LBNL-45917

Electricity Used by Office Equipment and Network Equipment in the U.S.

Kaoru Kawamoto, Jonathan G. Koomey, Bruce Nordman,
Richard E. Brown, Mary Ann Piette, and Alan K. Meier

Energy Analysis Department
Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720

To be presented at the 2000 ACEEE Summer Study Conference on Energy Efficiency in Buildings, Asilomar, CA.

http://enduse.lbl.gov/Projects/InfoTech.html

August 2000

This work was supported by the Office of Atmospheric Programs of the U.S. Environmental Protection Agency. Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Electricity Used by Office Equipment and Network Equipment in the U.S.

Kaoru Kawamoto, Jonathan G. Koomey, Bruce Nordman,
Richard E. Brown, Mary Ann Piette, and Alan K. Meier
Lawrence Berkeley National Laboratory

ABSTRACT

In spite of the recent explosive growth in use of office equipment and network equipment, there has been no recent study that estimates in detail how much electricity is consumed by that equipment in the United States.

In this study, we examined energy use by office equipment and network equipment at the end of 1999. We classified office equipment into 11 types; for each type we estimated annual energy consumption for residential, commercial and industrial use by combining estimates of stock, power requirements, usage, and saturation of power management. We also classified network equipment into 6 types, and estimated the annual energy consumption for each type.

We found that total power use by office equipment and network equipment is about 74 TWh per year, which is about 2% of total electricity use in the U.S. More than 70% of this energy use is dedicated to office equipment for commercial use. We also found that power management currently saves 23 TWh/year, and complete saturation and proper functioning of power management would achieve additional savings of 17 TWh/year. Furthermore, complete saturation of night shut-down for equipment not required to operate at night would reduce power use by an additional 7 TWh/year.

Finally, we compared our current estimate with our forecast in 1995. We found that the total difference between our current estimate and the previous forecast is less than 15%. We also identified the factors which led to inaccuracies in the previous forecast.

Introduction

The Internet has spread rapidly. Over the last ten years, the number of registered domain names[1] has increased from 16,000 to 15 million and the number of world-wide Web sites has increased from zero to 10 million in the world. Meanwhile, annual shipments of computers have increased by a factor of five (Information Technology Industry Council 1998) and network devices like routers and switches have become ubiquitous. In spite of this growth, there has been no recent study that assesses in detail how much electricity is dedicated to computer equipment or network equipment in the United States. The last comprehensive study in this area is LBNL's study in 1995 (Koomey et al. 1995), prior to the Internet's emergence as an important force in the U.S. economy.

In this study, which is a summary of a more detailed report (Kawamoto et al. 2000), we examine energy use by office equipment and network equipment in the U.S. We classified office equipment into 11 types. For each type, we estimated annual energy consumption [TWh/year] for residential, commercial, and industrial use by combining the stock, power requirement, usage, and saturation of power management. An estimate was made for the case of complete saturation of power management and proper functioning as well as current practice for power management and operation. Further, we estimated energy use in the case of complete shut-down during nights

[1] A definition of "domain name" can be found at http://www.register.com/faq/glossary.cgi .

and weekends of all the office equipment except servers, minicomputers, mainframes, and faxes. We also evaluated the uncertainties in our estimate by conducting a sensitivity analysis.

We classified network equipment into 6 types and estimated annual energy use [TWh/year] for each type based on sales revenue. We also surveyed energy use for the LBNL network and evaluated how reasonable our estimate is.

Finally, for energy use by commercial office equipment, we compared our current estimate with our forecast in 1995 and identified the factors which led to the inaccuracies in the previous forecast.

Methodology

Office Equipment

Classification. We classified office equipment into 11 types as shown in Table 1. Multi-function devices (MFDs) fall into several different categories, and while good energy data on these are not available, all indications are that each type behaves similarly to a conventional single-function type (copier, laser printer, or inkjet printer). So we allocated MFDs into appropriate single-function categories. Further, we classified each equipment type as residential, commercial, or industrial, based on the place it is used.

Table 1. Classification of Office Equipment

Equipment Type	*Definition*
Portable Computer	Notebook or sub-notebook computer
Desktop Computer	Desktop or deskside computer whose price is lower than $25,000 and which is used as a client computer.
Server	Desktop or deskside computer whose price is lower than $25,000 and which is used as a server.
Minicomputer	Computer whose price is from $25,000 to $350,000. Peripherals such as tapes and disk storage are considered as part of minicomputer.
Mainframe	Computer whose price is higher than $350,000. Peripherals such as tapes and disk storage are considered as part of mainframe.
Terminal	Non-programmable terminal usually connected to mainframes or minicomputers.
Display	Display for desktop computer including CRT and LCD.
Laser Printer	Including multifunction device whose major function is laser printing.
Inkjet Printer	Including dot matrix printers and multifunction device whose major function is inkjet printing.
Copier	Including multifunction device whose major function is copying.
Fax	Fax Machines

Definition of Power Management. For computers, displays, and laser printers, we considered only one low-power mode. While many machines have more than one power management mode, we do not believe that the power level differences and available data on the distribution of modes across the year justify using more than the one mode we chose.

