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California Investor Owned Utilities Comments: Computers - Response to Final Staff Report

Additional submitted attachment is included below.

Computers

Codes and Standards Enhancement (CASE) Initiative
For PY 2016: Title 20 Standards Development

Response to Final Draft CEC Staff Report,
Revised Analysis for **Computers**

Docket #14-AAER-2

May 23, 2016

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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. This document provides recommendations and supporting analysis in response to the CEC's Computers Final Draft Staff Report (herein in referred to as Draft 2).

The CASE team generally supports the energy efficiency standards for computers proposed by the CEC in Draft 2. Specifically, we strongly support CEC's cost-effective and feasible base allowances and expandability adder levels for desktops and thin clients, discrete graphics adder levels, as well as the power supply and power management requirements for workstations and small-scale servers. The CASE team also recommends, with supporting analysis, modifications to other aspects of the standards proposal in order to optimize energy savings and ensure robust compliance. Addressing these elements will allow California to even further address the statewide policy objectives of the Zero Net Energy California Long Term Energy Efficiency Strategic Plan and AB32 energy efficiency goals. A summary of the recommendations are found below:

a. **Categorization and limits:**

   i. Desktops: The CASE team supports the use of an expandability adder, however we have identified some areas for improvement, with two potential options for expandability, and categorization, if pursued. Option 1 uses a metric that combines power supply nameplate rating + simplified expandability score (SES) and separates products into 5 discrete categories. If the current Draft 2 proposed expandability adder scheme is deemed more appropriate but with categories instead of a continuous line, the CASE team recommends Option 2 (also with 5 discrete categories). Additionally, to optimize the robustness of this expandability calculation, the CASE team recommends several improvements whether categorization or a continuous line is used.

   ii. Notebooks: The CASE team supports the CEC proposal for notebooks, though given the high saturation of products, recommends a greater level of base allowance stringency for mainstream products at 16 kWh/yr.

b. **Power supply efficiency & power factor requirements:** The CASE team continues to recommend the cost-effective 80 PLUS Gold requirement for desktop internal power supplies. We also recommend CEC require power factor greater than or equal to 0.8 at 20% and 50% load.

c. **Integrated display adder:** CEC's current proposed levels significantly overstate the adder needed for both integrated desktops and notebooks. The CASE Team proposes more stringent levels that align with the standalone displays formula.

d. **Memory adder:** The CASE team proposes a more stringent memory adder for notebooks, dropping levels to 2.0 kWh/yr per DIMM. CEC should also consider a graduated memory adder that decreases after the addition of the first two DIMMs to discourage gaming of this adder in desktop systems.

e. **Secondary storage adder:** The CASE team recommends modifications to the secondary storage adder to limit unnecessary energy consumption allowances.

f. **Duty cycle:** The CASE team continues to recommend that CEC should require a single conventional duty cycle for calculating reported TEC values.

g. **Test method**: The CASE team recommends modifications to the test procedure for integrated desktops and notebooks to more fully account for real-world energy use and encourage manufacturers to optimize display brightness settings.

h. **Definitions:** The CASE team recommends several modifications and additions to the definitions to ensure optimal compliance for the products covered by the proposal.

i. **Power management:** The CASE team has been active in responding to industry concerns and requests that CEC continue this collaborative discussion.

j. **Registration:** The CASE team recommends registration requirements that improve upon ENERGY STAR version 6.1 requirements by specifying a different number of and type of configurations.

2 Categorization and limits

2.1 Desktops

Summary

We strongly support staff's Draft 2 base TEC and expandability adder levels. As the Aggios desktop comparison at the April 2016 workshop demonstrated, these levels are technically feasible today by incorporating relatively minor and cost-effective hardware and software improvements (see Appendix A for more details). Below, we analyze a dataset of desktop systems developed by the CASE team spanning a wide range of expandability scores and demonstrate the feasibility of Draft 2 levels for current systems.

The inclusion of an expandability adder in CEC's March 2016 proposal represented significant progress toward addressing industry concerns regarding high-performance desktop systems, particularly those with large power supplies making it more difficult to achieve low power at idle loads. CEC's current approach attempts to approximate desktop power supply sizing by computing an expandability score, akin to a system power budget. This expandability score metric is then used to establish which systems receive adders or are exempted from TEC requirements.

Industry voiced strong support for a desktop categorization system at the April 2016 workshop and expressed an openness to the use of expandability score as a metric to define categories (Eastman and Sheikh 2016*)*. Should CEC find that such a categorization system is preferable, we provide two acceptable approaches to desktop categorization based on the expandability concept: Option 1 — a new power supply nameplate rating + simplified expandability score (SES) (pg. 6) — and Option 2 — categorization utilizing the CEC's currently proposed Expandability Score scheme (pg, 7) — described in greater detail below. If the latter expandability score scheme is used, we propose several important refinements related to the calculation of the expandability score to ensure robust regulatory language and to minimize ambiguity in its interpretation.

Analysis of Staff Draft 2 Expandability Adder Proposal

Staff's Draft 2 expandability adder and base TEC levels form a reasonable foundation for energy efficiency regulations. When combined with other TEC adders, such as for discrete graphics and memory, they provide technically achievable levels that large numbers of desktop systems should be able to meet today using existing, common-sense, and low-cost efficiency strategies. The IOUs have assembled a dataset of 23 desktop computer systems spanning a range of expandability and performance, including mini desktops with almost no expandability, mainstream small form factor and micro tower systems with standard expansion slot/port configurations, as well as highly expandable tower systems. Figure 1 below provides a snapshot of systems' expected Draft 2 TEC allowances, the measured TEC per the ENERGY STAR version 6.1 test procedure, and our estimates of reasonable TEC improvements that each system should be able to achieve today. The systems are ranked in terms of increasing expandability score, with labels indicating the typical system form factors that fall within various ranges.

Our analysis modeled several energy efficiency mechanisms depicted in the green triangles. These include:

- **Discrete graphics efficiency:** all discrete graphics cards are assumed to meet the CEC's proposed Tier 1 discrete graphics adders. We have accounted for this by eliminating the TEC "gap" between this adder and cards measured by the IOUs in the 2014-15 timeframe and documented in our August 2015 comments on CEC's Draft 1 staff report.
- **Power supply efficiency:** for all systems requiring power supplies larger than 200W, we assume power supplies will be able to perform at best-available idle efficiency levels, per data reported by EPRI and Ecova (2016).
- **Hard drive efficiency:** we incorporate a 4Wac reduction in short idle power to model the impact of increased, low-latency power management techniques allowed under CEC's modifications to the ENERGY STAR test procedure.
- **CPU efficiency:** we incorporate an additional 2Wac power reduction in short and long idle to reflect increased enabling of CPU power management in low-power C states.

