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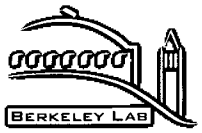

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It's Midnight ... Is Your Copier On?: ENERGY STAR Copier Performance

Bruce Nordman, Mary Ann Piette,
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Abstract

In the U.S., copiers use about 7 TWh/year of electricity, and a similar amount of energy is embodied in the estimated 2.2 million tons/year of paper used in copiers. These cost the economy about $500 million/year for the electricity and $2.2 billion/year for paper. The U.S. EPA launched the ENERGY STAR copier program in 1995 to save money plus reduce energy use and greenhouse gas emissions from copiers. This study evaluated the performance of ENERGY STAR copiers to assess the energy savings they currently achieve and the potential for increasing the savings. The main effect of the program is not to change power used in each operating mode, but to change the amount of time spent in each mode. We defined methods for auditing and energy use monitoring copiers and carried them out on 228 and 11 machines respectively. About 30% of both ENERGY STAR and conventional copiers were left on at night; while most conventional copiers were in a low-power mode, most ENERGY STAR compliant machines were fully off. Extrapolating these findings to all U.S. copiers results in higher electricity use than previous estimates, due to the night and weekend status and longer work days. However, this also implies a greater potential for saving energy with power management from ENERGY STAR copiers. A survey of users found general satisfaction with ENERGY STAR compliant copiers. Enabling of default duplex on two copiers raised their duplexing rate by 15% and 20%.

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Executive Summary

In the U.S., copiers use about 7 TWh/year of electricity, with a similar amount of energy use embodied in the 2.2 million tons/year of paper use. These cost the economy about $500 million/year for electricity and $2.2 billion/year for paper. The U.S. Environmental Protection Agency launched the ENERGY STAR copier program in 1995 to reduce greenhouse gas emissions and energy use, as well as save money. The ENERGY STAR criteria include requirements for copiers to automatically turn off or enter a low-power mode after a time of non-use, and sets specific limits on the power consumption in low-power and off modes. Default duplexing was initially required for some copiers and is now only recommended. This study evaluated the energy performance of ENERGY STAR copiers. We defined methods for copier auditing (configuration and operating patterns) and monitoring (energy use) and carried them out on 228 and 11 machines respectively. We also created a user satisfaction survey, to interview 56 copier users, and studied the effect of making duplexing the default mode on two copiers.

Previous copier energy estimates assumed that copiers are rarely left on at night. However, we found about 30% of both ENERGY STAR and conventional copiers on at full power at night. While most conventional copiers were in a low-power mode, most ENERGY STAR compliant machines were off. Not surprisingly, larger copiers were used for more hours per day than were smaller copiers. From the audits and monitored data, we defined a set of standard operating patterns for different speed categories of copiers. The operating patterns were combined with measures of power use for 130 copiers to estimate average annual energy use for conventional and compliant copiers. Energy savings were considerably below their potential due to power management being disabled on over one third of ENERGY STAR copiers audited.

With approximately one third of the stock of copiers now ENERGY STAR compliant, we estimate the current savings of the ENERGY STAR copier program to be 570 GWh/year. If the entire stock of copiers were compliant, the savings would be 1,700 GWh/year. The potential program savings—all copiers compliant and configured for high power management savings—are 4,200 GWh/year. These figures are higher than previous estimates, due to revised assumptions about the night and weekend operating status and longer work days. The savings are derived primarily from the auto-off feature. Low power modes were envisioned as accomplishing daytime savings, but their primary effect is reducing night and weekend energy on copiers with the auto-off feature disabled.

The user satisfaction survey indicated that most people are satisfied with the performance of their ENERGY STAR copiers. The major complaints cited were about paper jams and duplexing speed. The machines were perceived as more reliable than others, though perhaps this was simply because they were newer. Unfortunately, ENERGY STAR copiers are not faster at duplexing than conventional machines. The difference in speed remains a significant barrier to higher duplexing rates because duplex copying is slower than making simplex copies.

Default duplexing was found disabled on every copier we saw. However, when we enabled it on two machines, the duplexing rate rose by 15% and 20%. Thus, while the initial barrier to default duplexing is considerable (and manufacturers provide little guidance on how to implement it successfully), it remains a significant untapped opportunity for energy and cost savings and reduced greenhouse gas emissions. Survey respondents often cited confusing and hard to use controls as reasons for not using copier features such as duplexing. Copier efficiency could be increased with standardization of terms, symbols, and controls (both among and within brands). Manufacturers should provide information on these topics in operating manuals and on the web.

The greatest opportunity to improve on the current savings from ENERGY STAR copiers is to increase power management enabling rates. Sales and service personnel are probably responsible for most disabling. Anecdotal evidence suggests that service personnel often disable power management before customers ever use the copier, and may completely disable it on an inquiry from the customer rather than explaining the benefits of ENERGY STAR features or altering the configuration for the customers' needs.

1. Introduction

1.1. Background

Office equipment is estimated to have consumed about 7% (Koomey et al., 1995) of the electricity used in commercial buildings in 1990. The ENERGY STAR office equipment program was established in 1992 to reduce this demand to save money reduce greenhouse gas emissions. Copiers were added to the program in 1995, joining personal computers, monitors, printers, and fax machines. Copiers are estimated to currently use about 10% of office equipment electricity—about 7 TWh/year—and are expected to drop to about 5.7 TWh/year by 2000 with the effect of the program. The ENERGY STAR program operates by engaging equipment manufacturers in a dialogue to identify energy-saving criteria that are broadly achievable but represent a significant improvement over existing equipment. Compliant equipment may be labeled with the ENERGY STAR logo, and the EPA promotes the purchase of ENERGY STAR products. A separate program for multi-function devices[1] was launched in April 1997.

This study was initiated to evaluate the current energy savings and overall performance of ENERGY STAR[2] copiers, and to provide recommendations for program improvement. Components of the project included a review of the relevant literature, development of procedures for measuring copier performance, night-time auditing of copier status, detailed electricity monitoring, surveying of user satisfaction, and integration and analysis of results.

Table 1-1 shows the requirements for qualification as an ENERGY STAR copier. The criteria specify how the copier is to be configured when shipped to the customer; after installation, it can be changed by the customer or service personnel if desired. Default duplexing[3] was required for high speed machines (>44 copies per minute—cpm) for both Tiers until late 1997; since then it has been optional. As Table 1-1 shows, the main criteria for the program are delay timers that cause the machine to either enter a low-power state, or turn off. A notable feature of the copier program is that EPA expects no extra manufacturing cost for the ENERGY STAR features[4], so that the customer saves money from the first day of operation. Six months after the program took effect, it was estimated to have captured a notable 33% of the copier market and 7% of the stock (Dataquest, 1996). As copier models have turned over, these percentages have probably risen sharply since then.

Table 1-1. ENERGY STAR Copier Program Requirements

	Date in Force[f]	Speed (cpm)	Default Time to Low-power	Default Time to Off	Maximum Power (W) Low-Power[d]	Maximum Power (W) Off[e]
Tier 1[a]	July 1, 1995	1-20	N.A.[c]	30 minutes	N.A.	5
		21-44	N.A.	60 minutes	N.A.	40
		>44	N.A.	90 minutes	N.A.	40
Tier 2[b]	July 1, 1997	1-20	N.A.	30 minutes	N.A.	5
		21-44	15 minutes	60 minutes	$3.85 \cdot cpm + 5$	15
		>44	15 minutes	90 minutes	$3.85 \cdot cpm + 5$	20

Notes: [a]There are no low-power requirements for Tier 1 machines (only off-mode power requirements). [b]An additional requirement for Tier 2 mid-range copiers is a maximum recovery time from low-power of 30 seconds. [c]"N.A." means "Not Applicable"—that no requirement exists. [d]$3.85 \cdot cpm + 5 = 86$ W for 21 cpm, 169 W for 44 cpm, and 390 W for 100 cpm. [e]Copiers use some energy even when switched off (such as for electronic controls). [f]The date in force is the date of the model introduction, not the date of sale.

Several factors indicated a need for this study. As ENERGY STAR copiers were largely new to the market (some compliant models preceded the program), their performance had not been compared to conventional copiers. Previous evaluations of the ENERGY STAR PC and monitor program had found widespread disabling and other implementation problems that defeated power management (Nordman et al., 1996b). Anecdotal evidence of dissatisfaction with and disabling of default duplex indicated that there might be similar problems with the copier program. In addition, an evaluation of actual copiers and usage patterns would provide for close scrutiny of ENERGY STAR program savings estimates. The components of this project included: a review of the existing literature on copier operating patterns, energy use, and imaging rates[5]; the development of methods for field monitoring of

[1]A "multi-function device" (MFD) performs several imaging tasks often accomplished by separate devices. The ENERGY STAR program defines it as copying plus either printing, faxing, or both. Many MFDs can also function as scanners.

[2]We use 'ENERGY STAR' and 'compliant' interchangeably; similarly, we use, 'non-compliant', and 'conventional' for non-ENERGY STAR copiers (which generally do not meet the ENERGY STAR specifications).

[3]Default duplexing means that the standard operating mode is to make double sided copies (usually from single-sided originals).

[4]Manufacturers note the high cost of developing new copier models, though how much of this can be attributed to ENERGY STAR is not clear.

[5]The imaging rate for a copier is usually expressed as the number of images made per month. Similarly, the 'capacity' or 'rated capacity' of a copier is the maximum monthly imaging rate recommended by the manufacturer. It may be optimal or preferable to use a copier at a rate significantly below its rated capacity, but the rating serves as a useful reference point. The 'capacity factor' is the actual use rate divided by

copiers (electricity monitoring, audits of night-time status, and duplexing rates); conduct of the field monitoring; and an assessment of user satisfaction with copiers.

With the information developed in the project we: created standard operating patterns for conventional and ENERGY STAR copiers; made better assessments of conventional copiers and current savings from the ENERGY STAR copier program; identified opportunities to improve the program to increase customer satisfaction and energy savings; and made recommendations on program and copier design.

This paper covers the main findings of each part of the project; additional details and results are presented in the appendices (due to the size of the appendices, many are published only electronically[6]). Section 2 reviews previous work in this area, highlighting those findings that influenced the course of the project. Section 3 describes our monitoring and auditing approach, including lessons applicable to other copier research. Section 4 covers the project results, including our audits, electricity monitoring, assessment of ASTM test results, and estimates of annual energy use per copier. Other results include our assessment of user satisfaction, measures of paper use, extrapolations to national estimates of electricity and paper use (and ENERGY STAR copier program savings), and comparisons to similar estimates made by others. Section 5 summarizes key conclusions and research needs.

In this project, we did not attempt to gather statistically representative data for the entire stock of U.S. copiers (a huge task) but rather produced results that are indicative of copier performance and sufficient for program planning and evaluation purposes.

1.2. Overview of Copier Energy Use

Copier electricity use is complex in its details, particularly within individual imaging events (Acquaviva, 1992). However, for the purposes of this study—evaluating power management and overall energy use—representing that complexity is not required. Power management features include auto-off and low-power ("energy-saver") modes, or both.

To provide a basis for comparing the electricity use of copiers, the American Society for Testing and Materials issued a test procedure in 1987, with a significant revision in 1994 (ASTM, 1994). The ASTM test is the only standard test in widespread use in the U.S. or Europe. The ASTM test was designed to provide performance data suitable for comparing the electricity use of copier models. This is accomplished by recording average *power levels* for one hour periods as well as a monthly total energy use based on a standard *operating pattern*. Because it was developed for comparison and not prediction, the operating pattern is not derived from typical use patterns and so the monthly (annual) energy use figures derived from the test should be interpreted with caution. Copiers are assumed to be left on only two nights a month (never for copiers with an auto-off feature) and never on weekends. The ASTM test provides a basis for standard terminology.

Figure 1-1 shows a prototypical weekday loadshape for three copiers—a conventional copier always on, a conventional copier with an average use pattern, and an ENERGY STAR copier fully enabled. Active copying energy is not shown—it only adds about 10% to the electricity use and is not currently a target of power management. Any copier can be manually turned off at night and many conventional copiers have auto-off or low-power features. ENERGY STAR copiers are more likely to have and utilize the features.

Several key factors affect copier energy use, and influence the savings from the use of more efficient copiers. For conventional copiers this includes the fraction of copiers that have power management features, how they are configured (e.g. the fraction enabled), and the number of hours during which the copier is used. For ENERGY STAR copiers, we expect to see shorter delay times, higher enabling rates, and lower 'off' power levels. In addition, we expect to see daytime savings on some machines, depending on the distribution of imaging jobs across the day.

