Computers

Codes and Standards Enhancement (CASE) Initiative
For PY 2013: Title 20 Standards Development

Analysis *of* Standards Proposal for
Computers

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Prepared for:

PACIFIC GAS & ELECTRIC COMPANY

SOUTHERN CALIFORNIA EDISON

SAN DIEGO GAS AND ELECTRIC

SOUTHERN CALIFORNIA GAS COMPANY

NATURAL RESOURCES DEFENSE COUNCIL

Prepared by:
Nate Dewart, ENERGY SOLUTIONS
Pierre Delforge, NATURAL RESOURCES DEFENSE COUNCIL
Peter May-Ostendorp, XERGY CONSULTING
Clancy Donnelley, ECOVA

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1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers a standard proposal for computers.

Computers are ubiquitous and represent the second largest electronic energy end-use in the U.S., after televisions. There are approximately 35 – 45 million installed desktops and notebooks in California (KEMA 2010, Fraunhofer 2011) and they consume roughly 4-7 TWh annually, or between 1.5 to 2.5 percent of California electricity end-use. The higher estimate is equivalent to the electricity use of all the households in the city of Los Angeles, and costs Californians $1 billion in annual electricity bills. There is a wide range of energy use between computers of similar performance and functionality, reflecting differing levels of adoption of energy efficiency best-practices. While ENERGY STAR encourages innovation and accelerates this adoption in segments of the market that are sensitive to this type of recognition, the program is not intended to ensure that all products on the market meet minimal levels of energy efficiency nor to optimize cost-effective efficiency opportunities for customers.

Supported by cost-effectiveness testing results (PG&E 2012) provided through the CEC's Invitation to Participate and supplemental testing results and research provided in this report, we recommend that California adopt a two-tier, 2015 (Tier 1) and 2017 (Tier 2) standard for computers based largely on ENERGY STAR 6.0 categories and test-method with adjustments described in this report. For desktops (both conventional and integrated) and notebooks, this would entail setting performance-based typical electricity consumption (TEC, kWh/year) allowances with functional adders, along with power management enablement, an internal power supply efficiency requirement (for desktops only) and Energy Efficient Ethernet (EEE). For workstations and small-scale servers, we recommend internal power supply efficiency, power management and EEE requirements as well. For thin-clients, we recommend the latter two. These performance-based standards for idle, sleep and off modes for the primary form factors and the other simple, low-cost, cost-effective measures would increase the efficiency of computers without impeding the development of the technology. A standard covering only non-active modes should not impact the performance of the computer when performing intensive computing tasks.

From these cost-effective and feasible standards, consumers would be expected to see a net savings between $.70 and $79 per unit over the lifetime of the products, and an average benefit to cost ratio of 1.6. Statewide this represents savings of over 2,000 GWh/yr savings by stock turnover and demand reduction of 300 MW, equal to over half a medium-size 500 MW power plant. The CASE team estimates that this would save Californians over $870 million by 2020, and reduce California's CO_2 emissions by over 900,000 metric tons annually. The standards would address some of the statewide policy objectives of Zero Net Energy California Long Term Energy Efficiency Strategic Plan and AB32 energy efficiency goals.

2 Product Description

2.1 Technical Description

2.1.1 Overview

Computers play a prominent role in society, and have a wide-range of applications and performance capabilities for both business and residential use. For example, engineering, architecture, video editing and gaming software require higher performing hardware, i.e. faster graphics cards, memory, etc., while more universal functions e.g., internet browsing, email and word-processing, require lower performing equipment.

2.1.2 Hardware

The various form factors generally have the same category of components that provide basic functionality. Enhanced performance is provided by either more advanced components or additional components.

Figure 2.1 provides an example of a desktop's components. Connected devices, such desktop computer monitors, input devices, or peripherals like printers and scanners can also impact overall computer power use, but are outside the scope of the proposed standard. Note that notebook and integrated desktop monitors are covered under this proposed standard.

See Figure 2.2 for images of those products covered in this proposal and Section 2.4 for more details for product classes.

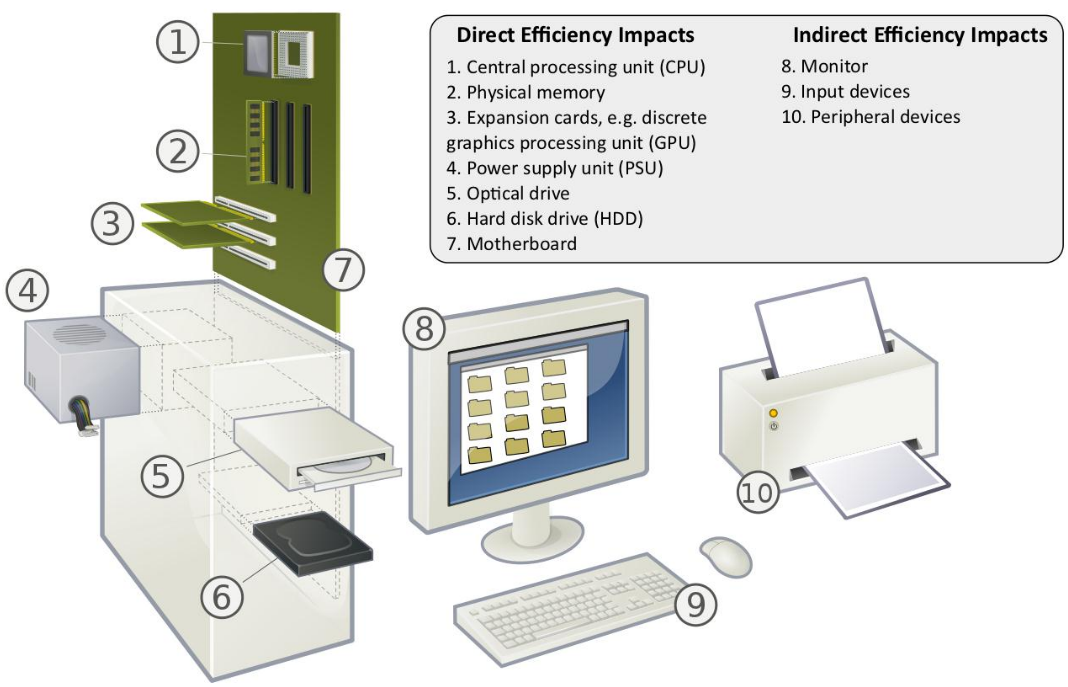

Figure 2.1 Desktop Computer Component Diagram

Source: adapted from Wikimedia Commons (https://commons.wikimedia.org/wiki/File:Personal_computer,_exploded_6.svg).

Figure 2.2 Form Factors within Scope of Standards Proposal

Source: Google images, Jan. 2013.

The ENERGY STAR 6.0 Specification Final Draft (EPA 2012a) provides relevant and sufficient technical description of several of the major computer hardware components impacting energy consumption: discrete and integrated Graphics Processing Units (GPUs), Display, Internal Power Supply and External Power Supply. Here are a few additional component definitions not listed by ENERGY STAR:

- **Memory:** physical devices used to temporarily store programs, instructions, and/or data for immediate access by a computer's central processing unit (CPU).
- **Storage:** physical devices used for long-term, non-volatile storage of programs and user data.
- **TV tuner card:** computer expansion card that provides the ability to tune over-the-air television signals for display on a computer monitor.
- **Audio card:** computer expansion card that enables the input/output of audio signals to/from a computer from external sources.
- **Ethernet Port:** a physical connector capable of accepting Category 5 twisted-pair cables for the purpose of establishing wired, local area network (LAN) connections per IEEE Ethernet (802.3) standards.

2.1.3 Software

The operating system is the fundamental software platform for the operation of the computer, and facilitates the interaction of the user to the hardware and other software[1]. Currently four main operating systems share the majority of the market — Windows 7, Windows XP, Windows Vista, MacOS X — while Linux and older versions of Windows sharing a very small percentage (See Figure 2.3).

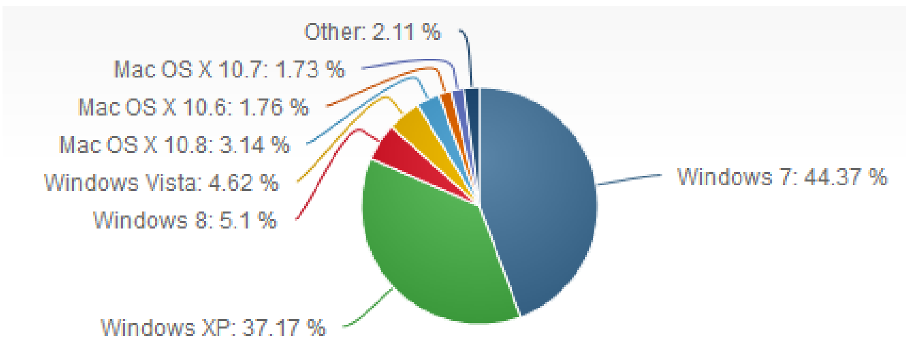

Figure 2.3 Desktop Operating System Market Share (Global)
Source: NetMarketShare June 2013 http://www.netmarketshare.com/

The operating system also has power management settings that determine the length of time before the operating system automatically switches the hard disk and the display in non-active modes from idle to sleep, with an optional Wake on LAN (WOL). This function allows the hard disk and display to wake from sleep or off when directed by a network request via Ethernet.

Power management settings of each model are determined by the manufacturer at shipment, and then can be further adjusted by the user, or administrators in the commercial settings, throughout the life of the unit. Power management capabilities vary slightly across operating systems. See Figure 2.4 and Figure 2.5 below for the power management settings for a recent version of Macintosh OS X and Windows 7, respectively.

[1] Non-operating system software varies in purpose and functionality, and requires varying levels of computer performance. Given that this software is customizable, usually purchased separately from the computer hardware itself, and does not directly determine a computer's energy consumption, it is excluded from this report.

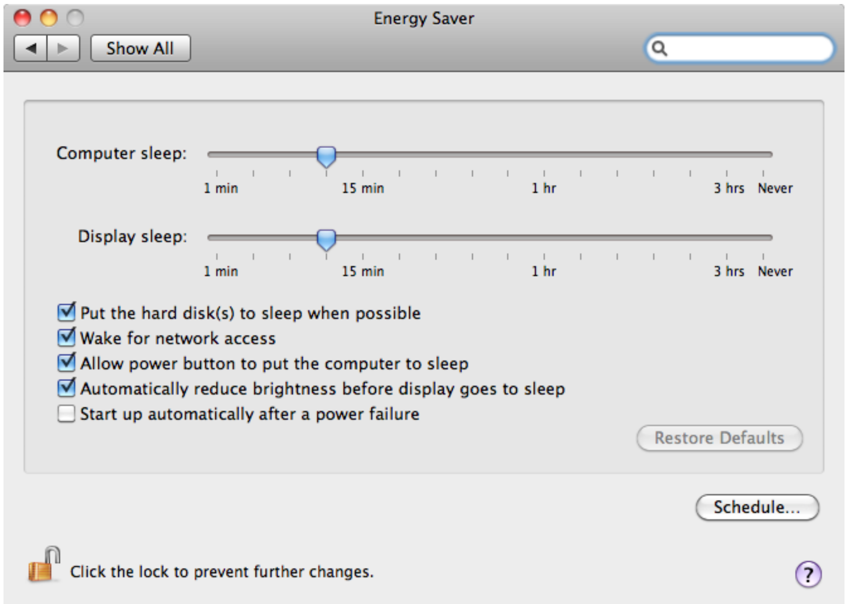

Figure 2.4 Macintosh OS X Version 10.6.8 Energy Saver – Default Power Management Settings for an Apple Integrated Desktop

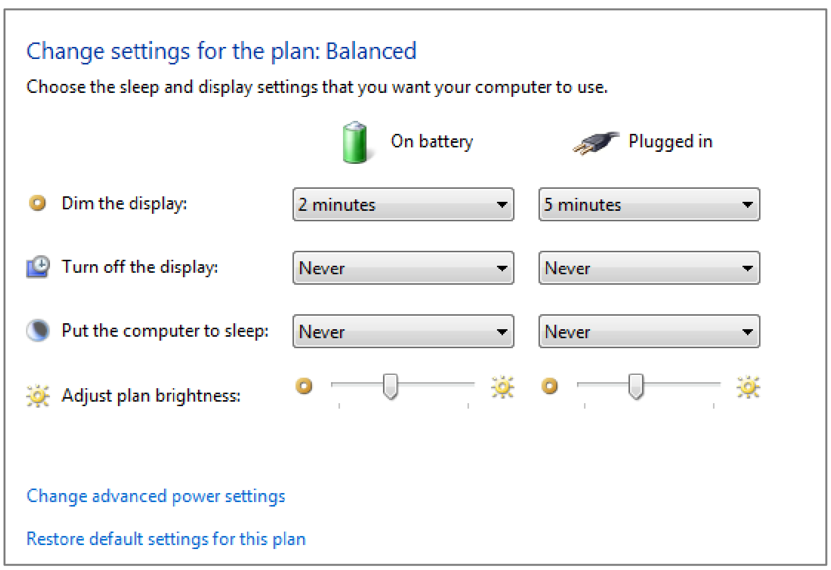

Figure 2.5 Windows 7 Default "Balanced" Power Management Settings for a Notebook

2.1.1 Modes

Computers have several modes in which they operate. Each mode requires a different power draw, determined by a number of factors, including but not limited to the processing capabilities and the power supply efficiency. The definitions for each mode widely accepted by industry and used in this analysis are based on ENERGY STAR Program Requirements for Computers Version 6.0 Final

Draft[2]. In summary, they are short idle, long idle, sleep and off. See Section 13, Proposed Title 20 Language, for full definitions.

To estimate annual energy consumption, ENERGY STAR uses a typical energy consumption (TEC) in kWh/yr which is calculated by multiplying the wattage in each of these four modes by the estimated percentage time the computer is in each mode, or mode weighting (see Section 3.2 for more details on the mode weighting). The CASE Team recommends aligning with this metric for calculating energy consumption for purposes of the standard. For energy savings and life-cycle benefit cost analysis, the CASE Team recommends using a real-world adjustment factor discussed in Section 3.1.

2.2 Technologies and Best Practices for Energy Use

2.2.1 Overview

The energy use of the four mainstream form factors – slates/tablets, notebooks, integrated desktops and conventional desktops – are typically not proportional to the performance capability differences between these platforms. Figure 2.6 illustrates that the magnitude of the energy consumption differences.

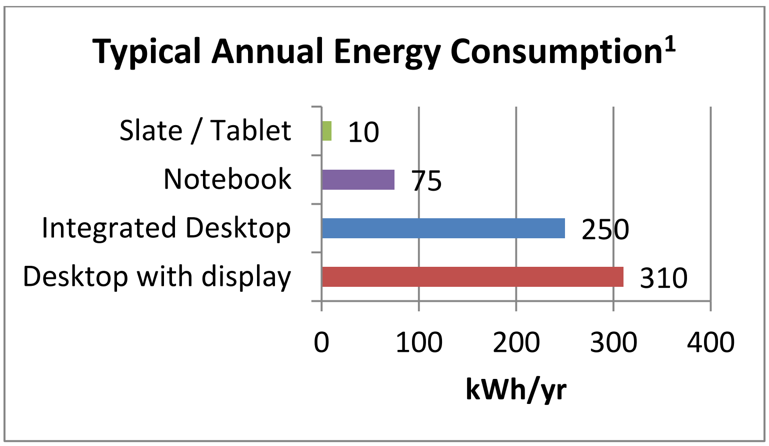

Figure 2.6 Comparison of Annual Energy Use of Tablet, Notebook, Integrated Desktop, Conventional Desktop

(1) iPad3, desktop and notebook TEC per averages of Dec 2012 ENERGY STAR qualified product list, including the version 6.0 display adder and 15%/30% real-world adjustment factor for active use and accessories for desktops and notebooks, respectively.

Desktops, integrated desktops, and notebooks reside at different points on the efficiency spectrum due to the intrinsic efficiency of their hardware architecture, which today is driven by design constraints and user preferences. For example, in notebook computers, portability, battery life, and small thermal enclosures necessitate the use of more efficient components while retaining enough performance to run applications identical to those used on desktops. Notebook computers

[2] The naming convention of duty cycle modes and estimation of length of time in each duty cycle mode vary throughout the research (e.g. Windows XP refers to “sleep” as “standby”) based on surveying and data collection methods (Barr et al. 2010; TIAX 2007; Pigg & Bensch 2010; Chetty 2009, ECMA-383). We use ENERGY STAR’s version because it is the most universal. See Duty Cycle Definitions for a more detail description of these other duty cycles.

also employ more aggressive power management strategies (beyond the operating system power management settings described above). Although possible in desktop computers, these strategies are not broadly employed. Integrated desktops do not have portability constraints, but are thermally constrained due to their form factor, and therefore may use more efficient notebook-style components to reduce waste heat. Conventional desktop computers are the least encumbered by the above design considerations. As a result, they often do not integrate efficiency best practices, optimizing for cost rather than efficiency and cost-effectiveness for the user.

Table 2.1, from an EPRI & Ecos 2008 study, provides a very general picture of the share of energy use and range of potential energy-savings improvements in desktops and notebooks. Sections 2.2 provides a more current assessment from 2012 and 2013 testing, research and analysis, with greater detail regarding these different technological opportunities that exist in desktop, integrated desktop, and notebook computers to improve their efficiency. The CASE Team made significant effort to suggest measures that provide comparable or improved performance and user experience compared to incumbent technologies.

Table 2.1 Share of computer energy use and range of potential energy-saving improvements

Component	Share of energy use	Savings opportunities
Power Supply	15-35%	• 80-Plus Bronze: <70% to 82% efficiency
Display	15-30%	• LED backlighting, more efficient panel technology
Motherboard	15-20%	• More efficient chipsets, voltage regulators and other components, mobile-on-desktop design
GPU	0-50%	• Higher power proportionality: low power in idle
CPU	5-15%	• Low power CPUs, voltage and frequency scaling
Disks	5-10%	• “Green” drives, solid state drives (SSD)
Memory	5-10%	• “Green” memory
Networking	2-8%	
System-level strategies		
• Advanced power management		• Graphics switching

2.2.2 Desktop Opportunities

Primary research was conducted under PG&E’s Computer Cost Effectiveness project (2012a), supplying in-depth examinations of efficient components for desktop computers that demonstrated consistent energy savings across a variety of desktop computer performance categories. These results indicate that improved design of internal power supplies, central processing units (CPUs), graphics processing units (GPUs), and hard drives represent significant component-level energy savings opportunities that can serve as cost-effective pathways to improve system efficiency. Component modifications were made to ensure comparable or, in many cases, improved system performance. The measures utilized in this project were intended to illustrate some, not necessarily the most, cost-effective efficiency pathways. Manufacturers have the flexibility to implement other efficiency improvements that may lead to even higher cost-effective savings.

