Who’s Snoozing in the Copy Room?
Addressing Active Mode in Imaging Equipment Efficiency Specifications

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ABSTRACT

The current ENERGY STAR specifications for imaging equipment address electricity consumption only in low-power modes. As products increase in functionality and speed, Active mode contributes to a greater portion of total product energy use. Additionally, consumer dissatisfaction with long recovery times can result in decreased use of energy-saving features. When EPA began to revise the imaging equipment specifications, the need to address Active mode for some products quickly became apparent. This was accomplished with the “typical electricity consumption” (TEC) approach that considers the electricity consumed by imaging equipment during its entire duty cycle. This method for assessing product energy efficiency has been received favorably by many stakeholders and demonstrates a forward-thinking approach to the development of an energy-efficiency specification. This paper reviews the process of creating the TEC method and resulting test procedure and specification levels. The authors present the key considerations for developing this innovative approach, including:

- Determining the universe of covered products;
- Harmonizing the approach with international standards;
- Developing the test method;
- Accounting for international usage patterns;
- Collecting new TEC data;
- Setting appropriate specification levels; and
- Securing stakeholder support.

The paper reviews specific lessons learned during this process and includes detailed examples that illustrate the vision for this new method.

The Roots of ENERGY STAR Imaging Equipment

In 1992, EPA introduced the first ENERGY STAR product specification for computers and monitors. The suite of products covered by ENERGY STAR expanded over the next five years to include imaging equipment such as printers, fax machines, copiers, multifunction devices, and scanners. The backbone of these and all ENERGY STAR specifications are performance criteria, which are developed in consultation with industry stakeholders to address a product’s energy or power consumption. The early ENERGY STAR imaging equipment specifications were generally characterized by performance criteria that addressed a product’s power consumption in low-power modes (e.g. Sleep or Off), and the default time in which the product’s low-power modes were activated. For example, the Version 1.0 ENERGY STAR copier specification launched in 1995 required that low-speed copiers enter an Off mode of fewer than five watts within 30 minutes of completing the last copy job.

Targeting low-power mode in imaging equipment was logical for EPA. Manufacturers were eager to participate in ENERGY STAR and there was available technology to employ power-saving modes in imaging products. By the time the copier specification had been in effect for one and one-half years, EPA had signed partnership agreements with copier manufacturers that produced more than 90 percent of the copiers sold in the United States, and had more than 100 models on the list of ENERGY STAR qualified products. Low-power mode consumption was the low hanging fruit that allowed EPA to engage industry enthusiastically in a new voluntary program that had achievable requirements and demonstrated value to partners and consumers.

Developing a New Approach

Factors Suggesting the Need for Change

ENERGY STAR adds value to a product category by assuring consumers that qualified models are more energy efficient than alternatives, allowing them to express a preference. The differentiation allows manufacturers to compete to satisfy consumer demand for efficient products, which will spur long-term market transformation and maximum energy savings over the long term. To achieve market differentiation, EPA sets a specification that not all products in the market can meet. Typically, approximately 25 percent of models will perform at a level sufficient to qualify when the specification is introduced.

In the beginning of 2003, EPA initiated a cycle of specification revision for imaging equipment. At that time, the specifications had been in effect for up to seven years and ENERGY STAR qualified printers, copiers, and fax machines accounted for 92 to 99 percent of units sold in 2000 (Gartner 2001). The high market penetration levels alone suggested that a review of ENERGY STAR performance specifications was warranted. In addition, revising the specifications allowed EPA to consider the following:

- Power and/or energy consumed in active modes;
- New technologies and functionalities that had entered the marketplace or become more prominent (e.g., color, digital, and multifunction capability);
- Consistency in requirements and terminology across imaging equipment and other ENERGY STAR products;
- Harmonization with other domestic and international organizations; and
- Streamlining of the product development process for manufacturers, as they tend to be involved in multiple imaging product categories.

Choosing a New Specification Approach – What Should It Accomplish?

At the outset of the specification revision process, EPA's consultants found a number of factors that shaped the approach: field data indicating long default times to low-power modes in many office equipment products, particularly in copiers and MFDs (Nordman et al. 1998); concerns over low power-management enabling rates (Roberson et al. 2004; Webber et al. 2001); and the apparent opportunity to achieve energy savings beyond that available in low-power modes. These factors prompted EPA to consider a new direction for some imaging equipment products. Information received from some partners and international stakeholders affirmed the importance of addressing the Active and Ready mode consumption of certain products.