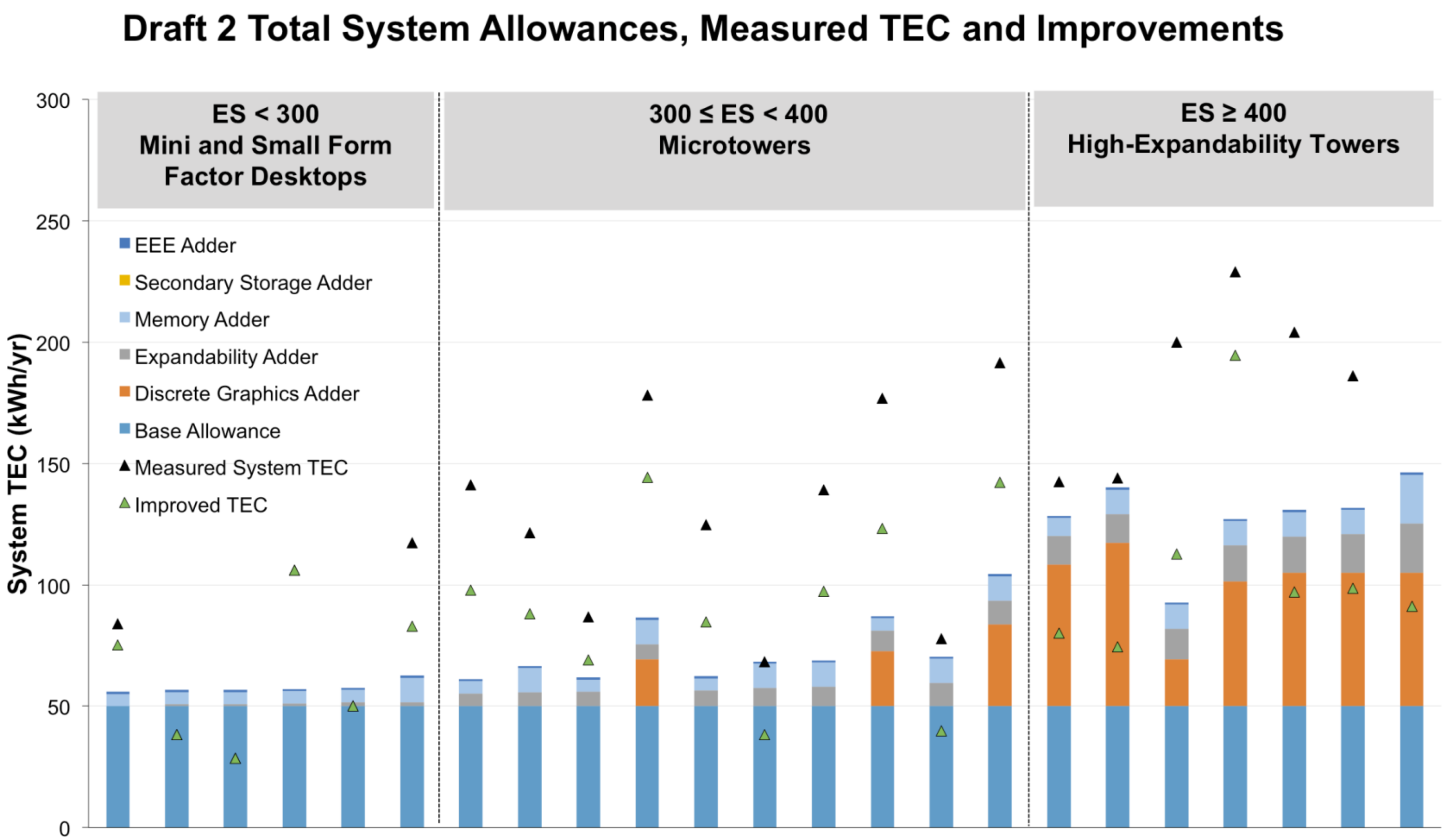

Figure 1: Desktop system compliance and modeled TEC improvements.

Six of the 23 systems would meet or be within 10% of meeting CEC's Draft 2 proposal. A total of 10 of the 23 systems investigated would be able to meet Draft 2 levels today with the modeled TEC improvements. Thus, using existing, low-cost efficiency measures, over 40% of our desktop dataset would meet CEC's Draft 2 proposal across a broad range of form factors and performance levels.

Alternative Desktop Categorization Options

At the April 2016 workshop, computer industry stakeholders expressed opposition to CEC's linear expandability adder approach in favor of a discrete category system based on aggregate I/O bandwidth. The CASE team maintains that I/O bandwidth is not an appropriate metric for defining expandability in standards for desktop computers because it will evolve rapidly over time and category definitions will quickly become obsolete.

We still favor a continuous adder approach for expandability over discrete categories due to the inevitable "boundary effects" that occur at the edges of product categories (e.g. systems near the "upper" edge of a category are highly incentivized to increase product performance to reach the next category threshold), however we are open to discrete categories if designed to mitigate this issue if they are based on more appropriate metrics that better reflect the realities of power supply up-sizing and idle load efficiency.

We have examined two frameworks that would establish 5 desktop categories: one as an alternative based on a combination of power supply size and a simplified expandability score (Option 1), and one based on the existing expandability score (Option 2). In such a five-category system, the first category (category 1) represents minimally expandable desktops that would receive no additional expandability allowance. Categories 2.1 through 2.3 represent mainstream desktops and would receive some additional expandability allowance. The last category (3), represents highly expandable, specialized systems that would be exempt from TEC requirements altogether. This framework is illustrated in Figure 1.

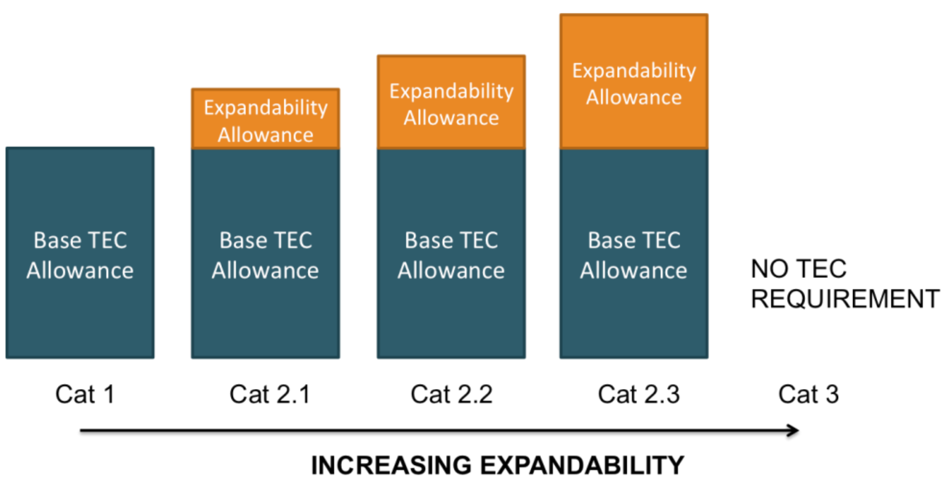

Figure 2: Category framework based on expandability attributes

Option 1: Power supply nameplate rating + simplified expandability score (SES)

Through experimentation with a variety of expandability-related metrics, we have developed an alternative metric for creating desktop categories that results in better grouping of systems compared to the original expandability score. It is also simpler, by focusing on three general system attributes (PSU size, expansion slots, and expansion ports) rather than a table of technology-specific connectors and protocols.

Power supply ratings are a direct reflection of a system's expandability needs, but basing system categories on PSU size alone is problematic, because it could unintentionally encourage additional oversizing of power supplies as a mechanism to gain greater TEC allowances. Therefore, we use a second criteria — a "simplified expandability score" (SES) — to ensure that a system cannot jump categories by upsizing its power supply alone.

In examining which hardware elements to include in the simplified expandability score, we found that the number of PCI Express (PCIe) lanes associated with motherboard PCIe expansion slots combined with the number of high-speed external data ports approximates actual PSU sizing very well. Specifically, we propose the following definition of simplified expandability score:

Simplified expandability score (SES) = (nPCIe lanes) + 2 x (nHigh-speed data ports).

Here, *nPCIe lanes* is the total number of PCIe lanes associated with motherboard PCIe slots (as opposed to the total number of PCIe lanes that the motherboard can theoretically control). *nHigh-speed data ports* represents the total number of externally accessible ports that have a maximum data throughput of ≥ 10 gigabits per second and that can deliver at least 5W of power. Examples of such ports would include Thunderbolt 2 and 3 or USB 3.1 ports.

Table 1 provides the combined criteria for each category based on both PSU size ranges as well as simplified expandability score. Systems must meet both PSU and SES criteria to qualify for a category and its TEC allowance. The TEC allowances proposed are roughly equivalent to Draft 2 levels. Figure 3 illustrates how current systems in our dataset would be assigned to these categories based on a combination of their power supply size and their simplified expandability score.