For inkjet printers and faxes, we ignored power management, because their power requirements are usually below the ENERGY STAR® standard low-power level even without power management, and because many of these machines have no low-power mode.

There are many terms for operating modes. To keep the terms consistent among all the equipment types, we used only three terms, "active," "low-power," and "off" as shown in Table

2. We defined active mode for copiers, faxes, and printers as the state when devices are ready but not printing or copying. Instead of defining another mode for printing or copying, we estimated the extra energy use for copying or printing separately.

Table 2. Power Management Mode*

Term in This Paper		Active	→ Low-Power	→ Off
Term in Industry	Desktop/Portable/Server	Active → ~~Standby~~	→ Suspend(Sleep)	→ Off
	Display/Terminal	Active → ~~Sleep~~	→ Deep Sleep	→ Off
	Laser Printer	Ready	→ Sleep	→ Off
	Inkjet Printer	Ready	→ ~~Sleep~~	→ Off
	Copier	Ready(Standby)	→ Sleep(Energy Zero)	→ Manual-Off/Auto-Off
	Fax	Ready(Standby)	→ ~~Sleep~~	→ Off

*Modes shown above with strikethrough are ignored in our analysis.

General Methodology. For each type of equipment, we estimated residential, commercial, and industrial energy use as summarized in Figure 1.

First, we estimated total stock using shipment data and device lifetime and then split it into residential, commercial, and industrial stock using the saturation at home and the ratio of commercial stock to industrial stock.

Second, we estimated the average power requirement in each mode (active, low-power, off), average usage (mode distribution over a week), and the power management enabled rates for residential and non-residential (i.e. commercial and industrial) use. We did not differentiate these parameters between commercial and industrial equipment. For printers, copiers, and faxes, we also estimated the extra energy use for printing or copying by combining the average imaging rate (number of images printed or copied in a year) with the average energy use for each image. This estimate is necessary because the power used when printing or copying is much higher than the active power.

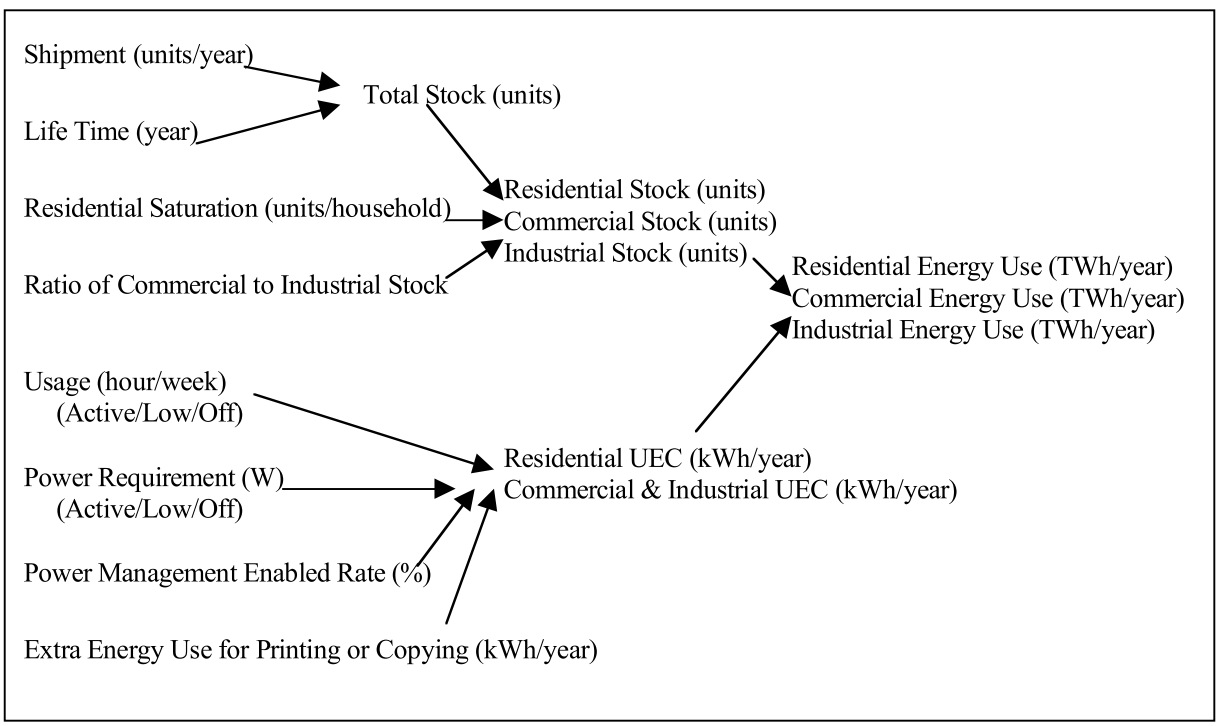

Figure 1. Calculation Flow

Third, we estimated the unit energy consumption (UEC) for residential and non-residential use by combining the power requirement, usage, power management enabled rate, and the extra energy use for printing or copying. The UEC is the average annual energy used by each unit.

