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Computers

Determining a Real-World Adjustment Factor for Computer Energy Use: Laboratory Testing the Impact of Real-World Idle, Active Mode and Peripherals

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Prepared for:



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1 Executive Summary

Current computer energy efficiency test procedures — such as those used in the ENERGY STAR version 6.1 specifications and the IEC 62623 international test standard — call for power measurements in idle (short and long), sleep and off modes under highly controlled conditions: the computer’s operating system has booted, the desktop screen is displayed, but no applications are or running on the computer. The main reason for stipulating these sorts of “sterile” test conditions is to ensure repeatable tests by limiting the number of third-party applications that could be running and taxing the system’s hardware during a test. However, an ideal energy efficiency test procedure should not only be repeatable under controlled laboratory conditions, but should also be able to approximate the real-world energy use of a given product.

In 2013, researchers and advocates for computer efficiency standards began to suspect that current test procedures might be failing this second criteria. The California Investor-Owned Utilities (CA IOUs) have been examining the impacts of test conditions on the energy consumption of computers since mid-2014, as part of their Codes and Standards Enhancement (CASE) efforts on client computers and proposals for a corresponding Title 20 mandatory standard for these products. Our research was initially motivated by testing and observations by the Natural Resources Defense Council (NRDC), submitted to the California Energy Commission in 2013, showing that the idle power of a given notebook computer could vary by 20 to 50% depending on the background applications and peripherals that were loaded or connected to it (NRDC 2013). In effect, NRDC’s estimates indicated that a notebook computer’s reported TEC could be 30% higher, on average, than the values reported using the ENERGY STAR test procedure due to significantly higher real-world idle power. Figure 1-1 illustrates the dramatic power fluctuations that can occur in notebook computers under different real-world loads, based on IOU spot measurements. Large spikes occur when new processes are being launched, but the 2-minute moving average power illustrates the general upward trend in system idle power, even after applications have been allowed to launch and stabilize.

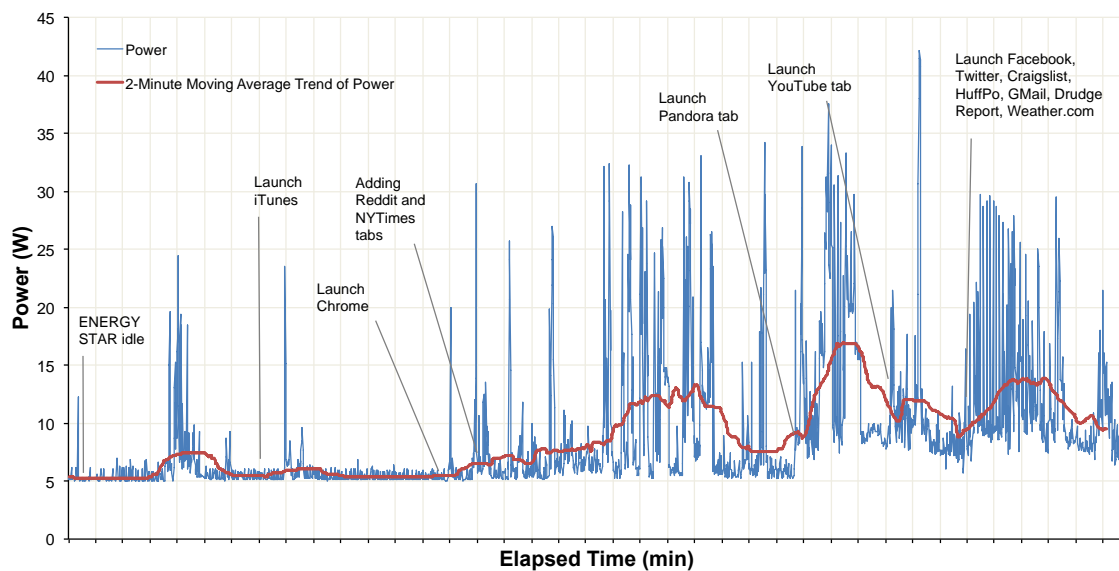


Figure 1-1: Power fluctuations in a notebook computer under real-world test conditions

Unfortunately, none of the available studies in the literature comprehensively address this issue, so in 2014, the CA IOUs funded a research project led by Ecova and Xergy Consulting to examine the impacts of real-world test conditions on TEC estimates made with the ENERGY STAR v6.0 test procedure. The project explored the impact of software and peripherals on idle power across a range of representative hardware. Researchers also tested several typical active usage scenarios on the systems to illustrate the additional error in TEC estimation that can occur when active usage is ignored. This report provides detailed descriptions of the methodology employed, test results, and potential errors in estimated TEC between ENERGY STAR and real-world test conditions.

At a minimum, IOU measurements of typical, real-world computing tasks have demonstrated what many already know to be true: computer energy use in the field will undoubtedly differ from what is measured under controlled laboratory conditions. However, the key findings of our research paint a starker picture of this disparity:

- Real-world usage of computers could result in 15 to 40% more energy use than estimated by the ENERGY STAR v6 test procedure, shown in Figure 1-2 below.
- Notebook computers — now the dominant PC format in the market — can use nearly 60% more energy under real-world conditions due to their improved power scalability and heightened sensitivity to even small increases in processing workload.
- Even if we completely ignore the active tasks that users conduct on their computers, we estimate that computers will still use 10 to 26% more energy than the ENERGY STAR procedure estimates because real-world idle power is significantly higher than under laboratory test conditions.

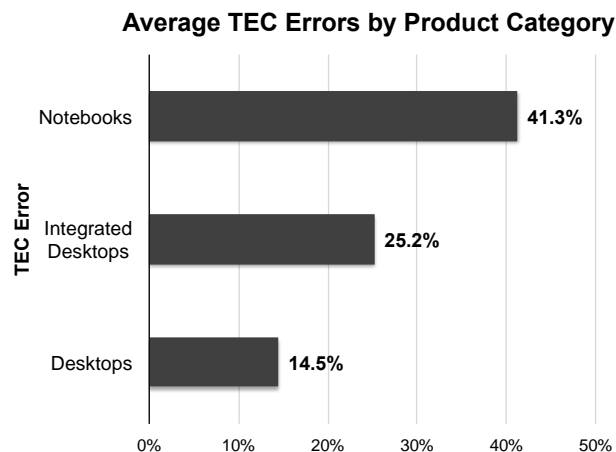


Figure 1-2: Percent increase in TEC under real-world test conditions compared to ENERGY STAR measured TEC

Given the large disparity between likely real-world computer TEC and established methods for testing and estimating TEC today, there are two major implications for computer energy efficiency policy. First, any regulatory analyses of computer energy consumption based on data collected with the ENERGY STAR v6 test procedure (or related test standards like IEC 62323) will contain significant error and substantially underestimate overall energy use and savings. Our analysis shows that about 50% of the adjustments presented in Figure 1-2 can be applied to energy savings

estimates. Secondly, policymakers will need to address the inadequacies in current test procedures and TEC estimation methods to account for real-world or field usage effects in some way.

Two main options are available to policymakers to address this issue:

1. **Modify existing test procedures with a field use factor.** Regulators could continue to conduct computer energy efficiency testing in the same manner and apply a field use factor after the fact, as has been done in the DOE clothes dryers test procedure, for example.
2. **Modify the test procedure routine itself to reflect real-world usage.** Test methods could generate more accurate TEC estimates directly by adopting test conditions that more closely replicate real-world conditions. For example, idle tests could be conducted with a standard suite of applications open to reflect the additional processing load incurred in the field. This option may impose slightly greater testing burden on laboratories or, in the case of self-certification, manufacturers, but would provide greater incentive for features that help to save energy under real-world conditions and not just ENERGY STAR idle.

For the current Title 20 rulemaking, the California IOUs continue to recommend the first option, however for future rulemakings recommend the second option as a more robust mechanism to encourage more accurate reporting of real-world computer energy use.

2 Introduction

Current computer energy efficiency test procedures — such as those used in the ENERGY STAR version 6.x specifications and the IEC 62623 international test standard — call for power measurements in idle (short and long), sleep and off modes. During idle testing, the computer’s operating system has booted, the desktop screen is displayed, but no applications are or running on the computer.¹ The main reason for stipulating these sorts of “sterile” test conditions is to ensure repeatable tests by limiting the number of third-party applications that could be running and taxing the system’s hardware during a test.² However, an ideal energy efficiency test procedure should not only be repeatable under controlled laboratory conditions, but should also be able to approximate the real-world energy use of a given product.

In 2013, researchers and advocates for computer efficiency standards began to suspect that current test procedures might be failing this second criteria. The California Investor-Owned Utilities (CA IOUs) have been examining the impacts of test conditions on the energy consumption of computers since mid-2014, as part of their Codes and Standards Enhancement (CASE) efforts on client computers and proposals for a corresponding Title 20 mandatory standard for these products. Our research was initially motivated by testing and observations by the Natural Resources Defense Council (NRDC), submitted to the California Energy Commission in 2013, showing that the idle power of a given notebook computer could vary by 20 to 50% depending on the background applications and peripherals that were loaded or connected to it (NRDC 2013). In effect, NRDC’s estimates indicated that a notebook computer’s reported TEC could be 30% higher, on average, than the values reported using the ENERGY STAR test procedure due to significantly higher real-world idle power.

2.1 Prior Research, Data Gaps and Project Motivation

The ENERGY STAR v6.0 specification is based on IEC 62623 Ed. 1.0, which is the dominant international standard addressing the energy efficiency of computers. The IEC 62623 standard includes provisions for measuring off, sleep, and short/long idle power as well as provisions for conducting measurements of power consumed during active workloads. ENERGY STAR decided not to test or adjust for active modes, based on the results of a 2010 profile study that showed energy consumed in active mode was negligible on an annualized basis (ECMA 2010). Although this approach may have characterized computer energy use in 2010, computing hardware and usage profiles have continued to evolve; today, power in idle and active modes can be significantly more sensitive to test conditions. There are several reasons for this, including:

1. Users typically have open windows, background applications and connected peripherals that all draw power or add processing load, even when the computer is idle.

