Monitoring Energy Use of Copiers to Determine Program Design and Potential Savings for the Energy Star Copier Program

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In the past five years, considerable attention has been focused on the electricity use of office equipment in commercial office buildings. Several groups have monitored energy use of PCs, monitors, printers and fax machines (Newsham and Tiller 1994, Szydlowski and Chvala 1994, Tiller and Newsham 1992, Piette et al 1991). However, little attention has been paid to monitoring energy use of copiers. Procedures for testing energy usage and usage profiles of copiers are needed to make valid comparisons between machines and to determine overall energy use and potential energy savings.

In this paper, we present a method to analyze the energy use and usage profiles of copiers. This method is determined through long-term measurements from a Watt-hour meter connected to the copier and by measuring light flashes from the copier. Energy use from the copier can also be estimated by using a test procedure developed by Dandridge (ASTM 1994). Results from using the long term monitoring methods will be presented for several different sized copiers, and compared to the estimated energy use derived from the American Society for Testing and Materials (ASTM) method.

After summarizing these results, we determine criteria for a program to recognize energy-efficient copiers. These criteria were submitted as an Energy Star Copier program to the Environmental Protection Agency (EPA). The new Energy Star Copier Program was announced in July 1995, with criteria based on our suggestions. Using the final Energy Star Copier program criteria (see section VI, below) and our data, we determine potential future savings for the program. The ability to automatically turn the copier off at night is the greatest energy-saving feature most copiers can have. The best way to reduce overall office costs is to have the copier set automatically to make double-sided copies.

INTRODUCTION

We can obtain power drawn from equipment and relative energy usage from test procedures. However, energy usage of a machine depends on both usage patterns and the ability of the machine to track that usage via energy-saving features. Measurements of energy alone give the net effect of these factors, but it is necessary to separate them to assess the potential for energy-saving features in a copier.

For copiers, obtaining power usage data can provide strong but unreliable clues about equipment usage. There is a need for more monitoring and for consideration of approaches that record information provided from the machine as a more direct indication of operating profiles.

We measured over fifteen different copiers in Europe and the United States and describe the results from three in this paper. We tested the machines with a Watt-hour meter, which gave a printout of both energy and power every 15 minutes. From these data, we compared the actual energy use of the machines to predicted usage using both measured operating profiles and the ASTM test procedure (ASTM 1994).

After examining these data, we were able to determine the features that would minimize the energy use of copiers. Discussions with manufacturers, and examination of other data obtained from the ASTM test procedures allowed us to specify criteria for a potential government program that would encourage manufacturers to design copiers to maximize their energy performance. The EPA then adopted criteria recommended by Dandridge and Norford for the Energy Star Copier program (see section VI, below), which was launched in April 1995.

METHOD FOR MONITORING OPERATING PROFILES OF COPIERS

We measured fifteen different copiers from April 1992 to December 1993, using the methods outlined below. To our knowledge, no other studies have been conducted that examine not only the ASTM data, but also compare these with actual usage profiles and long-term measurements.

Monitoring Copier Activity by Recording Light Pulses

Copiers optically record the image to be reproduced. Light lens copiers use a lamp to illuminate the image and focus the light onto a photosensitive drum to which toner adheres. The lamp is flashed once for each reproduced image and a count of the pulses of light provides an exact measure of copier usage. Such a technique would not work for digital copiers that scan an image, record it digitally, and make multiple copies from the digital image.

Relatively low-cost, stand-alone data loggers to record light pulses have been developed in response to substantial efforts sponsored by electric utilities to measure the benefits of lighting retrofit programs. These loggers measure operating profiles for lights by recording the transitions from lower to higher levels of light and back to lower levels.

The meter we selected, which had the photosensitive element mounted at the end of a fiber optic tube, can log light pulses at intervals as short as one second in duration and the time at which these light pulses occurred. Data are transferred out of the logger to a personal computer which utilizes the company's customized software. The data can be transferred to spreadsheet programs for analysis. As it indicates via an LED when it has received a pulse, we were able to observe in limited testing that the indication matched copier operation on both low and high speed copiers (up to 80 copies per minute).

