Lean, Green, and Solid State: Measuring and Enhancing Computer Efficiency

Kimberly Herb, Peter May-Ostendorp, and Chris Calwell, Ecos Consulting
Rebecca Duff, ICF International

ABSTRACT

Computers represent a growing share of the electric load for homes and businesses. What opportunities exist to trim that load cost-effectively? In 2005, major processor manufacturers, including Intel and AMD, began to market their CPUs on the basis of operational efficiency rather than raw computing power, bringing the term "performance-per-watt" into the computer industry's lexicon. The shift in focus toward efficiency has evolved out of necessity, as computer manufacturers seek to achieve ever-greater computer performance while limiting the amount of heat generated by processors and video cards.

Computer efficiency in the active mode – when the computer is operating and not in "standby" or "sleep" mode – can be enhanced through a handful of core components working collectively to shave watts. The incorporation of highly efficient and right-sized power supplies, processor power-throttling features, and more efficient video cards in desktop computer designs can reduce active mode power draw by 25% to 50% while maintaining a suitable level of performance for the user. However, this prescriptive approach, i.e. requiring manufacturers to install specific equipment or technology, does not allow for fair comparisons of energy consumption based on performance levels. New energy efficiency benchmarking techniques help to measure differences in performance-per-watt (or performance-per-kWh) across a reasonable duty cycle, allowing researchers, manufacturers, and policy makers to evaluate the system-level efficiency of computers.

This paper discusses the latest developments in efficient computer components, benchmarking techniques, and the programmatic and policy implications of more efficient computing for utilities, government agencies, and computer equipment buyers.

Introduction

Once a product of privilege, computers are now found in a majority of households and businesses across the U.S. End users increasingly want more out of their computers to support high-end functions such as gaming, graphics editing, wireless communication, and media storage. As the demand for increased computer performance, capability, and availability grows, so does the need for power, as evidenced by the recent introduction of desktop computer power supplies with 1 kilowatt of rated power output (PC Power and Cooling 2006). The U.S. Department of Energy (DOE) projects that delivered energy consumption in the residential and commercial sectors will increase an average of 0.9% and 1.9% per year between 2003 and 2025, respectively. Within both of these sectors, computers represent one of the most rapidly growing energy demands, with total energy use increases in each sector of approximately 3% annually between 2003 and 2025 (U.S. Department of Energy: Energy Information Administration 2005). Table 1 further details the estimated annual energy consumption and electricity costs of computers in different sectors.[1] For perspective, the roughly 86 billion kWh of electricity used by mass-market computers every year is slightly more electricity than was sold in the entire state of Washington in 2002 (U.S. Census Bureau 2004).

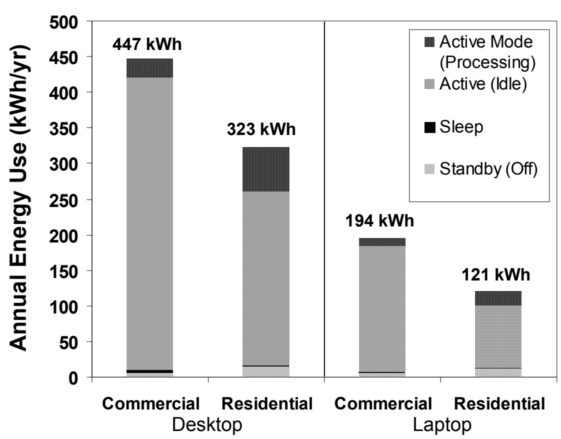
Table 1. National Energy Impacts of Computer Operation[2]

Product	Usage Pattern	National Stock (millions)[3]	Annual Energy Consumption (billions kWh)	Peak Load Contribution (GW)	Annual Electricity Costs (billions USD)
Desktop	Commercial	82	36	6	3.0
	Residential	50	14	3	1.1
Laptop	Commercial	85	16	2	1.3
	Residential	52	6	2	0.5
Pedestal Server[4]	Commercial	8	13	1	1.0
		TOTAL	**86**	**14**	**6.9**

While national energy consumption estimates help to illustrate the need for energy efficiency in this product category, understanding *how* computers consume energy and *where* the greatest losses occur enable us to identify opportunities for more energy efficient designs.