¹ In reality, dozens of background processes are running on the computer that are invisible to the user, so the stipulation of “no running applications” is somewhat of a misnomer. The intent of the test procedure is that no *user-initiated* applications are running while tests are conducted.

² There is evidence to suggest that, even under these seemingly static conditions, a computer’s idle power use can vary somewhat depending on the type and number of system background processes and maintenance tasks that may be running at any given time. This issue is beyond the scope of this report.

- Recent technological advances have increased the ability of computers to scale power up and down depending on the work performed, increasing the power difference between idle and active and also making hardware more sensitive to even light, background processing loads that may be present in idle. Specifically, CPUs and GPUs now widely employ dynamic voltage and frequency scaling, power islands, graphics switching and other techniques to reduce power when little or no processing is required (Mittal 2014). Several commercial microprocessors support these technologies, e.g. AMD PowerNow and Intel's SpeedStep. Some newer processors, both AMD (TurboCore) and Intel (TurboBoost), have frequency scaling technologies that allow for on-demand *up*-scaling, providing bursts of increased performance (and power) during certain active tasks. Figure 2-1 illustrates this dramatic power variability and the overall trend toward increased idle power as several common applications and web services are opened on a notebook computer. Large spikes occur when new processes are being launched, but the 2-minute moving average power illustrates the general upward trend in system idle power, even after applications have been allowed to launch and stabilize.

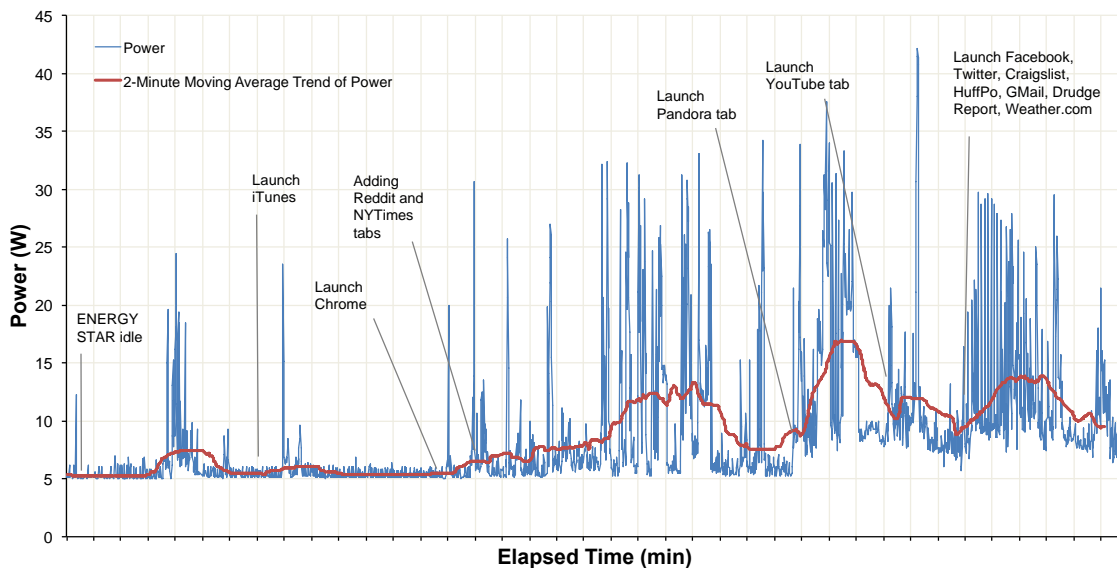


Figure 2-1: Power draw of notebook computer after launching various applications, based on 2014 IOU spot testing

- Although computers' energy consumption is still dominated by idle modes, the literature suggests that active computer usage continues to increase, especially in homes. Venkatesh *et al.*'s longitudinal analysis of four national U.S. surveys (1999, 2003, 2008, 2010), for example, showed increases in the number of activities performed on computers, including the rise of social media applications. Media market research firms, focusing more specifically at the online media consumption in homes, estimate U.S. households spend 0.9 to 3.1 hours per day online (Nielsen 2014, ComScore 2011 and EMarketer 2013), with computer usage increasingly dominated by online activities like video streaming and social networking (Short 2013). In the commercial sector, office desktop computers usage has also increased to an estimated 3.8 hours per day in active mode (Pixley and Ross 2014).

A few attempts have been made to measure the energy impacts of specific tasks and applications on computer energy consumption (Fraunhofer 2013, TÜV Rheinland 2012, NRDC 2014). Internet

browsers, for example, increase computer power draw by about 7 to 13 % for notebooks and 3 to 5 % for desktops, relative to the idle baseline (Fraunhofer 2013). Playing video content using Adobe Flash and HTML5 video increases power draw even more. Fraunhofer’s HTML5 benchmark test condition more than doubled the notebook power draw for all computers and browsers tested, while desktop power draw increased by approximately 50 % (Fraunhofer 2013).

Still, none of the literature fully addresses real-world usage impacts across multiple system types and diverse tasks. To more comprehensively explore this issue, in 2014 the CA IOUs funded a research project led by Ecova and Xergy Consulting to examine the impacts of real-world test conditions on TEC estimates made with the ENERGY STAR v6.0 test procedure. The project explored the impact of software and peripherals on idle power across a range of representative hardware. Researchers also tested several typical active usage scenarios on the systems to illustrate the additional error in TEC estimation that can occur when active usage is ignored. This report provides detailed descriptions of the methodology employed, test results, and potential errors in estimated TEC between ENERGY STAR and real-world test conditions. Our data suggest that the ENERGY STAR test procedure could underestimate computer energy use by 15 to 41%, depending on system type (i.e. notebook, desktop, or integrated desktop). Even if we ignore active tasks and only account for real-world idle conditions, real-world TEC could be 10 to 26% higher.

3 Establishing Real-World Test Scenarios

In the first phase of this research, the IOU technical team contacted computer industry experts — such as participants in ECMA 383 and IEC 62623 — and examined existing literature on computer duty cycles to determine representative idle conditions (referred to as “real-world idle”), active mode tasks and peripherals, estimate their prevalence in the marketplace, and establish approximate duty cycles. We prioritized tasks and peripherals based on a combination of their potential energy impacts, relative market prevalence, and duty cycle. Our estimates of market prevalence and duty cycle for individual tasks and peripherals are a combination of measurements/estimates from previous studies and common sense assumptions. We conducted preliminary testing on these most important tasks and peripherals to measure energy impacts (specifically, increases to short and long idle). Next, we combined the power draw with estimated prevalence and duty cycles to estimate the incremental TEC. Based on our rankings, we prioritized a total of 3 real-world idle scenarios, 5 active task scenarios, and two different peripheral configurations for testing. Since home and business computer usage differ, we developed separate sets tasks for each. There are several more universal tasks, such as web browsing, that are common to both home and business environments. Other tasks, such as gaming, are more sector-specific and were assigned accordingly.

The sections below describe the underlying intent and practical execution of each scenario and the peripheral configurations in detail.

3.1 Residential Scenarios

3.1.1 Real-World Idle Scenarios

1a) Real-World Idle Base Scenario – Scenario 1a forms the foundation for all other scenarios tested under this project and is the first incremental step toward estimating realistic usage. Rather than measuring idle values under “sterile” conditions (e.g. only the desktop is visible and the user has not loaded any programs into memory), our real-world idle scenario assumes that, even when most computers are idle, there are at least some programs loaded into memory and potentially some

third-party background applications operating in an automatic fashion that may influence power draw. In the residential setting, we test with the Google Chrome browser (v3.28.71) open and three tabs loaded: Google.com homepage, Gmail (user account logged in to main inbox), and the New York Times op-ed page.³ In addition, the user has three Microsoft Word 2013 documents (we used three different Word templates), one Adobe Acrobat Reader v11.0 window (a PDF copy of a brief, text-based memorandum), one Windows Explorer window (open to the computer's C drive), and one Windows Media Player 12 window open (not actively playing). A freely available anti-virus software suite is installed and running in the background (AVG AntiVirus v4.1), but not actively performing a system scan.⁴

1b) Real-World Idle Plus Additional Web Content – Scenario 1b builds on 1a by including three additional Chrome tabs: the LA Times homepage, Amazon.com homepage, and a Facebook.com newsfeed (user logged in).

1c) Real-World Idle Plus Flash Content – Scenario 1c adds one more tab to those already listed under task 1b. We include the Pandora web-based streaming music service, as it is freely available, prominent in the marketplace, and uses Adobe's Flash language as its foundation (our systems included version 15.0 of Adobe's Flash Player and browser plugin). A Pandora station is loaded, but the music itself is paused, making this a legitimate idle task.

3.1.2 Active Tasks

Note that for all active tasks, the applications listed in task 1a, Real-World Idle, are loaded.

2) Streaming Audio – We use the freely available Spotify desktop application (v1.8) to continuously stream an audio track. We chose an audio track of sufficient length that playback would not be interrupted by commercials during the test (i.e. one at least 5 minutes in length).

3) Streaming Video – The Netflix streaming video service is loaded in the Chrome web browser, launched in full-screen mode, and displays the opening episode of "Breaking Bad," a popular TV series. Our systems utilized the Netflix HTML5 player.

4) Video Chat – We utilize Skype (v6.2x), a freely available IP-based audio and video phone application, to hold a video call with another computer in full-screen mode. For most systems, we utilize a built-in web camera; however, in several systems without web cameras (desktops A, B and C), an external Logitech web camera was used. To minimize the image compression/decompression load on the system's processor, tests were conducted with the cameras of both systems trained on static images (e.g. a wall in the laboratory).