The ASTM test defines five copier modes: "copying", actively making copies; "standby", immediately ready to copy, but not doing so; "energy-saver", using less power than when in standby mode, but not off; "plug-in", plugged-in to an outlet, but not turned on; and "warm-up", becoming ready to copy. Many copiers use some energy in plug-in mode, even if they appear to be completely off. Copiers may be switched off manually, or automatically by an auto-off feature; the ASTM definitions do not distinguish between these states, though the copier may draw different levels of power[7]. Most copiers use heat in fusing the toner to the paper, so the warm-up energy and much of the copying energy is used to maintain the fuser roll at the required temperature.

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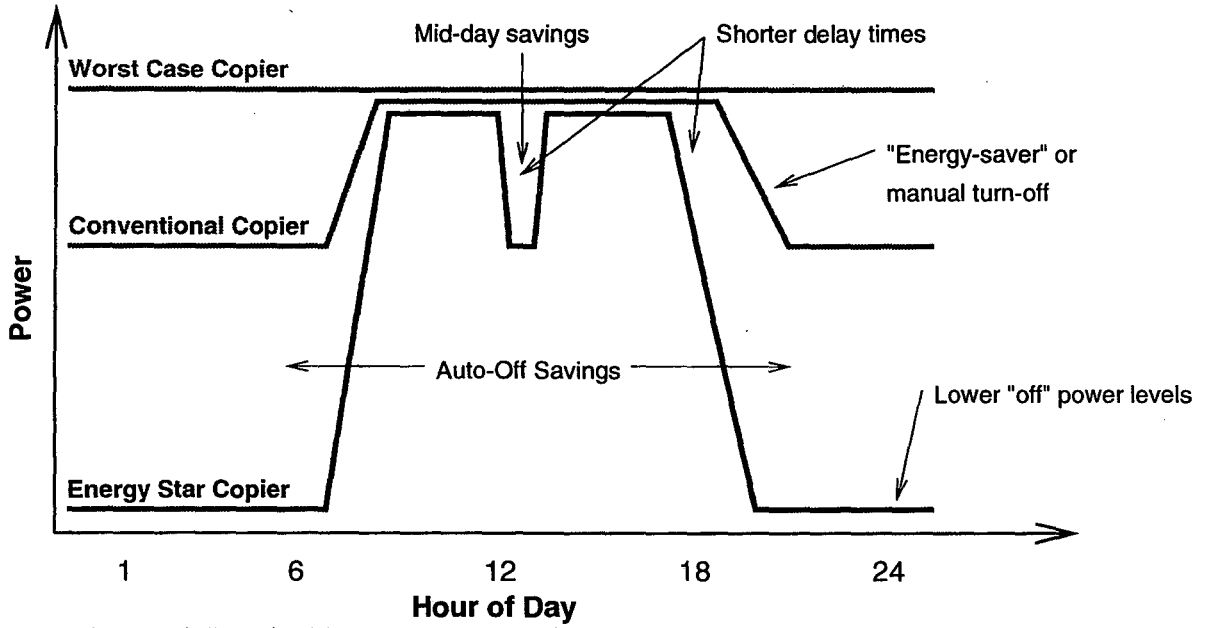
the rated capacity, as a percent.

[6] See http://eetd.LBL.gov/BEA/LBLReports/41332.

[7] We did not measure any copiers to determine if there is a difference, but it is unlikely to be big enough to substantially affect our results.

Figure 1-1. Prototypical Copier Loadshapes



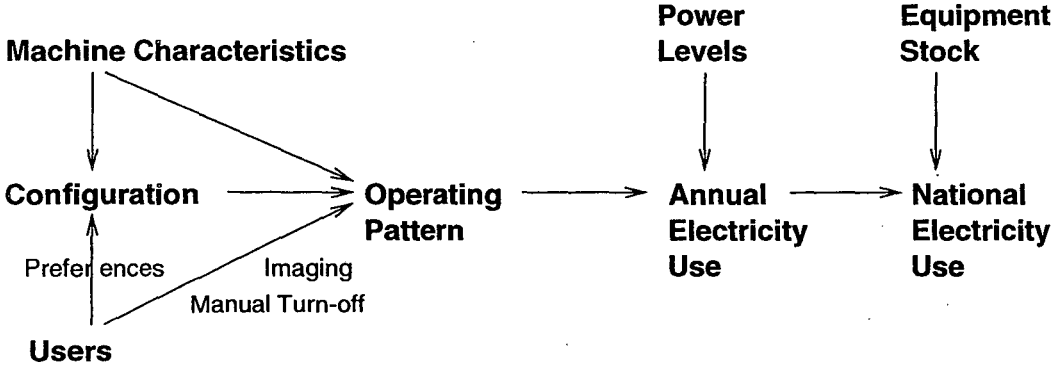
Notes: The arrows indicate electricity savings opportunities for ENERGY STAR copiers. These are *average* loadshapes for several copiers and days, and so do not correspond to any particular day.

A copier's operating pattern is the distribution of time spent by the copier in each mode plus the imaging rate. We define the three primary modes as "On", "Low-Power", and "Off". Our "on" mode combines the copying, standby, and warm-up ASTM modes. Our "low-power" and "off" modes correspond directly to the ASTM "energy-saver" and "plug-in" modes[8]. A "standard operating pattern" is an estimate of current use patterns from which annual energy use, existing program savings, or potential further savings can be calculated.

The ASTM test assumes that copiers are only rarely left on during nights and weekends, but the ENERGY STAR copier program was developed in part due to the belief that copiers are frequently left on during non-work hours. Thus, a key uncertainty is the level of power use typical during night and weekend hours (which far exceed daytime hours).

Figure 1-2 shows how several various factors combine to determine national energy use by copiers. Machine characteristics include any feature that can change the energy use of the copier; power management is the most apparent of these, but factors such as warm-up time and duplexing speed also affect electricity use. Copier users interact with the machine's controls, with the *effect* of this seen in the configuration chosen and the operating pattern. The operating pattern is the most variable and uncertain factor. Energy is also consumed in the production of copier paper (discussed briefly in Section 4), toner, and the copier itself.

Figure 1-2. Factors affecting Copier Energy Use



[8]Some copiers physically move the on/off switch when accomplishing auto-off so that automatic and manual off are identical. Some copiers do not move the switch but appear to be entirely off. Other copiers note their off status on the display.

A Japanese test procedure (MITI, 1994) was created to facilitate an energy efficiency standard for copiers, to be effective in 2000. However, Japan will probably adopt the ENERGY STAR program, making this test superfluous. The standard addresses daytime electricity use only; it says nothing about night or weekend use, perhaps presuming that the machine would be manually turned off during those times. Unlike the ASTM test, the imaging rate is specified by the test procedure.

Various specifications for efficient copier performance have been prescribed over the years. The ENERGY STAR criteria are the most widespread, and are the basis for the Green Seal energy criteria. The Green Seal recommendation adds several non-energy criteria and strengthens the duplexing requirement (Green Seal, 1995). The NUTEK (NUTEK, 1995) criteria are similar to ENERGY STAR. The Swiss "Target Values" for copiers are of the same form, but more stringent in low-power mode for most copier speeds (cited in Dandridge, 1994). An Australian implementation (SEDA, 1997) uses the US EPA criteria, but their savings estimates assume that copiers are left on 70% of nights and weekends.

2. Previous Work

To develop our assessment procedure for the performance of ENERGY STAR copiers, we first reviewed the available literature on copier electricity and paper use. There have been no previous efforts to measure ENERGY STAR copier performance. We interpret the term 'literature' broadly, including academic papers, gray literature, information from manufacturers, and industry market analyses and equipment evaluations.

ASTM Test Results

Given the importance of the ASTM test procedure for copier electricity measurement, wide availability of a database of ASTM test results would allow purchasers to make better purchasing decisions and would aid copier research. The only compilation we found was a database assembled by Dandridge in 1994 (Dandridge, 1997), developed to help design the ENERGY STAR program. The database contains test results for 130 copiers of varying speeds. There are only three ENERGY STAR models are represented, because the database predates the program. We used the data to determine average power levels for each copier speed segment, averaging the models by segment. The results are presented in Section 4.3.

We did not find ASTM test results accompanying field measurements of copier electricity use. We requested ASTM test results from manufacturers, as they often conduct the tests and provide the results to potential customers on request. We were largely unsuccessful in this; one company provided extensive results, but too late to incorporate into this study. Results for four copiers (from two different manufacturers) were obtained, but only under a condition of confidentiality.

Monitoring Studies and Audits

Acquaviva (Acquaviva et al., 1994a, 1994b) provides a detailed discussion of how copiers actually use energy. He reviews the effect of job type (as it effects cycle energy) and imaging rates, and assesses copier model efficiency over time.

Dandridge (Dandridge et al., 1994, 1996) studied copier energy use with the design of the ENERGY STAR program in mind, reporting measured copier use patterns from light sensor data and the electricity use of three copiers. The ASTM test was shown to provide a good approximation of measurements made during ordinary usage for the three copiers. Factors such as duplexing and distribution of jobs were assessed to determine their effect on electricity use. The light sensors reliably recorded when imaging occurred, but not the job type.

Several studies assessed office equipment electricity use. Pacific Gas & Electric measured the use of four copiers, compared it to copiers that use less electricity, and estimated savings from the use of timers to turn them off when not used during the day (Martin, 1991a, 1991b, 1992). ASTM tests were not used, but the power used in each mode was combined with actual operating pattern data to estimate annual energy use. This included identifying when each copying job occurred to estimate the benefit of 'idle' timers. A Swedish study (Levinsson et al., 1996) included detailed measurements of two copiers, one of which was an ENERGY STAR copier. An Electric Power Research Institute study (Arney et al., 1996) was designed to evaluate baseline office equipment loads and loadshapes. Nine copiers were monitored for periods ranging from two days to several weeks.

Tests have been made of controlling devices by the Florida Solar Energy Center (Floyd, 1997) and Bayview Technologies (Wood, 1997). Although the number of machines tested is small, the devices appear to be successful and accepted. Two British studies (Parsloe et al., 1992a, 1992b) provide limited measurements of copier power.

Several studies involved after-hours assessment of equipment on. A Thai study (Mungwititkaul et al., 1997) aggregated measurements by mode for 19 copiers. Detailed monitoring of four copiers resulted in a distribution of operating modes by time for power-managed and non-power-managed copiers. Power management was disabled in 90% of 19 copiers audited, but security personnel manually turned off machines each night. Night audits of equipment status were collected by Bayview Technologies (Wood, 1997), a manufacturer of controlling devices for office equipment. Our analysis of these data are presented in Section 4.1.

Policy Analyses

A variety of studies have assessed policy options for reducing copier electricity use. Harris et al. (1994) explored several issues related to copier energy use and efforts to increase their efficiency. The study includes estimates for current U.S. electricity use and the savings potential of copier power management and increased duplexing rates. Koomey et al. (1995) assessed office equipment energy use in commercial buildings for "Business-as-usual", ENERGY STAR, and "Advanced" scenarios; the purpose was to identify the savings from existing EPA programs, and a reasonable potential that could be gained with additional effort. All copiers were grouped into one category (not disaggregated by speed). A Swiss study (BEW, 1992, 1993) assessed electricity used by devices when they are not in active use. Measured power levels were reported for 15 copier models from one manufacturer. We compared these data to those from Dandridge and found 8 models in common. Standby energy ranged from identical values to up to 50% different. Low-power energy ranged from close values to 100% different. There is no clear explanation of these differences. An early assessment (Yanagawa, 1992) reviews methods to reduce copier electricity (including those that reduce imaging and reduce the total number of devices in an office), and the distribution of energy use within a copier. Extrapolations to national (U.S.) estimates of energy use or savings have been made in a variety of policy analyses. Three estimates (Dandridge et al., 1996, Harris et al., 1994, and Koomey et al., 1995) were made before the ENERGY STAR copier program was underway. The EPA makes its own estimates of program performance which are continuously modified as new data are available.

Duplexing rates

Duplexing increases electricity use by requiring extra energy for counting copies (when that occurs), more time at the copying power level due to the usually slower speed of duplex copying, and potentially by increasing total imaging with increased paper jams. The literature on duplexing rates is discussed in Section 4.4.

User Satisfaction

The Swedish study included a survey of copier users in two offices. At one, the acceptable warm-up time ranged from 10 seconds to 5 minutes, and at the other, no more than one minute was acceptable.

In assessing how previous efforts inform this project, it is important to note that they had different goals, and nearly all predate the ENERGY STAR copier program. Consequently, data critical to our analysis were not always recorded or reported (examples include the brand and model of each copier measured).

3. Field Measurement Techniques and Methods

This section presents a general overview of field measurements and techniques, followed by a discussion of the particular methods and approaches used in this study. The types of field measurements reviewed include auditing, monitoring, and user satisfaction surveys. Auditing consists of a one-time visit to ascertain a copier's state or configuration. Monitoring involves use of a datalogger to record electricity or imaging over a period of time, or periodic recording of imaging and paper counters. User satisfaction surveys queried users of copiers about their attitudes and actions regarding power management, duplexing, and overall copier performance. Audits require much less effort than detailed monitoring, facilitating the analysis of larger numbers of machines. The greater numbers of machines visited with audits gives more confidence than can be gained from detailed measurements only.