Energy use in computers varies depending on the mode in which a computer operates. These modes include standby (or off), sleep, and active. In standby and sleep modes, most components are powered down, but the power supply is idling and ready to power up the computer rapidly. In active mode, nearly all components of the computer are on and ready for quick response to user input. Idle state is a subset of active mode, where the computer is on, but no user input and minimal utilization of the central processing unit are occurring.

Figure 1. Estimates of Desktop and Laptop Computer Annual Energy Use



[1] Computer power consumption assumptions based on Ecos Consulting research. The energy savings calculations used to develop this table are based on U.S. EPA's methodology -- see www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Assumptions_Prelim_Draft_Comp_Spec.pdf.
[2] Note: these estimates exclude data center and enterprise servers. Electricity costs are based on a national average rate of $0.08 per kWh.
[3] Estimates of stock based on an assumed 4-year product lifetime and reported annual sales of desktops, notebooks, and servers made available by Gartner and through a report by Internet News at http://www.internetnews.com/stats/article.php/3578711.
[4] Pedestal servers are typically found in small businesses and use the same tower form factor common in many desktops. They are also referred to as "desktop-derived servers." Data center or server farm type servers are excluded from this category.

Figure 1 provides estimates of annual energy consumption by operating mode for desktops and laptops in commercial and residential environments. These estimates are based on lab measurements of active mode computer power consumption by Ecos Consulting and duty cycle surveys and estimates published by Lawrence Berkeley National Laboratory (Webber et al. 2001). In all cases, the majority of annual energy use occurs in the active mode. Ironically, the largest single portion of energy use occurs in idle state, when the computer performs little useful work for the user. Therefore, the largest opportunities for energy savings through more efficient computing can be achieved by addressing the active mode and particularly the idle state.

To date, energy efficiency advocates have focused primarily on sleep and standby power consumption. The current ENERGY STAR® computer specification is centered on power management (PM) features. These features have the potential to reduce energy use of computers by roughly 70%, but the potential has vastly gone unrealized, primarily because of very low enabling rates. (Nordman et al. 2000; Roberson et al. 2001; Webber et al. 2001). In the corporate and institutional world, information technology staff often disable PM to allow for network-wide software updates, data backups, and virus scans after the normal workday (Korn et al. 2004). Home users often disable (or simply fail to *enable)* power management in order to have immediate access to always-on broadband networking and digital entertainment features. Ironically, many users believe their computer *is* going to sleep when the monitor blanks after a few minutes of computer inactivity.[5] In short, EPA's best intentions to achieve universal power management have resulted in very intelligent hardware and software that are rarely used to their desired effect, though work is underway to address the problem in future revisions of the ENERGY STAR specification.

The current ENERGY STAR label has achieved such a high market penetration that it no longer highlights the most efficient computers. According to EPA, approximately 98% of all computers in the market are ENERGY STAR qualified. However, taking a closer look at qualifying models tells us that, while they might meet low power mode requirements, there can be significant differences in the energy used while in active mode. Take, for example, the two ENERGY STAR qualified computers shown in Table 2. Both have similar sleep mode power draw levels, but when tested in idle state, their power draw differs by more than 30 watts.

Table 2. Idle State Average Power Use (Watts) of Two ENERGY STAR Computers

Model Name	Sleep Mode	Active Mode/Idle State
HP Pavillion T250.fr	3.6	61.9
Acer Aspire T360	3.6	98.8

This variance is due in part to inefficient components that run in active mode. Our research suggests that, in the long term, a specification that addresses only the low power modes will overlook large potential energy savings. New efficiency specifications need to include consideration of active mode, while also distinguishing among computers with different levels of capability or performance. Currently no metric exists to ensure a fair assessment of computer efficiency that normalizes for overall system performance.

