection Agency's (EPA's) ENERGY STAR office equipment program. The methodology is also used to investigate the potential impacts of an Advanced Technology scenario, where energy-saving innovations are assumed to be pursued without regard to cost.

The next section summarizes the methodology used in the calculations. The Results section summarizes the policy-relevant results and conclusions emerging from our work. Further details about the calculations and results are contained in Koomey et al. (1995).

METHODOLOGY

As described in Koomey et al. (1995), we created a spreadsheet model that explicitly treats changes in power and usage for all relevant device types. We estimated base year office equipment densities by building type after reviewing recent surveys of office equipment ownership. These sources include studies from the Pacific Northwest (ADM Associates Inc. 1992); Sacramento, CA (ADM Associates Inc. 1990); New York (Michaels, DaSilva & Gould 1990; XENERGY 1989); and the U.S. as a whole (U.S. DOE 1994). Growth rates in these densities are derived from industry forecasts of equipment sales (CBEMA 1994) and estimated lifetimes for each type of equipment (IRS 1989). For certain equipment types (PC CPUs, monitors, fax machines, and printers), industry projections extrapolated past 2005 would lead to numbers of devices per person that exceed reasonable levels (e.g., two to three PCs per person). We adjusted industry projected growth rates downward for those equipment types to reflect the likely saturation of such equipment in the commercial sector.

Power levels are estimated based on measured data, trade press assessments, personal communications from industry participants, and from the ENERGY STAR requirements themselves (Acquaviva & Hartman 1993; Arthur D. Little Inc. 1993; Dandridge 1994; Froning 1994; Ledbetter & Smith 1993; Lovins & Heede 1990; Nadel 1994; Newsham & Tiller 1994; Norford et al. 1990; Rose 1993; Szydlowski & Chvala 1994; Tiller & Newsham 1993). Usage for different types of equipment is derived from surveys in Canada and the U.S. (Szydlowski & Chvala 1994; Tiller & Newsham 1993). Finally, projected commercial-sector floor area is taken from the U.S. Department of Energy's Annual Energy Outlook 1995 (U.S. DOE 1995).

We combine these data to calculate unit energy consumption (UEC) for each type of equipment from estimated power levels and hours of use. Device densities are computed to be consistent with current and future commercial-sector floor stock and industry projections of equipment sales. The UECs are then multiplied by the device densities and projected floor area in a given year for a given building type to get the total energy use by building type and device type.

RESULTS

This section describes the six scenarios and discusses results from the scenarios in terms of energy savings and cost-effectiveness.

Scenarios and uncertainties

Koomey et al. (1995) show the input assumptions and results for six scenarios that account for the significant uncertainties in the estimation of savings from the ENERGY STAR program:

(I) *Business-as-Usual case*: This baseline scenario assumes that ENERGY STAR and related federal procurement policies for office equipment do not exist. In this case, annual electricity consumption grows by about 30% over 1990 levels by 2010.

(II) *ENERGY STAR Current Practice Continues case*: ENERGY STAR equipment must be enabled in order to function properly, and until the EPA required last fall that computers be shipped with the ENERGY STAR features enabled, many did not. This scenario assesses the effect if ENERGY STAR equipment is enabled in the future at rates comparable to current levels (10% for PC CPUs and monitors, 50% for copiers, and 100% for laser printers and fax machines). The annual savings in 2000 relative to the Business-as-Usual case are about 6 TWh and grow to about 10 TWh by 2010. These annual savings are worth $500 to $800 million per year at current commercial-sector electricity prices. (All financial savings described in this report are expressed in terms of 1995$).

(III) *ENERGY STAR Worst case*: This scenario assumes that the enabling of ENERGY STAR-compliant equipment improves somewhat over the Current Practice Continues case, but that two additional factors increase energy use. First, we add the assumption of Minimum ENERGY STAR Compliance, in which the suspend power levels of PCs, monitors, and printers are 30W instead of the lower values that manufacturers have achieved to date. Second, we assume that ownership of ENERGY STAR equipment lulls many users into believing that they do not need to turn their equipment off when they leave the office. We model this situation by assuming a doubling in the number of ENERGY STAR PC CPUs, monitors, and printers that are left on at night and over the weekend. Like the Current Practice Continues case, the ENERGY STAR Worst case results in savings of 6 TWh/year in 2000 and about 10 TWh/year in 2010. These annual savings are worth $500 to $800 million per year at current commercial-sector electricity prices.

