Office Equipment Energy Efficiency: Taking the Next Few Bytes

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Electricity use by office equipment is growing faster than any other category of electricity use in commercial buildings in the United States. Office equipment directly consumed approximately 26 billion kWh in 1991 or approximately 3% of total commercial electricity consumption; this figure could increase up to fivefold in the next decade—absent effective technology development and market-transformation policies. This paper examines the energy consumption characteristics of conventional and state-of-the-art personal computers, printers, photocopiers, and facsimile machines. Indirect energy effects (peak electrical demand, air conditioning loads, and energy embodied in paper) are also discussed. Emphasis is given to recent developments in computing, computer display, and imaging technologies that reduce operating and standby energy use. The paper summarizes activities to develop standardized energy testing procedures and information programs, mandated in the Energy Policy Act of 1992, as well as recent efforts outside the U.S. The authors discuss current issues in implementing market-oriented energy efficiency programs for office equipment, and conclude with specific recommendations for both research and technology transfer.

Introduction

Office equipment is currently the fastest growing end use of electricity in commercial buildings in the United States, accounting for approximately 26 billion kilowatt hours (kWh) in 1991. This figure increases by 30-40% if the cost of space conditioning to offset the waste heat generated by office equipment is taken into account (Ledbetter and Smith 1993). Of the 26 billion kWh, approximately 50% is for PCs and monitors, 25% is for computer printers, with the remaining 25% for copiers, facsimile machines, and other miscellaneous equipment (Dandridge 1994). The total energy use figures are expected to increase by as much as fivefold by 2005 with more ubiquitous computing, larger and faster data processing, and greater demand for high-quality display technologies.

Technology Review

Personal Computers

The most significant energy-efficiency development for microcomputers is the introduction of 'power management' features in desktop machines. Similar to the battery-saving controls found in portables, this feature powers down unnecessary components within the computer while maintaining memory. Incorporation of this feature into desktop machines has been primarily encouraged by the Environmental Protection Agency's Energy Star program. This EPA voluntary program calls for participating manufacturers to have microcomputers power down to 30 Watts or less after a user-specified period of inactivity. Given that the 'typical' 486-based PC (without monitor) draws about 85 W during both active and inactive operation and that studies reveal microcomputers are used only 30-40% of the time during a typical workday (Tiller and Newsham 1993), power management can reduce daily PC energy use by as much as 60%. Figure 1 shows the distribution of PC standby power (in watts) for selected units.

Other low-energy technologies currently being introduced include: low voltage architecture (3.3V is becoming increasingly common, with 2.5V being introduced later in 1994), low-energy hard disk drives (2," and smaller), and CMOS chips.

Monitors

The Energy Star program also covers monitors, and again requires a power down to 30 W or less after a user-specified period of inactivity. With the popularity of larger, higher resolution color CRTs, typical display

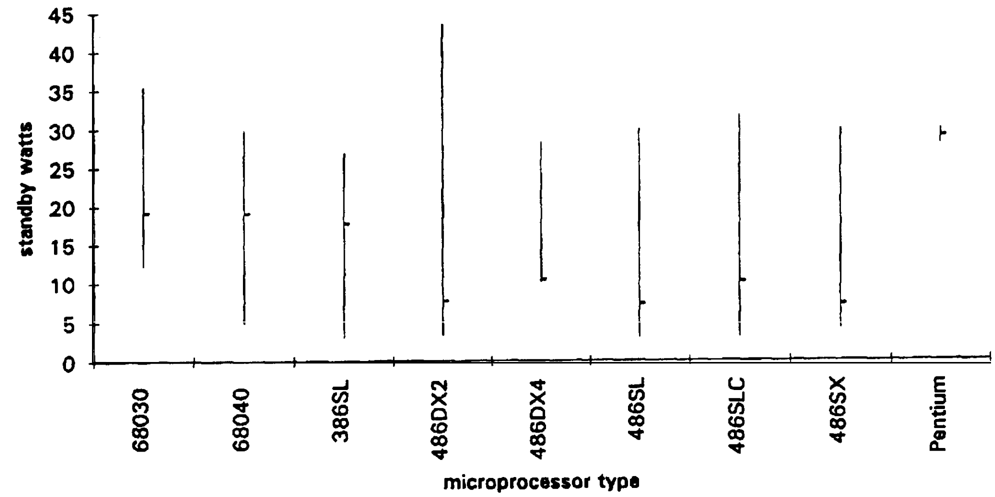

Figure 1. Standby Power Measurements Values for Various PCs (line indicates highest and lowest values in sample)

energy use has increased dramatically. For example, a 14" monochrome monitor draws about 40 W while a 20" SVGA color CRT draws over 120 W. Increasing CRT energy use thus makes power management more important.