2.2.2.1 Internal Power Supplies

One of the most ubiquitous opportunities in reducing energy consumption in desktops is through improving energy efficiency of internal power supplies. A percentage improvement in efficiency at one load point typically results in improvement at other load points, so savings are generally achieved across all modes in the conversion from dc to ac power, though the greatest savings occurs in the higher power modes of active and idle.

Higher efficiency computer internal power supplies are common, as voluntary computer specifications like ENERGY STAR and the utility-sponsored 80 PLUS labeling program[3] have been encouraging higher level units since 2005. Table 2.1 represents Climate Savers Computer Initiative and 80 PLUS power supply definitions and requirements of various “levels” of power supply efficiency performance for internal multi-output power supply units for desktop and servers. 80 PLUS also reports efficiency at 10% load, but does not require minimum efficiency levels at this load point for multi-output power supplies.

Table 2.2 80 PLUS Multi-Output Internal Power Supply Levels

Loading Condition	Bronze		Silver		Gold		Platinum	
	Eff.	Power Factor	Eff.	Power Factor	Eff.	Power Factor	Eff.	Power Factor
20%	82%	0.8	85%	0.8	87%	0.8	90%	0.8
50%	85%	0.9	88%	0.9	90%	0.9	92%	0.9
100%	82%	0.95	85%	0.95	87%	0.95	89%	0.95

Microprocessor manufacturer Intel has also encouraged vendors to achieve higher levels of efficiency through its form factor specifications.[4] A variety of power electronics design techniques can be employed to achieve the higher levels of efficiency required in these specifications.

All highly efficient desktop computer power supplies on the market today are “switching” or “switch-mode” power supplies, employing a combination of active, solid-state components to rectify incoming ac electricity into dc and to further down-convert that dc electricity to the voltages typically required in desktop computers (e.g. 12, 5, and 3.3V).

The drivers of the efficiency-related costs are primarily passive components (inductors and transformers, capacitors and non-semiconductor devices) and printed circuit boards that electrically connect all semiconductor devices and passive components, and secondarily transistors and diodes, and thirdly the integrated circuits (ICs). The high cost of the passive components comes from usage of large electrolytic capacitors and magnets, so changing designs and moving to high frequencies can reduce the size and count of costly passive components. Replacing passive conversion with active power conversion can change cost and efficiency rating as well (iSuppli 2011).

Despite the increased saturation of higher efficiency units over the past decade, cost-effective opportunities are not being optimized across all units. Results from the 2012 testing (PG&E 2012a) demonstrate desktops selected as baseline units had below 80 PLUS efficiency relative to what was cost-effectively available. Two samples of each shown in Figure 2.7, referred to as “baseline” and “efficient”.

[3] More information available at http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx.
[4] More information available at http://www.formfactors.org.

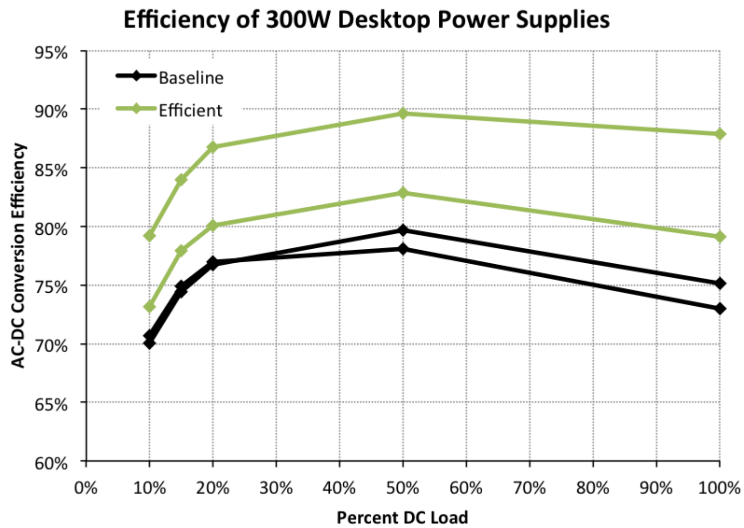

Figure 2.7 Measured Efficiencies in Baseline and Efficient Internal Power Supplies

2.2.2.2 Central Processing Units

Several trends in central processing unit (CPU) design have been contributing to dramatically improved efficiency in recent years. Primarily spurred by unacceptably high thermal emissions in the computer and battery life considerations in mobile units, but also by increased focus on idle power by energy efficiency policy (e.g. via ENERGY STAR), processor manufacturers have placed greater emphasis on lowering CPU power consumption in idle mode. In the 2004 – 2006 timeframe, CPUs and their associated motherboard components began incorporating techniques from notebooks to scale the power consumption of processors to the performance required at any given time by the user. CPUs and the chipsets that support them now dynamically scale the frequency or clock speed of the processor as well as the voltage delivered to the processor to "throttle" power consumption and performance during idle times. As multi-core processors have come to dominate the market, it is now possible to conduct power scaling on individual cores. For example, one core could be heavily taxed with an image processing workload, while the remaining three cores in the processor could sit idle at much lower power consumption.

Beyond improving the dynamic control of CPUs, manufacturers have also made great strides in their silicon fabrication processes, continuing to reduce the size of individual features to nanometers. While this process has dramatically increased the number of transistors in a given part, it has also given manufacturers greater control over losses in the silicon. Tighter fabrication processes have, for example, reduced the overhead losses caused by leakage currents in devices, enabling lower idle power values.

The most recent CPU architectures, such as Intel's Haswell, have also helped to lower the power consumption of the voltage regulator module (VRM), a type of dc-dc power supply and controller that supplies power to the processor. Haswell CPUs, for example, have gained some efficiency by integrating this component into the CPU itself. Silicon refinements have also resulted in lower power consumption in chipset components that interface with the CPU.

With Haswell, Intel has also introduced a new processor power state termed "Active-Idle" (S0ix) that allows the CPU to quickly transition between low-power states and active processing, which should enable lower and longer duration idle power. The technology has thus far only been deployed in mobile versions of Haswell processors. Overall, some initial third-party testing of Haswell desktop processors suggest that they will be able to achieve 25% lower idle power at the system level over the previous generation of Intel processors (see Figure 2.8), but Active Idle could further widen this margin.

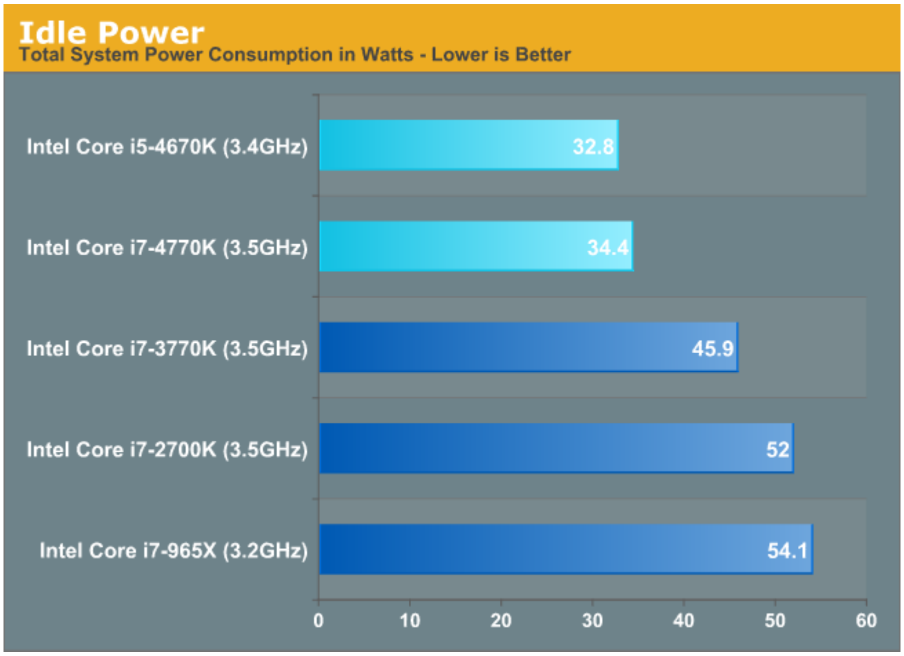

Figure 2.8: Idle power comparison between 3rd (dark blue) and 4th (light blue) generation Intel Core i7 processors

Source: AnandTech.com 2013. (http://www.anandtech.com/show/7003/the-haswell-review-intel-core-i74770k-i54560k-tested/2)

2.2.2.3 Graphics Processing Units

The two leading vendors of GPUs, AMD and NVIDIA, have both released significant updates to their flagship GPU architectures over the past year. Market research shows that two thirds of NVIDIA's and one quarter of AMD's current discrete desktop GPU product lineup utilize the Kepler or Graphics Core Next (GCN) architectures, respectively, which deliver significant savings relative to GPUs that use older architectures. In general terms, these new architectures allow the GPU to scale the power it demands to match the task it is performing, generating significant savings during idle mode (NVIDIA 2012). This is similar to the power scaling strategies discussed above for CPUs. The GCN architecture and its ZeroCore feature also allow the GPU to power down some components when the computer screen is off or not displaying content (AMD 2012). More than 80% of the GPUs released in 2012 use these more efficient technologies, and the remaining 20% are simply older GPUs that have been relabeled and re-released. In other words, Kepler and GCN represent a sea change in the way discrete GPUs are designed. Test results indicate that these latest architectures can save anywhere from 20% to 75% of discrete GPU energy consumption depending on the performance class of the card (generally, the greater the frame buffer bandwidth of the card, the greater the savings) (PG&E 2012b).

Of course many mainstream desktop computers utilize integrated graphics that share the memory controller interface and memory with the CPU. The power scaling and power management features discussed for discrete GPUs above remain a significant opportunity for integrated graphics as well, because not all integrated GPUs have yet incorporated the latest GPU efficiency technologies.

In systems with discrete graphics installed, it is extremely important that any existing integrated graphics is only utilized when necessary to minimize its power consumption.

2.2.2.4 Hard Drives

Hard drives present a key energy savings opportunity in desktop computers. Conventional spinning, magnetic hard drives are still by far the most widely used technology. Their power consumption can range by a factor of two from the most to least efficient versions (about 4 to 8 W) depending on the vendor, efficiency of the motor, and spindle speed. Some manufacturers like Western Digital have begun to offer "green" versions of their products that consume less power.

The latest, most efficient, and interestingly *highest* performance drives on the market are solid state drives (SSDs). SSDs use non-volatile flash memory rather than magnetic platters to store content, so require no moving parts and have significantly lower power consumption — anywhere from a fraction of a watt to about 1 W. SSDs are more widely used in mobile devices like notebooks, but are seeing increased penetration in high-performance desktops where users want to maximize read/write speeds.

Hybrid hard drives are low-cost alternatives to SSDs that incorporate a cache of flash memory for quick access to commonly used files and programs. They contain a larger reserve of spinning, magnetic memory for access to less frequently used files. Thus, hybrid hard drives can provide some of the performance advantages of SSDs at a lower cost. To date, hybrid hard drives have only been offered in 2.5" laptop form factors, but manufacturers are planning to release desktop versions as well.

2.2.2.5 Power Management

Power management is an important aspect to energy consumption and savings, however, there is significant variability in the implementation for a number of reasons and further improvements beyond current market practice require additional research.

More specifically, ENERGY STAR requires some power management (see Table 2.3) as default upon shipment, and most of the market, including non-ENERGY STAR products, appears to be adopting these settings as default as well. Therefore, additional opportunity for savings seems to be limited to the increased acceptance of more stringent power management settings than the 30 minutes for sleep mode activation and 15 minutes for display sleep.

Table 2.3 ENERGY STAR Version 6.0 Power Management Requirements

Specification Requirement	Shipment Requirements	Applicable to
Sleep Mode	Shipped with a Sleep mode which is set to activate within 30 minutes of user inactivity. Computers shall reduce the speed of any active 1 Gb/s Ethernet network links when transitioning to Sleep or Off.	• Desktop Computers • Notebook Computers
Display Sleep Mode	Shipped with the display's Sleep mode set to activate within 15 minutes of user inactivity.	• Desktop Computers • Notebook Computers • Small-Scale Servers (if display is present) • Thin Clients

2.2.2.6 Energy Efficient Ethernet

Energy Efficient Ethernet (EEE) can reduce the power draw of a Gigabit port, typically drawing 0.7W regardless of actual transfer speed to 0.1W, nearly the levels of a 100 Megabit port for low data rates. To achieve any benefit of EEE, however, the devices on both ends of an Ethernet connection must have EEE enabled.

2.2.3 Integrated Desktop and Notebook Opportunities

A variety of existing technologies can be applied today to improve the efficiency of notebooks and integrated desktops. We present these separately, as many of these techniques either do not apply to conventional desktops or require clarification due to the usage profiles and design of notebooks and integrated desktops.

2.2.3.1 Internal Power Supplies (Integrated Desktop Only)

Some integrated desktop computers can benefit from more efficient internal power supplies (most all-in-ones use external power supplies). The exact percentage of the integrated desktop market using internal power supplies is not currently known, but many flagship "all-in-ones" include them, including the Apple iMac. As desktop system testing has demonstrated, higher efficiency internal power supplies alone can save significant energy required by a desktop computer (PG&E 2012a). The technique readily applies to other form factors and should continue to be cost-effective.

2.2.3.2 Next-Generation CPU Architectures and Power Management Techniques

The computer industry is in the process of introducing new processor technologies that are expected to have profound energy savings implications, particularly for notebook computers. Since these processor technologies are being introduced today, they are expected to become the mainstream technology in use when standards go into effect and should afford significant low- and no-cost opportunities for notebook OEMs.

Processor manufacturer Intel claims that its new Haswell architecture will provide 50% greater battery life and 33% lower idle power consumption in notebook computers. This is achieved through several features that allow for greater power scaling. First, Haswell processors will be able to locally manage processor power, scaling performance and power consumption based on user demands. Mobile processors will also allow for a new "Active-Idle" state that enables processors to quickly enter and exit lower power states while the computer is still on from the user perspective (Shah 2013).

2.2.3.3 Switchable Graphics

As with desktop systems, notebooks can utilize either integrated or discrete GPUs. Many higher performance notebook computers incorporate mobile discrete graphics to provide improved graphics performance for games, video editing, and other graphics-intensive activities. It turns out that many integrated desktops also utilize *mobile* discrete graphics due to their smaller form factor and tighter thermal constraints.

When a system incorporates a discrete GPU, it often still contains a more efficient, lower performance, integrated GPU. This GPU is perfectly adequate for less computationally burdensome tasks, like web browsing or word processing. Systems with switchable graphics exploit this to save power and improve battery life by activating the more power-intensive discrete GPU only when the user requires it; at all other times, an integrated GPU handles the display, and the discrete GPU remains in an idle state. Spot measurements of switchable graphics in notebook computers by the IOU technical team have shown 20 – 30% reductions in idle power compared to the same system running in "discrete GPU only" mode.

Switchable graphics has mainly been used to extend battery life in notebooks, but it is equally applicable to integrated computers, because these systems commonly use mobile discrete GPUs and contain an integrated display. This likely presents an even greater untapped opportunity, since we are unaware of any integrated desktops that actively exploit graphics switching technology.

2.2.3.4 Display Efficiency

Approximately 15 - 35% of a notebook or integrated desktop's energy consumption can be attributed to its display. Display efficiency opportunities currently being pursued in proposed Title 20 standards for standalone displays readily apply to the integrated displays in notebooks and integrated desktops. The CASE Team for the Title 20 displays standard identified several important cost-effective energy-saving technologies in its Invitation to Participate response (CA IOUs 2013a), including:

- Switching from cold-cathode fluorescent (CCFL) panel backlights to light emitting diode (LED) backlights. Many notebook and integrated desktop displays already incorporate LED backlights, however improvements to LED efficacy will continue to provide options for more efficient backlighting technology.
- Improving liquid crystal display (LCD) panel transmissivity. LCD panels are composed of a stack of thin films that can be designed to maximize the transmittance of visible light, thus allowing manufacturers to use fewer backlights to achieve the same perceived brightness by the user.
- Use of reflective polarizing films in the display stack. Reflective polarizers effectively allow display panels to "recycle" light that is improperly polarized and that would otherwise be

absorbed in the panel as waste heat. Reflective polarizers are a key enabling technology for improving LCD panel transmissivity, as mentioned above.

- Dimming panel backlights depending on image brightness. Depending on the brightness of various parts of the image on screen, the display can dim its backlights. In LED-backlit displays, this dimming can occur at the local level, i.e. impacting only a small area of the display.
- Enabling automatic brightness control (ABC) to adjust backlight brightness of the panel according to ambient light levels. ABC dims the panel backlights when ambient light levels are low, usually using a small photo sensor in the display housing.

See more details in the California IOUs standards proposal for Electronic Displays (CA IOUs 2013b)

2.2.3.5 Display Panel Self-Refresh

The image on a computer's display must be refreshed or updated on a frequent basis (more than 60 times per second) as users manipulate the system's graphical user interface. However, displays and the computer's GPU must continue this refresh process even when the on-screen image is static, thus wasting energy. Microprocessor manufacturers are beginning to adopt a standard for panel self-refresh, which allows the display's image to be refreshed from a local buffer — and not by the GPU — when images are static. Intel has stated that it expects the technology to be "widely adopted" and provides support for it in its Haswell processors (Hollister 2013). Though exact energy efficiency benefits have not yet been measured, this technology will be available in mainstream notebooks during the timeframe of the standard and will afford an additional display-related energy savings mechanism. Some additional cost will be incurred, because a memory buffer is required to store and display static display images when the GPU has been throttled back.

2.2.3.6 Solid State Drives

Solid state drives (SSDs) are much more commonplace in notebook computers than in desktops, though they are mainly used today in high-end or small form factor systems. Although currently not cost-effective as a stand-alone energy savings measure, SSDs provide a compelling energy savings opportunity when incorporated in products that require their performance, reliability, and compact form factors. Prices continue to drop rapidly, and we anticipate the incremental cost of SSDs to be reduced by over 50% by the time proposed standards might go into effect in 2015. Energy savings are on the order of 5 kWh per year compared to conventional notebook HDDs, over 20% of a typical notebook's annual energy needs.

2.2.3.7 Motherboard Integration

Noted in previous research (PG&E 2012a), all other factors being equal, smaller form factor products with larger numbers of components directly integrated onto the motherboard, or portable "ultrabook" systems, tend to be more efficient than products with large numbers of discrete components. Product inspections of several notebook computers revealed motherboards in which physical memory and hard drives were permanently soldered to the motherboard. Soldered joints will have lower contact resistance than modular connectors, reducing losses. In addition, the compact form factors of these motherboards resulted in shorter conductor traces and lower resistive losses. Compact systems also tend to integrate bulkier passive components (e.g. resistors and capacitors) into more compact, purpose-built integrated circuits, which can save space, reduce part counts, and provide efficiency gains.