5) Virus/Security Scan – AVG anti-virus software (v4.1) is used to perform an active, user-initiated scan on the system's main hard drive.

6) Gaming – We capture five minutes of active gameplay using a web-based version of Angry Birds (an arcade-style action/puzzle game played through the Google Chrome browser) for systems with integrated graphics (A and F), and a copy of Team Fortress 2 (a team-based first-person shooter, in our case accessed and played through Steam, a popular online game platform).

7) Virtualization – Mac users frequently encounter situations in which they wish to access a Windows-based program and turn to virtualization software to run a Windows virtual machine on

³ We took care to avoid any web pages serving up highly animated ad content (e.g. Flash-based animations).

⁴ On Apple systems, Microsoft Office 2013 is replaced with Microsoft Office 2011 for Mac; Adobe Acrobat Reader is replaced with the native Apple Preview program (v8.0); Windows Explorer is replaced with a Finder window open to the computer's root directory in the startup drive; and Windows Media Player is replaced with Apple's iTunes software (v12.0).

their Mac. As a result, we only applied this scenario to Mac systems (D and F). We load the “host” Mac OS X operating system with the Real-World Idle task (1a), then launch a Windows 7 virtual machine using VMWare Fusion 7, a common virtualization product for Macs. The Windows 7 VM is then loaded with scenario 1a before taking measurements. Note that this scenario only applies to residential cases.

3.2 Business Scenarios

3.2.1 Real-World Idle Scenarios

Business real-world idle scenarios generally follow the same form as the corresponding home scenarios, but with some changes to applications to reflect enterprise usage.

1a) Real-World Idle Base Scenario – As with residential cases, Scenario 1a forms the foundation on which all other scenarios are built. The user has 3 Internet Explorer 11 browser tabs open, one to the Google home page, another to Gmail (user account logged in to main inbox), and another to the New York times op-ed page. Three Microsoft Word 2013 documents (stock templates), 2 Excel workbooks (again, stock templates), 2 Outlook 2013 windows (the main application window and a separate e-mail window), 2 PDF documents (text-based, open in Adobe Acrobat Reader 11), and 1 PowerPoint 2013 presentation (stock template), and 1 Windows Explorer window (open to the computer’s C drive) are open. In addition, AVG AntiVirus v4.1 software is running in the background, but not actively scanning.

1b) Real-World Idle Plus Additional Web Content – Scenario 1b for business is identical to the home version, except that Internet Explorer 11 is used instead of Google Chrome.

1c) Real-World Idle Plus Flash Content – Scenario 1c for business is identical to the home version, except that Internet Explorer is used instead of Google Chrome.

3.2.2 Active Tasks

Active tasks for business use were, in some cases, slightly modified to reflect applications more common in a workplace setting.

2) Streaming Audio – This task is identical to Scenario 2 for homes.

3) Streaming Video – The user streams a YouTube video in full screen-mode using a clip lasting greater than 5 minutes. Power values are only measured after any initial ad content has completed playing.

4) Video Chat – This scenario simulates an office video conferencing scenario. As with Scenario 4 for homes, we initiate a video call with another computer, training the web cameras of both machines on static images. GoToMeeting v6.3 web conferencing software is used instead of Skype, as it is more common among business users.

5) Virus/Security Scan – This scenario is identical to Scenario 5 for homes.

6) Screen Sharing – This scenario simulates screen sharing, an increasingly common task for collaboration among employees in different locations. The system under test shares its entire screen with a remote system using GoToMeeting v6.3 web conferencing software.

3.3 Peripheral Configurations

In addition to different software/task scenarios, systems were tested with different peripheral configurations. All scenarios were measured using the “low usage” peripheral scenarios, whereas a

subset of measurements were conducted under a “high usage” configuration as well. The high usage scenario might be a power user or enthusiast, whereas low usage is reflective of typical users. Configurations also varied based on the system type, since desktops and notebooks may have different peripheral requirements. Table 3-1 below describes the different configurations used.

Table 3-1: Peripheral Configurations

	Desktops		Notebooks	
	Low usage	High usage	Low usage	High usage
Home Configurations	Wired keyboard and mouse connected via USB, self-powered external speakers, Ethernet connected (1,000 Mbps link rate).	USB gaming (i.e. illuminated) keyboard, wireless USB mouse, USB-powered speakers, Ethernet connected (1,000 Mbps link rate), USB multi-function printer, USB audio headset, second monitor (1080x1920 resolution).	Self-powered external speakers, Wi-Fi connected to base station	USB-powered speakers, USB wireless mouse and keyboard, USB multi-function printer, second monitor (1080x1920 resolution, built-in screen still illuminated), Bluetooth wireless headset, Wi-Fi connected
Business Configurations	USB keyboard and mouse, self-powered external speakers, Ethernet connected (1,000 Mbps link rate)	USB wireless mouse and keyboard, USB-powered speakers, Ethernet connected (1,000 Mbps link rate), second monitor (1080x1920 resolution), USB audio headset	USB keyboard and mouse, self-powered external speakers, Wi-Fi connected	Docking station with USB keyboard and mouse, USB-powered external speakers, external monitor (1080x1920 resolution, built-in screen still illuminated), and Bluetooth wireless headset connected. Wi-Fi connected

3.4 Computer Selection

We selected eight different computers to provide a cross-section of typical hardware. Table 3-2 shows the systems tested: three conventional desktops, two integrated desktops, and three notebooks. We have indicated the ENERGY STAR performance category, market sector, and basic hardware configuration for each system. Our intent was to capture systems spanning a range of performance categories, form factors, and market segments. Market research was conducted using the ENERGY STAR qualifying products list and product listings from leading manufacturers to ensure that system selections were representative of typical products.

Table 3-2: Computer Systems

System ID	ENERGY STAR v6 Category	Sector	System Description
Desktops			
A	DT 0	Home	Dell Inspiron 660s (2013): Intel Celeron G465 1.9 GHz, 2GB memory, Windows 7
B	DT I2	Business	Dell OptiPlex (2014): Intel Core i3-4150 3.5 GHz, 4 GB memory, Windows 7
C	DT I3	Business	Lenovo ThinkCentre (2013): AMD A6-5400B 3.8 GHz, 4 GB memory, Windows 7
Integrated Desktops			
D	DT D2	Home	Apple iMac (2013): Intel Core i5-4670 2.9 GHz, NVIDIA GeForce GT 750M graphics, 8 GB memory, 1 TB hybrid hard drive, OS X 10.9 (Mavericks)
E	DT I3	Business	Dell XPS 27 Touch (2014): Intel Core i5-4440S 3.3 GHz, 8 GB memory, Windows 8
Notebooks			
F	NB I1	Home	Apple MacBook Pro (2014): Intel Core i5-4288U 2.4 GHz, 4 GB memory, OS X 10.9 (Mavericks)
G	NB I1	Business	Lenovo ThinkPad X1 (2014): Intel Core i5-4200U 1.6 GHz, 4 GB memory, Windows 7
H	NB D2	Home	Razer Blade (2013): Intel Core i7-4702HQ 2.2 GHz, NVIDIA GeForce GTX 765M, Windows 8

3.5 Testing Plan

Tables 3-3 and 3-4 below indicate the tasks and peripherals associated with each test. The numbers shown in the tables indicate the quantity of computers tested under each scenario; letters indicate the ID of the specific system tested (see Table 3-2 for a complete listing of computers, their hardware attributes, and associated IDs). Tables are also segmented into different peripheral-task combinations, with peripheral scenarios shown in the column headings and tasks indicated as rows. For a home user, the low peripheral case would indicate a casual computer user, whereas high peripheral use may indicate a “power user” with an extensive home office or entertainment setup. Similarly, the peripheral scenarios for the business cases indicate different intensities of peripheral use. We assumed that the power impacts of peripheral usage were independent of the underlying task scenario (i.e. there are no interactive or combinatorial effects between peripheral and task). As a result, peripherals were tested more sparsely than tasks to reduce the total number of tests performed. Though not all peripheral, task, and computer combinations could be explored under the scope of this project, we maintain that these scenarios are representative and still capture a diverse range of possible usage.

Table 3-3: Home Scenarios Test Plan

Tasks and Applications	Peripheral Combinations			
	Desktops		Notebooks	
	Low usage	High usage	Low usage	High usage
1a) Real-world idle	2 (A,D)	2 (A,D)	2 (F,H)	2 (F,H)
1b) Real-world idle 1a scenario plus web content	2 (A,D)	2 (A,D)	2 (F,H)	2 (F,H)
1c) Real-world idle 1b scenario plus Flash-based web content	2 (A,D)	2 (A,D)	2 (F,H)	2 (F,H)
2) Streaming audio	2 (A,D)	1 (A)	2 (F,H)	1 (F)
3) Streaming video	2 (A,D)	1 (A)	2 (F,H)	1 (F)
4) Video chat	2 (A,D)	1 (A)	2 (F,H)	1 (F)
5) Virus/security scan	2 (A,D)	1 (A)	2 (F,H)	1 (F)
6) Gaming	2 (A,D)	1 (A)	2 (F,H)	1 (F)
7) Virtualization	1 (D)	0	1 (F)	0

*Tasks 2 - 7 are performed running the applications specified in task 1a, real-world idle.

Note: All network interfaces, including wireless and Bluetooth, are powered on. In addition, the ENERGY STAR v6.0 test procedure requires that tests are conducted with a minimum of a mouse and keyboard connected (desktops only) and with an active Ethernet network connection.