Electrical Monitoring

Electrical monitoring will refer here to measurements of either true electrical power or, more simply, electrical current. Current alone is adequate to determine when a machine is drawing power and is therefore satisfactory as a tool for measuring operating cycles. We will uniformly refer to electrical power measurements for simplicity but note that future studies can utilize a simpler current measurement.

When measuring average power for copiers, there are distinct differences betweet the electrical power required when the machine is copying or is in a standby mode. Off-times are also easily detected, because the electrical power will be lower than for any other state and may be zero. A low-power mode will also reveal itself as a decrease in power from the standby mode. Finally, the increase in power required by some machines when warming up can also be seen. In short, different operating modes are associated with different average powers, measured over some period of time when the machine is in a single mode.

The disaggregation of modes of operation is not so precise as to permit an exact determination of operating profile, as measured by copied images. Consider, for example, copiers that use a combination of heat and pressure to fuse toner to paper. The fixer drum is kept at a thermostatted temperature with a heater. The heater electrical pulses are large and occur when the machine is making images as well as when it is in the standby and low power modes in order to keep the fuser hot. It is clear that there is not a one-to-one correspondence between heater pulses and copied images and that monitoring the power of the entire machine is not a simple method to determine operating profiles.

For most light lens copiers this is not a problem because it is straightforward to monitor light pulses. However, with the advent of the multi-function device, more and more copiers are using digital technology. It would be possible to measure sharp changes in electrical power drawn by the motors used to feed the paper, but the current transducer would need to be imbedded within the machine, making installation difficult. A magnetic transducer to sense the operation of a motor used to feed paper would also need to be placed within the copier.

Measuring a copier's duplexing rate over time requires knowing the numbers of sheets of paper used and the number of images made. Most copiers have a counter for the number of images made, as this is useful in servicing and billing. Some machines have counters for the number of sheets used (and/or processed by the duplexing unit); unfortunately, many of these are available only to service technicians. Some third-party accounting systems record copy job time, images, and run-time, and may be in future be configurable to report sheets used and duplexing rates.

There is an alternative to high-speed detection of electrical pulses and an attempt to associate these pulses uniquely with single images. The ASTM procedure for copiers (ASTM 1994) provides a procedure for measuring the energy consumption of the machine and associated accessories in various operating modes. The measurements of each of five modes, plug-in, warm-up, stand-by, energy-saver and copying, are given in Wh, but are measured over an hour period. Therefore, the particular energy measurements can also be used to determine the average power requirements of each mode. The results can be used as a definitive way of measuring power consumption of a device.

The required calculations produce two figures of merit: monthly energy consumption, in kWh, and energy use per page, in Wh. The results given by the procedures are intended to give accurate measurements under representative conditions that may not match actual usage of any given machine. Actual energy data depends primarily on the amount of time the machine is in use in each mode, and the nominal volume of imaging performed. Since this varies widely among users, certain assumptions were made. The four key assumptions in the the ASTM procedure are hours of use, standby and energy saver time, warm up time and distribution of copies. Each of the assumptions can be probed through a combination of measured usage patterns; sensitivity analyses in which the assumptions are changed and the results of the test procedures are recalculated; and comparisons of measured energy use over a period of a time (a week or longer) with energy consumption predicted by the test procedures. The test procedures also specify, as an alternative, that the testers can use actual usage data in the formulas.

In practice, it is not possible to mandate that a machine stay in a single mode for an hour period. But average power measurements at an interval shorter than an hour but longer than a second, where heater pulses are difficult to sort out, can be very fruitful. In the course of comparing measured energy consumption for copiers with predictions made on the basis of test procedures, we recorded average power at 15-minute intervals and found it possible to separate the modes of operation, as follows:

(1) Take one-hour measurements in each mode, as required by the ASTM test procedure for copiers. These measurements identify average power in each mode.

(2) Using the hour-long measurements as a guide, assign each 15-minute interval of measured electrical power to one mode. Uncertainties due to switching modes in the middle of an interval can be reduced by taking data at shorter intervals or by interpolation. Any 15-minute interval with average power higher than the measured average power for standby mode is assumed to have included some use of the copier.

Table 1. *Example of Data for Copier A.*

Time	wk avg Wh/15 min	wknd avg Wh/15 min	Day	Wh/15 min.
11:34	107.2	13	FRI	88
11:49	119.2	69.5	FRI	64
12:04	83.4	37	FRI	68
12:19	92	9	FRI	75
12:34	107	7	FRI	71

Intervals where no images are printed are those where power could be reduced, and therefore have energy-saving potential. Following is a specific example from Copier A, examined in more detail below.