The existence of common methods makes it more likely that information collected by different researchers will be correct, complete, and amenable to comparison or combination. Experience with analyzing the performance of PCs and monitors further reinforced the need for such guidelines. Finally, researchers need to know the appropriate parameters for field monitoring for variable such as granularity of data sampling, recording, and necessary days of recording.

3.1. Monitoring Techniques

We identified three major methods to evaluate the performance of energy-efficient copiers—model audits, night-time audits, and detailed monitoring. These illuminate the character and use of features that underlie the ENERGY STAR copier program. We also used user satisfaction surveys and measured duplexing.

Model Audits are used to identify 'machine characteristics' (see Figure 1-1), such as a model's power management and duplexing features, and determine how to inspect and change configurations. Examinations of the operating manual and the machine itself are the primary sources of model audit data. It is desirable to conduct model audits of relevant models before other field monitoring activities.

Night Audits reveal copier status during night and weekend hours. Night audits also offer an opportunity to check configurations. Night audits are most complete when the auditor has an inventory of all copiers to aid in locating machines and collecting relevant manuals. For most office environments, audits should take place after 9 p.m. to allow machines to equilibrate to their final state[9].

Detailed Monitoring can be used to evaluate operating patterns, verify operation of controls, and extrapolate to annual use. In addition to recording the information specified for a night audit, the value of the image counter should be recorded when the monitoring equipment is put on and again when it is taken off, to allow calculating imaging rates and electricity use per image.

Duplexing Measurement allows calculation of baseline measures of duplexing rates and the effect of enabling default duplex. Measurement of duplexing rates requires separate internal counters for total images, paper, and sheets through the duplexing unit (though with any two of these, the third can be calculated). Some machines have easily accessible counters; some have them accessible only to key operators or service technicians (and thus potentially available to researchers); and some do not have such counters at all.

User Satisfaction Surveying aims to reveal the reaction of copier users to the machines generally and to electricity and paper issues specifically. Paper handling (such as default duplex) has a much greater impact on the typical user than does most power management, so user satisfaction concerns were greater when default duplex was part of the ENERGY STAR copier program. In some PCs, power management would lead to equipment malfunction, raising the question of whether this occurred in copiers.

National Estimates of copier energy use and savings are extrapolations based on information about the stock of copiers present in the U.S., average power levels of copiers, and a standard operating pattern, as shown in Figure 1-1. They are used to indicate program potentials and savings.

Details of our techniques can be found on the web, along with a discussion of confounding factors that impede data collection or add uncertainty. These include difficulties in machine identification, ambiguous terms, duplexing issues, audit problems, and on-site problems.

3.2. Our Methods And Analysis

We reviewed the paper and electronic versions of copier characteristics data collected by Buyer's Laboratory, Inc. (BLI, 1997). These provide valuable data on specific models, and previous work (Nordman, 1996a) analysis of several characteristics, including the relative speeds of simplex and duplex copying. In the course of monitoring and auditing, we reviewed the product manuals for about 30 individual copier models and assessed their electricity and paper features.

During our night *audits*, we attempted to record the following information: copier location, brand, model number, power status (if off, manually, or by auto-off), if any error mode was extant, presence of controlling devices or unusual accessories, plugged-in status, and any relevant signs (to paper or power) posted in the vicinity. When possible, we recorded the power management and duplexing configuration. Weekly timers are used infrequently, but we checked for their use when possible. To allow calculation of duplexing rates, we recorded any available internal counters. We visited 228 copiers at seven sites, most after 9 p.m. The sites included LBNL itself, three city office buildings, a federal office building, the main offices of two large corporations, and a hospital.

We set the *monitoring* period for this project at two weeks[10]. We recorded power use every 30 seconds using a 15 Amp power transducer and a datalogger capable of storing about 65,000 readings[11]. We did not change the copier's configuration, even if any ENERGY STAR features were not enabled. We monitored eleven copiers at six sites. In reviewing results from detailed measurements, we produced a number of standard graphic representations of the electricity use. A particularly useful one is the 'calendar' graph of the daily use (Figure 4-2). We defined a method to derive standard figures of merit for each copier such as average weekday on-time, and annual energy use.

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[9]Even at 9 p.m., a copier with a four-hour delay might not have powered off, and people working late can also cause a 9 p.m. audit to not capture all auto-off occurrences.

[10]The operating patterns were reasonably consistent across the two-week period, so that just one full week of monitoring may be sufficient for future monitoring projects.

[11]In four of the early measurements, we used a different power monitoring system and in two cases monitored current rather than power.

We derived the average weekday and weekend day energy use, excluding any holidays and incomplete days. We then extrapolated to annual energy use based on 250 work days per year and 115 weekend/holiday days (see Table 4-4). We derived an average power level or 'Transition Value' for each copier, above which the copier is assumed to be on for the period. Energy above this level is assigned to copying activity and energy below this level to keeping the copier in a ready-to-copy state. This is intended to correspond to the ASTM "standby" level (so long as low-power and auto-off delay times are less than an hour). A separate transition value identifies the low-power mode level.

To measure the effect of default duplex, we recorded duplexing counters at one week intervals. We recorded this for at least one month with the machine in default simplex, so that the baseline rate was well-determined, and for newly installed copiers, for people to get used to the machine. After enabling default duplex, we recorded the duplexing rate for several months. We measured the effect of default duplex enabling on two copiers.

We surveyed 56 users of 11 ENERGY STAR copiers to determine their awareness of the model's energy saving features, level of satisfaction with them, and suggestions for improvements. We inquired specifically about their awareness of each feature's presence (auto-off, low-power, and default duplex), what they thought the delay time was that the machine was set to use, and if recovery times from low-power or off were too long. We asked about ease of use of duplexing as well as open-ended questions about the copier. We only included users who reported making at least 10 copies per week. Before surveying users, we audited the copier to find out which features were present and enabled. We did not ask about ENERGY STAR features that were disabled. A total of fifty-six people were surveyed.

To derive estimates for national copier electricity use and savings from ENERGY STAR copiers, we sought out the best available source for each of the main factors. For copier power levels, we used the ASTM test results collected in 1994 (Dandridge, 1997). For the standard operating pattern, we needed to estimate the hours of daytime use and the night-time status. For daytime hours, we relied on monitored data collected for this project and reported by others in the literature. For night status, we used the findings from our night-time audits. We defined an operating pattern for each of four copier speed categories.

4. Results

This section summarizes the results of our data collection and analysis efforts. We review findings from the late-night audits, detailed electricity monitoring, a comparison with ASTM operating patterns, duplexing estimates and measurements, the user satisfaction survey, and estimates of annual electricity use.

4.1 Audit Results

The primary purpose of the late night audits was to determine the percentage of compliant and non-compliant copiers in each major mode (on, low-power, or off) during night and weekend time. From loadshapes in the literature, we determined copier night-time status for 18 copiers (Arney et al., 1996; Levinsson et al., 1997; Martin, 1991; Allen, 1997; and Dandridge, 1997). We found an aggregate status of 31% on and 11% in a low-power mode for a total of 42% at least partially on.

The largest collection of night-time copier audit data we found was from audits conducted by Bayview Technologies, Inc (Wood, 1997). These audits were conducted at about 20 locations in the U.S. from late 1995 through 1997 and were primarily designed to survey the status of personal computers and monitors. Table 4-1 presents the main Bayview results. The Bayview audits were generally conducted between 6 and 7 p.m. on weeknights, early enough in the evening so that copiers would rarely have had enough time to automatically turn off. Thus, they are not late enough to reveal power management operation, they do indicate manual turn-off rates. These figures may therefore exaggerate the percent of copiers on. However, the large fraction of copiers on at night highlights the importance of the auto-off part of the ENERGY STAR program.

Table 4-1. Bayview Audit Results

	On (or Low-Power)	Off	Copiers (*n*=)
Conventional	82%	18%	57
ENERGY STAR	100%	0%	8
All Copiers	84%	16%	138

Notes: 'On' includes low-power modes. The total set includes many more copiers than the two subsets as the brand and model was not always recorded. The brand and model information are necessary to determine if a copier is ENERGY STAR compliant and its speed.

To further understand the after-hour state of copiers, we conducted a series of night-time audits, assessing a total of 228 copiers. The sites included most of LBNL, three municipal office buildings, a federal office building, two large corporation's offices, and a hospital. Audits were generally conducted after 9 p.m. so that the copiers had enough time to reach their final state for the evening. The primary results are presented in Table 4-2. The Bayview data suggest that the manual turn-off rate is 16% or 18%, while the LBNL audits suggest that it is *at most* 17%.

Table 4-2. Night-time Copier Status (LBNL audits)

	On	Low-Power	On *or* Low-power	Off	Copiers (*n=*)
Conventional	30%	53%	83%	17%	142
ENERGY STAR	27%	12%	39%	61%	81
All Copiers	29%	38%	67%	33%	223

Notes: Many of the ENERGY STAR copiers that were found 'on' were verified to have had the auto-off feature disabled. We also found two multi-function devices, both fully on, and three color copiers, two of which were fully on and one in a low-power mode. These raise the total to 228. We also found four copiers on and in an error mode—these seem to prevent auto-off features from taking effect. Three copiers were found broken and off. On 13 of the 22 ENERGY STAR copiers that were found on, we verified that auto-off had been disabled. On 12 compliant copiers at two sites, auto-off was verified disabled—interestingly all were the same model; one non-compliant copier was verified disabled. On 3 compliant copiers (and one non-compliant), auto-off was enabled but the low-power mode was disabled. Delay times were recorded at one site and 8 copiers had 90 minute delays with three having 120 minute delays to auto-off.

There is striking consistency between the Bayview results and the results of our audits for conventional copiers[12]. That ENERGY STAR compliance does not seem to lead to a significant improvement in the fraction of copiers fully on at night is surprising and distressing, but mirrors the problems with disabling that previously were seen to reduce power management savings in PCs and monitors. We expected that power management of copiers would vary significantly with copier speed, so we disaggregated the audits by the ENERGY STAR speed segments as shown in Table 4-3. The results follow no clear pattern; low-speed and high-speed ENERGY STAR copiers were more likely to be on than their conventional counterparts, but in all segments (except very high speed machines) ENERGY STAR copiers were more likely to be off. We added a separate very high speed category (>90 cpm) since such copiers are generally used by a single operator, and thus more likely to be turned off manually.

Table 4-3. Night-time status of LBNL-observed copiers (by speed segment)

Speed *(cpm)*		On	Low-Power	Off	Copiers (*n=*)
Low Speed	<=20				
Conventional		18%	36%	46%	11
ENERGY STAR		29%	0%	71%	7
Medium Speed	21-44				
Conventional		38%	41%	21%	34
ENERGY STAR		11%	3%	86%	36
High Speed	45-90				
Conventional		29%	59%	12%	93
ENERGY STAR		48%	17%	35%	29[a]
Very High Speed	>90				
Conventional		25%	25%	50%	4
ENERGY STAR		20%	40%	40%	5

Notes: [a]Over a third of these copiers were of one copier model, and so may not be representative of high speed ENERGY STAR copiers.

Given the small sample sizes (particularly for the small copiers) we interpret the quantitative results cautiously. Higher speed machines are likely to be used by more people (except very high speed machines which typically are used by a single operator) and have longer warm-up times. This could explain the greater disabling of power management of these ENERGY STAR copiers and the lower percentage of conventional copiers off. User complaints about power management may lead to complete disabling of power management rather than lengthening delay times or using only low-power modes[13]. Anecdotal evidence indicates that copier service personnel are partially or completely responsible for much of the disabling of power management[14]. Except for very high speed copiers, ENERGY STAR copiers are more likely to be off than are conventional machines. Low-power modes are also

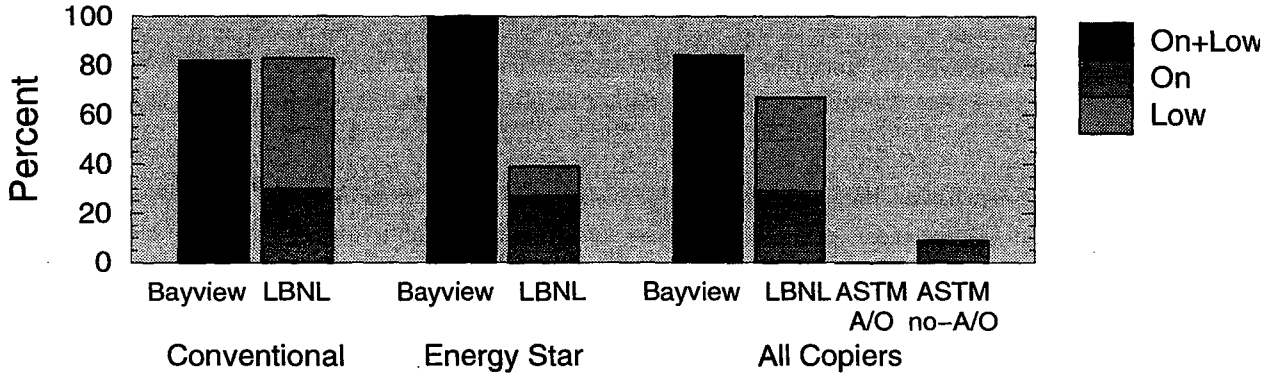
[12]With many conventional copiers having an auto-off feature, we would have expected a lower 'on' rate in the LBNL audits.