Rather than extending the existing system to specific criteria for Active and Ready modes, EPA proposed assessing energy efficiency through a product's entire duty cycle, by covering all states and activities. The TEC approach continues to provide an incentive to partners to minimize the energy consumption of products in low-power modes while rewarding equivalent progress in Active and Ready. It was intended that the TEC approach would attain the following objectives:

- Relevance and Longevity - The new specification should resume the differentiation the ENERGY STAR mark brings to the marketplace and the reasonably attainable goal it provides for manufacturers. The TEC approach also provides a general framework that does not impede long-term technical innovation.
- Harmonization - The definitions, measurement methods, and criteria levels should be harmonized with existing international standards and test procedures as much as possible.
- Simplicity - Simplicity in the TEC test procedure makes it less onerous and expensive to conduct and increases the transparency of the process and results.
- Universality - Products should be tested with a similar method where possible, which should result in a clearer, more consistent set of specifications across product types.

Establishing the Universe of Covered Products

An important, initial step in creation of the TEC approach was deciding which products would benefit most from this duty-cycle method. Theoretically, all products could be evaluated to TEC. However, this was a new approach that required development of a test method and collection of data, and the testing and reporting is more burdensome than the existing system. Using TEC is most critical when a significant portion of a product's energy demand is in Active/Ready modes and users tend to disable or lengthen time to power management settings.

Therefore, EPA determined that standard-size copiers, printers, fax machines, multifunction devices (MFDs), and digital duplicators using electrophotographic (EP), direct thermal, dye sublimation, solid ink, and thermal transfer marking technologies were best suited to the TEC approach. These marking technologies use heat-intensive processes in transferring images to the media, which causes Active and Ready modes to dominate energy consumption and potential savings. Additionally, field data shows that products using these technologies are more subject to power-management disabling due to longer recovery times (Nordman et al. 1998).

The TEC structure is designed for the preceding, standard-size products, both monochrome and color. Small-format products and scanners have different usage patterns, and there is no indication of a recovery time problem. In addition, these differing usage patterns would require a modified test procedure. Ink jet products were not considered for the first iteration of TEC as they use little power in Ready mode and lack long recovery times. Digital duplicators were selected for consideration under the TEC approach based on high productivity and functional similarities to traditional copiers and printers.

Much of the rationale for addressing products by TEC applies to large-format EP products as well. These were not included due to the newness of the approach, the relatively small aggregate energy consumption involved, and the paucity of models and data in this sector.

However, at some future time, it may be appropriate to bring these products under the TEC framework. For other product types (most notably the large category of standard-sized ink jet), the additional energy consumption in Active does not seem large enough to merit the additional complexity of the TEC approach.

Test Procedure Creation

Once EPA had established the set of imaging equipment products to be addressed by TEC, the next step was to develop a test procedure. The TEC test procedure would specify a series of events to apply to each piece of equipment as well as the recording of accumulated energy use during each step. As consultants to EPA, ICF and LBNL would then develop a calculation to apply to the results to arrive at a figure of energy use over time (expressed in kWh/week).

The primary purpose of the TEC test procedure is to provide a consistent method of measuring and comparing the relative energy efficiency of similar products. It is important to emphasize that the procedure is not intended to precisely replicate real-life operating patterns, in part, since this will vary by country and specific use. In addition, the procedure is not intended to cover all aspects of product usage, but only those which substantially affect the TEC result.

Review of Existing Test Procedures

ENERGY STAR consultants ICF and LBNL reviewed existing test procedures to identify structure, principles, and components that could be used in or adapted for the TEC test. ASTM's "Standard Test Method for Determining Energy Consumption of Copier and Copier-Duplicating Equipment" provides a procedure by which copiers, copier-duplicators, accessories, and similar office imaging equipment may be rated for energy consumption. The TEC test procedure draws from its overall structure and calculation approach. The International Electrotechnical Commission's IEC 62301 informed the test conditions and parameters of the TEC test. International harmonization reduces the testing burden on manufacturers as well as the time associated with the procedure's design.

Test Parameters

Next, ICF and LBNL proposed parameters to specify how products should be configured and tested. Following are a few key parameters from the TEC test procedure and an examination of how EPA arrived at a conclusion.