2.2.3.8 Power Management Settings

As illustrated in Table 2.3 in the previous section, notebook computers typically ship with default power management settings for battery-powered and adapter-powered modes. Many power-saving features, such as screen dimming, graphics switching, and hard drive spin-down, are more aggressively enabled in battery-powered operation than when the notebook is plugged in. Manufacturers can easily gain some reductions in idle power by more aggressively enabling power management features in plugged in modes. These savings are simply a matter of default system configuration and incur no additional cost.

2.2.4 Workstations, Thin-Clients and Small-scale Servers Opportunities

For workstations, thin-clients and small scale servers, the range of energy efficiency opportunities is less defined, however adoption of improved power management settings, higher efficiency internal power supplies and EEE are clear opportunities.

2.3 Design Life

While an examination of annual shipments (IDC 2012, 2013a, 2013b and 2013c) and stock data (KEMA 2010, Fraunhofer 2010) suggests the design life is significantly longer for some units in the residential sector, until further research is conducted, we recommend using 4 years for desktops, per ENERGY STAR (EPA 2013b) and 3 years for notebooks (Toshiba 2008), as a weighted commercial/residential value. The design life for workstations was assumed to be equal to desktops given the similarities in form factor, whereas thin clients and small scale servers was assumed to be 5 years, given less frequency of upgrades for new features and performance.

2.4 Product Classes

For this standards proposal, the CASE team recommends ENERGY STAR 6.0 Specification Final Draft July 2013 for the product definitions and scope (EPA 2013a) with the exclusion of slates (e. g., iPads and Surface). In terms of categorization and requirements for sub-classes, the CASE team recommends the ENERGY STAR 6.0 sub-classification for desktops and notebooks, with a separation of levels between conventional desktops and integrated desktops (all-in-ones) (see Section 6.1.1 for more explanation), and an additional performance categories and requirements. The recommendation for workstations, thin-clients and small-scale servers is no sub-classifications.

For desktops and notebooks, each ENERGY STAR 6.0 product class is defined by the performance score (number of CPU cores and CPU base frequency in GHz), as well as whether the graphics processing unit is integrated or discrete. For both desktops and notebooks, ENERGY STAR currently maintains six categories, as shown in Table 2.4 and Table 2.5.

Table 2.4 ENERGY STAR 6.0 Final Draft Categorization of Conventional and Integrated Desktops

Category	DT 0	DT I1	DT12	DT13	DT D1	DT D2
Performance Score, P	P ≤ 3	3 < P ≤ 6	6 < P ≤ 7	P > 7	3 < P ≤ 9	9 > P
Graphics Type	Any graphics	Integrated Graphics			Discrete Graphics	
Graphics adder	dGfx ≤ G7	N/A			dGfx ≤ G7	

Source: ENERGY STAR Final Draft (2013)

Table 2.5 ENERGY STAR 6.0 Final Draft Categorization of Notebooks

Category	NB 0	NB I1	NB I2	NB I3	NB D1	NB D2
Performance Score, P	P ≤ 2	2 < P ≤ 5.2	5.2 < P ≤ 9	P > 9	2 < P ≤ 9	P > 9
Graphics Type	Any graphics	Integrated Graphics			Discrete Graphics	
Graphics adder	dGfx ≤ G7	N/A			dGfx ≤ G7	

Source: ENERGY STAR Final Draft (2013)

In the case of desktops, market data suggests that the current categories are insufficient to capture the range of performance and energy consumption at the high end of the market. An analysis of the attributes of desktop systems currently sold on the market shows that there is a wide range of systems with performance scores greater than 9, as shown in Figure 2.9 below.

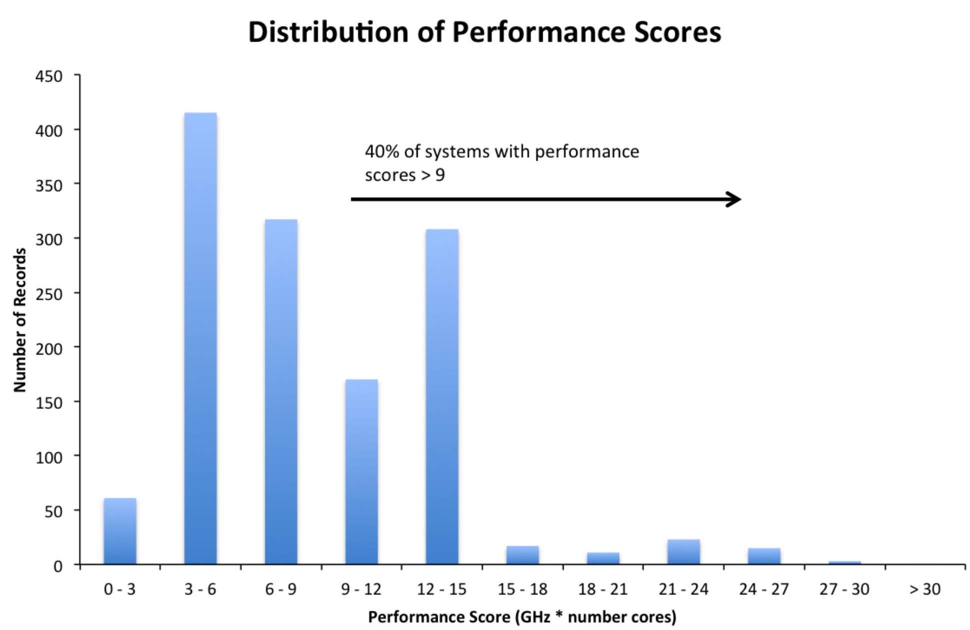

Figure 2.9 Distribution of desktop performance scores in currently available systems

Source: Analysis of Shopper.com retail data (June 2013).

Further analysis of this data has revealed that there is a distinct gap between the performance scores of most quad-core processors and those of available six- and eight-core CPUs. Most of the current six- and eight-core CPUs are used in systems with discrete graphics. For this reason, the CASE Team proposes a third discrete graphics desktop category, DT D3, that would capture higher performance discrete GPU desktops with performance scores greater than or equal to 15. Figure 2.10 illustrates how this new threshold would effectively separate many higher end systems from the DT D2 category.

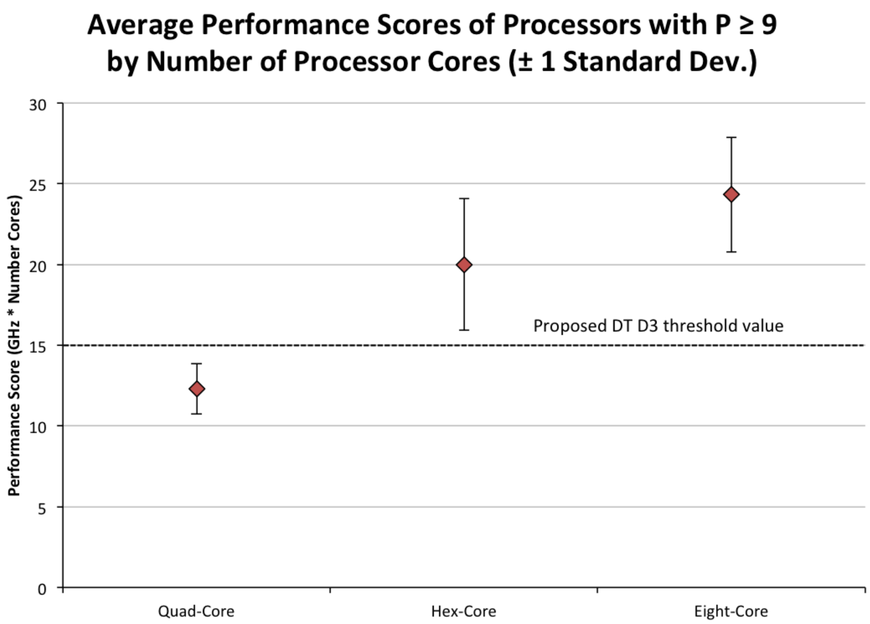

Figure 2.10: Average performance scores and proposed DT D3 threshold

The CASE team recognizes the need for specific treatment of very-high performance configurations that fall beyond the performance range for which the DT D3 category is intended. This will ensure that the standards do not restrict very-high performance from the market and leaves enough flexibility for future innovation.

However, very-high performance computers should not be given a "free-ride," as this could create a growing loophole and loss of savings by encouraging manufacturers to market more such configurations, or as technology evolves naturally toward higher computing performance. As very-high performance computers consume much higher amounts of energy than typical PCs, they present the most cost-effective opportunities to implement advanced energy efficiency technologies.

The CASE team proposes that very-high performance computers should be exempt from TEC requirements, but be required instead to use an 80 PLUS GOLD power supply with an efficiency of 84% at 10% load. This will minimize potential energy waste in high-end models, and limit the loss of savings should these models become more common as the market evolves.

2.5 Manufacturing and Market Channel Overview

Residential computers are sold through either brick-and-mortar, e.g. Walmart, Best Buy, etc., or online retailers, e.g. dell.com, hp.com, tigerdirect.com, newegg.com, Amazon.com, etc.

Commercial computers are sold through a combination of channels: in store (SMBs), through value-added retailers, or directly by OEMs to enterprise customers for large orders. Models in this environment typically consist of Configure to Order (CTO), Build to Order (BTO), and Build to Stock (BTS).

Power management settings are configured by OEMs through the "imaging" process. The options for configuration are limited to those provided by the operating system. As mentioned in Section 6.3.2, the end-user has the ability to adjust the settings throughout the life of the unit.

OEMs source the internal power supplies and control the efficiency levels that go into their systems. High-efficiency internal power supplies exist, but at a cost premium. Because the internal power supply is only one element of the product design, manufacturers of computers rely on other component manufacturers and subsystem integrators to provide other components such as the video cards, memory, hard drive, etc., which cumulatively affect overall energy consumption.

Discrete graphic cards are sourced and installed by OEMs, but they can also be sold after-market, both through brick-and-mortar (i.e. Walmart, Best Buy, etc.) or online retailers (dell.com, hp.com, tigerdirect.com, newegg.com, Amazon.com, etc.).

3 Unit Energy Usage

3.1 Overview

As computer technology advances, so do consumer preferences. Despite a shift towards less energy consumptive form factors and assistance from voluntary programs in improving efficiencies such as ENERGY STAR and 80 PLUS energy savings can still be gained on a per unit basis for all form factors.

Energy use varies per device and is dependent on the power draw in each different mode and the time in each mode or mode weighting. Drawing from substantive research and testing, we have established average energy usages and identified significant opportunity for reduction.

3.2 Duty Cycle

The duty cycle of computers is determined both by the extent of the computer's power management settings and by the extent the user manually switches the modes, and therefore varies considerably by ownership, though general usage trends have been documented. As discussed in the Invitation to Participate (CEC 2013), there are several studies which sample PC user behavior in both residential and commercial settings that capture an estimation of daily duty cycles with and without power management (PG&E 2010; Pigg & Bensch 2010; TIAX 2007, Fraunhofer 2010, ECMA-383, Microsoft 2008). Accounting for the limitations in these studies, including sample size, survey methods, and for a differentiation in short idle and long idle, during the Invitation to Participate, the CASE Team recommended aligning with ENERGY STAR 6.0 Final Draft for a sector-weighted duty cycle for notebooks, and making a modification to the duty cycle for desktops based on the research, that would increase the percentage of time in idle mode (short and long).

ENERGY STAR 6.0 Final Draft includes different duty cycles for computers that feature different levels of network connectivity in Sleep mode. Given the lack of data to support these network connectivity duty cycles and uncertainties both ways, the CASE Team recommends using the ENERGY STAR 6.0 conventional duty cycles for desktops and thin clients, and the other form factor-specific ENERGY STAR 6.0 duty cycles for workstations and small-scale servers (see Table 3.1).

Table 3.1 Estimated Duty Cycle For Each Form Factor

Mode	**Conventional Desktops, Integrated Desktops and Thin Clients**	**Notebooks**	**Workstations**	**Small-scale Servers**
Off	45%	25%	35%	0%
Sleep	5%	35%	10%	0%
Long Idle	15%	10%	15%	100%
Short Idle	35%	30%	40%	0%

3.1 Real-World Adjustment Factor To Estimate Computer Energy Use, Savings And Cost-Effectiveness

The annual energy consumption of computers is conventionally estimated using the ENERGY STAR Typical Energy Consumption (TEC) metric, which uses idle mode as a proxy for active mode power. While this proxy worked well with computers until recently using the ENERGY STAR Version 5 specification, this is no longer appropriate for two reasons:

1) The new ENERGY STAR 6.0 specification now includes both long and short idle modes, increasing the difference between typical active power and the average reported idle power using the ENERGY STAR test procedure;

2) Modern computers are able to better scale power down when inactive than recently, leading to a higher difference between idle and active power.

NRDC evaluated the difference between ENERGY STAR 6.0 TEC and real-world energy consumption over a day's work on a common commercial notebook computer (Lenovo T420s), using typical applications and accessories (docking station and second screen). NRDC found that the real-world active power of the computer is between 20 to 50 percent higher than Version 6.0 TEC depending on accessories and applications used. This is based on a sample of one; until further data becomes available, the CASE Team recommends the CEC uses real-world adjustment factors of 30% for notebooks and 15% for desktops and workstations when calculating energy use, savings and cost-effectiveness. The lower adjustment factor for desktops reflects our assumption that desktops, while benefitting from power scalability technology, do not implement it to the same extent as notebooks due to a lack of battery life incentive.

It is important to note that the standards levels do not account for the real-world adjustment factor; the CASE Team proposes keeping the ENERGY STAR 6.0 TEC calculations as is.

3.2 Energy Use per Unit for Non-Qualifying Products

The range of unit energy use in the computer market is wide, between and within performance categories. This section identifies the unit energy consumption of lower-efficiency products, or non-qualifying products, products that do not meet the proposed standard described in Section 6. Table 3.1 presents the non-qualifying product energy use for the proposed standard: estimates of both the average unit energy consumption of non-qualifying products for each product category, and for conventional desktops the unit energy consumption of selected as "baseline" units for testing, as having the most common components (see PG&E 2012a for more details regarding the selection process). For workstations and small-scale servers, the average non-qualifying products were estimated using 80 PLUS database (Ecova 2013) to have an 81% efficiency internal power supply at 20% load for Tier 1, and 82% for Tier 2 (for workstations only. For thin clients the non-qualifying product was estimated to have minimal power management settings enabled and no EEE.

For both desktops and notebooks, the average unit energy consumption of non-qualifying products was calculated using the methodology described in Section 4.2. For the other form factors, given the limited data, the ENERGY STAR 2012 Qualified Products List (QPL) was used, so these estimates are likely understating per unit energy use.

Table 3.1 Energy Use for Non-Qualifying Products

Product Class	Performance Category	Average Unit Energy Consumption of Non-Qualifying Products (kWh/yr)(1)		Unit Energy Consumption of Products Selected as Baseline Units and Tested (kWh/yr)(2)
		Tier 1	**Tier 2**	**Tier 1 & Tier 2**
Desktops - Conventional	DT 0	309	285	127
	DT I1	284	259	150
	DT I2	306	281	144
	DT 13	300	278	228
	DT D1	-	-	187
	DT D2	-	-	259
	DT D3	-	-	424
Desktops – Integrated(3)	DT 0	123	104	N/A
	DT I1	185	170	
	DT I2	166	151	
	DT 13	169	140	
Notebooks(3)	NB 0	37	37	N/A
	NB I1	40	38	
	NB I2	40	36	
	NB I3	43	40	
Workstations(4)	N/A	664	660	N/A
Small-scale Servers(4)	N/A	298	N/A	
Thin Clients	N/A	52	N/A	

(1) From ENERGY STAR 5.0 QPL 2012 and market model using methodology described in Section 4.2. Energy use for the avg. non-qualifying products for DT D1, DT D2, DT D3 are unknown due to limitations in the conversion from ENERGY STAR 5.0 to ENERGY STAR 6.0 categorization. The values for Desktops (both conventional and integrated), Notebooks and Workstations include a real-world adjustment factor described in Section 3.1.
(2) From PG&E 2012a and recent testing results. The values include a real-world adjustment factor described in 3.1.
(3) For Desktops – Integrated and Notebooks, the total energy use is without monitor energy consumption, given the absence of this data in the ENERGY STAR 5.0 QPL dataset.
(4) While the proposed standard includes power management and EEE requirements for workstations and small-scale servers, the energy use estimates did not account for the lack of these energy-saving features.

3.3 Energy Use per Unit for Qualifying Products

This section identifies the unit annual energy consumption of higher-efficiency products or qualifying products, products that meet the proposed standard described in Section 6. Table 3.2 presents the qualifying product energy use for the proposed standard: estimates of both the average unit energy consumption of qualifying products for each product category and energy consumption of conventional desktops modified from baseline units into higher efficiency products using cost-effective technologies (see PG&E 2012 for more details regarding the modification process). Similar to all of the non-qualifying products on the market, the market average unit energy consumption of qualifying products was calculated using the methodology described in Section 4.2.

For workstations and small-scale servers, the average non-qualifying products were estimated using the 80 PLUS database (Ecova 2013) to have an 87% efficiency internal power supply at 20% load for Tier 1, and 88% for Tier 2 (for workstations only). For thin clients the average qualifying product was estimated to have power management enablement and EEE.

Table 3.2 Energy Use for Qualifying Products

Product Class	Performance Category	Average Unit Energy Consumption of Qualifying Products (kWh/yr) [1]		Unit Energy Consumption of Cost-effective Efficiency Builds (kWh/yr) [2]	
		Tier 1	**Tier 2**	**Tier 1**	**Tier 2**
Desktops - Conventional	DT 0	46	40	101	90
	DT I1	77	50	109	99
	DT I2	101	75	135	86
	DT 13	97	77	163	154
	DT D1	-	-	129	118
	DT D2	-	-	170	146
	DT D3	-	-	320	316
Desktops – Integrated[3]	DT 0	40	-	N/A	
	DT I1	48	40		
	DT I2	63	-		
	DT 13	63	42		
Notebooks[3]	NB 0	19	19	N/A	
	NB I1	21	17		
	NB I2	24	18		
	NB I3	33	-		
Workstations[4]	N/A	621	616	N/A	
Small-scale Servers[4]	N/A	278	N/A		
Thin Clients	N/A	50	N/A		

(1) From ENERGY STAR 5.0 QPL 2012 and the market model methodology described in Section 4.2. Energy use for the avg. qualifying products for DT D1, DT D2, DT D3 are unknown due to limitations in the conversion from ENERGY STAR 5.0 to ENERGY STAR 6.0 categorization. The values for Desktops (both conventional and integrated), Notebooks and Workstations include a real-world adjustment factor described in Section 3.1.

(2) From PG&E 2012 and recent testing results. The values include a real-world adjustment factor described in Section 3.1.