Table 3-4: Business Scenarios Test Plan

Tasks and Applications	Peripheral Combinations			
	Desktops		Notebooks	
	Low usage	High usage	Low usage	High usage
1a) Real-world idle	3 (B,C,E)	3 (B,C,E)	1 (G)	1 (G)
1b) Real-world idle scenario 1a plus three IE tabs	3 (B,C,E)	3 (B,C,E)	1 (G)	1 (G)
1c) Real-world idle scenario 1b plus Flash content	3 (B,C,E)	3 (B,C,E)	1 (G)	1 (G)
2) Streaming audio	3 (B,C,E)	0	1 (G)	0
3) Streaming video	3 (B,C,E)	0	1 (G)	0
4) Video chat	3 (B,C,E)	0	1 (G)	0
5) Virus/security scan	3 (B,C,E)	0	1 (G)	0
6) Screen sharing	3 (B,C,E)	0	1 (G)	0

*Tasks 2 - 6 are performed running the applications specified in task 1a, real-world idle.

Note: All network interfaces, including wireless and Bluetooth, are powered on. In addition, the ENERGY STAR v6.0 test procedure requires that tests are conducted with a minimum of a mouse and keyboard connected (desktops only) and with an active Ethernet network connect

4 Laboratory Measurements

The laboratory tests commenced with a set of standard ENERGY STAR v6.0 tests, measuring power draw in off, sleep, long, and short idle modes. This provided baseline power draw values in different modes against which all real-world tests could be compared. Real-world idle measurements were conducted in the same way, except with the additional background tasks outlined in Tables 3-3 and 3-4.

Given the exploratory nature of this research, the various active mode measurements were conducted by adapting existing procedures. The IEC 62623 test standard (on which ENERGY STAR’s test method is largely based) *does* contain a section related to the measurement of active workloads (Section 5.3.6). We adapted this methodology by recording average power over a 15-minute window (at a sampling interval of one second), ensuring that we captured at least 5 minutes of usable data.⁵

All testing was conducted in Ecova’s lab, an EPA-recognized, CEC-approved, and ISO/IEC 17205 accredited laboratory.⁶ Equipment used for the testing phase of this project consists of high precision laboratory-grade instruments. Ecova maintained calibrated measurement equipment, conducted by an ISO/IEC 17025 accredited calibration laboratory. The equipment includes the following:

- Chroma Programmable AC Power Source 61602
- Yokogawa WT1600 Digital Power Meter

Testing complied with ENERGY STAR’s instrumentation measurement accuracy requirements:

- Power measurements with a value greater than or equal to 0.5 W shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level.
- Power measurements with a value less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level.

5 Formulating Real-World Adjustment Factors

The real-world adjustment factors or TEC errors calculated for this project were determined as according to methods outlined in the EMCA 383 standard, represented as:

$$\text{TEC}_{\text{err}} = \frac{\text{TEC}_{\text{new}} - \text{TEC}_{\text{old}}}{\text{TEC}_{\text{old}}}$$

Eq. 1

⁵ Background tasks can and do occur during active (and sometimes even idle) power measurements, so technicians and analysts took great care to exclude spurious power spikes from measurements and identify contiguous, 5-minute windows of “clean” data for averaging. The IEC 62623 test standard calls for using a prescribed workload of various tasks (rather than individual tasks) and for calculating the average power over the workload. It does not require power to be averaged windows of “clean” data.

⁶ For detailed information see http://www.energystar.gov/index.cfm?c=third_party_certification.tpc_labs and http://l-a-b.com/accredited-labs?field_scope_text_value=ecova&title=&field_state_value=All&field_country_value=All

where TEC_{new} is the real-world TEC of the test system and TEC_{old} is the TEC as computed using ENERGY STAR's default duty cycles (see sections below for discussion of duty cycle assumptions).

The ENERGY STAR TEC is the sum of energy consumption in off, sleep, short idle and long idle modes, each of which is a product of power, p , and time, t :

$$TEC_{old} = \sum_{\text{all modes}} p_{mode} t_{mode}$$

Eq. 2

To calculate the revised TEC — including the impacts of real-world short and long idle, active tasks, and peripherals — we use the same basic framework, but with three important modifications to account for real-world effects:

- We add the effects of active mode to the duty cycle and make appropriate modifications to annual usage hours (see discussion below).
- For each mode of operation, we substituted the standard ENERGY STAR modal power measurements with real-world measurements. For long and short idle, we used the average long and short idle observed in scenarios 1a-c. For active, we used the average power measured on each system for scenarios 2-6 (scenario 7 was included only for the Mac systems, D and F). Default ENERGY STAR values were used for off and sleep modes.
- Finally, we incorporated a fixed peripheral energy use term (E_{periph}) to the real-world TEC of all systems to account for those fraction of users in the field that use a greater number of peripherals. We conservatively assumed that only 25% of computer users actually use this higher peripheral configuration, so the high-peripheral configuration was weighted accordingly. This weighted average incremental power (p_{periph}) was multiplied with the total hours spent in all “on” modes (i.e. real-world short and long idle and active), as shown in equation 3 below.

$$E_{periph} = p_{periph}(t_{RW \text{ short idle}} + t_{RW \text{ long idle}} + t_{active})$$

Eq. 3

The total TEC_{new} used to calculate the TEC errors now includes the impacts of real-world usage, including higher idle power, active tasks, and peripherals:

$$TEC_{new} = E_{periph} + \sum_{\text{all RW modes}} p_{mode} t_{mode}$$

Eq. 4

5.1 Real-World Duty Cycle Modifications

The power for real-world long/short idle, active mode, and peripherals were measured as described in section 4, but we also adjusted the duty cycle to account for the time allocated to these modes for real-world usage. We used a 2013 study of residential digital media consumption conducted by James Short (2013) to infer the absolute time spent in homes conducting active tasks (video streaming, Web browsing, video chatting, etc.) (Figure 5-1). We conservatively estimate that homes use their computers for about 850 hours per year or about 2.3 hours per day for these active tasks. In this study, only tasks producing significant useful work are considered active tasks. We treat low-intensity tasks such as e-mail and productivity applications as equivalent to short idle mode. Note that this estimate is a little more conservative than the 4.3 hours per day used in the aforementioned Fraunhofer study (2013).

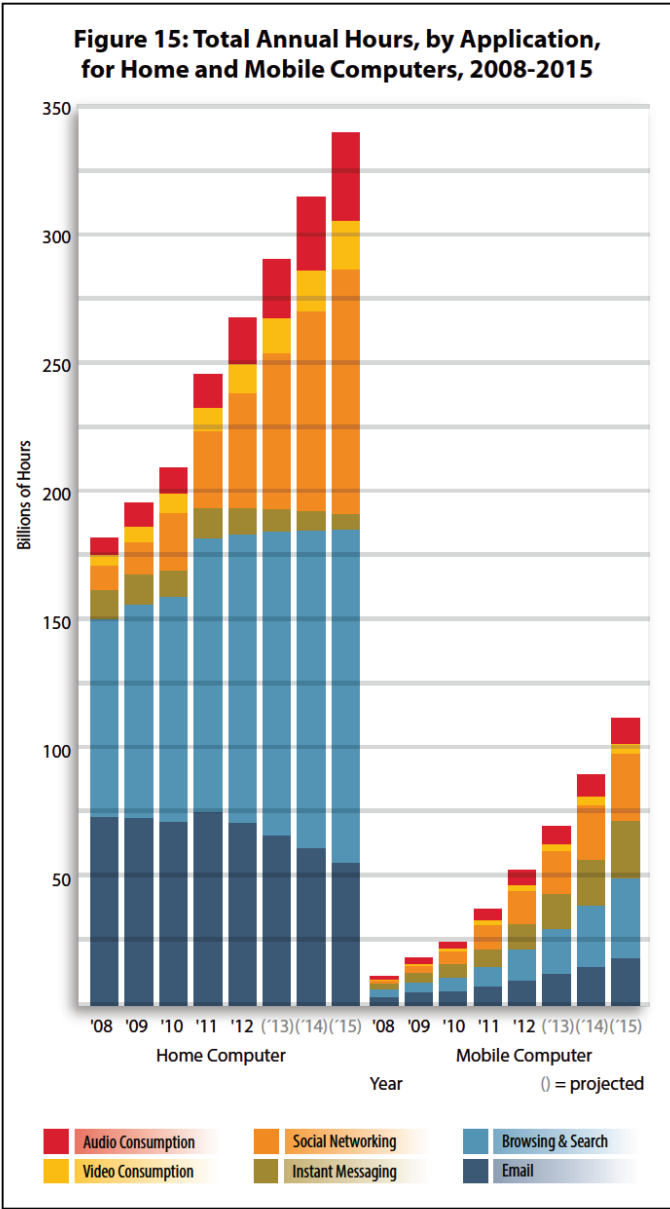


Figure 5-1: Home and Mobile Computer Usage from 2008-2015, by Application (Short 2013)

In the commercial sector, we used assumptions from a Dell client computer energy savings calculator and associated white paper to estimate active mode operation in office settings (Dell 2014). Dell’s calculator assumes that client computers are utilized for so-called “high performance” tasks — what we consider active tasks — about one hour per day or 250 hours per year (Figure 5-2). This is also a fairly conservative estimate, as it does not include productivity tasks (typical office work such as emails and document creation using standard office type applications) which Dell assumes constitute another 7 hours per day of activity. Other groups, such as the California Plug Load Research Center, have recently estimated the average active time for computers at 3.8 hours per day (Pixley and Ross 2014), so typical active usage in commercial computers could be nearly four times longer than we have assumed.