Finally, multiplying the UEC by the stock, we estimated residential, commercial, and industrial energy consumption. Figure 1 shows the flow of calculation for each type of equipment.

Stock. First, we estimated the total stock for each type of equipment based on shipment data (Information Technology Industry Council 1998, Appliance Magazine 1999) and lifetimes. The lifetimes are derived from our previous study (Koomey et al. 1995). The use of a single lifetime for each type of equipment is a simplification, but the available data do not justify a more complex formulation.

Second, the residential stock for each type of equipment is derived from the residential saturation rate (US DOE 1997 [RECS], CEMA 1999). For laser printers, survey data results indicate that the residential stock is larger than the commercial stock, but we believe this result to be unrealistic. We concluded that such inaccuracies are caused by the tendency for people to mistake inkjet printers for laser printers and so corrected it by assuming that half of the people made such mistakes.

Finally, we estimated non-residential stock by subtracting residential stock from the total stock and splitting the remainder into commercial and industrial stock using the ratio of commercial floor space to industrial conditioned space from Commercial Building Energy Consumption Survey in 1995 (DOE EIA) and Manufacturing Energy Consumption Survey in 1994 (DOE EIA).

Table 3 shows the stock for each type of equipment. The accuracy of commercial and industrial stock depends heavily on the accuracy of the assumed lifetimes. There are some uncertainties in the residential stock of printers, because of the inaccuracy of survey data.

Table 3. Stocks of Office Equipment at the End of 1999 (thousands)

	Total	*Residential*	*Commercial*	*Industrial*
Portable Computer	22,150	16,090	5,300	760
Desktop Computer	109,110	54,530	47,760	6,820
Server	3,330	0	2,910	420
Minicomputer	2,020	0	1,520	500
Mainframe	107	0	96	11
Display	109,180	54,530	47,760	6,820
Terminal	13,330	0	10,000	3,330
Laser Printer Total	27,990	6,300	18,980	2,710
<8ppm	7,780	6,300	1,300	180
8-12ppm	8,730	0	7,640	1,090
>12ppm	11,480	0	10,040	1,440
Inkjet/Dot Printer	74,070	50,200	20,890	2,980
Copier Total	11,260	3,800	6,530	930
<21cpm	6,620	3,800	2,470	350
21-44cpm	2,760	0	2,410	350
>44cpm	1,880	0	1,640	240
Fax	27,950	6,300	18,940	2,710

Power Requirement. For all the equipment except servers, minicomputers, and mainframes, we estimated the power requirements mostly based on our own measurements (unpublished) or measurements by others (Nordman 1998, Brown 2000, US EPA 2000 [ENERGY STAR]). To calculate power levels for copiers and laser printers, we have taken the weighted average of the power levels across device speeds, because power levels vary considerably by the speed (images/minute) of each unit. We assumed that the power requirements for residential use are same as those for commercial and industrial use except for desktop computers, laser printers, and copiers.

For servers, we measured the power requirements for several machines and we found it to range from 50 W to 270 W. We estimated average power use as 75 W.

For minicomputers and mainframes, it is difficult to estimate the average power requirement because of the wide range of power requirements for CPUs[2] (Central Processing Units) and the various kinds of peripherals such as tapes and disk storage.

For minicomputers, we assumed that the IBM AS/400 is the representative machine and we estimated the average power requirement for the CPU based on measured data (IBM 1999). By assuming the power requirement for peripherals, combined with the power requirement for the CPU, we estimated the average power requirement for minicomputers as 1,000 W.

For mainframes, we had two more difficulties, one of which is the recent significant decrease of power requirement and the other is the lack of measured data. We separated the stock of mainframes into the new stock which were shipped from 1996 until now and the old stock which were shipped before 1996. We assumed that the IBM S/390 is the representative machine for the new stock and estimated the power requirement for one type of IBM S/390 whose price is close to the average price of mainframes. We also estimated the average power requirement for the old stock based on Koomey et al. (1995). Finally, based on a weighted-average of power requirements for the new stock and the old stock, the average requirement for mainframes was estimated as 10,000 W.

We also assumed that CPUs of minicomputers and mainframes are always on but their associated peripherals are off at night. We did not consider power management for minicomputers and mainframes.

