Proposal Information Template for: **Computers**

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Prepared for:
Pacific Gas and Electric Company
San Diego Gas & Electric
Southern California Edison
Southern California Gas Company

Natural Resources Defense Council

Prepared by:
Nate Dewart, Energy Solutions
Pierre Delforge, NRDC

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Please note: all savings estimates and information in this document are preliminary and are based on data available to the authors at the time of the report. If the CEC moves forward with this topic, we anticipate updating our estimates and recommendations based upon additional input from stakeholders.

Proposal Information Template – Computers

2011 Appliance Efficiency Standards

Prepared for: Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison, Southern California Gas Company and NRDC

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Purpose

This document is a report template to be used by researchers who are evaluating proposed changes to the California Energy Commission's (Commission) appliance efficiency regulations (Title 20, Cal. Code Regulations, §§ 1601 – 1608) This report specifically covers Computers.

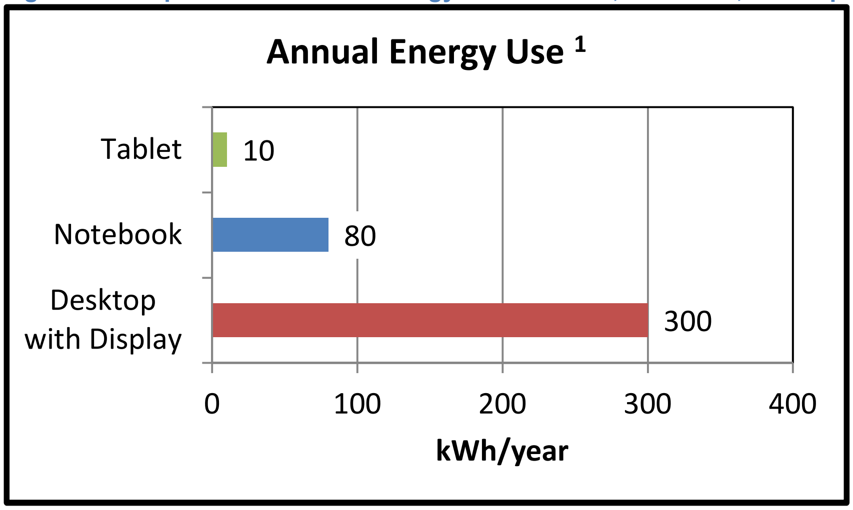
Background

Desktop and notebook (laptop) computers, also known as Personal Computers (PC's) are ubiquitous (see Appendix A for definitions). With approximately one per capita in the U.S., they play a prominent role in society, and have a wide-range of applications and performance capabilities for both business and personal 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 and word-processing, require lower performing equipment .

As the technology advances, so are consumer preferences. For example, desktops used with display monitors, are projected to reach a plateau in annual sales volume, while notebooks are growing both in professional and personal usage, due to their smaller size and greater mobility. Notebooks consume less electricity than desktops when comparing the same performance levels because they generally have greater component efficiencies due to a design focus on reducing waste energy for increased battery life. In addition, notebooks use external power supplies, which are currently covered by Federal standards (DOE 2008) and therefore not covered in this proposal.

Despite this shift towards less energy consumptive form factors and assistance from voluntary programs in improving efficiencies such as ENERGY STAR and 80 PLUS (a third-party certification power supplies 80% efficient and greater), there is still a significant amount of energy savings to gain on a per unit basis for both form factors.

Figure 1: Comparison of Annual Energy Use of Tablet, Notebook, Desktop Computers1



The above chart illustrates the magnitude of the differences in energy use between the 3 form factors. These differences are out of proportion of the capability differences between these platforms, and demonstrate that desktops and to some extent even notebooks use less efficient components and system architectures than tablets. Tablets demonstrate that computing devices of comparable capabilities and prices can use radically less energy.

PC's are a substantial electronic plug-load and in aggregate are a growing fraction of all energy consumed in California (EIA 2008), currently at an estimated 10,000 GWh/yr, or over 3% of California (excluding the energy consumption of monitors both in desktop and notebooks).

There are several design changes that can improve a PC's overall efficiency, including modifications to the platform (motherboard and CPU combinations), power supply units (PSUs),) hard drives, memory modules and case fans (EPRI & Ecos 2008), as illustrated below:

[1] Based on product samples, not necessarily exact representation of market average. Tablet is iPad, Notebook and Desktop are ENERGY STAR category B devices with integrated graphics. Monitor is 20-in model. Duty cycle include mix of ENERGY STAR and non-power managed computers.

Table 1: Computer Energy Use Breakdown and Efficiency Opportunities

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

Of the energy savings opportunities available, we recommend both a system-based energy use approach and a few, simple, low-cost, cost-effective measures of power supply efficiency and power management enablement requirements that would increase the efficiency of computers without impeding the development of the technology.