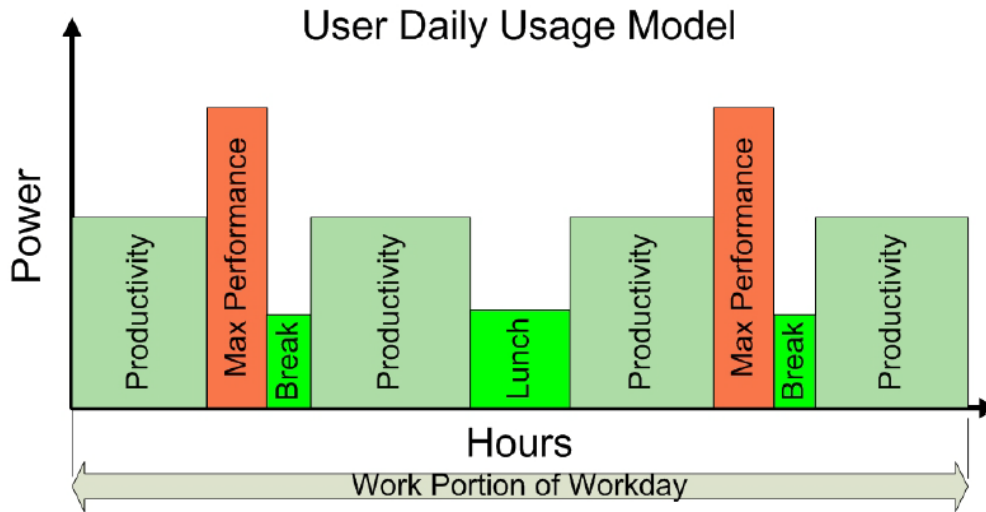
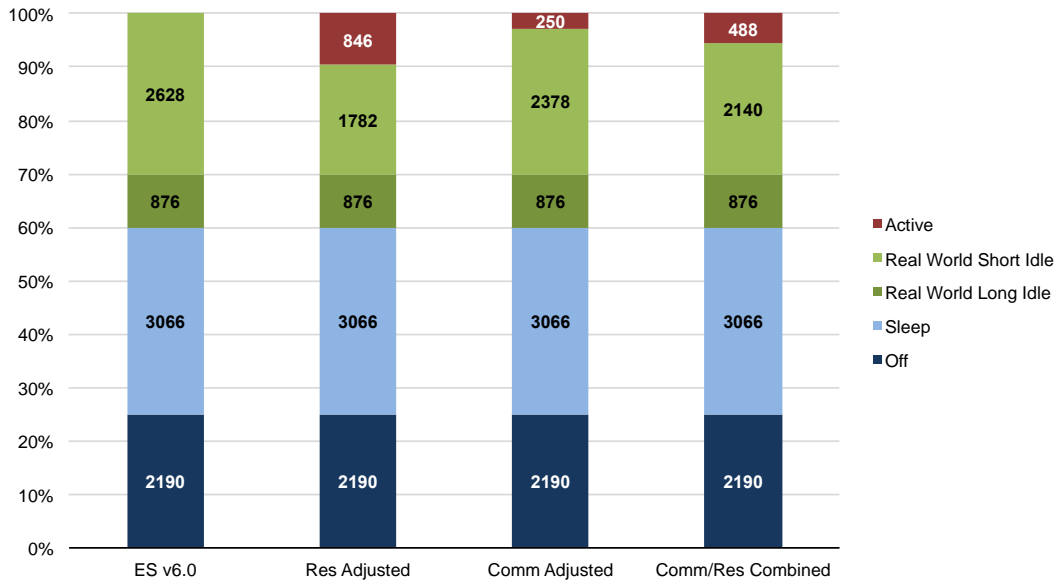


Figure 5-2: Typical Workday (Dell 2014)

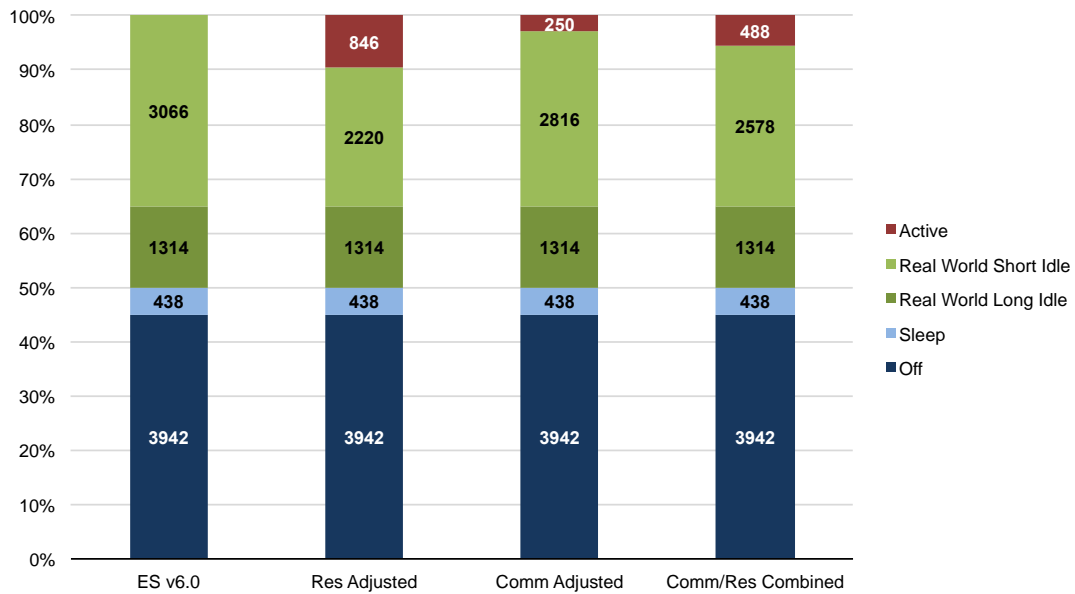
Finally, we assumed that active mode operation displaces time that would otherwise be spent in short idle mode. When combining residential and commercial duty cycles using a sector weighting — approximately 60% commercial and 40% residential based on sales and stock estimates (Hamm and Greene 2008)— we arrived at the following real-world duty cycles for notebooks and desktops (standard and integrated) (Figure 5-3). The baseline duty cycles on the left-hand sides of the charts represent the ENERGY STAR v6.0 duty cycles. Note that the time allocated to off, sleep and long idle modes remains the same in the baseline and the adjusted duty cycles, but that some of the time spent in short idle in the baseline duty cycles is spent in active in the adjusted duty cycles. We assume that any incremental power incurred by peripherals only applies to long and short real-world idle time as well as active time (3,504 and 4,380 hours per year for notebooks and desktops, respectively).

Notebook Real-World Duty Cycle (hours/year)



(a)

Standard and Integrated Desktop Real-World Duty Cycle (hours/year)



(b)

Figure 5-3: Notebook (a) and Desktop (Standard and Integrated) (b) Duty Cycles Adjusted for Real-World Usage

6 Results

In Figures 6-1 (home) and 6-2 (business), we compare the power values from the three real-world idle scenarios and active tasks with the power values from the ENERGY STAR v6.0 baseline measurements for all the systems we tested. Tests are grouped by mode (long idle, short idle, and active), with the ENERGY STAR baseline measurements highlighted in pastel at the bottom of each group. The average percent increase over the ENERGY STAR measured value is also labeled for each mode. In the case of active modes, the ENERGY STAR baseline value is the ENERGY STAR short idle measurement. Task 7 (Virtualization) was only measured on systems D and F, so other systems are shown as “n/a”. On several systems (B, C and F), reliable real-world long idle results were not obtained, so these appear as “n/a” as well. Values listed as “n/a” are ignored in calculating subsequent statistics.

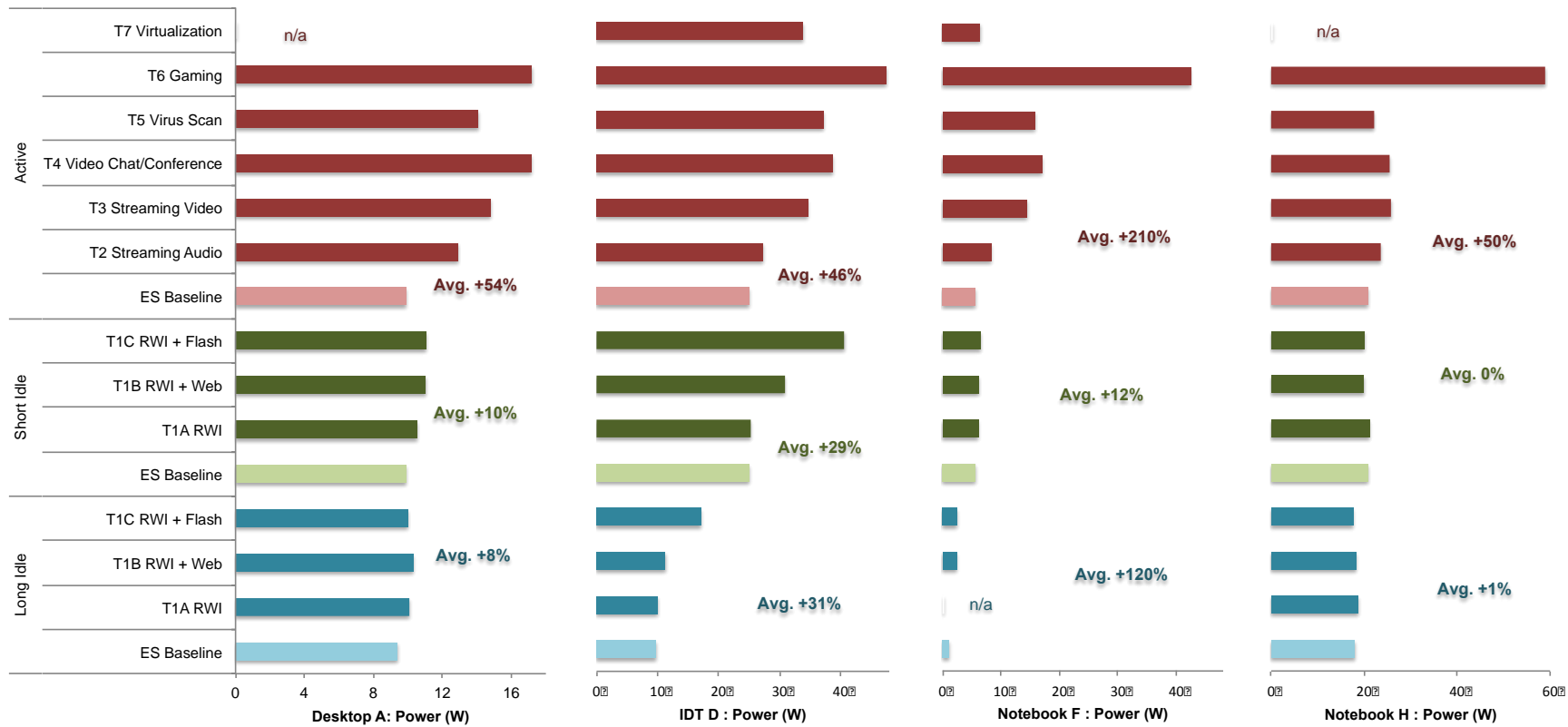


Figure 6-1: Home ENERGY STAR v6.0 Baseline and Real-World Power Measurements for each Idle Scenario and Active Task by Mode and System

