FINAL REPORT
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Consolidated Edison Co. and
the New York State Energy Research and Development Authority

OFFICE TECHNOLOGY ENERGY USE AND SAVINGS POTENTIAL IN NEW YORK

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NOTICE

ABSTRACT

This report discusses energy use by office equipment in New York State and the energy savings potential of energy-efficient equipment. We have developed a model containing equipment densities and energy-use characteristics for major categories of office equipment. The model specifies power requirements and hours of use for three modes of average operation for each device: active, standby, and suspend. The energy-use intensity for each device is expressed as a function of the average device density (number of units/1000 sq ft), the hours of operation in each mode, and the average power requirements in each mode. Increases in device densities through 2010 are based on market sales forecasts and commercial floor space projections. Output includes an estimate of total energy use (GWh) for each device by building type.

Three scenarios are developed. First is a business-as-usual efficiency baseline. Second is a future with increased use of power-managed devices projected under the current Energy Star Computers program sponsored by the U.S. Environmental Protection Agency (EPA). Third is a scenario that examines energy savings from greater use of products that go well beyond the standard Energy Star products. A series of sensitivity analyses were conducted to explore uncertainties in model inputs. One technology sensitivity test examined the energy impacts of multi-functional (combined fax, scanner, printer, copier) devices and related paper consumption.

The business-as-usual baseline forecast confirms that office equipment energy use has been rising over the past decade, and may continue to increase for the next decade and beyond. Office equipment currently consumes about 2900 GWh/year in the State of New York. Under our business-as-usual baseline forecast, this load may increase to 3300 GWh/year by the year 2000, and approximately double again before 2010. Widespread use of power management technologies adopted with the promotion of the Energy Star program could reduce this load growth by

about 30 percent by the year 2000. Use of more advanced energy-efficient technology could reduce total energy use by office equipment to about 1900 GWh/year in 2010, which is less than current consumption.

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EXECUTIVE SUMMARY

INTRODUCTION

This report examines energy use by office equipment within commercial buildings in New York State and explores the energy savings potential with widespread use of energy-efficient equipment. The office equipment end use has been one of the fastest-growing components of commercial-sector electric loads. There are opportunities for energy savings in computers and related office information-processing equipment from automated power management, improved components, and associated software and systems improvements.

This project developed a model containing energy-use characteristics and market data for major categories of office equipment in order to quantify the effects of current trends and policies. The eight **Of**ice **E**quipment **E**nergy-Use **M**odel (OFEEM) equipment categories are: personal computers (PCs), monitors, mainframe computers, mini-computers, copiers, printers, fax machines, and point-of-sale terminals. A ninth type of emerging equipment, multi-functional devices, are discussed in the sensitivity analysis. The four primary drivers of office equipment energy use in the OFEEM are changes in equipment densities, changes in equipment power requirements, operating patterns, and growth in commercial-sector floor space. The model output consists of unit energy consumption data (kWh/year for each unit), energy use intensities (kWh/sq ft-year), and total energy use for the commercial sector (GWh/year). The report examines energy use trends for the entire State of New York.

THREE FUTURE SCENARIOS

Three scenarios were developed to show the impact of changes in the energy efficiency of office equipment on energy use and peak electrical demand. These scenarios, combined with the sensitivity analyses, explore a range of possible market trends, technology developments, and policy options to improve energy efficiency. The first scenario is a business-as-usual baseline scenario projecting current technology and market trends into the future without the introduction of any policy efforts to introduce energy-efficient office equipment. Under this scenario the power requirements for most of the devices are kept constant, with the exception of monitors (increasing) and large computers (decreasing).

The Energy Star Computers scenario explores the savings that can be achieved assuming that the Energy Star equipment can obtain the market shares projected by leading information technology market researchers. The Energy Star program was developed by the U.S. Environmental Protection Agency (EPA) to urge manufacturers to add power-management features into office equipment. The program currently covers PCs, monitors, and printers, but a program for copiers and fax machines is being developed. We have made assumptions regarding the power savings and market trends for these new Energy Star equipment categories. We refer to this second scenario as the Energy Star scenario because of its relation to the EPA program, although it is only one interpretation of how savings might be achieved under the current and projected program.

A third, advanced energy-efficiency scenario provides us with a look at the savings from advanced equipment that is available today. These technologies will probably not be adopted without policies more aggressive than Energy Star, or major technological shifts. This scenario builds upon the second scenario. The difference is that we introduce more advanced technologies into the market three years after the introduction of the Energy Star equipment.

RESULTS

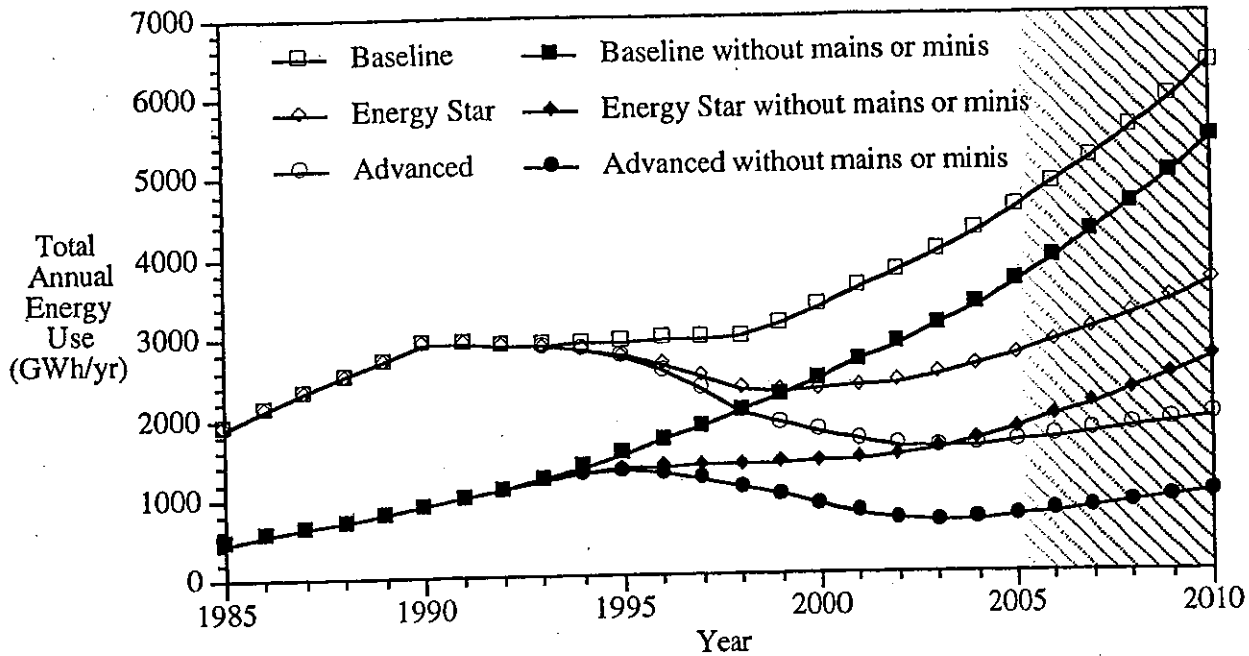
Energy used for information processing and office equipment has been rising over the past decade, and may continue to increase for the next decade and beyond. Office equipment currently consumes about 2900 GWh/year in the State of New York. Under our business-as-usual baseline forecast, this load may climb to 3300 GWh/year by 2000, and nearly double again to 6400 GWh/year in 2010. Figure S-1 shows the total load growth for all three scenarios together, which is also summarized in Table S-1.

Table S-1. OFEEM Results by Scenario for New York State

Scenario and Equipment Category	Total Energy Use 1994 (GWh/yr)	2000 (GWh/yr)	2010 (GWh/yr)
Baseline Scenario	2900	3300	6300
Energy Star Scenario	na	2300	3600
Advanced Scenario	na	1800	1900

The baseline scenario shows that the total load growth from the late 1980s flattens out until about 1998 because of the reduction in mainframe and mini-computer energy use (Figure S-1). After 1998, total energy use for office equipment begins to climb again, driven primarily by increases in equipment densities. This change illustrates that the most dramatic trend in office equipment energy use is the transition from centralized mainframes and mini-computers to personal computers (PCs). The most uncertain component of the office equipment end use, mainframes and mini-computers, is also the largest contributor to the total energy use, accounting for 1500 GWh/year in 1994. Figure S-1 also shows the three scenarios with mainframe and mini-computers excluded. Here we see that total baseline energy use climbs steadily over the full 25 years in the model. The dominance of large computers (mainframes and mini-computers) on total energy use will likely decline as energy use for and sales of large computers also decline. These declines are offset by increases in energy use for all other office equipment categories, which are driven primarily by increases in equipment densities (as opposed to changes in energy use per unit). PC and monitor energy use dominate the office equipment end use when large

Figure S.1. Total Annual Energy Use by Scenario.



Total commercial sector energy use is shown for three scenarios: Baseline, Energy Star, and Advanced Energy Efficiency. The total is shown with and without mainframe and mini-computers because of the uncertainties associated with large computer energy use.

computers are excluded.

There is significant potential to reduce energy use by office equipment. Using moderate assumptions regarding market penetration and performance, today's Energy Star equipment could decrease the total commercial sector energy use by 30 percent (about 1000 GWh/year) by the year 2000, and by 43 percent by 2010. Even with the potential savings from a program like Energy Star, the total commercial sector office equipment energy use increases over the forecast horizon, reaching 3600 GWh/year in 2010.

Comparing the scenarios over time, Energy Star equipment could reduce cumulative office equipment energy use by 3600 GWh in this decade, as shown in Table S-2. The cumulative savings are five times greater for the next decade, reaching nearly 20,000 GWh. This result is based upon the assumption that the equipment reaches 100 percent of the office equipment market after 2005.

Table S-2. Cumulative Energy Use and Savings from Energy Star

	Cumulative Total Sector Energy Use in New York	
	1994 to 2000 (GWh)	2001 to 2010 (GWh)
Baseline Scenario	21,200	47,900
Energy Star Scenario	17,600	28,600
Savings from Energy Star Equipment	3600	19,300

The use of advanced energy-efficient technologies could halt the load growth over the next 15 years, leading to a total decline in office equipment energy use to near 1900 GWh/year by 2010. In almost every equipment category there are readily available technological and hardware advances that suggest there are large potential savings from low-energy office technologies. However, it is unlikely that these advanced technologies will see widespread use because of increases in initial costs compared to standard or Energy Star models.

UNCERTAINTIES IN BASELINE ESTIMATES AND ENERGY SAVINGS

The fast-paced change of information and computing technologies clearly complicates our ability to forecast future energy requirements. We have examined the influence of several of the most uncertain input variables on our findings. There are basically two categories of uncertainties: those associated with the baseline scenario, and those concerning the penetration and performance of Energy Star equipment. The advanced energy efficiency scenario was excluded from these analyses because of its exploratory nature.

Mainframe and Mini-Computer Energy Use

We have estimated that large computers (mainframes and mini-computers) presently consume as much as, if not more than, PCs and monitors. These results are consistent with several other studies discussed in the report. This equipment category is by far the most uncertain component of current energy use for information and computing technology. Further research is needed to better quantify the overall trends in energy use of large computers. This research should also examine the opportunities for greater energy efficiency in large computers.

Uncertainties in Energy Star Savings

The Energy Star program has launched a new generation of power-managed office equipment that has tremendous savings potential. However, these savings are uncertain for two reasons: performance and market penetration. Clearly our ability to forecast savings from Energy Star equipment is linked to its market share. The market for energy-efficient office equipment appears to be smaller than early projections from market researchers. The sensitivity analysis of market trends shows that doubling the number of years that is required for the Energy Star equipment to reach the market reduces the cumulative energy savings between now and 2010 by 14 percent. In general, there are few published reports from the field that examine whether the equipment is performing as expected. Early reports show mixed results. Both energy savings and user acceptance need to be examined. Without such feedback, it is unclear how much energy savings are being delivered from the equipment that is currently reaching the market.

To better understand the savings potential of power-managed office equipment it is also important to better understand how conventional equipment is used. For example, there is little information available as to whether copiers and other equipment are turned off at night. The sensitivity analysis on operating schedules found that doubling the OFEEM inputs for nighttime hours of use for PCs, monitors, printers, and copiers increased the savings from Energy Star equipment by 37 to 82 percent, depending on the equipment category.

The economics of energy-efficient office equipment were beyond the scope of this study. Further research is needed to evaluate the technology costs associated with further improvements of PCs, monitors, and other equipment. Similarly, further work is needed to assess the potential hassle and lost labor costs associated with operating current and emerging energy-efficient office technologies. This comment is based on field studies that suggest that the first generation of power-managed PCs and monitors were not always reliable in ensuring energy savings. For example, some Energy Star PCs were incompatible with local-area networks. Another common problem was that users were not aware of how to properly enable or configure their power management systems. These problems are reportedly less frequent in second generation Energy Star PCs.

Section 1

INTRODUCTION

This report examines energy use by office equipment within commercial buildings in New York State and explores the energy savings potential associated with widespread use of energy-efficient equipment. The office equipment end use, often treated in the past as part of a ''miscellaneous'' category, is now recognized as one of the, if not the, fastest-growing components of commercial-sector electric loads. There are important new opportunities for cost-effective energy savings in computers and related office information-processing equipment from automated power management, improved components, and associated software and systems improvements.

This project developed a spreadsheet model containing energy-use characteristics and market data for eight major categories of office equipment. The **Office Equipment Energy-Use Model** (OFEEM) is used to estimate how much energy might be saved with widespread use of energy-efficient office equipment. OFEEM tracks changes in the four primary drivers of office equipment energy use, which are increases in equipment densities, changes in equipment power requirements, operating patterns, and growth of commercial-sector floor space. OFEEM output consists of unit energy consumption data, energy use intensities, and total annual energy use for the commercial sector. The project builds upon a previously developed, and now greatly expanded, model (Piette et al., 1991). Our analysis examines energy use trends in the entire State of New York. The total commercial floor space in New York consists of about 3600 million sq ft, of which 30 percent is office buildings.

Before describing the project in more detail we present a brief description of federal and international programs and policies that are influencing the development and implementation of energy-efficient office equipment.

PROGRAM AND POLICY DEVELOPMENTS

The past few years have seen the dawning of several programs and policies designed to reduce energy use by office equipment. Probably the most significant activity in the U.S. is the U.S. Environmental Protection Agency's (EPA) Energy Star Computers program. This program, announced during the summer of 1993, has ushered a new generation of power-managed office technologies into the fast-paced office technology marketplace. Over 2000 computers, monitors, and printers are now listed as Energy Star qualified products. The EPA will soon announce the expansion of the program to copiers and fax machines. To qualify as an Energy Star PC or monitor, the equipment must be able to reduce power consumption to 30 W or less during idle periods (Table 1-1). Printer power requirements are related to printer speed, as shown in Table 1-1.

Table 1-1. Energy Star PC, Monitor, and Printer

Equipment Category	Default Time to Low-Power State	Max. Power in Low-Power State
PC (without monitor)	na	30 W
Monitors	na	30 W
Printers (1-7 pages per minute)	15 min.	30 W
Printers (8-14 pages per minute)	30 min.	30 W
Printers (color and >15 pages per minute)	60 min.	45 W

Not all Energy Star units are equal in their energy efficiency. Efforts to assess, specify, and procure more efficient equipment are hampered by the lack of standard methods for measuring and reporting the energy use of each device. Currently the EPA allows manufacturers to conduct their own measurements, and the data in the EPA Energy Star product list has not been verified by an independent test. To address this void, the Energy Policy Act of 1992 calls for a voluntary national testing and information program for office equipment. The Department of Energy is working with a newly formed organization headed by industry representatives and representatives from the Council on Office Product Energy Efficiency (COPEE) to develop such standards. COPEE is organized by the Computer and Business Equipment Manufacturing Association (CBEMA).

The signing of executive order (E.O. 12845) by President Clinton is another significant activity that should be noted. Under this order, the world's largest purchaser of office equipment, the U.S. government, is required to purchase Energy Star PCs, monitors, and printers. This market-pull strategy has had a significant effect on the market penetration of Energy Star equipment.

Similar activities to promote energy-efficient office technologies are underway in several European countries, plus Japan (Smith et al., 1994; Dandridge, 1994). Two notable activities in Europe demonstrate the broad interest in reducing the energy use of office equipment. First, the Swedish Board for Industrial and Technical Development (NUTEK) has subsidized the development of power-managed monitors and is continuing to encourage power management in several additional devices. Second, the Swiss Federal Institute of Technology recently announced that the target level for standby power for PCs will be 10 W by 1998, which is only one-third of the EPA's Energy Star target.

PROJECT OVERVIEW

Three scenarios were developed to show the impact of changes in the energy efficiency of office equipment on energy use and peak electrical demand. These scenarios, combined with the sensitivity analyses, explore a range of possible market trends, technology developments, and policy options to improve energy efficiency. Table 1-2 lists the eight equipment categories tracked in OFEEM: personal computers (PCs), monitors, mainframe computers, mini-computers, copiers, printers, fax machines, and point-of-sale terminals. (A ninth category, multifunction machines, is discussed but not included in the model.) The nine building categories are: office, school, warehouse, retail, health care, hotel, grocery, restaurant, and miscellaneous.

The first scenario is a business-as-usual baseline scenario projecting current trends into the future without the introduction of any policy efforts to introduce energy-efficient office equipment. Under this scenario the power requirements for most of the devices are kept constant, with the exception of monitors (increasing) and large computers (decreasing), as listed in Table 1-2. This baseline does not include current forecasts of the savings that may be achieved with the EPA's Energy Star Computers program. The Energy Star program is still in its infancy, and it is important to define a baseline against which to evaluate its savings.

The Energy Star scenario explores the savings that can be achieved assuming the Energy Star equipment penetrates the market at the projected rates. We are calling this an Energy Star scenario because of its relation to the EPA program, but it is only one interpretation of how savings might be achieved under the current and projected program plans. Our estimates can serve as a starting point for future evaluations of the savings to be achieved from the Energy Star and related programs. This scenario differs in two ways from the baseline scenario. First, the Energy Star equipment gain market share based on projected sales as a percent of total sales and retirement rate. Second, the power requirements differ, as discussed in Section 3. We developed Energy Star scenarios for each equipment category except large computers (mainframes and mini-computers). The year that the Energy Star equipment is estimated to enter the market varies in relation to the EPA's program activities (also discussed in Section 3). Operating patterns (hours of use and time of use) are held constant in all three scenarios. This assumption of constant operation in time is subject to question and is explored in the sensitivity analysis.

The advanced energy-efficiency scenario provides us with a look at the savings available from energy-efficient office equipment if more advanced policies are adopted or related technological shifts occur. It is unlikely that these technologies will see widespread use in the near future. This scenario builds off the second, with market trends based on the Energy Star equipment sales and stock replacement, but with energy efficiency and power management going well beyond Energy Star. These advanced technologies are also discussed in Section 3, and are currently available or near-term products.

The fast-paced change of information and computing technologies clearly complicates our ability to forecast future energy requirements. As with any forecast, however, we have greater certainty in the short as opposed to the long term. The forecasts are based on anticipated success of the current programs and policies outlined in the next section. The implications of uncertainty in key assumptions are explored in sensitivity analyses that examine how the results differ as one modifies key OFEEM inputs. Variations in equipment use, equipment densities, technology turnover rates, and market sales trends were examined. One interesting sensitivity examines the energy impacts of future multifunction image-processing products (combined fax, scanner, printer, copier) and related paper consumption.

Table 1-2. Summary of Scenario Analyses

Scenario and Equipment	Power per Unit Trend	Year Introduced
I. Baseline Business-as-Usual Scenario		
PCs	No Change	
Monitors	Increasing	
Mainframes & Mini-Computers[1]	Decreasing	
Copiers	No Change	
Printers	No Change	
Faxes	No Change	
Point-of-Sale Terminals	No Change	
II. Energy Star Scenario		
PCs	Energy Star	1993
Monitors	Energy Star	1993
Mainframes & Mini-Computers	Decreasing	
Copiers	Energy Star	1995
Printers	Energy Star	1993
Faxes	Energy Star	1995
Point-of-Sale Terminals	Energy Star	1993
III. Advanced Energy Efficiency		
PCs	Advanced Practice	1998
Monitors	Advanced Practice	1998
Mainframes & Mini-Computers	Decreasing	
Copiers	Advanced Practice	2002
Printers	Advanced Practice	2000
Faxes	Advanced Practice	2002
Point-of-Sale Terminals	Energy Star	

1. Mainframes and mini-computers are two separate categories.

ECONOMICS

This project analyzes trends in office equipment energy use, but it does not examine the economic impacts or assumptions underlying these trends. It is important to note, however, that there appears to be no additional cost necessary to include Energy Star equipment within PCs or monitors. 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). Some of the more advanced energy-efficient products do have considerably higher prices than common Energy Star equipment, such as low-power liquid-crystal display technology for PC monitors. This subject warrants further exploration. In any case, we have not examined the costs required to implement the Energy Star program or other policies.

REPORT ORGANIZATION

The report is organized as follows. After this introduction, the remainder of the report is divided into eight sections. Section 2 outlines the general structure of OFEEM. Section 3 reviews the office technology characteristics and power requirements for each equipment category as a separate subsection, concluding with a review of the inputs to OFEEM. Section 4 describes the technology operating profiles and OFEEM inputs. Section 5 discusses the equipment densities and future penetration estimates. Section 6 describes the results of the baseline, Energy Star, and advanced energy-efficiency scenarios. Section 7 reports on the sensitivity analyses conducted to explore uncertainties in the data inputs and uncertainties regarding whether the savings will be achieved as projected. Section 8 is a summary with comments on forecasting and policy implications and topics that warrant future research. References are listed in Section 9.