(IV) *ENERGY STAR Most-Likely case*: This scenario is our principal ENERGY STAR case, and it represents our best guess as to the most likely scenario. About half of the ENERGY STAR PC CPUs are assumed to be enabled, as are 70% of the monitors, 90% of the copiers, and 100% of the fax machines and laser printers. The scenario results in annual savings of 11 TWh in 2000 and 17 TWh in 2010, savings that are worth $900 million per year and $1.4 billion per year for 2000 and 2010, respectively.

(V) *ENERGY STAR Best case*: This scenario assumes that 100% of ENERGY STAR-compliant equipment is enabled and that the program leads to behavioral changes that reinforce the energy savings attributable directly to the purchase of the more efficient equipment. It assumes that the ENERGY STAR program raises the awareness of all consumers about energy use, and reduces nighttime and weekend diversity by about 75% (this assumption implies that 75% of owners of ENERGY STAR equipment who would not otherwise have done so turn off that equipment when they leave work). This case results in savings of 16 TWh/year in 2000 and about 23 TWh/year in 2010. The savings are worth about $1.3 billion per year and $1.8 billion per year for 2000 and 2010, respectively.

(VI) *Advanced Technology case*: This scenario estimates office equipment electricity use assuming that the best current technology is used regardless of economics. Energy savings for the Advanced Technology case exceed the savings of the ENERGY STAR Most-Likely case by about 18 TWh/year by 2000 and 29 TWh/year by 2010. These savings are worth an additional $1.4 billion per year and $2.3 billion per year for 2000 and 2010, respectively.

These calculations do not count any savings that will accrue in office equipment used in residences or in the industrial sector, nor do they count the savings in other countries that adopt the ENERGY STAR regulations to harmonize their office equipment markets with that of the U.S. Recent discussions at the International Energy Agency indicate that many European countries and Japan are likely to adopt the ENERGY STAR requirements for office equipment purchased within their boundaries.

We also ignore the paper savings from the ENERGY STAR copier program as well as the benefits from reduced pollutant emissions. Although we do not calculate these benefits, the existence of these ‘‘spillover benefits’’ in other sectors implies that our Worst case/Current Practice estimates represent an absolute lower bound on expected savings. Actual savings for the U.S. and for the world are almost certain to be larger than this lower bound.

Effect of ENERGY STAR Most-Likely and Advanced Technology scenario assumptions

Figure 1a summarizes the results for the Business-As-Usual, ENERGY STAR Most-Likely, and Advanced Technology scenarios. It shows commercial-sector floorspace, energy use intensities (EUI, in kWh/unit floorspace), and total TWh/year, all normalized to 1990. Floorspace is projected to grow by 33% over the 20-year analysis period. EUIs in the Business-as-Usual case go down slightly through the mid-1990s, and are stable through the rest of the analysis period. Total TWh growth by 2010 is less than the growth in floorstock because of the decline in EUIs.

Figure 1a. *Normalized Trends in floorspace, EUI, and Annual Energy Use*

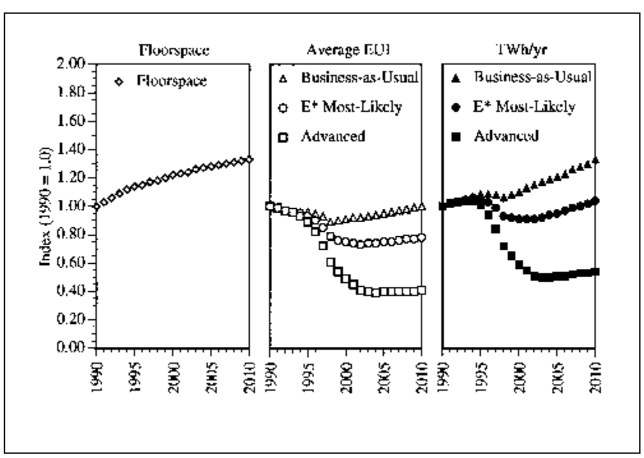


Figure 1b. *Normalized Trends in Floorspace, EUI, and Annual Energy Use Without Mainframes or Mini-Computers*