This paper identifies the existing challenges faced in trying to address computer energy efficiency and builds the case for policy makers and energy efficiency leaders to consider a standard benchmarking metric that incorporates computer performance into the efficiency

[5] Indeed, the distinction between computer and monitor sleep modes is understandably difficult to discern when a computer's principal means of conveying information to the user is via the monitor.

equation. We will discuss: 1) the latest trends and developments in efficient computer components; 2) current efforts to address active mode efficiency and their limitations; 3) the performance-based benchmarking concept, including key findings from preliminary test results; and 4) the programmatic and policy implications benchmarking presents to utilities, government agencies, and computer equipment buyers.

Computer Market Developments and Barriers

Trends and Successes

Several trends and successes in the computer market are helping to support the cause of higher active mode energy efficiency, albeit indirectly. These include:

Need for heat reduction. Manufacturers are coping with a series of performance-related barriers in their products that are resulting in the development of more energy-efficient product designs. In trying to increase performance by packing more transistors into CPUs, manufacturers are approaching the physical limits of how much heat can be reasonably generated and dissipated within the computer. As a result, the industry has started to move away from single-core processors with fast clock speeds to multi-core processor designs that can split tasks between separate processing cores (Intel Corporation 2005).

Migrating improved battery life strategies to desktops. Efficiency strategies that extend battery life in laptops are also energy saving opportunities for desktops. Prospects to significantly improve the battery itself are limited, thus, computer manufacturers are left with the challenge of extending battery life by lowering the loads that the batteries power. This has spurred a number of innovative power-saving features in CPUs and graphics cards, some of which already exist in desktops and others that could be migrated to desktop platforms.

Demand for smaller form factor. At the same time, consumers are increasingly showing a preference for small, quiet, unobtrusive home computers such as Apple's iMac. The smaller form factors in these exceptional designs limit options for heat removal, so manufacturers use highly efficient components to prevent heat from being created in the first place.

Together, the need for cooler, high performance processors, the demand for long battery life, and the constraint of small form factors have resulted in a growing market for energy efficient computer components. This has opened the door to new opportunities where active mode efficiency can be addressed by encouraging several best-in-class component technologies.

Highly Efficient Computer Components

There are two primary mechanisms to reduce the overall ac power consumption of computers when operating:

- Improve the *power conversion* processes inside computers by boosting efficiency in the ac-dc power supply (PSU) and various dc-dc power converters
- Lower the *power consumption* of key components inside the computer that demand dc power from the PSU, such as the CPU, graphics card, hard drives, etc.

We assembled a base case computer and then incorporated many of these energy saving features into a second design with similar performance to assess energy savings potential. Table 3 summarizes the estimated differences in power consumption by component. The low power use of the efficient desktop is achieved using a highly efficient power supply and two other optimized components – a mobile-based processor/chipset, and mobile-based motherboard-integrated graphics. The inefficient system uses an inefficient commodity PSU, a standard desktop processor/chipset, and more power-consumptive motherboard-integrated graphics.[6]

Table 3. Comparing Desktop Computer Power Budgets

Component Configuration	***Range of Idle Power (watts)***	***Base Desktop Idle Power (watts)***	***Efficient Desktop Idle Power (watts)***
CPU [a]	1 – 30	20	8
Video card [b]	10 – 30	15	10
1 hard drive, 1 optical drive, 1 GB memory, 1 case fan, motherboard [c]	20 – 35	26	21
TOTAL DC POWER	31 – 95	61	39
PSU Efficiency (300W)	65% – 83%	70%	80%
TOTAL AC POWER [d]	37 – 146	87	49