(3) For Desktops – Integrated and Notebooks, the total energy use is without monitor energy consumption, given the absence of this data in the ENERGY STAR 5.0 QPL dataset.

(4) While the proposed standard includes power management and EEE requirements for workstations and small-scale servers, the energy use estimates did not account for these energy-saving features.

4 Market Saturation & Sales

4.1 California Stock and Shipments

4.1.1 Stock

There are approximately 36 million computers in California in 2013: 9.6 million conventional desktops, 3.6 integrated desktops and 23 million notebooks (see Table 4.1).This estimate was derived using shipment data from IDC (2012, 2013a and 2013b), a design life of 4 years for desktops and 3 years for notebooks, an approximate division of 59% to 41% between the commercial and residential PC market (Hamm and Greene 2008), an ENERGY STAR QPL (NRDC 2013a) split between conventional and integrated desktops (66% and 34%, respectively, in 2012), and a California / U.S. GDP percentage of 13% (BEA 2012),

It is important to note that this is a very conservative number relative to California-specific and national surveys completed for 2009 and 2010 estimates (KEMA 2010 and Fraunhofer 2011, respectively), which reported a significantly greater number of units. The new estimates using the IDC data are therefore much lower than those reported by the IOUs and NRDC in the response to the Invitation to Participate (CA IOUs 2013a; NRDC 2013a). KEMA (2010) reported that in 2009 at least 9.6 million desktops and 8.6 million notebooks are in use in the residential sector. Using the same commercial/residential split and California / U.S. percentage as above, this equates to 13.8 million desktops and 12.4 million notebooks in the commercial sector, for a total of 23.4 million desktops and 21 million notebooks. Fraunhofer (2011) reported an even larger number of units and shift between desktops and notebooks in the U.S. For California this would equal 32 million desktops and 42 million notebooks, respectively in 2010.

Workstation stock in California is estimated at 419,000, using global shipments from Jon Peddie Research (2013), multiplying by the U.S. ratio of EPA shipment data in 2011 (EPA 2011), and using a California / U.S. GDP percentage of 13% (BEA 2012). Stock for small-scale servers in California are estimated at 185,000, derived from shipment data (EPA 2011), so a low estimate given the source, and a design life of 5 years. Stock for thin clients is estimated at one million, an estimate developed from (PG&E 2010) and IDC (2013c) for worldwide shipments and US shipments in 2011 (Microsoft 2011), using a California / U.S. GDP percentage of 13% (BEA 2012).

4.1.2 Shipments

For 2011 and 2012, IDC (2013a) reported 71.3 million and 66.5 million total shipments for desktops, notebooks ("portables" and min-notebooks) and workstations, respectively in the U.S. There was a 35% / 65% split between desktops and notebooks in 2011 (IDC 2012) in mature markets (U.S. Western Europe, Canada, Japan) and a 37% / 63% split in 2012 (IDC 2013b). Using the California / U.S. GDP percentage of 13% (BEA 2012), not accounting for workstations, there were approximately 3.2 million desktops and 6.0 million notebooks sold in 2011 and 3.2 million desktops and 5.5 million notebooks sold in 2012. Annual shipments for workstations at 115,700 was developed using the same data as for the stock. Small-scale servers are estimated to be 61,750 using EPA shipment data (EPA 2011), which is only for ENERGY STAR, so again a low estimate. Thin clients are estimated at 270,000 shipments annually using the same methodology as for stock.

4.1.3 Future Shipments

In terms of future shipments in mature markets (U.S. Western Europe, Canada, Japan) desktops and notebooks are expected to stay relatively flat, using IDC (2013b). Between 2017 and 2020, a flat projection was assumed. Workstations are anticipated to increase by 7% annually (Jon Peddie 2013). Without additional data, the small-scale servers are assumed to remain flat. Thin clients are estimated to grow 12-16% per year (Microsoft 2011 and IDC 2013c).

Table 4.1 California Stock and Sales

Year	Product Class	Annual Sales Units (millions)	Stock Units (millions)
2013	Desktops - Conventional	2.0	9.6
	Desktops - Integrated	1.0	3.6
	Notebooks	5.3	22.9
	Workstations	.11	.4
	Thin-clients	.26	1.0
	Small-scale Servers	.06	.18
2015 (Tier 1)	Desktops - Conventional	2.0	8.0
	Desktops - Integrated	1.0	4.1
	Notebooks	5.2	21.2
	Workstations	.13	.46
	Thin-clients	.35	1.3
	Small-scale Servers	.06	.18
2017 (Tier 2)	Desktops - Conventional	1.9	7.8
	Desktops - Integrated	1.0	4.0
	Notebooks	5.2	20.9
	Workstations	.15	.53
	Thin-clients	.47	1.8
	Small-scale Servers	.06	.18
2019 (Stock Turnover)	Notebooks	5.2	20.8
2020 (Stock Turnover)	Desktops - Conventional	1.9	7.7
	Desktops - Integrated	1.0	4.0
	Workstations	.18	.65
	Thin-clients	.75	2.8
	Small-scale Servers	.06	.18

4.2 Market Share of High Efficiency Options

To estimate the current saturation of desktops, integrated desktops and notebooks relative the proposed standards levels, a "whole market model" was used. The ENERGY STARQPL provides a useful dataset of products including their TEC, however, the QPL only includes products that qualify for ENERGY STAR, by nature, and therefore does not represent the entire market. The CASE team extrapolated the ENERGY STAR QPL 2012 to represent the entire market. Aligning the ENERGY STAR 5.0 QPL dataset with the ENERGY STAR 6.0 categorization also required re-classification (NRDC 2013a).

In summary, the whole market model process extends the QPL category by category to include the following products:

1) Products that meet ENERGY STAR TEC limits, but are not qualified either because their power supply does not meet ENERGY STAR requirements, or because they were not submitted for qualification by their manufacturers due to budgetary priorities;
2) Products that do not meet ENERGY STAR TEC limits.

The whole market model is then divided between the qualifying and non-qualifying products, those products that do and do not meet the proposed standard. Averages of each product category, for both qualifying and non-qualifying products, are calculated assuming whole market model-weighted sales in the absence of more detailed data. For workstations and small-scale servers, the 80 PLUS database from July 2013 was estimated to be representative of the whole market, and was divided accordingly relative to the proposed standard to determine the market saturation of qualifying and non-qualifying products.

2013 market saturation of ENERGY STAR power management enabled upon shipment is estimated to be quite high given sample testing provided by an undisclosed major retailer, but there seems still to be some opportunity for market improvement for this zero cost solution by making it a regulatory compliance requirement.

Thin clients' saturation of qualifying products was estimated referencing the California IOUs standards proposal on small network equipment (2013) regarding saturation of EEE, in the absence of more detailed information regarding this specific form factor.

The market saturation for all form factors is estimated below in Table 4.2.

Table 4.2 2012 Market Saturation of Products Meeting the Standard

	Tier 1	Tier 2
Desktops - Conventional	25%	13%
Desktops - Integrated	30%	10%
Notebooks	30%	11%
Workstations	40%	27%
Small-scale Servers	40%	N/A
Thin-clients	20%	N/A

Regarding the distribution of internal power supply efficiencies, 2013 market saturation of desktops with 80 PLUS internal power supplies is estimated to be over 50% of the market (iSuppli 2011, NEEA 2012, GLTG 2013). Within the 80 PLUS market, 80 PLUS Bronze, Silver, Gold, and Platinum internal power supplies are estimated to be 20%, 4%, 9%, and 2% respectively, with the remaining 80 PLUS base (Ecova 2013). For the higher wattage power supplies found in workstations and small-scale servers, the saturation of 80 PLUS products appears to be even higher, as evidenced by the greater percentage of 600 watt power supplies that are 80 PLUS Silver and above (38%), compared to under 600 watts (24%). Future Market Adoption of High Efficiency Options

Natural adoption of high efficiency options is occurring in some but not all segments of the computer market. For example, about half of the desktop market still uses non-80 PLUS power supplies even though 80 PLUS power supplies are highly cost effective. A large part of the desktop market is driven primarily by purchase price minimization at the expense of lifecycle cost savings for the user.

Even in the notebook market, there are many cost-effective savings opportunities that are not broadly adopted or could be adopted more rapidly, such as higher integration, and more efficient CPUs, motherboards and displays. There is still a large efficiency gap between most notebooks and slate/tablet devices, which are used almost exclusively on battery power, and have therefore implemented more advanced power saving technologies. In addition, energy efficiency improvements could be offset by regressions in other areas absent energy standards. For example, new "always connected" modes could displace sleep modes, offsetting efficiency gains achieved by the reduction of time spent in active mode just to maintain the network connection.

The proposed standards will accelerate the adoption of cost-effective efficient designs compared to slower and more partial natural market adoption. They will guarantee that technology innovation is harnessed to reduce the energy use of computers in California, and will also provide safeguards against energy efficiency backsliding as performance increases and new features are introduced.

5 Statewide Energy Usage

The current statewide energy use of computers in 2013 is between 4-7 TWh, equal to energy consumption of the city of Los Angeles. The stock estimates in Table 5.1 are on the lower end of this range, with desktops and notebooks derived from multiplying historical shipments starting in 2010 (IDC 2012, 2013a, 2013b, and 2013c) by the avg. unit energy consumption of each form factor, market model-weighted by performance category. The rest of the table shows the business-as usual scenario beyond 2013 if the proposed standard is not adopted. The values assume no per unit energy consumption improvement beyond the current market levels.

Table 5.1 California Statewide Non-Standards Case Energy Use

Year	Product Class	Annual Sales		Stock	
		Energy Use (GWh/yr)	Coincident Peak Demand (MW)[a]	Energy Use (GWh/yr)	Coincident Peak Demand (MW)[a]
2013	Desktops - Conventional	493	75	2,900	444
	Desktops - Integrated	137	21	557	85
	Notebooks	183	28	623	95
	Workstations	75	11.4	271	41.5
	Thin-clients	13.9	2.1	57	9
	Small-scale Servers	17.9	2.9	89.5	13.7
	Total	920	140	4,500	688
2015	Desktops - Conventional	486	74	1,990	304
	Desktops - Integrated	135	21	554	85
	Notebooks	181	28	546	84
	Workstations	86	13.1	311	47.5
	Thin-clients	18.8	2.9	72.3	11.1
	Small-scale Servers	17.9	2.9	89.5	13.7
	Total	925	142	3,560	545
2017	Desktops - Conventional	481	74	1,939	296
	Desktops - Integrated	134	17	540	79
	Notebooks	183	28	545	83
	Workstations	98	15.1	356	54.5
	Thin-clients	25.5	4	96	14.7
	Small-scale Servers	18	2.9	89.5	13.8
	Total	940	141	3,570	541
2019 (Stock Turnover)	Notebooks	183	28	546	84
	Thin Clients	34.6	5.3	130	20
2020 (Stock Turnover)	Desktops - Conventional	481	74	1,926	295
	Desktops - Integrated	134	17	536	69
	Workstations	121	18.5	438	67
	Small-scale Servers	18	2.7	89.3	14
	Total (of all form factors)	970	146	3,670	549

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002).

6 Standards Proposal

6.1 Summary of Standards Proposal

Of the energy savings opportunities available, a system-wide, performance-based energy use approach allows manufacturers to select a suite of options, while accommodating for functionality. To this end, the CASE Team proposes both a Tier 1 and Tier 2 standards requirement based on the ENERGY STAR 6.0 framework, summarized in Table 6.1, and the base allowances and graphics adder levels in Table 6.2.

Table 6.1 Summary of Standards Proposal for Computers

		Tier 1 – 2015	Tier 2 - 2017
	TEC Base levels – Conventional Desktops	Cost-effective levels as per Table 6.2. An alternative compliance option of a Gold PSU for the most highest-performing desktops (defined by EU: DT>=6cores, dGfx>320GB/s, >=16GB RAM, PSU >=1000W)	Cost-effective levels as per Table 6.2. An alternative compliance option of a Gold PSU for the most highest-performing desktops (defined by EU: DT>=6cores, dGfx>320GB/s, >=16GB RAM, PSU >=1000W)
	TEC Base levels – Integrated Desktops	Cost-effective levels as per Table X. An alternative compliance option of a Gold PSU for the most highest-performing desktops (DT>=6cores, dGfx>320GB/s, >=16GB RAM, PSU >=1000W).	Cost-effective levels as per Table X. An alternative compliance option of a Gold PSU for the most highest-performing desktops (DT>=6cores, dGfx>320GB/s, >=16GB RAM, PSU >=1000W)
	TEC Base levels – Notebooks	Cost-effective levels as per Table 6.2.	Cost-effective levels as per Table 6.2.
ADDERS	**Graphics adders - Desktops**	Linear regression of 2012 testing results (PG&E 2012). Can claim adder only if graphics switching is not enabled by default.	20% more stringent than linear regression of 2012 testing results (PGE 2012). Can claim adder only if graphics switching is not enabled by default.
	Graphics adders - Notebooks	41% of Desktop graphics adders. Can claim adder only if not capable of graphics switching.	20% more stringent than Tier 1. Can claim adder only if not capable of graphics switching.
	Display adder	Same ENERGY STAR Version 6.0 Final Draft	Same as Tier 1
	Enhanced performance display adder	Same ENERGY STAR Version 6.0 Final Draft	Same as Tier 1
	Storage adder	Same as ENERGY STAR v6: 26 (DT)/2.6(NB) kWh /internal drive above first one	Same as Tier 1
	Memory adder	Same as ENERGY STAR v6 (0.8 kWh/GB in above baseline)	Same as Tier 1
	Audio card adder	Same as EU EcoDesign (15 kWh DT only)	Same as Tier 1

OTHER REQUIREMENTS	**IPSU efficiency**	80 PLUS Bronze + 10% requirement of 79% efficiency + PF = 0.9 at 100%	80 PLUS Silver + 10% requirement of 82% efficiency + PF = 0.9 at 100%
	Power Management	Same as ENERGY STAR v6	Same as Tier 1
	Energy Efficiency Ethernet	Enabled	Same as Tier 1
OTHER COMPUTER TYPES	**Workstations**	80 PLUS Silver + 10% requirement of 82% efficiency + PF = 0.9 at 100% Power Management - Same as ENERGY STAR v6 for desktops Energy Efficient Ethernet	80 PLUS Gold + 10% requirement of 84% efficiency + PF = 0.9 at 100% Power Management - Same as ENERGY STAR v6 for desktops Energy Efficient Ethernet
	Small- scale servers	80 PLUS Silver + 10% requirement of 82% efficiency + PF = 0.9 at 100% Power Management - Same as ENERGY STAR v6 Energy Efficient Ethernet	Same as Tier 1
	Thin Clients	Power Management - Same as ENERGY STAR v6 Energy Efficient Ethernet	Same as Tier 1

Table 6.2 TEC Base Allowances, and Graphics Adders – Tier 1 and Tier 2

Product Class	Performance Category	Tier 1 - 2015	Tier 2 - 2017	Adder Category[(1)]	Tier 1 - 2015	Tier 2 - 2017
		Maximum Base TEC (kWh/yr)			Adder	
Conventional Desktops	DT0	66	52	G1	21	17
	DT I1	106	84	G2	25	20
	DT I2	114	90	G3	32	26
	DT I3	128	101	G4	40	32
	DT D1	92	73	G5	48	38
	DT D2	102	81	G6	51	41
	DT D3	226	178	G7	57	46
Integrated Desktops	DT0	41	28	Same as Above		
	DT I1	67	45			
	DT I2	72	48			
	DT I3	81	54			
	DT D1	69	46			
	DT D2	81	54			
Notebooks	NB0	13	10	G1	9	6
	NB I1	21	15	G2	10	7
	NB I2	23	17	G3	13	8
	NB I3	27	20	G4	16	10
	NB D1	15	11	G5	20	13
	NB D2	17	13	G6	21	13
				G7	23	15

(1) The graphics adders are for DT 0, DT D1, DT D2, DT D3 and the categories do not correlate with the rows of the performance category in this table.

6.1.1 Adjustment to ENERGY STAR Version 6.0

A summary of adjustments to ENERGY STAR Version 6.0 are as follows:

1. **TEC levels:** Adjusted from ENERGY STAR Version 6.0 as explained in Section 7 below;
2. **Graphics adders**: Adjusted to match the average results of PG&E testing of twelve 2012 graphics cards (PG&E 2012b);
3. **Conventional desktops** and **integrated desktops** were split into separate product classes. As described in response to the Invitation to Participate (NRDC 2013), the two form factors have very different power profiles. The separation enables the standards to drive adoption of efficient designs by each form factor. Differences are not limited to energy use, as integrated and conventional desktops also provide different functions:

- Conventional desktops are fully upgradeable, whereas integrated desktops have limited upgradability.
- Conventional desktops offer more flexibility with the choice of display: users can either reuse existing displays, or upgrade to different displays over the life of the product.
- Integrated desktops offer sleeker designs, which is the main raison d'être of this type of computers.

4. The **DT D2 category** (high-end desktops with discrete graphics) was split in two separate categories (DT D2 and DT D3) due to the wide range of performance capabilities in this category. This allows to set differentiated levels for vast majority of the market with a performance score lower than 15, and for the small minority of the market with performance scores higher than 15.
5. **Mode weightings** for desktops and notebooks are based on ENERGY STAR 6.0 conventional duty cycle only. The proposal does not include the adjusted "Full Network Connectivity" duty cycles, because there is no evidence that network connectivity reduced idle time by these amounts, while there is evidence that real-world duty cycles may actually be higher than ENERGY STAR 6.0 as discussed in Section 3.2. We believe the ENERGY STAR 6.0 conventional duty cycle is a fair estimate given these uncertainties, until new evidence is available. In addition, network-adjusted duty cycles could dramatically weaken the standards if the majority of the market adopts network connectivity, which is likely given Haswell networking capabilities.
6. **Switchable graphics:** Under our proposal, notebooks can claim a graphics adder only if they are not capable of switchable graphics. Desktops can claim a graphics adder if graphics switching is not enabled by default in idle mode, however they do not get the switchable graphics incentive. This change from ENERGY STAR 6.0 Final Draft is due to the concern that EPA's proposal could result in notebooks disabling switchable graphics when plugged in, in order to claim a graphics adder, as explained in NRDC comments to EPA on ENERGY STAR 6.0 Final Draft (NRDC 2013b).
7. **Discrete audio card adder:** An adder for discrete audio cards was added to the proposal, aligning with the draft EU EcoDesign Lot 3 regulation, in order to account for the energy use in idle mode of these cards.
8. **Internal power supply efficiency:** An efficiency requirement at 10% load was added compared to the ENERGY STAR 6.0 requirements, to ensure internal power supplies are designed to be efficient at the typical load point of modern computers.
9. **Very high-end alternative compliance pathway:** In order not to prevent extremely high-end computers from being sold in California, the proposal offers an alternative compliance pathway for computers meeting very-high end performance criteria. The alternative compliance pathway does not require meeting TEC levels, however it requires an 80 PLUS Gold power supply with an equivalent 10% load efficiency requirement instead.
10. **Power Management:** ENERGY STAR 6.0 Final Draft does not have power management settings for workstations. We recommend the same requirement as for desktops.