In sum, there are significant uncertainties in the power requirements for servers, minicomputers, and mainframes.

Usage (Mode Distribution). We estimated the average usage (mode distribution over a week) for each type of office equipment in the case that it has power management capability and that it is enabled. Several factors combine to determine the average mode distribution. The causative factors are the work habits of the machine's users, the configuration of power management features, and the degree to which equipment is turned off manually. We defined the following three parameters which describe those factors.

1. *Night Status - Whether the equipment is active, low-power, or off during nights and weekends.*
2. *Daytime Status --- Whether the equipment is active, low-power, or off during daytime.*
3. *Daytime Length --- The length of the time when the equipment is regularly used.*

These parameters for commercial and industrial use are estimated mainly based on the results of power datalogging and audits for night status (Nordman 1998, and 2000, Brown 2000). However, we were not able to locate any comparable data about servers, minicomputers, and

[2] We use the term "CPU" for central processing units of minicomputers and mainframes. Peripherals are not included in CPUs.

mainframes, so we made assumptions for those three types. The parameters for residential use are estimated based on the survey data (US DOE 1997[RECS], CEMA 1999), other studies (Meyer and Schaltegger 1999) and some assumptions. There are certainly businesses run out of houses and computers provided by businesses for use at home, but we folded those into our estimate.

Based on the estimated parameters, we calculated the average mode distribution of each type of office equipment. There is a significant uncertainty in the usage for servers, minicomputers, and mainframes. There are also some uncertainties in residential usage because of the lack of data.

Power Management Enabled Rate. The power management enabled rate is the percentage of equipment that has power management capabilities whose power management is properly operating. Equipment that has power management capability but that has not been correctly enabled is not included in this category.

We estimated the rate for each type of equipment mainly based on the results of audits for night status (Nordman 1998, and 2000). For portable computers and servers, we made assumptions because of the lack of data, so there are some uncertainties.

Extra Energy Use for Printing or Copying. Extra energy use for printing or copying is the energy required beyond the energy use in active mode. We estimated it by combining the average imaging rate[3] with the average extra energy use for each image. Making assumptions about the paper use rates[4] and duplexing rates[5], we estimated the imaging rate for each type of equipment. We also assumed the average extra energy use for each image as 1 Wh for all the types of equipment.

Because most assumptions are based on the data cited by other papers or our own judgements, there are uncertainties. However, this methodology is potentially more accurate, because the total paper consumption is well known and so this limits the inaccuracies in total energy consumption for printing or copying.

Unit Energy Consumption (UEC). UEC is the average annual energy use by each piece of equipment. The UEC for each type can be described by the following equation. EPC_i is zero for computers, displays, and terminals.

$$\begin{aligned} UEC_i = & \left(SPM_i \times \left(PA_i \times HA_i + PL_i \times HL_i + PO_i \times HO_i\right)/7\right) \times 365/10^3 \\ & + \left(\left(1 - SPM_i\right) \times \left(PA_i \times \left(HA_i + HL_i\right) + PO_i \times HO_i\right)/7\right) \times 365/10^3 \\ & + EPC_i \end{aligned}$$

where

UEC_i = *Unit Energy Consumption for equipment type i (kWh/year)*
i = *index for equipment type*
PA_i = *Average active mode power for equipment type i (W)*
PL_i = *Average low-power mode power for equipment type i (W)*
PO_i = *Average off mode power for equipment type i (W)*

---

[3] The imaging rate is the average number of images printed or copied by each unit in a year.

[4] The paper use rate is the average amount of paper printed or copied by each unit in a year.

[5] The duplexing rate is the fraction of images that are placed onto duplexed sheets. A 100% duplexing rate uses half as much paper as a 0% duplexing rate. Duplexing Rate = (Imaging Rate – Paper Use Rate) * 2 / Imaging Rate

HA_i = *Hours of operation in active mode for equipment type i (hours/week)*
HL_i = *Hours of operation in low-power mode for equipment type i (hours/week)*
HO_i = *Hours of operation in off mode for equipment type i (hours/week)*
SPM_i = *Power management enabled rate for equipment type i (%)*
EPC_i = *Extra energy for printing or copying for equipment type i(kWh/year)*
365 = days per year
7 = days per week

The UEC for each type of equipment is shown in Table 4.

Table 4. Best Estimate of Unit Energy Consumption for Office Equipment in 1999

Equipment Type	*Residential UEC (kWh/year)*	*Commercial/Industrial UEC (kWh/year)*
Portable Computer	8.6	24.6
Desktop Computer	49	213
Server	*	560
Minicomputer	*	5,840
Mainframe	*	58,400
Terminal	*	183
Display	57	205
Laser Printer	16	283
Inkjet/Dot Printer	22	74
Copier	288	874
Fax	70	119

* We assume that there are no servers, minicomputers, mainframes, and terminals in the residential sector.