a. Source: Chin, Michael. "Desktop CPU Power Survey." *SilentPCReview*. April 5, 2006. http://www.silentpcreview.com/article313-page1.html
b. Source: Anton Shilov, Alexey Stepin, and Yaroslav Lyssenko. "The Grand Clash for Watts: Power Consumption of Modern Graphics Cards." *X-bit Laboratories*. February 1, 2006. http://www.xbitlabs.com/articles/video/display/gpu-consumption2006.html
c. Source: Patrick Schmid and Achim Roos. "The Intel and AMD Energy Crisis." *Tom's Hardware Guide*. July 13, 2005. http://www.tomshardware.com/2005/07/13/the_amd_and_intel_energy_crisis/page16.html
d. Source: measurements conducted by Ecos Consulting using a true power meter.

Barriers to Energy Efficiency in Computers

A handful of market barriers are currently impeding more efficient computing technology from entering the marketplace, including:

- **Initial Price Point** – The computer market is extremely competitive, with $299 entry-level machines putting enormous price pressure on more feature-rich designs. Computers have become a commodity product, especially for large purchasers with constrained capital budgets, such as the federal government. Computers that offer greater performance or capability command higher prices, but few desktop designs have been marketed on their energy efficiency, even if they reduce total cost of ownership.
- **Identification Method** – For years, computer manufacturers have sold and marketed computers based on performance characteristics. No other information about the machines' energy use under typical operating conditions is typically disclosed, so consumers have no basis for selecting more efficient equipment. A standard test procedure is needed to assess differences in operating efficiency.

Interest by typical consumers in more efficient computers might be modest initially, but there are already signs of substantial interest in high efficiency designs among companies and institutions with large numbers of computers in use. Financial firms have been reaching out to manufacturers since 2005, seeking computers with more efficient power conversion and, more

[6] This graphics card will provide higher performance to the user when exercising its 3D rendering capabilities, but for the most common computing tasks such as web surfing, office applications, e-mail, etc., it confers no major advantages over the motherboard integrated graphics processor.

recently, improved power management. But to help a market transformation towards more energy efficient computers, a few initiatives are emerging in the U.S. that target computer energy use and help consumers and institutions identify more efficient models.

Existing Computer Efficiency Initiatives and Approaches to Improve Active Mode Efficiency

The 80 PLUS® Program and the draft revision (version 4.0) of the ENERGY STAR desktop computer specification both address active mode computer efficiency through a focus on standard components that can deliver significant energy savings when computers are actively processing, idling, or in low power modes. Both programs focus on mainstream computers and low-end servers at present, but could move to address high-end servers (the type often found in data centers) in future revisions.

The 80 PLUS Program

The 80 PLUS Program,[7] a buy-down incentive program funded by utilities and market transformation organizations, encourages the use of highly efficient ac-dc power supplies in desktops and desktop-derived (pedestal) servers. The program provides incentives to manufacturers for computers sold in participating service territories that include power supplies certified as 80 PLUS compliant. 80 PLUS means that a power supply must be 80% or greater efficiency at 20%, 50% and 100% of rated load have a true power factor of 0.9 or greater at 100% rated load. In addition to acquiring cost-effective energy savings, the program supports manufacturers of highly efficient power supplies through buy-down incentives, which in turn reduces their cost and increases their competitiveness.

Revisions Underway for the ENERGY STAR Program

ENERGY STAR adopted similar power supply efficiency targets in its revised computer specification (Version 4.0), in addition to establishing new power consumption levels for sleep mode, standby/off mode, and idle state (U.S. EPA 2006). The revised computer specification is creating challenging efficiency targets for computer manufacturers to meet that will help differentiate labeled models from other available machines.

The challenge with setting an active mode specification in any product is to limit energy use without hindering advances in technology to meet consumer needs. EPA rejected limits on maximum power consumption when computers are actively processing in favor of a focus on idle state. The proposed specification does not specify which processors, video cards, or memory components must be used, but allows manufacturers to select preferred combinations of components that still yield the desired performance within the idle power budget allowed. More capable systems will be allowed high levels of idle power. Capturing differences in energy use when computers are actively processing will require a more comprehensive approach, deferred by ENERGY STAR until a Tier 2 revision of the specification in 2008 or later. This could take one of three approaches: prescriptive, functional adder, or benchmarking.