[13]An ENERGY STAR copier with auto-off enabled may lead to more complaints than a non-compliant copier with low-power enabled, and more than the ENERGY STAR with only low-power enabled.

[14]When asked why they disable power management, some service personnel have cited the desire to avoid callbacks if the users don't want the feature. Many users are unfamiliar with power management or default duplex

common and frequently enabled in conventional copiers[15]. As people learn that ENERGY STAR copiers turn themselves off, they may abandon manual turn-off altogether. We show the Bayview and LBNL audit results, as well as the ASTM test assumptions, in Figure 4-1.

Figure 4-1. Copier Night-time Status



Notes: A/O is Auto-off. The data source for the "On+Low" bar did not distinguish between copiers fully on and those in a low-power mode.

4.2 Electricity Field Monitoring

We had several reasons to monitor ENERGY STAR copiers: to verify that the power management features were working as expected; to see what the delay times were; to measure the distribution of imaging events across the day and week; and to compare the monitored data to estimates based on test results to ensure that the test methods are correct.

We did not monitor conventional copiers, as we presumed that the power levels and energy per copy figures from ASTM tests provide reliable estimates. We monitored eleven copiers, six at LBNL with the rest at a variety of local businesses and public facilities. We were unable to record the full two weeks in some cases, and in others could not access the image counters.

In general, the ENERGY STAR features performed well. All ENERGY STAR copiers that were confirmed to have auto-off enabled had turned off as expected[16]. Only two of the copiers powered off for a significant period during the day (copiers C and H). Copier H (45 cpm) turned itself off once every other day on average; we estimate that this reduced its electricity use by 6%. The rest had only minimal daytime off-times or none at all.

All but two of the monitored copiers are Tier I copiers and thus are not required to have a low-power feature[17]. Neither of the Tier II copiers show any off mode time in the monitored period, though both enter the low-power mode reliably. Neither could be audited for its configuration. Of the 7 copiers for which a clear off mode could be identified, one was 11 W with the rest no more than 5 W; four were zero W. Two of the measured off levels were much less than listed on the ENERGY STAR product list and two were approximately the same, while the remaining three had no power listed[18].

Copier C (21 cpm) utilizes 'instant-on'("rapid fusing") fusing technologies, and powers off completely after each copying job. This copier was estimated to be on four hours/day, based on 15-minute data (finer data would indicate even less on-time). Because there is no low-power mode, imaging events are readily apparent. This copier has a low capacity factor and as it is at the low end of segment 2, it is better compared to segment 1 copiers. The annual energy use is estimated to be just above 128 kWh. This compares to our estimates for average segment 1 copiers of 790 kWh for a conventional copier, 540 for an average compliant copier of that segment, and 260 with maximum savings[19]. Copier A (the smallest at 16 cpm) behaves much like the rapid-fusing copier, returning quickly to its low-power state. While it is fully on for only 3.5 hours per day, it never powers off entirely. An

[15]However, auto-off and low-power modes on conventional copiers do not necessarily meet the program's Tier II power or initiation requirements.

[16]We were not able to check the configuration on some copier models and locations.

[17]One of the models has a low-power mode, but it does not meet the Tier II power criterion and is only initiated by user selection.

[18]ENERGY STAR program participants submit lists of compliant products and have the option of reporting their low-power and off-mode power levels. As this is not a program requirement, there is some inconsistency in data on both the products and energy levels.

[19]'Average' refers to a machine configured and used as typically found in our audits. 'Maximum' is the energy use from a machine configured for the most energy savings from auto-off.

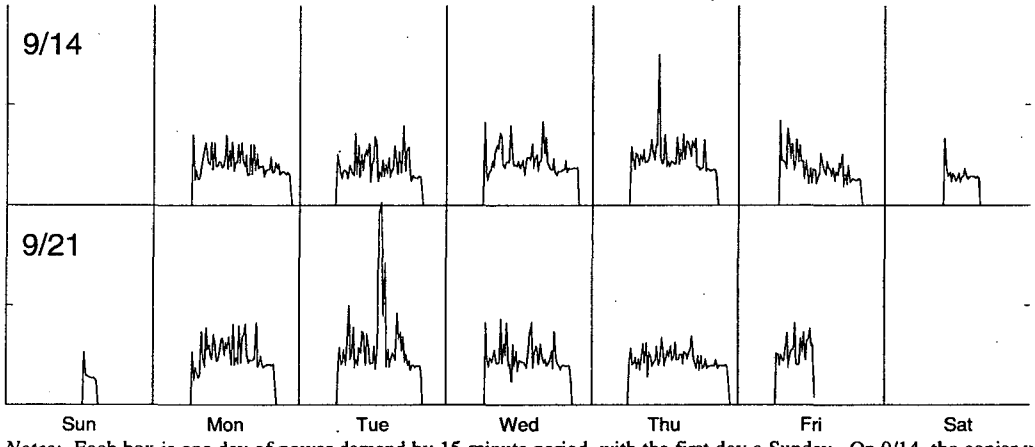
effort is underway to create a market (demand and supply) for a higher speed machine with the same characteristics of 'instant on' and low overall energy use (EPA, 1998).

Copier F (30 cpm) is a digital copier, and while it has MFD capabilities, it was used primarily as a copier prior to and during the monitoring period. It entered a low-power mode, but never turned entirely off. It is possible that the auto-off was disabled, or that it is fundamentally incompatible with the fax and printing functionality. This copier had two low-power modes. The higher low-power mode activates for about an hour before the lower one initiates. The higher low-power mode occurs occasionally during the day with the lower one occurring only once in the daytime.

Power management on copier E (25 cpm) was completely disabled so it was on 24 hours per day, 7 days per week. Copier B (20 cpm) was also disabled, but was reliably powered off at the end of each work day. Copiers D, A, and F never entered an off state, but reliably powered down to a low-power level.

Figure 4-2 shows a 'calendar' graph excerpt; these are extremely useful for quickly assessing the use pattern and behavior of a copier. Tables 4-4a and 4-4b summarize key figures of merit for the monitored copiers. Copying energy was estimated by identifying the standby (ready to copy but not actively copying) power level from the calendar graph for each copier and summing the energy used above that level.

Figure 4-2. An excerpt from one copier's 'calendar' graph



Notes: Each box is one day of power demand by 15-minute period, with the first day a Sunday. On 9/14, the copier was monitored but never turned on (more monitored data precede 9/14). On 9/26 (Friday), the monitoring was ended. As this graph's purpose is to show the operating pattern so the y-axis scale is simply adjusted to the maximum demand.

The average day length[20] varied considerably by copier speed: 6.9 hours for low speed machines, 10.7 hours for medium speed machines, and 13.1 hours for high speed. We did not monitor any very high speed machines. The average weekend on-time (for the whole weekend) was zero for slow, 1.3 hours for medium, and 3.8 for high speed machines. On every copier with a clear auto-off delay time from the monitored data, the delay time was two hours, as was the delay time till low-power on the digital copier.

We applied the derived power levels to the ASTM operating pattern. The resulting actual annualized electricity use was less than the that derived by using the ASTM calculation for all but the copier with auto-off disabled. We do not have ASTM test results for any of these models.

4.3 Annual Energy Use

Another goal of the project was to develop estimates of typical copier energy use based on the data we collected and identified. As with previous studies, we made a separate assessment for each of the six copier speed segments for which stock data are available. We estimated the energy used by conventional copiers, that used by ENERGY STAR copiers in current use patterns, and that attainable by maximum use of energy-saving features.

The monitored data were used to develop operating patterns. The electricity monitoring results were used to determine average day length for the copiers and the night-time audits were used for the night and weekend status. The ASTM test results are reliable data on power levels (though the calculation embodies an unrealistic operating

[20] This report refers to the "day length" as amount of time between the copier's first warm-up and when it accomplishes the last transition to a low-power or off mode. Thus it includes all of the active time and the time for delays to operate, and also includes low-power and off time during the day.

pattern and no guidance on imaging rates). We combined these two sources to estimate average energy use by copiers.

Table 4-4a. Monitored Copier Electricity Summary

Speed Range	ID	Tier	Speed *cpm*	Daily Energy-*kWh* Weekday	Daily Energy-*kWh* Weekend	Annual *kWh*	Copying *kWh*	Comments (PM="Power Management")
Low	A*	2	16	1.09	0.74	358	52	Auto-off disabled; low standby
	B	??	20	1.43	0.20	388	26	PM disabled; manual power-off
	Average			1.26	0.47	373		
Medium	C*	1	21	0.47	0.08	128	15	PM working; instant-on
	D*	1	25	4.77	2.06	1,429	210	Auto-off disabled**
	E	1	25	4.52	4.35	1,629	88	PM disabled; always on
	F	2	30	2.95	1.52	911	68	Low-power working; auto-off not
	G*	1	40	2.84	0.00	709	61	PM working
	Average			3.11	1.60	961		
High	H	1	45	2.07	0.12	531	68	PM working
	I	??	45	3.49	0.32	910	369	PM working
	J*	1	50	4.87	0.38	1,261	274	PM working
	K*	1	50	3.96	1.41	1,151	294	PM working
	Average			3.60	0.56	963		

Notes: *Marked copiers were monitored at LBNL. Copier B and copier I are labeled ENERGY STAR and have ENERGY STAR features but do not appear on the EPA list of compliant copiers; however, they are most likely Tier I. **Copier D behaves in a way that makes it difficult to separate out copying energy so this figure may be an overestimate.

Table 4-4b. Monitored Copier Electricity Summary

Speed Range	ID	Speed *cpm*	Annual Energy Use *(kWh)* Monitored	Annual Energy Use *(kWh)* Conventional	Annual Energy Use *(kWh)* Savings	Annual Energy Cost *($)* Monitored	Annual Energy Cost *($)* Conventional	Annual Energy Cost *($)* Savings
Low	A*	16	358	790	430	29	63	34
	B	20	388	790	400	31	63	32
	Average		373	790	420	30	63	33
Medium	C*	21	128	1,200	1,070	10	96	86
	D*	25	1,429	1,200	—	114	96	—
	E	25	1,629	1,200	—	130	96	—
	F	30	911	1,200	290	73	96	23
	G*	40	709	1,190	480	57	95	38
	Average		961	1,200		77	96	
High	H	45	531	1,620	1,090	42	130	88
	I	45	910	1,620	710	73	130	57
	J*	50	1,261	1,620	360	101	130	29
	K*	50	1,151	1,620	470	92	130	38
	Average		963	1,620	660	77	130	53

Notes: *Marked copiers were monitored at LBNL. Copier B and copier I are labeled ENERGY STAR and have ENERGY STAR features but do not appear on the EPA list of compliant copiers. The "conventional" columns are the estimated typical energy use for copiers in the relevant segment (from Table 4-7) based on the LBNL operating pattern.

Operating Patterns

An operating pattern embodies the number of hours in each mode (on, low-power, off) during each workday as well as the night time status (on, low, or off). We derived both types of data from our monitored and audit data and in four monitoring studies in the literature (Arney et al., 1996; Levinsson et al., 1996; Martin, 1991a, 1991b, 1992; and Dandridge et al., 1994). From the literature, we found weekday on-times of about 12 hours per day, with machine speeds typically not specified. From our monitored data, we found on-times from 4 to over 14 hours per

weekday. With the diversity of office worker schedules and the time necessary for an auto-off mode to engage, this is not surprising. The daily on-time is correlated highly with copier speed, so our standard operating pattern has on-times of 6, 10, 13, and 12 hours, for the low, medium, high, and very high speed ranges [21].

The monitoring studies included graphs of loadshapes, from which we extracted average on and off times, and estimated the night time mode distribution, and typical weekend status. We found weekday on-times of about 12 hours, with 31% of copiers 'fully on' on weeknights, 11% in a low-power mode, and 58% off. Weekend results were similar. Only one of the 18 copiers was identifiable as ENERGY STAR, though many were not identified at all.