In the initial draft of the procedure, it was specified that the test be performed in duplex mode for machines that are duplex-capable. Several stakeholders expressed concern that performing the test in duplex mode could be problematic. Since not all products that fall under the TEC approach have duplex capability, testing in duplex could mean that products of the same speed would be tested differently. In addition, limited data were obtained that indicated there were not appreciable differences in simplex and duplex imaging energy use for current products, so that no meaningful change in the TEC result was at stake. Allowing simplex output alleviated these concerns and provided for greater consistency across all products tested under the TEC approach.

Color-capable products are to be tested making monochrome images, unless they are incapable of doing so. EPA initially proposed monochrome-only testing on the assumption that energy efficiency of units tested making monochrome images is highly correlated to their efficiency producing color. Because some stakeholders argued that color imaging should be part of the test and would affect the results, both in general, and specifically, how serial and parallel color printers appear in comparison to each other, EPA decided that empirical data was required to proceed further. An additional color job was added to a draft of the TEC test procedure to collect data on how color image processing compares with monochrome, and several stakeholders submitted data, representing 16 products. For the 12 parallel EP models, the energy consumption for monochrome and color jobs was virtually identical. For the four serial EP models, color imaging was notably more energy-intensive than monochrome. EPA excluded four models from the 16-model dataset that were only instantaneous power measurements, and ranked the remaining 12 according to the calculated TEC result while printing in monochrome. These printers were then re-ranked according to their TEC result using only color imaging. For three of the serial units, the ranking for color printing as compared to monochrome printing changed slightly. However, a test involving 100% color imaging, as implied through color-only ranking, is not realistic. For example, one proposed ASTM test procedure for color-capable products includes approximately equal rates of monochrome and color imaging in the job tables. When the 12-printer dataset from above was re-ranked with half monochrome and half color imaging, there is only one very small difference from the monochrome-only ranking, resulting from a serial machine. Thus, a monochrome-only ranking essentially provides the same result as a mixed ranking.

The product shall be configured as-shipped and recommended for use, particularly for key parameters such as power-management default-delay times and resolution. Many TEC products have hardware components that can be added or removed, software settings that can be adjusted by users or service technicians, or settings that may be determined by incoming print jobs. The procedure's requirement for testing "as shipped and recommended" ensures transparency in test results and that users can readily achieve them in normal use. Testing a product other than as-shipped would offer the opportunity to "game" the system. This provision reassures manufacturers that other companies are not submitting skewed data.

Products are tested to the appropriate conditions of intended markets**.** Product testing should be performed at the relevant market conditions since energy consumption values may vary according to the input voltage/frequency combination and media type. Testing to market-appropriate voltage and frequency conditions has been the general procedure for ENERGY STAR testing in the past. As the ENERGY STAR program develops an increasingly international scope, EPA has determined that it is important to confirm that products meet the new specification at the representative market conditions where the products are sold. Parameters of concern are voltage, frequency, media size, and media basis weight.

Table 1. Testing to Global Conditions

Market	Supply Voltage, Frequency	Media Size	Media Weight
North America/Taiwan	115 V, 60 Hz	8.5" x 11"	75 g/m^2
Europe/Australia/New Zealand	230 V, 50 Hz	A4	80 g/m^2
Japan	100 V, 50 Hz / 60 Hz	A4	64 g/m^2

MFDs are tested in print mode, where possible. Users employ the print function on an MFD more often than the copy function, and testing both the print and copy functions of an MFD would complicate and lengthen the testing. If the page rendering process increases consumption, then the procedure should take that into account. EPA has not seen evidence showing that measuring both printing and copying would change the results enough to merit the added complexity of the procedure and calculations. The majority of stakeholders support these conclusions.

EPA did not initially propose a standard test image, believing EP products would require the same energy to produce any basic image. Even if very complicated images did use more energy, no manufacturer would choose to disadvantage their product during testing by using these. Some stakeholders felt very strongly about the value of a standard test image, and as there was no detriment to the procedure's development or testing burden, this was accommodated using an existing test image widely used in industry.