---

[7] Visit www.80PLUS.org for more information on the program.

The Future of Computer Efficiency Programs

The Prescriptive Approach

One way to account for performance and capability enhancements is to establish minimum efficiency levels or maximum power levels for a handful of the most power-consumptive components in a computer system. The power supply, processor, video card, and hard drive, for example, might be covered by such a specification.

Rather than specifying energy use of the whole computer, many components would be bound to specifications, each of which would require continual updating with the advent of new component technologies, networking protocols, video cards, or processors. The research and development burden on policymakers and industry stakeholders to find viable specification levels for a large number of components would likely be extremely burdensome.

Functional Adder

The functional adder approach allows a specified level of power consumption for a certain base computer system with minimal features and performance. The specification would then allow for increased power use for additional features such as higher performance processors, video cards, extra drives, etc. Rather than specify power use limits component by component, a functional adder formula would be created that adjusts the allowed total energy budget for the computer based on the number of added features and components present. As functionality increases, the allowable power consumption increases as well.

This option might allow manufacturers some additional flexibility in how they choose to meet efficiency targets. The appropriate blend of computing components could be chosen to optimize a system's overall functionality, efficiency, and cost. However, the approach suffers some of the drawbacks of the prescriptive approach, treating a computer system as a static collection of components instead of as a synergistic whole designed to accomplish particular tasks. The formula would require continual updating in order to keep pace with rapid technology development to ensure fairness and an accurate representation of the market.

The Benchmarking Approach

Rather than attempting to create specifications for a number of different elements of the computer, benchmarking software tools could be used to specify the efficiency of the entire system in various operational modes on a "sliding scale." This provides the potential for a holistic, system-level, software-based computer efficiency measurement approach that not only tracks the system's energy consumption but also normalizes for its performance.

Benchmark programs act as a "test driver" on the computer, performing a series of tasks (word processing, mathematical computation, image editing, etc.) that correspond with typical user behavior. A high quality power meter is able to log computer power use once per second during the benchmarking process, integrating over the course of the test to determine total energy use. Powerful computers might draw more power while the test is running but complete it faster, allowing them to compete against less powerful systems on an efficiency basis. Done properly, benchmarking captures both the performance of the computer and the energy investment required to achieve that level of performance. An ideal benchmark would emulate typical user behavior and duty cycles to achieve a reasonable snapshot of computer usage.

Much like Japan's Top Runner program,[8] a metric for computer efficiency under this approach would be expressed in terms of "performance-per-Wh," where "performance" is the score determined by benchmark software and "Wh" represents the total watt-hours of electrical energy consumed by the computer while the benchmark software evaluates its performance. Such a metric would be conceptually similar to miles per gallon, lumens per watt, and other common efficiency metrics expressed as the service provided divided by energy or power use.

Testing the Benchmarking Concept

Methodology

We analyzed three currently available benchmark programs for their suitability in efficiency benchmarking. All of the benchmarks examined are applications-based, meaning that they test computing performance using components of actual OEM software applications such as Microsoft Office and Adobe Photoshop. The first benchmark, PC Mark 2004, assessed computers' absolute speed and performance by timing the completion of computationally intensive tasks. The next two benchmarks, PC WorldBench 5 and SYSMark 2004, emulated typical user behavior by timing the completion of routine home and office tasks like word processing and file copying.

We configured two different desktop computer systems with a variety of different hardware components to assess the benchmarks. Each test system had three energy usage configurations (low, medium, and high) corresponding to the configuration of components listed in Table 4. We expected that the substitution of an efficient power supply in the "low" configuration would improve the efficiency of the system over the "medium" scenario by lowering power draw while keeping the performance the same. Similarly, we expected that the substitution of a high-end graphics card in the "high" configuration would decrease overall efficiency over the "medium" scenario by greatly increasing power consumption.