A plethora of after-market devices to shut monitors off during periods of inactivity have entered in the market-place in the past 18 months. While these devices serve a useful function, their cost is often prohibitive (typically $100 or more, although newer models are retailing below $70).

Non-CRT display technologies have not yet made significant headway into the desktop system market. Their cost is generally four to five times higher than comparable size CRTs. This cost premium is not as important with the need for lighter weight in laptops, but for desktops it is prohibitive. There are conflicting opinions about the possibility of flat panel display cost decreases: some sources state that higher production volumes will reduce flat panel display costs to competitive levels, while others state that even high volume production costs will be significantly higher than CRTs and will never compete except where there is a non-cost-related market advantage. Additionally, there appears to be a significant embodied energy penalty associated with the production of flat panel displays; some data indicate that this high embodied energy may offset any energy use savings (Dandridge 1994).

Computer Printers

The Energy Star program currently covers computer printers. Similar to the standard for computers and monitors, it requires a 'power down' to 30 W or less after a period of inactivity; a 45 W level is allowed for high-volume printers. Several laser printers have entered the market since June 1993 with power management, but all are limited to 4 pages per minute (Luhn 1993).

Non-laser print technologies afford great potential for energy savings. Ink jet printers, which offer slightly lower print quality and are limited to low-volume production, use 20-25% of the power of comparable laser printers. Impact printers also use a fraction of the energy of laser printers.

Copiers

For many years, a significant portion of the photocopier market included machines with power management features, frequently marketed as an "energy saver" feature. However, most copiers are shipped with this feature disabled and as the feature often requires a technician to activate, it is vastly unutilized in the field (Ledbetter and Smith 1993).

Copier energy technology innovation is currently lagging behind printers and computers. However, use of lower temperature fusing and smaller fusing surfaces can afford significant energy reduction. Digital duplicators and liquid ink copiers, currently a small portion of the photocopier market, use much less energy than conventional heat and pressure fusing copiers but due to quality and volume restrictions are appropriate for limited applications. Alternative low-energy copy technologies are currently being developed in Europe and Japan; introduction of a copier "Energy Star" or equivalent program is likely needed to transfer these technologies to the United States.

Facsimile Machines

While facsimile machine energy use is low compared to computers and printers, the continual operation of these machines and their relation to office paper use makes their energy use consideration important. Individual machine energy use can vary by more than 50%, with laser and LED machines typically drawing the most power, followed by thermal faxes and then low-energy ink jet machines. However, paper use is by far the most dominant total energy use, as it requires 15-20 Watthours to produce a sheet of virgin paper versus 0.5 to 2 Wh to image on the paper (Nordman 1993 and Dandridge 1994). The energy and purchase cost penalties associated with thermal paper is even greater. However, ink jet machines can utilize used paper, thus reducing the machine's total associated energy use and operating costs. Fax modems use less energy than any stand-alone fax; if a computer is left on overnight to receive faxes, however, the energy use associated with use of the device obviously is much higher.

Multifunction Office Equipment

New developments in combined-function machines, or "hydras", which provide (for example) printing, fax, scanning, and/or copying all in one machine, present great potential for reducing imaging equipment energy use as well as initial cost and non-energy operating costs. These devices are often ideal for small offices, since they require much less space and only one print engine running instead of three or four. However, use of a multifunction machine without good power management can result in higher total equipment energy use if it is left on all night to receive incoming faxes (Ledbetter and Smith 1993).

Recent Trends and Issues

Testing, Information, and Product Data Bases

An industry-based organization, the Council on Office Product Energy Efficiency (COPEE) is working with DOE and other interested parties to develop a national testing and buyer information program on office equipment energy efficiency, as mandated in the 1992 Energy Policy Act (U.S. Congress 1992). This program is still being shaped, but will likely adopt the revised ASTM energy test procedures for office copiers, adapt these for printers and faxes, and develop a parallel approach for PCs and monitors. The basic ASTM approach is to conduct short-term tests of equipment in specific operating modes, then combine these values as a weighted function to estimate an energy operating budget either for a typical annual usage pattern or for a specific set of tasks (e.g., energy use to produce a specified number of copies of a specified number of original pages in a given time).