Designing the Test

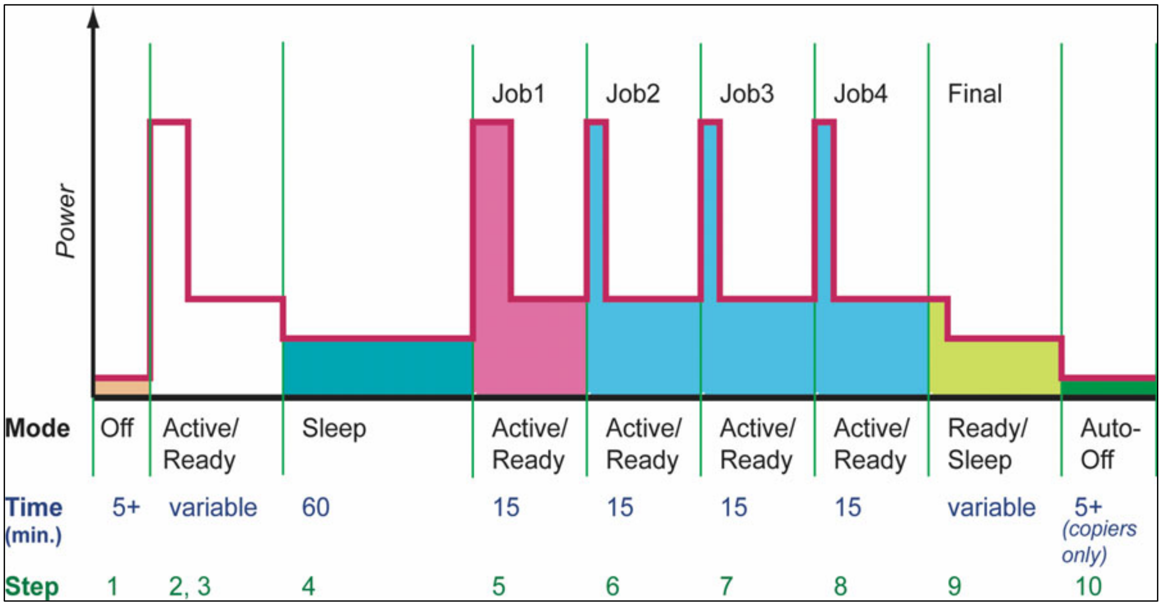
In creating the new TEC test procedure, ICF and LBNL had to assist EPA in determining what actions the product undergoes, the number of images to be made during active imaging, and how the energy measurements from the test would be extrapolated to a weekly TEC figure. Throughout all of this, it was important to address key testing variables that can differ by product speed and/or country/region. This was especially important, given that the specification will be used globally.

The measurement procedure. The TEC test procedure contains two measurement protocols—one for products assumed not to utilize an Auto-off function (printers, fax machines, and digital duplicators and MFDs with print capability), and one for products that do use Auto-off (copiers, and digital duplicators and MFDs without print capability). For all products, the test pattern consists of measuring:

- Off energy for five minutes or longer;
- Sleep energy for one hour;
- Four, 15-minute "job intervals," which capture the energy associated with recovery from Sleep, active imaging, Ready, and possibly Sleep; and
- "Final" energy, which includes energy used from completion of a job interval until the product reaches its final mode (Sleep or Auto-off).

ICF and LBNL carefully considered what number of jobs was necessary to reliably estimate job energy while not lengthening the test unnecessarily. The first job incorporates recovery from Sleep and so requires more energy than the rest. Job 2 is usually greater than job 3 as the thermal conditions in the fuser have yet to reach a steady state. Examination of early TEC test data made clear that three jobs would be too few, but that four jobs was sufficient. The average of jobs 2, 3, and 4 is taken as the average for all jobs after job 1 in the calculations.

Figure 1. The TEC Measurement Procedure



The job interval is 15 minutes for all products tested under TEC. Some stakeholders suggested that the job interval should be greater for lower speed products to better reflect sleep time during the day. Other stakeholders supported the static 15-minute job interval, noting that for EP products, residual heat from one job reduces the consumption of successive jobs. EPA decided to retain the 15-minute job interval in the final TEC procedure because it seemed to be the best single interval to use across the full range of imaging products.

Defining the job structure. One of the most difficult parts of creating the TEC test procedure was defining the imaging "job" — how many originals are presented, how many images of each original are made, and how often a job is performed. An example job is three images (duplexed) of five originals, every 15 minutes. This amounts to 15 images per job, 60 per hour, 480 per day, 9,600 per month, and 115,200 per year (based on eight hours per day of active use, and 20 days of use per month). The number of images made over a period of time is the "imaging rate."