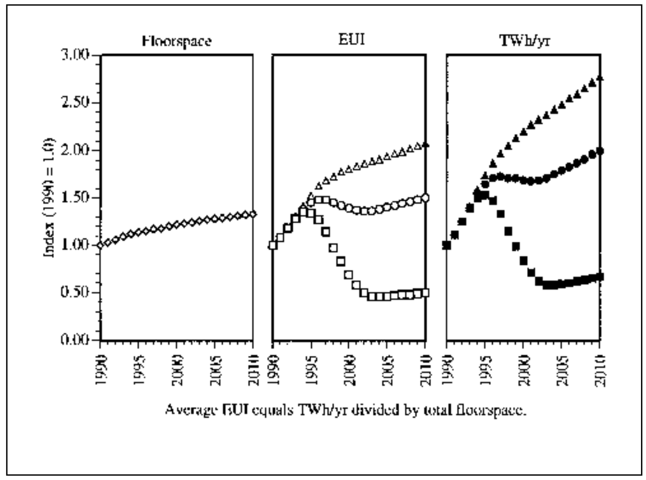


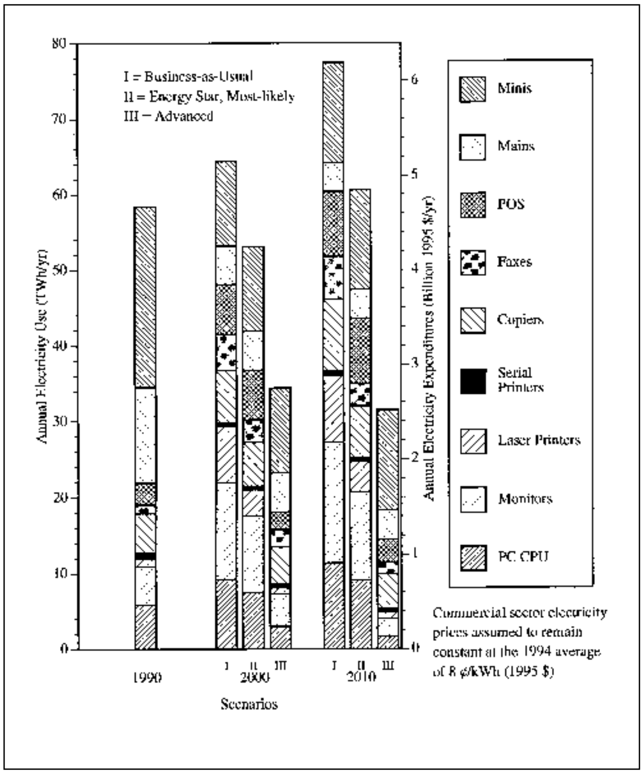
Figure 1b shows the same trends for office equipment with mainframes and mini-computers removed from the equipment mix. This figure reveals that the decline in overall EUI in the mid-to late-1990s is caused entirely by declines in the energy used by the larger computers. EUIs for the other equipment are growing rapidly through the late 1990s, and total energy is experiencing substantial growth throughout the analysis period.

In the ENERGY STAR Most-Likely case, total office equipment EUIs decline about 30% by 2000 and are roughly constant after that time. This decline in EUIs is enough to keep total office equipment energy consumption at about 1990 levels through the year 2010.

The Advanced Technology case, which illustrates the outer range of technological options without regard to cost, shows declines in EUI of more than 50% by just after 2000. This decline is more than enough to compensate for the growth in commercial floor space, resulting in total energy use in 2010 of about 55% of 1990 levels. This level of energy use represents a lower bound to office equipment energy use in 2010, barring drastic changes in the equipment sales forecasts described above or large improvements in technology beyond those assumed in this scenario.

Figure 2 shows the projected annual electricity use by equipment type for the baseline, ENERGY STAR Most-Likely, and Advanced Technology cases. PC CPUs and monitors together comprise about one-third of the projected energy use in 2000 and 2010. Mainframe and mini-computer energy use declines by more than 50% from 1990 to 2000, and remains roughly constant in absolute terms from 2000 through 2010.

Figure 2. *Comparison of Annual Electricity Use for U.S. Office Equipment by Equipment Type in Business-as-Usual, ENERGY STAR, and Advanced Technology Scenarios*



Total annual savings attributable to the ENERGY STAR program are about 17 TWh in 2010. The Advanced Technology case reduces total electricity use by about a factor of two relative to the ENERGY STAR Most-Likely case in 2010. Annual savings in electricity expenditures are about $1.4 billion per year in 2010 for the ENERGY STAR Most-Likely case, and an additional $2.3 billion per year for the Advanced Technology case relative to the ENERGY STAR Most-Likely case.