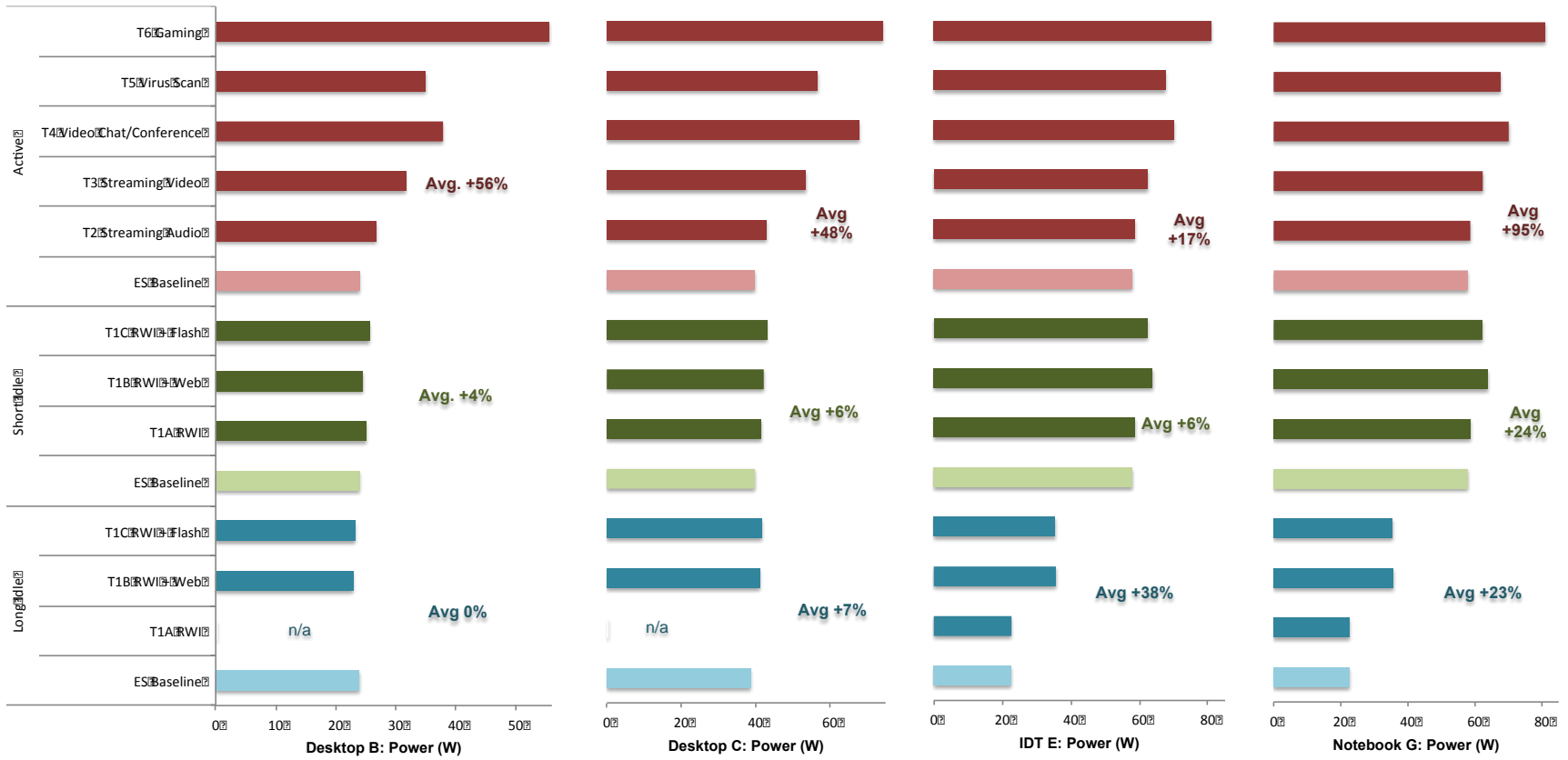


Figure 6-2: Business ENERGY STAR v6.0 Baseline and Real-World Power Measurements for each Real-World Idle Scenario and Active Task by Mode and System

Figures 6-1 and 6-2 show that for all systems in the residential and business sectors, the real-world idle impact was significant. Depending on the system, the idle power increased up to 120% in long idle (29% on average) and up to 29% in short idle (11% on average). For most systems we tested, there were no significant differences amongst the three real-world idle scenarios. For two notebooks (F and G) and the two integrated desktops, however, we found that the presence of certain web content during idle periods, particularly web content with animations, could drive up idle power by up to 70% in long idle and 61% in short idle.

Active tasks had an even more pronounced effect on power draw — on average, up to 210% compared with ES short idle. However, the amount of this increase can vary widely depending on the task and system — power draw measurements increased from 1% to 657% compared with baseline values depending on the task and system. Gaming and video chatting were among the most power-intensive activities for the residential sector. Gaming used an additional 26 W on average, 171% more than the ENERGY STAR baseline. Video chatting drew an additional 9 W on average, a 60% increase. For the business sector, power draw increased the most for screen sharing and video conferencing. Screen sharing used an additional 25 W, a 78% increase; video conferencing used 16 W more for a 50% increase.

We found that the same tasks impacted desktop and mobile hardware quite differently. Desktops typically saw a power increase of 53% for the active scenarios, while notebooks increased nearly 120%. This is likely due to the fact that, while both desktops and notebooks now contain power-scaling processors and graphics, notebooks with their incentive for longer battery life, still implement this technology more effectively and aggressively than desktops.

Peripherals generally did not have as dramatic of an impact as originally expected. The low peripheral configuration did not differ significantly from ENERGY STAR v6.0 test conditions, so the high peripheral configuration is effectively the only result of interest. Depending on the system, more intensive use of peripherals increased idle and active power draw from 1.2 to 6.2 W and, not surprisingly, did not “scale” with the overall power draw of the system.

Figure 6-3 provides a comparison of the TEC as computed using standard ENERGY STAR v6.0 measurements and the estimated real-world TEC based on laboratory measurements. Each mode is impacted differently. TEC associated with long idle increases across all computer systems because the time allocated to long idle in the adjusted duty cycle did not change, but the power increased by a factor of up to 1.38 depending on the system. Somewhat counterintuitively, the overall share of TEC in short idle *decreases*. Although short idle power increases by a factor of up to 1.29 under real-world conditions, our adjusted duty cycle now assumes that some of that time is spent in active — 16% and 19% for desktops and notebooks, respectively. Peripherals generally contribute very little to the TEC of the system, about 3.7 kWh per year on average. Active mode, however, can be another substantial portion of the TEC, particularly with today’s highly power-scalable processors.

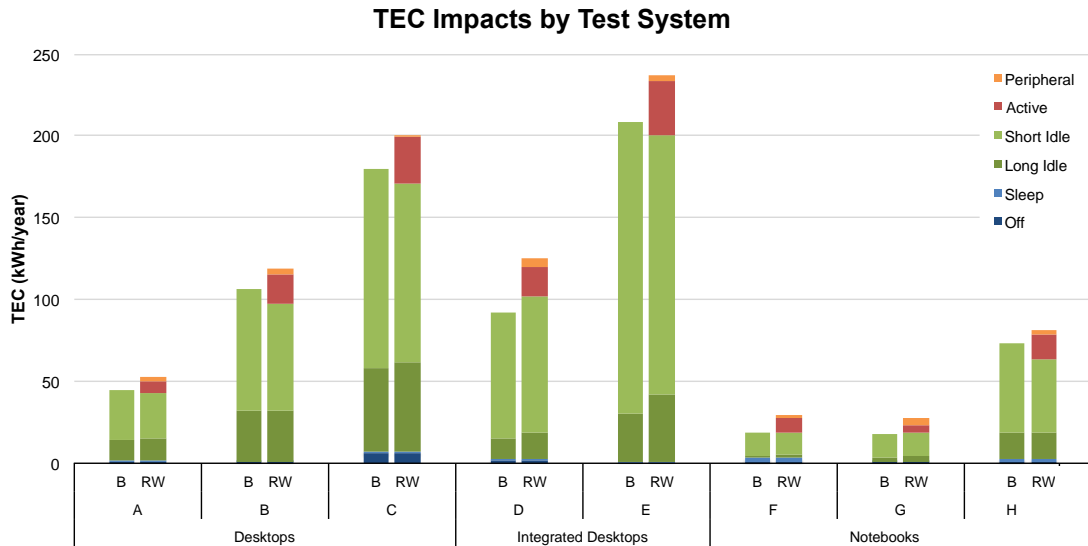


Figure 6-3: Baseline (B) and Real-World (RW) TEC Impacts by Test System

After averaging results by product form factor, we have illustrated the overall estimated TEC adjustment factors in Figure 6-4. The TEC adjustment factors used in the 2013 CASE report generally agree well with the TEC errors reported in this work (the CASE report estimated a factor of 15% for desktops and 30% for notebooks). The adjustment factors for integrated desktops and notebooks may, in fact, have been somewhat more conservative than our measurements suggest. The figure also illustrates the impact of ignoring active tasks when computing the TEC error. In other words, how would the real-world adjustment factors change if we applied our findings exclusively to the approved ENERGY STAR duty cycle and modes of operation? Note that even without any consideration of active modes, the estimated TEC still increases anywhere from 9.5 to 25.9%, depending on the product category.