Table 1: Categories Based on PSU Nameplate Rating and Simplified Expandability Score

Category	PSU Nameplate Rating (W)	Simplified Expandability Score (SES) = nPCIe lanes + 2*nHigh-speed external data ports	TEC Allowances (kWh/yr)	Estimated Share of Desktops and Integrated Desktops
DT 1	W < 225	Any	0	35%
DT 2.1	W ≥ 225	SES ≥ 10	3	48%
DT 2.2	W ≥ 375	SES ≥ 16	10	15%

DT 2.3	W ≥ 575	SES ≥ 20	20	1%
DT 3	W ≥ 900	SES ≥ 36	N/A, exempt from TEC requirements	1%

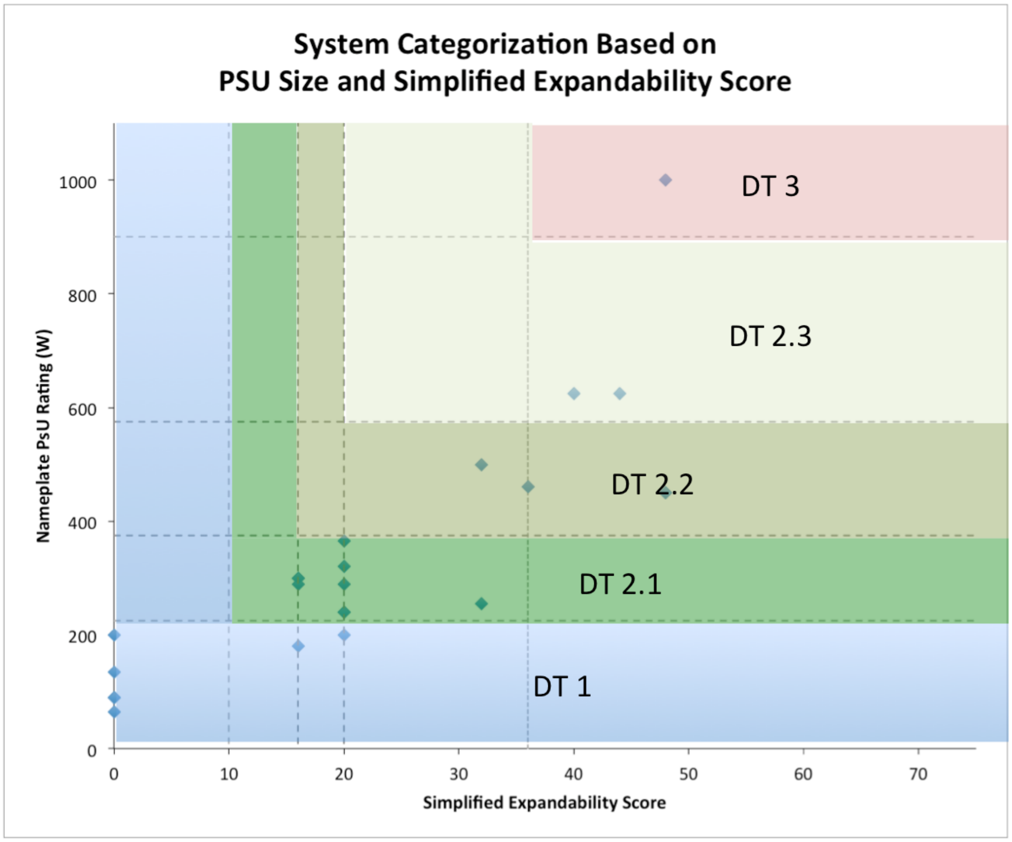

Figure 3: System categories based on PSU size and simplified expandability score

Option 2: Expandability Score Categories

One option for creating system categories would be to use CEC's Draft 2 expandability score calculation. We recommend a system with five categories to most closely approximate CEC's continuous expandability adder line and reduce the impact of boundary effects at the edges of categories. Below we provide category boundaries and TEC allowances by category (TEC allowances have been designed to approximate staff's Draft 2 expandability adder levels). We recommend that categories are narrowest in areas where the greatest number of systems may be sold and broader in regions with lower market share, hence the relatively narrow categories 2.1 and 2.2 compared to category 2.3.

Table 2: Categories Based on CEC proposed Expandability Score

Category	Expandability Score (ES) Criteria	TEC Allowances (kWh/yr)	Estimated Market Share
DT 1	ES < 200	0	16%
DT 2.1	200 ≤ ES < 300	3	57%
DT 2.2	300 ≤ ES < 450	10	23%
DT 2.3	450 ≤ ES < 750	20	4%
DT 3	ES ≥ 750	N/A, exempt from TEC requirements	1%

Comments on Expandability Score Calculation Approach

We include the following recommendations to improve the robustness of the expandability score framework and calculation method for use in regulation, if the currently Draft 2 scheme is used with or without categories:

Issue 1: The current proposed language needs to be more clear about which expansion slots/ports can be counted to improve usability and reduce opportunities for gaming the expandability score.

> ***Suggested improvements***: regulatory language should specify that only physically hard-wired ports can be counted in tallying the expandability score. Manufacturers should not be allowed to use a system's maximum theoretical port capacity (e.g. the maximum number of USB ports allowed by the system's chipset or CPU, regardless of motherboard configuration) in computing expandability scores.

Issue 2: Certain power budgets used in the expandability score calculations and referenced in section 1604 (v)(4)(C) are too high based on known power limitations of the referenced protocols.

> ***Suggested improvements***: USB 2.0 ports can only support a maximum of 2.5 Wdc (400 mA at 5 Vdc) compared to the 5 Wdc allocated in CEC's calculations. USB 2.0 ports should only be allocated 2.5 Wdc per physical port in the expandability score.
>
> USB 3.0 ports can only support a maximum of 4.5 Wdc (900 mA at 5 Vdc) compared to the 10 Wdc allocated in CEC's calculations. USB 3.0 ports should only be allocated 4.5 Wdc per physical port in the expandability score.
>
> USB 3.1 ports support a maximum of 7.5 Wdc (1,500 mA at 5 Vdc) for standard ports, so would need to be added as a separate row in the table.
>
> IDE and SATA ports do not deliver power to internal drives per se, but they are a reasonable proxy for the maximum number of internal drives that might be installed.

However, the 15 Wdc allocated to each IDE/SATA port in CEC's current language is too large for typical drive sizing. We recommend using a value of 10 Wdc per physical port.

***Issue 3*:** USB Power Deliver (USB-PD) and Thunderbolt 3.0 power provisions allow for multiple power use profiles up to and including 100 Wdc. In many cases, manufacturers will limit the power use profile of a given port to some lower value (e.g. 18 Wdc), but the current expandability score would give "full credit" for 100 Wdc, inflating the adder for some systems.

***Suggested improvements*:** We recommend that CEC incorporate a more nuanced view of USB-PD to reflect the 5 accepted power profiles in the USB-PD standard.[1] Since the Thunderbolt 3.0 standard effectively inherits its power provisioning from USB-PD, these values would apply to any Thunderbolt 3.0 port as well. Table3 below illustrates the values that should be allocated for each profile.

Table 3: USB-PD Power Profiles and Associated Port Scores

Port Capabilities	Port Score
USB-PD Profile 1	10
USB-PD Profile 2	18
USB-PD Profile 3	36
USB-PD Profile 4	60
USB-PD Profile 5	100

***Issue 4*:** USB Type C is technically a new physical connector type and does not uniquely identify the maximum power requirements of a USB port. For example, a USB Type C ports will be used to deliver Thunderbolt 3.0 connectivity in certain computers, whereas in others, a USB Type C might be used to deliver USB 3.1 functionality.

***Suggested improvements*:** We recommend dropping USB Type C from the port score table, as the USB power provisions associated with USB 2.0, 3.0, 3.1, power delivery, etc. will likely supersede it.

***Issue 5*:** CEC's current language is ambiguous on whether certain ports, particularly USB, may be eligible for more than one port score. We believe CEC's intent is that each port only be counted once, but that language should be made clear. For example, a USB 3.1 port that also supports USB-PD might erroneously receive two port scores, thereby inflating the expandability score and associated adder.

[1] http://www.usb.org/developers/powerdelivery/PD_1.0_Introduction.pdf].