Using the ASTM measured energy values for the different modes of this copier, we can determine the operating profiles of the machine, but only up to a certain point. For instance, on Friday at 12:34, the energy use per 15 minutes was 71 Wh/15 minutes. Standby energy for this machine is 67 Wh/15 minutes. It is unclear whether the machine was warming up the fuser, which caused a slight increase in energy, or whether one or two copies were made during that time period. A general usage pattern can be determined, as Figure 1 shows, giving a graphical image of the amount of energy the above copier used as a function of the time of day.
It is easy to see that usage dropped off between 12:00 noon and 2:00 PM. This fits with the activity in this particular office; the employees had a two hour lunch break between 12:00 and 2:00. Also, usage dropped off between 4:30 and 5:00, which was when the copier was generally shut off.

EVALUATION OF ASTM PROCEDURES FOR ESTIMATING ENERGY USE OF COPIERS.

Comparison of Measured and Estimated Energy Consumption for Copier A.

The first copier was a large light lens copier that fixed toner to paper with a combination of heat and pressure. It was the only copier in a university office of 50–100 people. The door to the copier was locked at 5:00 pm, but the key was accessible. It was turned on again in the morning at about 7:00 or 8:00 am.

Figure 1. *Daily Energy use for Copier A*

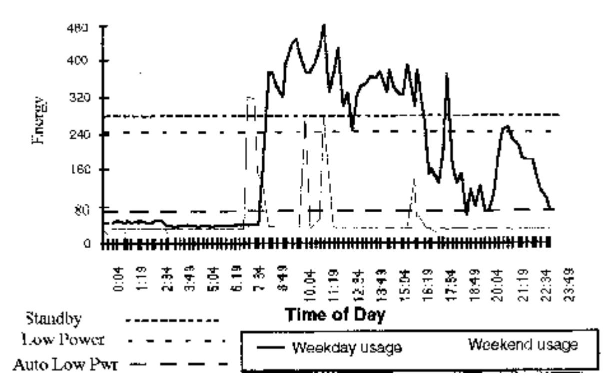


Table 2. *Estimated Power and Energy Usage for Copier A based on the ASTM Test Procedure.*

	Simplex	Simplex ADH	Duplex	Duplex ADH
plug-in power	28	28	28	28
warm-up + standby power	352	352	352	352
standby power	269	269	269	269
low-power mode power	243	243	243	243
copying + standby power	360	345	363	359
copying energy	91	76	94	90
copying energy/copy	0.45	0.38	0.47	0.45
total energy/month	93526	91041	94236	93526
average energy/copy	2.63	2.56	2.65	2.63
fraction plug-in energy	0.16	0.16	0.15	0.16
fraction idle energy (54 min. idle time)	0.60	0.61	0.59	0.60
fraction copying energy	0.17	0.15	0.18	0.17

This copier was evaluated with the ASTM procedure, on the basis of 35500 copies per month. The plug-in power is the power used by the copier when the machine is plugged in but turned off. The machine included an automatic document handler and was capable of duplexing, normal features given its size. We measured the copying energy in each of four combinations of these two features: single-sided or simplex copying with manual feed; simplex with automatic feed; duplex with manual feed and duplex with automatic feed. Hour-long measurements yielded energy consumption data shown in Table 2.

The data in Table 2 are noteworthy, even prior to comparison with the energy consumed by the copier during long term measurements. First, the four different methods of making copies make a noticeable difference in copying, total and average energy per copy. The automatic document handler reduces copying energy because the copies are made more quickly and there is less heat loss from the fixer drum. Duplexing requires slightly more energy than simplexed copying, due to the extra mechanical work to flip pages or the time the machine spends in the copying mode. The relatively low copying energy for single-sided copying with the document handler should not be considered a definitive statement about the benefits of this mode, as will be shown in a second test.

Also noteworthy are the two different low power modes. The one recorded above was arrived at by pressing a button on the machine that put the copier into a preliminary low power mode. However, when examining particular usage data for this machine, we noticed that after a long period when the copier was on but not in use, an automatic low power mode was activated, using 76 W. Having two different low power modes is something which the ASTM procedure does not account for.