The number of images per job is determined by calculations of jobs per day and images per day. The result reflects the assumption that products with greater imaging speeds typically produce greater numbers of jobs per day. The calculation of jobs per day was developed in response to stakeholder comments, which called for the calculated number of jobs per day to increase according to product speed, generally consistent with the ASTM test for copiers (ASTM 1997). The Job Table numbers in the TEC test procedure are based on regressions of manufacturers' monthly rated volumes. EPA took 20% of these figures to be closer to typical usage. In the context of the TEC test procedure, "speed" is the maximum claimed simplex speed making monochrome images.

Weekly extrapolations. The TEC calculation result could be expressed per day, per week, per month, or per year. EPA initially proposed a daily TEC result but changed it to weekly in response to strong stakeholder preference. The energy associated with events in the TEC test procedure is extrapolated to a total TEC value in kWh per week. The TEC calculations embody two clusters of jobs during the day, with the unit going to its lowest power mode in between (as during a lunch break), as illustrated in Figure 2. The "lunch" period was added in direct response to international stakeholders who commented that this slow down time is common. The TEC calculations assume that weekends have no usage and no manual switching-off is done.

Figure 2. A Typical Day, per TEC Calculations

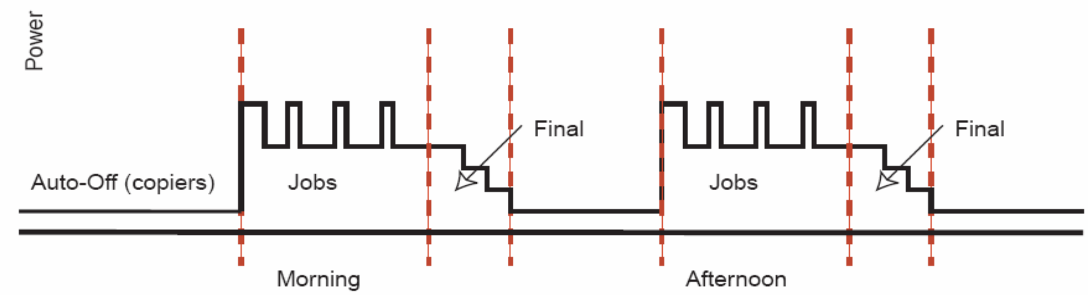


Figure 2 shows a schematic example of an eight-ipm copier that performs four jobs in morning, four jobs in afternoon, has two "final" periods and an Auto-off mode for the remainder of the workday and all of the weekend. The figure is not drawn to scale. Jobs are always 15 minutes apart and in two clusters. There are always two full "final" periods regardless of the length of these periods. Printers, digital duplicators and MFDs with print capability, and fax machines use Sleep rather than Auto-off as the base mode but are otherwise treated the same as copiers.

Establishing TEC Performance Criteria

Data Collection

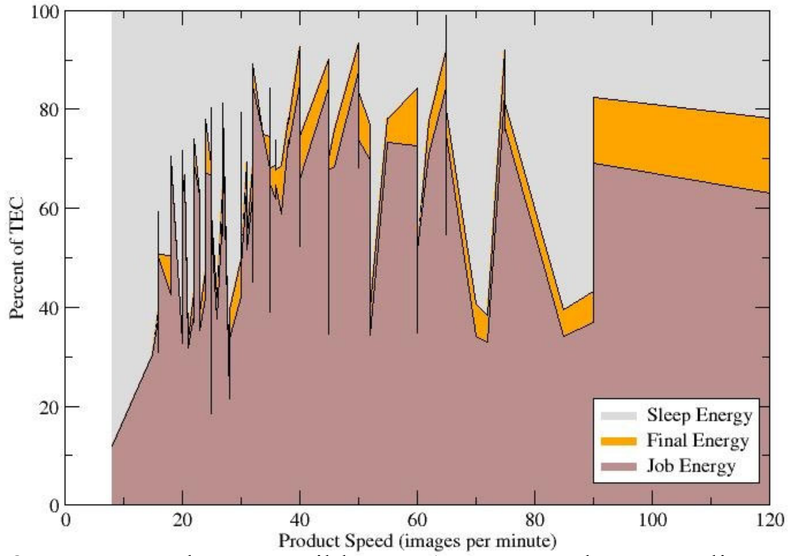
Once the TEC test procedure was finalized, EPA asked industry to test products and submit the results for analysis. Stakeholders were given just under four months to complete testing, were encouraged to test their newest models, and were invited to submit data on products that both could and could not meet the current ENERGY STAR specifications. In advance, EPA created a data worksheet to ensure all important data were captured and reported in a consistent format for easy analysis. Stakeholder participation in testing and data reporting was a critical component to this effort, as this was a new test procedure and previous data were unavailable.