6.1.1 Requirements of Configurations

Some computer models can be configured by customers at time of purchase. In this Configure-to-Order model, manufacturers may offer a handful of configurations for each of a dozen different components for a desktop computer. For example, a given computer model may offer a choice of processor, memory, graphics card, hard drives, etc. These options can lead to thousands of possible permutations. Registering all possible permutations in CEC's appliance database would cause a significant burden for manufacturers.

The CASE Team recommends that CEC follows the same approach as the ENERGY STAR program by requiring manufacturers to test and report "product configurations that represent the worst-case power consumption for each product category within the family". This approach is suitable for Title 20 as it provides a sufficient assurance that all other configurations meet the standard, and has the merit to be consistent with ENERGY STAR.

6.2 Implementation Plan

The expected implementation for this standards proposal is for the CEC to proceed with its appliance standards rulemaking authority, from pre-rulemaking and rulemaking through adoption, and for manufacturer compliance upon effective date.

6.3 Test Methods

6.3.1 Typical Energy Consumption

For desktops and notebooks, the main test method is ENERGY STAR's test method for its 6.0 specification (EPA 2012a). This test procedure measures power consumption by operational mode using the following specifications:

- Approved meter
- Accuracy
- Test conditions
- Test configuration
- Models capable of operating at multiple voltage/frequency combination

In ENERGY STAR's specification, these wattages are used with mode weighting (or duty cycle) to calculate Typical Energy Consumption (TEC) or kwh/yr.

6.3.2 Power Management Settings

There currently is no test procedure for enabled power management settings, as power management is a configuration, not a performance requirement. However, ENERGY STAR Version 6.0 Computer Specification Program provides shipment requirements for mode-switching triggers (see Table 2.3).

6.3.1 Power Supply Unit Efficiency

The U.S. Environmental Protection Agency (EPA) and Department of Energy (DOE) ENERGY STAR Program has established the test procedure for power supply efficiency sponsored by the CEC Public Interest Energy Research (PIER) Program, written by the Electric Power Research

Institute (EPRI) and Ecos (2012). The writing of this procedure began in February 2004, and has been revised several times, including a merger of the *Server Test Protocol Rev 1.2* with the *Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-Dc and Dc-Dc Power Supplies Rev 6.6.*[5]

The CASE Team recommends the use of this test procedure with additional testing at 10% load.

7 Standards Justification and Technical Feasibility

7.1.1 TEC Limits - Desktop Computers

The cost-effectiveness evaluation was made by replacing high-energy using components by more efficient ones on a representative sample of eight desktop computers while not impacting computer performance. Proposed TEC limits were set so that they capture all the cost-effective savings opportunities that could be demonstrated via component replacements on this test sample while also providing some net lifecycle savings for users from the first year.

Note however, that the demonstrations included only a limited number of possible pathways for cost-effective savings, not necessarily the most cost-effective way to meet standard levels. Moreover, given the use of incremental retail price differences for all of the components, except for power supplies, rather than the incremental price of efficiency, there may have been additional opportunities not pursued. The proposed standard levels are therefore conservative. The CASE team is confident that more cost-effective ways exist and that market competition and innovation will lead industry to find even more cost-effective ways to meet these proposed standards. As technology evolves and standards transform the market, we expect actual user savings to be higher and cost less than those estimated in the proposal.

The computer cost-effectiveness testing conducted by the California IOUs (see PG&E 2012a and Appendix C-1) includes consideration of all proposed desktop system categories, examining dozens of different system configurations across the categories to arrive at builds that represent cost-effective pathways to meet proposed standards levels in 2015. Since the proposed standard also includes a more stringent Tier 2 that would become effective in 2017, we included measurement and cost effectiveness analysis of more aggressive energy savings measures that could be used toward compliance with Tier 2. The measured "cost-effective efficient" systems are about 6% below the required Tier 1 standards levels, on average. The measured "most efficient" systems are within 6% of complying with Tier 2 standard levels, on average. Both sets of measurements represent currently available, off-the-shelf technologies and do not factor in new processors released by Intel and AMD during the first two quarters of 2013. As noted in earlier sections, system idle power levels can be expected to drop further with incorporation of new processor technologies by 2017.

7.1.2 TEC Limits - Notebook and Integrated Desktop Computers

The CASE Team pursued a different approach in evaluating the feasibility and cost-effectiveness of notebook and integrated desktop computers. Due to the highly integrated and compact designs used in these products, a rigorous re-engineering of individual products was not possible. However, we provide several justifications for the ultimate feasibility and cost-effectiveness of the proposed standards approach.

[5] See: http://www.efficientpowersupplies.org/methods.asp for the full test protocol.

In Section 2.2.3 , we provided a list of existing technologies, many of which can be incorporated into designs with little to no cost, that can be used to help notebooks and integrated desktops meet the proposed standards levels cost-effectively. The technologies we have provided are either already available in the market or are expected to be readily available by the time the proposed standards take effect.

Certain technological developments will be transformative, effectively establishing a new baseline for efficiency. This includes upgrades to processor architecture like the recently introduced Haswell architecture from Intel. Since these processor technologies are being introduced today, they will be the dominant, mainstream technology in use when standards go into effect and should afford significant low- and no-cost opportunities for notebook OEMs to comply with the proposed standards. Processor manufacturers such as Intel and AMD can be expected to refresh their products at least one more time before the anticipated effective date of standards in 2015, meaning that even the most current technology today would be “previous-generation” technology during Tier 1 of the standard.

It is important to note that the list is only a sample of promising energy efficiency technologies and is meant to illustrate the technology potential for cost-effective energy savings in computers. This technology potential can be deployed at scale in the market given appropriate regulatory signals.

7.1.3 Why Use the ENERGY STAR Version 6.0 Framework Instead of the Version 5.0 Framework

This standards proposal is based on ENERGY STAR Version 6.0 framework because it is closely aligned with the current market, while the Version 5.2 was developed in 2008, went into effect in 2009, and is much less relevant to modern computers given the fast pace of computer technology evolution.

Version 5 categories are defined largely based on number of processor cores and amount of memory. The market has evolved considerably over the past few years relative to these two factors: dual- and quad-core processor machines with 4+GB of memory represented the very high-end of the market in 2008 but are now main-stream, and this trend is expected to continue over the foreseeable future. There are very few products left on the market in category A, entry and mainstream products are increasingly migrating towards categories C and D, leading to a situation where two categories will cover most of the market. This does not allow for appropriate differentiation for performance-based standard setting, and this situation will worsen over the next few years as this migration toward higher categories continues.

The Version 6.0 categories are much better suited to the current market and will ensure California computer standards are more effective and remain effective for a longer period of time.

8 Economic Analysis

8.1 Incremental Cost

PG&E’s 2012 study and the following supplemental research into achievable, cost-effective efficiency identified incremental cost data for three of the four desktop component opportunities outlined above (CPUs, GPUs, and hard drives) using retail price points from several online computer parts retailers (e.g. Newegg.com, TigerDirect.com). Incremental retail prices between products can be higher than the incremental cost of efficiency improvements only, as incremental retail prices can include the costs of non-efficiency related features and components. For internal power supplies, more refined data for costs of efficiency improvements were provided during the Invitation to Participate (CEC 2013). Table 8.1 presents a range of incremental costs for the various components based on price differences between the components used in baseline systems and the components installed in the final cost-effective efficient systems. Further details are provided in PG&E's final CCE report (PG&E 2012a), although numbers have been updated to reflect current price trends.

Table 8.1 Conventional Desktop Computer Component Incremental Costs

Component	Incremental Cost ($ retail in 2013 dollars)	Notes
Internal Power Supplies	$5-$13	During the Invitation to Participate (CEC 2013), stakeholders provided a range of incremental costs for internal power supply efficiency improvements across the 80 PLUS spectrum. For the analysis provided here, the CASE Team relied on bill of material (BOM) data and efficiency data from iSuppli (2011) to determine the relationship between power supply BOM cost and efficiency, and then applied a retail markup factor of 1.31 (DOE 2012). The incremental cost range, which represents power supply efficiencies slightly below 80 PLUS up to 80 PLUS Gold, was found to be consistent with the information provided by stakeholders during the Invitation to Participate.
CPU	Negligible	In many cases, a fundamental change in CPU type will require a change in processor socket and motherboard as well. It is therefore extremely difficult to isolate the energy and cost impacts of the processor alone except when making upgrades within a given processor family. This $0 - $5 incremental cost estimate is for minor upgrades within a given processor family and not for a significant technology shift.
GPU	Negligible for higher performance GPUs.	Recent market data suggest that Kepler and GCN architectures are being offered in higher performance graphics cards (ECMA categories G4 and above) at prices comparable to cards with older technology. In lower performance cards, availability of the newer GPUs is still limited.
Hard Drives	$1 - $9	Incremental costs are relatively low when upgrading to more efficient, conventional spinning HDDs, which represent the low end of our incremental cost range. However, there is still significant incremental cost between conventional HDDs and SSDs. With a small incremental cost, hybrid solid state drives (those containing a combination of conventional magnetic and solid-state flash memory storage) can be used. Hybrid hard drives represent the high end of this incremental cost range.
Power Management Settings	Negligible	No incremental cost due to existing operating system configuration.
Energy Efficient Ethernet	Negligible	Little to zero incremental cost. See California IOUs standards proposal for Small Network Equipment for details (2013b).

Table 8.2 presents the range of opportunities for savings potential and their estimated incremental costs identified in integrated desktop and notebooks discussed previously in Section 2.2.3.

Table 8.2 Integrated Desktop and Notebooks Component Incremental Costs

Component	Incremental Cost ($ retail in 2013 dollars)	Notes
Internal Power Supplies (Integrated Desktops Only)	$5-$13	Same as above.
External Power Supplies (Notebooks only)	$1.70-$2.30	The U.S. Department of Energy's 2010 analysis of external power supply standards found an incremental cost of anywhere from about $1.70 to $2.30 to require average efficiencies of 88% and above (DOE 2010). The range of values covers incremental costs for external power supplies ranging from 60 W to 120 W in rated dc output power.
Display Efficiency	$7	See CA IOUs standards proposal for Electronic Displays (2013c)
Next generation CPU architecture and Power Management Techniques	Negligible	Next-generation CPU architectures from Intel and AMD are expected to provide up to 30% idle power savings in notebooks. As these architectures are being introduced into current models, they will be widely available at negligible incremental cost by the time standards go into effect in 2015.
Switchable GPU	Negligible	Switchable graphics allows notebooks to automatically select the most suitable GPU (integrated or discrete) for the current task, preserving battery life. Notebooks with discrete GPUs can achieve lower idle power by ensuring that this technology is also enabled when the laptop is plugged in. Switchable graphics is supported by the latest CPU architectures and is predominantly a power management strategy, meaning that it can be achieved at negligible incremental cost.
Solid State Drives	2015: $32-$45 2017: $2.60-$10.50	SSD prices continue to drop rapidly, and historical retail price trends for storage suggest prices falling at a CAGR of -28%. Even at these rates, SSDs will present significant incremental cost for Tier I of the proposed standard. By Tier II, incremental costs should be about $10 or less, making SSDs a viable Tier II compliance option. These estimates have been informed by California IOUs desktop computer research.
Power Management Settings	Negligible	No incremental cost due to existing operating system configuration.
Energy Efficient Ethernet	Negligible	Little to zero incremental cost. See the California IOUs standards proposal for Small Network Equipment for details (CA IOUs 2013b).
Motherboard	N/A	Motherboard integration is a design choice that may be

Integration		driven by non-efficiency factors, such as form factor, thermal constraints, and in notebooks, portability. Costs will vary widely depending on the level of integration, much of this cost cannot be ascribed to efficiency due to the other benefits or design drivers, listed above, that influence such integration design decisions.

With Tier 1 and Tier 2 of the standard taking effect in 2015 and 2017, respectively, estimates for future incremental costs of various component upgrades used technology experience curves derived from historical prices. The 2015 prices are forecast based on compound annual decline in prices for different components shown in Table 8.3. Price trends were obtained from a number of sources, including online computer component retailers (Newegg.com, BestBuy.com, Amazon.com), processor manufacturer MSRPs (e.g. Intel and AMD), and third-party computer hardware reviewers (e.g. TomsHardware.com). Products were released between 2006 and the present, and prices were tracked on a quarterly basis for the first 2 - 2.5 years of their release. From these trends, the CASE Team was able to establish the average compound annual price decline in each component category.

Power supply incremental costs were held constant, although this is likely a conservative assumption, as data provided during the Invitation to Participate (CEC 2013) indicates that the incremental costs of 80 PLUS power supplies at various levels of efficiency have dropped in recent years.

Table 8.3 Experience Curve Assumptions by Component

Component	Compound Annual Growth Rate
CPU	-10%
Hard drive - Magnetic	-11%
Hard drive - Solid state	-28%
Internal Power supply	0%
GPU	-15%

For Workstations and Small-Scale Servers, the incremental cost between the non-qualifying products and the standard-level products is associated with improved power management, which is negligible, and for workstations and small-scale servers, the internal power supply cost. Data provided by Information Technology Industry Council (ITI) in the ITP response (ITI 2013) was used for the higher wattage (460 W) power supply costs, using instead a 1.31 Retail Markup (DOE 2012). The incremental cost between the average non-qualifying product of 80 PLUS base with 81% Efficiency at 20% load and 80 PLUS Silver is $6.90, with an additional $10.70 to reach 80 PLUS Gold in 2013 dollars. For 600 W power supplies, the estimated average size for these form factors, an additional 1.5 multiplier was used, taken from the average multiplier between the reported 300 W and 460 W costs. Power management enablement and EEE, including its default enablement, are configurations which require no additional cost.

9 Savings Potential

9.1 Statewide California Energy Savings

Table 9.1 provides the annual energy use and peak demand estimates as a result of the standard for sales and stock starting in 2015, the effective year of Tier 1, through 2020, the year in which the Tier 2 desktop stock turns over (Tier 2 notebooks turn over in 2019).

Table 9.2 provides the savings estimates as a result of the standard, which are equal to over 2,000 GWh and 300 MW.

Table 9.1 California Statewide Standards Case Energy Use - After Effective Date

Year	Product Class	Annual Sales		Stock	
		Energy Use (GWh/yr)	Coincident Peak Demand (MW)	Energy Use (GWh/yr)	Coincident Peak Demand (MW)
2015 – Tier 1	Desktops - Conventional	176	27	1,680	257
	Desktops - Integrated	58	9	477	73
	Notebooks	119	18	484	74
	Workstations	82	12.6	307	47
	Thin Clients	18.2	2.8	71.7	11.0
	Small-scale Servers	17.2	2.6	88.8	13.6
	Total	470	72	3,110	476
2017 – Tier 2	Desktops - Conventional	134	21	974	149
	Desktops - Integrated	41	6	293	45
	Notebooks	90	14	329	50
	Workstations	94	14.3	344	52.7
	Thin-clients	24.7	3.8	94	14.4
	Small-scale Servers	17	2.6	87.2	13.3
	Total	400	62	2,120	324
2019 (Stock Turnover)	Notebooks	90	14	271	41
	Thin Clients	33.5	5	126	19.3
2020 (Stock Turnover)	Desktops - Conventional	134	21	537	82
	Desktops - Integrated	41	6	165	25
	Workstations	115	17.6	416	63.7
	Small-scale Servers	17	2.6	86.4	13.1
	Total	430	66	1,600	244

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002).

Table 9.2 California Statewide Energy Savings and Peak Demand Reduction for Standards Case – After Effective Date

Year	Product Class	Annual Sales: Energy Savings (GWh/yr)	Annual Sales: Coincident Peak Demand Reduction (MW)	Stock: Energy Savings (GWh/yr)	Stock: Coincident Peak Demand Reduction (MW)
2015 – Tier 1	Desktops - Conventional	310	47	310	47
	Desktops - Integrated	77	12	77	12
	Notebooks	62	10	62	10
	Workstations	4	0.5	4	0.5
	Thin clients	0.6	0.1	0.6	0.1
	Small-scale Servers	0.7	0.1	0.7	0.1
	Total	454	70	454	70
2017 – Tier 2	Desktops - Conventional	347	53	965	147
	Desktops - Integrated	93	11	247	34
	Notebooks	93	14	216	33
	Workstations	4	0.8	12	1.8
	Thin Clients	0.8	0.2	2	0.3
	Small-scale Servers	1	0.3	2.3	0.5
	Total	539	79	1,444	217
2019 (Stock Turnover)	Notebooks	93	14	275	43
	Thin Clients	1.1	0.3	4	0.7
2020 (Stock Turnover)	Desktops - Conventional	347	53	1389	213
	Desktops - Integrated	93	11	371	44
	Workstations	6	0.9	22	3.3
	Small-scale Servers	1	0.1	2.9	0.9
	Total (for all form factors)	540	79	2,060	305

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002).

9.2 Non-energy Standards Impacts

The proposed standard does not mandate the use of a specific computer technology. Rather, it establishes TEC levels for different computer categories and performance subcategories that can be met by manufacturers using a variety of technologies and components of the system. As mentioned in earlier sections, potential energy efficiency pathways could include the use of more efficient device-level power management, silicon (CPUs, GPUs, etc.), hard drives, or power supplies, just to name a few. It is extremely difficult to comprehensively characterize non-energy impacts for such a diverse array of compliance pathways, but here we generalize some non-energy trends based on the CASE Team's research and observations:

- Many of the most efficient computing devices, particularly in notebooks, are more compact, portable, lightweight, and as a result incorporate overall less material than their less efficient counterparts. This dematerialization can result from increased integration of components (i.e. integrating a large number of discrete electronic components into one integrated circuit), resulting shrinkage of printed circuit boards, and a reduced need for thermal management (e.g. smaller heat sinks, elimination of large fans, etc.). There should be a general trend toward dematerialization as computing devices become more efficient. This lowers the mass of end products, reducing their shipping costs and the energy associated with transporting individual units.
- In testing conducted on cost-effective desktop efficiency, the CASE Team took care to implement energy-saving measures that maintained or improved the performance and responsiveness of systems (PG&E 2012a). In the case of hard drives, we observed a significant system performance advantage moving from conventional, magnetic hard drives to solid state drives. Increased use of solid state drive technology would generally improve the speed and throughput of computers.
- Computer components with higher efficiencies also produce less waste heat in the product enclosure. A cooler thermal environment will generally result in quieter and more reliable end products.

9.3 State or Local Government Costs

There are no known additional costs to state or local governments from the implementation of the standards proposal, given the CEC's existing authority for establishing appliance standards and staffing to administer the process. Energy savings are expected for local and state governments from the purchase of more efficient products as a result of the proposed standard, with the savings amount dependent on the volume and nature of products purchased.