The operating pattern for a copier can be summarized as the distribution of time across the three primary modes—on, off, and low-power—plus the imaging rate[22]. As Table 4-5 shows, there is a great disparity between the pattern embodied in the ASTM test and that found by observation of actual copiers.

Table 4-5. Copier Time Distribution *(%)* and Day Length and Delay Time *(hours)*

	On	Low-power	On *or* Low-power	Off	Day Length	[a]Delay Time
ASTM Test Assumptions						
Without Auto-Off	27%	5%	32%	68%	9	0
With Auto-off	28%	—	28%	72%	9	0
Standard Operating Pattern						
ENERGY STAR						
Low	40%	5%	45%	55%	6	1
Medium	43%	6%	49%	51%	10	2
High	59%	9%	68%	32%	13	2
Very High	50%	16%	66%	34%	12	2
Aggregate	52%	8%	60%	40%	12	2
Conventional						
Low	37%	37%	74%	26%	6	1
Medium	53%	34%	87%	13%	10	2
High	56%	35%	91%	9%	13	2
Very High	53%	27%	80%	20%	12	2
Aggregate	54%	35%	89%	11%	12	2

Notes: This is the average time distribution so could apply to a full week, month, or year. [a]The delay time is till auto-off after the work day has ended. The standard operating pattern includes no weekend on-time.

Power Levels

To estimate copier power levels, we used the ASTM test results for 130 copiers[23] of varying speeds collected by Dandridge (personal communication; noted in Dandridge, 1996) in 1994[24]. We averaged the energy figures from those tests for all copiers (ENERGY STAR and conventional) by six copier segments (see Section 2)[25]. Table 4-6 summarizes the power levels of the ASTM results. Copying energy ranges from 18% to 68% above the standby level; low-power from 27% to 62% of standby (four segments under 40%), and the off load under 10% for all but one of the segments.

[21]These are the ENERGY STAR copier speed ranges except that we have separated very high speed copiers (>90 cpm) from the high speed category as these are typically operated by a single user rather than being a general "walk-up" copier.

[22]The imaging rate affects total on-time as well as increasing copying energy.

[23]Based on the number of copiers listed in the Spring 1997 BLI Copier Specification Guide (BLI, 1997), this is about a quarter of the copier market in terms of number of models, but is not weighted by unit sales.

[24]It would be desirable to compare ASTM test results for a range of ENERGY STAR and non-compliant copiers to see if there were systematic differences, but results for ENERGY STAR copiers were not available.

[25]Copier capacity ratings are much higher than average use rates. The capacity factors used in the tests range from about 20% for segment 1 to 50% for segment 5, and so are broadly comparable to typical U.S. usage. Rated capacity factors by segment are from Nordman (1995), summarizing information from BLI (1992). Capacity factors as found by Nordman (1996) and also as reported in INFORM (1991). Higher imaging rates imply more copying energy and usually more total on-time. The capacity factor is specified by the tester, not the ASTM test procedure.

Table 4-6. ASTM Test Results: Speed and Average Power

ENERGY STAR speed	Segment	Speed cpm	n=	Plug Wh/h	Warm-up Wh/h	Standby Wh/h	Low-power[a] Wh/h	n=	Copying Wh/h
Low	1	<=20	37	8	138	115	—	—	136
Medium	2	21-30	31	13	205	172	106	1	208
Medium	3	31-44	22	16	224	183	70	6	241
High	4	45-69	28	39	399	266	97	9	358
High	5	70-90	9	20	507	358	98	1	583
High	6	>90	3	21	826	622	221	1	1,044

Notes: The low-power column averages *only* those copiers that have a low-power mode reported; the small number of these copiers is notable. The units are reported as Wh/h rather than W as they are all the average power used over one hour.

Annual Energy Use

We combined the operating patterns and power levels above to estimate annual energy use per copier for several scenarios as follows (also see Table 4-5):

- The basic ASTM operating patterns (manual turn-off).
- The auto-off ASTM operating pattern.
- Our standard operating pattern for conventional (non-ENERGY STAR) copiers.
- Our standard operating pattern for ENERGY STAR copiers as currently used.
- Operation (configuration) of ENERGY STAR copiers for 'maximum' savings.

The results are shown in Table 4-7. For the LBNL Operating Pattern, the aggregate set of operating patterns is our standard pattern for all segments; the second number is the standard pattern by segment. All further data apply the 'by-segment' standard operating patterns.

Table 4-7. Annual Energy Use per Copier *(kWh/year)*

	ASTM Op. Pat.		LBNL Standard Operating Pattern						
Seg-ment	No Auto-off	Auto-off	Conventional Aggr.	Conventional Seg.	ENERGY STAR Aggr.	ENERGY STAR Seg.	Maximum Aggr.	Maximum Seg.	*Copying*
1	400	360	930	790	670	540	400	260	*40*
2	590	560	1,220	1,200	980	830	610	530	*80*
3	660	640	1,210	1,190	1,060	920	710	620	*130*
4	1,090	1,070	1,780	1,820	1,620	1,760	1,160	1,210	*190*
5	1,450	1,430	2,470	2,520	2,240	2,460	1,550	1,630	*480*
6	2,500	2,440	4,490	4,300	3,940	3,960	2,660	2,660	*900*

Notes: The energy used for copying does not vary across these estimates and is included with the totals (it is not to be added to them). Copying energy is the extra energy used compared to the copier being on the same amount of time but making no copies. The number of copies depends on the monthly volume selected for the test. All scenarios use the ASTM test power levels, differing only in the operating pattern used. For the Standard Operating Patterns, the "Aggr"egate is a single pattern for all segments; the by-"Seg"ment pattern is different for each of the four speed ranges. "Maximum" assumes that all the copiers have auto-off enabled and low delay times. The percentage savings (by segment operating patterns) are 32, 30, 23, 3, 2, and 8% for current ENERGY STAR use patterns, and 67, 56, 48, 33, 35, and 38% for the maximum savings scenarios.

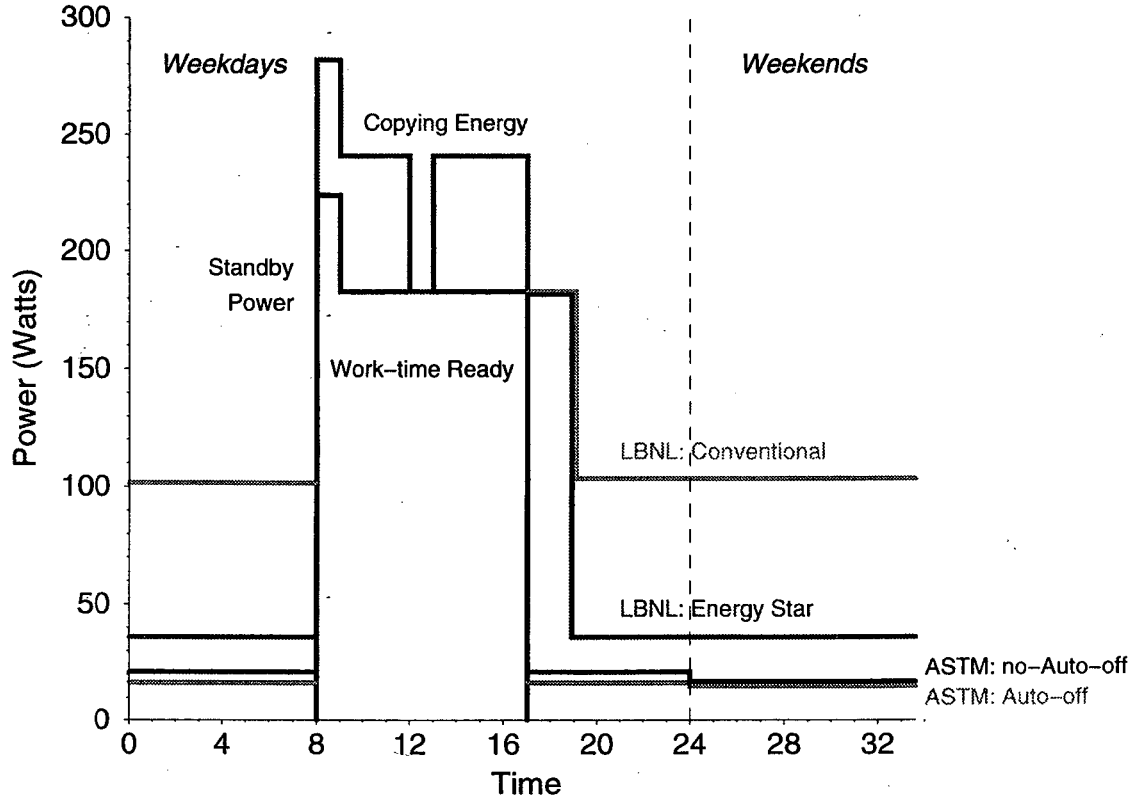
The average reduction that the auto-off accomplishes with the ASTM calculation is only about 10% for the first four segments and about 25% for the last two. By contrast, the LBNL operating pattern indicates a 2% to 32% savings over current use and 37% to 67% reductions with the maximum savings scenario. The annual reduced electricity cost from current ENERGY STAR practice ranges from $20 for the smallest copiers to $27 for the largest ones (at 8 cents/kWh)—however, this rises to $42 and $131 for the maximum savings scenario. Figure 4-3 shows aggregate data for Segment 3 copiers graphically. It combines the operating pattern and relative power levels reported in this section.

4.4. Paper Use

The ENERGY STAR program initially included paper efficiency strategies with requirements for duplex capability and default duplexing, as well as the capability to use recycled-content paper. Default duplexing was dropped from the copier program in 1997. Reducing paper demand and using recycled fibers saves production energy and reduces greenhouse gas emissions throughout the paper cycle. The technical potential for duplexing depends on the fraction of jobs which have an odd number of images, the portion of imaging that needs to be simplex copied to

be used properly, and the portion that are simplex copied because the user prefers it that way. Because of the significant capital cost of an automatic duplexing unit, many small copiers will never support duplexing.

Figure 4-3. Energy consumed under ASTM and LBNL Operating Patterns



Notes: The graph shows copier energy use under four scenarios. The "Work-time Ready" energy is used under all scenarios, as is the "Copying Energy" actually used for imaging (the spike at hour 8 is the extra energy for warming-up the copier). The hours above 24 reflect the extra time for weekends; this graph includes no copying or on-time on weekends. The scenarios differ in the night and weekend energy use, with the two ASTM cases presuming only a few hours per month of on-time at night. The LBNL scenarios include the delay time before the auto-off feature takes effect and neither includes day-time low-power modes. In all scenarios the night and weekend power levels account for copiers in both on and low-power modes by showing the weighted average power level for the scenario.

The duplexing rate is the fraction of images that are on duplexed sheets. A 100% duplexing rate requires 50% less paper than a 0% duplexing rate[26]. The following equation shows how to calculate it.

$$\textit{Duplexing Rate} = \frac{\textit{Duplexed Images}}{\textit{Total Images}} = \frac{\textit{2*(Images through duplexing unit)}}{\textit{Total Images}}$$

Copy paper is estimated to embody approximately 16 Wh/sheet (electricity equivalent) of production energy[27]. Thus, producing the roughly 2.2 million tons of paper used in copiers requires the equivalent of about 7 TWh/year of electricity. This means that the amount of energy in the paper used in copiers is similar to the amount that copiers use in direct electricity. However, due to cost differences, the paper costs over $2 billion to purchase compared to about $500 million for the electricity.

Paper can be thought of as a form of energy, both in the production energy it embodies and in terms of use rates and efficiency. The typical office worker uses 10,000 sheets/year of copy paper[28], or 5 sheets/hour. At the 16 Wh/sheet rate this is 80 W of electricity-equivalent energy. However, paper is four times as expensive as electricity

[26] As an example, three images on two sheets (two images on one sheet, one on the other) results in a 67% duplexing rate. Changes in the duplexing rate do not always translate directly to paper reduction; for example, changing from a 50% to a 100% duplexing rate reduces paper use by 33%, changing from a 0% to a 50% duplexing rate reduces paper use by 25%.

[27] An estimate developed for the ENERGY STAR program is 17 Wh/sheet for 100% virgin fiber and 12 Wh/sheet for 100% recycled fiber, based on U.S. paper mills (Nordman, 96). This is the amount of electricity available if the same energy inputs had been used to generate electricity rather than to make copy paper, and so is equivalent to the copier electricity use on an energy basis. There are about 200,000 sheets of U.S. standard 20 lb paper in a ton (220,000 per metric ton).