Overview

<table>
<tr>
<td>Description of Standards Proposal</td>
<td>
We recommend that California adopt a two-tier, 2014 (Tier 1) and 2016 (Tier 2), standard for Computers based on the typical electricity consumption (TEC), in units of kWh/year, for an individual device, with additional power supply efficiency and power management enablement requirements. The TEC limit will be determined by the class of the device and with allowances for advanced features. Recommendations for specific base TEC levels and allowances will be developed upon the incorporation of updated market energy use data.
Power management enablement requirements are based on ENERGY STAR 5.0 specifications. Device classifications and testing procedures should also follow current ENERGY STAR 5.0 specification.
Power supply efficiency requirements are based on 80 PLUS levels (See Appendix B), with an additional requirement for 10% load (level TBD).
<table>
<tr><th>Maximum Power Rating</th><th rowspan="2">Loading Condition</th><th>Tier 1 - Effective January 1, 2014</th><th>Tier 2 - Effective January 1, 2016</th></tr>
<tr><th></th><th>Minimum Efficiency</th><th>Minimum Efficiency</th></tr>
<tr><td>*≥ 50W and < 300W*</td><td>10%</td><td>TBD</td><td>TBD</td></tr>
<tr><td></td><td>20%</td><td>82%</td><td>87%</td></tr>
<tr><td></td><td>50%</td><td>85%</td><td>90%</td></tr>
<tr><td></td><td>100%</td><td>82%</td><td>87%</td></tr>
<tr><td>*> 300W*</td><td>10%</td><td>TBD</td><td>TBD</td></tr>
<tr><td></td><td>20%</td><td>85%</td><td>90%</td></tr>
<tr><td></td><td>50%</td><td>88%</td><td>92%</td></tr>
<tr><td></td><td>100%</td><td>85%</td><td>90%</td></tr>
</table>
</td>
</tr>
<tr>
<td>California Stock and Sales</td>
<td>Based on sales data from IDC (2011) and RASS (2009), we estimate there to be 6.5 million desktops and 8.6 million notebooks in homes, and 9.4 million desktops and 12.4 million notebooks in the commercial sector by 2014. We estimate annual sales for desktops at 4 million and notebooks at 8 million in California, with no future growth for desktops and an average 8% increase of notebooks through 2017.</td>
</tr>
</table>

Energy Savings and Demand Reduction	We estimate there to be a per unit lifetime energy savings of 320 kWh and 60 kWh by stock turnover for Tier 2 (assuming TEC levels set to reduce average energy use by 25% compared to the current market), for desktops and notebooks, respectively. Collectively, this standard would result in 2,500 GWh of energy savings and 440 MW of peak demand (equal to about one power plant) after stock turnover, using peak demand ratio from Koomey and Brown (2002).
Economic Analysis	The full life-cycle costs, benefits and ratios for the TEC component of the standard are still to be determined. Power supply unit efficiency and power management enablement components have shown cost-effectiveness over the life-cycle of the product, however. Preliminary material cost analysis indicates that power supply efficiency improvements are approximately \$.80 per 1% increase in efficiency for the manufacturer (iSuppli 2011). Assuming a price-mark up range for the end consumer of 1.6 -2 times, this is \$2.0 - \$2.40 per 1% increase in efficiency for the consumer. In a separate study, Navigant (2011) concludes a cost range of approximately \$7-\$23 for an average efficiency improvement to 80 PLUS, depending on the starting efficiency. With no additional cost for power management enablement, given that the computers are already configured before they ship, we estimate the resulting energy cost savings for these two components of the standards would range between \$25-\$45 for Tier 2 for the average computer on the market. This results in a benefit cost ratio range between a 2.20 to 1 and 1.10 to 1.. Again, this does not include additional savings (or costs) from other approaches to meet the TEC limits.
Non-Energy Benefits	This proposal will increase greenhouse gas reduction at the power generation source, helping California to meet its AB 32 goals (1990 levels by 2020). One benefit from both increasing the power supply efficiency and implementation of power management settings is the reduction in cooling needs at peak electricity demand in summer months, due to a reduction in waste heat in office and to a lesser extent residential buildings. While the waste heat may increase natural gas demand in winter months, this tradeoff is a net environmental benefit. Another potential external benefit to increasing power supply efficiency is the effect on the efficiencies of other products, for example, of internal power supplies for other consumer electronics and external power supplies for notebooks.

Environmental Impacts	We are not aware of any adverse environmental impacts that will be created by the proposed standard, but further research will be performed regarding the toxicity of computer components.
Acceptance Issues	Using ENERGY STAR's definitions and test procedure and energy consumption calculation should help to minimize any acceptance issues. We will further analyze the interaction and potential coordination between this proposed standard and forthcoming update to the ENERGY STAR specifications (to 6.0) as they are published. TEC requirements in this proposal have no effect on active mode power consumption, only on idle, sleep and off modes. There is therefore no adverse consequence on computer performance. For ENERGY STAR, the TEC approach requires testing of the highest energy consuming configuration in each ENERGY STAR category per model. We propose adopting a similar approach for the registration of models complying with this California standard.
Federal Preemption or other Regulatory or Legislative Considerations	There are no known interactions with other existing laws for this standard. There is currently no federal mandatory standard, and there is significant potential California to influence the direction of national adoption. The Department of Energy is scheduled to begin a rulemaking for 'Computers, Computer Equipment and Certain Computer Components,' however, given that this rulemaking is in its very early stages, there is significant uncertainty in the schedule. At the very earliest, the effective date would be in 2018, when California's standard would have already reached full stock turnover.