The low power mode button reduced the average power required in standby mode from 269 W to 243 W, only 10%. However, the automatic low power mode reduced the average power from 269 W to 76 W, a reduction of about 72%. For the copy volume considered in this test, over 80% of the total energy is used non productively, when the machine is turned off or idle.

Energy use and copy count were measured for this copier over a 7 day period and scaled up to a 30-day month, for which the machine would have made 45223 copies and used 107110 Wh of electrical energy. To permit a direct comparison with test data, the test procedure results can be scaled to a higher volume or, more accurately, the test can be repeated. To scale the results, a lower bound for average energy per copy is derived by dividing the total energy per month found with the test procedure by the higher copy volume, yielding 1.95–2.02 Wh/copy. The lower bound assumes that more copies can be made with no increase in total energy. The upper bound assumes that the same copying energy per copy would apply to a larger copying volume, even though larger volumes are typically produced more efficiently; this assumption yields 2.03–2.12 Wh/copy. To check the validity of the upper and lower bounds and to determine a more precise answer, the hour-long copying test was repeated for a higher copying volume, as shown in Table 3.

The second test shows that the document handler reduced copying energy for both simplexed and duplexed copying by a very modest amount. Interestingly, duplexed copying was measured to use slightly less energy than simplexed copying, a counter-intuitive result that may be due to the fuser's being slightly warmed for the duplexed tests. The results estimated by ASTM fall between the upper and lower bounds, as anticipated, and underestimate long-term measured values by 11–13%.

The comparison between measurement and prediction can be extended to the energy required when the machine is idle or turned off as well as when it is making copies. Using the 15-minute average energy data and disaggregation methodology described above, we first separated and classified the data by operating modes and summed the time the machine spent in each mode. We then assigned to each mode the separately measured average power, a more streamlined approach than adding the energy from each 15-minute segment, and calculated the disaggregated energy use shown in Table 4.

Plug-in energy is lower than estimated from the test procedure, because the copier was powered for 71 more hours

Table 4. *Disaggregation of Copier Energy Use and Comparison with Estimate for Copier A.*

	Disaggregation of Measured Energy	Estimate from Test Procedure
Hours/Month		
plug-in	418	489
warm-up + stdby	56	20
standby	166	181
low power	80	30
Total	720	720
Energy/Month		
plug-in	11700	13690
warm-up + stdby	19710	7040
standby	44650	48689
low power	19440	7290

Table 3. *Estimated Energy Consumption Data for Copier A—Higher Copying Volume.*

	Simplex	Simplex ADH	Duplex	Duplex ADH
copying energy	106	104	99	93
copying energy/copy	0.41	0.41	0.39	0.36
total energy/month	95436	95083	94200	93140
average energy/copy	2.11	2.10	2.08	2.06
fraction plug-in energy	0.14	0.14	0.15	0.15
fraction idle energy	0.59	0.59	0.60	0.60
fraction copying energy	0.20	0.20	0.19	0.17

per month than estimated. The copier was also turned on 36 more times than estimated, due to users working at night and over weekends.

The machine spent 15 fewer hours in standby and 50 more hours in energy-saver mode than assumed by the test procedure. The total energy spent for all activities except copying, 95510 Wh, exceeded prediction. For simplexed copying with the document handler, the measured monthly total energy exceeded the estimated total by 12,027 Wh, less than the difference when copying is excluded. This indicates that the difference in total monthly energy is due mainly to longer hours of operation and more warm-up cycles. It also points to the limited accuracy of the energy disaggregation procedure that we used, because it leads to the conclusion that the copier used less than the predicted amount of copying energy to make more copies.

It should be noted that the test procedure assumes that copying takes place during the time allocated to standby. The energy data alone are not sufficient to pinpoint those 15-minute intervals in which copies were made, because there is some scatter in the data and intervals with a small number of copies cannot be distinguished from those with none.

Comparison of Measured and Estimated Energy Consumption for Copier B

The comparison between measurements and predicted energy consumption was repeated for a second high-volume copier that uses heat and pressure to fix the toner to paper. The copier was in an administrative office of 10–20 people. The office was locked at 5:00 pm, and reopened at 7:00 or 8:00 am.