Section 2

OFFICE EQUIPMENT ENERGY-USE MODEL STRUCTURE

This section outlines the general principles of the data and calculations in OFEEM, setting the stage for the discussion of the data inputs in subsequent sections of the report. The four primary drivers of office equipment energy use are power requirements, operating patterns, density of equipment, and commercial floor space. OFEEM forecasts estimates of the density of equipment. The model is calibrated with historical utility surveys of equipment densities by building type. We then input industry sales projections for each category of equipment with retirement rates to forecast increases in equipment densities. The equipment densities are combined with estimates of power requirements and hours of use by primary operating mode for each equipment category to estimate energy use. Equipment operating schedules are held fixed in time. The following nine building types are covered in OFEEM: office, retail, hotel, school, warehouse, restaurant, grocery, health care, and miscellaneous.

CALCULATING ENERGY USE AND COINCIDENT PEAK DEMAND

OFEEM combines average power requirements and annual hours of use for each device in three modes of operation — active, standby, and suspended — to estimate an average unit energy consumption (UEC). The three modes of operation are defined uniquely for each category or device, as further described in Section 3. The power requirements, also described in Section 3, change by year. The annual hours of use estimates are fixed, as described in Section 4. The UEC for each equipment category can be described by the following equation:

$$UEC_i = P_i \ x \ (A_i \ x \ HA_i + SB_i \ x \ HSB_i + SP_i \ x \ HSP_i \ ) / 10^3$$

where

UEC =	Unit Energy Consumption for equipment type i (kWh/year)
i =	index for office equipment type
P =	Peak power equipment type i (W/unit)
HA =	Hours of operation in active mode for equipment type i (hours/year)
HSB =	Hours of operation in standby mode for equipment type i (hours/year)
HSP =	Hours of operation in suspend mode for equipment type i (hours/year)
A =	Average active mode power as a percent of peak for equipment type i (%)
SB =	Average standby mode power as a percent of peak for equipment type i (%)
SP =	Average suspend mode power as a percent of peak for equipment type i (%)

Average power levels (A, SB, and SP) of standard and low-power or power-managed office equipment are tracked separately within the model. In the current version of OFEEM, A is equivalent to P for all equipment categories, i.e., the average active power and peak power requirements are identical. This can be interpreted as modeling average hourly peaks rather than 15-minute peaks. Higher resolution data, such as 15-minute peak data, were largely unavailable for most devices, such as copiers and printers. However, 15-minute demand modeling could be added to a future version of OFEEM with ease.

The estimates of equipment densities by building type (number of units per area) are combined with the UECs to calculate the energy-use intensity (EUI) for each device by building type, as shown in Figure 2.1. The scaling factor shown in the figure relates the density of each category of office equipment in offices to the density of equipment in other building types. These data and the change in equipment densities over time are described in Section 5. The office equipment EUI for each building type can be expressed as:

$$EUI_j = \sum_{i=1}^{n} D_{ij} \, (UEC_i) / 10^3$$

where

EUI =	Energy-Use Intensity for building j (kWh/sq ft-year)
i =	index for office information technology equipment type
n =	8 (number of office equipment categories)
j =	index for building type
D =	Density of equipment type i in building j (# of units/1000 sq ft)
UEC =	Unit Energy Consumption for equipment type i (kWh/year)

Notice that the density of equipment (D) varies by building type, as discussed in Section 5. The office equipment EUIs serve as the foundation for the EUIs in other buildings for all equipment categories except the point-of-sale (POS) terminals. Implicit in this method is the assumption that the operating patterns of office equipment in office buildings are identical to the use in non-office buildings. These data are discussed in Section 5. The POS terminal densities were based on utility surveys of POS terminal densities, also discussed in Section 5.

Each EUI is combined with total sector floor space by building type to estimate total GWh/year for each building type. All data are in site energy units (1 kWh = 3413 Btu). The above calculations can also be divided to look at the contribution of each equipment type to total sector office equipment energy use. The calculations are performed for each year. OFEEM currently extends from 1985 to 2010. The commercial floor space data are presented in Section 5. The next subsection describes how the model treats changes in equipment densities over time.

Estimating the utility peak demand requires consideration of coincidence of timing of the operating states and diversity of use (which were individually accounted for and are discussed in Chapter 4). Our approach involves three steps:

(1) identify utility peak demand periods;

Figure 2.1. OFEEM Calculation of EUI and GWh/yr.

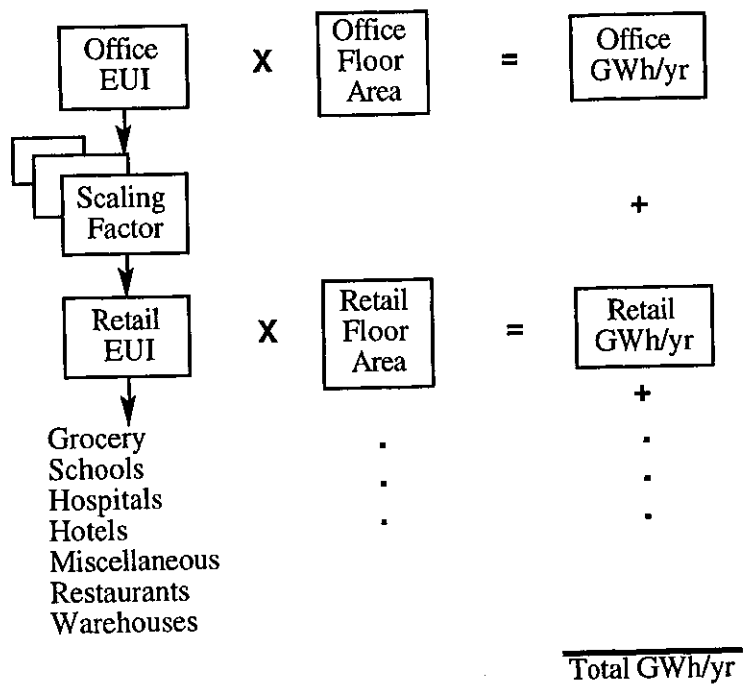
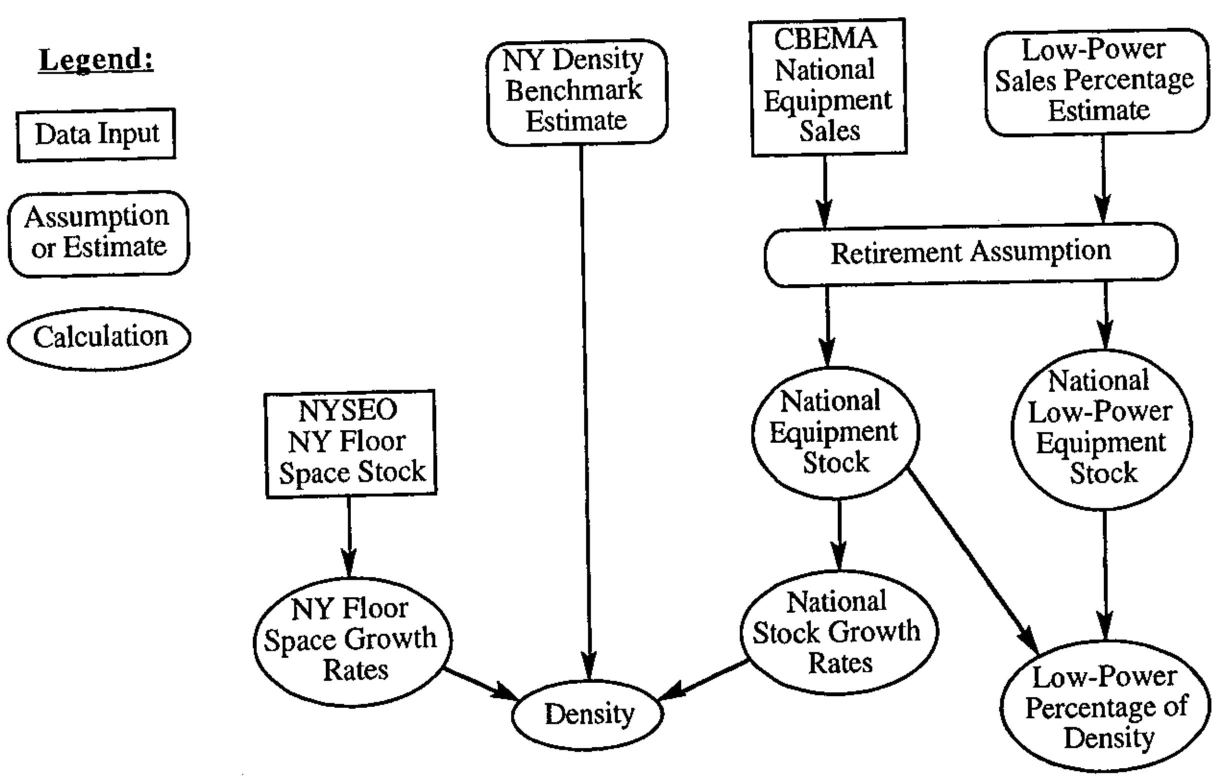


Figure 2.2 OFEEM Structure of Equipment Density



(2) map operating states and diversity of use into these periods; and

(3) calculate time-weighted average demands for each period.

First, we develop separate peak demand periods for both winter and summer. The time periods correspond roughly to the on-peak demand rating periods used by New York utilities for rate design purposes. The winter peak demand period is defined as winter weekdays between 8 a.m. and 10 p.m. The summer peak demand period is defined as summer weekdays between 12 p.m. and 6 p.m.

The mapping of operating hours into time-of-day periods consists of assigning a number of hours to the morning (4 hours), the afternoon (6 hours) and the evening (4 hours). The summer peak is an afternoon period when utility demand is driven by air conditioning needs. The winter demand periods are broader, with all three periods: morning, afternoon, and evening. To map the hours of use data into these periods we considered both typical daily work schedules and information on hourly operation from several sources, as discussed in Section 3. Hours of use by mode were mapped into the daytime periods by splitting active-mode hours into the morning and afternoon periods. Standby-mode operating hours were added if the active hours did not add up to the total number of hours for each period. Most of the suspend-mode operating hours were evening and nighttime periods. After making these assignments, we calculate average demands as the average of each operating mode, weighted by the hours of operation during each peak demand period.

MARKET PROJECTIONS AND EQUIPMENT DENSITIES

As mentioned, one of the primary drivers of the increase in office equipment energy use is the increase in equipment densities. The flow chart in Figure 2.2 shows the structure of the office equipment density model, which is developed for each category of equipment. We begin by estimating, or benchmarking, a single year's equipment density (listed as the NY Density Benchmark estimate in the figure) based on our review of available utility survey data. The selection of these inputs is discussed in Chapter 5. Historical and future device densities are estimated using market sales projections and floor space growth. This is done by tracking two data streams: floor space growth and equipment sales. The floor space data were provided by the New York State Energy Office. Floor space estimates were tracked from 1985 through 2010. For equipment sales data we drew upon the most complete and readily available source of information, the annual report on industry marketing statistics from the Computer and Business Equipment Manufacturing Association (CBEMA, 1994). This trade association compiles historical sales data and projects future sales for several classes of hardware. We further discuss these data in Section 5.

For each year, the floor space growth rate (calculated from the NYSEO data) and the equipment stock growth rate are combined to estimate the change in equipment densities. The equipment stock growth rate includes an estimate of the equipment lifetime as older equipment is retired from the stock. The lifetimes used in the stock derivation are six years for all equipment except mainframes (nine years) and mini-computers (eight years), and PCs and monitors (four years).[1] The lifetime data are used to estimate how equipment is retired from the stock. For example, with a four-year PC or monitor life, all devices installed in 1990 are retired from the stock in 1994.

As shown in Figure 2.2, the sales of energy-efficient office equipment are approximated exogenously, or outside or the model, and combined with the equipment stock and retirement data. The sales of energy-efficient office equipment are expressed as a percentage of the equipment density. These data are highly uncertain and market researchers have differing opinions regarding the future markets for office equipment. Dataquest forecasted that in 1993, 30 percent of all desktop and deskside PCs would meet the Energy Star criteria, increasing to 100 percent by 1997 (Dataquest, 1993). More recent market analysis suggests that about half of the PCs sold to are Energy Star compliant (Dataquest, 1994). Assuming a four-year PC lifetime, or four-year stock turnover, this suggests that the complete stock of PCs would comply with Energy Star recommendations in 2001. More recent conversations with Dataquest suggest that the actual market share of Energy Star PCs in 1993 was probably lower than their original estimate. Our estimates are further described in Section 5 and are the subject of further sensitivity analysis in Section 7.

INDIRECT ENERGY USE BEYOND OFEEM

Heating, Ventilation, and Air-Conditioning Energy

The energy-use estimates in OFEEM represent electricity used directly by office equipment. They do not include any impacts of heating or cooling energy. In many commercial buildings the excess heat generated by the equipment increases cooling loads. However, the interaction between office equipment heating, ventilation, and air-conditioning (HVAC) energy use is a complex problem since it varies with the type of HVAC equipment. The increase in cooling loads associated with various types of office equipment is difficult to estimate.

Paper Consumption

The energy embodied in paper is greater than the energy used directly by office equipment to print, copy, or fax. OFEEM does not include embodied energy in paper or in the device itself from equipment manufacturing. However, we have tracked imaging processing speeds (pages copied or printed per minute or hour) and hours of use in order to characterize active operating hours related to average print, copy, or fax jobs. We further discuss paper and image processing in Section 3.

1. These lifetimes are consistent with the Internal Revenue Service's Depreciation Tables, which show "lives" of dozens of classes of commercial and industrial equipment (IRS, 1989). This is the same general technique used in the CEDMS model used by the New York utilities and the Energy Office.

Section 3

TECHNOLOGY CHARACTERISTICS AND POWER REQUIREMENTS

This section describes power consumption characteristics of office technologies. Historical, current, and projected future trends are reviewed in relation to the selection of OFEEM input data. As described in Section 2, the power requirements for each equipment category in OFEEM are combined with operating profiles (discussed in Section 4), yielding an average annual unit energy consumption (kWh/year, or UEC) for each device.

It has been difficult to develop fixed equipment definitions because of the fast-paced change in office technologies. Where possible, the data are based on measured results. The lack of standard methodologies for measuring power requirements, plus the lack of knowledge about standard operating patterns and duty cycles, makes comparing results from various studies difficult.[2,3] Furthermore, large sets of statistically relevant monitored data are not widely available for most categories of office equipment. The exception is the work on PCs and monitors by Szydlowski and Chvala (from Pacific Northwest Laboratory, PNL, 1994), and Tiller and Newsham (from the National Resource Council of Canada, NRC, 1993 and 1994). We also draw heavily on measurements reported by Dandridge (1994).

The discussion below is divided into eight sections that separately describe each of the eight OFEEM equipment categories; the mainframe and mini-computer discussion is combined into one section, but another section discusses multifunction machines, even though they are included only in the sensitivity analysis. Each section has three subsections. The first, Equipment Description and Historical Trends, defines the equipment category and discusses energy consumption trends over the past decade. The second, Energy Efficiency and Future Trends, describes use innovations that will affect future technologies. The third, OFEEM Inputs, identifies the power requirements used in the three scenarios described in Section 6.

PERSONAL COMPUTERS

Equipment Description and Historical Trends

Our goal is to characterize how the mean PC wattage is changing. We start with the CBEMA definition of personal small or computers (PCs). CBEMA defines micro-computers as systems that include central processing unit (CPU), basic storage, keyboard, and monitor, excluding

2. Widespread use of the proposed American Society for Testing and Materials (ASTM) methods for copiers, printers, and fax machines should help produce useful energy use data. Similarly, COPEE is currently developing measurement methods for PCs and monitors.

3. In the past some analysts have cited nameplate ratings as a proxy for power requirements. Power requirements are usually about 20 to 40 percent of the nameplate ratings (Norford et al., 1990). Nameplate power is based on the maximum electric load for which the power supply is sized, and power supplies are typically oversized.

systems less than $1000 list price (including the monitor) because these are considered non-business games and home computing systems. Some PCs that sell for less than $1000 may be used in small businesses. Our comparisons of CBEMA and Dataquest market data, however, have shown them to be consistent in their definition of home versus business PC sales and stocks, indicating that using the CBEMA data for commercial sector market trends appears to be reliable. To keep track of changes in monitor and computer technologies, we refer only to the computer and not the monitor in our reference to PCs, unless noted otherwise. Workstations are included in our definition of PCs, although the lack of power consumption data for these devices adds some uncertainty to the mean power estimates for the PC category. The CBEMA price definition for micro-computers extends to $14,999.

Historically, desktop and deskside PCs were basically constant power devices, though the use of a floppy drive may temporarily increase power by up to about 7 W (Norford et al., 1990). The electronics in PCs account for about 25 percent of the total power requirements, while the remaining 75 percent is required for the operation of the hard disk drive. Additional energy use occurs when peripherals are added, such as extra boards and floppy disk drives. The range in the power consumed by PCs is large. On the low end, many laptop computers consume less than 15 W while active, including the monitor (Norford et al., 1990). PCs loaded with add-on features, but not including the monitor, can consume over 140 W.

The general trend during the first few years of production was that energy use of PCs first increased, then decreased. (Although monitor power requirements have been increasing as discussed below.) For example, average power consumption of the IBM PC, XT, and AT were 68 W, 88 W, 135 W, respectively, with a simple average of 97 W, which we will assume as the power for our 1985 vintage PC (Norford et al., 1990), as listed in Tables 3-1 and 3-2 below.

Typical power requirements for computers and monitors between 1990 and 1992 have been presented in recent research by Szydlowski and Chvala (1994) and Tiller and Newsham (1993). Combining data from both studies results in measured data from a sample of 287 PCs (including Macintosh computers), with an average power requirement of 75 W.

Energy Efficiency and Future Trends

New PCs support a tremendous increase in computing power. The Pentium chip at 8.6 MIPS/W (millions of instructions per second) provides ten times more computing power per W than PCs of the early 1980s (Dandridge, 1994). Another development, one that is related to laptop technologies and techniques to reduce internal heat, are the features with new power-managed Energy Star PCs to slow or shut down various components after some period of idle time. There is no standard set of terminology to describe various operating modes. We provide the following definitions, which are based on the Intel/Microsoft Advanced Power Management (APM) Protocol (1992).

- Ready (On) - fully powered state, ready for use. The APM definition suggests ready can be active or idle.

- Standby - intermediate state which attempts to conserve power with instant recovery; the system is idle. (This mode is probably non-existent for a standard PC or monitor.)
- Suspend - lowest power level with longer recovery time. Often referred to as sleep or coma. (This mode is non-existent for a standard PC or monitor.)
- Off - plugged-in, powered down state, inactive (may consume some power), which we found to be zero for most PCs (and other devices, with the possible exception of copiers).
- Active - on, and in use, which for the purpose OFEEM, is identical to ready. Power may vary slightly by type of activity, such as the size of a spreadsheet or number of processes running at once on a PC. Active power may also be influenced by operation of add-on cards and devices, such as a modem card or CD-ROM drives.

Many Energy Star computers also use less power in active mode. It is unclear, however, if this is an overall trend. The trade articles report "ready" power measurements for Energy Star PCs that are far below the measurements from PNL and NRC for standard PCs (see e.g., Nadel, 1994). The articles do not report on measurements of new non-Energy Star PCs. The uncertainty in baseline power is further discussed in the sensitivity analysis in Section 6.

Some market research groups expect that most PCs will meet the Energy Star power-management criteria within five years (Dataquest, 1993; InfoCorp, 1993). Several Pentium PCs comply with Energy Star criteria. One power-managed 486SL CPU reportedly consumes only 24 W in operation and 16 W in a non-active state. Based on a review of manufacturer's literature, most of today's "Green PCs" consume about 35 W in active mode, 25 W in standby, and have no low-power suspend mode (listed as identical to the standby power mode in Table 3-1).

Table 3-1 Variation in PC Power (excluding monitors)

	Active (W)	Standby (W)	Suspend (W)
Average Mid-1980s Stock[a]	97	97	97
Average 1991 Stock[b]	75	75	75
Average Energy Star Compliant 486 CPU[c]	34	25	25
Today's Best Practice[d]	15	na	5
Likely Late-1990s Practice[e]	15	5	1

a. Simple average of IBM PC, XT, and AT (Norford et al., 1990).
b. Average from 287 individually monitored PCs (Szydlowski and Chvala, 1994, and Tiller and Newsham, 1993). Assumed to be identical to power requirements for today's new PCs.
c. Average of 37 Energy Star 486 PCs (Nadel, 1994).
d. Lowest-power desktop (Nadel, 1994).
e. Swiss target for 1998 suspend power at 1 W.

Dandridge (1994) concludes that the potential for low power use in power-managed PCs is impressive. Resume time is less than one second for electronics in a lower-power mode, requiring only 0.9 W in the "standby mode." Powering down disk drives takes the PC into a deeper "suspend mode," with power at 0.06 W, requiring 3 seconds to power up to an active "ready" state. Recent research has shown that PCs and monitors can be powered down with no negative effect on equipment lifetime (Miteff, 1992a). In fact, some industry analysts suggest that there is a net benefit from decreasing active on time because the product life will be extended (Dataquest, 1993).

Interest in reducing PC power is not limited to the U.S. The Swiss Federal Institute of Technology recently announced that the target level for standby power for PCs will be 10 W by 1998, and 1 watt in an "off" mode, which we will consider equivalent to suspend. There are no target levels for reducing "active" power.

Overall there are conflicting opinions whether trends of energy use for PCs is increasing or decreasing. Increased power requirements for new chips suggest power use is rising. Dandridge described that 286 CPUs and earlier versions require around 30 W, 386 CPUs use an average of 46 W, and 486 CPUs need about 80 W (1994). However, lower-voltage (3.3V versus 5V) systems drive power use down. Future computers will likely require large bandwidths for their data bus, making the most common current PC architecture obsolete. This presents the opportunity to build power management into future technologies. The future also may bring lower voltages than today's 3.3V system. Increases in storage density will probably also not require more power.