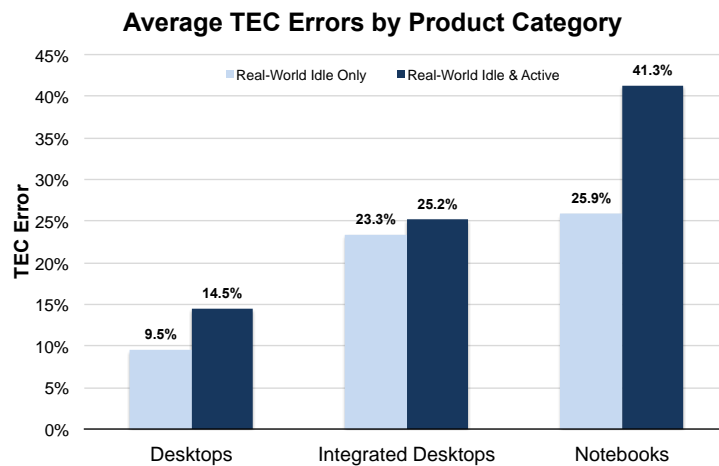


Figure 6-4: Real-World TEC Adjustment Factors by Product Category

*Note: The overall TEC adjustment factor for notebooks has changed slightly since the publication of the CA IOUs' CASE report supplement due to a data reporting error in that report (CA IOUs, 2014).

6.1 Applicability of TEC Adjustment Factors to Energy Savings Analyses

While some of the energy-using components in a system (e.g. hard drives, optical drives, network interfaces) demand about the same amount of power whether the system is under short idle conditions or intense workloads, other system components—CPUs, GPUs, power supplies, and memory—will be driven harder and consume more power under real-world loading.

To illustrate the concept, consider the energy savings calculations below between a base system (B) and efficient system (E). Each system's energy budget consists of "scalable" and "fixed" portions. Real-world workloads only exercise the power-scalable pieces of hardware, so in the energy savings calculation, the $TEC_{\text{adjustment}}$ only multiplies the scalable part of the energy budget:

$$\begin{aligned} TEC_{B,\text{real world}} &= TEC_{B,\text{scalable}} * TEC_{\text{adjustment}} + TEC_{B,\text{fixed}} \\ TEC_{E,\text{real world}} &= TEC_{E,\text{scalable}} * TEC_{\text{adjustment}} + TEC_{E,\text{fixed}} \\ TEC_{\text{savings,real world}} &= TEC_{B,\text{real world}} - TEC_{E,\text{real world}} \\ &= (TEC_{B,\text{scalable}} - TEC_{E,\text{scalable}}) * TEC_{\text{adjustment}} + TEC_{B,\text{fixed}} - TEC_{E,\text{fixed}} \end{aligned}$$

The $TEC_{\text{adjustment}}$ should only apply to a portion of the energy savings, but which portion and how much? Our technical team has established two basic criteria for applying this factor. Energy savings measures that 1) provide meaningful savings in idle and active modes and 2) are power-proportional (generate larger savings as the system's workload and power increase) are applicable. Figure 6-5 illustrates a number of promising energy-savings strategies for computers and maps them by mode and power proportionality. Measures highlighted in green are considered applicable. Measures highlighted in red either do not apply to idle/active modes or provide fixed savings.

Operational Modes	Savings Scale Proportional to System Workload	
	Yes	No
Off		Improved PSU standby rail efficiency
Sleep		Real-time power management of unused network interfaces, peripheral ports, etc.
ES Idle	Improved power supply AC/DC conversion efficiency	Reducing power supply parasitic/fixed losses
Real-World Idle	CPU & GPU power scaling, keystroke sleep	Efficient HDD technology
Active	Next-generation silicon process improvements	Real-time power management of unused network interfaces, peripheral ports, etc.

Green = applicable measures
Red = inapplicable measures

Figure 6-5. Matrix of Computer Energy Efficiency Measures and Applicability to $TEC_{\text{adjustment}}$ Multiplier

The energy savings from several energy-saving strategies are likely to be increased when taking real-world usage into account. Improving AC/DC power supply efficiency remains a promising, cost-effective compliance path, and associated savings will increase if systems are more heavily loaded. Similarly, die shrinkage and continued refinements to silicon components will continue to

reduce power demand at a variety of load points. Implementation of low-latency, device-level power management—sometimes referred to as “keystroke sleep”—will also help to lower power demand across a range of CPU and GPU load conditions.

We cannot anticipate the exact paths that manufacturers will pursue to comply with standards, but we assume that at least 50% of the savings generated by standards will be derived from a combination of the strategies highlighted in green. Therefore, we recommend that the TEC adjustment factors in Figure 6-4 be applied with a 50% weighting when applying them to energy savings estimates (i.e. 21%, 13% and 7% for desktops, integrated desktops, and notebooks, respectively).

7 Conclusions and Implications

At a minimum, IOU measurements of typical, real-world computing tasks have demonstrated what many already know to be true: computer energy use in the field will undoubtedly differ from what is measured under controlled laboratory conditions. However, the key findings of our research paint a starker picture of this disparity:

- Real-world usage of computers could result in 15 to 40% more energy use than estimated by the ENERGY STAR v6 test procedure.
- Notebook computers — now the dominant PC format in the market — can use nearly 60% more energy under real-world conditions due to their improved power scalability and heightened sensitivity to even small increases in processing workload.
- Even if we completely ignore the active tasks that users conduct on their computers, we estimate that computers will still use 10 to 26% more energy than the ENERGY STAR procedure estimates because real-world idle power is significantly higher than under laboratory test conditions.

Given the large disparity between likely real-world computer TEC and established methods for testing and estimating TEC today, there are two major implications for computer energy efficiency policy. First, any regulatory analyses of computer energy consumption based on data collected with the ENERGY STAR v6 test procedure (or related test standards like IEC 62323) will contain significant error and substantially underestimate overall energy use. Similarly, energy savings analyses based on these data will underestimate potential benefits, significantly limiting the levels of cost-effective savings that could be justified in a rulemaking. Therefore, the California IOUs recommend the TEC adjustment factors in Figure 6-4 be applied with a 50% weighting when applying them to energy savings estimates: 21% for desktops, 13% for integrated desktops, and 7% for notebooks. Secondly, the large disparity between likely real-world computer TEC and established methods for testing and estimating TEC today implies that policymakers will need to address the inadequacies in current test procedures and TEC estimation methods to account for real-world or field usage effects in some way. Accounting for field usage in test procedures is not a foreign concept in the energy efficiency sphere. For example, the current DOE clothes dryer test procedure includes field usage factors to account for the differences between laboratory test loads

and the more complex and energy-intensive loads handled by clothes dryers in a real-world setting.⁷ Addressing real-world usage in computers should be no different.

Two main options are available to regulators to address the current field usage issue:

1. **Modify existing test procedures with a field use factor.** Regulators could continue to conduct computer energy efficiency testing in the same manner and apply a field use factor after the fact, per the clothes dryers example above. The adjustment factor could be developed using the data we present here or potentially a larger dataset that takes into account a broader range of computer types and software scenarios. The field usage factor might require periodic updating if there are significant shifts in computing hardware and applications.
2. **Modify the test procedure routine itself to reflect real-world usage.** Test methods could generate more accurate TEC estimates directly by adopting test conditions that more accurately replicate real-world conditions. For example, idle tests could be conducted with a standard suite of applications open to reflect the additional processing load incurred in the field. This option may impose slightly greater testing burden on laboratories or, in the case of self-certification, manufacturers, but would ultimately be a more accurate and equitable way to estimate the TEC of a system, which can vary greatly depending on hardware, power management techniques, etc. Incorporating realistic test conditions into the test procedure itself also has the virtue of incentivizing manufacturers to develop innovative, real-time power management technologies that can bring idle power levels down under realistic test conditions. Today, such technologies are mainly used in notebook products as a means to extend battery life, but desktop form factors currently have little incentive to improve in this regard. An example of such a technology is Apple's "App Nap" feature in OS X, which actively reduces loads on the CPU/GPU based on the visibility of content (background applications are given lower priority and, in effect, slowed down).

For the current Title 20 rulemaking, the California IOUs continue to recommend the first option, however for future rulemakings recommend the second option as a more robust mechanism to encourage more accurate reporting of real-world computer energy use.

⁷ See Table II.1 of DOE's *2013-08-14 Energy Conservation Program: Test Procedures for Residential Clothes Dryers; Final Rule* for example applications of field use factors in the DOE's dryer test procedure, available at <http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0054-0024>.