In addition to an overall index of energy performance for each type of office equipment, information of use to consumers would include:

- annual or lifetime energy operating costs
- power required in both active and standby/sleep modes
- recovery time from each sleep or standby mode

Users also need some assurance of (or information about) compatibility of power management between PCs and monitors, the ability of a power-managed PC to use common operating systems and to function as a client (or server) in a local network, and how the power management features work with peripherals such as fax-modems and answering machines. Many users are also interested in the ease with which power management functions can be set and modified. Corporate or institutional buyers may also want information on peak electrical demand and power quality of the power supply.

Such product data can be communicated to buyers, large and small, by a number of means other than the familiar energy-rating stickers placed on home appliances. A labeling approach might be effective in retail outlets, but a large fraction of computers and related equipment are now purchased through catalog sales, through contract sales, or from third-party suppliers ("system integrators") who provide a broad range of products and services to large government and non-government clients. In these cases, other ways will have to be found to make purchasers aware of energy efficiency features and differences in energy use—including more creative use of electronic information media themselves, such as on-line bulletin boards and product data bases distributed on floppy disk or CD-ROM. Already, the U.S. General Services Administration (GSA) provides on-line information on those Energy Star computers and peripherals available through GSA schedules. Anyone with a modem can access for this information. EPA data on Energy Star-complying products is also now available in electronic form, and various private services that feature on-line computer shopping and purchasing could easily include additional information on product energy efficiency.

It may be impractical for a uniform national testing and rating system to provide these diverse types of information; reliance on product review articles in the trade press may be the best approach (Byte 1994, Luhn 1993, and Marshall et al. 1994). However, to avoid the confusion of competing manufacturer or product-review claims—some of which are already in evidence—there must be a standardized method of testing and rating energy use and power consumption by mode.

The need for standard testing and rating methods will continue to evolve, along with the rapid pace of information technology advances and the introduction of new products such as multifunction "hydras," multimedia home and office machines, and wireless or portable computing and communications systems.

Implementation Issues

The enthusiastic launching of a new program like the Energy Star label, or the requirement that Federal agencies buy Energy Star computers, does not guarantee continued success. A serious follow-up effort will often be needed, especially where the ultimate aim is to transform the market so that energy-efficient products, once an exception to standard practice, become the norm for both sellers and buyers.

While several studies have examined user response and actual energy savings from external power-management switches, there are as yet no published data on the measured results of deploying the new generation of energy-efficient computers, monitors, and printers designed to meet the EPA Energy Star criteria which have internal power management. Feedback of this sort from actual operating experience is important for any new energy-saving technology, but especially so in this case, given the ease with which a user can disable power-management features without loss of the equipment's computing power or other functions. In fact, the ease of disabling power management on many desktop PCs may be a liability in some cases, if it turns out to reduce user feedback to distributors or manufacturers, in the form of complaints about power-management features that are incompatible with networks, with certain software, or between a PC and a monitor purchased from different sources. Feedback on problems with power management features is thus far inconclusive.

Because of concerns that a new owner may think her power-managed machine is malfunctioning the first time it enters a sleep mode, some manufacturers still ship their products with power-management features disabled. As a result, a significant fraction of buyers (or subsequent users) may not even be aware of the energy-saving features of their equipment—absent special efforts to inform and educate them. Such education should include the appropriate use of screen-savers with power-managed PCs and monitors.

Consumers also need to be reminded of the importance of shutting off equipment, even power-managed equipment, when not in use for extended periods of time. It could, for example, lead to a net increase in annual energy use if those users who formerly shut off their PCs, monitors, and printers began to leave their new, power-managed machines on (even in low-power sleep mode) at night and on weekends.

If monitoring and feedback are important at the level of the office and user, it is equally important to be able to track and evaluate the impact of programs like Energy Star labeling on the market as a whole. What fraction of products sold are energy-efficient? How is this changing over time? Who is buying (or refusing to buy) models with energy-saving features—and why?