OFEEM Inputs for PCs

Table 3-2 shows the power requirements for PCs used in OFEEM for the three scenarios that examine energy use of PCs. The baseline scenario inputs are average stock inputs. The Energy Star and advanced scenario PC power inputs are for new machines that enter the market over time, thereby reducing the stock average power. The Energy Star PCs appeared on the market in 1993. As further discussed in Section 5, we estimate that Energy Star PCs capture 100 percent of the PC market, or new sales in the year 2000, and with an average life of four years, the stock is 100 percent Energy Star in 2004. We estimate that the average Energy Star PC uses 6 W more than the average listed in Table 3-1 to account for increases from add-on cards. To explore energy savings potential beyond Energy Star we developed an advanced energy-efficiency scenario (III) that lags behind the Energy Star market by three years.

Table 3-2 OFEEM Inputs for PCs (excluding monitors)

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	97	97	97
Average Stock	1990	79	79	79
Average Stock	1995	75	75	75
Average Stock	2000	75	75	75
Average Stock	2005	75	75	75
II. Energy Star Scenario				
Enters Market	1993	40	25	25
III. Advanced Energy-Efficiency Scenario				
Enters Market	1998	15	5	5

MONITORS

Equipment Description and Historical Trends

The large majority of office monitors and display terminals use cathode-ray tube (CRT) displays, which function by exciting a layer of phosphors with an electron gun. Our definition of these devices include those used with PCs and terminals with mainframes or mini-computers. Features such as color, resolution, and size influence power requirements. Most PC monitors are sold in screen sizes of 14 inches, 15 inches, 17 inches, and 21 inches, with 14 inches and 15 inches holding the lion's share of the market. Today's PC users are buying larger, higher resolution color CRTs, whereas the typical monitor five years ago was a smaller (14 inches) monochrome.

As with PCs, historically CRTs were basically constant-power devices. Average power of the IBM PC, XT, and AT monitors were 26 W, 27 W, and 31 W, respectively, with an average of 28 W, which we will assume as the power for our 1985 vintage monitor (Norford et al., 1990), as shown in Table 3. Today most monitors are color. Average power based on 270 monitors was 55 W (Szydlowski and Chvala, 1994; and Tiller and Newsham, 1993). Less than 10 percent of the monitors today are monochrome.

Energy Efficiency and Future Trends

Power-managed CRTs typically have standby and suspend modes that use less power than full active power. Power-managed CRTs are available for use with PCs and with larger workstations, mainframes, and mini-computers. We have considered standby power as that reached during operation with a blank, dark screen without a screen saver. This mode of operation reduces power consumption by about 25 percent. (Note, that screen savers alone do not reduce power requirements.) Recovery time from standby is nearly instantaneous. A lower-power suspend mode can be achieved after some period of idle time by turning off additional components of the CRT, but recovery time increases dramatically. One CRT reduced active power by about 90 percent by turning off the video display card and electron beam control (coils), but leaving the cathode hot, allowing for near-instantaneous recovery.

Flat-panel displays used with today's laptop computers use far less power than CRTs, but their high cost limits their use to the laptop arena. There are three types of flat-panel displays: liquid crystal (LCD), plasma, and electroluminescent emission (EL). Color LCDs are likely to increase their share of the monitor market. One manufacturer offers a 23-W, 10 inch LCD display for use with desktop computers. LCDs can also be powered up and down more rapidly than most CRTs.

Market-pull strategies abroad are moving manufacturers to produce power-managed office equipment. As mentioned, the Swedish Board for Industrial and Technical Development (NUTEK) has subsidized the development of power-managed monitors. One model is listed in Table 3-3 (Dandridge, 1994). The Swiss target for standby power for monitors has been set at 5 W, again with no target for ''active'' mode.

Table 3-3. Variation in Monitor Power

	Active (W)	Standby (W)	Suspend (W)
Typical Mid-1980s (monochrome)[a]	28	28	28
Average 1991 Stock[b]	55	55	55
Typical New 15" CRT[c]	80	80	80
Typical New 17" CRT[c]	100	100	100
Typical Energy Star Compliant CRT[d]	55	43	5
Typical 14" Swedish NUTEK CRT[e]	75	<13	<3
Desktop 10" LCD[e]	23	5	5

All monitors are color accept as noted.

a. Average of IBM PC, XT, and AT monitors (Norford et al., 1990).

b. Average from 270 individually measured monitors (Szydlowski and Chvala, 1994; Tiller and Newsham, 1993). Less than 10 percent were monochrome monitors.

c. Trade press (Froning, 1994).

d. Average Energy Star monitor from trade press and product literature, which exceeds the minimum requirements.

e. Dandridge, 1994.

There are several ways monitors are configured to determine when to go into a suspend mode and not all power management is equivalent. Some monitors require a signal from the CPU to enter a reduced-power mode, which can be a problem if the CPU does not have the proper communications protocol to send the signal to the monitor. Other monitors determine when to go the PC. A third approach is to have the CPU shut down the monitor completely; this allows a standard monitor to be controlled like a power-managed one. One drawback of this approach is that a monitor may require up to 30 seconds to reach full power.

OFEEM Inputs for Monitors

Table 3-4 shows the power requirements for monitors used as inputs for the three scenarios that examine energy use of monitors. The Energy Star monitors appeared on the market in 1993. Monitors are the only device in the model for which we estimate that average power is increasing because of increases in screen size.

Table 3-4. OFEEM Inputs for Monitors

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	28	28	28
Average Stock	1990	51	51	51
Average Stock	1995	59	59	59
Average Stock	2000	64	64	64
Average Stock	2005	65	65	65
II. Energy Star Scenario				
Enters Market	1993	65	51	5
III. Advanced Energy-Efficiency Scenario				
Enters Market	1998	23	5	5

Total PC and Monitor Power

It is useful to add the monitor and computer power estimates in Tables 3-1 and 3-2 to examine the overall trends for a PC plus monitor. We estimate that the average complete PC in the mid-1980s required about 125 W (97 + 28 W) and the average in 1991 used 130 W (75 + 55 W), a slight increase. Monitor energy use nearly doubled from 22 percent to 42 percent of the total. Our estimates of average Energy Star monitor power (65 W) is greater, however, than the average Energy Star PC (40 W), with the monitor now accounting for 62 percent of the total.

MAINFRAMES AND MINICOMPUTERS

This subsection is not separated by the "Equipment Description and Historical Trends" "Energy-Efficiency and Future Trends" subheadings. This is because while we track mainframes and mini-computers as two separate categories in the model, there are no Energy Star or advance energy-efficiency scenarios. We estimate that overall energy use is decreasing for large computers because electrical power requirements are decreasing.

CBEMA defines mainframes and mini-computers as systems with CPU, basic storage, and console or comparable display. The difference in the two categories is price. Mini-computers are considered those between $15,000 and $349,000, while mainframes are any computer above $350,000.

Large mainframes and mini-computers have been estimated to account for the greatest fraction of information technology energy use in commercial buildings during the 1980s (Baker Reiter Associates, 1989; Piette et al., 1991; Arthur D. Little, 1993). They are difficult to characterize because power requirements vary by more than two orders of magnitude. At one end of the computing spectrum are large supercomputers. A study by the Electric Power Research Institute (EPRI) listed the power rating of an IBM 3090 with two processors as 91 kW, not including cooling requirements, though measured power may be lower (Roach, 1988). At the low end, IBM's new AS400 mini-computers use substantially less power than older systems they often replace; the AS400 9406 CPU requires less than 500 W, approaching the power of personal workstations. Another difficulty in identifying an average multi-user system is that each system consists of several components such as disk storage, CPUs, and non-computing components such as printers and terminals.

Major changes have occurred in computing environments with the migration from large central computers to distributed computing. The buzzword in the industry is "downsizing," and the last five years have signaled dramatic changes in markets for large computers. For the first time ever revenues from sales of computers decreased during 1991, with the largest decline from mainframe sales (Zorpette, 1993, quoting Dataquest). Mainframe sales are being challenged by networked PCs served by mid-range computers.

Newer, large computers use less energy to provide similar levels of service. One utility (Consumer's Power in Michigan) recently offered direct financial rebates to customers who replaced energy-intensive mainframe computers with significantly lower-power mini-computers. New, low-power computer systems may provide more computing power than the equipment they replace. The analysis of replacing older mainframes did not include a comparison of the computing power, data storage, or speeds of the systems. Clearly, power requirements for equivalent computing capacity and speed continue to dramatically decrease. The estimates for typical power requirements in large computing systems in Table 3-5 are based on case studies from seven commercial buildings.

Table 3-5. Changes in Mainframe and Mini-Computer Power

System or Component	Active Power (kW)
1980s Vintage Mainframe Computer System	
Central Processing Unit	3.0
Four Disk Drives	3.6
Line Printer	1.8
Tape Drive	1.6
Total	10.0
Early 1990s Replacement Mini-Computer	
Central Processing Unit	0.8
Two Disk Drives	0.1
Line Printer	1.6
Tape Drive	1.0
Total	3.5

OFEEM Inputs for Mainframes and Mini-Computers

Table 3-6 shows the power requirements for mainframes and mini-computers for the baseline scenario. Based on commercial building case study data, we estimate that power requirements for large computers have been falling and will continue to decrease [4]. The uncertainties in large computer energy use are further discussed in Section 7.

Table 3-6. OFEEM Inputs for Mainframe and Mini-Computers.[a]

	Year	Active (W)	Standby (W)
I. Mainframe Baseline			
Average Stock	1985	25,000	12,500
Average Stock	1990	25,000	12,500
Average Stock	1995	16,600	8,300
Average Stock	2000	10,000	5000
I. Mini-Computer Baseline			
Average Stock	1985	3500	1750
Average Stock	1990	3500	1750
Average Stock	1995	2050	1025
Average Stock	2000	1250	625

a. There is no Energy Star or Advanced Energy-Efficiency Scenario for Mainframes or Mini-Computers.

4. LBL reviewed energy savings estimates for changing large mainframe computers to mini-computers in seven commercial buildings. This technical review was conducted in 1992 for Consumers Power and the Michigan Public Service Commission.

There are no programs or policies that seek to reduce power for these large machines. Therefore we have no information on advanced energy-efficiency technologies for large computers.

COPIERS

Equipment Description and Historical Trends

The majority of copiers in the commercial sector use heat and pressure technologies to fix an image to paper. The basic principle consists of forming an image on a photosensitive drum with a laser or lamp. The drum is then covered with toner, which is transferred to a sheet of paper. The drum is heated to about 200°C and is kept hot while the machine is in a "standby" mode, ready for the next copy. Some copiers have an energy-saver or "suspend" mode in which the drum temperature is reduced. At present, the large majority of printing and copying is monochrome, though color-image processing is on the rise.

The American Society for Testing and Materials (ASTM) developed a test procedure to compare energy use of copy machines (ASTM, 1986). This procedure is currently being updated, and we refer to the draft of the new standard in our discussion of the test procedure (Dandridge, 1994). There are five modes of operation: plug-in, warm-up, copying, standby, and suspend (energy-saver). It is more difficult to develop a simple model for typical energy use of copy machines than PCs. Energy use of copiers is related not only to the number of hours the equipment is on, but also to the number of copies made, plus time spent and power requirements in each of the five modes. Energy required to copy a page is also correlated with the copier speed. Slower personal copiers (less than 15 copies per minute), many consume about 4 to 12 Wh/page, while larger high speed copiers (greater than 60 cpm) may use only slightly more than 1 Wh/page (Dandridge, 1994).

Several other factors influence energy use per page, such as whether duplexing is used or the size of the copy job. Single-page jobs are the most energy intensive on a per copy basis. Many copiers have energy-saving features to reduce standby power by 20 to 40 percent (Dandridge, 1994). Unfortunately, the energy savings are usually not available because the power-down feature is not enabled. Szydlowski and Chvala found this to be the case in their examination of 13 copiers (1994). Reasons for this are unclear; users may be unaware of the energy-saving modes or they may not be willing to wait during warm-up periods that may require several minutes before copying can proceed. Many of the copiers are shipped with the energy-saving mode disabled, or set at large delay times.

It is likely that energy use for copiers has been slowly decreasing. During the 1980s energy use per copy for medium and high speed machines decreased by about 1.5 percent per year as copier technology improved (Acquaviva and Hartman, 1993). A counter, and probably more dominant, trend is the increase in copying volumes, which is not a function of the machine speed but of the number of copiers in use and average copying rate. Acquaviva and Hartman quote from Dataquest that copying rates increased from 0.5 trillion copies in 1988 to 0.7 trillion in 1992 (40 percent in four years!).

The ASTM defined modes for copiers incorporated into our model as follows (further described in Section 4):

- Active = copying energy and warm-up energy
- Standby = standby power without energy saver
- Suspend = energy saver mode

Dandridge showed that the majority of energy is used during standby operation (1994). The ASTM test also measures plug-in energy, which is the small amount of energy the device consumes while off, which we will ignore.

Energy Efficiency and Future Trends

A recent study built on a ''top-down'' approach to estimating energy savings potential for office equipment reported on the following strategies for lower energy copying (Arthur D. Little, 1993):

- Reduced temperature fusing (saves 30 percent of fuser energy use, which accounts for about 60 percent of copier energy use, or 18 percent overall.
- Digital copiers making multiple copies from memory, which is applicable to high-volume (of same image) copying (5 percent savings).
- Lower-power exposure lamp (12 percent).

The strategies for increased energy efficiency are based on currently available technologies. Total energy use with all three strategies would be reduced by about 30 percent (Table 3-7). Further energy savings may be achieved in the future with high-resolution inkjet copying, highly focused light sources, and low-voltage chips. Clearly copy machine energy use will decrease if less paper is used. Although the paperless office has intrigued many, paper use is currently increasing in spite of advances in paperless communication (electronic mail, bulletin boards, multi-media CD-ROM, etc.).

The EPA hopes to encourage energy savings in copying with the soon-to-be announced Energy Star program for copiers. This program design is being coordinated with the European Economic Community. Table 3-7 summarizes the general trends for medium-speed copiers with and without energy-saver modes. While energy saver modes are available for about 40 percent of the copiers in this medium-speed category, we estimate that these are not typically enabled. We expect that the Energy Star program will begin to capture some of the savings available from the use of copier power management by increasing the awareness of the presence of the features.

Table 3-7. Variation in Medium-Speed (31-44 cpm) Copier Power

	Active (W)	Standby (W)	Suspend (W)
Typical Copier Without Energy Saver[a]	220	190	190
Copier With Energy Saver[a]	220	190	150
Technically Feasible Low-Energy Copier[b]	150	130	100

a. Based on ASTM measurements for 22 copiers compiled by Dandridge, July, 1994. Assumes power management features available for about 40 percent of the machines are not enabled.
b. 30 percent savings for a typical copier based on Arthur D. Little, 1993, which is similar to the preliminary advanced power-down targets for EPA's copiers in this speed class.

In the final stages of this analysis we obtained additional information from EPA regarding the plan for the Energy Star Copiers Program. It will include an auto-off requirement for copiers to literally power down completely after a specified period, such as one or two hours. The savings from this feature have not been included in our analysis, and it is possible our savings are therefore underestimates of savings for Energy Star copiers. As described below, we estimated that about 20 percent of all copiers are left on at night. The nighttime standby energy use from these machines would be greatly reduced with Energy Star copiers.

OFEEM Inputs for Copiers

Table 3-8 shows the power requirements for copiers. We estimate that the Energy Star copiers will appear on the market in 1995 (though only two percent are assumed to be sold in that year).

Table 3-8. OFEEM Inputs for Copiers

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	250	215	215
Average Stock	1990	233	200	200
Average Stock	1995	220	190	190
Average Stock	2000	220	190	190
II. Energy Star Scenario				
Enter Market	1993	220	190	150
III. Advanced Energy-Efficiency Scenario				
Enter Market	2002	220	100	100

PRINTERS

Equipment Description and Historical Trends

Two trends have caused an increase in energy used for printing. First, there has been rapid change in the last decade from impact printing, such as daisy wheel and dot-matrix techniques, to non-impact printing, dominated by energy-intensive laser printing. Second, as with copiers, paper use has increased. Increased use of low-energy inkjet printing has probably counterbalanced some of the increase, though this slower technology is more common in the residential market. A third trend, the emergence of color printing, will also increase energy use for printing; we mention this in passing and have not considered it in detail.

As with copying, energy use is generally linked to print speed. (Energy use is also strongly related to volume.) As a result, we also base the model on medium-speed office printers. The current laser printer market is dominated by 8 pages per minute machines, although some slower printers are shown in Table 3-9.

Laser printing is relatively energy intensive because of the heat and pressure requirements for the electrographics. Most of the energy is consumed while the printer sits idle keeping the rollers warm. Measurement techniques to evaluate laser printer power consumption differ greatly and our ability to compare power requirements is complicated since precise conventions are not followed. The draft ASTM measurement method does not include measurements of peak power, only hourly averages under various modes of operation similar to the standard for copy machines. (We define the operating modes of active, standby, and suspend as identical to those for copying.) Average and peak power measurements are typically well below nameplate ratings. A close look at the complex cycle of power demands shows that high-resolution measurements have instantaneous peaks that approach or even greatly surpass nameplate ratings during periods when fusers and motors are simultaneously energized (Lovins and Heede, 1990).

Energy Efficiency and Future Trends

Today, a growing number of laser printers have power management features to comply with the EPA Energy Star program, as listed in Table 3-9. Only a few such models were available before the Energy Star program began. Inkjet printer market shares are catching up with those of laser printers because of their low price and improving quality. Inkjet printers use far less energy than laser printers, requiring a small amount of heat to vaporize the liquid ink, no heat during standby, and no suspend mode. Surprisingly, the most energy-efficient heat-and-pressure printing technologies require little more energy than inkjet technologies. Many of the strategies discussed for reduced-energy copying also apply to heat-and-pressure printing.

Table 3-9. Variation in Printer Power

	Active	Standby	Suspend
Typical Mid-1980s Dot Matrix[a]	45	15	15
Typical Laser (8 ppm)[b]	250	80	80
Power-Managed Laser (8 ppm)[b]	250	80	25
Lowest-Power Laser (4 ppm)[c]	118	7	5
Inkjet (3 ppm)[b]	20	8	8

a. Norford et al., 1990.
b. Dandridge, 1994.
c. Luhn, 1993 and product literature.

OFEEM Inputs for Printers

Table 3-10 presents the model inputs for printers. The baseline scenario shows an increase in energy used for printing as dot-matrix printers are replaced by laser printers. The Energy Star scenario consists of a laser printer that powers down to 25 W in both standby and suspend modes. We learned from a recent conversation from a large manufacturer that most Energy Star laser printers power down immediately after printing has ended, so standby and suspend power levels are identical.

The advanced scenario considers energy savings that could be achieved with widespread use of today's lower-power printing technologies. As shown in Table 3-10, the power levels are lower for active, standby, and suspend modes. These levels for an advanced low-power printer are similar to the power requirements for today's slower (4 ppm) machines. We anticipate that low-power fast printers are technically feasible (Dandridge, 1994).

Table 3-10. OFEEM Inputs for Printers

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	45	15	15
Average Stock	1990	200	80	80
Average Stock	1995	200	80	80
II. Energy Star Scenario				
Enters Market	1993	200	25	25
III. Advanced Energy-Efficiency Scenario				
Enters Market	2000	120	5	5

FAX MACHINES

Equipment Description and Historical Trends

Facsimile machines, or fax machines, are the newest major technology in the list of significant energy consuming office equipment. In fact, they were not even present in typical commercial buildings at the start of our forecast (1985). These devices send and receive information from printed documents or electronic files over telephone lines. Three common types of fax machines to consider in modeling fax machine energy use are: direct thermal, laser, and inkjet, as listed in Table 3-11. Direct thermal faxes apply heat to thermally sensitive paper, while inkjet and laser fax machines are similar to the printers discussed in the previous section.

Energy Efficiency and Future Trends

While there were only a few fax machines a decade ago, it is likely that the technology may change quickly again in the next decade. Fax cards used with computers suggest the possibility of a future with reduced paper communication by eliminating the need to print a document before sending it. The Energy Star program to reduce standby power of fax machines will soon be announced. The power-managed fax in Table 3-11 is our estimate of the power modes that might be achieved with an Energy Star fax machine.

Table 3-11. Variation in Fax Machine Power

	Active	Standby	Suspend
Direct Thermal[a]	175	12	12
Inkjet[b]	24	13	13
Laser[a]	175	35	35
Power-Managed Laser[a]	175	35	16
Fax card[c]	1	<1	<1

a. Values from review of Dandridge (1994) and Newsham and Tiller (1994). Active and standby power requirements for laser fax machines range from about 60 W to nearly 1000 W, standby power requirements from 12 W to 65 W.
b. Dandridge (1994), reports on a common machine which uses 25 W for transmission and 23 W for receiving.
c. Power for fax card only; total power will include the computer, which should be power managed for relative energy savings.

OFEEM Inputs for Fax Machines

The key trend over the past decade has been the change from thermal to laser fax technologies. Since active power requirements for laser and thermal faxes are similar, the active power is held constant in the baseline scenario (Table 3-12). The standby power increases because standby for laser faxes is greater than for thermal faxes. The Energy Star scenario lowers the standby power. The advanced scenario is an extrapolation of general trends that suggest the possibility of a very-low-power laser fax machine.

All of the data we reviewed showed only two modes, active and standby, for fax machines. We therefore simplified the input, attributing all of the non-active hours to standby, and dropping the use of suspend. This could be revisited within future versions of OFEEM if future Energy Star fax machines are tri-modal. We have not seen evidence of this yet.

Table 3-12. OFEEM Inputs for Fax Machines

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	175	19	na
Average Stock	1990	175	28	na
Average Stock	1995	175	35	na
Average Stock	2000	175	35	na
II. Energy Star Scenario				
Enters Market	1995	175	15	na
III. Advanced Energy-Efficiency Scenario				
Enters Market	2000	175	5	na

POINT-OF-SALE TERMINALS

Equipment Description and Historical Trends

Point-of-sale (POS) terminals are cash registers at points of sale in retail trade that are interconnected to a computerized data system. POS terminals currently dominate the stock of cash registers. They include a display monitor and CPU. These computerized systems have largely replaced mechanical cash registers.