This machine featured a different type of energy saver mode: it turned off after two hours of inactivity. As with copier A, the test procedure was initially run for a copying volume that differed from measurement and was subsequently adjusted.

This copier uses no power when it is plugged in but turned off, an improvement compared to copier A. But standby energy use is high (703 W) and the duplexer is less efficient than in copier A. For simplex copying, only 12 % of the total energy is used productively.

Based on a week of measured data, this copier would produce 11090 copies per month rather than the estimated 25000 copies, and consume 198690 Wh per month or 17.9 Wh/copy, compared to the estimated 6.7–7.9 Wh/copy. The measured data were disaggregated as for copier A. The comparison for copier B indicates that the measured value for warm-up plus standby energy was 2% less than estimated. The estimate for standby energy was 25% more than measurement, because the copier in fact spent more time in standby, and a little less in a warm-up mode than the test procedure estimates. The major difference between the measured and estimated values for average energy per copy is both that the copier was on for a longer period of time, and made fewer than the estimated number of copies.

The impact of the difference in copying volume can be bounded as we did for copier A. The copying energy per copy as estimated from the test procedure can be divided by 63 copies rather than 144, and then multiplied by 11090 rather than 25000, yielding an estimated average energy per copy of 15.5–17.9 Wh, depending on the method of making copies (simplex with ADH at the low end, duplex with ADH at the high end). A lower bound comes from using the same amount of copies, 144 under which the test was performed, which takes no account of the variation in copying energy per copy with copying volume. This calculation yields 14.3–15.4 Wh/page. The first figure contains the measured value of 17.9 Wh/page. However, since the machine was in fact idle for longer than estimated, we can assume that this would account for most of the difference.

The hour-long measurement of copying energy was repeated as a check, for simplex copying with and without the automatic document handler. Copying energy per copy was about 63% that required when the document handler was used, rather than a slightly higher value, as expected on the basis of other tests. There are inaccuracies associated with taking the difference of two large numbers—energy required for standby alone and that used during an hour of standby and copying activity—to derive a smaller number—copying energy. There was very little decrease in total energy as the copying volume decreased.

Comparison of Measured and Estimated Energy Consumption for Copier C

Copier C is a light-duty table-top machine in use in a small office of 20–30 people. Access to the copier was available at all times of the day. Primarily, the copier was shut off at 7:00 pm and turned on in the morning at 6:00 or 7:00 am. The ASTM test shows that this copier requires an average of 55.8 Wh/copy to make each of 2500 copies per month. Only three percent of the energy is used productively. The test was repeated for a copy rate to match the measured copy volume of 4272 copies per month and the average energy per copy dropped to 34.6 Wh/copy, with nine percent of the total energy used productively.

Measurements were made of the copier's energy. Because the copier lacked a counter, we used the optical sensor to record the number of copies. For copy volume of 4272 copies per month, the average energy per copy was measured to be 36.8 Wh/copy. Using the measured usage patterns for the copier, the average energy per copy was estimated to be 41.4 Wh/copy. For the same copying volume, the estimated energy use was six percent lower than the measured value. The measured data have not been disaggregated to pinpoint the cause of the discrepancy.

Summary of Comparisons for All Machines

Close agreement between the average energy per copy predicted by the test procedure and measured performance can be expected if the test procedure accurately estimates the actual hours of operation and the number of copied images. The estimate becomes stronger if there is no low power mode, because it is difficult to predict the time a given machine will spend in this mode. When there is no low power mode, total energy is not sensitive to the volume of output.

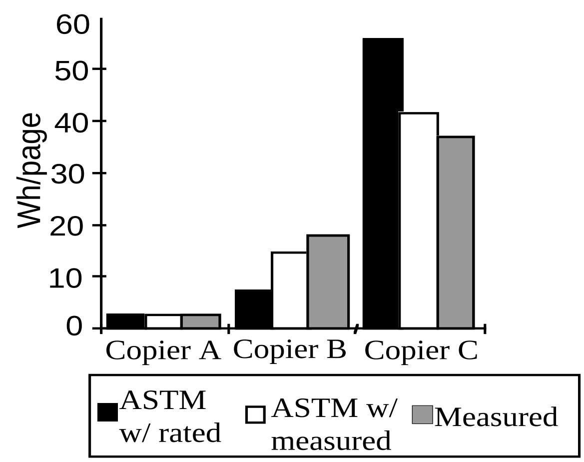
For machines with a low power mode, it is anticipated that the test procedure will underestimate the time spent in this mode for low copy volumes and overestimate the time under high usage.