Still another type of follow-through is needed to help assure that today's market-leading criteria do not become a drag on the future development and marketing of new technical innovations. The emergence of multifunction "office appliances" is one example alluded to above; others include new, highly portable products for personal communications and computing services, and the possibility of a whole array of new consumer-oriented electronics providing home-based information services. Indeed, it may soon be time to re-examine the entire concept of an office-centered workplace, as technology advances continue to improve portability, connectivity, and the sophistication of low-cost electronic services in the home.

International Developments

The market for most computers and related office equipment is a truly international one. However, the size of the U.S. market means that our domestic policies and programs, such as the EPA Energy Star label, quickly attract the attention of overseas manufacturers, buyers, and policy-makers alike. Over the years a number of non-U. S. research institutes, government agencies, and individual firms from Europe, Canada, and Japan have participated in meetings, conferences, and other activities sponsored by the Office Technology Consortium and by U.S. utilities. At the same time, new public and private sector initiatives in other countries have added significantly to both our technical information and the experience base with policies and programs for efficient office equipment. This section summarizes some important recent activities outside the U.S.

While the informal network of international contacts remains active, there is a need for more explicit agreements that can help reduce—if not eliminate—the proliferation of separate methods for testing and rating energy performance. Coordinated international efforts, building on the Energy Star program, could also encourage common performance targets for energy-efficient labels, government or corporate purchasing criteria, and utility DSM programs.

Sweden. Beginning in 1992, the Swedish National Board for Industrial and Technical Development (NUTEK) has pursued a market-pull strategy for monitors with an "auto-power-down" feature, in conjunction with Swedish office-worker unions concerned about workstation ergonomics. In 1992 NUTEK announced an energy performance standard for monitors, in the form of two options. Option A specifies a two-level power reduction: standby power under 30 W (preferably under 15 W) after one hour, with a 3 second recovery time, followed by a "power-off" setting of under 8 W (preferably under 5 W) after another 70 minutes. Option B, for dumb terminals only, calls for standby power of up to 15 W after 5-30 minutes idle time, with a 3-second recovery time (NUTEK 1994).

These requirements are more stringent than the single criterion of a 30-W sleep mode set by the U.S. Environmental Protection Agency for "Energy Star" monitors, and the important addition of a 3-second recovery time is likely to encourage more users to take full advantage of the standby feature during working hours, as well as for night and weekend power-down.

As of late 1993, monitors complying with the standard were offered by six Swedish and overseas manufacturers, representing 25% of the Swedish market. NUTEK is now pursuing an even more stringent standby-power target for monitors and perhaps other office equipment: a "coma" mode of under 1 W after an hour of idle-time (Molinder 1993). A number of products now on the U.S. market achieve low-power sleep modes comparable to the Swedish standard (Byte 1994).

France. Beginning in 1986, a research team at the University of Bordeaux has led a series of studies on office technology efficiency measures, fabrication and testing of prototype controls for low-power operation, field measurements of office equipment loads in typical buildings, and analyses of the potential savings from national programs. These projects laid the groundwork for a multinational project ("OT3E") sponsored by the European Community, to develop a common set of office technology efficiency criteria and policy options for consideration by several European countries (Roturier et al. 1993, Roturier and Harris 1993).

Switzerland. The Swiss Federal government has adopted "target values" for low-power standby of office equipment, to be achieved by the late 1990s. The initial strategy for achieving these targets is a voluntary product label, developed by the Federal Office of Energy as part of its "Energy 2000'" program (Aebischer 1993 and Bachmann et al. 1993). Swiss law also provides for mandatory efficiency standards if the government determines that voluntary measures are not achieving the targeted savings. The Swiss program concentrates on reducing standby losses when equipment is idle during work periods, or not in use at night and on weekends. The criteria were set on the basis of an extensive program of field measurement and analyses of the impact of power-down and power-off features on electronic equipment reliability (Swiss Federal Office of Energy 1993), followed by consultation with industry.

The initial label for copiers, printers, and faxes is aimed at identifying and promoting consumer purchase of the most efficient 20-30% of current models. Target values and initial labeling criteria (power by mode of operation, in watts) are listed in Table 1.

As of early 1994, a total of 43 models (7 manufacturers) had qualified for the Swiss printer label, 55 models (8 manufacturers) qualified for the copier label, and 24 models (10 manufacturers) for the fax label [1]. Target values for PCs and monitors were announced as of February 1994, with labeling criteria still under development. In the consumer electronics sector, labeling criteria and target-values have also been designated for televisions and video recorders, whose standby losses account for a significant electricity load in Switzerland. The target for TVs also includes active power as a function of screen size.