*Suggested improvements***:** CEC should simply clarify that each physical report may only receive one port score that reflects its capabilities.

Issue 6**:** Although the current table of interfaces is relatively comprehensive, it may become quickly outdated if new technologies or interfaces are developed during the course of the standard's useful life.

*Suggested improvements***:** CEC's current proposal addresses this by including catch-all language for future versions of certain protocols (e.g. "USB 3.0 and greater" or "PCIe 3.0 and greater"). However, this may still not address all future cases. CEC could include a generalized definition for other internal or external expansion interfaces and assign a nominal power budget to those interfaces as well. This is not a perfect solution, but it would at least allow a manufacturer to account for technologies not yet conceived or otherwise not listed in the existing table.

Great care must be taken in crafting such definitions such as not to create loopholes. We would recommend assigning fairly narrow definitions for such interfaces, such as:

Internal expansion port: an integrated, physical connector for the transfer of both data and power from a computer's motherboard to hardware devices housed within the computer's product enclosure and that can provide at least 5W of DC power and peak data transfer of at least 10 gigabits per second.

External expansion port: an integrated, physical connector for the transfer of both data and power from a computer's motherboard to peripheral hardware devices housed outside the computer's product enclosure and that can provide at least 5W of DC power and peak data transfer of at least 10 gigabits per second.

2.2 Notebooks

Summary: We encourage the development of two notebook categories coupled with more appropriate allowances which reflect the performance levels and idle power demand of notebook computers on the California market. CEC's March 2016 proposal does not provide categories or adders to separate higher from lower performance notebooks as it does for desktops. The single TEC metric for notebook computers hides the fact that the degree of energy efficiency within notebook computers on the market can vary considerably as can the level of computational performance. Given these two variables within the notebook product type it is important to separate notebooks into two categories with appropriate allowances.

Notebook Categorization Proposal

As with desktop computers, the CASE team does not support categorization of notebook computers based solely on I/O bandwidth as technological developments can quickly make any such categorization obsolete. Nevertheless, we recognize that the amount of bandwidth provided via some computer components can be indicative of the level of computational functionality that a notebook computer may afford the user, especially when considered alongside other technical characteristics. We also recognize that some hardware features such as external power supply (EPS) rating can also be indicative of the level of computational performance in a notebook computer. Given these factors we propose to subdivide notebooks into two categories based on product features that are indicative of computational performance and set appropriate allowances for each.

Unlike desktop computers, notebook computers are not traditionally designed to support significant amounts of expandability. As such, the CASE team does not propose to develop an expandability approach for notebook computers but rather subdivide products based on technical features as shipped.

On assessing the performance of notebooks on the California market it is clear that both EPS rating and the total amount of PCIe bandwidth supported by the included CPU are strongly correlated with increased performance and idle power. This is not to say that these two factors are the only technical features which are related to computational performance and idle power as other factors such as graphics performance are also strong indicators of overall product performance levels. The CASE team recognizes that appropriate allowances have already been provided for high performance graphics components and so it would be inappropriate to further subdivide notebooks on graphics functionality levels.

In assessing the data it became clear that notebook computers that have EPS' with maximum rated output power of 150W or greater, and CPUs that support PCIe bandwidths of 15 GB/s or greater have higher than average energy use requirements compared to other notebooks computers.

The CASE team proposes to maintain the base allowance for high performance notebook computers at 30 kWh/year, and to reduce the base allowance for mainstream notebooks to 16 kWh/year which is reflective of a roughly 50 percent pass-rate for notebook computers that are currently on the market.

Table 4: Notebook categories based on EPS and CPU PCIe support

Category	**Criteria**	**TEC Base Allowance (kWh/yr)**
Mainstream Performance	EPS rating <150 W OR CPU PCIe bandwidth < 15 GB/s	16
High Performance	EPS rating >=150 W AND CPU PCIe bandwidth >= 15 GB/s	30

3 Power supply efficiency requirements

We recommend CEC require power factor greater than or equal to 0.8 at 20% and 50% load, the same load points as for efficiency requirements so that they can be tested together to minimize testing burden. If CEC chooses not to set 20% and 50% efficiency requirements, we recommend power factor requirements at the short and long idle load points, so that power factor can be tested at the same time as short and long idle. Power factor correction in low power modes such as sleep and off is important too, but we are not recommending it in this standard because this could potentially be done more effectively through a horizontal standard that comprehensively addresses these low power modes.

Non-power-factor-corrected computers can have a power factor of 0.75 or lower in active mode (Fortenberry 2006), and recent testing conducted by EPRI and Ecova shows PF can be less than 0.5 at low load (EPRI and Ecova 2016). We estimate that correcting desktop PSU power factors to 0.9 in idle mode would save up to an additional 46 GWh/yr statewide (about 2 kWh/yr per desktop) on the consumer side of the meter, with additional savings on the utility side of the meter. While distribution-level savings cannot be counted as direct customer benefits, they add up and represent real energy losses, unnecessary generation capacity, and GHG emissions.

Our analysis shows that most 80 PLUS power supplies could easily pass the proposed power factor requirements, and since the 80 PLUS program already requires power factor correction for certification, the cost of implementation is effectively bundled with the incremental cost of 80 PLUS Bronze (less than $1, as noted in the section above). At less than $1, the combined 80 PLUS Bronze efficiency and power factor requirements should be highly cost-effective.

4 Adders

4.1 Integrated Displays

Summary:

CEC's proposed display allowances are much higher than physically required by current display technology, particularly in high resolution and large sizes. This results in large unwarranted allowances that make the overall standard ineffective. The CASE team recommends that the integrated display allowances for both integrated desktop and notebook computers are adjusted to better reflect actual energy use by integrated displays.

Discussion:

CEC's proposal uses a single linear equation with area and megapixels. The problem is that this yields much higher adders than warranted for displays of larger size and resolution. This is because area and megapixels increase quadratically with size and resolution, whereas power draw does not.

To correct this problem, we propose to leverage the approach proposed by CEC in its standalone displays proposal: linear equations within size bins and with a constant resolution adder beyond 5 MP. This would be consistent with the standalone display standard, enhancing simplicity for manufacturers and enforcement, while better reflecting how physical power needs vary with size and resolution.

Integrated desktop displays

For integrated desktop adders, we propose to align with the levels and size bins in CEC's standalone displays proposal, with an extra bin above 29 inches, consistent with our comments on displays.

Table 5: Integrated desktop display adders

Diagonal Screen Size in Inches (d)	Screen Area in Square Inches (A)	Desktop and Thin-Client Integrated Display Adder (kWh/yr)
d < 12”	A< 62	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.04*A) + 1.8) * 0.80
12” ≤ d < 17”	62 ≤ A < 123	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.01*A) + 3.5) * 0.80
17” ≤ d < 23”	123 ≤ A < 226	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.02*A) + 2.2) *0.80
23” ≤ d < 25”	226 ≤ A < 267	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.04*A) -2.4) * 0.80
25” ≤ d < 29”	267 ≤ A < 359	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.07*A) -10.2) *0.80
29” ≤ d	359 ≤ A	8.76 * 0.35 * (1+EP) * ((4.2*r) + (0.032*A) + 3.29) * 0.80
r = Display resolution in megapixels (MP) where r equals a maximum of 5. A = Viewable screen area in in^2 EP = Enhanced Performance Display		
Enhanced Performance Display Adder		
Color Gamut Criteria		**Allowance Adder**
Color Gamut support is 38.4% of CIE LUV or greater (99% of Adobe RGB)		EP = 0.4

This corresponds to a 29% pass-rate relative to the ENERGY STAR 6.1 QPL (models between November 2013 and March 2015). We believe this is reasonable given the wide range of cost-effective opportunities to improve display efficiency described in CEC’s proposal and IOU comments on displays.