Network Equipment

Classification. We classified network equipment into 6 types as shown in Table 5. We did not include the switching equipment contained in the telephone system.

Table 5. Classification of Network Equipment

	Equipment Type	*Definition*
WAN[6] Equipment	Router	Throughout capacity is multigigabit. Interfaces and controllers are specialized for WAN. (e.g. Cisco 12000)
	Switch	
LAN[6] Equipment	Router	Routers and switches usually used for LAN. (e.g. Cisco 2500, 4500, 7000)
	Switch	
	Access Device	Access concentrators and access servers.
	Hub	Passive hubs and switching hubs.

General Methodology. We were not able to get any shipment data for network equipment and we had no alternative but to estimate the energy use in the U.S. from the worldwide sales revenue for each equipment type. First, we estimated the domestic sales revenue over the past 4 years by allocating the worldwide revenue based on the ratio of the number of host names or domain names in the U.S. to the world. Second, we assumed a representative model for each equipment

[6] WAN means Wide Area Network. LAN means Local Area Network.

type and estimated the virtual stock number of the representative model by dividing the domestic revenue by the unit price of the representative model. Finally, assuming all the network equipment operates for 24 hours per day throughout the year, we estimated annual power use for each type of network equipment by the following equation:

$$TEC_i = \left(REV_i / PRICE_i\right) \times PA_i \times 8760 / 1000$$

where

TEC_i = Total energy consumed by all devices belong to equipment type i in a year (kWh/year)
i = index for equipment type
REV_i = Domestic sales revenue for equipment type i ($)
$PRICE_i$ = Price of representative model for equipment type i ($)
PA_i = Average active mode power of representative model for equipment type i (W)
8760 = hours per year

Results and Discussion

Results

Table 6 and Table 7 show annual energy use for office equipment and network equipment, which totals 74 TWh/year for both types of equipment.

Figure 2 shows the percentage of annual energy use by residential, commercial, and industrial office equipment and network equipment. Commercial office equipment accounts for more than 70% of energy use, while energy use for network equipment is less than 5%. The remainder is split evenly between residential and industrial.

Figure 3 shows the percentage of annual energy use by active mode, low-power mode, off mode, and printing/copying. We found that 86% of all energy (64 TWh/year) is consumed in active mode, and 4% of all energy (3 TWh/year) is consumed in off mode.

Table 6. Best Estimate of Annual Energy Use for Office Equipment in 1999 (TWh/year)

Equipment Type	*Residential*	*Commercial*	*Industrial*	*Total*
Portable Computer	0.14	0.13	0.02	0.29
Desktop Computer	2.67	10.21	1.46	14.34
Server	0	1.60	0.23	1.83
Minicomputer	0	8.86	2.95	11.81
Mainframe	0	5.62	0.63	6.25
Terminal	0	1.83	0.61	2.44
Display	3.13	9.82	1.40	14.35
Laser Printer	0.10	5.36	0.77	6.23
Inkjet/Dot Printer	1.10	1.56	0.22	2.88
Copier	1.10	5.71	0.82	7.63
Fax	0.44	2.26	0.32	3.02
Total	8.67	52.95	9.42	71.04

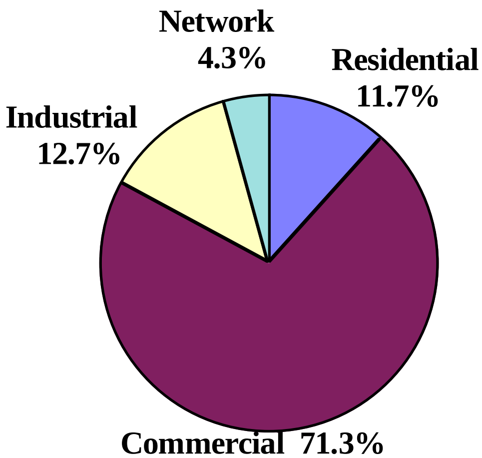

Figure 2. Percentage of Annual Energy Use by Each Sector at the End of 1999

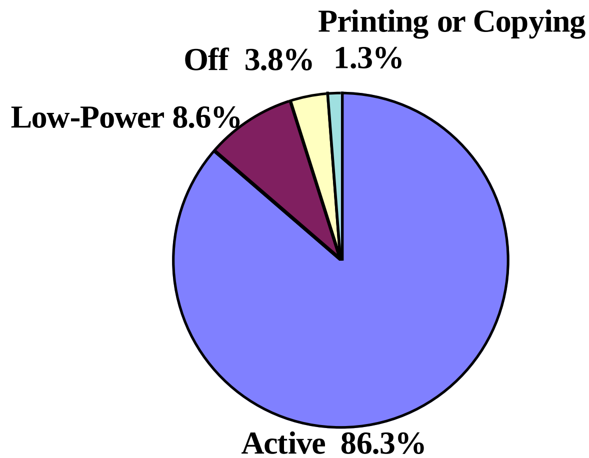

Figure 3. Percentage of Annual Energy Use by Each Mode at the End of 1999

Table 7. Best Estimate of Annual Energy Use for Network Equipment in 1999 (TWh/year)