Denmark. In Denmark, a recently enacted law gives the Danish Energy Agency authority to set minimum efficiency standards for a range of consumer products and commercial and industrial equipment, including office equipment such as PCs, monitors, printers, copiers, and fax machines (Danish Energy Agency 1994). The office equipment standards will emphasize automatic shut-off and reduced power use when equipment is in standby mode. Standards are to be adopted by 1995 and to take effect as of 1997. However, staff of the Agency have indicated that the initial effort may be limited to voluntary "target values" as in Switzerland, with mandatory standards remaining as a back-up option if the voluntary approach does not achieve the anticipated improvement in energy efficiency. An initial analysis (Rebsdorf 1993) suggests the standby power levels listed in Table 2.

For all appliances and equipment covered by the new Danish law, there will also be programs to inform buyers about specific models that are energy-efficient, and to encourage the early retirement of older, less efficient units now in use.

Table 1. Swiss Labeling Criteria; Initial and Target Values

	Energy 2000 Label		Target Values	
	Standby ("sleep")	**"Off"**	**Standby ("sleep")**	**"Off"**
Printers	30 W[(a)]	n/a	2 W	0.5 W
Copiers	20/4*cpm[(b)]W	10 W	27/3.23 cpm W	1 W
PCs	n/a	n/a	10 W	1 W
Monitors	n/a	n/a	5 W	1 W

(a) Standby is 10 W for printers at ≤8 pages per minute.
(b) cpm = copies per minute (standard copier speed rating).

Table 2. Danish Energy Agency Suggested Standby Power Levels

	Maximum Power in Standby ("sleep") Mode	**% Reduction**
PCs	10 W	70%
Monitors	30 W	60%
Laser Printers	46 W	4-50%
Plain-Paper Fax	2 W	95%
Copiers	6-223 W	35-50%

N.B. Wide range in copier power and percent reduction reflect range of values for various size copiers with various copy speeds.

Canada. In Canada, early leadership in the field of external power management was taken by the National Research Council (NRC), in a series of projects to develop and field-test power-management strategies for PCs and other office equipment. The Canadian studies focused on the use of external switches for monitors (and printers), controlled by PC keyboard or mouse activity. Measured energy savings averaged about 60%, with daytime peak demand savings of about 30% (Tiller and Newsharn 1993). A separate part of the experiment measured savings from reminding users to manually shut off their PCs and related equipment when not in use; savings were significantly lower, and persistence much poorer than with the automated switches. A software-based monitoring tool developed for the NRC made the monitoring of actual PC usage profiles (idle-time when machines are left on) both simpler and much less expensive; the software has since been adopted for similar studies in the U.S. and elsewhere. A follow-on project by the NRC is now compiling measured data on the operating profiles and idle-time of fax machines.

The Canadian Ministry of Energy, Mines, and Resources has drawn heavily on the ACEEE Buyers Guide **to** French/English version. The Ministry has also initiated a program to evaluate technology options and market opportunities for more energy-efficient copiers[2]. The Canadian government is considering how government procurement can help advance the market for efficient office technologies—as in the U.S. where Federal agencies, since October 1993, have been required to buy Energy Star PCs, monitors, and printers (Office of the President

1993 and GSA/IRMS 1993). At least one major utility (Ontario Hydro) has also begun developing efficiency criteria for its own office equipment and as recommendations to its customers.

Japan. In Japan, individual manufacturers have closely followed activities to promote efficient office technologies in the U.S. and Europe, and a number of Japanese manufacturers have products that qualify for the EPA Energy Star label and the NUTEK monitor label. Both the Japanese government and the industry association (JEIDA) have taken an interest in guidelines, ratings, and possible future standards for computer system efficiency; the initial attention has focused on efficiency of central processor units for mainframe systems (JEIDA 1993). Discussions now underway may lead to explicit or de facto adoption of U.S.-developed test procedures and EPA labeling criteria by Japanese industry and/or JEIDA itself.