Table 4. Configurations of Computer Test Systems

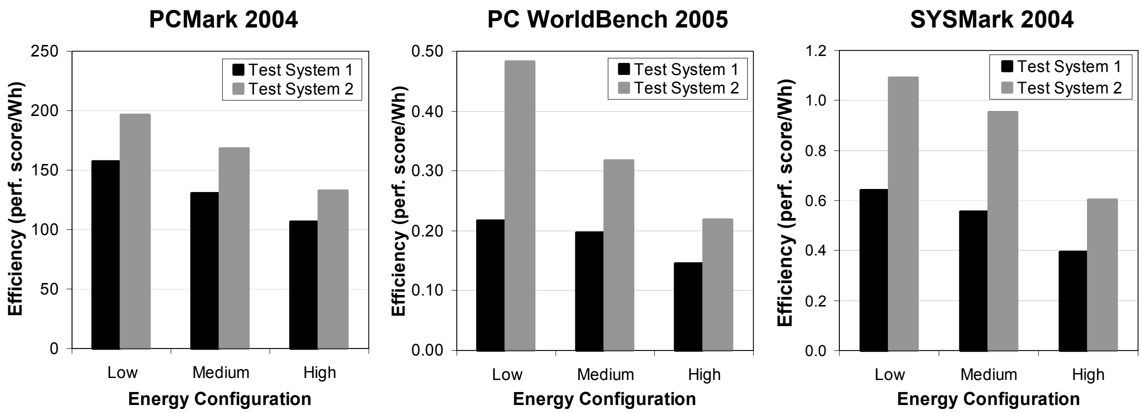
Energy Usage Configuration	Components Used
Low	Stock graphics, Efficient PSU
Medium	Stock graphics, Stock PSU
High	High-end graphics, Stock PSU

For each configuration, we ran one of the benchmark tests while recording energy use at one-second intervals. When the benchmark program was complete, we recorded the performance score and the energy consumed during the benchmark. By dividing the performance score by the

[8] The Top Runner Program determines computer energy efficiency by averaging idle and low power state wattage and then dividing by composite theoretical performance (CTP) in millions of calculations. According to the Ministry of Economy Trade and Industry (METI) Survey, the average energy efficiency per computer was improved by 4% in the four years after the program was introduced in 1997. Top Runner claims that the energy savings as a result of standards implementation are increasing faster than initial forecasts General Resources Energy Investigation Committee 2003. "Computer and Hard Disk Drive Judging Standards Subcommittee Final Report." http://www.eccj.or.jp/top_runner/pdf/tr_comp_magdisk.pdf.

energy in Wh, we arrived at the performance-per-Wh metric presented in the results in Figure 2. Because the score the benchmark generates is comparable only to other scores from the same software and because each benchmark runs for a different length of time, efficiency scores can only be fairly compared within one benchmark program.

Figure 2. Efficiency Benchmark Results



1. HP MediaCenter PC with 2.66 GHz Pentium 4 HT processor, 1 GB memory, 80 GB hard drive, CD-R/DVD-ROM combo drive
2. Custom-built AMD Athlon 3500+-based PC, 1GB memory, 120 GB hard drive, CD-R/DVD-ROM combo drive

Findings

We can draw several conclusions from this preliminary study that are encouraging to the cause of efficiency benchmarking:

- **All three benchmarks consistently ranked the efficiency of different system configurations.** The "low power" configuration with the highly efficient power supply was consistently ranked the most efficient configuration on both test systems using all three benchmarks. Similarly, the "high power" configuration with the high-end graphics card was consistently ranked the least efficient configuration because the card draws significantly more power while contributing little performance to most everyday tasks that do not require high-end 3D graphics processing.
- **All three benchmarks consistently ranked Test System 2 as the more efficient system.** Test System 2 contained an AMD Athlon 3500+ processor with Cool 'n' Quiet technology enabled, allowing the computer to cut its energy consumption by roughly 20% when idling. As such, it was not surprising that its efficiency scores as computed by this method were nearly double those of Test System 1. The results were somewhat closer using the PC Mark 2004 scores, but we believe this is because PC Mark is a "maximum performance" benchmark as described earlier. With fewer rest periods between tasks, the AMD processor might not have been able to take full advantage of its Cool 'n' Quiet technology to reduce processor voltage and clock speed dynamically, thus resulting in closer efficiency scores overall.