Energy Efficiency and Future Trends

Power management techniques developed for computers are applicable to POS terminals, as evidenced by one Energy-Star certified terminal, as shown in Table 3-13. This new device offers DOS- or Windows- based applications for retail point-of-sale terminals or financial tellers, including an integral UPS and recyclable plastic cabinet (M. Rose, 1993).

Table 3-13. Variation in Point-of-Sale Terminal Power

	Active (W)	Standby (W)	Suspend (W)
Typical 1990 stock	130	130	130
Power-managed	70	10	10

Source: Rose, 1993.

OFEEM Inputs for POS Terminals

The power requirement for the baseline POS terminal is held fixed in time (Table 3-14). The Energy Star POS equipment entered the market in 1993. There is not an Energy Star program for POS terminals, but they qualify as monitors under the Energy Star Computers program. Paralleling the simplification of the modes for fax machines, we have modeled POS terminals as bi-modal because we have not seen evidence of a suspend mode.

Table 3-14. OFEEM Inputs for POS Terminals

	Year	Active (W)	Standby (W)	Suspend (W)
I. Baseline Scenario				
Average Stock	1985	130	130	na
Average Stock	1990	130	130	na
Average Stock	1995	130	130	na
Average Stock	2000	130	130	na
II. Energy Star Scenario				
Enters Market	1993	70	10	na
III. Advanced Energy-Efficiency Scenario				
Same as Energy Star				

MULTI-FUNCTIONAL IMAGE PROCESSORS

Description, Energy Efficiency, and Future Trends

Multi-functional image processors, also known as hydras, are integrated devices that may include some combination of printer, fax, scanner, and copier. These devices are available with various combinations of capabilities. Some of today's digital copiers can be used as faxes and printers. Some all-in-one products even include a personal computer (Dandridge, 1994).

The primary motivation for purchasing these products is the reduction in the footprint, and possible lower first cost of a combined unit compared to each additional component. Dandridge reports that one machine that combines five capabilities costs $4,000, versus about $12,000 for each component. It is unclear whether these products will lead toward an increase in office equipment energy use, or a decrease. Energy use may increase if the machine is left on during all hours as a fax machine and standby power is high. However, power-managed multi-functional equipment could greatly reduce image processing power requirements since one machine could replace the use of three. Local area network (LAN) connected multi-functional devices could be optimally controlled to maintain lower power levels until a user requested a print or copy job.

Multi-functional products can be separated into single-user and multi-user machines, similar to desktop versus floor-model copiers. Information on power requirements for these machines are limited. One manufacturer reported an 8 ppm multi-function machine that consumes 40 W standby, 300 W active (Ledbetter and Smith, 1993), as listed in Table 3-15. The second entry of a 12-W multi-functional device has a battery that provides internal power management and peak demand load management. The device was designed to comply with Energy Star criteria. Larger machines are more like medium sized, floor-model copiers.

Table 3-15. Power Requirements of Multifunction Devices

	Active (W)	Standby (W)	Suspend (W)
Laser Printer-Fax-Scanner-Copier (8 ppm)	300	40	40
Inkjet Printer-Fax-Scanner-Copier (7 ppm)	12	12	12

OFEEM Inputs for Multi-functional Equipment

Multi-functional equipment are modeled as part of the sensitivity analysis, not as one of the three primary scenarios, because of the significant uncertainty regarding the technology and market trends. There are no historical trends to report because these devices are an emerging technology. The sensitivity analysis for these devices is built upon the Energy Star scenario because we have examined the energy savings from using Energy Star multi-functional equipment.

As with any new technology, it is unclear how quickly multi-functional devices will replace current image processing and electronic information transfer technologies. This sensitivity analysis explores possible energy implications of an energy-efficient multi-functional device. The power requirements were calculated as a weighted average between a 12-W, constant-load small multi-functional device and a full-size, 220-W copier. The speed of the average machine was also a weighted average of the small model (7 ppm) and a faster copier (35 cpm). The weighting of the small machine was based on printer sales, and that for large machine was based on small and medium-sized copier sales, as described further in Section 5. The printer sales result in a higher weighting compared to the copier sales, and the 17-W input was modeled as a constant power to mimic a "smart" load-managed multi-functional device currently on the market. The device replaces new printers, copiers, and fax machines. We assumed that multi-functional devices would replace small and medium sized copiers, but high-speed, large-volume copiers are likely to remain as stand-alone copiers. We therefore estimated that average copier power would increase under the multi-functional device scenario, as discussed in Section 6.

MISCELLANEOUS PERIPHERALS

Today's offices contain many devices not discussed in the model. We have, however, described the most important energy-consuming devices. Before computers were prominent, typewriters were probably the most significant information processing machine, excluding mainframes and mini-computers. We have not included typewriters in the model because of their low energy use, accounting for less than 5 percent of office equipment energy use.

Szydlowski and Chvala (1994) measured the average power for the following miscellaneous devices: external floppy disk drives (22 W), external modem (8 W), scanner (19 W), autocad (6 W), and other PC equipment (26 W). These devices were present in less than 15 percent of the typical workstations. On average, these peripherals added only an additional 5 W to the workstation demand, and were therefore excluded from the model.

Another source of future load growth is with local-area-network (LAN) servers. The PCs we have tracked in the market data are the workhorse of today's offices: desktop and deskside models. We have not tracked LAN servers, such as concentrators or bridges. Very little information is available on the energy use characteristics of these devices. It is likely that they are on 24 hours per day, and perhaps there will be about one concentrators and bridge for each ten networked PCs.

Future technologies will likely include more portable computing, multimedia capabilities, and wireless communication. We have not estimated power use for new devices such as electronic notebooks and digital assistants. In addition to use as individual computing tools, these devices may appear in diverse applications such as on shopping carts or automobile dashboards. Greater use of multimedia, including video and CD-ROM is also on its way. In general, energy use for most of these new technologies is not expected to be large (Dandridge, 1994).

AFTERMARKET RETROFITS OF POWER-MANAGEMENT DEVICES

Aftermarket retrofits of power-management devices are used to control existing computers and peripherals. For example, one product is a ''smart'' programmable power strip into which users plugs devices that are to be controlled (ESOURCE, 1992). We do not include these devices in the model because their impact will likely be dwarfed by the changes in energy use by PCs and other equipment described above.

Section 4

OFFICE TECHNOLOGY OPERATING PROFILES

This section describes the estimation of annual hours of operation in active, standby, and suspend modes for each equipment category. These data are combined with the power requirements described in Section 3 to estimate annual energy use, or unit energy consumption (UEC) in kWh/year. Measured data on operating profiles are available for PCs and monitors, but scarce for other equipment types. The percent of annual hours by mode for each equipment category is summarized in Table 4-1. These data are further described in each subsection.

Table 4-1 Annual Hours of Use by Equipment Category (Percent of 8760 Hours)

	PCs	Monitors	Mains & Minis	Copiers	Printers	Faxes	POS Terminals
% Yr Active	9	9	44	4	1	4	30
% Yr Standby	13	13	45	14	4	96	20
% Yr Susp.	13	13	0	28	30	0	0
Total On (%)	35	35	89	46	35	100	50
Total Off (%)	65	65	11	54	65	0	50
Total	100	100	100	100	100	100	100

PERSONAL COMPUTER AND MONITOR OPERATION

In developing the hours of use data for PCs and monitors we again drew upon the Pacific Northwest Laboratory (PNL) and National Research Council (NRC) studies (Szydlowski and Chvala, 1944; Tiller and Newsham 1993). PNL developed a "Standard Demand Profile" to quantify the average operating patterns. Daily PC use was from 8:00 a.m. to 5:30 p.m., or 9.5 hours per day. Hours of use measured by NRC were approximately the same. PNL found that on average, 76 percent of the PCs were used or turned on each day. That is, 24 percent were off because of vacations, meetings, sick days, or other such events. This daytime diversity is extremely close to NRC's measured diversity of 73 percent. PNL found that 18 percent of the workstations were left on at night, while NRC measured 20 percent again showing remarkable agreement. These estimates of nighttime hours of use are lower than Dataquest's estimate of 30 percent based on their small survey (Dataquest, Inc., 1993).

Although a PC may be on for 9.5 hours per day, it is often sitting idle. NRC found that when PCs were powered down after 15 minutes of idle time, as sensed by keystrokes, average operating hours reduced to 14.2 hours per week, or 2.8 hours per day. Using a 60-minute inactivity switch the average use was 4.5 hours per day. Based on these results, we assume that PCs are active for about 4 hours a day, and in a standby state for the other 5.5 hours.

As discussed in Section 3, we defined three modes of operation for PCs and monitors: active, standby, and suspend. Equipment that is not power managed has identical power requirements in all three modes. Distinguishing between the two non-active modes is particularly important for monitors since many power-managed monitors have two tiers of power management. Since the opportunities for power management during the daytime are less than those during the night when the systems are idle for longer time periods, we considered the savings during the daytime idle periods to be first-tier, or standby power-managed periods. During the nighttime PCs and monitors that are left on reach the lower-power suspend mode.

The annual hours of operation in each mode combine estimates of diversity, hours of use, and workdays. We assume there are 22 workdays per month. Thus, the average annual hours of use for all computers and monitors in a typical building is:

Active	= (0.76 PCs "on"/total PCs) x (4 hrs/day) x (264 workdays/yr)	= 803 hours/yr
Standby	= (0.76 PCs "on"/total PCs) x (5.5 hrs/day) x (264 workdays/yr)	= 1104 hours/yr
Suspend	= (0.18 PCs "on"/total PCs) x (13.5 hrs/day) x (264 workdays/yr)	
	+ (0.20 PCs "on"/total PCs) x (24 hrs/day) x (101 non-workdays/yr)	= 1126 hours/yr

These estimates translate to 9 percent of annual hours in active mode, 13 percent in standby, and 13 percent in suspend. These hours of use are assumed to be fixed in time.

MAINFRAME AND MINI-COMPUTER OPERATION

Many components of mainframes and mini-computers operate 24 hours per day, 365 days per year. However, certain tape and disk drives operate on a more limited basis. We estimate that these large computers are active 44 percent of all hours of the year, and in a lower-power standby mode during 45 percent of the year. The final 10 percent of the hours the system is off. This 10 percent also accounts for diversity of use. This is the equipment category for which we have the least amount of information. (Both power requirements and operation of large computers are uncertain, as further discussed in Section 7.)

COPIER AND PRINTER OPERATION

For copiers, hours or use are derived from the standard operating profile assumed in the ASTM test procedure because measured operating data are not available. The procedure assumes 20 hours per month in warm-up mode, 106 hours in standby, and 106 in the energy-saver, or suspend, mode, which includes two days per month left on at night. Surprisingly, the amount of time spent copying is small. A medium sized, 40 copies per minute copier reproduces an average of 11,600 pages per month (Dataquest, 1993). This amounts to about 5 hours per month copying, which we add to the operating hours. We have added additional hours to the ASTM profile to account for the fact that some copiers are left on a night. To be consistent with PCs and monitors, we assume that 20 percent of the copiers are left on at night. There is no separate time in the standard for copying, so energy is added to the energy use in the other modes.

Printer operating modes are similar to those of copiers. The active hours of use for printers, at 1 percent per year, are even lower than copiers. This estimate is based on an average speed of 8 pages per minute, 6 jobs per hour, and 2 pages per job. The job rate data are estimates from a leading manufacturer's tracking of toner and cartridge replacements. The annual hours of on time are assumed to be identical to the PCs and monitors, resulting in our estimate of 1 percent active, 4 percent standby, and 30 percent suspend. As discussed in Section 3, standby power is equivalent to suspend power for printers that are not power managed. The leading manufacturer also reported that the Energy Star printers power down essentially immediately after each job is finished printing. Therefore they spend the majority of their hours in the suspend mode, and there is only a short intermediate standby period.

FAX MACHINE OPERATION

Fax machines are typically left on for each hour of the year in order to receive incoming transmissions. A recent study of 32 fax machines throughout the U.S. and Canada found that the average machine was actively transmitting or receiving faxes 4 percent of all hours (Newsham and Tiller, 1994). This amounted to about 20,000 pages sent or received per year. As discussed in Section 3, there are essentially only two modes of operation, active and standby. We therefore have dropped the suspend mode category for this device.

POINT-Of-SALE TERMINAL OPERATION

We estimate that point-of-sale (POS) terminals are used more than PCs because the hours of use in average retail and grocery stores extend beyond working hours. POS terminals are assumed to be in use for half of the year, or 30 percent of all hours active and 20 percent in standby.

MULTI-FUNCTIONAL EQUIPMENT

The multi-functional devices may slowly replace printers, copiers, and fax machines, and the hours of use are related to each of these devices. To estimate the hours of use multi-functional equipment are active we considered the speed of an average device, which was a weighted average of the smaller model (7 ppm) and a faster copier (35 cpm). This supports our assumption that the average multi-functional device is active about 13 percent of annual hours. Most multi-functional equipment need to be on 24 hours/day to receive incoming faxes.

Section 5

EQUIPMENT DENSITIES AND MARKETS

This section describes the equipment densities and the commercial floor space data within OFEEM. As discussed in Section 2, equipment densities are the link between the equipment unit energy consumption (UEC, in kWh/year for each equipment category) and the energy use intensity (EUI in kWh/sq ft per year). There are six subsections. The first two subsections discuss equipment densities from utility surveys and the selection of the OFEEM inputs. The equipment densities in OFEEM are based on market sales and stock changes relative to a starting, benchmark year, which was selected to be 1988 because of the availability of utility surveys of equipment densities for 1988. The third section discusses the OFEEM inputs for mainframe and mini-computer densities that were developed using a different technique (and a different year, 1989) than for the other equipment categories. The fourth discusses how the equipment densities are estimated with historical sales and market projections from CBEMA. The fifth section discusses our market estimates for energy-efficient office equipment. The final section presents the commercial floor space data used in OFEEM.

SURVEYS OF EQUIPMENT DENSITIES

This subsection discusses the equipment density data for each building type and equipment category except for mainframes and mini-computers (described separately below). To estimate the density of office equipment in commercial buildings we have looked at supporting data for utility end-use models that forecast electricity demand. Several utilities developed extensive supporting data, some of which include actual inventories of office equipment. We have compiled the data from three such surveys to estimate how many devices were present in commercial buildings during the late 1980s, which serves as the starting point for the equipment densities.

The first source of data is from on-site surveys in the Sacramento Municipal Utility District (SMUD) service territory (ADM Associates, 1990). The survey report contains equipment saturations for 13 types of office equipment. These are reported separately for the nine building categories used in this report.

The second source is surveys from Consolidated Edison's project with Xenergy, Inc. to examine the load growth for electronic equipment (Michaels et al., 1990; Xenergy, 1989). The Xenergy study included equipment densities for seven types of office equipment that match reasonably well with our categories. We also obtained the underlying primary data from this study of office equipment inventories for several hundred buildings from 1985 and 1988. There sample sizes range from 17 to 50 buildings for each building type.

The third source of data is the Pacific Northwest Non-Residential Survey, conducted during 1987 to 1990 (ADM Associates, 1992). This survey was a variation of a format used in the

SMUD survey, with samples of 29 to 99 buildings for each building type. We developed the equipment densities reported below from unpublished data. The tables below show the averages from 1987 through 1990. Vacant buildings were included in this study, which is appropriate since they are included in the commercial floor space forecasts.

The equipment densities by building type from each survey are listed in Tables 5-1 through 5-3. Our OFEEM inputs are also shown for comparison. Comparable data from all three surveys were available for three of the ten building categories: office, retail, and grocery buildings. There is a large amount of variation among the equipment densities, although most of the general trends in the equipment densities by building type are consistent with expectations. For example, as expected, most of the office equipment densities are higher in offices than other building types. The SMUD data showed higher equipment densities for most equipment in office buildings than the Consolidated Edison and Pacific Northwest data suggest, even though the data for the Pacific Northwest include 1989 and 1990 surveys. Most notably, the SMUD density for PCs (1.72/1000 sq ft) is nearly twice as high as the Pacific Northwest data and more than four times the Consolidated Edison estimate.

Table 5-1. Comparison of SMUD (SM), Pacific Northwest (NW), and Consolidated Edison (CE) Equipment Densities (# of units/1000 sq ft) in Office, Retail, and Grocery Buildings with OFEEM for New York State

Building Type	Equipment Type	SM	NW	CE	OFEEM
Office	PC	1.72	0.93	0.41	0.50
	Monitor (stand alone)	0.55	0.70	0.28	na
	(PC + stand-alone)	2.27	1.63	0.69	0.84
	Printer	0.94	0.62	0.12	0.18
	Copier	0.27	0.18	0.08	0.12
	Fax	0.12	na	na	0.04
	POS Terminal	0.00	0.13	na	0.01
Retail	PC	0.24	0.30	0.09	0.11
	Monitor (stand alone)	0.06	0.16	0.02	na
	(PC + stand-alone)	0.30	0.46	0.11	0.19
	Printer	0.10	0.14	0.01	0.04
	Copier	0.06	0.05	0.01	0.03
	Fax	0.00	na	na	0.01
	POS Terminal	0.30	0.21	na	0.19
Grocery	PC	0.02	0.04	0.01	0.01
	Monitor (stand alone)	0.00	0.01	0.01	na
	(PC + stand-alone)	0.02	0.05	0.02	0.02
	Printer	0.06	0.03	0.00	0.01
	Copier	0.03	0.05	0.00	0.01
	Fax	0.00	na	na	0.01
	POS Terminal	0.43	0.23	na	0.23

The Consolidated Edison data showed the lowest equipment densities for all categories. This is somewhat counter intuitive. We expected to see high equipment densities in New York City where commercial space is at a premium. Office equipment densities are generally thought to be linked to occupant density. However, both the Consolidated Edison and the Pacific Northwest studies averaged about 270 sq ft/person. Occupant densities are not available for the SMUD study. The relationship between occupant density and equipment density is further discussed in the next subsection.

The Consolidated Edison data are also available for school, hospital, and hotel buildings, as shown in Table 5-2. Again, the densities are lower than the SMUD results except for monitors in schools and hospitals, and copiers in schools. The monitor data, however, are questionable since the 0.49 units/1000 sq ft for schools is nearly twice their estimate for offices! We assume that monitors are stand-alone terminals, not part of PCs, but served by mainframes or mini-computers. Unfortunately, none of the three surveys covered colleges. We therefore include colleges, primary schools, and high schools in one general category.

Table 5-2. Comparison of 1988 SMUD (SM) and Consolidated Edison (CE) Equipment Densities (# of units/1000 sq ft) in School, Hospital, and Hotel Buildings with OFEEM for New York State

	Schools			Hospital			Hotel		
	SM	CE	OFEEM	SM	CE	OFEEM	SM	CE	OFEEM
PC	0.72	0.61	0.21	0.61	0.37	0.25	0.07	0.03	0.04
Monitor (stand-alone)	0.15	0.49	na	0.03	0.75	na	0.06	0.00	na
(PC + stand-alone)	0.87	1.10	0.35	0.64	1.12	0.42	0.13	0.03	0.06
Printer	0.23	0.18	0.08	0.55	0.05	0.09	0.08	0.01	0.01
Copier	0.06	0.08	0.05	0.23	0.08	0.06	0.01	0.01	0.01
Fax	0.00	na	0.02	0.18	na	0.02	0.01	na	0.03
POS Terminal	0.02	na	0.00	0.02	na	0.02	0.02	na	0.01

Equipment densities for three final building categories, miscellaneous, restaurants, and warehouses, are shown Table 5-3. The equipment densities for the miscellaneous buildings are surprisingly close for this ''catch-all'' category. The Pacific Northwest densities are higher than the SMUD data for restaurants, though the unit densities are small. The SMUD warehouse equipment densities are again higher than the Pacific Northwest data for all but the monitors.

We examined some of the longitudinal data from both the Consolidated Edison and the Pacific Northwest surveys to evaluate the relative change in equipment densities from 1985 through 1990. Although the data are problematic, as discussed above, we generally found increases in equipment densities during those years. For example, in the Pacific Northwest survey, for which we had different buildings sampled in the two vintages, nearly all of the densities were higher in the 1989-90 sample: among the 42 categories, only seven were greater in the 1987-88 sample. One of the categories with a lower density was mainframe or mini-computer disk drives, which we expected to decrease as PCs captured some of the large computer market.

Table 5-3. Comparison of SMUD (SM) and Pacific Northwest (NW) Equipment Densities (# of units/1000 sq ft) in Miscellaneous, Restaurant, and Warehouse Buildings with OFEEM for New York State

	Miscellaneous			Restaurant			Warehouse		
	SM	NW	OFEEM	SM	NW	OFEEM	SM	NW	OFEEM
PC	0.18	0.19	0.102	0.02	0.04	0.02	0.37	0.15	0.08
Monitor (stand-alone)	0.00	0.12	na	0.00	0.04	na	0.05	0.11	na
(PC + stand-alone)	0.18	0.31	0.17	0.02	0.08	0.04	0.42	0.26	0.14
Printer	0.15	0.18	0.04	0.01	0.03	0.01	0.21	0.11	0.03
Copier	0.07	0.12	0.03	0.00	0.03	0.01	0.06	0.06	0.02
Fax	0.00	na	0.01	0.00	na	0.00	0.03	na	0.01
POS Terminal	0.00	0.13	0.01	0.64	0.30	0.34	0.00	0.00	0.00

The longitudinal data from the Consolidated Edison study are more informative than the Pacific Northwest study because the same buildings were sampled during 1985 and 1988. In general there was an increase in equipment densities. However, the data were again found to be problematic, as evidenced by the finding that there were more color monitors (28 percent) in 1985 than in 1988 (17 percent). This result runs contrary to the general market trends.