Koomey et al. (1995) show the breakdown of electricity savings by equipment type in 2010. That report shows savings of the ENERGY STAR Most-Likely case relative to the Business-as-Usual baseline, and savings of the Advanced Technology case relative to the ENERGY STAR Most-Likely case. PC CPUs, monitors, and laser printers together account for about two-thirds of the energy savings attributable to the ENERGY STAR program, with faxes and copiers making up the remainder. About three-quarters of the savings of the Advanced Technology case relative to the ENERGY STAR Most-Likely case are attributable to monitors, PC CPUs, and point-of-sale (POS) terminals.

Koomey et al. (1995) also summarize the annual energy use by building type in the Business-as-Usual and ENERGY STAR cases, respectively. PC CPUs, monitors, and printers dominate office equipment energy use in most building types, with POS terminals dominating in Retail, Restaurants, and Groceries. By 2000, the ENERGY STAR program has actually reduced or kept approximately constant office equipment energy use in all building types. Slight growth occurs in most building types over the 2000 to 2010 period. The building types that show growth over the 1990 to 2010 period in the ENERGY STAR case are those in which POS terminals (which are not subject to ENERGY STAR) are the dominant equipment type (Retail, Restaurants, and Groceries). This result suggests that EPA should explore expanding ENERGY STAR to include POS terminals.

Cost-effectiveness of the ENERGY STAR program

The analysis above demonstrates that savings from the ENERGY STAR program are likely to be significant in both energy and dollar terms. However, the following components of cost-effectiveness need to be addressed to determine whether the ENERGY STAR policy is beneficial to society:

(1) *Direct costs of manufacturers modifying the equipment and software to meet the* ENERGY STAR *criteria:* Extensive discussions with manufacturers during the design of the program showed that ENERGY STAR features could be added to PC CPUs and monitors at *negligible cost* to the purchaser (Johnson and Zoi 1992). Examination of data from a recent trade article showed that there was no cost difference between color monitors with power-management features and those without (Froning 1994). Data on direct costs for other equipment types are not available, but because the ENERGY STAR program is voluntary, and because the office equipment industry is highly competitive, it is reasonable to believe that manufacturers will not subscribe to program requirements that will increase costs to consumers and place the manufacturer at a competitive disadvantage.

The one case where we might expect additional costs for ENERGY STAR equipment would be copiers, because of the duplexing (double-sided printing) requirement for high-speed copiers. Even here, however, the additional costs imposed by the program are likely to be small or negligible, because ‘‘almost all’’ such high-speed copiers already have duplexing capability (Graff and Fishbein 1991). The main effect of requiring default duplexing is paper savings, which (at about 5¢ to 7¢ per sheet saved) would offset some or all of any additional cost for those few high-speed copiers that do not already have duplexing. The mailing and storage savings for double-sided material can be even more significant than the savings in the initial purchase cost of the paper.

(2) *Indirect costs imposed on the user by equipment that does not work as advertised:* Some manufacturers' early

ENERGY STAR-compliant PC CPUs and monitors interfered with network services. Others take more than a second or two to return to a usable state from the sleep mode. We assume that the problems associated with the first incarnation of the program will have been eliminated by 2000. This assumption is reasonable because the product life-cycles are so short in the computer industry, the new Memorandums of Understanding (MOUs) for PC CPUs and monitors (as well as MOUs for other equipment types) explicitly address these problems, and the manufacturers can more effectively incorporate power-saving features into their equipment as they gain experience with the early versions of ENERGY STAR equipment.

(3) *Direct administrative costs of the program:* The cumulative cost to the government for running this program is at most a few million dollars (the office equipment portion of the ENERGY STAR program has only a few employees).

(4) *The expected direct dollar savings to consumers:* In the ENERGY STAR Most-Likely case, we estimate consumer savings to exceed $1 billion per year after the year 2000 (excluding paper savings). Even in the Worst/Current Practice Continues cases, savings are more than $0.5 billion per year after 2000. In the Best case, savings are more than $1.3 billion per year after 2000

(5) *The dollar value of the external costs associated with emissions of criteria pollutants and greenhouse gases avoided by the energy savings*: We do not assess these potential impacts here, but they make the policy more cost-effective than it would be based simply on the expected direct dollar savings to consumers.