Methodology and Modeling used in the Development of the Proposal
We developed savings estimates using the best available data from a number of sources. Given ongoing developments in the marketplace, we are planning to update these estimates upon obtaining new data, particularly for energy usage data from ENERGY STAR 6.0, and costs of compliance to meet the determined TEC levels.

Key assumptions for the base case energy consumption are below (more detailed assumptions will be provided upon the submission of a full CASE report). We used these estimates to calculate stock turnover energy consumption reduction from the base case of 12.5% for Tier 1 and 25% for Tier 2. Savings from power supply efficiency improvements and power management enablement would contribute to these tiered requirements, not be additional, and were calculated as such to demonstrate the feasibility of these levels.

Per Unit Assumptions for Base Case PC's:

- Power use by mode (ENERGY STAR 5.0). Since this data reflects the top tier of the market, rather than the market average, these numbers were adjusted accordingly. Again, this data reflects past market values and will be updated with current market data and projected into the future for the base case.
- Duty cycle and Power management enablement differing by notebooks, desktops and by sector (Barr et al 2010, Pigg & Bensch 2010 and, TIAX 2007).
- Power supply efficiency market saturation and costs (iSuppli 2011, Navigant 2011).
- Design life: Desktops is 4-5 years; ENERGY STAR reports 4 years (EPA 2010a). Notebooks is estimated to be 2-3 years (Toshiba 2008).
- Electricity pricing: currently $.14/kwh CEC (2011), and future prices projected using CEC 2004 methodology, weighting commercial and residential (Energy Solutions 2011).
- Residential to Commercial market saturation = 60/40 (Hamm and Greene 2008)

State-wide

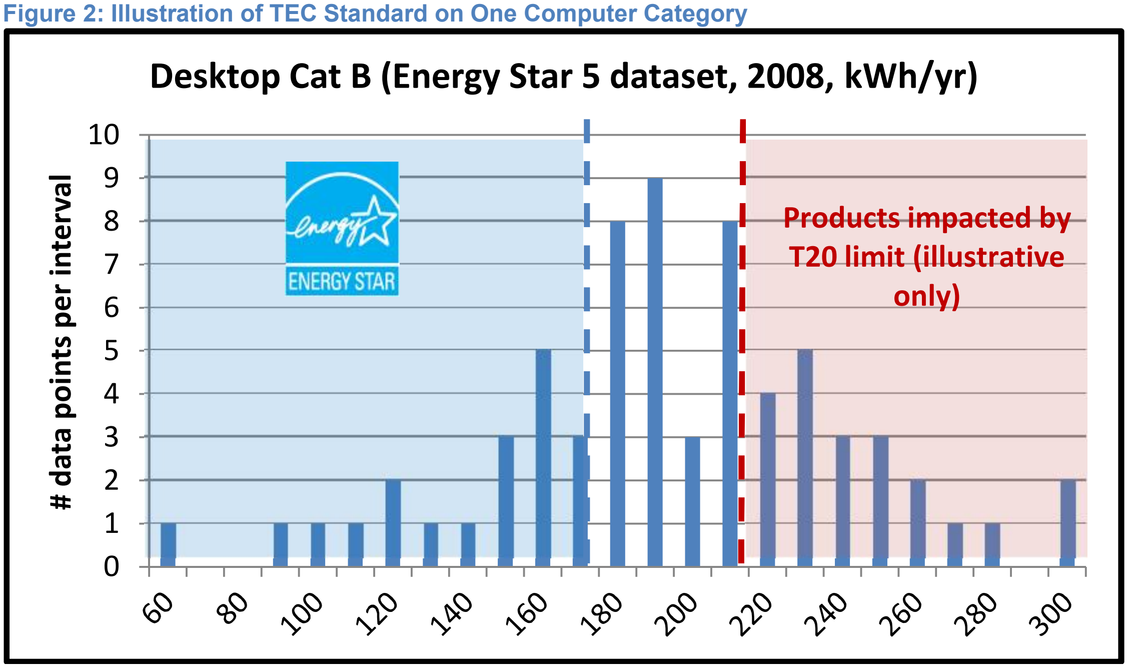
- US Sales (IDC 2010, 11) * 12%, a CA / US factor

Data, Analysis, and Results

Illustrative TEC Limits

The chart below illustrates how the proposed TEC standard would work for computers. This is illustrative only since actual limits will be determined later based on Energy Star 6 and cost-effectiveness data.

Figure 2: Illustration of TEC Standard on One Computer Category



The TEC standard proposal works in a similar manner as ENERGY STAR, but instead of recognizing the most efficient computers with a label, a TEC standard sets system-level limits requiring the worst energy performers in the market to meet minimum efficiency standards. This flexible, performance-based approach enables manufacturers to find the most cost-effective way to meet the standard.

Capability Adjustments (aka adders) provide extra allowances for specific capabilities, ensuring that the standard is performance and functionality neutral.

The standard is inspired from ENERGY STAR, however it uses adjusted limit and adder values in order to ensure that specific applications are unduly impacted.

Power Use by Mode
The power draw of each mode for both desktops and servers is determined by a number of factors, including but not limited to the processing capabilities, the power supply efficiency and if the power supply is redundant capable. The wattage for each mode used in this analysis and in the model was developed with inputs and definitions based on ENERGY STAR 5.0.