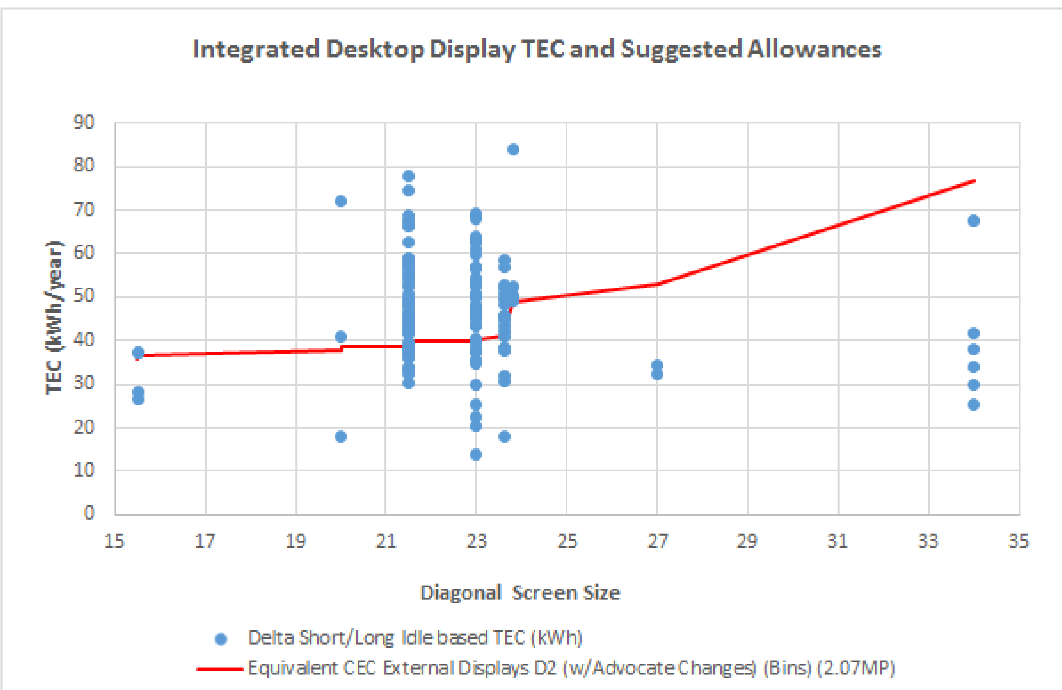

Figure 4: Integrated desktop display adders

The chart above shows the suggested TEC display allowances (red line) for integrated desktop computers alongside TEC values calculated from the short and long idle deltas of integrated desktop computers in the ENERGY STAR database (limited to products with resolutions of 2.07MP to facilitate easier comparison between the measured TEC and allowance values).

Notebook displays

For notebook adders, we propose to reduce adders to achieve a roughly 50% pass-rate relative to the ENERGY STAR 6.1 database, and to limit resolution to 5MP consistently with integrated display adders.

Table 6: Notebook display adders

Diagonal Screen Size in Inches (d)	Notebook Display Adder (kWh/yr)
All	8.76 * 0.3 * (1+EP)* (0.43 * r + 0.0263 * A)
r = Display resolution in megapixels (MP) where r equals a maximum of 5. A = Viewable screen area in in^2 EP = Enhanced Performance Display	
Enhanced Performance Display Adder	
Color Gamut Criteria	Allowance Adder
Color Gamut support is 38.4% of CIE LUV or greater (99% of Adobe RGB)	EP = 0.4

This corresponds to a 54% pass-rate relative to the ENERGY STAR 6.1 QPL (models between November 2013 and February 2015). We believe this is reasonable given the wide range of cost-effective opportunities to improve display efficiency described in CEC's proposal and IOU comments on displays.

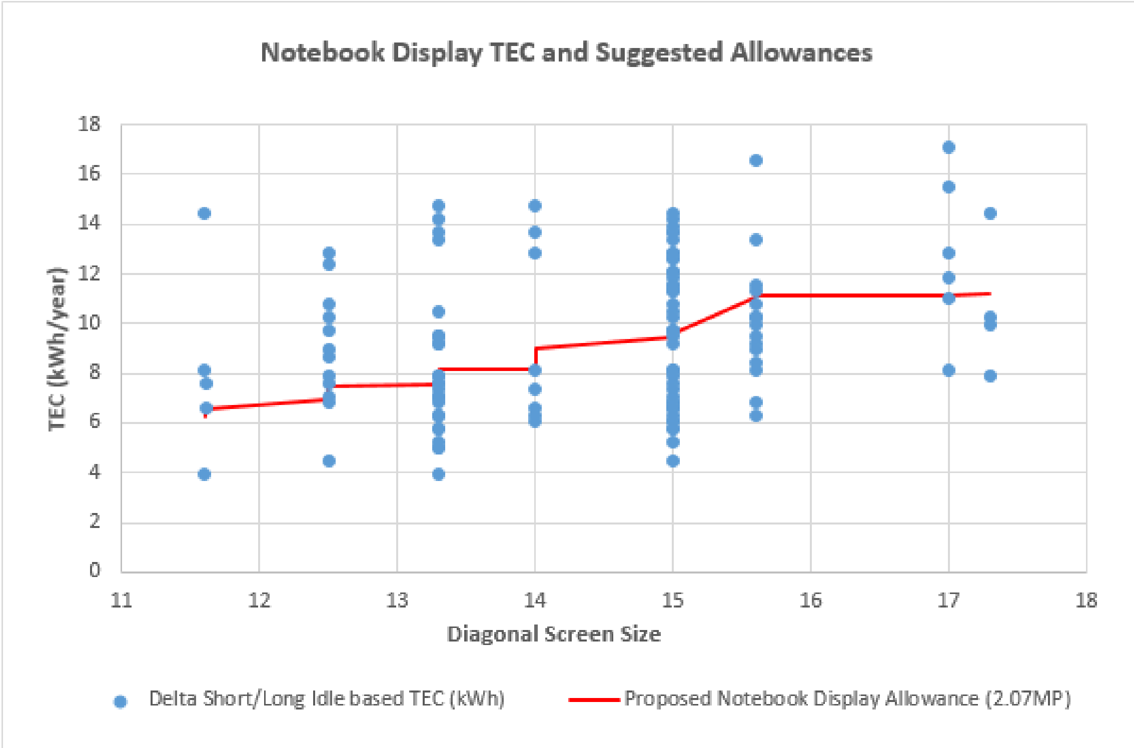

Figure 5: Notebook display adders

The chart above shows the suggested TEC display allowances (red line) for notebook computers alongside TEC values calculated from the short and long idle deltas of notebook computers in the ENERGY STAR database (limited to products with resolutions of 2.07MP to facilitate easier comparison between the measured TEC and allowance values).

4.2 Memory

Summary

The CASE team recommends that CEC adapt its proposed memory adder for notebooks by dropping levels to 2.0 kWh/yr per DIMM. CEC should also consider a graduated memory adder that decreases after the addition of the first two DIMMs to discourage gaming of this adder in desktop systems.

Detailed Comments

CEC's current staff proposal includes a TEC allowance for system memory at 2.5 kWh/yr per installed dual inline memory module (DIMM) for both desktops and notebooks. In general, the CASE team sees this as a positive step compared to staff's March 2015 proposal, which scaled based on total GB of installed memory. The per-DIMM approach corresponds much better with the actual power requirements of memory in computers today, per the CASE team's August 2015 comments.

In its August 2015 comments, the CASE team noted that TEC adders of 1.3 - 2.2 kWh/yr per installed DIMM would be warranted for today's desktop computers with DDR3 memory based on testing conducted by Aggios.[2] A 2.5 kWh/yr per DIMM memory allowance should be more than adequate for desktop systems.