In the following figure, the average energy per page for each machine is graphically represented. The ‘‘ASTM w/ rated’’ values represent the average energy per page using the manufacturers rated monthly volumes for each machine, and the usage patterns assumed by the ASTM procedures. The ‘‘ASTM with measured’’ values represent the average energy per page of the machine, using the estimated number of hours the machine would be in each mode from the measured usage patterns. Finally, the ‘‘Measured’’ values are the measured total energy of the machine, divided by the measured number of imaged pages per each machine. The second two values are measured for one week, and correlated to an average month, as defined by the ASTM procedures.

This figure shows a strong correlation primarily between the ASTM value calculated with actual usage data and the measured value. With Copier C, usage was spread over the day, which does not match the ASTM predicted usage pattern in the job matrix, which might account for the discrepancy. Because of the spread usage patterns, it was very difficult to judge when the machine was in a standby mode, so it was hard to predict actual usage data.

Using ASTM rated values can give a very good basis for comparison between like machines, but does not often give the same values as using actual usage patterns would give. Collecting usage data by examining energy usage over a certain interval and predicting hours of machine usage in each mode, and applying them in the ASTM procedure, we arrived at values very close to the measured values for each machine.

Figure 2. *Average Energy for Each Copier, Varying Methods of Measurement*



POWER MANAGEMENT IN COPIERS

As can be seen from the previous analysis, copiers will consume less energy if turned off when not in use for extended periods (overnight and weekends) and if they can switch from standby to a low-power mode. Many copiers currently incorporate energy saving modes, with varying implementation strategies. Control that is exclusively manual is almost certainly less effective than automatic switching as was shown with copier A. Users of copier A did not take advantage of the manual feature at all. Luckily, there was a second low power mode that the copier could enter.

However, the presence of even an automatic low power mode is no guarantee that it will be used. Many manufacturers ship the copier with this mode disabled. Thus it is reasonable to assume that the mode is frequently never enabled.

Given the thermal dynamics of the fuser unit and a desire on the part of manufacturers to minimize the time required to heat the fuser unit to initiate a printing sequence, the fuser unit is often kept at temperatures well above ambient in the low power mode. Data for a product line of heat-and-pressure copiers from a single manufacturer show that the low power mode uses 59–79 % as much power as standby mode (Bundesamt fur Energiewirtschaft 1993). This ratio could be reduced if the temperature of the fuser unit could be restored more rapidly to operating levels, or if the unit is better insulated. Many light duty copiers utilize a low mass or belt fuser that enables rapid or ‘‘instant-on’’ fusing. This technology is currently limited to copiers with speeds up to

13 copies per minute, so is not a solution for high volume copiers.

ESTABLISHING CRITERIA FOR A VOLUNTARY LABELING PROGRAM FOR COPIERS

The copier program we presented to the EPA for use as an Energy Star Copier program was not a ‘‘best that can be acheived’’ program, but rather one that could be accepted by both manufacturers and consumers, and therefore have higher potential of actually transforming the market towards more efficient copiers. All Energy Star Copiers should be shipped with the default settings as outlined below. The default time for the low-power mode is set at 15 minutes.

Table 5 shows our recommendations for the Energy Star Copier program, which were eventually adopted by the EPA. There were a number of important considerations that entered into our recommendation.

Auto Shut-Off

The ability to automatically turn the copier off at night is by far the greatest energy-saving feature most copiers can have. In our preliminary study of copiers, we found that roughly half of the copiers were left on overnight. In a large office or where there is no centralized use of the copier, the machine is often left on so that users can have instant access to making copies. One copier with centralized usage was supposedly turned off every night, but we found that 10% of the time it was left on. That percentage might be even higher during times when users didn’t know they were being monitored. Having an auto-off feature that automatically turns the copier off would automate this behavior, ensuring that the copier is not left on when not in use.