Despite these promising findings, there are still challenges to overcome before policy makers could embrace and implement a benchmarking approach.

Benchmarking Shortcomings

Our results confirm that a performance-based efficiency benchmarking test could be used to measure the operational efficiency of desktop computer systems using programs that are readily available today. However, a number of significant technical hurdles still need to be overcome before this method could be applied with confidence and convenience across a broad range of computer products:

- **An ideal efficiency benchmark should reflect *all* modes of operation, not merely the active modes of operation.** Although a computer's performance may be determined by what it can accomplish while turned on, computers today also spend periods of time in low-power modes like "sleep" or "hibernate." It is important that any efficiency benchmark capture the energy consumption of the computer in these modes as well. And since many computers consume most of their energy simply idling (turned on but not actively processing commands for the user), the duty cycle of any benchmark should reflect this fact by providing ample time between tasks to "rest".
- **An ideal benchmark program would be universal and could be compiled from source code on any commonly available operating system, Linux and Mac OS X included.** All of the benchmark software investigated for the purposes of this study ran solely on the Microsoft Windows 2000 or XP operating systems.
- **An ideal benchmark would be free from bias and incapable of being gamed.** Fairness is a concern with any benchmark program, and any benchmark developed for the purpose of measuring computer efficiency would certainly need to guard against inherent bias toward one technology, manufacturer, platform, etc. Additionally, it is not difficult to utilize information from the benchmarking code to make one system *appear* to perform better than others. Efforts to guard against this would be critical.
- **Benchmarks would be needed for a variety of specific user groups and product categories.** The benchmark programs discussed in this paper contain tests and applications that are specific to office and residential users. To measure product categories like servers or workstations, different tests should be used that reflect the common uses of those products.
- **The benchmark should address capability in addition to performance.** Many popular features do not generally improve processing speed but do increase energy use and add capability such as sound cards, TV tuners, multiple hard drives, and multiple optical drives.

Further Research

Despite these shortcomings, we believe that a benchmarking approach is worth further investigation. We did preliminary tests with two other benchmark software programs: SPEC CPU 2000 and software developed by Alterion, Inc. Each offers insight into what might be an ideal benchmarking approach, yet neither fully addresses the above mentioned shortcomings. SPEC CPU 2000 has the ideal qualities of being compiled from source code, thus working across platforms, and it is created by a non-profit organization through the coordination of industry stakeholders.[9] Alterion designs software specifically to help NASA determine which computers

[9] SPEC CPU is limited to benchmarking the performance of the CPU only and is highly dependent upon the performance of the compiler. There is no mechanism for capturing different modes of operation and no way to test

will best meet its needs. What they provide illustrates how benchmark software can be created with specific user groups in mind, but also presents installation and cost-platform challenges.

We assume that the bulk of active mode energy savings will come from targeting computers in the commercial sector; government procurement, large corporations, schools, etc., where a set of basic tasks are interspersed with long period of computer idle time. This suggests that future benchmarking efforts should include mechanisms for addressing the shortcomings detailed above, and the use of public domain or operating system-embedded software programs executing very common tasks – word processing, email, internet use, creating and extracting zipped files, viewing and searching PDFs, creating MP3s, etc. Most importantly, it would automate the creation of different duty cycles to reflect various usage patterns, interspersing periods of idle power as needed to estimate annual energy use in different environments.