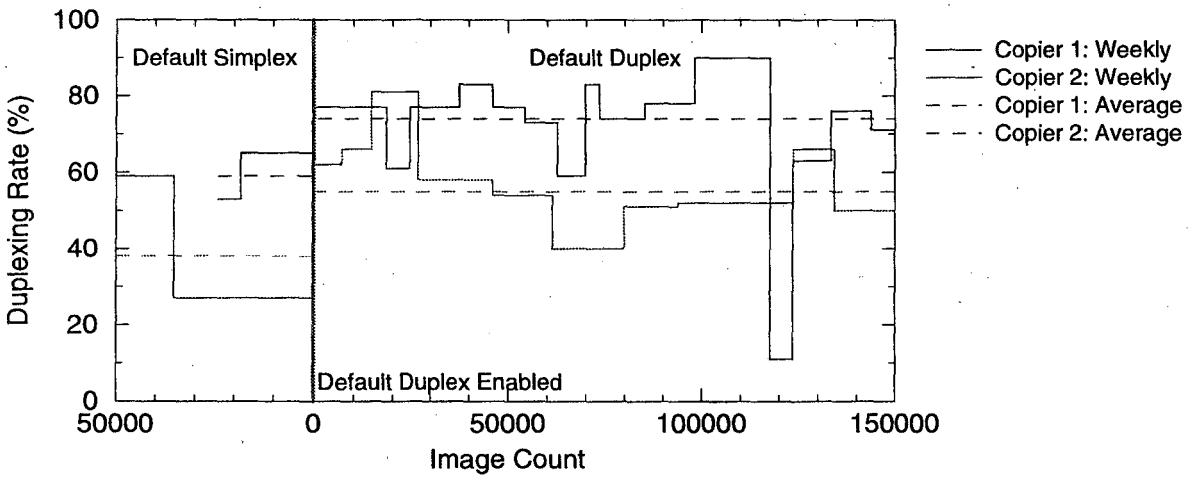
[28] Copy paper is used in copiers, laserprinters, inkjet printers, and fax machines. Slightly more than half is estimated to be used in copiers.

(on an energy basis), the *cost* of the paper is equal to over 300 W of electricity. A key to viewing paper in efficiency terms (as we do energy) is to treat paper as a *flow*, not as discrete *objects* (sheets), just as we do with energy. Reducing paper use through increased 'paper efficiency' (defined as the "mass of paper per unit of service delivered") can be accomplished by four primary methods:

- Duplexing
- Image Avoidance (elimination or shifting to electronic)
- Increasing the Content/Area ratio (e.g. n-up imaging)
- 'Lighter' Paper (reduced basis weight)

To measure the effect of default duplex, we identified two 50 cpm ENERGY STAR copiers at LBNL that had been installed with default duplex disabled. We measured the duplexing rate weekly for several weeks, then enabled default duplex, and continued the measurements for several months after that. Simply enabling default duplex would likely result in many users being confused about the change, as few copier users have experience with default duplex machines. To alleviate this problem, we created labels that were placed on the machine in several places (including right next to the "Start" button) that identified the machine as having been changed to default duplex, indicated exactly how to select single-sided copies, and gave a name and phone number of someone to contact with questions or comments. Figure 4-4 shows the effect on duplexing rates of enabling default duplex on the two copiers. The duplexing rates were already high for their speed segment (according to the INFORM rates), but default duplex raised them by 15% and 20% respectively.

Figure 4-4. Effect of enabling "Default Duplex" on two copiers



Notes: The x-axis is images, though the scale has been adjusted for one of the copiers to make them more readable on the graph. The x-axis corresponds to time, with the graph showing 3.5 and 5 months (for the higher rate copier) of data. The dashed lines are the overall average duplexing rates before and after the change; individual data points shown by the solid lines. The default duplex setting increased the duplexing rates by about 15% and 20% for these two copiers. However, it should be noted that the pre-existing duplexing rates were quite high on these copiers so that machines with lower rates could gain even more from default duplex. The duplexing rate shown below 20% is most likely a data collection error, as the data point before it seems equally anomalously high.

Two other studies attempted to increase duplexing rates and included measurements of them. Duncan tested several behavior modification methods (Duncan, 97), and Nordman tested the effect of duplexing reminder signs (Nordman, 95). Table 4-8 lists the average 'before' and 'after' duplexing rates for these studies. McPhail utilized service technicians to collect duplexing rate data. The duplexing studies conducted by Duncan and Nordman show wide ranges between duplexing rates on the same copier model in different locations, and also for the same copier between sequential one week to one month periods. The averages shown here mask these ranges.

There is not much known about duplexing rates, but results from the default duplex experiment above and four other studies are presented in Table 4-8. The most widely cited duplexing rates are from INFORM (INFORM, 1991), which estimates a 26% national duplexing rate for the stock of copiers in 1991. Harris (Harris et al., 94) specified a potential for duplexing, to indicate the magnitude of improvement that could be made. The low duplexing rates on lower speed machines is expected due to the higher portion of 1-image copy jobs and the lack of duplexing units on many of these machines (understandable given the extra cost and low potential benefit).

Duncan tested several intervention strategies to increase duplexing rates—feedback, information, and social persuasion—with mixed results. Interestingly, procedural knowledge of how to duplex seemed most highly

correlated with duplexing. This could explain why default duplexing, which has the character of 'forcing' such knowledge, seems to be successful at increasing duplexing rates.

Table 4-8. Duplexing Rate Estimates and Measurements

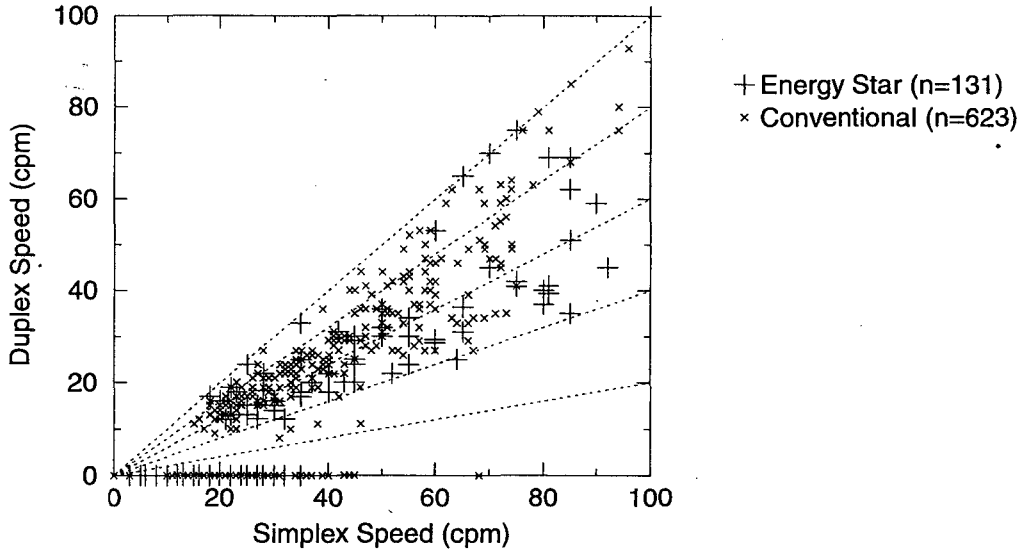
Segment	1	2	3	4	5	6	Notes
Speed *(cpm)*	*≤20*	*21-30*	*31-44*	*45-69*	*70-90*	*>90*	
Estimates							
Existing	1	5	11	18	38	55%	INFORM, 1991; Agg: 26%
Potential	0	20	40	60	80	90%	Harris, 1994
Measured							
Duncan		*n = 6*	31 to 39[a]	26 to 38[a]	*n = 4*		Duncan, 1997
LBNL—Signs				32 to 40[a]	*n = 37*		Nordman, 1996
LBNL—Def. Duplex				48 to 65[a]	*n = 2*		This Study
McPhail	0	8	14	31	16	—	*n = ~100*

Notes: [a]"x to y" entries represent a before-and-after experiment with "x" the before rate and "y" the after rate.

While duplexing in general is not well understood, many of the barriers to increased duplexing rates are known. Some barriers reflect the ultimate use of the image (e.g. in a fax machine that doesn't handle duplexed originals), but others are characteristics of the copier, and so could be avoided with different copier design. Dandridge (Dandridge, 94) notes the lack of the ability to "eject copies after a job interrupt" during duplexing, which causes extra effort to clear the duplexing unit. INFORM noted lack of (automatic) duplexing capability on many copiers, less reliability (particularly from paper curl), slower speed, lack of duplexing in purchase criteria (presence and reliability), and the expense of all of these. Duncan (Duncan, 97) identified the complexity of some copier controls, the extra capital cost for a duplexing unit (when it is optional), and the relatively lower speed of duplexing as duplexing barriers.

The lower speed of duplexing (compared to simplex copying) is a major barrier to higher duplexing rates. Figure 4-5 shows the duplex speed vs. the simplex speed for individual copiers, both conventional and ENERGY STAR machines. ENERGY STAR copiers are not any faster (for duplexing) on average than older machines; if they were faster, then less paper would be used and hence less energy used and fewer greenhouse gases emitted. Compliant machines are newer, and so might have been expected to have better paper handling and hence a higher duplexing speed. That some machines in both categories report duplexing speeds at (or nearly at) the simplexing speed suggests that attention to this factor can result in better performing machines.

Figure 4-5. Duplex Speed vs. Simplex Speed



Notes: The small "x"s are pre-1993 copiers, making 10 copies of a 10 page original, 1:2, as measured by BLI (n=614). The large "+"s are ENERGY STAR copiers as reported to EPA by manufacturers (n=88), making 3 copies of 10 originals, 1:2, but may be less reliable than the BLI data. Thus, the data are not strictly comparable, but we expect that comparable data would show the same trend. The BLI average is 68%; the ENERGY STAR average is 61%. That the ENERGY STAR copiers are slower on average may be an artifact of the difference in test procedure.

4.5. User Satisfaction

We conducted a total of 56 surveys, at four different sites, for 11 copiers. All interviews were conducted in person, in late 1997, by the same interviewer. The subjects were selected randomly from among the copier users found near the machines in question. As the discussion in section 3.2 reviewed, we asked about the power management features, the duplexing performance (including default duplex), and overall satisfaction with the machine.

The users surveyed were roughly split between individuals who make copies primarily for themselves and those who did so for others. The median reported copies per week was 40, but the average was 130 (which is consistent with estimates of average nationwide copying rates for office workers). 75% had a favorable impression of the copier, and only 17% thought that the time for the first copy to come out was too long.

Regarding power management, of the 65% that knew that the copier turned itself off after a time of non-use, the median delay time for auto-off was thought to be about 30 minutes[29]. However, for most of these machines the *actual* delay time was 2 hours. About 40% thought that the 'delay from off' was too long. For suggestions on how to improve the auto-off, three people suggested a 'time until ready' timer (a few copier models have this) and one an alarm when ready.

The median reported duplexing rate was 50%, which is high compared to national estimates. Duncan (Duncan, 1997) found reported duplexing rates corresponding well to measured rates on average, and measured rates on two of these machines were similarly high, so that the reported rates are plausible[30]. When asked for possible improvements, 15% of responders noted the extra time duplexing requires.

We conducted 20 interviews for users of copiers with default duplex enabled. The only machines found with default duplex enabled were two copiers at LBNL[31]. 80% of these people reported being accustomed to default duplex. About half agreed that they make more duplex copies with the default feature enabled. This was confirmed on both machines by closely tracking the duplexing rate (see Section 4.4).

Default duplexing can cause behaviors that increase imaging or paper use; 22% reported regularly duplexing by accident (which would increase paper use if they subsequently repeated the copy job single-sided), and about half sometimes copy blank pages when copying one single-sided original (which increases imaging though not paper use). About 60% agreed it is easy to tell that the machine is default duplex (both machines had three labels on them), and about 75% got used to default duplex within a month (30% within a week). Over 85% agreed it is easy to select single-sided copies; one of the labels indicated which button to press to do so and only one button-press is necessary on this model. For improvements, three users mentioned speed, two wanted to eliminate original counting (which greatly increases copying time), and three found the menus confusing.

On their overall impression of the copier (not just ENERGY STAR features), the users were quite satisfied and over 80% would recommend the copier to others. A quarter of the respondents made comments about duplexing, half favorable and half unfavorable. The unfavorable comments focused on the particular implementation of duplexing, such as controls, relative speed, or jamming problems. Of 11 comments that used the word "jam", only two were negative, the rest commenting on how few jams occurred. Only one comment even referred to power management. Thus, we found high levels of satisfaction with the ENERGY STAR copiers, though it should be noted that many of these copiers were relatively new, which may have contributed to their reliability.

4.6. National Estimates

We estimated the national energy use of copiers along with the existing and potential savings of the ENERGY STAR program. We combined the estimates of energy per copier in Table 4-7 (LBNL operating pattern, by segment) with the number of copiers in the stock in 1995 (Dataquest, 1994); the results are shown in Table 4-9. For comparison, the total electricity use that results from the ASTM operating pattern is 4,400 GWh for the regular operating pattern and 4,190 GWh for the auto-off operating pattern. These scenarios apply each operating pattern to the entire stock of U.S. copiers and so do not reflect the turnover of stock. With approximately a third of the stock of copiers now compliant, the current savings would be one third of the difference between the conventional and ENERGY STAR totals, or 570 GWh/year (a 7% savings); for the entire stock it is 1,700 GWh/year (a 21% savings).