	Equipment Type	*Annual Energy Use*
WAN	Router	0.05
	Switch	0.24
LAN	Router	0.68
	Switch	1.31
	Access Device	0.29
	Hub	0.65
Total		3.22

Energy Savings by Power Management and Night Shut-Down

Figure 4 shows a breakdown of annual power use by equipment type in the case of 0% power management present and enabled, current estimates for power management and operation, complete saturation of power management and proper functioning, and complete shut-down of all office equipment except servers, minicomputers, mainframes and faxes while not used during nights.

Current saturation of power management has achieved 23 TWh/year energy savings, compared with a hypothetical case with 0% power management present and enabled. Complete saturation of power management (capability and enabling) would save an additional 17 TWh/year, most of which is achieved by desktop computers, displays and copiers. That is because the power management enabled rate for desktop computers is low (= 25%) and also because power reductions by power management for displays and copiers are large (for displays, active power = 85 W, low-power = 5 W; for copiers, power in auto-off is less than 10 W)

Furthermore, complete saturation of night shut-down to all equipment except servers, minicomputers, mainframes, and faxes would reduce energy use by an extra 7 TWh/year, most of which is achieved by night shut-down for desktop computers and laser printers. That is because power reductions by shut-down for desktop computers and laser printers are large (low-power level for desktop computers and laser printers is 25 W) and also because laser printers are frequently left on at night (according to our survey, 73% of laser printers are on at night).