However in notebooks, the 2.5 kWh/yr per DIMM allowance may be too generous mainly because CEC's assumed duty cycles for desktops and notebooks are significantly different in their total idle time.[3] Desktops are estimated to spend a combined 4,380 hours per year in idle and sleep modes, whereas notebooks only spend 3,504 hours per year, or 20% lower. Assuming notebook memory requires the same amount of power, then by virtue of duty cycle alone the notebook memory adder should be 20% lower, or only 2.0 kWh/yr per DIMM. Memory power should continue to decrease in desktops and notebooks as manufacturers transition from DDR3 to DDR4, with manufacturers claiming power reductions of over 35%.[4]

Finally, as industry members noted in presentations at the April 26, 2016 CEC workshop, the current per-DIMM memory adder could be construed as an incentive to populate systems with the maximum number of DIMMs. Doing so might slightly benefit performance, but at the expense of energy efficiency. One potential way for CEC to avoid this loophole is to design the adder such that it decreases beyond the first two DIMMs. An example for desktops is provided in Table 7 below (notebook memory expansion is more limited by form factor, so we only recommend this approach in desktops).

Table 7: Graduated Memory Adder Approach

Number of installed DIMMs	Desktop Adder (kWh/yr)
First and second installed DIMMs	2.5 kWh/yr per DIMM
Third and fourth installed DIMMs	1.25 kWh/yr per DIMM
Beyond fourth DIMM	No additional allowance

4.3 Secondary Storage

Summary

The CASE team recommends that CEC reduce its secondary storage adder for 3.5" hard drives to 12 kWh/yr per disk in order to require sensible power management of secondary drives. Furthermore, CEC should expand the category of solid-state hard drives to include hybrid hard drive technology, allotting hybrid drives the same 0.5 kWh/yr secondary storage adder as SSDs. Finally, CEC should either eliminate the "other" drive category or at a minimum reduce its adder to

[2]Adder levels have been computed using DC power measurements of per-DIMM power consumption, dividing by 0.75 to account for 75% AC-DC power supply conversion efficiencies, and finally converting AC power values to kWh/yr by applying the long and short idle portions of the ENERGY STAR v6.1 duty cycle.

[3]Memory power consumption is significantly lower in sleep mode, so the main impact of memory on computer power consumption is in idle modes, and memory power in low-power modes will be further reduced in the future as DDR4 memory technology begins to supplant DDR3.

[4]http://www.samsung.com/global/business/semiconductor/file/media/DDR4_Brochure-0.pdf

SSD/hybrid levels of 0.5 kWh/yr. Other drives should be explicitly limited to internal storage media to avoid confusion.

Detailed Comments

The CASE team supports CEC's efforts to distinguish between the capabilities and power levels of different hard drive technologies in its proposed secondary storage adders. However, the proposed adders for 3.5" and "other" hard drives are still too generous and miss an opportunity to encourage sensible and cost-effective power management strategies.

In meetings conducted since CEC's 2015 stakeholder workshop, industry storage manufacturers have noted several low-latency device power management states that could be used to reduce the energy impacts of secondary (and primary) drives with minimal latency impacts to the user. As depicted in Figure 4, we have utilized docketed hard drive power data to model TEC impacts of 3.5" hard drives under three power management scenarios with increasing power savings and latency impacts.[5] Under all scenarios, we assume that the HDD is placed into standby (spun down) during long idle mode. Under scenario 1 ("standard power management"), we assume that the disk incorporates "idle" timers that allow it to enter a reduced speed, low-power state within the first 5 minutes of user activity (in alignment with proposed addenda to the ENERGY STAR test procedure), meaning it would be applicable to short idle mode under ENERGY STAR testing and real-world conditions. Scenario 2 ("moderate power management") assumes further motor speed reductions in short idle.[6] Scenario 1 results in TEC impacts of 14-17 kWh/yr and latencies of less than 0.5s in short idle, whereas scenario 2 yields TECs of 9-12 kWh/yr and latencies of 1-3s. Under scenario 3 ("maximum power management"), the drive is spun down in short and long idle, yielding TECs of about 5 kWh/yr and latencies of 4.5-7s.

Note that disk power management in short idle could be triggered after 5 minutes of user inactivity, and still be fully accounted for by the test method. This would avoid any user impacts during the first 5 minutes of inactivity, and would keep power state changes down to a relatively low number.

[5] Data docketed by ITI and Western Digital, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN206314_20151009T064443_Chris_Hankin_Information_Technology_Industry_Council_Comments_I.pdf

[6] Scenarios 1 and 2 correspond to "idle3" and "idle4" functionality, respectively. Idle3 parks the drive's heads and reduces motor speeds to 5,400 rpm; idle4 further reduces motor speeds.]

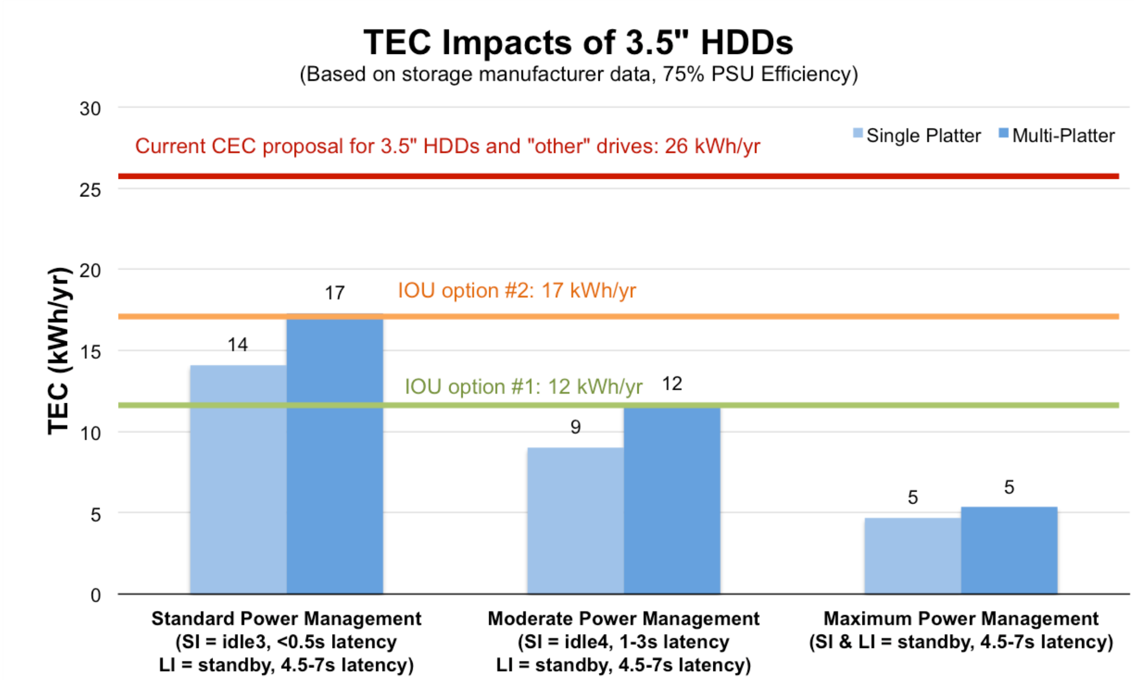

Figure 6: TEC Impacts of Secondary Storage Under a Variety of Power Management Scenarios

The CASE team proposes that CEC lower its secondary storage adder to 12 kWh/yr for 3.5" drives. This would provide enough allowance for even multi-platter drives under moderate power management (i.e. parking drive heads and reducing motor speeds). According to the aforementioned industry-docketed presentation, this type of power management is achievable today and incurs minimal latency (1-3s).

The CASE team also requests additional clarification regarding the definition of "other" drive technologies. The only drive technology not already listed in CEC's adder proposal is hybrid. Hybrid drives incorporate a solid state buffer alongside a traditional spinning, magnetic drive. Frequently used files are stored and accessed from the solid state portion, and less frequently used files remain on the spinning disk. The hybrid drive manifests itself to the computer and user as a single volume; however, internally the spinning drive can be more aggressively power-managed separately from the solid state portion. In a secondary storage context, the CASE team recommends that CEC treat hybrid drives the same as solid state and grant them a 0.5 kWh/yr adder.

We recommend either dropping the "other" category altogether or reducing its allowance to SSD levels of 0.5 kWh/yr. If maintaining the other category, CEC should clarify that it only applies to internal storage drives.