Ongoing and Proposed Research and Development

Technology Development

When energy-efficiency advocates started trying to influence the market for office technology in 1991 and 1992, it was evident that significant potential for efficiency improvement in all the major equipment categories existed. For example, by incorporating features such as LCD screens (for CRTs), power management software and hardware, better power supplies with higher efficiency and power quality, smaller hard drives or solid state memory, desktop PCs could use energy as efficiently as laptop/ notebook units. While power management has become available in desktop PCs, other energy-saving features have not seen widespread application.

Energy savings for printers, copiers and faxes were projected to be 50 to 90% if features such as better power management, heater cycle control, low heat or pressure-only fusing, ion deposition technology, or faster inkjet systems were developed. In response to the Energy Star program, power management features have begun being incorporated into printers, but the market has seen very little in the way of other improvements.

Thus, researchers and manufacturers need incentives to develop technologies that can make office equipment more efficient and to incorporate these technologies into commercially-available hardware. The Office Technology Efficiency Consortium, founded in 1990, was organized to coordinate these technology development efforts. Currently, this group is exploring improved power supplies, enhanced flat-panel displays, and wider use of low-standby power copiers in their next round of research.

Technology Demonstration

As more efficient office equipment becomes available, energy savings need to be verified. The most-needed function is field testing and publication of actual versus specified energy use and demand. Emerging Energy Star-complying equipment should be included in these field evaluations.

Another emphasis of technology demonstration efforts should be measurement of existing equipment power quality effects, as well as equipment sensitivity to power line disturbances. This information should be published along with recommendations for enhancing equipment performance.

Technology Assessment

The Office Technology Efficiency Consortium has sponsored office-equipment technology assessments by ACEEE and MIT to provide both energy-use benchmarks and better understanding of the specific sources of inefficient energy use within office equipment. The results of these assessments are the basis for the suggested new-technology development energy savings and features cited above.

Much more needs to be done in continuing technology assessment. The state-of-the-art in copiers, faxes, computers, monitors, and printers should be studied, with particular emphasis on the potential for improving energy efficiency with increased non-energy-related advances. Attention should be focused on attributes already known to need improvement, such as energy use, demand, power quality, and equipment reliability.

The economic penalties of poor power quality characteristics, in particular, need to be better documented. This understanding will provide the proof of benefits needed to encourage large-scale buyers and makers of electronic office equipment to raise their standards for power quality specification. This includes both the equipment's immunity to power quality deficiencies as well as its creation of power quality problems for other nearby connected loads.

As electronic office technologies evolve and require users to replace their equipment more and more frequently, alternatives to full replacement need to be assessed for feasibility. These alternatives can include retrofitting, upgrading, remanufacturing, and recycling.

Technology Transfer/Market Pull

Here the needed focus is on "pulling" new high-efficiency electronic office technologies into the market by creating user demand and other incentives for manufacturers. The Energy Star program is one example already in place. EPRI, ACEEE, DOE, and others have also sponsored workshops for major equipment users, manufacturers, and other interested parties such as Federal and state energy-related agencies and electric utilities. Outreach to users via publications is also beginning; examples include the Electronic Office Equipment brochure and Guide to Energy-Efficient Office Equipment (produced by ACEEE), both sponsored by the Office Technology Efficiency Consortium, which are distributed by electric utilities nationwide to their commercial account representatives and customers.

An international seminar on the status and prospects for high-efficiency /high-productivity office equipment is scheduled for late 1994 in New York City, to be sponsored by the Office Technology Efficiency Consortium. This event is intended to promote sharing the work being done in the United States, Sweden, France and other countries to aggressively develop and promote better office technologies.

Other needed efforts in technology transfer include the following:

- Prepare and publish a compilation and update of product listing of Energy Star-qualified and other efficient equipment. Provide electronic databases for energy-efficient equipment.
- Prepare and publish an update to the ACEEE *Guide to Energy-Efficient Office Equipment* to include product-specific data on efficient office equipment.
- Sponsor regional trade shows to display state-of-the-art efficient office equipment, systems, and user practices.

Also needed are market-pull activities, including participation by the electric utility industry, to encourage manufacturers to produce and aggressively market efficient power supplies, computers, copiers, printers, and faxes as well as new multi-function equipment.

We have come a long way in the two and one-half years since the Office Technology Efficiency Consortium was formed. The synergism created by unselfish striving toward the common goal of improving office equipment efficiency has been heartening. We expect even greater achievements in the next two and one-half years.

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