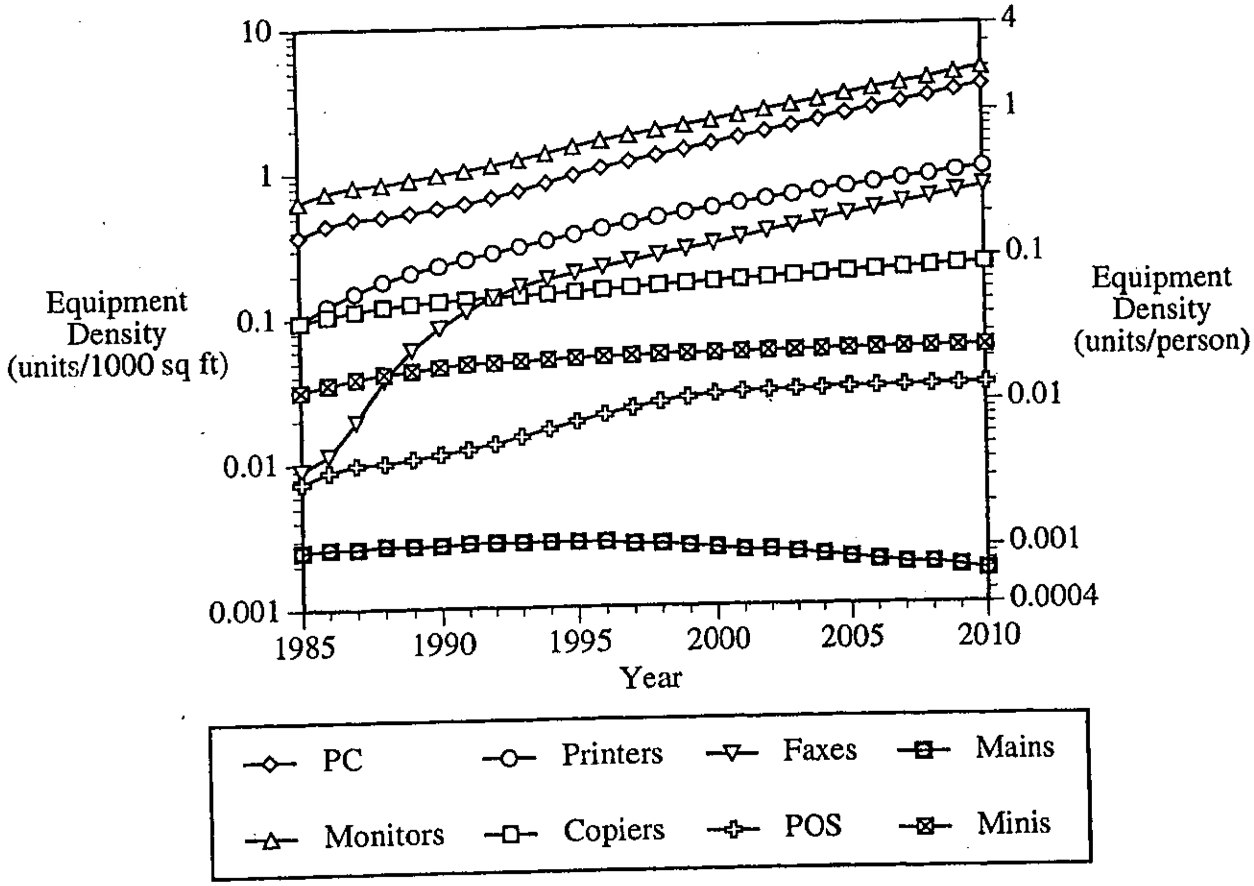
OFEEM EQUIPMENT DENSITY INPUTS

The New York State Energy Office (NYSEO) estimates that office building occupant densities are an average of 400 sq ft/person (Bowman, 1994). This is close to the U.S. average of 425 sq ft/person for office buildings reported in the Commercial Buildings Energy Consumption Survey (CBECS) (Energy Information Administration, 1991). These numbers may be higher than the Pacific Northwest and Consolidated Edison estimates if they include large areas of unoccupied or vacant space. There may also be differences in floor space definitions. CBECS estimates often include parking areas, causing the floor area per person to increase. Other density estimates might be based only on net rentable area.

The 1988 OFEEM PC input of 0.500 units/1000 sq ft translates to 5 people per unit. The relationship between equipment and people was tracked within the model, as shown below in Figure 5.1. All three surveys distinguished between PCs and stand-alone monitors used with large computers. In OFEEM PCs and monitors are modeled separately. To account for the monitors associated with PCs, the PC density was added to the monitor density. The monitor density is therefore greater than the PC density, showing 3 people per monitor.

Considerable effort was spent examining the equipment densities for non-office buildings to select OFEEM inputs. We determined that the most straightforward way to estimate non-office building equipment densities was to relate the densities of equipment back to the ratio of PCs in non-office settings to PCs in offices. This resulted in equipment densities that were similar to those reported in the surveys, although occasionally outside the range from the surveys. This is

Figure 5.1. OFEEM Equipment Densities.



understandable because there were inconsistencies in the surveys as discussed in the previous section. For example, there were more copiers than printers in the hospital Consolidated Edison data, which is highly unlikely for an average hospital. Two exceptions were: POS terminals densities were chosen from the surveys, and the mainframe and mini-computer densities were selected as discussed in the next section.

MAINFRAME AND MINI-COMPUTER DENSITIES

Echoing the problem of estimating power requirements, estimating equipment densities for mainframes and mini-computers is difficult because of inconsistencies in defining a system and its components. A "top down" approach was used in developing large computer equipment densities. The estimates combine information on the total stock of large computers from CBEMA with the total commercial sector floor space and with computer room floor space from CBECS (Energy Information Administration, 1991). These computer rooms usually have dedicated HVAC equipment to maintain carefully controlled environments for large mainframe and mini-computers. These data are based on 1989 U.S. floor stock estimates and are used as the 1989 OFEEM inputs.

We assume that 20 percent of the 1989 stock of mainframes and mini-computers are in industrial buildings outside of the commercial sector. This estimate is supported by industry shipments of computers and electronics for 1989. The total value of these shipments was $85 billion, as shown in Table 5-4. The subcategories available from the Electronics Industry Association are also shown. We assume that there are large mainframes and mini-computers in industry (rather than in commercial buildings) associated with the second, third, and fifth categories listed in the table.

Table 5-4. U.S. Shipments of Computers and Electronics Equipment

Equipment Category	1989 Shipments Value ($ billion)	Percent
Computers and peripheral equipment	62.5	73%
Controlling, processing equipment	9.1	11%
Testing, measuring equipment	6.5	8%
Medical electronic equipment	6.4	7%
Nuclear electronic equipment	0.6	1%
Total	85.4	100%

Source: U.S. Bureau of the Census, 1991, Table No. 1343.

The OFEEM estimates of densities of mainframes and mini-computers for commercial buildings in 1989 are listed in Table 5-5. Office buildings have the greatest computer room floor area, followed by schools, warehouses, and retail buildings. Therefore, the densities of The large computers in schools are located in universities, while those in warehouses support inventory control systems.

Table 5-5. Mainframe and Mini-Computer Densities in Commercial Buildings
(# units/1000 sq ft)

Building Type	Mainframe Densities	Mini-Computer Densities
Office	0.0027	0.044
Schools	0.0011	0.017
Warehouse	0.0010	0.016
Retail	0.0005	0.009
Health care	0.0005	0.007
Hotel	0.0003	0.004
Miscellaneous	0.0002	0.003
Restaurant	0	0
Grocery	0	0

EQUIPMENT DENSITIES OVER TIME

In this subsection we discuss the historical and future equipment densities estimated within the OFEEM. As discussed in Section 2, we drew upon industry market statistics on historical and projected sales from the Computer and Business Equipment Manufacturing Association (CBEMA; 1994). The CBEMA data project sales out to 2004. Beyond 2004 the sales volumes are assumed to continue to grow at the same rate. Table 5-6 shows the sales growth rates (percent) after 1996 for each equipment category, which translate into stock growth when combined with the equipment lifetime. The variation in the sales growth rates by equipment category influences the change in equipment densities over time. Among the equipment categories, the PC density is the fastest growing and the mainframe density is actually decreasing. We also found a decrease in the total U.S. floor space dedicated to large mainframe and mini-computers between 1989 and 1992 despite growth in the total commercial sector floor space (Energy Information Administration, 1991 and 1994).

There is a range in monitor sales growth over time because their sales rate is a combination of stand-alone terminals and PC sales, weighted by the volume of sales, which changes over time. Figure 5.1 shows the OFEEM equipment densities for each equipment category from 1985 to 2010. Over the past decade, the most dramatic growth has been the increase in fax equipment.

Table 5-6. Sales Growth Rates After 1996

	PC	Monitor	Main	Mini	Copier	Printer	Fax	POS Term.
Sales growth (%/yr)	10.3	8.7 - 9.7	-3.1	1.6	3.5	7.0	10.0	2.0

We tracked the number of people per each device to ensure that the equipment densities are reasonable compared to the occupant densities. As mentioned earlier, we estimate that in 1988 there were 3 people per monitor in office buildings. OFEEM's growth rate estimates 1 monitor per person in 2001, and 1 PC per person in 2005. It is possible that there may never be one computer or monitor per person because of the number of people in office buildings whose responsibilities do not involve using computers. There are, of course, people today with more than one PC or monitor in their office, but we do not anticipate that the average will exceed, or reach, one to one. Another factor to consider is that if office space is currently overbuilt, than the occupant densities may increase (of area per person decrease), and the density of equipment could correspondingly increase. The occupant densities in the model are fixed in time, but in reality the relationship between people, equipment, and floor space is not fixed in time. Increased telecommuting in the future will also complicate such comparisons traditionally used in electrical load forecasts.

ENERGY-EFFICIENT OFFICE EQUIPMENT MARKET SHARE

Market researchers differ regarding how quickly the energy-efficient PCs will gain some significant portion, or all, of the PC market share. Dataquest estimated that in 1993, 30 percent of all desktop and deskside PCs met the Energy Star criteria, increasing to 100 percent by 1997. InfoCorp's estimate of Energy Star PC sales was lower at 15 percent for 1992, reaching 72 percent in 1998. To be conservative, we choose InfoCorp's estimate for PCs as input to OFEEM for sales of Energy Star PCs. The same market trends were assumed for monitors, as shown in Table 5-7.

More recent information from Dataquest suggest that about half of all desktop and deskside PCs are currently Energy Star compliant (Dataquest, 1994). We have not increased the sales volumes to reflect the higher reported values because it is widely believed that many of these machines are not functioning as power-managed PCs. An unknown, but large fraction (perhaps half), of Energy Star PCs and monitors may not be saving energy because of installation and compatibility problems (Piette, 1994). So, while the machines may be Energy Star compliant, only a certain fraction are functioning as intended. These problems are expected to be decreased as the EPA works with manufacturers to improve the performance and configuration of Energy Star equipment (Latham, 1994).

The sales of Energy Star printers has increased more quickly than those of PCs because of the faster adoption of Energy Star features by major printer manufacturers. As of mid-1994, nearly all of the printers from the largest printer manufacturer comply with Energy Star criteria. Similarly, we suspect that the adoption of Energy Star POS terminals will be quick because the dominant manufacturer has promoted their Energy Star machines.

We assume a quick market uptake of Energy Star copiers because many of the copiers already have the capability for power management, but they are not shipped with the feature enabled. We suspect this will be a key feature of the Energy Star program for copiers and printers. Similarly, it is likely that the Energy Star fax machines will also quickly capture a significant market fraction because the standby power requirements for these machines are relatively low already, and the technological innovation should be relatively straightforward.

Table 5-7. OFEEM Estimates for Sales of Energy-Efficient Office Equipment (percent of sales)

Year	PC	Monitor	Printer	Copier	Fax	POS Terminals
1992	0%	0%	0%	0%	0%	0%
1993	15%	15%	10%	0%	0%	10%
1994	26%	26%	50%	0%	0%	50%
1995	38%	38%	90%	10%	10%	90%
1996	49%	49%	100%	20%	50%	100%
1997	61%	61%	100%	40%	100%	100%
1998	72%	72%	100%	80%	100%	100%
1999	83%	83%	100%	90%	100%	100%
2000	95%	95%	100%	100%	100%	100%
2001	100%	100%	100%	100%	100%	100%

In the advanced energy-efficiency scenario we use the same sales rates for energy-efficient office equipment as developed in the Energy Star scenario. The difference in the scenario is based on the decrease in power for the equipment over the years that the new technology is introduced (see Section 3 for year of market entry).

MULTI-FUNCTIONAL EQUIPMENT MARKET TRENDS

The multi-functional device sensitivity analysis assumes that printers, copiers, and fax machines are replaced with these devices starting in 1998. The sales of printers, copiers, and faxes drop to 90 percent, 50 percent, and then 10 percent of what CBEMA forecasts for the years 1998, 1999, and 2000, respectively. For example, CBEMA forecasts that if printers sales are 1,000,000 units in 1997 with a sales growth rate of 10 percent per year, in 1998 the sales would be 1,100,000, but OFEEM includes only 90 percent of those. The following year, the sales would be 1,210,000, but the spreadsheet includes only 50 percent of the new printers. >From the year 2000 and beyond, the sales are 10 percent of the CBEMA forecast.

Multi-functional equipment were derived from small and medium-sized copier sales forecasted by CBEMA. In 1998, the multi-functional equipment sales are assumed to be 10 percent of that sum, growing to 50 percent in 1999, and then remaining at 90 percent from 2000 onward. The multi-functional equipment sales growth rates are fixed in time, except during 1998 through 2000 when the sales drop. This results in a smooth transition in stock and equipment densities.

CHANGES IN COMMERCIAL FLOOR SPACE

The final step in OFEEM is to combine office equipment energy-use intensities with the total commercial sector floor space for each building type, resulting in estimates of total energy use (GWh/year) by building and equipment type. Table 5-8 lists the floor space data by building type for New York State from 1985 to 2010.

Table 5-8. Commercial Floor Area in New York State (million sq ft)

Year	Office	Rest.	Retail	Groc.	Ware.	School	Health	Hotel	Misc.	Total
1985	991	89	467	94	256	408	187	113	625	3,231
1986	1,001	90	474	95	258	412	190	115	639	3,275
1987	1,012	92	480	96	259	414	193	117	654	3,318
1988	1,030	94	489	98	263	415	197	119	670	3,375
1989	1,046	96	494	100	265	417	200	121	682	3,419
1990	1,060	97	498	101	267	422	204	123	689	3,461
1991	1,063	98	503	102	268	425	209	126	699	3,493
1992	1,077	99	509	103	269	429	214	129	713	3,540
1993	1,084	99	509	103	271	432	217	132	733	3,579
1994	1,094	101	516	105	274	436	221	137	756	3,639
1995	1,098	102	523	106	280	440	225	141	780	3,694
1996	1,104	104	533	108	283	443	230	144	802	3,751
1997	1,108	106	541	110	286	446	234	148	824	3,803
1998	1,116	108	548	112	287	449	239	151	845	3,855
1999	1,125	109	555	113	288	451	243	154	865	3,903
2000	1,135	110	562	114	289	453	247	156	884	3,950
2001	1,141	111	567	115	289	454	252	158	902	3,989
2002	1,150	112	572	116	290	456	256	160	920	4,031
2003	1,159	113	577	118	291	457	260	162	938	4,075
2004	1,168	114	582	118	291	459	264	165	955	4,115
2005	1,177	115	586	119	291	460	268	167	973	4,156
2006	1,187	116	591	120	292	461	273	169	990	4,198
2007	1,199	117	595	121	292	462	277	171	1,007	4,241
2008	1,211	117	599	122	292	463	281	173	1,024	4,282
2009	1,223	118	604	123	292	464	285	175	1,040	4,324
2010	1,236	119	608	124	292	465	288	178	1,055	4,364

Section 6

RESULTS AND DISCUSSION

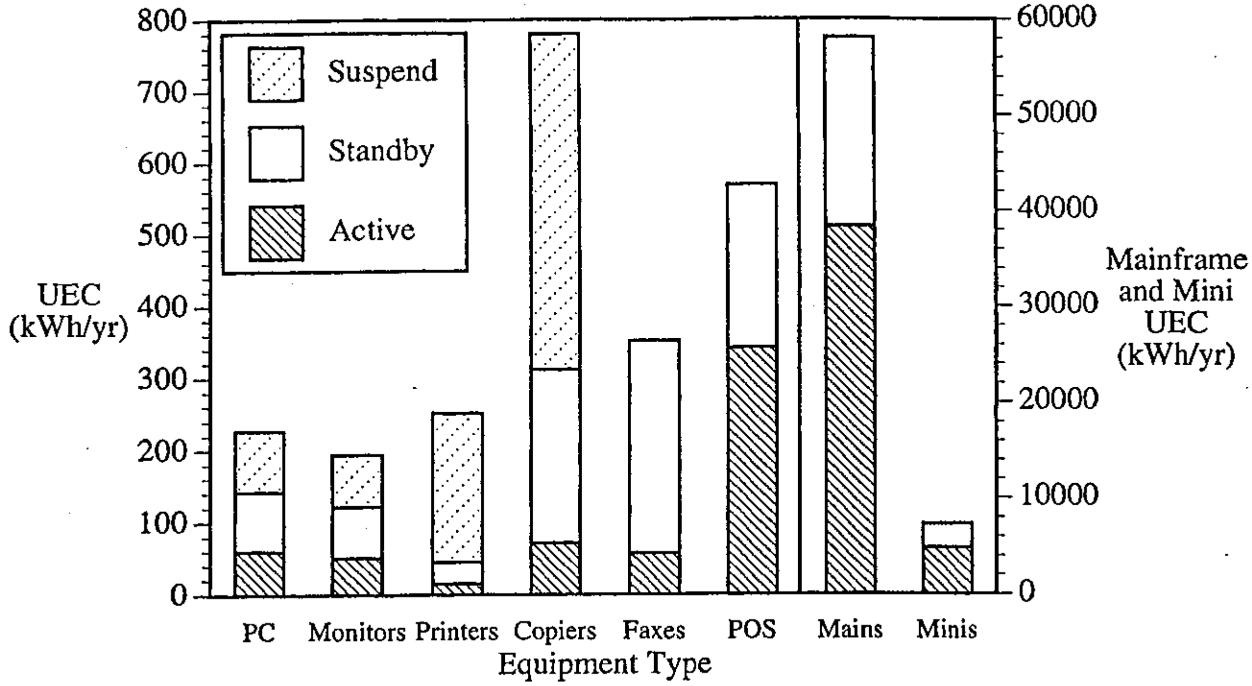
The purpose of the scenario analysis is to explore projected energy use by conventional office equipment and examine the energy-saving potential of new, energy-efficient hardware and software. This section discusses the OFEEM output for the three scenarios. First, we present the unit energy consumption (UEC) values for the equipment in each scenario to compare energy savings per unit. Second, we examine how these UECs translate into energy-use intensities (EUIs) based on equipment densities for offices and other building types over time. Third, we present the total electrical energy use (GWh/year) for office equipment in the commercial sector, as we combine EUIs with floor space projections. Fourth, we present total commercial sector peak demand. The discussion in these sections covers the statewide results unless otherwise noted.

UNIT ENERGY CONSUMPTION

Figure 6.1 shows the UECs for each equipment category for 1994 for the baseline scenario. Active, standby, and suspended energy use is shown. For the standard equipment, standby power is equivalent to suspended power. Excluding mainframes and mini-computers, copiers are the highest energy users, followed by POS terminals, which have long hours of use. Similarly, fax machines use more energy than printers because of their long hours of use. The PCs and monitors have the lowest UECs. But, as discussed below, although the UECs are low, the equipment densities are high, and these two devices are responsible for most of the load growth because of increases in equipment densities (as shown in Figure 5.1).

Figures 6.2 through 6.7 show the 1990, current 1994 baseline, Energy Star, and advanced energy efficiency scenario UECs for each equipment category except mainframes and mini-computers, which are listed below in Table 6-1. The figures illustrate the relative change between the three scenarios, and the change in energy use by mode. For example, PC energy use is reduced by more than 50 percent between the baseline and Energy Star scenario, with savings distributed fairly evenly among the three modes (Figure 6.2). By contrast, Energy Star monitors use 40 percent less energy than the baseline, with the large majority of savings in the suspended mode (Figure 6.3). Similarly, all of the reduction in energy use for printers is in standby and suspended power modes, reducing the overall UEC by about 60 percent (Figure 6.4). Energy savings for Energy Star copiers are far less dramatic, reducing the total UEC by 13 percent with a 21 percent reduction in the suspended mode energy use (Figure 6.5). The Energy Star fax UEC is about half of the baseline (Figure 6.6). The final graph in this series shows the highest reduction, with the Energy Star POS terminal UEC at 65 percent of the baseline (Figure 6.7). The mainframe and mini-computer UECs are identical in each of the scenarios because they are not part of current efforts to increase energy-efficiency in office equipment, such as the Energy

Figure 6.1. Baseline Scenario Unit Energy Consumption (Year 2000).



Note: For the standard equipment, standby power is equivalent to suspended power.

Figure 6.2. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for PCs.

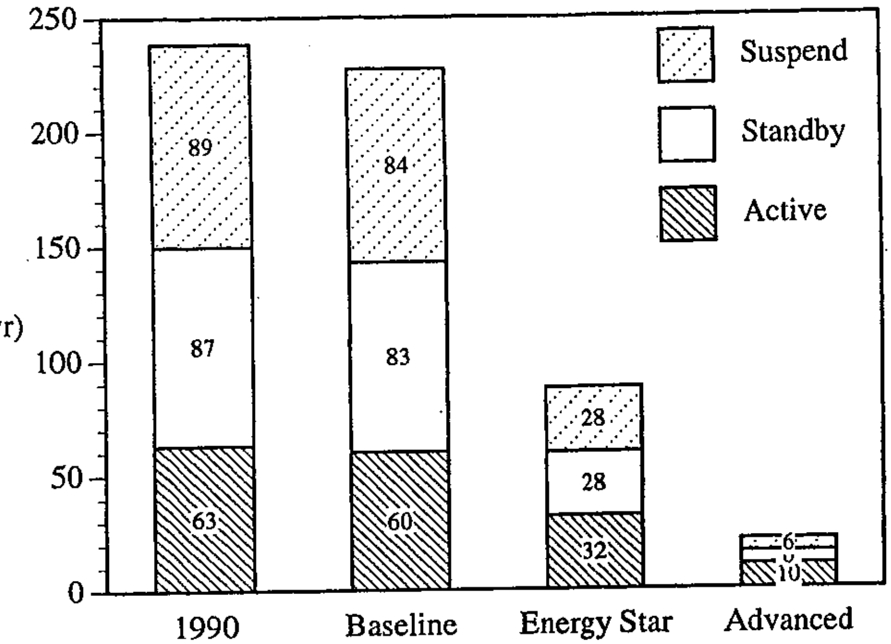


Figure 6.3. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for Monitors.