Adding these costs and benefits together reveals that this policy will save more than $1 billion annually in the U.S. after the year 2000, at a cumulative cost to society of a few million dollars. Put another way, a one-time per capita expenditure of roughly 2- in the U.S. has purchased annual monetary benefits per capita of about $4 for each and every U.S. resident.

The U.S. market for PCs, monitors, fax machines, and laser printers

We found in our analysis of device densities per person that sales of PC CPUs, monitors, fax machines and laser printers in offices are likely to saturate over the next five to ten years. Assuming, as we do in this analysis, that relative densities among building types remain constant at 1988 levels, it is likely that sales to the entire commercial sector will saturate over the same period. This result may take longer to occur if densities of office equipment in other building types grow at a faster pace than in offices. In any case, the industry forecasts seem to indicate higher levels of sales of this equipment than can be sustained based on sales to the commercial sector alone.

Mainframes and mini-computers

We project that mainframe and mini-computer energy use will decline by more than 50% over the 1990 to 2000 period. This decline is entirely the result of a decrease in power levels for these machines. Equipment densities for mainframe computers remain roughly constant from 1990 to 2000, while densities of mini-computers go up by almost 30%. This growth in the number of units is more than offset by a 60% to 65% reduction in per unit power. These estimates reflect current trends as embodied in industry projections, and include a substantial shift towards client-server computing and less energy-intensive parallel processing machines (Reinhardt 1995). The data on current densities and equipment power for these devices is relatively poor, and the characteristics of particular installations can vary by two orders of magnitude. Such variations and uncertainties highlight the need for further research and data collection in this area.

POS terminals

POS terminals account for 6.6 to 8.6 TWh/year of electricity consumption in the 2000 to 2010 period. If these terminals were improved to the levels shown for our ''advanced'' equipment (about 60% savings in UEC relative to the baseline) then savings would be 4.3 to 5.6 TWh, which would add about 30% to the savings already attributable to ENERGY STAR by 2010. EPA should consider developing an ENERGY STAR program for these devices because of this untapped savings potential.

Advanced technology

This scenario assumes the universal penetration of a variety of advanced technologies throughout the office equipment stock. These technologies include the use of liquid crystal display (LCD) technologies in place of cathode ray tubes (CRTs), the use of low-power complementary metal oxide semiconductor (CMOS) chips, and a variety of other options. We show this scenario to characterize the outer bounds of what is possible given current technology, but it would be foolhardy to insist that these outer bounds will remain so for very long. This scenario does not, of course, deal with what is economically justified, only what is technically possible. The results do indicate that there is a technical potential for significant savings even beyond the ENERGY STAR Most-Likely case. The challenge is to achieve those savings at competitive costs.

One recent note regarding LCD screens deserves mention, because that technology is the one assumed for monitors in our Advanced Technology scenario. Prices for these screens (now used almost exclusively in laptops) have been falling rapidly. Over the calendar year 1995, prices for 10.4-inch active matrix screens dropped from over $1000 to about $350 (Crothers 1995). This price drop was caused by improvements in production processes and an increase in manufacturing capacity.

Several manufacturers are now producing larger screens that approach the usable screen area of the most common CRT systems, and the prices of these screens are also falling. One manufacturer (Sharp) is explicitly targeting its larger LCD screens at the desktop monitor market, starting in 1996 (Crothers 1996). Only time will tell if these efforts are successful, but the inherent advantages of LCD screens (compact size, low mass, negligible electromagnetic emissions, and low power consumption) will make them attractive options if the price can be brought within about a factor of two of CRT screens.

CONCLUSIONS

While the energy use of office equipment has grown rapidly in recent years, this growth is likely to slow in the next decade because the U.S. commercial-sector market is becoming saturated (especially in the cases of PC CPUs and monitors). Significant uncertainties remain in creating such forecasts, particularly with regard to energy used in mainframe and mini-computers.

The likely energy and dollar savings in the commercial sector from the ENERGY STAR program are significant on a national scale. Total electricity savings in 2010 will most likely be about 17 TWh/year, with a range of 10 to 23 TWh/year. This level of savings represents the annual output of three 1000 MW power plants, and results in net benefits to society exceeding $1 billion per year after the year 2000. Significant additional savings may be achieved from advanced technologies if these technologies can be reduced in cost from current levels.

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