Duty Cycle & Power Management
The duty cycle for PC's varies considerably by ownership, though general usage trends have been documented. There are several studies which sample PC user behavior in both residential and commercial settings to capture an estimation of daily duty cycles (Barr et al 2010; Pigg & Bensch 2010; TIAX 2007). The duty cycle is determined both by the extent of the PC's power management settings (see Appendix C for definitions) and by the extent the user manually switches the modes. The power management settings determine the length of time before the operating system automatically switches off 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 PC model are determined by the PC 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, of which currently four main ones share the majority of the market: Windows XP, Windows 7, Windows Vista, MacOS X, with Linux representing a small percentage. If 2011 is an indicator of the near future, Windows 7 is likely to further replace Windows XP and Vista and be the dominant operating system until Microsoft's next version, Windows 8. MacOS X has risen in market share, but is still about 10% of new shipments.

Based on a preliminary assessment of current market saturation, we determined that approximately 70% of desktops and 90% of notebooks have power management enabled at shipment. This data highlights a higher saturation than previous research suggests for existing stock in both residential and commercial sectors (Pigg & Bensch 2010; Chetty et. al 2009, Barr et al. 2010) but that there is still opportunity for industry implementation and continuity, both in enablement rate and the length of time before sleep.

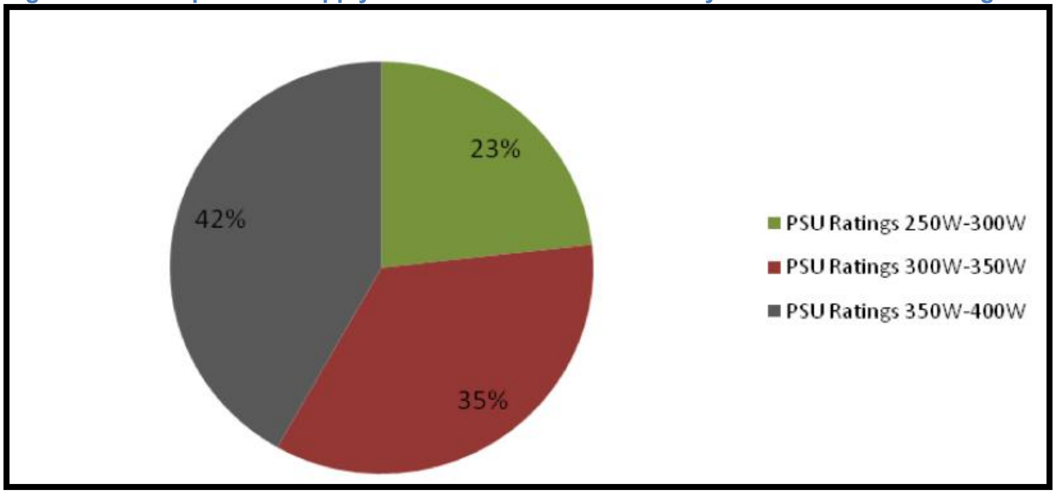
Both the user adjustment rates from the default set by the manufacturer upon shipment and the manual switching of modes were also included in the estimation of duty cycle using the previous research (Pigg & Bensch 2010; Chetty et. al 2009, Barr et al. 2010). Reasons for disabling power management are not well understood, however it appears that this is caused both by user behavior due to perception of inconvenience and by software and hardware incompatibilities with power management functionality of the system.

PSU Efficiency:
A range of PSU efficiencies currently exist in the marketplace, with higher power ratings having higher efficiencies. The vast majority of desktop PSUs have name plate power ratings of 300 - 350W (see Figure 3) and will continue to increase as percentage of the whole (iSuppli 2011).

Figure 4 shows one estimate of the current efficiencies at 50% load, with nearly half of desktop PSUs below 80%, an important threshold for efficiency. Navigant reports that more than half, approximately 63% are non-80 PLUS certified.

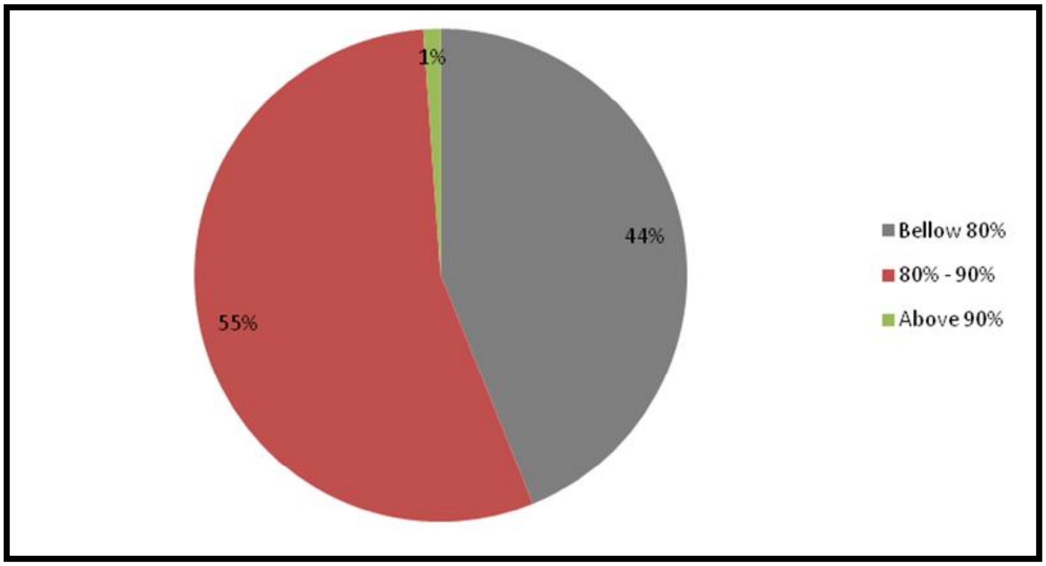
Preliminary findings suggest that computers are idling in the 10%-20% range, but that these Loads, which are currently not included in 80 PLUS for computers (though is for servers) have disproportional efficiencies relative to the other three load efficiencies that are addressed by 80 Plus (20%, 50% and 100%).