Initial Conclusions from Data Analysis

As of this paper's preparation date, ICF and LBNL are in the process of assisting EPA with finalization of the specification. Therefore, the following section on establishing criteria presents the best thinking to date, although some details of the final energy efficiency criteria may change.

The role of job energy in total TEC. As shown in Figure 3, job energy contributes significantly to the Total TEC. Specifically, job energy accounts for an increasing percent of total TEC as product speed increases; products with speeds above 25 ipm always attribute greater than 50 percent of the total TEC to job energy.

Figure 3. Share of TEC Energy Consumption among Key Modes



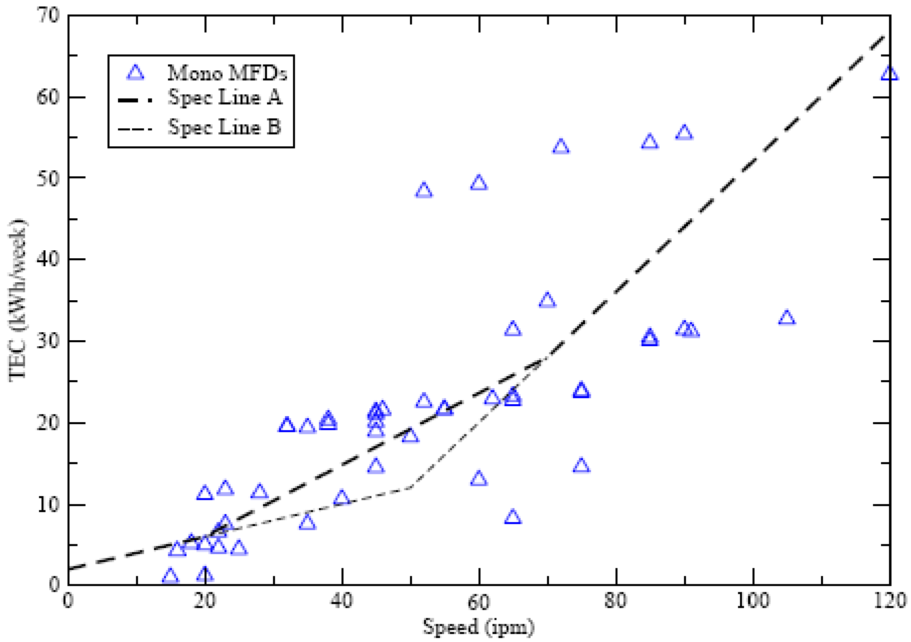
Use of efficiency formulas. Where possible, EPA attempted to use linear formulas when defining energy efficiency criteria that consider speed as the determining factor. Many stakeholders expressed a preference for this method, in particular, to avoid sharp jumps from small changes in product speed when bins of speed ranges are used. This suggestion is implemented in the Job Table as well as the proposed TEC specification.

The simplest approach to setting a specification line is a linear formula based on product speed. This works well across large speed ranges, but the imaging equipment specification covers an order of magnitude in speed and such a large range necessitates more than one single line. At low speeds, TEC energy is dominated by Sleep/Off energy, which is well correlated with speed. At high speeds, however, Active energy dominated and is driven by the number of images per week, which varies with the square of speed. A pair of two linear segments generally seemed adequate for the job, and the TEC data suggested that their "elbow" should be close to 50 ipm.

Figure 4 shows the TEC data submitted to EPA for monochrome MFDs, contrasting the TEC metric with product speed in images per minute. As an interim measure, the ENERGY STAR specification includes an additional allowance for products between 20 and 70 ipm for MFDs. The line was drawn to ensure a sufficient number of models above and below the line at a variety of speed points, and to be consistent with the lines for other products (printers, copiers, and color versions of all).