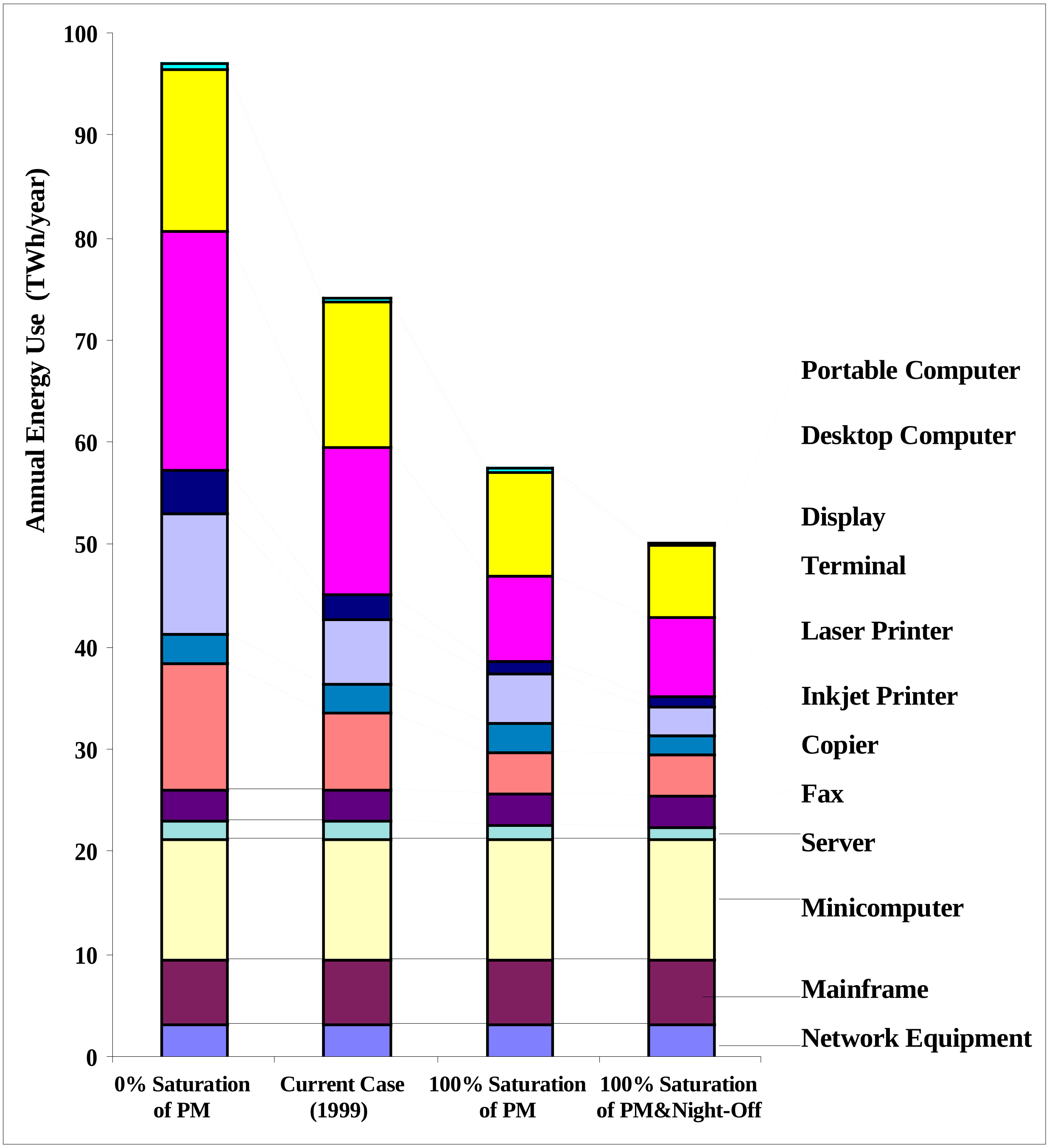

Figure 4. Energy Use by Equipment Type as a Function of Power Management Levels

Uncertainties

For all the input data for office equipment, we conducted sensitivity analyses to evaluate the uncertainties in our estimate of energy use. We estimated the error range for each piece of input data and calculated the resulting error range for annual energy use caused by the error associated with each piece of input data. We found that the uncertainties in the following data might lead to more than 1 TWh/year error in our estimate for energy use.

1. Stock, power requirement, and usage for minicomputers and mainframes.
2. Commercial or industrial stock for desktop computers, displays, laser printers, and copiers.
3. Usage for residential desktop computers and displays.

To check whether our estimate for LAN network equipment is reasonable or not, we estimated the power requirement of the LBNL network equipment, which connects about 5,000 computers, and compared the result with our estimate by scaling up the LBNL network to all networks in the U.S. We found that the total difference in LAN network energy per personal computer was less than 20% between LBNL and the U.S. We were not able to check the accuracy of our estimate for WAN equipment, though we are confident that the total error in our estimate for network equipment is less than 1.5 TWh/year.

Comparison with Our Forecast in 1995

We compared our current estimate for commercial office equipment with our forecast in 1995 for the year 1999 (Koomey et al. 1995). Results are shown in Figure 5 for the office equipment types that are common to both studies. The total difference is less than 15%. Energy use for desktop computers, printers, and displays is higher than our forecast in 1995. That is because desktop computers and laser printers are left on at night more frequently than we expected, and also because active power for displays is higher than we expected (active power for displays is 85 W, while our previous forecast was 63 W). There is little difference in energy use for minicomputers and mainframes.