9.4 Lifecycle Cost / Net Benefit

Results of the cost effectiveness analysis for Tier 1 and Tier 2 of the standard are presented in Table 9.3 and Table 9.4. These builds were specifically designed to achieve maximum energy savings while still maintaining benefit-to-cost ratios greater than one. Using the most efficient combinations of components identified in California IOU-funded research, all categories of systems would generate substantial cost-effective savings by 2017. By stock turnover, the aggregate net present value of savings from the standard, accounting for the incremental costs and savings over the lifetime of the products, is estimated to be over $860 billion to customers.

Table 9.3 Costs and Benefits per Unit for Standards Case (in $2013 Dollars)

Product Class	Design Life (years)	Lifecycle Costs per Unit Present Value (PV) $ Incremental Cost	Add'l Costs	**Total PV Costs**	Lifecycle Benefits per Unit (Present Value $) Energy Savings[a]	Add'l Benefits	**Total PV Benefits**
Desktops – Conventional	4						
Tier 1 (2015)		$54[b]	n/a	**$54**	$106[b]	n/a	**$106**
Tier 2 (2017)		$48[b]		**$48**	$127[b]		**$127**
Desktops – Integrated	4						
Tier 1 (2015)		$40[c]	n/a	$40	$55	n/a	**$55**
Tier 2 (2017)		$45[c]		$45	$60		**$60**
Notebooks	3						
Tier 1 (2015)		$3 [c]	n/a	$3	$5.70	n/a	$5.70
Tier 2 (2017)		$5 [c]		$5	$8.20		$8.20
Workstations							
Tier 1 (2015)	4	$10	n/a	$10	$19	n/a	$19
Tier 2 (2017)	4	$21		$21	$26		$26
Small-scale Servers	5	$9.8[d]	n/a	$9.8	$10.5	n/a	$10.5
Thin-Clients	5	Negligible	n/a	Negligible	$2	n/a	$2

[a] For price of electricity, average annual rates were used, starting in the effective year (see Appendix B: for more details).
[b] The incremental costs reflect the market model-weighted average costs between the non-qualifying products and the standard levels across performance categories DT0, DTI1, DTI2 and DT I3, using the same incremental cost per kwh of savings as between the market "baseline" computers and cost-effective builds. See Appendix C: for more details regarding the cost-effectiveness of the market "baseline" computers, including cost-effectiveness for DT D categories.
[c] One possible incremental cost scenario equal to the aggregate cost of some of the technology improvements described in Section 2.2.3: internal power supplies (for integrated desktops only), CPU architecture and power management techniques, switchable graphics, display efficiency, display panel self-refresh, solid state drives, and mother integration.
[d] Calculated using current incremental cost and 3% discount rate.

Table 9.4 Lifecycle Costs and Benefits for Standards Case

Product Class	Lifecycle Benefit / Cost Ratio[a]	Net Present Value ($)[b]		
		Per Unit	For First Year Sales ($)	Stock Turnover ($) [c]
Desktops – Conventional				
Tier 1 (2015)	1.9	$52	$76,000,000	$305,000,000
Tier 2 (2017)	2.6	$79	$133,000,000	$706,000,000
Desktops – Integrated				
Tier 1 (2015)	1.4	$15	$11,000,000	$45,000,000
Tier 2 (2017)	1.3	$15	$13,000,000	$84,000,000
Notebooks				
Tier 1 (2015)	1.9	$2.7	$10,000,000	$30,000,000
Tier 2 (2017)	1.6	$3	$15,000,000	$67,000,000
Workstations				
Tier 1 (2015)	1.9	$9	$706,000	$3,200,000
Tier 2 (2017)	1.2	$5	$520,000	$4,300,000
Small-scale Servers	1.1	.70	$28,000	$430,000
Thin-Clients	N/A	$2	$463,000	$3,900,000
			Total (Tier 1)	$398,000,000
			Total (Tier 2)	$866,000,000

[a] Total present value benefits divided by total present value costs. It should be noted that while the proposed standard is cost-effective, it may be more cost-effective if using alternative rate structures. For example, marginal utility rates may more accurately reflect what customers save on utility bills as result of the standard.
[b] Positive value indicates a reduced total cost of ownership over the life of the appliance.
[c] Stock Turnover NPV is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year, i.e., the NPV of "turning over" the whole stock of less efficient products that were in use at the effective date to more efficient products, plus any additional non-replacement units due to market growth, if applicable. For example, for a standard effective in 2015 applying to a product with a 5 year design life, the NPV of the products purchased in the 5th year (2019) includes lifecycle cost and benefits through 2024, and therefore, so does the Stock Turnover NPV.

10 Acceptance Issues

10.1 Infrastructure issues

There are no known infrastructure issues, given the market technical feasibility of meeting the standard.

10.2 Existing Standards

10.2.1 External Power Supplies

Though there are current federal efficiency standards for external power supplies that have been in effect since July 2008 (and which DOE is currently updating), some computer form factors can benefit from using more efficient power supplies.

10.2.2 Battery Chargers

No federal efficiency standards currently exist for battery chargers though a DOE rulemaking is currently underway, with a potential effective date of September 2015. The CEC completed state-level standards for consumer battery chargers —including notebook battery chargers—in January 2012 and took effect starting in 2013 for consumer chargers. California standards for consumer chargers will be preempted once national standards go into effect.

10.2.3 ENERGY STAR for Computers

The ENERGY STAR program is the building block for most voluntary and mandatory computer efficiency program worldwide. The version currently in effect is Version 5.2. Version 5.0 was developed in 2008 and has been in effect since July 1, 2009. Version 6.0 is currently under development. The final draft was published on July 1, 2013. The final specification is expected to be adopted in August 2013 and go into effect in April 2014.

10.2.1 80 PLUS for Power Supplies

The utility-sponsored 80 PLUS labeling program have been encouraging higher levels of efficiency in computer power supplies since 2005, beyond the ENERGY STAR requirement of 80 PLUS Bronze for desktops.

10.2.2 International Minimum Energy Performance Standards (MEPS)

Mandatory computer energy performance standards are already in effect in China, Australia and New Zealand, and South Korea. The European Union is expected to adopt standards in Q2 2013.

South Korea: e-Standby Program, effective since July 30, 2012 is a voluntary program with mandatory warning label for products that fail. It is based on ENERGY STAR Version 5.2 framework and TEC limits, with additional power allowance for memory, discrete graphics, storage, TV tuner and removable audio card.

China: Standards (GB 28380-2012) are in effect since September 2012. They consist of multi-level standards based on the ENERGY STAR Version 5 framework. Grade 3 is less stringent than ENERGY STAR and is mandatory. Grades 1 and 2 are voluntary with Grade 2 being equivalent to ENERGY STAR and Grade 1 more stringent.

Australia and New Zealand: Standards will go into effect since in Q3 2013. They are based on ENERGY STAR Version 5 with higher graphics adders by ECMA categories.

European Union: Standards are expected to be adopted summer 2013. They are based on ENERGY STAR Version 5.2 with higher graphics adders and slightly lower TEC levels. Tier 1 is expected to become effective in July 2014 and Tier 2 in January 2016.

10.3 Stakeholder Positions

Refer to Invitation to Participate responses (CEC 2013) for stakeholder comments.

11 Environmental Impacts

11.1 Hazardous Materials

While increased integration has the effect of decreasing the overall mass of products, life cycle analysis has not been conducted to assess its overall pre- and post-consumer impacts, including embedded energy, process water consumption, hazardous waste generation, etc. Further study would be required to determine if any significant impacts exist, although we do not anticipate significant changes in lifecycle non-energy impacts.

There are no known incremental hazardous materials impacts from the efficiency improvements as a result of the proposed standards.

11.2 Greenhouse Gases

Table 11.1 shows the annual and stock GHG savings by year and the range of the societal benefits as a result of the standard. By stock turnover in 2020, this standard would save over 900,000 metric tons of CO2e annually, which is equal to between $47 million and $143 million of societal benefits using a range of annual dollar per metric ton of CO2. The total avoided CO2e is based on CARB's estimate of 437 MT CO2e/GWh of energy savings from energy efficiency improvements, and includes additional electrical transmission and distribution loses estimated at 7.8% (CARB 2008).The range of societal benefits per year is based on a range of annual dollar per metric ton of CO2 (in 2013 dollars) sourced from the U.S. Government's Interagency Working Group on Social Cost of Carbon (SCC) (Interagency Working Group 2013). The low end uses the average SCC, while the high end incorporates SCC values which use climate sensitivity values in the 95th percentile, both with 3% discount rate. It is important to note that this range can be lower and higher, depending on the approach used. Policy judgments should consider this uncertainty. See Appendix E: for more details regarding this and other approaches.

Table 11.1 Estimated California Statewide Greenhouse Gas Savings for Standards Case

Year	Annual GHG Savings (MT of CO2e/yr)	Stock GHG Savings (MT of CO2e/yr)	Value of Stock GHG Savings - low ($)	Value of Stock GHG Savings - high ($)
2015 (Tier 1)	198,000	198,000	$9,200,000	$27,000,000
2017 (Tier 2)	235,000	631,000	$31,000,000	$90,000,000
2020 (Stock Turnover)	236,000	902,000	$47,000,000	$143,000,000

11.3 Air Quality

This proposed measure is estimated to reduce total criteria pollutant emissions in California by 350,000 lbs/year in 2020 as shown in Table 11.2 due with an estimated value of $17 million. Criteria pollutant emission factors for California electricity generation — Nitrogen Oxides (NOx) and Reactive Organic Gases (ROG), Sulfur Oxides (SOx) and fine particulates under 2.5 micrometers (PM2.5) — were calculated per MWh based on California Air Resources Board data of emission rates by power plant type and expected generation mix (CARB 2010). The monetization of these criteria pollutant emission reductions is based on CARB power plant air pollution emission rate data times the dollar per ton value of these reductions based on Carl Moyer values where available, and San Joaquin Valley UAPCD "BACT" thresholds for sulfur oxides (SOx). These dollar per ton values vary significantly for fine particulates, as discussed in Appendix D: (CARB 2011a, CARB 2013a and San Joaquin Valley UAPCD).

Table 11.2 Estimated California Criteria Pollutant Reduction Benefits (lbs/year) in 2020

	lbs/year	Carl Moyer $/ton (2013)	Monetization
ROG[a]	56,751	$17,460	$495,000
$N0_x$	193,559	$17,460	$1,690,000
$S0_x$	20,344	$18,300	$186,000
PM2.5	83,652	$349,200	$14,600,000
Total	354,300		$17,000,000

12 Federal Preemption or other Regulatory or Legislative Considerations

Department of Energy (DOE) announced a Proposed Determination in July 2013 for computers. The timeline for a rulemaking is unknown, but if DOE proceeds with the rulemaking, the earliest the adoption date would likely be no sooner than 2015, with an effective date no sooner than 2020.

13 Proposed Changes to the Title 20 Code Language

The following is proposed language for the core requirements of the standards proposal, by Section, for the Title 20 Appliance Efficiency Regulations.

Section 1602

(u) Power Supplies

…

"Internal Power Supply (IPS)" means component internal to the computer casing and designed to convert ac voltage from the mains to dc voltage(s) for the purpose of powering the computer components. For the purposes of this specification, an internal power supply shall be contained within the computer casing but be separate from the main computer board. The power supply shall connect to the mains through a single cable with no intermediate circuitry between the power supply and the mains power. In addition, all power connections from the power supply to the computer components, with the exception of a DC connection to a display in an Integrated Desktop Computer, shall be internal to the computer casing (i.e., no external cables running from the power supply to the computer or individual components). Internal dc-to-dc converters used to convert a single dc voltage from an external power supply into multiple voltages for use by the computer are not considered internal power supplies.

~~"Computer" means an electronic machine which, by means of stored instructions and information, performs rapid, often complex calculations or compiles, correlates, and selects data.~~

"Personal Computer" means a device which performs logical operations and processes data. For the purposes of this specification, computers include both stationary and portable units, including Desktop Computers, Integrated Desktop Computers, Notebook Computers, Small Scale Servers, Thin Clients, and Workstations. Although computers are capable of using input devices and displays, such devices are not required to be included with the computer up on shipment. Computers are composed of, at a minimum: a) A central processing unit (CPU) to perform operations. If no CPU is present, then the device must function as a client gateway to a server which acts as a computational CPU b) User input devices such as a keyboard, mouse, or touchpad; and c) an Integrated Display screen and/or the ability to support an external display screen to output information.

( ) Personal Computer.

"Product Category" means a second-order classification or sub-type within a product type that is based on product features and installed components. Product categories are used in this specification to determine qualification and test requirements, as further defined below.

Desktop Computers and Integrated Desktop Computers

Category	DT 0	DT I1	DT12	DT13	DT D1	DT D2	DT D3
Performance Score, P	P ≤ 3	3 < P ≤ 6	6 < P ≤ 7	P > 7	3 < P ≤ 9	9 < P ≤ 15	P > 15
Graphics Type	Any graphics	Integrated Graphics			Discrete Graphics		

Notebooks Computers

Category	NB 0	NB I1	NB I2	NB I3	NB D1	NB D2
Performance Score, P	P ≤ 2	2 < P ≤ 5.2	5.2 < P ≤ 9	P > 9	2 < P ≤ 9	P > 9
Graphics Type	Any graphics	Integrated Graphics			Discrete Graphics	

"Personal Computer" means a device which performs logical operations and processes data. For the purposes of this specification, computers include both stationary and portable units, including Desktop Computers, Integrated Desktop Computers, Notebook Computers, Small Scale Servers, Thin Clients, and Workstations. Although computers are capable of using input devices and displays, such devices are not required to be included with the computer up on shipment. Computers are composed of, at a minimum: a) A central processing unit (CPU) to perform operations. If no CPU is present, then the device must function as a client gateway to a server which acts as a computational CPU b) User input devices such as a keyboard, mouse, or touchpad; and c) an Integrated Display screen and/or the ability to support an external display screen to output information.

"Desktop Computer" means a computer whose main unit is designed to be located in a permanent location, often on a desk or on the floor. Desktop computers are not designed for portability and are designed for use with an external display, keyboard, and mouse. Desktop computers are intended for a broad range of home and office applications.

"Integrated Desktop Computer" means a Desktop Computer in which the computing hardware and display are integrated into a single housing, and which is connected to ac mains power through a single cable. Integrated Desktop Computers come in one of two possible forms: (1) a system where the display and computer are physically combined into a single unit; or (2) a system packaged as a single system where the display is separate but is connected to the main chassis by a dc power cord and both the computer and display are powered from a single power supply. As a subset of Desktop Computers, Integrated Desktop Computers are typically designed to provide similar functionality as Desktop systems.

"Notebook Computer" means a computer designed specifically for portability and to be operated for extended periods of time both with and without a direct connection to an ac mains power source. Notebook Computers include an Integrated Display and integrated keyboard and pointing device and are capable of being powered by an integrated battery or other portable power source. Notebook computers are typically designed to provide similar functionality to Desktops including operation of software similar in functionality as that used in Desktops. For purposes of this specification, Notebook Computers include models with touch sensitive screens.

"Small-scale Server" means a computer that typically uses desktop components in a desktop form factor, but is designed primarily to be a storage host for other computers. Small-scale Servers are designed to perform functions such as providing network infrastructure services (e.g., archiving) and hosting data/media. These products are not designed to process information for other systems or run web servers as a primary function. A Small-scale Server has the following characteristics: a) Designed in a pedestal, tower, or other form factor similar to those of desktop computers such that all data processing, storage, and network interfacing is contained within one box/product; b) Designed to operate 24 hours/day 7 days/week, with minimal unscheduled downtime (on the order of hours/year); c) Capable of operating in a simultaneous multiuser environment serving several users through networked client units; and d) Designed for an industry accepted operating system for home or low-end server applications (e.g., Windows Home Server, Mac OS X Server, Linux, UNIX, Solaris).

"Thin Client" means an independently-powered computer that relies on a connection to remote computing resources (e.g., computer server, remote workstation) to obtain primary functionality. Main computing functions (e.g., program execution, data storage, interaction with other Internet resources) are provided by the remote computing resources. Thin Clients covered by this specification are (1) limited to devices with no rotational storage media integral to the computer and (2) designed for use in a permanent location (e.g. on a desk) and not for portability.

"Integrated Thin Client" means a Thin Client in which computing hardware and display are connected to ac mains power through a single cable. Integrated Thin Client computers come in one of two possible forms: (1) a system where the display and computer are physically combined into a single unit; or (2) a system packaged as a single system where the display is separate but is connected to the main chassis by a dc power cord and both the computer and display are powered from a single power supply. As a subset of Thin Clients, Integrated Thin Clients are typically designed to provide similar functionality as Thin Client systems

"Ultra-thin Client" means a computer with lesser local resources than a standard Thin Client that sends raw mouse and keyboard input to a remote computing resource and receives back raw video from the remote computing resource. Ultra-thin clients cannot interface with multiple devices simultaneously nor run windowed remote applications due to the lack of a user-discernible client operating system on the device (i.e., beneath firmware, user inaccessible).

"Workstation" means a high-performance, single-user computer typically used for graphics, CAD, software development, financial and scientific applications among other compute intensive tasks. Workstations covered by this specification (a) are marketed as a workstation; (b) provide mean time between failures (MTBF) of at least 15,000 hours (based on either Bellcore TR-NWT-83000332, issue 6, 12/97 or field collected data); and (c) support error-correcting code (ECC) and/or buffered memory. In addition, a workstation meets three or more of the following criteria:

> Provide supplemental power support for high-end graphics (e.g., PCI-E 6-pin 12V supplemental power feed); b) Wired for greater than x4 PCI-E on the motherboard in addition to the graphics slot(s) and/or PCI-X support c) Do not provide support for Uniform Memory Access (UMA) graphics; d) Provide 5 or more PCI, PCI-E, or PCI-X slots; e) Provide multi-processor support for 2 or more processors (shall support physically separate processor packages/sockets, i.e., requirement cannot be met with support for a

single multi-core processor); and/or f) Qualification by 2 or more Independent Software Vendor (ISV) product certifications; these certifications can be in process, but shall be completed within 3 months of qualification

"Graphics Processing Unit (GPU)" means an integrated circuit, apart from the CPU, designed to accelerate the rendering of either 2D and/or 3D content to displays. A GPU maybe mated with a CPU, on the system board of the computer or elsewhere to offload display capabilities from the CPU.

"Discrete Graphics (dGfx)" means a graphics processor (GPU) with a local memory controller interface and local graphics-specific memory.

"Integrated Graphics (iGfx)" means a graphics solution that does not contain Discrete Graphics

"Display" means a commercially-available product with a display screen and associated electronics, often encased in a single housing, that as its primary function displays visual information from (1) a computer, workstation or server via one or more inputs (e.g., VGA, DVI, HDMI, DisplayPort, IEEE 1394, USB), (2) external storage (e.g., USB flash drive, memory card), or (3) a network connection.