The effect of parallel requirements. To support other important energy efficiency initiatives, the criteria for ENERGY STAR qualified imaging equipment will include parallel requirements beyond a target TEC number. As examples, EPA plans to require standard and optional duplexing capability in various speed segments and will require that products with an external power supply use one that can meet ENERGY STAR requirements. As could be expected, these parallel requirements affect which models can meet ENERGY STAR and have an impact on EPA's goal to include approximately the top 25 percent of products on the market at the time the specification is set. To ensure parallel requirements do not reduce the number of qualified products below the intended level, EPA will consider the number of products that would fail the parallel requirements before creating formulas to set the TEC criteria.

Figure 4. Specification Line: Standard-Sized Monochrome MFDs



Engaging Stakeholders

The open participation of industry and other energy-efficiency authorities is crucial to the success of ENERGY STAR specifications and is comprised of three main components: A) open communication that ensures everyone involved has equal access to information; B) ensuring that stakeholders' feedback is considered carefully and regarded in some manner in the specification; and C) providing sufficient lead time before a specification becomes effective to ensure the levels are attainable. Even the most refined process will fail if there is a general perception that stakeholder feedback is disregarded or that timeframes are unreasonable.

Communication

EPA began the imaging equipment specification revision process with an open letter to all interested parties to explain the upcoming effort and anticipated timeframes. EPA then began meeting with individual manufacturers to understand concerns about the current specifications and changes they would like implemented. A Directional Draft (February 10, 2004) preceded a more official first draft specification and identified objectives, summarized thinking to date, proposed a general specification framework, presented comments received and responses, shared a timeline, and invited further input. The Directional Draft contained many placeholders and was a unique opportunity for stakeholders to comment at the very early stages of the process. The Directional Draft also contained definitions and terminology. The definitions and terminology associated with TEC were circulated early and often for feedback to establish a common language stakeholders could use when sharing additional feedback. Since the release of the Directional Draft, EPA has distributed for comment three drafts of the specification; six drafts of the TEC test procedure; summaries of and responses to all comments received; numerous interim updates, rationale, and discussion documents; and all data sets upon which conclusions have been drawn. To further ensure this process was transparent and collaborative, EPA has made all of the abovementioned documents available on the ENERGY STAR Product Development Web site at www.energystar.gov/productdevelopment, which is updated regularly.

EPA also gathered invaluable feedback from stakeholders during many meetings held in the US, Europe, and Asia. These meetings provided a unique opportunity to work through issues in an open forum, and for participants to hear the opinions of other stakeholders.

Incorporating Feedback

EPA's goal for the TEC approach was to develop a test procedure that allowed for the relative energy efficiency of imaging equipment to be measured and compared in a precise, repeatable way, and to create a specification that recognized approximately the top 25 percent of the market while fairly accounting for the increased energy required of higher-functionality products. Industry representatives and international program implementers know their products and markets better than anyone else, and their comments throughout this process contributed to a quality result.

EPA attempted to accommodate all comments that would lead to the best possible specification. As an example, requests for small changes or additions that would not affect the outcome were not deliberated extensively in an effort for simplicity. However, other comments did not align with ENERGY STAR guiding principles and could not be accommodated. Perhaps the most difficult comments to resolve were those that conflicted with other feedback received, or those that presented plausible changes whose impact could not be understood immediately. In addressing these last two categories of comments, EPA attempted to obtain empirical data to support the final decision. This ensured that all feedback was investigated carefully, and that ultimate decisions were easily understood by all. The issue of monochrome versus color imaging presented earlier in this document is an example of where EPA consulted test data to inform a decision.

Sufficient Transition Time

As product specifications come up for revision, EPA is committed to accommodating production cycles via establishing reasonable effective dates for new requirements. EPA strives to allow a minimum of nine months transition time between the final specification's publication and the effective date.

Conclusions

In summary, the time was right for EPA to address Active mode consumption in imaging equipment and TEC provided a flexible framework in which EPA could consider Active while achieving other important goals. The process was methodical and done in collaboration with stakeholders, and should lead to significantly more energy efficient imaging equipment products. This paper has presented a number of principles that were critical throughout the TEC development process. They include:

- Use of empirical data to drive key decisions;
- Embracing simplicity over strict "correctness" in many cases;
- The need for transparency, in process and result; and
- Cautious, deliberative decisions over time to produce a quality result.

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