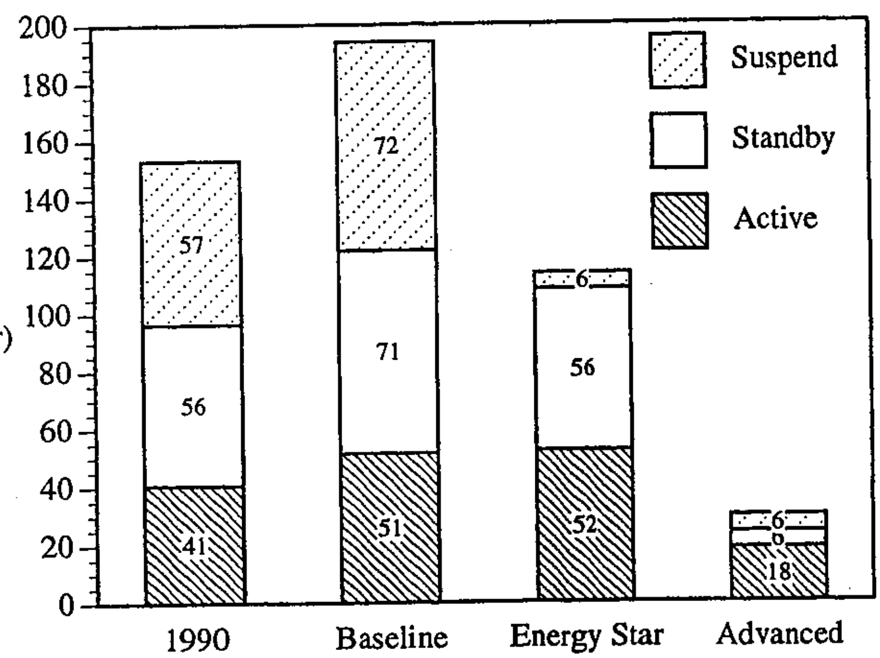


Figure 6.4. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for Printers.

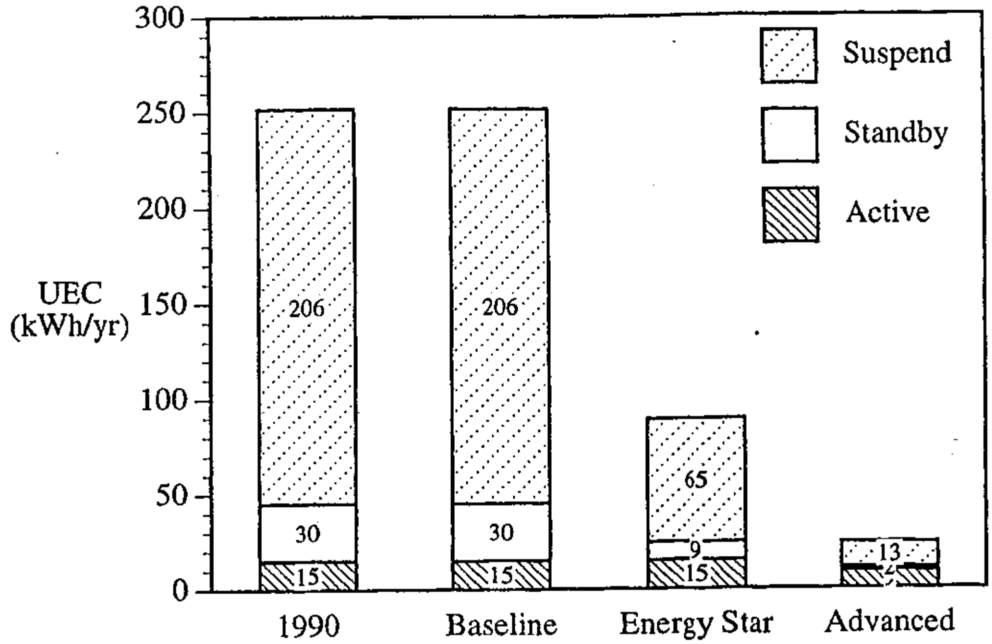


Figure 6.5. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for Copiers.

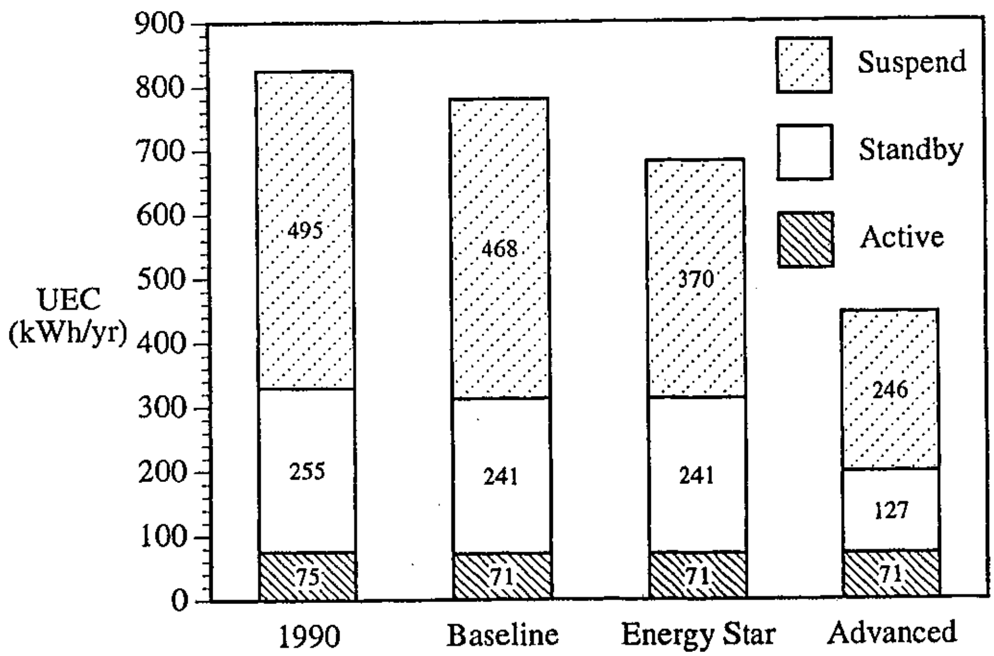


Figure 6.6. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for Fax Machines.

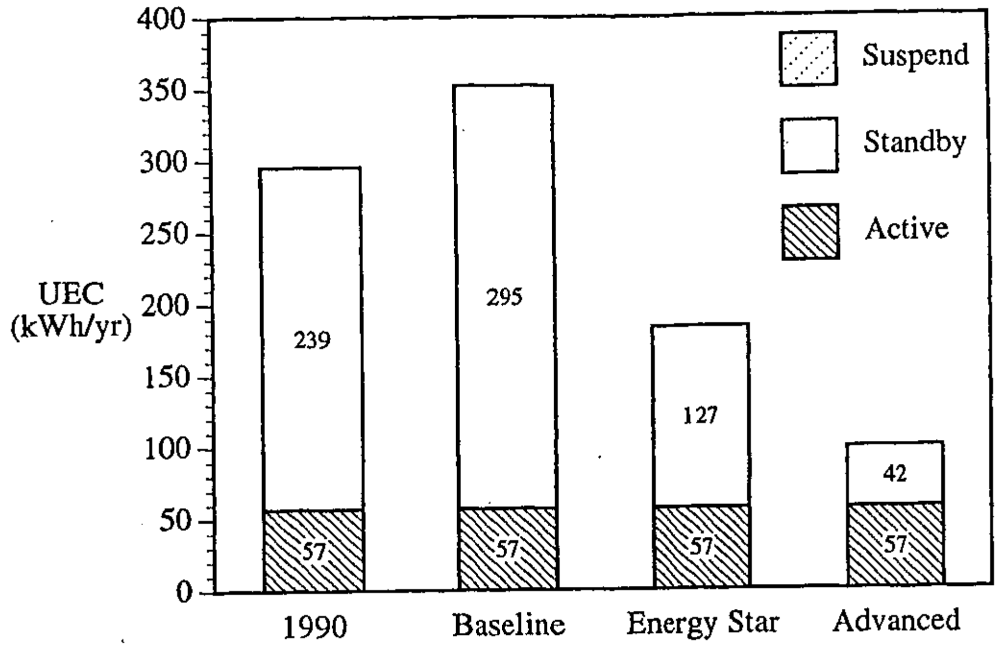
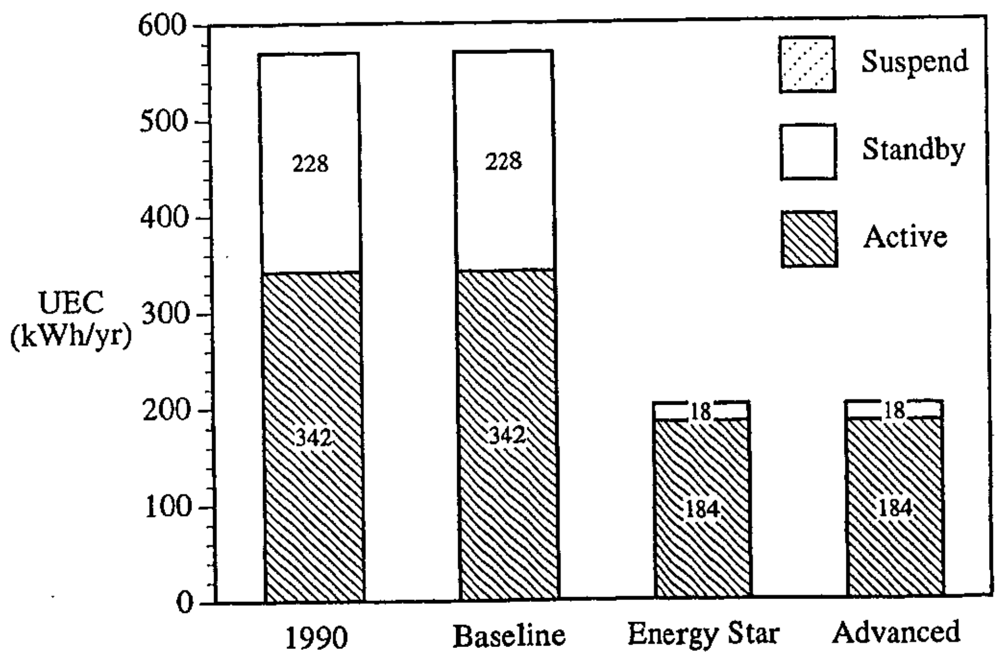


Figure 6.7. Baseline (1990 and 2000), Energy Star, and Advanced Scenario Unit Energy Consumption for POS Terminals.



Star Program. The mainframe and mini-computer UECs are listed in Table 6-1.

Table 6-1 Mainframe and Mini-computer UECs

	1985 (kWh/year)	1995 (kWh/year)	2005 (kWh/year)
Mainframe Computers	145,088	124,740	58,035
Mini-Computers	20,312	11,886	7,254

ENERGY-USE INTENSITIES

Energy-use intensities (EUIs) are derived by combining the UECs discussed in the last section with equipment densities discussed in Section 5. We focus here on the office building EUIs because energy used by office equipment in these buildings accounts for about half of the energy used by office equipment in all commercial buildings. Also, the EUI trends over time are identical for the EUI trends in the other building types over time. The most dramatic trend in office equipment energy use is the current change from mainframe and mini-computer energy use to other office equipment, most notably PCs and monitors. It is important to emphasize, however, that the mainframe and mini-computer energy use estimates are among the most uncertain. We comment further on the policy implications of this issue below. Table 6-2 shows the relative office building EUIs by equipment type.

Table 6-2. Office Building EUIs (kWh/sq ft-year) for the Three Scenarios

Equipment	Baseline			Energy Star	Advanced Energy-Efficiency
Category	1985	1995	2005	2005	2005
PCs	0.11	0.22	0.55	0.21	0.06
Monitors	0.05	0.27	0.65	0.37	0.10
Mainframes	0.37	0.27	0.12	0.12	0.12
Mini-computers	0.64	0.62	0.42	0.42	0.42
Copiers	0.08	0.12	0.15	0.14	0.09
Printers	0.01	0.09	0.19	0.07	0.02
Faxes	0.00	0.07	0.17	0.09	0.05
POS Terminals	0.00	0.01	0.02	0.01	0.01
Total	1.27	1.66	2.27	1.43	0.86

Baseline Scenario EUIs

Bearing in mind the uncertainty of mainframe and mini-computer use, we estimate that (as shown in Figure 6.8), office equipment EUIs in office buildings increased by about 40 percent between 1985 (1.27 kWh/sq ft-year) and 1990 (1.81 kWh/sq ft-year). The average EUI has leveled off since about 1990 because the reduction of energy caused by fewer large computers balanced by the increase from other office equipment. However, when large computers are excluded, office equipment energy use has nearly tripled in the last decade from 0.26 kWh/sq ft-year in 1985 to 0.70 kWh/sq ft-year today (1994). The largest increase in energy use was from monitors, as smaller monochrome displays were replaced with larger color displays. If this growth were to continue without an intervention such as the Energy Star program, the EUI (excluding mainframes and mini-computers) could again double in the next decade, reaching 1.73 kWh/sq ft-year in 2005.

Among the decentralized equipment (i.e., ignoring the large computers) PC and monitor energy use dominate the office equipment end use. This suggests that there is a great value in the potential savings from the Energy Star program, as outlined in the next section. As discussed in Section 5, future equipment densities are increased based on sales growth projections from CBEMA for 2004. One surprising outcome is that the high sales for fax equipment, which translates into growing densities, cause the fax EUI to pass the copier and printer EUIs after 2005.

Figure 6.9 shows the EUIs for all nine building categories. Office building EUIs are about twice as large as the next highest non-office EUIs. Next to offices, schools currently have the highest EUI, followed by hospitals, retail establishments, warehouses, restaurants, grocery stores, hotels, and miscellaneous. The school and warehouse EUIs have been dropping in the past few years from the decrease in large computer use. Next to offices, these building types had the largest rooms for mainframe and mini-computers because of sophisticated inventory systems. Also of note, hospitals EUIs are steadily climbing during the forecast horizon because of the increasing number of PCs and monitors, surpassing the school EUI in 2002.

Also of note is the steady climb of the hospital sector equipment EUIs during the forecast horizon. This is attributed to the increase in the use of PCs and monitors in hospitals. The hospitals office equipment EUI is expected to surpass the school office equipment EUI by the year 2005.

Energy Star EUI

The office building EUIs for the second scenario that includes Energy Star office equipment are shown in Figure 6.10. The mainframe and mini-computer energy use trends are identical to those shown in the baseline scenario, as are the historical EUIs for each equipment category from 1985 through 1993. The primary difference in this scenario compared to the baseline scenario is the flattening of the EUI growth from 1994 to 2000 for the total of all office equipment excluding large computers. During the early years of the next century this scenario sees new load growth as the equipment densities climb. The Energy Star equipment is expected to replace the baseline stock by 2005. There is, of course, greater uncertainty in technology trends as we reach the beginning of the second decade of the next century.

Figure 6.8. Baseline Scenario: Energy-Use Intensity by Equipment Type for Office Buildings.

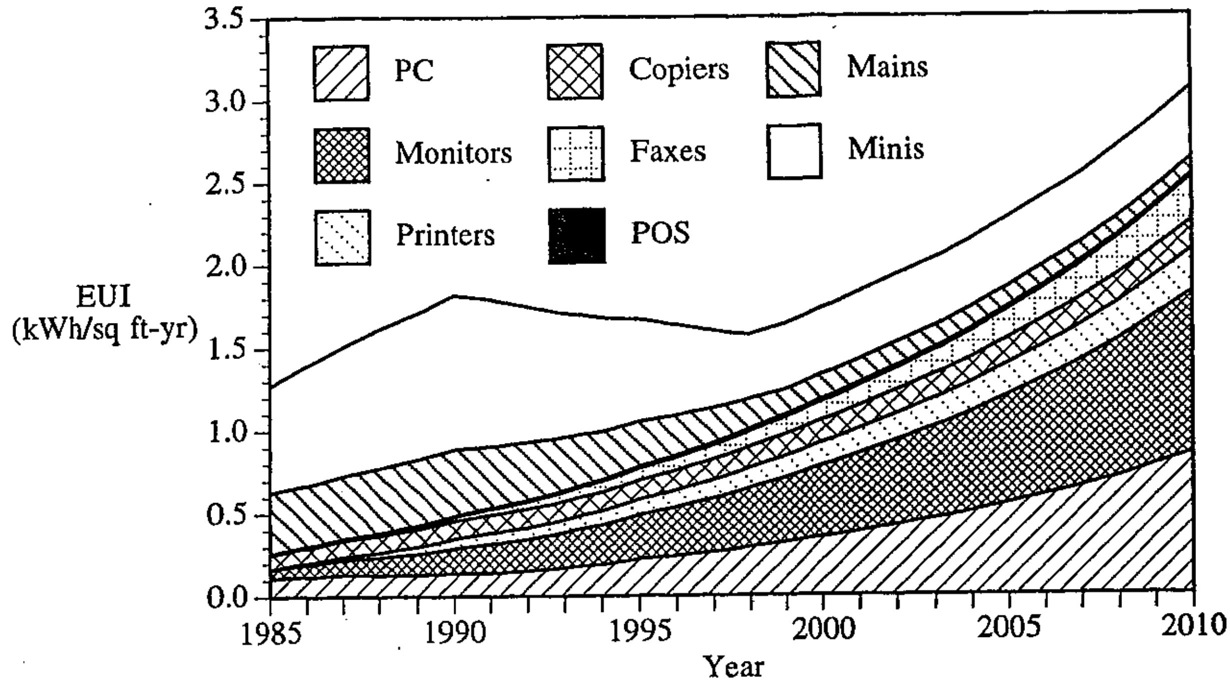
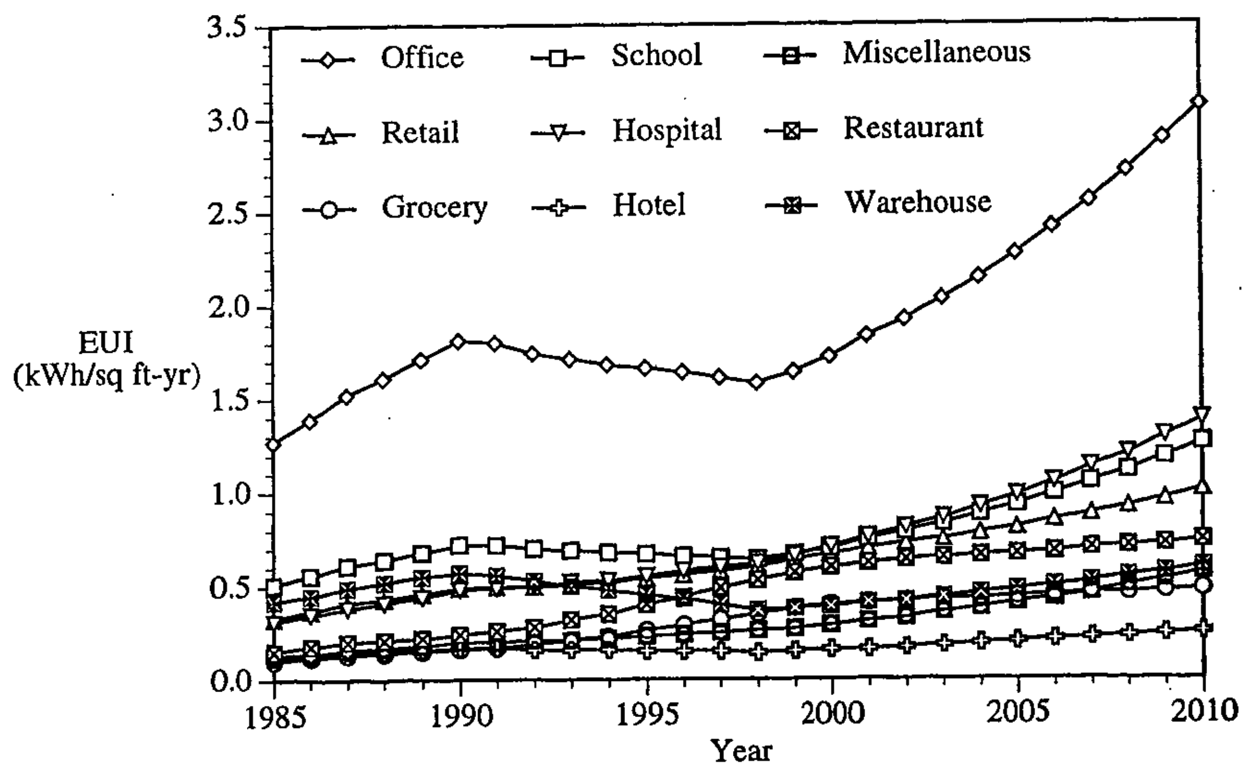


Figure 6.9. Baseline Scenario: Energy-Use Intensity by Building Type.



Advanced Energy Efficiency EUIs

Building upon the results of the Energy Star scenario, the advanced energy-efficiency scenario (Figure 6.11) shows that the office equipment EUI is less in 2010 than the EUI today. Again, when large computers are excluded from the forecast, the office equipment EUI is also reduced in 2010 compared to today's level.