Figure 3: Desktop Power Supply Unit Market Shares in 2010 by Maximum Power Rating



Source: iSuppli, Cost of Efficiency, prepared by iSuppli for Energy Solutions. 2011

Figure 4: Desktop Power Supply Market Share in 2010 by Efficiency @ 50% Load



Costs of Efficiency

The incremental materials cost for manufacturers would be $.80 per one percent efficiency improvement for desktop PSUs. In practical terms, this means that a manufacturer producing a PSU with a name plate wattage of 375 and an estimated 2014 market average of 83% efficiency (at 50% load) would need to spend less than $7 to meet Tier 2. A mark-up of 1.6 - 2 times the cost from manufacturer to PSU consumer results in a cost premium range of $18-$23 cost premium. Power management enablement is estimated to have little to no cost associated with it. With the energy savings from this efficiency improvement and power management enablement of $35, the resulting NPV life cycle cost of the standard would be $17-12 for desktops for Tier 2. Again, notebooks would only be required to comply with the power management enablement requirement and would not endure these costs, but would gain all of the energy savings benefits, between $.75 and $2.00.

If the distribution of nameplate power rating for the desktop PSU market remained roughly the same over the next four years, 23% would be required to meet the 80 Plus® Bronze standard of Tier 1 (85% efficiency at 50% load) and then the Gold standard of Tier 2 (90% efficiency at 50% load). The remaining 77% would be required to meet the Silver standard in Tier 1 (88% efficiency at 50% load) and the Platinum standard of Tier 2 (92% efficiency at 50% load).

As discussed above, the life cycle costs and benefit cost ratios for system-wide TEC limit is not yet complete, however, the analysis for PSU efficiencies and power management enablement demonstrates significant efficiency improvement opportunities that are cost-effective.

Statewide Stock & Sales, Energy Use and Savings

Table 2: California PC Stock and Sales in 2014

	California Stock	**California Annual Sales**	
Design Options	Units (millions)	Units (millions)	’12-17 Estimated Average Annual Growth Rate
Desktops	15	3.8	-0.8%
Notebooks	21	8.8	8%

Source: Energy Solutions and NRDC 2011

Table 3: California Statewide Baseline Energy Use 2014

	For First-Year Sales		**For Entire Stock**	
Design Options	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)
Desktops	300	1,760	1,285	7,550
Notebooks	180	1,050	440	2,570

Source: Energy Solutions and NRDC 2011

Table 4: Estimated California Statewide Energy Savings for Proposed Standards

	For First-Year Sales		After Entire Stock Turnover	
Design Options	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)
Tier 1	60	350	215	1,265
Tier 2 (relative to BAU)	120	710	440	2,600

Source: Energy Solutions and NRDC 2011

Proposed Standards and Recommendations
We recommend that California adopt a two-tier, 2014 (Tier 1) and 2016 (Tier 2), standard for Computers based on the typical electricity consumption (TEC, kWh/year) for an individual device, with addition of power supply efficiency and power management enablement requirements. The TEC limit is determined by the class of the device with allowances for advanced features. Recommendations for specific base TEC levels and allowances will be developed upon the incorporation of updated market data.

We also recommend a two-tier, 2014 and 2016, based on 80 PLUS levels, with an additional requirement for 10% load (efficiency to be determined).

Finally, we recommend a power management enablement requirement based on ENERGY STAR 5.0 specifications. Device classifications and testing procedures should also follow current ENERGY STAR 5.0.

To the Title 20 Code language, we recommend the following changes and additions:

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.

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 6.5 dated" dated July 7th, 2010.

(__) **Personal Computers.**
The test method for Typical Energy Consumption for Personal Computers is ENERGY STAR Computer Test Method (Version 5.0) Section III.

NOTE: There is no test procedure for enabled power management settings, as power management is a configuration, not a performance requirement.