Summary and Recommendations

While there are still many challenges to overcome, the benchmarking approach offers a number of benefits over the prescriptive and functional adder approaches. It may enable better harmonization globally, allowing for consistency across different efficiency programs worldwide, easing implementation for the manufacturer. Engineers would be given the flexibility to innovate and design to energy efficiency standards while balancing increasing performance and capability demanded by the marketplace. Providing consistent and valid energy use estimates to consumers puts the energy cost decisions into the hands of consumers and allows them to make comparisons between computers of similar performance, but not necessarily similar energy use.

Efforts to improve computer efficiency in the active mode could be remarkably easier and more flexible with the creation of an efficiency benchmark. Until then, what can the energy efficiency community do?

- **Join the Computer Efficiency Specification Process** – ENERGY STAR's meetings benefit from the inclusion of other perspectives beyond those of the manufacturers and the government. Customers, procurement officers, and utilities bring important viewpoints about total cost of ownership to the table to balance interest in always minimizing first cost.
- **Develop Procurement Guidelines** – Use available data on power supply efficiency and power use in various operating modes to specify more efficient products prior to the ENERGY STAR specification's scheduled effectiveness date of July 1, 2007. Manufactures such as Apple, Dell, and HP are beginning to include some of that data on their websites, while other data can be collected readily with a power meter from existing systems in offices and homes.
- **Promote Continuous Improvement in Computer Efficiency** – For many utilities and market transformation organizations, participation in 80 PLUS incentives and marketing has helped get computer efficiency efforts underway in their region. Subsequently adding a focus on idle power consumption, low power modes, and eventually full system performance via benchmarking, will give manufacturers additional reasons to compete with each other to minimize energy use.

---

for specific user groups. Additionally, because it is created by industry, everyone involved has access to the source code and it is possible to fine tune systems to perform well on the benchmark.

References

General Resources Energy Investigation Committee 2003. "Computer and Hard Disk Drive Judging Standards Subcommittee Final Report." http://www.eccj.or.jp/top_runner/pdf/tr_comp_magdisk.pdf

Intel Corporation 2005. Innovative Intel Power Solutions Increase Performance Per Watt. Technology at Intel.

Korn, D., R. Huang, et al. 2004. "Power Management of Computers: $1.5 Billion in Potential Energy Savings Annually." Presented at IEEE International Symposium on Electronics and the Environment, Arizona, May 2004.

Nordman, B., A. Meier, et al. 2000. "PC and Monitor Night Status: Power Management Enabling and Manual Turn-off".in *ACEEE 2000 Summer Study on Energy Efficiency in Buildings*. Washington, D.C., American Council for an Energy Efficient Economy. 7**:** 89-99.

PC Power and Cooling. 2006. *What's new at PC Power and Cooling*. Accessed on January 1, 2006. Available online:http://www.pcpowercooling.com/about/whatsnew/index.php#1KW.

Roberson, J. A., R. E. Brown, et al. 2001. "Field Surveys of Office Equipment Operating Patterns." LBNL-46930. Berkeley, CA: Lawrence Berkeley National Laboratory.

U.S. Census Bureau 2004. "No. 904. Electric Energy Retail Sales by Class of Service and State".in *2001Statistical Abstract of the United States: 2004-2005*. Washington, DC.

U.S. Department of Energy: Energy Information Administration 2005. "Residential Sector Key Indicators and Consumption." Washington, D.C.: Energy Information Administration. http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_4.pdf

U.S. EPA 2006. "ENERGY STAR Program Requirements for Computers: Draft 1 Version 4.0." Washington, D.C.: U.S. Environmental Protection Agency, ENERGY STAR Program. http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Program_Requirements_Draft1.pdf

Webber, C. A., J. A. Roberson, et al. 2001. "Field Surveys of Office Equipment Operating Patterns." LBNL-46930. Berkeley, CA: Lawrence Berkeley National Laboratory. http://enduse.lbl.gov/info/LBNL-46930.pdf