Table 6-3. OFEEM Results by Scenario for New York State

Scenario and Equipment Category	Total Energy Use 1994 (GWh/yr)	2000 (GWh/yr)	2010 (GWh/yr)
I. Baseline Scenario Total	2897	3334	6349
PCs	327	632	1696
Monitors	406	780	1931
Mainframes	462	242	177
Mini-Computers	1079	662	771
Copiers	194	244	347
Printers	146	254	507
Faxes	111	201	524
POS Terminals	170	319	396
II. Energy Star Scenario Total	na	2303	3613
PCs	na	325	655
Monitors	na	520	1114
Mainframes		no change	
Mini-Computers		no change	
Copiers	na	226	303
Printers	na	92	179
Faxes	na	123	273
POS Terminals	na	113	177
III. Advanced Scenario Total	na	1776	1944
PCs	na	183	173
Monitors	na	258	290
Mainframes		no change	
Mini-Computers		no change	
Copiers	na	196	198
Printers	na	27	48
Faxes	na	94	147
POS Terminals	na	113	140

Figure 6.10. Energy Star Scenario: Energy-Use Intensity by Equipment Type for Office Buildings.

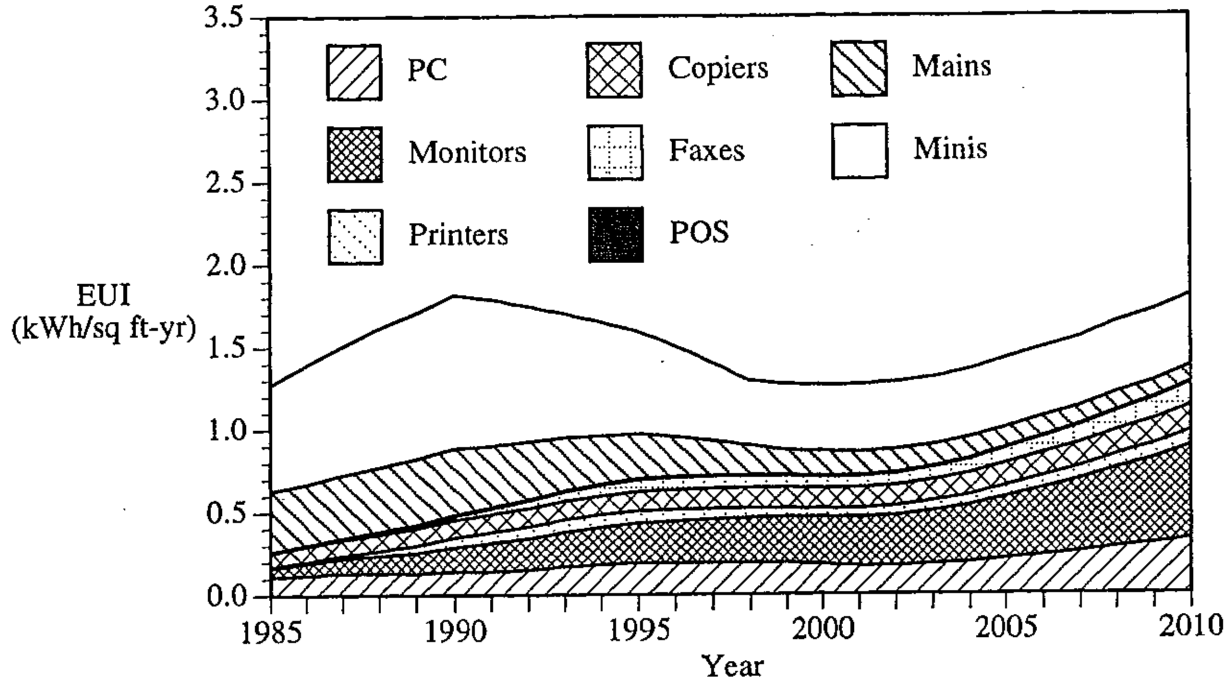
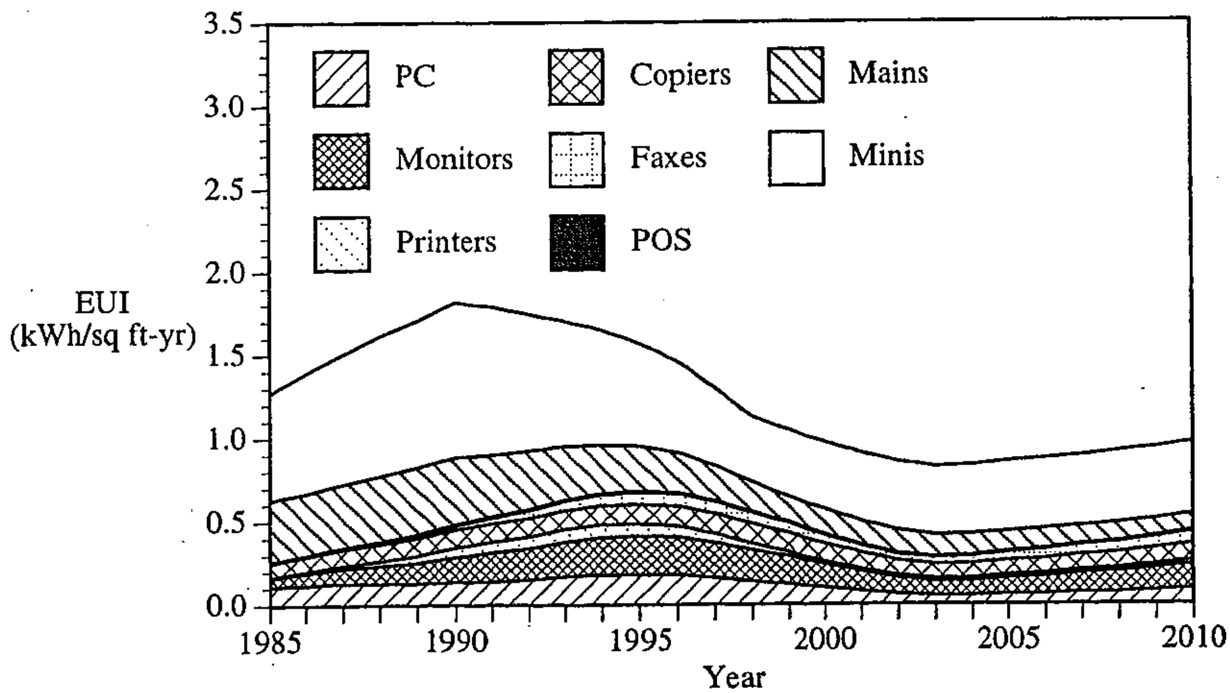


Figure 6.11. Advanced Scenario: Energy-Use Intensity by Equipment Type for Office Buildings.



TOTAL COMMERCIAL SECTOR ENERGY USE

We estimate that office equipment currently consumes about 2900 GWh/year in New York State. Excluding large computers, office equipment uses about 1350 GWh/year, as shown in Table 6-3. Total commercial sector energy use by office equipment over time is shown in Figure 6.12. This figure shows the same general trends for the three scenarios as seen in the EUI plot, except for two key differences. First, the load growth is higher because total GWh/year are determined by combining the EUIs with the growing commercial sector floor space. Second, the relative contribution of total commercial sector energy use differs from that found in office buildings because of equipment differences. For example, POS terminals are not significant in the office building EUI, but are significant in other building categories such as retail and groceries. Also, the relative contribution of large computers decreases because they are less common in non-office buildings.

Figure 6.13 shows the total load growth for all three scenarios together. The baseline scenario shows that when all of the equipment energy uses are added for all building types the load growth that we saw in the late 1980s has flattened until about 1998. After 1988 total energy use for office equipment begins to climb again as equipment densities continue to increase and the total commercial sector floor space increases. The baseline scenario suggests that energy use could more than double from 2900 GWh/year today to 6350 GWh/year in 2010 under current trends.

Over the next 15 years the Energy Star scenario shows an increase in total energy use of only 25 percent over current consumption, reaching 3600 GWh/year in 2010. In comparison, the advanced energy-efficiency scenario halts the load growth over the next 15 years, showing a total decline to 1950 GWh/year in 2010.

Figure 6.13 also shows the same three scenarios with large computers excluded. Here we see that total baseline energy use climbs steadily over the full 25 years. Given the floor space increase, the Energy Star scenario no longer flattens the near-term load growth for office equipment. Rather, we see a slight increase between 1994 and 2000 from 1350 GWh/year to 1400 GWh. Furthermore, even with the potential savings from a program like Energy Star, the total commercial sector energy use doubles from today (1350 GWh/year) to the start of the second decade in the next century (2700 GWh/year in 2010). And again, the advanced energy-efficiency scenario shows a net decrease to about 1000 GWh/year in 2010.

Comparing the scenarios over time, Energy Star equipment could reduce office equipment energy use by 3600 GWh in this decade, as shown in Table 6-4. The savings are five times greater for the next decade, reaching nearly 20,000 GWh.

Figure 6.12. Baseline Scenario: Annual Energy Use in Commercial Sector.

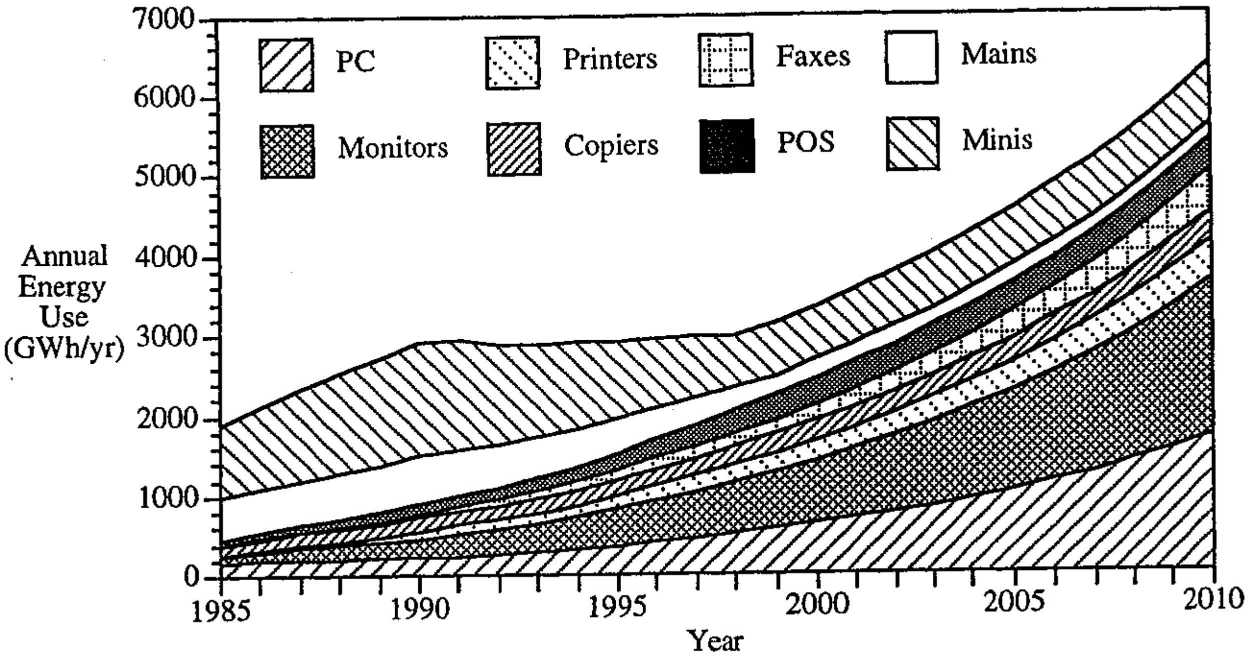
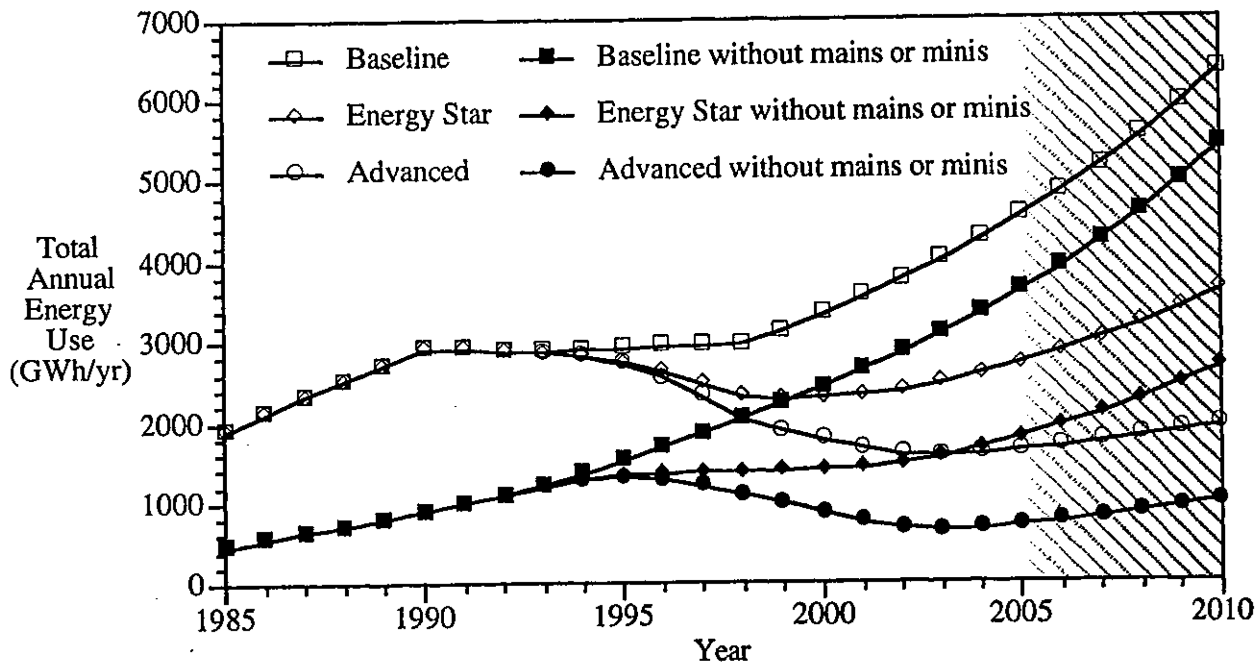


Figure 6.13. Total Annual Energy Use by Scenario.



Note: The scenario totals are shown with and without mainframes and mini-computers.

Table 6-4. Cumulative Energy Use and Savings from Energy Star

	Cumulative Total Sector Energy Use 1994 to 2000 (GWh)	2001 to 2010 (GWh)
Baseline Scenario	21,200	47,900
Energy Star Scenario	17,600	28,600
Savings from Energy Star Equipment	3600	19,300

TOTAL COMMERCIAL SECTOR DIVERSIFIED PEAK DEMAND

We estimate that the current (1994) coincident summer peak demand from office equipment in New York State is 370 MW (Figure 6.14). Historically the load growth from office equipment has been steep but is now relatively constant, though it is likely to increase again in the late 1990s. The baseline scenario predicts that today's coincident demand will double by 2010, reaching 860 MW. The difference between the baseline and Energy Star scenarios is for less peak demand savings than for energy savings. For example, in the year 2000 the Energy Star equipment reduces energy use from the baseline of 3334 GWh/year to 2303 GWh/year, a reduction of 31 percent. For that same year the summer peak demand is reduced from a baseline of 426 MW to 320 MW, a reduction of 25 percent. This occurs because much of the energy savings are from nighttime loads when systems are in low-power, suspended modes. Daytime hours have more of the active mode power, which does not change much in the Energy Star scenario.

The current winter peak demand of 240 MW is less than the summer demand because the winter peak period is spread over more hours of the day, and therefore includes more hours of the suspended mode (Figure 6.15). Unlike the baseline scenario summer peak demand, which is slightly decreasing, the winter peak demand is currently growing, although slowly. Like the baseline summer peak demand, the winter peak demand grows quickly at the turn of the century. In the advanced energy-efficiency scenario both the winter and summer peak demands in 2010 are slightly reduced from today's demand.

Figure 6.14. Summer Peak Power Demand by Scenario.

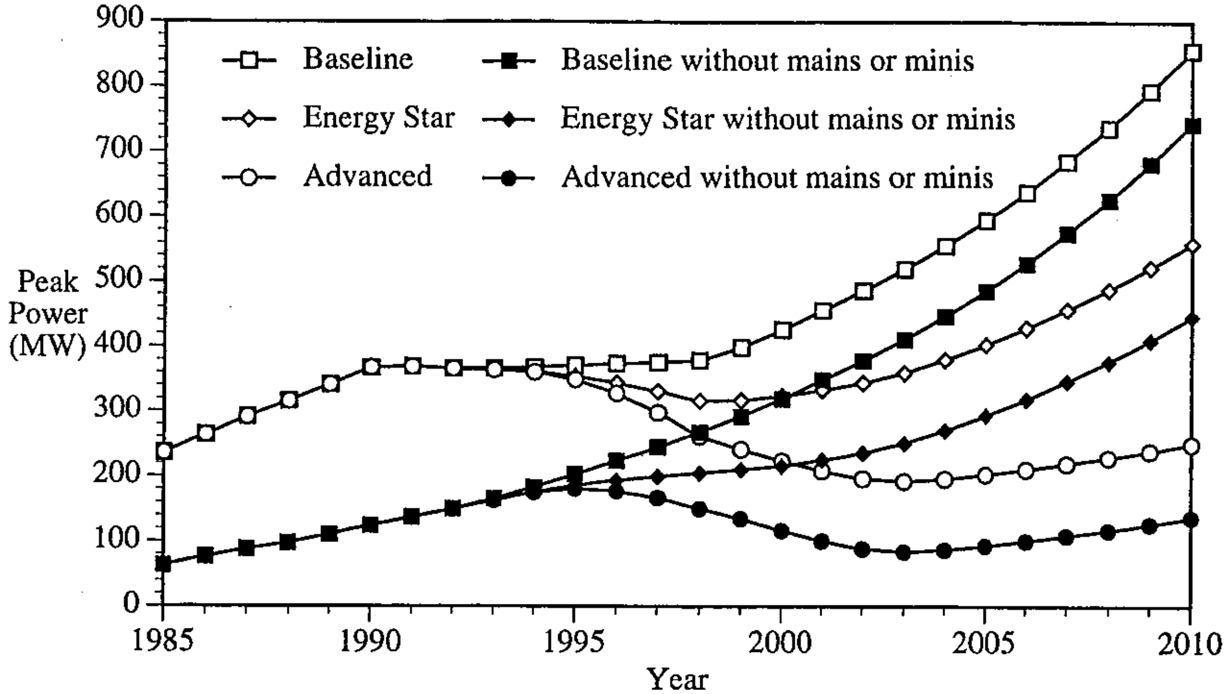
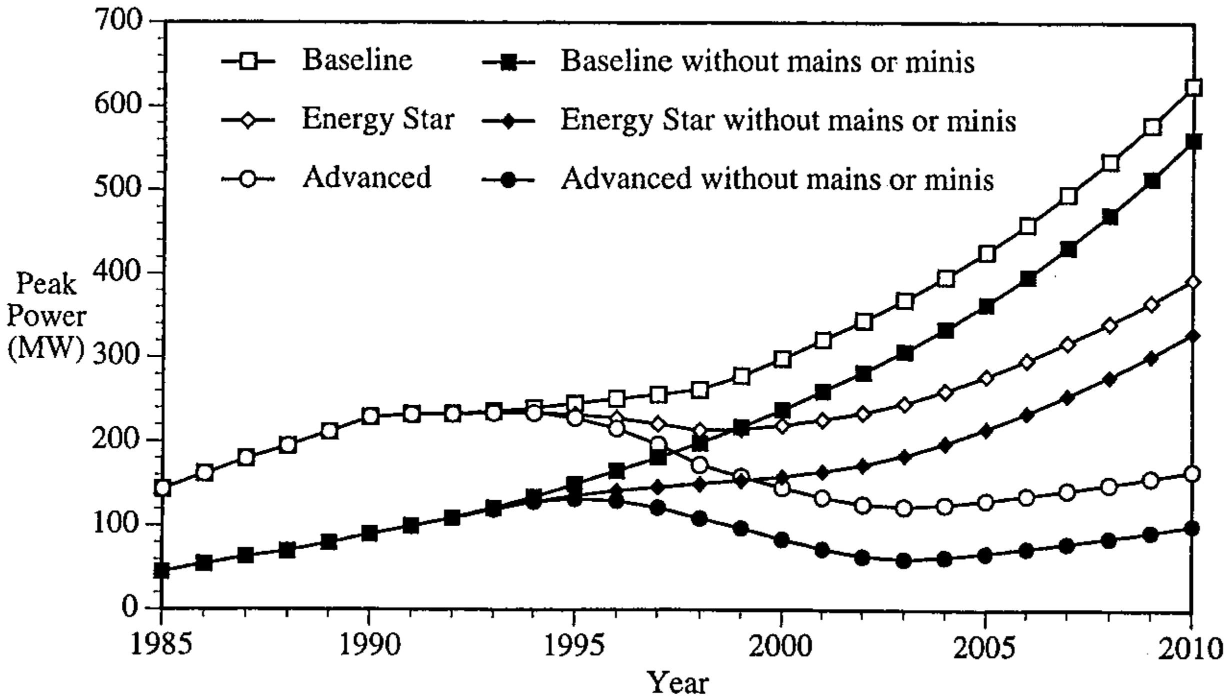


Figure 6.15. Winter Peak Power Demand by Scenario.



Section 7

UNCERTAINTIES AND SENSITIVITY ANALYSES

OVERVIEW OF SENSITIVITY ANALYSIS

The sensitivity analyses described in this section were performed to examine the influence of the most uncertain input values on the overall results. This section also describes how the OFEEM results compare with past studies. Separate sensitivities were conducted for both the baseline and the Energy Star Scenarios. The advanced energy-efficiency scenario was excluded from these analyses because it is an exploratory scenario. We report the results by comparing various outputs for both the baseline and Energy Star scenarios with and without the input parameters modified as defined by the sensitivity test.