5 Duty Cycle

The CASE Team recommends that CEC require a single conventional duty cycle for determining calculated and reported TEC values, as proposed in Table. ENERGY STAR's network connectivity mode weightings are meant to provide an incentive for manufacturers to implement network connectivity in sleep modes. However, there is no publicly available data that explains these numbers or that shows network connectivity in sleep mode actually reduces computer on time. These numbers may under-represent time spent in operational modes, and therefore the energy consumption, by 10%. In addition, there are no strict criteria to determine the type of connectivity, thereby creating a loophole and weakening the standards. Compliance could occur by simply changing the assumed duty cycle without any actual energy savings. With the absence of evidence of the benefits of network connectivity, it would be prudent, and simpler, to treat all computers equally and use a single duty cycle.

Table 8: Mode Weightings for Desktops, Thin Clients and Integrated Desktop Computers

Mode Weighting	Conventional	Full Network Connectivity			
		Base Capability	Remote Wake	Service Discovery/ Name Services	Full Capability
T_{OFF}	45%	40%	30%	25%	20%
T_{SLEEP}	5%	15%	28%	36%	45%
T_{LONG_IDLE}	15%	12%	10%	8%	5%
$T_{SHORT\ IDLE}$	35%	33%	32%	31%	30%

Table 4: Mode Weightings for Notebook Computers

Mode Weighting	Conventional	Full Network Connectivity			
		Base Capability	Remote Wake	Service Discovery / Name Services	Full Capability
T_{OFF}	25%	25%	25%	25%	25%
T_{SLEEP}	35%	39%	41%	43%	45%
$T_{LONG\ IDLE}$	10%	8%	7%	6%	5%
$T_{SHORT\ IDLE}$	30%	28%	27%	26%	25%

6 Test Method

Section 1604 Test Methods for Specific Appliances.

(v) Computers, Computer Monitors, Signage Displays, Televisions, and

Consumer Audio and Video Equipment

1. <u>Display Brightness</u>

CEC proposal:

(page 42) Follow the ENERGY STAR test procedure with the following modifications. CEC did not propose a modification of the ENERGY STAR test procedure for display brightness. ENERGY STAR 6.1 requirements are as follows:

Calibrate the UUT display brightness to the closest brightness setting that is at least **90 cd/m2 for Notebook Computers**, at least **150 cd/m2 for Integrated Desktop Computers, Portable All-In-One Computers and Slates/Tablets.**

Comment:

This method is not representative of real-world energy use, and it does not incentivize manufacturers to optimize display brightness settings on their computers. In fact, testing of two sample all-in-one computers showed one was shipped with maximum brightness, when the other used auto-brightness control (ABC).[7] Enabling ABC on the first computer reduced the computer total idle power draw by 22% as shown in Figure 5. This is a large energy saving opportunity which costs nothing.

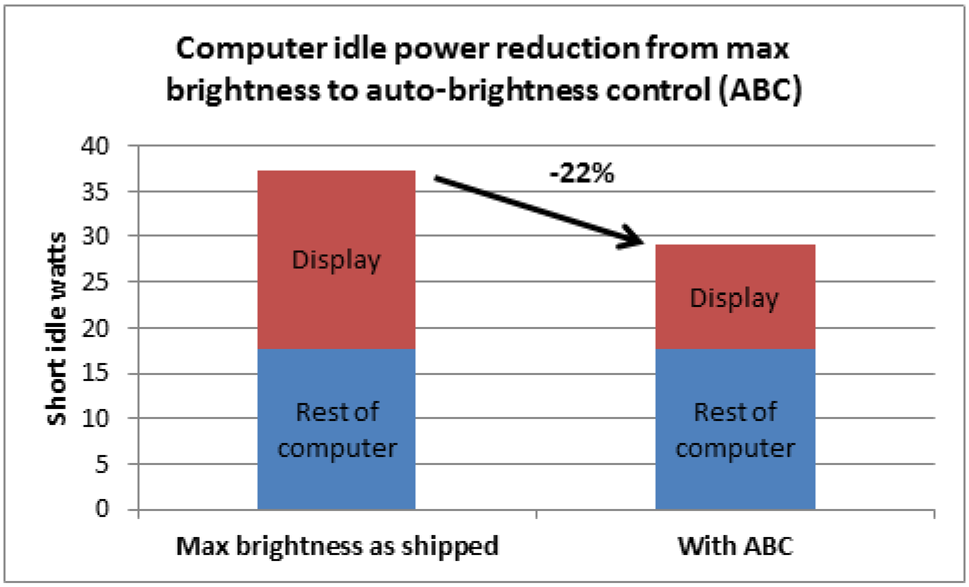

Figure 7: Demand reduction as a result of Auto-brightness control

CASE team proposal:

If ABC is enabled as shipped, keep it enabled and test with a light source so that 300 lux directly enter the ABC sensor.

If the display is shipped at a fixed brightness that is at least 90 cd/m2 for notebook computers, and 150 cd/m2 for integrated desktop computers, test with display brightness as shipped.

If the display is shipped at a fixed brightness that is less than 90 cd/m2 for notebook computers and 150 cd/m2 for integrated desktop computers, set the display to 90 cd/m2 for notebook computers and 150 cd/m2 for integrated desktop computers. If the unit under test (UUT)'s brightest setting cannot achieve the specified brightness, then set the UUT display to the brightest setting" (per ENERGY STAR).

[7] Zivojnovic, V., Mista, D., "All-In-One Computer Idle Power Analysis", April 2016, https://www.nrdc.org/sites/default/files/aggios-aio-report-20160429.pdf

7 Definitions

1. Manufacturer definition

CEC proposal: (page 39) “Basic model” of a computer means a group of models of computers that are made by a single manufacturer and that have the same chassis, power supply, and motherboard. Models within the basic model all contain the same expandability score.
Comment: The term "manufacturer" is not defined. The term "manufacturer" can be interpreted in different ways and could lead to shared "basic models" across OEM's which have branded an off-the-shelf computer by a Chinese manufacturer.

CASE team proposal: “Basic model” means a high-level description referring to a group of computers that have the same chassis, motherboard and power supply combination but may contain multiple other hardware and software configurations. Product models within a family (i.e. a group of basic models) differ from each other according to one or more characteristics or features that either have no impact on product performance with regard to compliance to the Regulatory limits, or are specified as acceptable variations within a “basic model”. For Computers, acceptable variations within a “basic model” include:
1) Color;
2) Housing; and
3) Electronic components other than the chassis, motherboard and power supply combination, such as the processor, memory, GPU, etc.

2. Medical products

CEC proposal: (page 39) A computer does not include a tablet, a game console, a handheld gaming device, a server other than a small-scale server, or an industrial computer.

Comment: There is no exclusion for medical computers (although there is an exclusion included for medical displays). This could result in unintentional removal of some bespoke medical computers from the Californian market as they would currently remain within scope.

CASE team proposal: Products that are classified for use as medical devices by the United States Food and Drug Administration for use as medical devices and that either prohibit power management capabilities or do not have a power state meeting the definition of sleep mode.

3. Tablets

CEC proposal: (page 39) A computer does not include a tablet, a game console, a handheld gaming device, a server other than a small-scale server, or an industrial computer.

Comment: There is no definition of tablet included in the draft rulemaking. Excluded products should be defined to clarify scope.

CASE team proposal:

Slate/Tablet: A computing device designed for portability that meets all of the following criteria:
a) Includes an integrated display with a diagonal size greater than 6.5 inches and less than 17.4 inches;
b) Lacking an integrated, physical attached keyboard in its as shipped configuration;
c) Includes and primarily relies on touchscreen input; (with optional keyboard);
d) Includes and primarily relies on a wireless network connection (e.g., Wi-Fi, 3G, etc.); and
e) Includes and is primarily powered by an internal battery (with connection to the mains for battery charging, not primary powering of the device).

4. Display in desktop definition

CEC proposal: (page 40) A desktop computer includes computers that may be sold with a display integrated into the unit or a display that is powered through the power supply of the desktop computer.