The copier could implement this feature by turning off after a certain period of non-use, or turning off at a certain time. The second solution is more desirable in some cases, since the copier would not shut off during daytime usage, making it more convenient (and thus more acceptable) to the user. However, most offices do not have a set time when everyone leaves. Predicting a standard default time for most copiers is nearly impossible.

Low Power Mode

The recovery time of the machine is a major issue, both for users and manufacturers. While the non-productive energy use by a copier is generally very high, having an energy-saving feature that requires a long wait before the copier can be used productively is unacceptable to most users. There are two different types of solutions to minimize the recovery time of a copier. The first is to have a relatively low reduction in the fuser temperature, which would not require much of a design change, but would also not achieve high energy savings. The other is to implement a design change so the fuser can achieve lower temperatures without affecting the recovery time. For instance, extra insulation could be added around the casing. Manufacturers are currently working to implement such design changes for a variety reasons (lowering the initial warm-up time, which is a

Table 5. *Criteria for Energy Star Copiers*

Copier Speed (copies per minute)	Low-Power Mode (Watts)	Recovery Time 30 seconds	Off Mode (Watts)	Off Mode Default Time	Automatic Duplex Mode
Tier 1: Effective June 1995–July 1997					
$0 < cpm \leq 20$	Not required	Not required	< 5	≤ 30 minutes	N/A
$20 < cpm \leq 44$	Not required	Not required	< 40	≤ 60 minutes	Optional
$44 < cpm$	Not required	Not required	< 40	≤ 90 minutes	Default
Tier 1: Effective June 1995–July 1997					
$0 < cpm \leq 20$	None	NA	< 5	≤ 30 minutes	N/A
$20 < cpm \leq 44$	3.85 * cpm + 5	Yes	< 40	≤ 60 minutes	Optional
$44 < cpm$	3.85 * cpm + 5	Recommended	< 40	≤ 90 minutes	Default

major selling point for copiers). Focusing our efforts on this solution would call for more of a ‘‘Golden Carrot’’ type of program, offering a reward to the manufacturer that comes up with such a solution. Since the Energy Star program tries to find solutions that encourages manufacturers not to increase the cost of the Energy Star product, we chose to make our recommendations around the first solution.

We recommended that the EPA adopt a tiered approach to the Energy Star Copier program, which included an auto-off mode in Tier 1, which has greater energy savings than the low power mode, and added a low power mode in Tier 2. This was to ensure that manufacturers had time to make possible design changes for implementing the low power mode (design changes are not neccisarily needed for the auto-off mode).

Duplexing

Another major energy use in copying is that embodied in the paper used. An evaluation of several Swedish paper mills (Molinder & Bryntze 1994) and a broad review of papermaking data (Nordman 1995) both found the embodied energy ranging from 12 to 17 Wh/sheet (electricity equivalent), where the low end is 100% recycled content and the high end all virgin content. Significant reductions in copy paper through increased use of the duplex mode use are possible. Current paper use in offices is over 4 million tons/year, about half of which is for copiers.

A review of paper use practices at a national laboratory (Nordman 1995) found copiers were used on average at 20% of their rated capacity. Duplexing rates were measured for about 50 machines. The initial baseline period revealed an average duplexing rate of about 32%. A simple reminder was then taped to the top of the machine asking people to duplex their copies; this raised the average duplexing rate by 8 % to 40%. After the second period, a complex reminder was substituted, which included detailed instructions on how to duplex, and many of the benefits of duplexing. Curiously, the duplexing rate remained at about 40%. While the average duplexing rate was stable, the rate for individual machines varied considerably among the periods, up to 70% in one case. The national average duplexing rate for this class of copier (Graff & Fishbein 1991), was only 18%. The high duplexing rate observed at the laboratory, even before the intervention, may be due to higher consciousness among the employees about paper use. These measurements relied on entering the copier service mode. Paper use costs (imaging, storage, mail, fax, etc.) were found to be approximately ten times the cost of purchasing paper, so that savings from reducing paper use can be many times the cost of buying the paper. A default duplex feature would be expected to have a larger effect than the 8% increase in the duplexing rate that the simple reminder had.