"Enhanced-performance Integrated Display" means an integrated Computer Display that has all of the following features and functionalities: (1) A contrast ratio of at least 60:1 at a horizontal viewing angle of at least 85°, with or without a screen cover glass; (2) A native resolution greater than or equal to 2.3 megapixels (MP); and (3) A color gamut of at least sRGB as defined by IEC 61966-2-1. Shifts in color space are allowable as long as 99% or more of defined sRGB colors are supported.

"Internal Power Supply (IPS)" means a component internal to the computer casing and designed to convert ac voltage from the mains to dc voltage(s) for the purpose of powering the computer components. For the purposes of this specification, an internal power supply shall be contained within the computer casing but be separate from the main computer board. The power supply shall connect to the mains through a single cable with no intermediate circuitry between the power supply and the mains power. In addition, all power connections from the power supply to the computer components, with the exception of a DC connection to a display in an Integrated Desktop Computer, shall be internal to the computer casing (i.e., no external cables running from the power supply to the computer or individual components). Internal dc-to-dc converters used to convert a single dc voltage from an external power supply into multiple voltages for use by the computer are not considered internal power supplies.

"Switchable Graphics" means a functionality that allows both integrated and discrete graphics to be used at different times depending on the graphics rendering needs of the user.

"Active" means the power state in which the computer is carrying out useful work in response to a) prior or concurrent user input or b) prior or concurrent instruction over the network. Active State includes active processing, seeking data from storage, memory, or cache, including Idle State time while awaiting further user input and before entering low power modes.

"Idle" means the power state in which the operating system and other software have completed loading, a user profile has been created, activity is limited to those basic applications that the system starts by default, and the computer is not in Sleep Mode. Idle State is composed of two sub-states: Short Idle and Long Idle.

"Long Idle" means the mode where the computer has reached an Idle condition (i.e., 15 minutes after OS boot or after completing an active workload or after resuming from Sleep Mode) and the main computer display has entered a low-power state where screen contents cannot be observed (i.e., backlight has been turned off) but remains in the working mode (Advanced Configuration and Power Interface G0/S0). If power management features are enabled as-shipped in the scenario described in this definition, such features shall engage prior to evaluation of Long Idle (e.g. display is in a low power state, HDD may have spun-down), but the computer is prevented from entering Sleep Mode. PLONG_IDLE represents the average power measured when in the long idle mode.

"Short Idle" means the mode where the computer has reached an Idle condition (i.e., 5 minutes after OS boot or after completing an active workload or after resuming from Sleep Mode), the screen is on and set to as-shipped brightness, and Long Idle power management features have not engaged (e.g. HDD is spinning and the Computer is prevented from entering sleep mode). PSHORT_IDLE represents the average power measured when in the Short Idle mode.

"Sleep" means a low power mode that the computer enters automatically after a period of inactivity or by manual selection. A computer with Sleep capability can quickly "wake" in response to network connections or user interface devices with a latency of less than or equal to 5 seconds from initiation of wake event to system becoming fully usable including rendering of display. For systems where ACPI standards are applicable, Sleep Mode most commonly correlates to ACPI System Level S3 (suspend to RAM) state.

"Off" means the lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For systems where ACPI standards are applicable, Off Mode correlates to ACPI System Level S5 state.

"Product Family" means a high-level description referring to a group of computers sharing one chassis/motherboard combination that often contains hundreds of possible hardware and software configurations. Product models within a family differ from each other according to one or more characteristics or features that either (1) have no impact on product performance with regard to ENERGY STAR qualification criteria, or (2) are specified herein as acceptable variations within a product family. For Computers, acceptable variations within a product family include: 1) Color; 2) Housing; and 3) Electronic components other than the chassis/motherboard, such as the processor, memory, GPU, etc.

"Memory" means physical devices used to temporarily store programs, instructions, and/or data for immediate access by a computer's central processing unit (CPU).

"Storage" means physical devices used for long-term, non-volatile storage of programs and user data.

"TV tuner card" means a computer expansion card that provides the ability to tune over-the-air television signals for display on a computer monitor.

"Audio card" means a computer expansion card that enables the input/output of audio signals to/from a computer from external sources.

"Ethernet Port" means a physical connector capable of accepting Category 5 twisted-pair cables for the purpose of establishing wired, local area network (LAN) connections per IEEE Ethernet (802.3) standards.

Section 1604. Test Method for Specific Appliances.

(u) **Power Supplies.**

The test method for Class A federally regulated and state-regulated external power supplies is US EPA "Test Method for Calculating the Energy Efficiency of Single-Voltage External AC-DC and AC-AC Power Supplies" dated August 11, 2004, except that the test voltage specified in Section 4(d) of the test method shall be only 115 volts, 60 Hz.

<u>*The test method for Class XX state-regulated internal power supplies is EPRI & ECOS "Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-Dc and Dc-Dc Power Supplies Rev 6.6". The internal power supply should also be tested at10% load.*</u>

(__) **Personal Computers.**

<u>*The test method for Typical Energy Consumption for Personal Computers is ENERGY STAR Computer Final Draft Test Method (Version 6.0) Rev. Jul-2013. <insert language in its entirety>*</u>

Section 1605.1

(u) **Power Supplies.**

1. *Multi-output State-regulated Internal Power Supplies. The efficiency of a multi-output state regulated internal power supply manufactured shall not be less than the applicable values shown in Table U-1 at each loading condition.*

Table U-1: Standards for Multi-Output Internal Power Supplies with Maximum Power Ratings greater than 75W

			January 1, 2015	January 1, 2017
Applicable Appliance	Maximum Power Rating	Loading Condition	Minimum Efficiency	
Desktop Computer, Integrated Desktop Computer	≥ 75*W*	10%	79%	82%
		20%	82%	85%
		50%	85%	88%
		100%	82%	85%
Workstations and Small-scale Servers (Tier 1 only)	≥ 75*W*	10%	82%	84%
		20%	85%	87%
		50%	88%	90%
		100%	85%	87%

(___) **Personal Computers.**

1. *Desktops Computers, Integrated Desktops Computers and Notebook computers manufactured on or after the effective dates shown shall meet the requirements in Table ( )*

Table ( )

Product Class	Product Category	Tier 1 - 2015	Tier 2 - 2017	Adder Category	Tier 1 - 2015	Tier 2 - 2017
		Maximum Base TEC (kWh/yr)			Additional Allowance for Graphics (kWh/yr)	
Conventional Desktops	DT0	66	52	G1	21	17
	DT I1	106	84	G2	25	20
	DT I2	114	90	G3	32	26
	DT I3	128	101	G4	40	32
	DT D1	92	73	G5	48	38
	DT D2	102	81	G6	51	41
	DT D3	226	178	G7	57	46
Integrated Desktops	DT0	41	28	Same as Above		
	DT I1	67	45			
	DT I2	72	48			
	DT I3	81	54			
	DT D1	69	46			
	DT D2	81	54			
Notebooks	NB0	13	10	G1	9	6
	NB I1	21	15	G2	10	7
	NB I2	23	17	G3	13	8
	NB I3	27	20	G4	16	10
	NB D1	15	11	G5	20	13
	NB D2	17	13	G6	21	13
				G7	23	15

[insert requirements for additional adders]

2. *Power Management Settings. Personal Computers and workstations manufactured on or after XXXX shall have upon shipment Power Management Settings enabled with Sleep Mode set to activate within 30 minutes of user inactivity. Computers shall reduce the speed of any active 1 Gb/s Ethernet network links when transitioning to Sleep or Off. Display Sleep Mode shall be set to activate within 15 minutes of user inactivity. Small-scale servers with a display and thin clients manufactured on or after XXXX*

<u>shall have upon shipment Power Management Settings with Display Sleep Mode set to activate within 15 minutes of user inactivity.</u>

Table X: Data Submittal Requirements

Section	Appliance		Required Information	**Permissible Answers**
U	Power Supplies	State-regulated Internal	Input & Output Power (watts) at 10% Load Input & Output Power (watts) at 20% Load Input & Output Power (watts) at 50% Load Input & Output Power (watts) at 100% Load	
			Efficiency at 10% Load Efficiency at 20% Load Efficiency at 50% Load Efficiency at 100% Load	
			Power Rating at 10% Load Power Rating at 20% Load Power Rating at 50% Load Power Rating at 100% Load	
X	Personal Computers		Wattage in Long Idle mode	
			Wattage in Short Idle mode	
			Wattage in Sleep mode	
			Wattage in Off mode	
			Minutes from user inactivity before computer Sleep mode is enabled	*30*
			Minutes from user inactivity before display Sleep mode is enabled	*15*
Z	Discrete Graphics Cards		Wattage of Personal Computer in Idle Mode with Discrete Graphics Cards Wattage of Personal Computer in Idle Mode without Discrete Graphics Cards Difference between Wattage of Personal Computer with and without Discrete Graphics Cards	

<*<u>Insert rows for additional reporting requirements</u>*>

References

Ackerman, Frank and Elizabeth A. Stanton. 2012. Stockholm Environment Institute. *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon*. http://www.economics-ejournal.org/economics/journalarticles/2012-10. Economics. April 4.

AMD. 2012. AMD Powertune Technology. White Paper. http://www.amd.com/la/Documents/amd_powertune_whitepaper.pdf

[BEA] Bureau of Economic Analysis. 2012. Widespread Economic Growth Across States in 2011. http://www.bea.gov/newsreleases/regional/gdp_state/2012/pdf/gsp0612.pdf.

Barr, Harty & Nero. 2010. Enterprise PC Power Management Tools: Greening IT from the Top Down. http://www.verdiem.com/sites/default/files/enterprise_pc_power_management_tools_greening-it.pdf

Brown, Richard E. and Jonathan G. Koomey. 2002. "Electricity Use in California: Past Trends and Present Usage Patterns." Energy Policy (also LBNL-47992). vol. 31, no. 9. July. pp. 849-864.

[CA IOUs] California Investor-Owned Utilities. 2013a. Response to Invitation to Participate. Prepared by Energy Solutions and Ecova.

__. 2013b. Codes and Standards Enhancement (CASE) Initiative: Small Network Equipment. Prepared by Ecova. July 29, 2013.

__. 2013c. Codes and Standards Enhancement (CASE) Initiative: Electronic Displays. Prepared by Energy Solutions. July 29, 2013.

[CARB] California Air Resources Board. 2008a. AB 32 Technical Stakeholder Working Group Meeting. *Cost-Effectiveness*. http://www.arb.ca.gov/cc/scopingplan/economics-sp/meetings/060308/ce_white_paper.pdf. June 3.

__. 2008b. *Climate Change Scoping Plan Appendices Volume II: Analysis and Documentation*. http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume2.pdf. December.

__. 2010. Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D. http://www.arb.ca.gov/regact/2010/res2010/res10isor.pdf. Accessed July 24, 2013.

__. 2011a. California Air Resources Board. *Appendix C: Cost Effectiveness Calculation Methodology*. http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/appc_3_10_11.pdf. March 10.

__. 2011b. *Emission Reduction Offsets Transaction Cost Summary Report for 2011*. http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2012. *Emission Reduction Offsets Transaction Cost Summary Report for 2012*. http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2013a. *Mail-Out #MSC 13-09*. http://www.arb.ca.gov/msprog/mailouts/msc1309/msc1309.pdf. March 25.

___. 2013b. California Air Resources board Quarterly Auction *3, May 2013 – Summary Results Report*. www.arb.ca.gov/cc/capandtrade/auction/may-2013/results.pdf.

[CEC]. California Energy Commission. 2004. "Designing AC-DC Power Supplies for Improved Energy Efficiency: A Technical Primer." Prepared by EPRI Solutions and Ecos Consulting. http://www.efficientpowersupplies.org/pages/Power_Supply_Technical_Primer_FINAL.pdf

___. California Energy Commission. 2004. Update of Appliance Efficiency Regulations. California Energy Commission. CEC Publication # 400-04-007D; Appendix A, Table 22. July.

___. 2012. *Adopted California Energy Commission Demand Forecast Report 2012-2022.* Mid-Case Final Demand Forecast. Updated September 19, 2012.

___. 2013. Responses to the Invitation to Participate in the 2013 Appliance Efficiency Rulemaking. http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/.

[CLTG] Clean Technology Leadership Group. 2013. Response to CEC's Invitation to Participate. May 9th, 2013.

Chetty, Marshini, A.J. Bernheim Brush, Brian Meyers, and Paul Johns. 2009. "It's Not Easy Being Green: Understanding Home Computer Power Management." Paper presented at CHI 2009 Conference in Boston, MA, 4-9 April. http://research.microsoft.com/pubs/79362/chihomepowermanagementchetty.pdf

[DOE] Department of Energy. 2008. Current Regulations: Energy Conservation Standards: Efficiency Standards for Class A External Power Supplies. http://www1.eere.energy.gov/buildings/appliance_standards/residential/battery_external.html,

___. Department of Energy. 2010. Preliminary Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Battery Chargers and External Power Supplies. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0031

___. Department of Energy. 2012. Energy Conservation Program: Energy Conservation Standards for Battery Chargers and External Power Supplies. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0070

___. Department of Energy. 2012. Market Assessment and Markup Spreadsheet. Microsoft Excel. http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0005-0082.

___. Department of Energy. 2013. *Energy Conservation Program: Energy Conservation Standards for Standby Mode and Off Mode for Microwave Ovens.* http://www.regulations.gov/#!docketDetail;rpp=10;po=0;D=EERE-2011-BT-STD-0048. June 17.

[DOL] United States Department of Labor. 2012. Bureau of Labor Statistics, CPI Inflation Calculator. http://www.bls.gov/data/inflation_calculator.htm. Accessed June 13, 2013.

ECMA International. 2010. Standard ECMA-383. 3rd Edition. Measuring the Energy Consumption of Personal Computing Products. http://www.ecma-international.org/publications/files/ECMA-ST/ECMA-383.pdf

Ecova. 2013. 80 PLUS Certified Power Supplies and Manufacturers. http://www.plugloadsolutions.com/80PlusPowerSupplies.aspx Accessed on July 26th, 2013.

[EPA] U.S. Environmental Protection Agency. 2010. ENERGYSTAR 5.2 Program Requirements for Computers, Partner Commitments. http://www.energystar.gov/ia/partners/product_specs/program_reqs/Computers_Program_Requirements.pdf?3a05-e0a9.

__. ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2011 Summary. http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2011_USD_Summary_Report.pdf?334a-549e.

__. 2012a. ENERGY STAR Program Requirements. Product Specification for Computers. Draft 3 Test Method. Rev. Nov 2012. http://energystar.gov/products/specs/node/143.

__. 2012b. Products Program Strategic Vision and Guiding Principles. May 2012. http://www.energystar.gov/ia/partners/prod_development/downloads/ENERGY_STAR_Strategic_Vision_and_Guiding_Principles.pdf.

__. 2013a. ENERGY STAR Program Requirements. Product Specification for Computers. Version 6.0 Draft 3. http://energystar.gov/products/specs/node/143.

__. 2013b. ENERGY STAR; Computers for Consumers http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CO. Accessed May 6th, 2013.

EPRI. 2012. Generalized Test Protocol for Calculating the Energy Efficiency of Internal Ac-DC and Dc-Dc Power Supplies R6.6. April 2, 2012. http://www.efficientpowersupplies.org/methods.asp.

Fraunhofer. 2011. Energy Consumption of Consumer Electronics in U.S. Homes in 2010. Final report to the Consumer Electronics Association (CEA). December 2011. By Bryan Urban, Verena Tiefenbeck and Kurt Roth. Pg. 17

Hamm, Steve and Jay Greene, 2008. That Computer Is So You. January 2, 2008 http://www.businessweek.com/magazine/content/08_02/b4066000313325.htm. Accessed May 2nd, 2013.

Hollister, Sean. 2013. "Intel launches Haswell processors: here's what you need to know." theVerge.com. http://www.theverge.com/2013/6/1/4386292/intel-launches-haswell-processors-heres-what-you-need-to-know

Horii, Brian and Dr. Jim Williams, Energy and Environmental Economics. 2013. *CPUC Workshop on Societal Cost Test*. http://www.cpuc.ca.gov/NR/rdonlyres/E7263960-03C4-4BB2-8FD2-2FBF7DAD3436/0/SCTWorkshop6102013.pdf. June.

IDC. 2012. Press Release. IDC Worldwide Quarter PC Tracker, February 2012. http://www.idc.com/getdoc.jsp?containerId=prUS23371512. Accessed May 5th, 2013.

IDC. 2013a. Press Release. IDC Worldwide Quarter PC Tracker: United States PC Shipments, January 2013. http://www.idc.com/getdoc.jsp?containerId=prUS23903013. Accessed May 5th, 2013

IDC. 2013b.Press Release. IDC Worldwide Quarter PC Tracker, February 2013. http://www.idc.com/getdoc.jsp?containerId=prUS23987313. Accessed May 5th, 2013.

IDC. 2013c. IDC Worldwide Quarter PC Tracker, June 2013. http://www.idc.com/getdoc.jsp?containerId=prUS24180013. Accessed on July 9, 2013.

[ITI] Information Technology Industry Council. 2013. Response to CEC's Invitation to Participate. May 9th, 2013.

[Interagency Working Group] Interagency Working Group on Social Cost of Carbon, United States Government. 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf.

iSuppli. 2011. "Cost of Efficiency." Prepared for Energy Solutions. Microsoft PowerPoint. Marijana Vukicevic and Ahmed Abdallah.

Johnson, Laurie T. and Chris Hope. 2012. Journal of Environmental Studies and Sciences, Journal no. 13412. *The social cost of carbon in U.S. regulatory impact analyses: an introduction and critique*. http://www.eenews.net/assets/2012/09/17/document_gw_05.pdf. September 12.

Jon Peddie Research. 2013. http://jonpeddie.com/publications/workstation_report/ Accessed July 7th 2013.

[KEMA] KEMA, Inc. 2010. *2009 California Residential Appliance Saturation Study*. California Energy Commission. Publication number: CEC- 200-2010-004-ES.

Microsoft. 2011. "What's the Skinny on Thin Clients?" http://www.microsoft.com/en-us/news/features/2011/feb11/WENC02-17ThinClient.aspx. Accessed on Jul 11th, 2013.

[NEEA] Northwest Energy Efficiency Alliance. 2012. Market Progress Evaluation Report #4: 80 PLUS. Prepared by Navigant. http://neea.org/docs/reports/80-plus-mper-4-final-06-11-12.pdf.

[NEEA] Northwest Energy Efficiency Alliance. 2011. Market Progress Evaluation Report #3: 80 PLUS. Prepared by Navigant. http://dev.neea.oaktree.com/docs/reports/neea-market-progress-evaluation-report-3-80-plus--e11-226.pdf?sfvrsn=6

[NRDC] Natural Resources Defense Council. 2013a. Invitation to Participate Response.