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 50W

Maximum Power Rating	**Loading Condition**	**Tier 1 - Effective January 1, 2014**	**Tier 2 - Effective January 1, 2016**
		Minimum Efficiency	**Minimum Efficiency**
≥ 50W and < 300W	10%	TBD	TBD
	20%	82%	87%
	50%	85%	90%
	100%	82%	87%
> 300W	10%	TBD	TBD
	20%	85%	90%
	50%	88%	92%
	100%	85%	90%

(__) **Personal Computers.**

1. *Typical Energy Consumption: Personal Computers manufactured on or after XXXX shall have no more than the following values: (TABLE TBD)*

2. *Power Management Settings. Personal Computers 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.*

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Reference and Appendices

Appendix A:

Hardware Definitions

<u>Computers:</u>
For purposes of this specification, we define computers as follows, based on ENERGY STAR Program Requirements for Computers v5.0.

A device which performs logical operations and processes data. Computers are composed of, at a minimum: (1) a central processing unit (CPU) to perform operations; (2) user input devices such as a keyboard, mouse, digitizer or game controller; and (3) a computer display screen to output information. For the purposes of this specification, computers include both stationary and portable units, including desktop computers, integrated desktop computers, notebook computers, thin clients, and workstations. Although computers must be capable of using input devices and computer displays, as noted in numbers 2 and 3 above, computer systems do not need to include these devices on shipment to meet this definition.

<u>Internal Power Supply:</u>
For purposes of this specification, per the scope of ENERGY STAR Program Requirements for Computers v.5.0:

A component internal to the computer casing and designed to convert AC or DC 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 must be contained within the computer casing but be separate from the main computer board. The power supply must 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 computer display in an Integrated Desktop Computer, must 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.

Image of Internal Power Supply

Source: Electric Power Research Institute accessed http://www.efficientpowersupplies.org/efficiency_opportunities.html

<u>Single Output vs. Multi-Output Power Supplies</u>

For the purposes of this specification, per the scope of Climate Savers Computing (http://www.climatesaverscomputing.org/tech-specs):

A Multi-output PSU refers to desktop and server application power supplies in non-redundant applications. A Single-output PSU typically refers to volume servers power supplies in redundant configurations (1U/2U single, dual, four-socket and blade servers).

Appendix B:

Power Supply Efficiency Level Definitions:

The following represent definitions of various “levels” of power supply efficiency performance. These are consistent with the Climate Savers Computer Initiative and 80 Plus power supply definitions.

Multi-output Power Supply Unit:

Desktop and server application power supplies in non-redundant applications:

Loading Condition	**Bronze**		**Silver**		**Gold**		**Platinum**	
	Efficiency	**Power Factor**	**Eff.**	**p.f.**	**Eff.**	**p.f.**	**Eff.**	**p.f.**
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

Appendix C: Duty Cycle Mode Definitions

The definitions for each mode used in this analysis and in the model developed by Energy Solutions and NRDC (2011) are as follows, based on ENERGY STAR Program Requirements for Computers Version 5.0[2]:

> *Active*: The 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. This 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:* The electrical power consumed by a device when it is powered on, operating system and software are loaded, and the system is not processing any user data, but is ready to process new data or requests with no or minimal delay due to power management.
>
> *Sleep:* A low-power state that the IT equipment is capable of entering automatically after a period of inactivity or by manual selection. A system with sleep capability can quickly "wake" in response to network connections or user interface devices, like hibernate with a latency of ≤ 5 seconds from initiation of wake event to system becoming fully usable.
>
> *Off:* The power consumption level in 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.

Other Duty Cycle Definitions:

- Barr et al. (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."

[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). We use ENERGY STAR version because it is the most universal. See **Appendix D** for a more detail description of these other duty cycles.

Appendix D: ENERGY STAR Power Use Test Procedure

APPENDIX A:
ENERGY STAR Test Procedure for Determining the Power Use of Computers/Game Consoles in Off, Sleep, and Idle

The following protocol should be followed when measuring power consumption levels of computers/game consoles for compliance with the Off, Sleep, and Idle levels provided in the ENERGY STAR Version 5.0 Computer Specification. Partners must measure a representative sample of the configuration as shipped to the customer. However, the Partner does not need to consider power consumption changes that may result from component additions, BIOS and/or software settings made by the computer user after sale of product. *This procedure is intended to be followed in order and the mode being tested is labeled where appropriate.*

Computers must be tested with configuration and settings as shipped, unless otherwise specified in the test procedure in this Appendix A. Steps requiring alternative setup are marked with an asterisk (" ").*

I. Definitions

Unless otherwise specified, all terms used in this document are consistent with the definitions contained in the Version 5.0 ENERGY STAR Eligibility Criteria for Computers.

UUT
UUT is an acronym for "unit under test," which in this case refers to the computer being tested.

UPS
UPS is an acronym for "Uninterruptible Power Supply," which refers to a combination of converters, switches and energy storage means, for example batteries, constituting a power supply for maintaining continuity of load power in case of input power failure.

II. Testing Requirements

Approved Meter
Approved meters will include the following attributes[1]:

- Power resolution of 1 mW or better;
- An available current crest factor of 3 or more at its rated range value; and
- Lower bound on the current range of 10mA or less.

The following attributes in addition to those above are suggested:

- Frequency response of at least 3 kHz; and
- Calibration with a standard that is traceable to the U.S. National Institute of Standards and Technology (NIST).