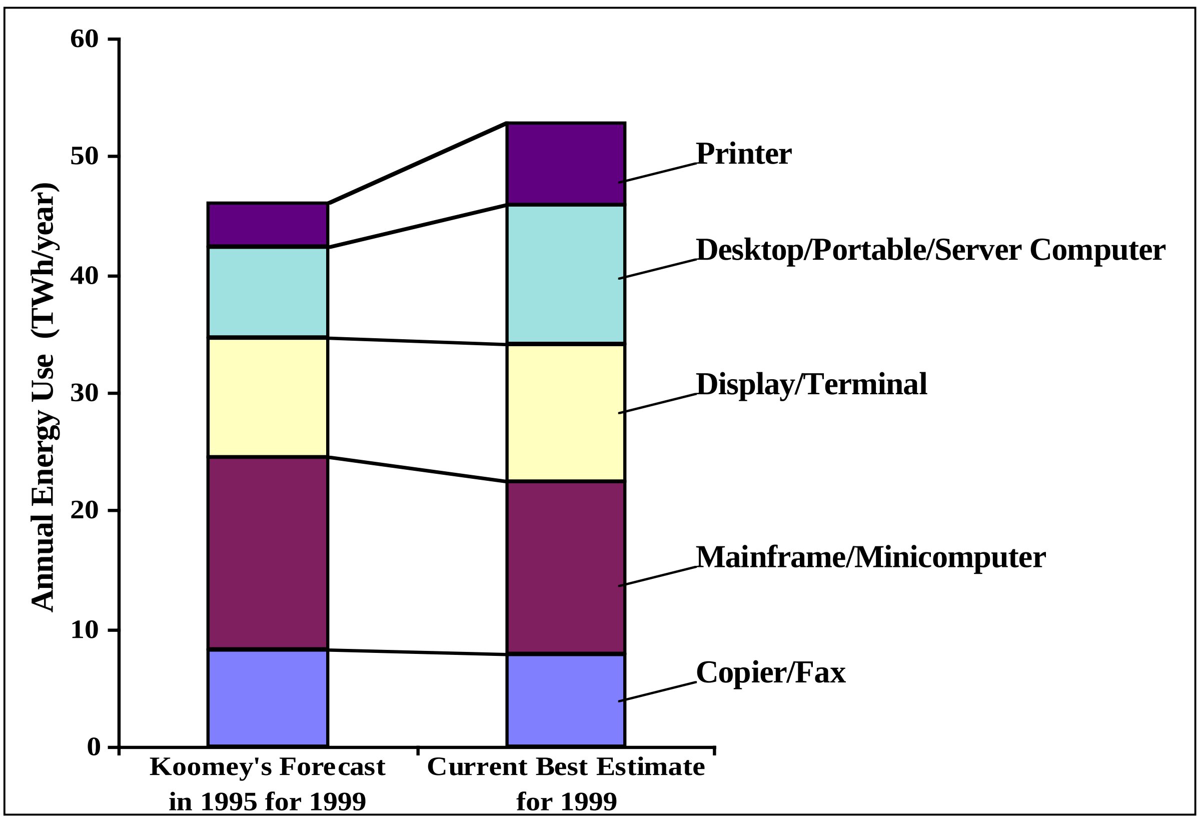

Figure 5. Comparison of Energy Use for Commercial Office Equipment in 1999 Between Current Estimate and Koomey's Forecast in 1995

Conclusions and Future Work

Annual energy use by office and network equipment is about 74 TWh/year, which is about 2% of total U.S. electricity consumption today. More than 70% of this energy use is dedicated to office equipment for commercial use, while less than 5% is for network equipment. The rest is split equally between residential and industrial uses. About 3 TWh/year, which is 4% of all the energy use, is consumed in off mode.

Current energy savings achieved by power management are estimated as 23 TWh/year. Complete saturation and proper functioning of power management would achieve additional savings of 17 TWh/year. Furthermore, complete saturation of night shut-down for applicable equipment types would reduce the power use by an extra 7 TWh/year.

The difference between current estimate and our previous forecast (Koomey 1995) is less than 15%. The differences are caused mainly by the fact that people leave office equipment on at night more frequently than we expected. Equipment with power management operating may be left on at night more frequently than conventional equipment is.

This study estimated the energy use and the energy saving potential for current office equipment. However, office and network equipment are changing rapidly. New equipment such as Web TVs, Web phones, and palm-size computers are already emerging. We need to estimate energy use for such emerging equipment in near future. We also need to estimate energy used by the telephone system, which is not part of our current estimates. On the other hand, the use of office and network equipment may influence energy and resource use in indirect ways that can be important. A complete assessment of these effects is beyond the scope of this paper, but is a worthy topic of future research.

Acknowledgements

This work was supported by the Office of Atmospheric Programs of the U.S. Environmental Protection Agency. Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF0098. We would like to thank Skip Laitner at EPA for funding this work. We would also thank Jeff Harris for his helpful comments.

References

Appliance Magazine. 1999. "1999 Statistical Review." *Appliance 46th Annual Report*. April.

Brown, R. 2000. "Power Consumption of Commercial Printers." *Draft LBNL Report*. February.

Consumer Electronics Manufacturing Association. 1999. "1999 Survey."

IBM. 1999. "Energy Use Comparison of AS/400 Products." http://WWW.as400.ibm.

Information Technology Industry Council. 1998. "1998 Information Technology Industry Databook."

Kawamoto, K., Koomey, J.G., Nordman, B., Brown, R.E., Piette, M.A., and A. Meier. 2000. "Electricity Used by Office Equipment and Network Equipment in the U.S.: Detailed Report and Appendices." *Draft of LBNL-45917*. June. http://enduse.lbl.gov/Projects/InfoTech.html.

Koomey, J.G., Cramer, M., Piette, M.A., and J.H. Eto. 1995. "Efficiency Improvements in U.S. Office Equipment : Expected Policy Impacts and Uncertainties." *LBNL Report-37383*. December.

Meyer and Schaltegger. 1999. "Bestimmung des Energieverbrauchs von Unterhaltungselektronikgeraten, Burogeraten und Automaten in der Schweiz." Federal Office for Energy, Switzerland. March.

Nordman, B., Meier, A., and M.A. Piette. 2000. "PC and Monitor Night Status: Power Management Enabling and Manual Turn-off." *In Proceedings of the ACEEE Summer Study on Energy Efficiency Buildings.* August.

Nordman, B., Piette, M.A., Pon, B., and K. Kinney. 1998. "It's Midnight … Is Your Copier On? : Energy Star Copier Performance." *LBNL Report-41332*. February.

US DOE. 1999. "Residential Energy Consumption Survey (RECS): Household Energy Consumption and Expenditures 1997." *DOE/EIA-0632(97).* November.

US EPA. 2000. "Energy Star Labeled Office Equipment." http://www.epa.gov/appdstar/esoe/index.html.