Savings from the Energy Star Copier Program

By using our monitoring method and data from almost 150 copiers (with speeds ranging from 4 cpm to 110 cpm) combined with figures for current stock and future sales of copiers (Dataquest 1994), we were able to determine the potential savings from an Energy Star Copier program. We made certain assumptions about the percent of copiers where the Energy Star features would remain activated, and the percent that would be sold each year. Average hourly usage patterns were adjusted from the ASTM procedure for the different copier speeds. Table 6 outlines the savings for each of the three Energy Star Copier categories. The savings were evaluated after the program was administered, by employees (including the author) of the EPA.

The total savings from an Energy Star Copier program, with fairly conservative assumptions, is quite significant. The energy and CO_2 reductions are equivalent to 950,000 cars taken off the road by the year 2000, and 717,000 forested acres of trees not cleared by 2000.

The data on copier use rates are relatively unavailable, but we estimate the default duplex feature of the Energy Star program might reduce the 200 billion copies made each year by 15 billion sheets. Given this figure, about 75,000 tons/year of paper use would be avoided, saving consumers $75 million, with other savings (storage, shipping) probably several times this amount. The energy content of this paper reduction would be about 240,000 Mwh/year. We calculated that for one 60 cpm Energy Star copier, an office could save over $700 in paper purchasing costs.

CONCLUSION

In this paper, we presented methods to monitor the energy usage of copiers, one which uses short term measurements and the ASTM test procedure, and one that uses long term measurements and actual usage profiles. By testing the machines with a Watt-hour meter, we were able to get results that showed the usage profiles of copiers with different speeds and different types of power management. We used our results, combined with ASTM data from over 150 other copiers to determine the criteria for an Energy Star Copier Program.

The Energy Star Copier Program was announced in July 1995, with criteria based on our suggestions. This program could save over 2,221 GWh of electricity use by the year 2000, which is equivalent to $177 million. The paper savings are also significant, amounting to 75,000 tons per year or $375 million by the year 2000.

Table 6. *Yearly savings from Energy Star Copiers*

Speed	1996	1997	1998	1999	2000
Yearly Energy Savings (GWh/year)					
Low	109	183	271	373	490
Medium	113	188	274	371	479
High	282	473	697	957	1,252
Total	504	844	1,242	1,701	2,221
Energy Savings ($M 1995/year)					
Low	9	15	22	30	39
Medium	9	15	22	30	38
Highd	22	38	56	77	100
Total	40	68	100	137	177

REFERENCES

ASTM (American Society for Testing and Materials), 1994. ''F757, Standard Test Method for Determining Energy Consumption of Copiers and Copier Duplicating Equipment.'' Philadelphia, Pa.

Bundesamt fur Energiewirtschaft (Federal Bureau for Energy Science). 1993. ''Die Heimlichen Stromfresser. Standby-Verluste von Buro- und Unterhaltungselekronikgeraten. (The Power Use of Residential and Communication Appliances in Standby Mode).''

Dataquest, 1994. ''1994 Market Trends for Copiers of North America.'' COPYNAMT94:01. San Jose, Ca.

Graff, R., and B. Fishbein, 1991. ''Reducing Office Paper Waste: An INFORM Special Report.'' ISSN # 1050-8953, Volume 2, Number 3.

Molinder, O. and G. Bryntze, 1994. ''1 Year Later; A One Year Follow up on 'One Watt after One Hour in One Year.' '' Report for The Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Department of Energy Efficiency (DOEE).

Newsham, G., and D. Tiller, 1994. ''The Energy Conservation Potential of Power Management fo Fax Machines.'' Institute for Research in Construction report # 666.

Nordman, B., and E. Moseley, 1995. ''Draft Interim report: LBNL Paper Efficiency Project.'' Paper presented to Lawrence Berkeley National Laboratory's Waste Minimization Program.

Piette, M.A., J. Eto, and J.P. Harris, 1991. ''Office Equipment Energy Use and Trends.'' Lawrence Berkeley Laboratory report LBL-31308.

Sydlowski, R.F., and W.D. Chvala, Jr., 1994. ''Energy Consumption of Personal Computer Workstations.'' Pacific Norwest Laboratory report PNL-9601.

Tiller, D.K., and G. Newsham, 1992. ''Desktop Computers and Energy Consumption: A Study of Current Practice and Potential Energy Savings.'' Institute for Research in Construction, National Research council of Canada, Ottawa, Ontario.