It is also desirable for measurement instruments to be able to average power accurately over any user selected time interval (this is usually done with an internal math's calculation dividing accumulated energy by time within the meter, which is the most accurate approach). As an alternative, the measurement instrument would have to be capable of integrating energy over any user selected time interval with an energy resolution of less than or equal to 0.1 mWh and integrating time displayed with a resolution of 1 second or less.

[1] *Characteristics of approved meters taken from IEC 62301 Ed 1.0: Measurement of Standby Power*

Accuracy
Measurements of power of 0.5 W or greater shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level. Measurements of power of less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level. The power measurement instrument shall have a resolution of:

- 0.01 W or better for power measurements of 10 W or less;
- 0.1 W or better for power measurements of greater than 10 W up to 100 W; and
- 1 W or better for power measurements of greater than 100 W.

All power figures should be in watts and rounded to the second decimal place. For loads greater than or equal to 10 W, three significant figures shall be reported.

Test Conditions

Supply Voltage:	North America/Taiwan:	115 (± 1%) Volts AC, 60 Hz (± 1%)
	Europe/Australia/New Zealand:	230 (± 1%) Volts AC, 50 Hz (± 1%)
	Japan:	100 (± 1%) Volts AC, 50 Hz (± 1%)/60 Hz (± 1%)
		Note: For products rated for > 1.5 kW maximum power, the voltage range is ± 4%
Total Harmonic Distortion (THD) (Voltage):	< 2% THD (< 5% for products which are rated for > 1.5 kW maximum power)	
Ambient Temperature:	23°C ± 5°C	
Relative Humidity:	10 – 80 %	

(Reference IEC 62301: Household Electrical Appliances – Measurement of Standby Power, Sections 4.2, 4.3, 4.4)

Test Configuration
Power consumption of a computer shall be measured and tested from an ac source to the UUT.

If the UUT supports Ethernet, it must be connected to an Ethernet network switch capable of the UUT's highest and lowest network speeds. The network connection must be live during all tests.

III. Test Procedure for Off, Sleep and Idle for All Computer Products

Measurement of ac power consumption of a computer should be conducted as follows:

UUT Preparation
1. Record the manufacturer and model name of the UUT.
2. Ensure that the UUT is connected to network resources as detailed below, and that the UUT maintains this live connection for the duration of testing, disregarding brief lapses when transitioning between link speeds.
    a. *Desktops, Integrated Desktops, and Notebooks* shall be connected to a live Ethernet (IEEE 802.3) network switch as specified in Section II., "Test Configuration," above. The computer must maintain this live connection to the switch for the duration of testing, disregarding brief lapses when transitioning between link speeds. Computers without Ethernet capability must maintain a live wireless connection to a wireless router or network access point for the duration of testing.
    b. *Small-Scale Servers* shall be connected to a live Ethernet (IEEE 802.3) network switch as specified in Section II., "Test Configuration," above, and that the connection is live.

   c. *Thin Clients* shall be connected to a live server via a live Ethernet (IEEE 802.3) network switch and shall run intended terminal/remote connection software.
3. Connect an approved meter capable of measuring true power to an ac line voltage source set to the appropriate voltage/frequency combination for the test.
4. Plug the UUT into the measurement power outlet on the meter. No power strips or UPS units should be connected between the meter and the UUT. For a valid test to take place the meter should remain in place until all Off, Sleep, and Idle power data is recorded.
5. Record the ac voltage and frequency.
6. Boot computer and wait until the operating system has fully loaded. If necessary, run the initial operating system setup and allow all preliminary file indexing and other one-time/periodic processes to complete.
7. Record basic information about the computer's configuration – computer type, operating system name and version, processor type and speed, and total and available physical memory, etc.
8. Record basic information about the video card or graphics chipset (if applicable) - video card/chipset name, frame buffer width, resolution, amount of onboard memory, and bits per pixel.
9. * Ensure that the UUT is configured as shipped including all accessories, WOL enabling, and software shipped by default. UUT should also be configured using the following requirements for all tests:
   a. *Desktop* systems shipped without accessories should be configured with a standard mouse, keyboard and external computer display.
   b. *Notebooks* should include all accessories shipped with the system, and need not include a separate keyboard or mouse when equipped with an integrated pointing device or digitizer.
   c. *Notebooks* should have the battery pack(s) removed for all tests. For systems where operation without a battery pack is not a supported configuration, the test may be performed with fully charged battery pack(s) installed, making sure to report this configuration in the test results.
   d. *Small-Scale Servers* and *Thin Clients* shipped without accessories should be configured with a standard mouse, keyboard and external computer display (if server has display output functionality).
   e. For Computers <u>with</u> Ethernet capability, power to wireless radios should be turned off for all tests. This applies to wireless network adapters (e.g., 802.11) or device-to-device wireless protocols. For Computers <u>without</u> Ethernet capability, power to a wireless LAN radio (e.g. IEEE 802.11) should remain on during testing and must maintain a live wireless connection to a wireless router or network access point, which supports the highest and lowest data speeds of the client radio, for the duration of testing.
   f. Primary hard drives may not be power managed ("spun-down") during Idle testing unless containing non-volatile cache integral to the drive (e.g. "hybrid" hard drives). If more than one internal hard drive is installed as shipped, the non-primary, internal hard drive(s) may be tested with hard drive power management enabled as shipped. If these additional drives are not power managed when shipped to customers, they must be tested without such features implemented.