__. 2013b. Natural Resources Defense Council. Comments regarding Version 6.0 Final Draft Computer Specification, to U.S. Environmental Protection Agency. July 18.

NVIDIA. 2012. NVIDIA's Next Generation CUDA Computer Architecture: Kepler GK110: The Fastest, Most Efficient HPC Architecture Ever Built. White Paper. http://www.nvidia.com/content/PDF/kepler/NVIDIA-Kepler-GK110-Architecture-Whitepaper.pdf

Pigg & Bensch. 2010. "Electricity Savings Opportunities for Home Electronic and Other Plug-In Devices in Minnesota Homes: a technical and behavioral field assessment." Prepared by the Energy Center of Wisconsin.

[PG&E] Pacific Gas & Electric Company. 2010. "Thin Client Investigation including PC and Imaging State Data." DRAFT. Emerging Technologies Program. Prepared by QDI Strategies. June.

[PG&E] Pacific Gas and Electric Company. 2012a. Cost-Effective Computer Efficiency. Prepared by Ecova.http://www.etcc-ca.com/reports/cost-effective-computer-efficiency.

[PG&E] Pacific Gas and Electric Company. 2012b. Updated Discrete Graphics Processing Unit Testing Results. Prepared by Ecova. http://energystar.gov/products/specs/sites/products/files/California%20IOU%20%20NEEA%20Comments_Public.pdf.

San Joaquin Valley UAPCD. 2008. *Final Staff Report:* Update to Rule 2201 Best Available Control Technology (BACT) Cost Effectiveness Thresholds. http://www.valleyair.org/busind/pto/bact/May%202008%20BACT%20cost%20effectiveness%20threshold%20update%20staff%20report.pdf. May 14.

Shah, Agam. 2013. "Intel claims Haswell will offer 50% more battery life in laptops." ComputerWorld.com. http://www.computerworld.com/s/article/9239509/Intel_claims_Haswell_will_offer_50_more_battery_life_in_laptops

Shimpi, Anand. 2013. "The Haswell Review: Intel Core i7-4770K & i5-4670K Tested." AnandTech.com. http://www.anandtech.com/show/7003/the-haswell-review-intel-core-i74770k-i54560k-tested

Toshiba 2008. "Old Laptops Can Put Business at Risk" http://us.toshiba.com/content/pc/b2c/downloads/tech-brief-pdfs/Old-Laptops-Can-Put-Business-at-Risk.pdf

Appendix A: Duty Cycle Definitions

- PG&E (2010) defines duty cycle modes as "ON," "SLEEP," and "OFF."
- TIAX (2007) defines duty cycle modes as "ACTIVE," "SLEEP," and "OFF."
- Pigg & Bensch (2010) define duty cycle modes as "ACTIVE," "SLEEP," and "OFF."
- Chetty (2009) defines duty cycle modes as "ACTIVE," "ON (but not ACTIVE)," and "LOW POWER and OFF."

Appendix B: Cost Analysis Assumptions

The electricity rates used in the analysis of this CASE Report were derived from projected future prices for residential, commercial and industrial sectors in the CEC's "Mid-case" projection of the 2012 Demand Forecast (2012), which used a 3% discount rate and provide prices in 2010 dollars. The sales weighted average of the 5 largest utilities in California was converted to 2013 dollars using an inflation adjustment of 1.07 (DOL 2013). A sector weighted average electricity rate was then calculated using 59% commercial, 41% residential, 0% industrial (Hamm & Greene 2008). See the rates by year below in Table B.1.

Table B.1 Statewide Weighted Average Electricity Rates 2015 - 2040 (PG&E, SCE, SDG&E, LADWP and SMUD - 5 largest Utilities) in 2013 cents/kWh

Year	Residential	Commercial	Industrial	Sector Weighted Average
2015	16.82	14.67	11.31	16.07
2016	17.02	14.84	11.43	16.63
2017	17.24	15.02	11.56	16.61
2018	17.47	15.22	11.70	16.35
2019	17.71	15.42	11.84	16.21
2020	18.00	15.67	12.01	15.95
2021	18.34	15.98	12.23	14.93
2022	18.70	16.29	12.45	14.79
2023	19.06	16.61	12.67	13.78
2024	19.43	16.93	12.90	13.66
2025	19.81	17.27	13.13	13.81
2026	20.19	17.60	13.37	16.09
2027	20.59	17.95	13.61	16.81
2028	20.98	18.30	13.86	15.79
2029	21.39	18.66	14.12	14.70
2030	21.81	19.03	14.38	14.50
2031	22.23	19.40	14.64	15.54
2032	22.66	19.78	14.92	15.01
2033	23.10	20.17	15.19	14.28
2034	23.55	20.57	15.48	15.04
2035	24.01	20.97	15.77	15.24
2036	24.48	21.38	16.06	15.24
2037	24.96	21.80	16.37	14.91
2038	25.44	22.23	16.68	15.14
2039	25.94	22.67	16.99	15.36
2040	26.44	23.12	17.32	15.55

Appendix C: Lifecycle Costs per Unit – Conventional Desktops Expanded

Table C.1 Costs and Benefits per Unit for Standards Case, Conventional Desktop Computers – Tier 1

Performance Category	Design Life (years)	Lifecycle Costs per Unit (Present Value $)			Lifecycle Benefits per Unit (Present Value $)		
		Incremental Cost (2015)	Add'l Costs	**Total PV Costs**	Energy Savings[b]	Add'l Benefits	**Total PV Benefits**
DT0 (80 PLUS Gold power supply)	4	$13.44	n/a	**$13.44**	$16.59	n/a	**$16.59**
DT I1 (next-generation CPU, efficient conventional HDD, standard 80 PLUS power supply)	4	-$2.74	n/a	**-$2.74**	$25.54	n/a	**$25.54**
DT I1 (budget system, efficient conventional HDD, 80 PLUS Gold PSU)	4	$14.96	n/a	**$14.96**	$33.04	n/a	**$33.04**
DT I2 (hybrid hard drive, 80 PLUS Gold power supply)	4	$22.06	n/a	**$22.06**	$26.42	n/a	**$26.42**
DT I3 (hybrid hard drive, 80 PLUS Gold power supply)	4	$22.06	n/a	**$22.06**	$41.48	n/a	**$41.48**
DT D1 (Efficient conventional hard drive, 80 PLUS Gold PSU)	4	$14.96	n/a	**$14.96**	$36.17	n/a	**$36.17**
DT D2 (next-generation CPU, next generation GPU, efficient conventional hard drive, 80 PLUS Platinum power supply)	4	$11.40	n/a	**$11.40**	$56.34	n/a	**$56.34**
DT D3 (next generation GPU, efficient conventional hard drive, 80 PLUS Platinum power supply)	4	$42.50	n/a	**$42.50**	$65.92	n/a	**$65.92**

PV = Present Value

[b]For price of electricity, average annual rates were used, starting in the effective year (see Appendix B: for more details).

Table C.2 Costs and Benefits per Unit for Standards Case, Tier 2, Conventional Desktop Computers

Performance Category	Design Life (years)	Lifecycle Costs per Unit (Present Value $) Incremental Cost (2017)	Add'l Costs	**Total PV Costs**	Lifecycle Benefits per Unit (Present Value $) Energy Savings[b]	Add'l Benefits	**Total PV Benefits**
DT0 (80 PLUS Gold power supply, solid state drive)	4	$23.99	n/a	**$23.99**	$24.20	n/a	**$24.20**
DT I1 (next-generation CPU, efficient conventional HDD, standard 80 PLUS power supply)	4	$10.61	n/a	**$10.61**	$28.84	n/a	**$28.84**
DT I1 (budget system, solid state drive, 80 PLUS Gold PSU)	4	$22.16	n/a	**$22.16**	$42.36	n/a	**$42.36**
DT I2 (next-generation CPU, solid state drive, 80 PLUS Gold power supply)	4	$19.48	n/a	**$19.48**	$37.50	n/a	**$37.50**
DT I3 (solid state drive, 80 PLUS Gold power supply)	4	$22.16	n/a	**$22.16**	$48.56	n/a	**$48.56**
DT D1 (solid state drive, 80 PLUS Gold PSU)	4	$22.16	n/a	**$22.16**	$44.67	n/a	**$44.67**
DT D2 (next-generation CPU, next generation GPU, efficient conventional hard drive, 80 PLUS Platinum power supply)	4	$55.88	n/a	**$55.88**	$73.33	n/a	**$73.33**
DT D3 (next generation GPU, efficient conventional hard drive, 80 PLUS Platinum power supply)	4	$42.50	n/a	**$42.50**	$69.70	n/a	**$69.70**

PV = Present Value

[b]For price of electricity, average annual rates were used, starting in the effective year (see Appendix B: for more details).

Appendix D: Criteria Pollutant Emissions and Monetization

D.1 Criteria Pollutant Emissions Calculation

To calculate the statewide emissions rate for California, the incremental emissions between CARB's high load and low load power generation forecasts for 2020 were divided by the incremental generation between CARB's high load and low load power generation forecast for 2020. Incremental emissions were calculated based on the delta between California emissions in the high and low generation forecasts divided by the delta of total electricity generated in those two scenarios. This emission rate per MWh is intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario instead of the high load scenario. While emission rates may change somewhat over time, 2020 was considered a representative year for this measure.

D.2 Criteria Pollutant Emissions Monetization

Avoided ambient ozone precursor and fine particulate air pollution benefits were monetized based on avoided control costs rather than damage costs due to the availability of emission control cost-effectiveness thresholds, as well as challenges in quantifying a specific value for damages per ton of pollutants.

Two sources of data for cost-effectiveness thresholds were evaluated. The first is Carl Moyer cost-effectiveness thresholds for ozone precursors and fine particulates (CARB 2011a, CARB 2013a and 2013b). The Carl Moyer program has provided incentives for voluntary reductions in criteria pollutant reductions from a variety of mobile combustion sources as well as stationary agricultural pumps that meet specified cost-effectiveness cut-offs.

The second is the San Joaquin Valley UAPCD Best-Available Control Technology ("BACT") cost-effectiveness thresholds study. Pollution reduction technologies that are not yet demonstrated in practice (in which case they are required without a cost-effectiveness evaluation) can be required at new power plants and other sources if technologically feasible and within cost-effectiveness thresholds. San Joaquin Valley UAPCD conducted a state-wide study as the basis for updating their BACT thresholds in 2008.

This CASE report relies primarily on the Carl Moyer thresholds due to their state-wide nature and applicability to combustion sources[6]. In addition, the Carl Moyer fine particulate values for fine particulate apply to combustion sources with specific health impacts, while BACT thresholds include both combustion sources and dust. The Carl Moyer values are somewhat more conservative for ozone precursors than San Joaquin Valley UAPCD BACT thresholds, and significantly higher for fine particulate[7].The Carl Moyer program does not address sulfur oxides, however, thus the San Joaquin BACT thresholds were used for this pollutant.

Price reports for California Emission Reduction Credit (ERCs, i.e. air pollution credits purchased to offset regulated emission increases) for 2011 and 2012 were also compared to the values selected in this CASE report. For each pollutant there is a wide range of ERC values per ton that are both

[6] Further evaluation of the qualitative impacts of combustion fine particulate emissions from power generation and transportation sources may be beneficial.

[7] We note that both the Carl Moyer and San Joaquin Valley UAPCD BACT cost-effectiveness thresholds for fine particulates fall within the wide range of fine particulate ERC trading prices in California in 2011 and 2012.

higher and lower than the values per ton used in this CASE report (CARB 2011b and 2012). Due to wide variability and low trading volumes, ERC values were evaluated for comparative purposes only.

Appendix E: Greenhouse Gas Valuation Discussion

The climate impacts of pollution from fossil fuel combustion and other human activities, including the greenhouse gas effect, present a major risk to global economies, public health and the environment. While there are uncertainties of the exact magnitude given the interconnectedness of ecological systems, at least three methods exist for estimating the societal costs of greenhouse gases: 1) the Damage Cost Approach 2) the Abatement Cost Approach and 3) the Regulated Carbon Market Approach. See below for more details regarding each approach.

E.1 Damage Cost Approach

In 2007, the U.S. Court of Appeals for the Ninth Circuit ruled that the National Highway Transportation Traffic Safety Administration (NHTSA) was required to assign a dollar value to benefits from abated carbon dioxide emissions. The court stated that while there are a wide range of estimates of monetary values, the price of carbon dioxide abatement is indisputably non-zero. In 2009, to meet the necessity of a consistent value for use by government agencies, the Obama Administration established the Interagency Working Group on the Social Cost of Carbon to establish official estimates (Johnson and Hope).

The Interagency Working Group primarily uses estimates of avoided damages from climate change which are valued at a price per ton of carbon dioxide, a method known as the damage cost approach.

E.1.1 Interagency Working Group Estimates

The Interagency Working Group SCC estimates, based on the damage cost approach, were calculated using three climate economic models called integrated assessment models which include the Dynamic Integrated Climate Economy (DICE), Policy Analysis of the Greenhouse Effect (PAGE), and Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) models. These models incorporate projections of future emissions translated into atmospheric concentration levels which are then translated into temperature changes and human welfare and ecosystem impacts with inherent economic values. As part of the Federal rulemaking process, DOE publishes estimated monetary benefits using Interagency Working Group SCC values for each Trial Standard Level considered in their analyses, calculated as a net present value of benefits received by society from emission reductions and avoided damages over the lifetime of the product. The recent U.S. DOE Final Rulemaking for microwave ovens contains a Social Cost of Carbon section that presents the Interagency Working Group's most recent SCC values over a range of discount rates (DOE 2013) as shown E.1. The two dollars per metric ton values used in this CASE report were taken from the two highlighted columns, and converted to 2013 dollars.

Table E.1 Social Cost of CO_2 2010 – 2050 (in 2007 dollars per metric ton of CO_2)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

Source: Interagency Working Group on Social Cost of Carbon, United States Government, 2013

The Interagency Working Group decision to implement a global estimate of the SCC rather than a domestic value reflects the reality of environmental damages which are expected to occur worldwide. Excluding global damages is inconsistent with U.S. regulatory policy aimed at incorporating international issues related to resource use, humanitarian interests, and national security. As such, a regional SCC value specific to the Western United States or California specifically should be at similarly inclusive of global damages. Various studies state that certain values may be understated due to the asymmetrical risk of catastrophic damage if climate change impacts are above median predictions, and some estimates indicate that the upper end of possible damage costs could be substantially higher than indicated by the IWG (Ackerman and Stanton 2012, Horii and Williams 2013).

E.2 Abatement Cost Approach

Abating carbon dioxide emissions can impose costs associated with more efficient technologies and processes, and policy-makers could also compare strategies using a different by estimating the annualized costs of reducing one ton of carbon dioxide net of savings and co-benefits. The cost of abatement approach could reflect established greenhouse gas reduction policies and establish values for carbon dioxide reductions relative to electricity de-carbonization and other measures. (While recognizing the potential usefulness of this method, this report utilizes the IWG SCC approach and we note that the value lies within the range of abatement costs discussed further below.)

The cost abatement approach utilizes market information regarding emission abatement technologies and processes and presents a wide-range of values for the price per ton of carbon dioxide. The California Air Resources Board data of the cost-effectiveness of energy efficiency measures and emission regulations would provide one source of potential data for an analysis under this method. To meet the AB 32 target, ARB has established the "Cost of a Bundle of Strategies Approach" which includes a range of cost-effective strategies and regulations (CARB 2008b). The results of this approach within the framework of the Climate Action Team Macroeconomic Analysis are provided for California, Arizona, New Mexico, the United States, and a global total identified in that same report, as shown in Table E.2 below.

Table E.2 Cost-effectiveness Range for the CAT Macroeconomic Analysis

Exhibit 3: Cost-effectiveness Range for the CAT Macroeconomic Analysis, Selected States, United States, Global -

State	Cost-effectiveness Range $/ ton CO_2eq	Tons Reduced MMtCO_2e/yr	Percent of BAU
California 2020 (CAT[1], CEC[2])	- 528 to 615	132	22
Arizona[3] 2020	- 90 to 65	69	47
New Mexico[4] 2020	- 120 to105	35	34
United States (2030)[5]	-93 to 91	3,000	31
Global Total (2030)	-225 to 91	26,000	45

Source:
1. Climate Action Team Updated Macroeconomic Analysis of Climate Strategies, Presented in the March 2006 Climate Action Team Report, September 2007.
2. California Energy Commission, *Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California*, July 2005, ICF ($/MTC$0_2$eq).
3. Arizona Climate Change Advisory Group, *Climate Change Action Plan*, August 2006, ($/MTC$0_2$eq).
4. New Mexico Climate Change Advisory Group, Final Report, December 2006.
5. McKinsey & Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* December 2007.
6. The McKinsey Quarterly, McKinsey & Company, *A Cost Curve for Greenhouse Gas Reduction*, Fall 2007.

Source: CARB 2008b

Energy and Environmental Economics (E3) study defines the cost abatement approach more specifically as electricity de-carbonization and is based on annual emissions targets consistent with existing California climate policy. Long-term costs are determined by large-scale factors such as electricity grid stability, technological advancements, and alternative fuel prices. Near-term costs per ton of avoided carbon could be$200/ton in the near-term (Horii and Williams 2013), thus as noted earlier the value used in this report may be conservative.

E.3 Regulated Carbon Market Approach

Emissions allowance markets provide a third potential method for valuing carbon dioxide. Examples include the European Union Emissions Trading System and the California AB32 cap and trade system as described below. Allowances serve as permits authorizing emissions and are traded through the cap-and-trade market between actors whose economic demands dictate the sale or purchase of permits. In theory, allowance prices could serve as a proxy for the cost of abatement. However, this report does not rely on the prices of cap-and-trade allowances due to the vulnerability of the allowance market to external fluctuations, and the influence of regulatory decisions affecting scarcity or over-allocation unrelated to damages or abatement costs.

E.3.1 European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) covers more than 11,000 power stations, industrial plants, and airlines in 31 countries. However, the market is constantly affected by over-supply following the 2008 global recession and has seen prices drop to dramatic lows in early 2013, resulting in the practice of "back-loading" (delaying issuances of permits) by the European parliament. At the end of June 2013, prices of permits dropped to $5.41/ton, a price which is well below damage cost estimates and sub-optimal for encouraging innovative carbon dioxide emission abatement strategies.

E.3.2 California Cap & Trade

In comparison, California cap-and-trade allowance prices were reported to be at least $14/ton in May of 2013, with over 14.5 million total allowances sold for 2013 (CARB 2013b). However, cap-and-trade markets are likely to cover only subsets of emitting sectors of the industry covered by AB 32. In addition, the market prices of allowances are determined only partly by costs incurred by society or industry actors and largely by the stringency of the cap determined by regulatory agencies and uncontrollable market forces, as seen by the failure of the EU ETS to set a consistent and effective signal to curb carbon dioxide emissions.