There are basically two categories of uncertainties. The first major category are uncertainties in the baseline assumptions, of which two outstanding issues are equipment densities and mainframe and mini-computer power requirements. Second, there are uncertainties associated with both the operation and performance of Energy Star equipment, its sales fraction or market penetration, and technological innovations. Table 7-1 lists the sensitivity analyses, focusing on uncertainties in the Energy Star scenario.

Table 7-1 Sensitivity Tests of OFEEM Inputs

Sensitivity Description	Baseline Change	Energy Star Change
• Equipment Performance		
Hours of use		
Double nighttime "on" hours	Yes	Yes
Eliminate nighttime "on" hours	Yes	Yes
Minimum (30 W) Compliance with Energy Star	No	Yes
• Market Penetration		
Energy Star Sales Halved	No	Yes
Energy Star Sales Delayed	No	Yes
• Technological Change		
Baseline PC Power Decreasing	Yes	No
Multi-Functional Equipment	No	Yes

We performed three sensitivity analyses to explore equipment performance, with three of the four looking at hours of use. The first examines energy savings from Energy Star equipment if nighttime hours of use were twice as high as those we assumed. The second explores the lower boundary of these savings if office equipment were turned off at night. The third sensitivity analysis explores the reduction in energy savings if Energy Star equipment only met, but did not use less than, the required 30-W low-power target.

Two sensitivity analyses examined market penetration. One halved the sales of Energy Star equipment by year, so at full penetration only half of the equipment is Energy Star compliant. The second doubled the number of years required for Energy Star equipment to reach the 100 percent market share we assume in OFEEM.

The final two sensitivities examine technological changes. The first looks at the decrease in energy savings that would occur if baseline PC power requirements decrease. The second looks at the savings possible with the use of energy-efficient multi-functional devices (combined printer, copier, fax machine) machines.

EQUIPMENT PERFORMANCE SENSITIVITIES

Hours of Use

As discussed in Section 4, we have assumed that on average, 18 percent of all PCs are left on at night and 20 percent are left on during weekends. The EPA assumes that 30 to 40 percent of the PCs are left on at night, which leads to greater savings from Energy Star equipment. Our sensitivity analysis consisted of doubling the nighttime hours for PCs, monitors, printers. The hours of use were not changed for the fax machines, POS terminals, mainframes, or mini-computers. The effect of this change is summarized in Table 7-2. Doubling the number of hours the average PC is used at night and on weekends increases the average PC energy use from 227 kWh/year to 311 kWh/year, an increase of 37 percent. These UECs are representative of 2005 and beyond. The increase in the UEC for an Energy Star PC is slightly less (32 percent) from 88 kWh/year to 116 kWh/year. With the increase in nighttime operation, the difference between the baseline and Energy Star UECs is 40 percent greater (227 to 88 kWh/year versus 311 to 116 kWh/year). The change in the UEC with greater nighttime operation of monitors is greater; savings from Energy Star are increased by 82%. in savings for Energy Star compared to the base case. The savings are even higher for copiers, at 50 percent.

Table 7-2 also shows the change in the office building EUI and total commercial sector energy use in 2010. Again the results are similar. Doubling the nighttime hours increases the difference between the Energy Star and baseline EUI for office buildings by 48 percent. This change in the EUI includes the large computers. Similarly, with the assumption used in the primary scenarios the savings from the Energy Star program for the entire commercial sector in 2010 is 2736 GWh, but is 46 percent greater if nighttime hours were doubled. The difference between the baseline and Energy Star scenarios is lower in earlier years because mainframe and mini-computer energy use decreases over time. Overall, this sensitivity test verifies the somewhat obvious fact that power-managed office equipment will save more energy when the operating schedule includes greater hours of operation while equipment is idle.

Table 7-2. Double nighttime hours for PCs, Monitors, Printers, and Copiers

OFEEM Output for 2010	Base	Increase in Base	Energy Star	Increase Energy Star	Added Energy Star Savings
PC UEC (kWh/year)	227	37%	88	32%	40%
Monitor UEC (kWh/year)	197	37%	114	4%	82%
Printer UEC (kWh/year)	252	36%	89	31%	37%
Copier UEC (kWh/year)	780	29%	681	26%	50%
Office EUI (kWh/sq ft-year)	3.06	27%	1.80	12%	48%
Total Sector Energy (GWh/year)	6349	26%	3613	11%	46%

It is also useful to explore the reversed case in which all equipment is turned off at night. When nighttime hours of use are eliminated, the savings from power management are reduced. The UECs are now reduced by the same percentage that they were increased with greater nighttime hours of use, as shown in Table 7-3 for PCs. And, the savings from power management relative to the baseline are lessened by the same percentage that they increased before. The net effect of the total commercial sector energy use in 2010 is also symmetric.

Table 7-3. Eliminate nighttime hours for PCs, Monitors, Printers, and Copiers

OFEEM Output for 2010	Base	Change to Base	Energy Star	Change to Energy Star	Diff. in Energy Star Savings
PC UEC (kWh/year)	227	-37%	88	-32%	-40%
Total Sector (GWh/year)	6349	-26%	3613	-11%	-46%

Minimum Compliance with Low-Power Targets (30 W)

In Section 3 we discussed the power requirements for equipment that currently meets the Energy Star program criteria. Most of the equipment uses less power than the minimum power requirements specified in the program. To examine the savings from minimal compliance with Energy Star we calculated the savings that would be achieved if the standby and suspended power for PCs, monitors, and printers were equal to 30 W (the low-power maximum, see Table 1-1). The impact of this change is shown in Table 7-4. This change is most significant for monitors; increasing the UEC for the Energy Star Scenario by 25% percent because of the large difference between the current 5 W in suspend and the minimum compliance of 30 W. This decreases the savings from Energy Star by 34%. Total commercial sector energy use under the Energy Star scenario would increase by 11 percent, and the difference between the baseline and Energy Star scenario is reduced by 16 percent.

Table 7-4. Increase Standby and Suspended Power to 30 W.

OFEEM Output for 2010	Base	Change to Base	Energy Star	Increase in Energy Star	Diff. in Energy Star Savings
PC UEC (kWh/year)	227	0%	88	13%	-8%
Monitor UEC (kWh/year)	197	0%	114	25%	-34%
Printer UEC (kWh/year)	252	0%	89	16%	-9%
Office Building EUI (kWh/sq ft-year)	3.06	0%	1.80	11%	-15%
Total Sector Energy (GWh/year)	6349	0%	3613	11%	-16%

MARKET PENETRATION SENSITIVITIES

Reducing the fraction of new sales of Energy Star equipment was modeled by doubling the number of years (listed in Table 5-7) until the market reaches saturation. This had the effect of slowing down the energy savings from the Energy Star program. Under this sensitivity test, total annual energy use for the commercial sector with Energy Star equipment is 2 percent less in 2010 than the primary scenario. The savings are reduced in earlier years. The biggest difference is in 2003 when the Energy Star sensitivity test results in 17 percent less energy use for the commercial sector. On the other hand, cumulative energy savings between 1994 and 2000 are reduced by 50 percent (from 3600 GWh to 1800 GWh), as shown in Table 7-5. Cumulative savings from 2001 to 2010 are reduced by only 7 percent (from 19,300 GWh to 9600 GWh).

The second test consisted of halving all sales of Energy Star equipment, which has the affect of limiting the market share to 50 percent. This halves the cumulative savings from Energy Star equipment, as shown in Table 7-5 (22,800 GWh versus 11,400 GWh).

Table 7-5. Market Penetration Analysis: Cumulative Energy Use and Savings from Energy Star

	Cumulative Commercial Sector Energy Use		
	1994 to 2000 (GWh)	2001 to 2010 (GWh)	Total (1994-2010) (GWh)
Original Results			
Baseline Scenario	21,200	47,900	69,000
OFEEM Energy Star Scenario	17,600	28,600	46,200
Cumulative Savings	3600	19,300	22,800
Double Yrs until Energy Star Penetration	19,400	30,000	49,400
Cumulative Savings	1800	17,900	19,700
Halve Penetration of Energy Star	19,400	38,300	57,700
Cumulative Savings	1800	9600	11,400

TECHNOLOGICAL CHANGES SENSITIVITIES

Increased Baseline PC Power

There are conflicting trends affecting the active power requirements for today's PCs, so it is not clear whether overall energy use is greater or less than the average machine from 1991, as discussed in Section 3. The OFEEM baseline scenario assumed a constant baseline energy use of 75 W. Reducing the power requirements from 75 W to 60 W from 1992 to 1996 reduces the baseline UEC by 20 percent. Changing the active power mode of standard machines in the Energy Star scenario reduces the savings from the program by about 33 percent as shown in Table 7-6 because the baseline power is reduced. We have assumed that the active-power requirements of the power-managed PCs are lower (40 W) because the design changes to incorporate power management influenced the overall design.

Table 7-6. Change Baseline Active PC Power from 75 to 60 W

OFEEM Output for 2010	Base	Change to Base	Energy Star	Change to Energy Star	Diff. in Energy Star Savings
PC UEC (kWh/year)	227	-20%	88	0%	-32%
Total Sector PC (GWh/year)	1696	-20%	655	0%	-33%

Multi-Functional Devices

The introduction of energy-efficient multi-functional devices into the image processing market could significantly reduce energy use for image processing. Multi-functional equipment could greatly reduce energy use associated with idle operating hours because of the change from three separate (fax, copier, and printer) machines to one. Table 7-7 shows the results of the multi-functional device sensitivity analysis comparing results in 2010 with the Energy Star scenario. We estimated that the sales of these devices begins in 1998. Equipment densities and EUIs of conventional machines will have decreased, while the copier UEC will have increased. Multi-functional devices are assumed to use more energy than an Energy Star printer, and slightly less than a fax machine. Printers, copiers, and fax machines are forecasted to account for 761 GWh/year or 21 percent of the total commercial sector office equipment energy use in 2010 under the Energy Star scenario. This is reduced to 233 GWh/year under the multi-functional device sensitivity analysis.

Table 7-7 Multi-Functional Equipment Replacing Printers, Copiers, and Fax Machines for 2010

Equipment Category	Energy Star Scenario			Multi-Funct. Equip. Sensitivity		
	Density (#/ 1000 sq ft)	UEC (kWh/ year)	EUI[a] (kWh/ sq ft-year)	Density (#/ 1000 sq ft)	UEC (kWh/ year)	EUI (kWh/ sq ft-year)
Printer	1.01	89	0.09	0.56	89	0.05
Copier	0.22	681	0.15	0.05	1178	0.05
Fax Machines	0.75	183	0.14	0.07	183	0.01
Multi-Funct. Equip.	na	na	na	0.04	153	0.02

a. The EUI is for office buildings.

UNCERTAINTIES IN REALIZING ENERGY STAR SAVINGS

The Energy Star program is launching a new generation of power-managed office equipment that offers tremendous savings potential. However, these savings are uncertain for two reasons: performance and market penetration. There are very few published reports on the field performance of Energy Star equipment, and the results that have been presented are mixed (Lapujade and Parker, 1994). Probably the most likely reason energy savings may not be achieved is that the power management features are never enabled. In a recent survey of 30 Energy Star computers here at Lawrence Berkeley Laboratory we found only five of the machines had the power-management feature enabled. EPA plans to require that manufacturers produce Energy Star equipment with the power-management feature enabled starting in October 1995.

There is also little information on how people operate power-managed PCs and monitors compared to standard office equipment. It is possible, for example, that Energy Star equipment will be left on longer hours because of the perception that the power management will turn everything "off." This is not the case, however, because energy use for some equipment in the low-power mode may be only slightly less than full, or active power. The energy savings for the Energy Star printers are far more certain because they are shipped with the power-management feature enabled. Our estimates of the savings are perhaps optimistic, but they are based on forecasts by market research groups. The estimates of the energy savings from copier and fax equipment are approximations based on trends extrapolated from the PC and monitor market trends. The Energy Star program for these devices is in the formative stages and the market response can only be surmised.

Analysis of user satisfaction is also needed to understand how people perceive the strengths and weaknesses of Energy Star equipment. There may be costs associated with the time needed to properly configure the power-management systems for a PC. Koomey et al. (1993) found that the cost of lost labor (from time delays in reaching active working state) can overwhelm the value of the potential energy savings.

COMPARISON OF OFEEM WITH RELATED STUDIES

It is useful and important to compare results from OFEEM with other similar efforts. OFEEM has been completely rebuilt for this project from the model originally developed in 1990 (Piette et al., 1991). The results are similar; office equipment EUIs in the mid-1980s are nearly identical, although the distribution of the EUIs by equipment category differs slightly. The primary difference between OFEEM results discussed in this report and the earlier model is that the earlier model did not include the decline in mainframe and mini-computer energy use that we project for the next decade. Rather, in the earlier study we held large computer energy use fixed over time. Only in 1994 did CBEMA for the first time project that mainframe sales were declining. The sales estimates used in the 1990 study showed an increase. A second difference between this study and the earlier one is that we did not have any estimates of savings from power management because the Energy Star program was far from conceptualization in 1990.

In the 1991 report we compared the model output to results from several studies of office equipment load growth. In general we found our results to be consistent with other studies, such as Pratt, R., et al (1990) or Baker-Reiter (1989). The exceptions were two studies that projected extremely high EUI increases (Hamzawi et al., 1989, Nguyen, H.D. et al., 1988). These later two studies, conducted by a utility and the California Energy Commission, were likely to have overestimates because of the use of nameplate data for power requirements. The studies projected EUIs for 1994 (9 and 12 kWh/sq ft-year) that are higher than our baseline projections for 2010.

Energy Savings from Energy-Efficient Office Equipment

We are aware of only one other study that examines the trends in office equipment between now and the turn of the century. Molinder of NUTEK compared the energy use of baseline and energy-efficient computers, monitors, printers, copiers, and fax machines from 1992 to 2000 (Molinder, 1994). The study concluded that the total baseline energy use for office equipment in Sweden is decreasing from about 570 GWh/year in 1994 to 430 GWh/year in 2000. NUTEK efforts to promote energy-efficient office equipment are expected to reduce the total by more than 75 percent, to about 100 GWh/year. Our analysis differs in that we expect to see equipment densities greater than those forecasted by Molinder, plus our baseline does not assume such dramatic reductions in power for each device, except mainframes and mini-computers (which are not consider by Molinder). We have not found ample evidence to suggest that power requirements are decreasing for most devices (except mainframes and mini-computers). Our analysis also differed in that our methodology looks more closely at equipment operating modes. The Swedish energy estimates were based on average power requirements, which do not allow comparison of energy use or hours of use by active and idle modes.

Energy Use of Mainframes and Mini-Computers

There are three studies worth mentioning that considered large computer energy use. These are important to provide a reality check against the OFEEM output. All three concluded that mainframe and mini-computer energy use was larger than PC energy use. The first, a study of miscellaneous end uses in commercial buildings, concluded that in 1990, mainframes used about 60 percent more energy than PCs (Arthur D. Little, 1993). The second, a European assessment of macroscopic load growth, concluded that PCs accounted for 0.7 GW in 1989 and 1.1 GW in 1993, while larger computers accounted for 0.7 GW in 1989 and 0.85 GW in 1993 (Roturier, 1994). Assuming hours of use similar to OFEEM for PCs and large computers, these estimates are more consistent with OFEEM, suggesting that large computers currently use about twice as much energy as PCs. The third study examined total energy use for computing in Switzerland in 1988 (Spreng, 1991). This study concluded that PCs used about 10 percent of the total 1120 GWh/year used in computing, which is even less than the 17 percent we found with OFEEM for 1988. Large computers may account for a larger fraction of computing in Switzerland than in the U.S. because of the presence of large financial institutions that operate mainframe systems. Among all three studies there are significant uncertainties regarding the hours and and diversity of use, and the power requirements for the large computers. Further research to examine differences in the estimates of energy use for large computers is warranted.

Section 8

CONCLUSIONS

FORECASTING AND POLICY IMPLICATIONS

Commercial Sector Energy Use

Energy use for information processing and office equipment has been increasing over the past decade, and will likely continue to increase in the next decade and beyond. Office equipment currently consumes about 2900 GWh/year in the State of New York. Under our business-as-usual baseline forecast without Energy Star equipment, this load may climb to 3300 GWh/year by 2000, and to 6400 GWh/year in 2010.

The most dramatic trend in office equipment energy use is the switch from centralized mainframes and mini-computers to personal computers (PCs). Looking broadly at all information processing equipment in commercial buildings, the most uncertain component of the end use, mainframes and mini-computers, appears to be the largest contributor to the current total end use, accounting for 1541 GWh/year in 1994. The dominance of large computers in the total end use will likely decline as energy use for and sales of large computers decline and as existing ones are retired from service. A counter trend is that energy use for all other office equipment, which in OFEEM consists of personal computers, monitors, printers, copiers, fax machines, and point-of-sale terminals, is on the rise. This increase is primarily driven by increases in equipment densities. PC and monitor energy use dominate the office equipment end use when large computers are excluded.

There is significant potential to reduce energy use of office equipment. Assuming moderate market penetration and performance, the Energy Star equipment could decrease the total commercial sector energy use by 31 percent, or about 1000 GWh/year by 2000, and by 43 percent by 2010. There are significant uncertainties as to whether those savings will materialize. To be successful, Energy Star equipment needs to be promoted and the energy savings features needs to be properly enabled, as further discussed below.

In almost every equipment category there are readily available technological and hardware advances that suggest there are large achievable savings from low-energy office technologies. These advanced technologies could not only reduce the load growth, but could decrease the overall commercial sector load. However, it is unlikely that these technologies will see widespread use without policy interventions because of their increased initial cost.

We have examined the influence of modifying several of the most uncertain input variables. These sensitivity analyses showed that doubling the frequency of machines left on at night increases the saving from the Energy Star program relative to the baseline by 46 percent by 2010. This is an important finding because of the lack of information on how office equipment is operated. Today's Energy Star office equipment exceeds the program's minimum low-power requirements. If the technologies simply met, but did not surpass, the low-power requirements, the savings from the Energy Star Scenario are decreased by about 15 percent. The inclusion of energy-efficient multi-functional devices could reduce energy use for image processing equipment to one-third of that projected under the Energy Star scenario.

The results of our study provide feedback on which are the most important types of office equipment to target in policies and programs such as the EPA's Energy Star program. We found that PCs and monitors are the largest source of load growth. This result is consistent with the EPA's strategy to begin the Energy Star program with PCs and monitors. The program will clearly be more successful if the technologies and their field operating performance are carefully evaluated. Energy-efficient office equipment market penetration should also be evaluated to improve promotional efforts. There is a tremendous need to educate purchasers of the potential benefits of power-managed office equipment, such as lower operating costs and possibly other attributes such as reduced noise or longer life. Equally important is the need to educate users about how to enable and optimize performance of the energy-saving features. Not all products are equal. Those on the market should be tested and compared in order to evaluate which achieve the greatest energy savings without compromising user satisfaction.

The Energy Star program cannot be looked at in isolation. There are a variety of activities underway to help increase the awareness of opportunities to reduce energy use for office equipment. Other efforts both within and beyond the U.S. contribute to ensuring that the energy savings projected by this report for the Energy Star program can be achieved. Further advanced efficiency opportunities beyond Energy Star technologies promise even greater potential savings.

Beyond the Commercial Sector

Although this study is focused on the commercial sector, the energy use for office equipment and information technologies in the residential and industrial sector is significant. Residential sector energy use for office equipment is on the rise as more PCs, printers, copiers, and fax machines find their way into the home office. Energy use by industrial sector office and computing equipment is also known to be significant and should not be ignored in future forecasts. In Section 5 we estimated that 20 percent of the mainframes and mini-computers are used outside of the commercial sector. That suggests that about 300 GWh/year are used by New York State industries outside of the commercial sector as defined here. It is likely that the energy use for these systems is dropping, but probably not as fast as the drop in commercial buildings, where PCs are rapidly gaining in the share of computing.

RESEARCH ISSUES

Based on our findings, we list the following five topics as outstanding issues that warrant future research.

- Energy Use of Mainframes and Mini-Computers - We have estimated that large computers presently consume more energy than PCs and monitors. These results are consistent with several other studies. This equipment category is by far the most uncertain component of current energy use with respect to information and computing technology. Further research is needed to better quantify the overall trends in energy use of large computers. This research should also examine the opportunities for greater energy efficiency in large computers. Furthermore, there may be opportunities to modify and improve the energy efficiency of the heating, cooling, ventilating, and lighting systems that serve computer rooms if computer systems are being downsized.
- Market Trends of Energy Star Equipment - Are energy-efficient types of office equipment capturing a significant portion of today's office equipment market? Clearly our ability to forecast energy savings from use of Energy Star equipment is linked to the market share. The sensitivity analysis showed that doubling the number of years that is required for the Energy Star equipment to reach the market reduced the cumulative energy savings between now and 2010 by 14 percent. The market for energy-efficient office equipment appears to be less than that shown by early projections from market researchers.
- Energy Savings from Energy Star Equipment - In general, there are few studies from the field that examine whether the equipment is performing as expected. Early investigations show mixed results. Both energy savings and user acceptance need to be examined. This topic is the subject of several research projects that are being planned and a few that are underway. Without such feedback, it is unclear how much energy savings is being delivered from the equipment that is currently reaching the market.
- Operating Patterns of Conventional and Power-Managed Office Equipment - To better understand the savings potential of power-managed office equipment it is important to better understand how conventional equipment is used. For example, there is little information about whether copiers or other equipment is turned off at night. The sensitivity analysis found that doubling the OFEEM inputs for nighttime hours of use for PCs, monitors, printers, and copiers reduced the savings from Energy Star equipment by 46 percent.
- Economics - Evaluating the economics of energy-efficient office equipment is difficult because of the fast-paced change in information technologies. Further research is needed to evaluate the technology costs associated with further improvements of PCs, monitors, and other equipment. Further work is also needed to assess the time spent learning to use new equipment and the resulting lost labor costs associated with energy-efficient office technologies.

Section 9

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