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[29] Our survey instrument included questions about low-power modes, but all of the copiers we surveyed people about were Tier I copiers and so none of the machines surveyed had ENERGY STAR low-power modes. Thus, we did not ask the low-power questions of anyone.

[30] For these two copiers, the median duplexing rate was 65%, very similar to what the metering showed.

[31] These were the two copiers enabled in the default duplex experiment in Section 4.4; the users are people working in the LBNL Environmental Energy Technologies Division and so may be more amenable than average to efficiency efforts such as default duplex.

The potential savings—all copiers compliant and configured for "Maximum" savings—are 4,240 GWh/year, a 52% savings over conventional copiers.

Table 4-9. Scenarios of Annual Energy Use, all U.S. Copiers *(GWh/year)*

Segment	Conventional	ENERGY STAR	Maximum	*Copying*	Stock (000)
1	3,130	2,130	1,020	*170*	3,950
2	1,280	890	570	*90*	1,070
3	860	660	450	*80*	720
4	1,730	1,680	1,150	*140*	950
5	540	530	350	*80*	210
6	660	610	410	*70*	150
Total	8,190	6,490	3,950	*625*	7,060

Notes: Copying does not vary across these estimates and is included with the other values (it is not to be added to them). All scenarios use the ASTM test power levels, differing only in the operating pattern used. 'Maximum' assumes that all the copiers have auto-off enabled.

Table 4-10 presents energy, carbon, and cost savings derived from the estimates in Table 4-9. The first set of columns—Current Stock—is one third of the difference between the Conventional and ENERGY STAR columns above, reflecting the estimated fraction of the U.S. stock that is now ENERGY STAR compliant. The Maximum columns are the entire difference between the Conventional and Maximum estimates above. The embodied carbon in electricity is 0.25 million metric tons of carbon equivalent (MMTCE) per TWh. Electricity savings are calculated as 0.8 cents/kWh, though actual savings may be higher due to reduced cooling requirements with less heat output from copiers (Cramer, 1995). Each TWh of energy savings embodies approximately $80 million.

Table 4-10. Energy, CO_2, and Dollar ENERGY STAR savings all U.S. Copiers

	Standard Op. Pattern, Current Stock (Current Savings)			Maximum—all ENERGY STAR (Potential Savings)		
Seg-ment	**Energy** *GWh/year*	**Carbon** *MTCE/year*	**Money** *million $/year*	**Energy** *GWh/year*	**Carbon** *MMTCE/year*	**Money** *million $/year*
1	330	0.083	27	2,110	0.53	169
2	130	0.032	10	710	0.18	57
3	70	0.016	5	410	0.10	33
4	20	0.004	1	570	0.14	46
5	4	0.001	0.4	190	0.05	15
6	20	0.004	1	250	0.06	20
Total	570	0.141	46	4,240	1.06	339

Notes: The portion of the total energy used for copying does not vary across these estimates and is included with the other values (it is not to be added to them). All scenarios use the ASTM test power levels, differing only in the operating pattern used. 'Maximum' assumes that all the copiers have auto-off enabled.

We found no copiers in our night audits that had the default duplex feature operating, so we do not estimate any savings at present. However, if it were operating, then we estimate that paper use by copiers in segments 4 and 5 would drop by approximately 10%. Assuming 1 million tons of paper per year are used in copiers these segments, then a 10% reduction would be 100,000 tons of avoided paper production, with a retail value of $100 million, an energy content equivalent to 320 GWh/year and a carbon benefit of 1.62 MMTCE per year (EPA, 1997a).

We compared our estimates to others we found in the literature for all copier energy. The results are presented in Table 4-11. Note that the 6.2 TWh/year figure for our standard operating pattern for ENERGY STAR copiers "as-is" reflects the entire stock being compliant. With only about a third of the stock compliant, the as-is estimate is about 7.3 TWh/year. The "CCAP" estimate is based on one made by the EPA to track the effectiveness of the EPA's Climate Change Action Plan.

Major findings of our study are that copiers use more electricity than has been estimated in the past due to more copiers actually on nights and weekends, and that ENERGY STAR features are disabled more often than previously thought. This makes the potential energy savings from power management larger than had been anticipated but the portion of this that is currently being attained is smaller. Reducing energy use embodied in paper remains an as-yet-untapped resource.

Table 4-11. Comparisons of National Estimates *(TWh/year)*

Scenario	year estimated for	Conventional	ENERGY STAR As-is	ENERGY STAR Max.	Power Mgmt. Savings	Comments
Dandridge	2000				2.2	
Harris et al.	1994	3.7			0.2	
Koomey et al.	2000	7.0		5.5	2.3	
EPA CCAP	1995	5.0	2.8	2.5	2.2, 2.5	CCAP power levels
ASTM Op. Pattern	1995	4.2			0.2	This study
Standard Op. Pat.	1995	8.2	6.5	3.9	1.7, 4.3	This study; actual, pot.
Paper Use	*1995*	*7.0*	*7.0*	*6.7*	*0.0, 0.3*	*This study; potential*

Notes: All estimates except Koomey use stock levels from Dataquest. The CCAP figures shown here are **not** those estimated by the CCAP spreadsheet, but rather one using the CCAP annual energy use figures and the total stock. The paper savings are hypothetical, reflecting a 10% reduction in paper use in segment 4 and 5 copiers due to default duplexing. The "years" above are those that the scenarios are estimated for, not necessarily the year in which the estimate was made or the reference. The energy use and savings listed for paper use are the electricity equivalent of the embodied savings in avoided paper production; "Max" in this case is for the default duplex only, and does not address the potentials of other paper efficiency measures.

5. Conclusions and Next Steps

5.1 Outstanding Issues and Future Directions

The greatest opportunity to improve on the current savings from ENERGY STAR copiers is to increase power management enabling rates. The rate at which ENERGY STAR copiers have power management features disabled seems well beyond what is necessary. Evidence suggests that sales and service personnel are responsible for most disabling, and this informed previous EPA efforts to increase copier enabling (EPA, 1997b). Service personnel sometimes disable power management before the customer uses the copier[32]. Further field studies and other work is needed to understand why disabling occurs and what measures are successful at preventing or reversing it. Manufacturers could improve manuals by including specific sections on the benefits of power management; how to check the configuration; how to enable power management features; and suggested signage/labeling.

Reducing paper use (with default duplex for example) remains a significant untapped opportunity for energy and cost savings and reduced greenhouse gas emissions. More research is necessary to better understand how to raise duplexing rates and to document the savings from doing so. This would be aided by the availability of instructions, tailored to each copier model, on how copier users can successfully implement default duplex. The development of a standard symbol for default duplex would allow users easy recognition of machines that are set that way. As with power management, manufacturers could improve manuals by including specific sections on the benefits of duplexing, how to enable default duplexing, how to calculate actual duplexing rates (if possible), and suggested signage/labeling of default duplex machines. The same information could be made available on the web.

For future copier models, standardization of terms, symbols, and controls could reduce confusion among users and make power management and duplexing more acceptable. In our auditing of copier models, we found much diversity and contradiction in use of terms. Copiers could incorporate feedback mechanisms to "count down" time till ready (making low-power and auto-off more acceptable), and include screens that calculate the benefits of power management and duplexing (as currently set or used, or as they could be). This would allow users to see the energy and economic benefits of the features. Controls should be more transparent and consistent across models, and frequent tasks (e.g. to switch between 1:1 and 1:2) should take just one button push or touch screen touch. A standard 'eject' feature to empty the duplex unit should be defined (e.g. 2 'reset's in a row), and power switches should be placed near the front top of the copier for easy access.

The advent of digital copier and multi-function devices suggests convergence among these and computer printers and possibly fax machines. Test procedures need to be created to properly assess the electricity and paper use of these devices. We can expect new devices to be considerably more configurable than current ones, both in hardware options and in the interface and other software. The behavior of computers on the network that send information to the multi-function device may affect its behavior, as may the content of the images made. All of this will be affected by trends in office document management, particularly the shift towards a more digital rather than paper basis. All of this amplifies the need for better and more standard controls. Finally, copiers that arise out of

[32]The service personnel may completely disable power management on an inquiry from the customer rather than explaining its benefits or trying longer delay times or weekly timers

the International Energy Agency sponsored project (Aebischer, 1997; EPA, 1998) for highly efficient copiers may confound the ASTM test, as might machines that utilize occupancy sensors to power up and down. Adaptive controls that respond to usage patterns and the time of day and week seem promising, but as we found no cases of their use, field research should be done before their wide deployment.

5.2 Conclusions

With approximately a third of the copier stock now compliant, we estimate the current savings of the ENERGY STAR program to be 570 GWh/year; with the entire stock compliant copiers, the savings would be 1,720 GWh/year. The potential program savings—all copiers compliant and configured for 'Maximum' savings—are 4,270 GWh/year. Our baseline estimate of copier energy use (without any ENERGY STAR copiers) is 7.9 TWh/year.

Our estimates of national copier energy use are considerably higher than previous estimates. The potential savings is also higher, and so while the program is currently garnering only a portion of the potential, the absolute savings are still compelling. Maximally implemented power management would raise annual savings from $45 million (current stock and use), to $240 million/year (all stock). The energy savings estimates were based on a combination of ASTM test results, auditing and monitoring results, and stock data from market research.

The savings achieved are primarily from the auto-off feature. Low power savings were envisioned as accomplishing daytime savings; however, they may instead have their primary effect as saving night and weekend energy on copiers for which a low-power mode is acceptable but for which auto-off is not. As average copier use patterns differ across countries, energy use and savings per copier can be expected to vary as well.

We estimate that approximately 15% of *conventional* copiers are manually turned off. Our audits indicate that power management on conventional copiers puts most of them into a low-power mode at night but few accomplish auto-off. We found 61% of ENERGY STAR copiers off at night, so the program has had considerable success in reducing night and weekend copier energy use. However, compliant copiers are just as likely as non-compliant machines to remain fully on (not in low-power or off). Thus, the program has not diminished the common practice of disabling power management, but has shifted copiers from low-power to off mode.

Our detailed monitoring found little operation of auto-off during weekday daytime hours. Only very small copiers entered a low-power mode during the day, though only a few of the medium and large copiers were even required to have a low-power mode. On copiers configured for auto-off, it appeared to operate reliably, with two hour delay times dominant (this was initially the maximum). An 'instant-on' copier had particularly low energy use. Not surprisingly, larger copiers were used for more hours per day than were smaller copiers. We found one week of detailed monitoring at 15-minute intervals sufficient for assessing copier performance of most copiers. However, for copiers that power down frequently during the day, finer measurements are needed. In this study, the uncertainties and variables of most concern are the variations amongst brands and models[33], sites, user needs, and operating patterns.

Our survey found most people quite satisfied with the performance of their ENERGY STAR copiers. The major complaints cited were about paper jams and duplexing speed. The machines were perceived as more reliable than others. Unfortunately, ENERGY STAR copiers are not faster at duplexing than conventional machines; the difference remains a significant barrier to higher duplexing rates. Default duplexing was found disabled on every copier we saw. However, when we enabled it on two machines, the duplexing rate rose 15% and 20%. While the initial barrier to default duplexing is considerable, the benefits are significant.

[33] In this report we assumed that power levels for ENERGY STAR and conventional copiers are not significantly different; while we have no specific indication that they would be different, this should be checked by comparing ASTM test results.

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Appendix A. Glossary

(includes Acronyms)

ASTM Test

The test procedure "F757-94, Standard Test Method for Determining Productivity of Copiers", created by the American Society for Testing and Materials originally in 1987 then revised in 1994, for comparing energy use among copiers.

Auto-off, Automatic Shut-off Mode

A "variable energy state"—(it is unclear what this means). Can be induced by either "non-use" or by a timer. [ASTM].

BLI

Buyer's Laboratory Inc. A company that tests and rates imaging equipment.

Capacity, Capacity Factor, Rated Capacity

The (rated) capacity is the monthly imaging rate that the manufacturer recommends as a maximum use rate. The capacity factor is the fraction that actual use represents as a percentage of the rated capacity.

Configuration

A copier's settings for power management and duplexing functions. These are typically a combination of on/off switches and adjustable values for delay times. They may be available to any user or only to key operators or service technicians.

Controlling Devices

A device external to the copier, from a third-party manufacturer, that controls power to the copier to reduce energy use.

Copier

A device that produces images on paper, derived only from images from the device's platen (though they may be changed in size or selectively erased).