10. * The following guidelines should be followed to configure power settings for computer displays (adjusting no other power management settings):
    a. <u>For computers with external computer displays (most desktops):</u> use the computer display power management settings to prevent the display from powering down to ensure it stays on for the full length of the Idle test as described below.
    b. <u>For computers with integrated computer displays (notebooks and integrated systems):</u> use the power management settings to set the display to power down after 1 minute.
11. Shut down the UUT.

Off Mode Testing

12. With the UUT shut down and in Off, set the meter to begin accumulating true power values at an interval of less than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period.[2]

Idle Mode Testing

13. Switch on the computer and begin recording elapsed time, starting either when the computer is initially switched on, or immediately after completing any log in activity necessary to fully boot the system. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed. Between 5 and 15 minutes after the initial boot or log in, set the meter to begin accumulating true power values at an interval of greater than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period.

Sleep Mode Testing

14. After completing the Idle measurements, place the computer in Sleep mode. Reset the meter (if necessary) and begin accumulating true power values at an interval of greater than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period.
15. If testing both WOL enabled and WOL disabled for Sleep, wake the computer and change the WOL from Sleep setting through the operating system settings or by other means. Place the computer back in Sleep mode and repeat step 14, recording Sleep power necessary for this alternate configuration.

Reporting Test Results

16. The test results must be reported to EPA or the European Commission, as appropriate, taking care to ensure that all required information has been included, including modal power values and eligible capability adjustments for Desktops, Integrated Desktops, and Notebooks.

IV. Maximum Power Test for Workstations

The maximum power for workstations is found by the simultaneous operation of two industry standard benchmarks: Linpack to stress the core system (e.g., processor, memory, etc.) and SPECviewperf® (latest available version for the UUT) to stress the system's GPU. Additional information on these benchmarks, including free downloads, can be found at the URLs found below:

Linpack	http://www.netlib.org/linpack/
SPECviewperf®	http://www.spec.org/benchmarks.html#gpc

This test must be repeated three times on the same UUT, and all three measurements must fall within a ± 2% tolerance relative to the average of the three measured maximum power values.

Measurement of the maximum ac power consumption of a workstation should be conducted as follows:

UUT Preparation

1. Connect an approved meter capable of measuring true power to an ac line voltage source set to the appropriate voltage/frequency combination for the test. The meter should be able to store and

[2] *Laboratory-grade, full-function meters can integrate values over time and report the average value automatically. Other meters would require the user to capture a series of changing values every 5 seconds for a five minute period and then compute the average manually.*

output the maximum power measurement reached during the test or be capable of another method of determining maximum power.

2. Plug the UUT into the measurement power outlet on the meter. No power strips or UPS units should be connected between the meter and the UUT.
3. Record the ac voltage.
4. * Boot the computer and, if not already installed, install Linpack and SPECviewperf as indicated on the above Websites.
5. Set Linpack with all the defaults for the given architecture of the UUT and set the appropriate array size "n" for maximizing power draw during the test.
6. Ensure all guidelines set by the SPEC organization for running SPECviewperf are being met.

Maximum Power Testing

7. Set the meter to begin accumulating true power values at an interval of less than or equal to 1 reading per second, and begin taking measurements. Run SPECviewperf and as many simultaneous instances of Linpack as needed to fully stress the system.
8. Accumulate power values until SPECviewperf and all instances have completed running. Record the maximum power value attained during the test.

Reporting Test Results

9. The test results must be reported to EPA or the European Commission, taking care to ensure that all required information has been included.
10. Upon submittal of data, manufacturers must also include the following data:
    a. Value of the n (the array size) used for Linpack,
    b. Number of simultaneous copies of Linpack run during the test,
    c. Version of SPECviewperf run for test,
    d. All compiler optimizations used in compiling Linpack and SPECviewperf, and
    e. A precompiled binary for end users to download and run of both SPECviewperf and Linpack. These can be distributed either through a centralized standards body such as SPEC, by the OEM or by a related third party.

V. Test Procedure for All Modes for Game Consoles

Measurement of ac power consumption of a computer should be conducted as follows:

UUT Preparation

1. Record the manufacturer and model name of the UUT.
2. Record basic information about the computer's configuration – computer type, operating system name and version, processor type and speed, total and available physical memory, etc.
3. Ensure that the UUT is connected to a TV(s) which support all of the output types supported by the UUT.
    a. *For each output that supports APD, repeat step 10 of this procedure.*
4. Connect an approved meter capable of measuring true power to an ac line voltage source set to the appropriate voltage/frequency combination for the test.
5. Plug the UUT into the measurement power outlet on the meter. No power strips or UPS units should be connected between the meter and the UUT. For a valid test to take place the meter should remain in place until all power data is recorded.
6. Record the ac voltage and frequency.
7. Turn on the console and wait until the operating system has fully loaded.
8. If necessary, run the initial system setup and allow all preliminary tasks and other one-time/periodic processes to complete.
9. Ensure that the UUT is configured as shipped including all accessories, power management settings and software shipped by default.
10. For each applicable output, wait for 15 minutes and ensure the output drops after the prescribed time.
11. Place the system in a state without the game loaded.