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Appendix A Test Results

Table A-1: Real-World Adjustment Factors and TEC Calculations

	Desktops			Integrated Desktops		Notebooks		
	A	B	C	D	E	F	G	H
Real-World Testing Impacts								
Real-world long idle impact factor	1.1	1.0	1.1	1.3	1.4	2.2	1.2	1.0
Real-world short idle impact factor	1.1	1.0	1.1	1.3	1.1	1.1	1.2	1.0
Active impact factor	1.5	1.6	1.5	1.5	1.2	3.1	2.0	1.5
Peripherals low (W)	n/a	n/a	n/a	0.3	0.04	n/a	n/a	0.8
Peripherals high (W)	2.5	3.5	1.2	4.1	3.0	2.6	4.9	1.2
Peripherals blend (W)	0.6	0.9	0.3	1.3	0.8	0.7	1.2	0.9
ES v6.0 Baseline Power (W)								
Off	0.3	0.2	1.6	0.5	0.1	0.3	0.2	0.4
Sleep	1.0	1.0	1.9	1.0	1.3	1.1	0.2	0.6
Long Idle	9.4	23.9	38.7	9.8	22.6	4.0	3.0	17.9
Short Idle	9.9	24.0	39.9	25.1	58.0	5.6	5.3	20.7
Real-World Power (W)								
Off	0.3	0.2	1.6	0.5	0.1	0.3	0.2	0.4
Sleep	1.0	1.0	1.9	1.0	1.3	1.1	0.2	0.6
Real-World Long Idle	10.1	23.9	41.5	12.8	31.2	4.0	3.7	18.2
Real-World Short Idle	10.9	25.1	42.3	32.2	61.6	6.3	6.5	20.7
Active	15.2	37.4	59.0	36.6	68.0	17.4	10.3	31.2
ES v6.0 TEC (kWh/yr)								
Off	1.2	0.7	6.2	1.8	0.3	0.7	0.4	0.9
Sleep	0.5	0.4	0.8	0.4	0.6	3.4	0.7	1.9
Long Idle	12.3	31.4	50.9	12.8	29.7	3.5	2.7	15.7
Short Idle	30.4	73.6	122.2	76.9	177.7	14.7	13.8	54.5
Active	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peripheral Adder	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	44.3	106.1	180.1	91.9	208.2	22.3	17.7	73.0
Adjusted TEC (kWh/yr)								
Off	1.2	0.7	6.2	1.8	0.3	0.7	0.4	0.9
Sleep	0.5	0.4	0.8	0.4	0.6	3.4	0.7	1.9
Long Idle	13.3	31.4	54.5	16.9	41.0	3.5	3.3	15.9
Short Idle	28.0	64.6	108.9	83.1	158.7	13.4	13.9	44.4
Active	7.4	18.2	28.8	17.9	33.2	8.5	5.0	15.2
Peripheral Adder	2.7	3.8	1.4	5.5	3.4	2.3	4.3	3.0
Total	53.1	119.2	200.6	125.5	237.2	31.7	27.7	81.4
TEC error	20%	12%	11%	37%	14%	42%	57%	11%

*Note: Test results were rounded to the nearest tenth for presentation purposes

Table A-2: Real-World Adjustment Factor Test Results

	Desktops		Integrated Desktops		Notebooks			
	A	B	C	D	E	F	G	H
ES v6.0 Baseline (W)								
Off	0.3	0.2	1.6	0.5	0.1	0.3	0.2	0.4
Sleep	1.0	1.0	1.9	1.0	1.3	0.9	0.2	0.6
Long Idle	9.4	23.9	38.7	9.8	22.6	1.1	3.0	17.9
Short Idle	9.9	24.0	39.9	25.1	58.0	5.6	5.3	20.7
Real World Idle Testing, Task 1 (W)								
Real World Long Idle, Low	10.1	n/a	n/a	10.1	22.7	n/a	3.0	18.7
Real World Short Idle, Low	10.5	25.1	41.5	25.3	58.7	6.1	5.5	21.2
Real World Long Idle, Mid	10.3	22.9	41.2	11.3	35.6	2.4	3.9	18.3
Real World Short Idle, Mid	11.0	24.5	42.2	30.9	63.8	6.2	7.2	19.9
Real World Long Idle, High	10.0	23.3	41.8	17.1	35.4	2.5	4.3	17.6
Real World Short Idle, High	11.1	25.6	43.1	40.6	62.3	6.5	6.8	20.1
Real World Long Idle Impact Factor	1.1	1.0	1.1	1.3	1.4	2.2	1.2	1.0
Real World Short Idle Impact Factor	1.1	1.0	1.1	1.3	1.1	1.1	1.2	1.0
Real World Active Mode Testing (W)								
Task 2 (Streaming audio)								
Long Idle	n/a	26.5	n/a	12.2	24.5	4.6	4.9	n/a
Active	12.9	26.8	42.9	27.4	58.6	8.4	7.1	23.6
Task 3(Streaming video)								
Long Idle	n/a	n/a	n/a	n/a	n/a	9.3	n/a	n/a
Active	14.8	31.7	53.6	34.7	62.4	14.4	8.0	25.8
Task 4 (Video chat/conference)								
Long Idle	n/a	n/a	n/a	33.0	n/a	n/a	n/a	n/a
Active	17.2	37.9	67.9	38.7	70.1	17.0	14.8	25.5
Task 5 (Virus scan)								
Long Idle	n/a	25.9	n/a	20.7	22.6	n/a	n/a	n/a
Active	14.1	34.9	56.8	37.2	67.7	15.8	6.3	22.1
Task 6 (Residential-gaming, commercial-screen share)								
Long Idle	n/a	n/a	n/a	n/a	n/a	n/a	13.1	n/a
Active	17.2	55.5	74.2	47.5	81.0	42.5	15.2	58.9
Task 7 (Virtualization, residential only)								
Long Idle	n/a	n/a	n/a	16.5	n/a	n/a	n/a	n/a
Active	n/a	n/a	n/a	33.8	n/a	6.4	n/a	n/a
Average Long Idle Power, All	n/a	26.2	n/a	20.6	23.5	6.9	9.0	n/a
Average Active Power, All	15.2	37.4	59.0	36.6	68.0	17.4	10.3	31.2
Average Long Idle Impact Factor	n/a	1.1	n/a	2.1	1.0	6.3	3.0	n/a
Average Active Impact Factor	1.5	1.6	1.5	1.5	1.2	3.1	2.0	1.5

	Desktops		Integrated Desktops		Notebooks			
	A	B	C	D	E	F	G	H
Peripheral Usage Testing (W)								
Low Usage								
Task 1 (Real World Idle)								
Real World Long Idle	10.1	n/a	n/a	10.1	22.7	n/a	3.0	18.7
Real World Short Idle	10.5	25.1	41.5	25.3	58.7	6.1	5.5	21.2
Task 2 (Streaming audio)								
Long Idle	n/a	-	-	-	-	4.6	-	-
Active	12.9	-	-	-	-	8.4	-	-
Task 3 (Streaming video)								
Long Idle	n/a	-	-	-	-	9.3	-	-
Active	14.8	-	-	-	-	14.4	-	-
Task 4 (Video chat/conference)								
Long Idle	n/a	-	-	-	-	n/a	-	-
Active	17.2	-	-	-	-	17.0	-	-
Task 5 (Virus scan)								
Long Idle	n/a	-	-	-	-	n/a	-	-
Active	14.1	-	-	-	-	15.8	-	-
Task 6 (Residential-gaming, commercial-screen share)								
Long Idle	n/a	-	-	-	-	n/a	-	-
Active	17.2	-	-	-	-	42.5	-	-
High Usage								
Task 1 (Real World Idle)								
Real World Long Idle	n/a	26.5	42.2	12.0	24.8	n/a	7.6	19.4
Real World Short Idle	13.5	28.5	42.7	31.5	62.5	10.1	10.8	22.8
Task 2 (Streaming audio)								
Long Idle	n/a	-	-	-	-	5.73	-	-
Active	14.3	-	-	-	-	11.0	-	-
Task 3 (Streaming video)								
Long Idle	n/a	-	-	-	-	14.5	-	-
Active	18.0	-	-	-	-	15.1	-	-
Task 4 (Video chat/conference)								
Long Idle	n/a	-	-	-	-	n/a	-	-
Active	20.3	-	-	-	-	17.4	-	-
Task 5 (Virus scan)								
Long Idle	n/a	-	-	-	-	9.8	-	-
Active	16.2	-	-	-	-	17.2	-	-
Task 6 (Residential-gaming, commercial-screen share)								
Long Idle	-	-	-	-	-	n/a	-	-
Active	17.6	-	-	-	-	43.3	-	-

	Desktops			Integrated Desktops		Notebooks		
	A	B	C	D	E	F	G	H
Peripherals Impact								
Real World Long Idle - ES v6.0 Baseline Idle	n/a	n/a	n/a	0.3	0.04	n/a	n/a	0.8
High Peripheral Long Idle - Low Peripheral Long Idle	n/a	n/a	n/a	1.9	2.2	n/a	4.6	0.7
High Peripheral Short Idle - Low Peripheral Short Idle	3.0	3.5	1.2	6.2	3.8	4.0	5.2	1.6
High Peripheral Active - Low Peripheral Active	2.0	-	-	-	-	1.2	-	-
Adjustment Factors								
Real world long idle impact factor	1.1	1.0	1.1	1.3	1.4	2.2	1.2	1.0
Real world short idle impact factor	1.1	1.0	1.1	1.3	1.1	1.1	1.2	1.0
Active impact factor	1.5	1.6	1.5	1.5	1.2	3.1	2.0	1.5
Peripherals Low (W)	n/a	n/a	n/a	0.3	0.04	n/a	n/a	0.8
Peripherals High (W)	2.5	3.5	1.2	4.1	3.0	2.6	4.9	1.1

*Note: Test results were rounded to the nearest tenth for presentation purposes.

n/a: Values were either not measured or a reliable reading could not be obtained.