Copier Speed, Multi Copy

"The amount of time the copier takes to make multiple copies after the first copy of a job". There is no specification about job characteristics, such as duplexing or image source (platen or document feeder). [ASTM]

Copies Per Minute (cpm; also ipm)

The number of copies (images) that a machine makes per minute. May be "rated" (nominal), which indicates the general speed of the machine though it may not ever reach this speed in practice. Often the speed varies by source of paper (platen, document handler, and whether it is a 1 or 2-sided original), final paper size, or output duplex status. The ENERGY STAR MFD MOU uses 'ipm' (images per minute).

Copying Energy

Only energy above the stand-by power is counted, and per the definition of "copying", it is the entire copying cycle. [ASTM] Another definition is all energy used while the machine is actually copying. [Acq.]

Cycle

Transitions between standby mode and copying mode [Acq.].

Day length

The amount of time between the copier's first warm-up and when it accomplishes the last transition to a low-power or off mode. Thus it includes all of the active time and the time for delays to operate, and also includes low-power and off time during the day.

Default Time

"The time period set by the Partner prior to shipping that determines when the multifunction device will enter the low-power and sleep modes" [MFD]

Duplexing Rate

The fraction of images made that are duplexed (imaged on both sides). A 100% duplexing rate will reduce paper use by 50% compared to a 0% duplexing rate. Confounding factors (not clarified here) include non-standard paper sizes and overlay copies (two images placed separately on the same side of a sheet of paper, though not two pages placed simultaneously on a sheet with reduction).

Duty Cycle

The fraction of time during which a machine is actually copying, but not including "cycle time". [Acq.] Could be measured either with respect to just work hours or to all hours of the week.

Energy Per Copy

Measured either just with respect to copying (not including cycle time/energy), or as copying plus cycling (but regardless not including standby energy). [Acq.]

Energy-saver Delay Time

"The amount of time that the machine takes to go into and to come out of the energy-saver mode". The "go into" part seems ambiguous—the *term* sounds like the time between the last copying event and changing to energy-saver mode, but the *definition* sounds like the transition time between the modes. The 'and to come out of' part presumably means the extra time to come out of the energy saver mode over an equivalent standby. [ASTM]

Energy-saver Mode

"consuming less power than when the machine is in stand-by mode". ASTM uses stand-by to refer to the operating mode between copying jobs. [ASTM] A synonym for a low-power mode.

Job Type

The number of originals, whether the originals are single- or double-sided, the number of copies to be made, whether the copies are single- or double-sided, and any functions such as reduction, image combination, or overlay that may affect energy or paper use.

Idle Time

All non-copying time. [ASTM]

Image Source

Glass, Document Feeder, or digital source.

Imaging Rates

While generally expressed in copies/month or copies/day, 21 workdays will be taken as the standard month, as weekdays that get little or no use due to being a holiday will not be counted as a workday. Imaging rates are independent of duplexing. A confounding factor is non-standard sheets, which could be counted the same as a standard sheet or pro-rated by length or area.

Low-power Mode

"The condition that exists when the multifunction device is not producing hard copy output, and is consuming less power than when in a standby or ready mode". [MFD] Also called an 'energy-saver mode', 'Power Save', or 'sleep' mode.

Machine Energy

"energy consumed by a copier that is plugged-in 24 h/day and turned on 10.5 h but that is not making copies". This seems to assume no energy-saver time or auto-off feature operating. [ASTM]

Multifunction Device

"A physically integrated device or a combination of functionally integrated components whose primary function is copying, but is also able to perform one or both of the additional core functions of printing or faxing. The multifunction device (MFD) may be connected to a network, and may output black-and-white, gray scale, or color images". [MFD]

Night-time

In most cases, night -time also includes weekends (day and night), in discussions of power levels, operating mode, or whether the device is switched off.

Night-time Equilibration

The point at which a copier has reached its final state for an evening (after all imaging has ceased). Could be fully on, in a low-power mode (manually or automatically), switched off manually, or off from an auto-off feature.

Nominal Volume

This is the volume used in an ASTM test, *not* the manufacturer's rated volume for the particular machine. If these are close to manufacturer volumes, then the test may overestimate typical use. [ASTM]

Operating Mode

A particular state such as plug-in (off), warm-up, copying (active), standby, suspend. The device often uses a constant power, though some will vary in power consumption but in a predictable fashion that can be simplified to a constant power level.

Operating Pattern

The distribution of time amongst copier modes as well as the imaging rate.

Plug-in Mode

Plugged in but not turned on. [ASTM]

Power Management

The ability of a device to vary its power use depending on the users actions.

Ready

A synonym for Standby

Recovery Energy

Energy use above energy-saver energy duringthe transition from a low-power to ready mode. [ASTM]

Recovery Time

The amount of time needed to bring the multifunction device from the low-power mode to the standby mode. [MFD]

Run Mode

"A particular combination of originals per job and copies per original". It would seem as though this should have specifiedthe job type. [ASTM]

Sleep Mode

"The lowest power state the multifunction device can automatically enter without actually turning off' [MFD]. A particular low-power mode.

Standard Work Day

10.5 hours (up from 9 in the 1982 version of the standard). [ASTM]

Standard Month

30 days; 22 weekdays and 8 weekend days. [ASTM]

Standby Mode

"when the machine is not making copies, has reached operating conditions, but has not yet entered into energy-saver mode". [ASTM] Stand-by is *not* a low-power mode, but simply the regular 'ready' energy. Some copiers and some sources in the literature use "standby" to refer to energy-saver mode.

Also, plug-in and auto shut-off are not specifically synonymous as defined (they might be different for machines that do not move the on/off switch on auto-off). [ASTM]

Warm-up mode

"after the machine is turned on and before it has reached stand-by". [ASTM]

Weekly timer

A copier feature to track the day of the week and time of the day and turn the copier on or off automatically at set times for each day of the week.

Sources

MFD ENERGY STAR Multi-function device definitions, March, 1997.
ASTM ASTM Test Procedure, ASTM, 1994.
Acq. Acquaviva, 1994a, 1994b.

Appendix B. Sample Copier Instructions

Note: These were developed by LBNL in the course of our monitoring experience, and are an example of what manufacturers should provideto customers.

Sample Copier Instructions: Canon 6050

The 6050 has auto-off, low-power, and default duplex features. The low-power is not Tier 2 ENERGY STAR low-power compliant, but it is a Tier 1 copier so need not have low-power to be compliant.

Auto Off: The copier can be set to power-off after 10, 20, 30, 40, or 50 minutes, or 1 or 2 hours. The copier can also be set to power-off at a certain time each day of the week (that is, up to seven different power-off times). In addition, a switch in the copier's service mode can be set to disable the auto-off entirely. The switch physically moves to off when auto-off occurs.

To check or change the delay time, press the `Additional Function` key at the right of the control panel. Then, on the touch screen, select `Timer Settings` then `Auto Power-Off Time`. This will show the current auto-off delay time. To change it use the + and - touch-screen keys. To finish select `OK`, then `End`, then `End`; or `Reset`.

Auto-off can only be enabled or disabled in the copier's service mode.

To enable the timer, first set the date and time. Press the `Additional Function` key then `Timer Settings` then `Day/Time Settings`; then set the day of the week by touching the appropriate day on the touch screen; then type the time as 4 digits on the keypad in 24-hour time (e.g. 5:15 p.m. is set as `1715`); then select `OK` to return to the Timer menu.

To set the timer, select `Daily Timer Settings` then for each day that an auto-off time is desired, select it and enter the auto-off time as 4 digits of 24-hour time. "`--:--`" indicates no auto-off time for that day of the week.

Low-power: The 6050s low-power mode is not automatic; it only operates when the `Energy Saver` key (upper right of the keyboard) is pressed. When `Energy Saver` is pressed, it lights up and the touch screen goes off; to exit the mode, press the `Energy Saver` key again; the low-power mode is independent of and does not affect auto-off operation. Since this requires active effort from the user, it is unlikely to get much use in most situations.

To check the effect of the `Energy Saver` key, press the `Additional Function` key, select `Custom Settings`, press the down-arrow icon on the touch-screen, then select `Energy Saver Adjustment`, then `-10%`, `-25%`, `-50%`, or `Return Directly To Standard Mode`, then `OK`, `End`, `End`. `Return Directly` ... reduces energy use by 8% with apparently no recovery time penalty. The delay times for the others are 50 seconds, 1 minute 40 seconds, and 2 minutes 50 seconds. Only the 50% reduction is below the ENERGY STAR Tier 2 low-power criterion, but this is not an automatic low-power mode in any case.

Default Duplex: If the machine is set to default duplex, the two original/copy buttons on the touch screen will likely be 1-SIDED and 1➡2-SIDE, with the *second one highlighted.* If it is default simplex then the buttons will likely be 1➡2-SIDE and 2-SIDE with *neither highlighted.* It is possible to set these to other defaults, but trying to set it to default duplex without changing the internal service mode switch is not advised. If the buttons are different from these, it is simplest to simply make a copy in the default mode and see if it is making a duplex copy.

On this copier, default duplex can only be properly enabled in the service mode. It is possible to change the default screen to include 1:2 copying as the default, but you might not be able to then select 1:1 copying. Thus, changing in the service mode is the only good method for this.

Auditing: The machine will either be off (switched off), in `Energy Saver` mode (touch screen off, energy saver light on), or fully on. With the machine on, check the auto-off time, daily auto-off timers, and low-power level. Make sure the default mode is present (press `RESET` twice) and record the original/copy buttons on the touch screen to see if is set to default duplex. If you can enter service mode check the auto-shutoff and default duplex switches. If accounting is activated on the copier you will not be able to see the default settings.

Appendix C: Survey Instrument

Copier Location: _____ ***OPTIONAL* User Name:** _____
Date: _____, 1997 ***OPTIONAL* User Phone #:** _____

Copier User Satisfaction Survey

[Ask Survey Intro Script]

0. Is the ___ copier the one where you make most of your copies?)
If the answer is No, do not continue with the survey.

User Profile

1. Do you make most copies for yourself or for others?
❑ Yourself ❑ Others ❑ About even

2. How many copies do you estimate you make each week? _____
[If they ask, confirm that this is for all copiers at work, not just this one, but only copies they make personally; if don't use copier in question much (e.g. <10 copies per week), do not continue]

General

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree	Not Applicable
3. My overall impression of the copier is favorable.	1	2	3	4	5	9
4. The time for the first copy to print is usually too long.	1	2	3	4	5	9

Electricity—Auto Off *[Only for copiers with auto-off enabled]*

5. Are you aware that this copier turns itself off after it has not been used for a time?
❑ Yes ❑ No

6. How long do you think the copier waits after being used to turn itself off?
_____ minutes ❑ Don't know

7. Is the delay from being 'off' while it warms up: ❑ Too long ❑ Acceptable ❑ Not noticeable

8. Any problems with this feature? ❑ Yes _____ ❑ No

9. Any suggestions (other than a shorter delay) on how to improve it?
_____

If they suggest to get rid of it, explain that the saved electricity saves money and reduces environmental impacts.

Electricity—Low Power *[Only for copiers with low-power enabled]*

10. Are you aware that this copier goes to sleep after it has not been used for a time? (That is, it partly turns off).
❑ Yes ❑ No

11. How long do you think the copier waits after being used to go to 'energy-saver' mode?
_____ minutes ❑ Don't know

12. Is the delay from 'sleep': ❑ Too long ❑ Acceptable ❑ Not noticeable

13. **Any problems with this feature?** ❑ Yes _____ ❑ No

14. **Any suggestions on how to improve it?** _____
If they suggest to get rid of it, explain that the saved electricity saves money and reduces environmental impacts.

Duplexing

15. **What percentage of the copies you make do you think are double-sided?**

❹_____ %

16. **Is there anything about this copier that discourages you from making more double-sided copies?**

❹_____

The remainder only for copiers with default duplexing enabled

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree	Not Applicable
copier making double-sided copies as the default.	1	2	3	4	5	9
18. I copy double-sided more often now that it is the default.	1	2	3	4	5	9
19. I now only make excess copies occasionally due to the double-sided default.	1	2	3	4	5	9
20. It is easy to tell that the copier defaults to double-sided.	1	2	3	4	5	9
21. It is easy to select single-sided copies when needed.	1	2	3	4	5	9

22. **How long did it take to get used to double-sided being the default?**

❑ a week or less ❑ a month or less ❑ several months ❑ never/not-yet
(if not yet, how long has copier been that way?)

23. **Any problems with this feature?** ❑ Yes _____ ❑ No

24. **Any suggestions on how to improve it?** _____
If they suggest to get rid of it, explain that the reduced paper use saves money and reduces environmental impacts.

❹_____

General

25. **Would you recommend this copier to others?**
❑ Yes ❑ No Why/Why Not _____

26. **Any other comments?** [on the survey, copiers, energy-saving or paper-saving]

❹_____

Thank you!

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