Comment: The language around displays could be interpreted such as that a computer that is sold without either a "*display integrated into the unit*" or a "*display that is powered through the power supply of the desktop computer*" is not a desktop computer.

CASE team proposal: Computers that are sold with a display integrated into the unit, or a display that is powered through the power supply of the computer are also considered desktop computers.

5. Integrated Desktop Computers with Separate Displays

CEC proposal: (page 40) "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 power through a single cable. Integrated desktop computers come in one of two 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.

Comment: The above definition suggests that a desktop computer that is sold with an external display that is powered by a DC power cord (e.g. via a USB-PD or Thunderbolt connection) would be considered an integrated computer. As such, the external display in this instance would be tested alongside the computer as an integrated desktop computer system. The same external display would also need to be tested as a separate external display in order to meet any regulatory measures on standalone displays.

CASE team proposal: DC-powered displays shipped as part of integrated desktop computers, need only be tested as part of the integrated desktop computer, not as a standalone display.

6. Portability

CEC proposal: (page 40) A computer that has both an integrated display and integrated energy storage capable of operating the computer for more than 30 minutes in short-idle mode is not a desktop computer.

Comment: There is currently no guidance in the report to identify how the 30 minutes in short-idle would be measured. That is, it is unclear whether the product would be tested as an "integrated desktop" or "notebook" as per the ENERGY STAR test procedure. The difference in luminance levels between the integrated desktop and the notebook compared test procedures would have an influence on the energy use and therefore operational time on battery power.

CASE team proposal: A computer that has both an integrated display and integrated energy storage capable of operating the computer for more than 30 minutes in short-idle mode when tested according to the test procedure for integrated desktops, is not a desktop computer.

7. Game console

CEC proposal: (page 40) "Game console" means a device that is designed and marketed for video game usage and that does not have the ability to expand volatile memory.

Comment: A computer that is shipped with the maximum amount of RAM supported by the motherboard (i.e. all DIMM slots are filled with either removable RAM or RAM is soldered into a single DIMM) would meet the definition of "game console" as listed above if it was also marketed as for use with video games. The requirement that a product also be "designed" for video game usage is unlikely to act as a scope filter since almost all personal computers can provide some level of video gaming functionality.

CASE team proposal: "Game console" means a device that is designed and marketed for video game usage as its primary functionality and is not designed in such a way to allow users to either add or remove volatile memory.

8. Notebook computers

CEC proposal: (page 40) Notebook computer" means a computer designed specifically for portability and to be operated for extended periods both with and without a direct connection to an alternating current (AC) main power source. Notebook computers are sold with an integrated display, a physical keyboard with a wired connection, and a pointing device. Notebook computers include models with touch-sensitive screens.

Comment: "Hybrid computers" with detachable keyboards would not be covered by the above definition.

CASE team proposal: "Notebook computer" means a computer designed specifically for portability and to be operated for extended periods both with and without a direct connection to an alternating current (AC) mains power source. Notebook computers are sold with an integrated display, a detachable or non-detachable physical keyboard with a wired connection, and a pointing device. Notebook computers include models with touch-sensitive screens.

9. Workstations

CEC proposal:
(page 41) a) Do not support altering frequency or voltage beyond the CPU and GPU manufacturer's' operating specifications

Comment: The requirement that overclocking of the CPU and GPU is not supported is somewhat ambiguous as third party applications are often available which facilitate overclocking of locked processors and GPUs.

CASE team proposal: "Product as shipped, does not support altering frequency or voltage beyond the CPU and GPU manufacturer's operating specifications".

8 Power management

During the last half of 2015 and early 2016, the CASE team and industry stakeholders collaborated on a joint proposal to address two situations facing computer manufacturers with regards to power management, described below:

1. **Minimally provisioned systems.** It is our understanding that, in certain instances, manufacturers may ship desktop computers with no operating system or with a "one-time-use" operating system, neither of which would comply with proposed power management provisions such as in sections 1605.3 (v)(4)(B)(1) and (2). Such configurations would allow corporate IT departments to provision the systems with a custom software image without having to uninstall/overwrite one that the manufacturer might install.
2. **Use of non-standard low-power modes**. Almost any major client operating system today — Apple's OS X, Ubuntu Linux, Chrome OS, Android OS, and various versions of Microsoft Windows — will support a low-power mode that maintains system context using minimal power. This state is referred to as "Sleep" in CEC's draft (section 1602 (v)). In instances where the operating system does not default to a "suspend to RAM" mode like the ACPI S3 state (the "traditional" sleep state for desktop computers), manufacturers have requested that CEC explicitly allow them to use an alternative and equivalent low-power mode in its place.

We believe both scenarios 1 and 2 above are legitimate and ask that CEC work with the CASE team and industry stakeholders to develop appropriate regulatory language that would accommodate both situations.

9 Registration (Section 1606. Filing by Manufacturers; Listing of Appliances in Database)

1. Which Configurations Need to be Registered

CEC proposal: Page 46

The problem: CEC needs to specify how many and which configurations to register. The ENERGY STAR v6 approach to configuration selection is not suitable to CEC's regulatory needs.

CEC proposes data submittal requirements for covered products sold in California. However each computer model can have hundreds or even thousands of configurations. CEC does not specify how many and which configurations manufacturers should test and register with CEC and the ENERGY STAR v6 approach (highest energy configuration in each category) is not appropriate because:

- The highest energy configuration does not guarantee that typical configurations sold in California meet CEC levels: The highest energy configuration may achieve CEC levels only thanks to high adders (e.g. with maximum memory configuration supported by the system), but not with lower adders in more commonly sold configurations.
- The highest energy configuration may not be representative of typical models sold in CA homes and businesses
- The highest energy configuration may not be available or easy to buy at retail for enforcement purposes.
- If CEC adopts a single category with a linear adder framework, ENERGY STAR's approach could result in just one model tested and registered per product family, and one that is likely not representative of products sold in CA.

CASE team proposal:

For each basic model (unique chassis, power supply and motherboard combination as defined in 1602 (a)), manufacturers shall file 3 configurations:

- Highest energy
- Lowest energy
- Default configuration (or most typical if this can work from a regulatory perspective).

Rationale:

Inspired from ENERGY STAR for Servers' 5-point family structure:

- Highest: TEC worst-case, high risk of non-compliance
- Lowest: TEC best-case, lower bound, ensure compliance with no or minimal adders
- Default/Most typical: best assurance that highest sales volume models comply. While manufacturers may not be able to predict the exact highest selling model at time of registration, this provides a directional requirement that tested configurations should not be atypical, which can be enforced by analysis of the database.

Analysis of potential impact on manufacturer registration and testing burden

We analyzed two random product families (same marketing name as in Table 8 below) by Dell and found that this approach would result in a similar number of configurations to be tested and registered as ENERGY STAR, while being much more representative of products sold, and therefore facilitating enforcement:

Table 9 - Registration requirements for two sample product families

Product Type	Product family	Number of configurations available	Number of configurations to be tested – ESTAR v6	Number of configurations to be tested – CASE team proposal
Notebook	Latitude 14 5000 Series	1287	2	3
Desktop	New OptiPlex 3000 Series Desktops (3040)	409	5	4

The difference with ENERGY STAR in models to be registered depends on how many ENERGY STAR categories a product family spans:

- If the product spans 3 ENERGY STAR categories, then both approaches require registering 3 products
- If the product only spans 1 or 2 ENERGY STAR categories, then this approach may require 1 or 2 additional products to be registered than ENERGY STAR
- If the product spans more than 3 ENERGY STAR categories (e.g. integrated and discrete graphics), then this approach would require fewer products to be registered than ENERGY STAR

On the whole, both approaches require a similar number of products to be registered.

2. Data Submittal Requirements

CEC proposal: Page 46, Table X

Comment: We generally support CEC's proposed data submittal requirements with the following additions and changes:

1. The term "Core Speed" needs to be further defined otherwise this could apply to the GPU not the CPU as presumably intended.
2. Include the number of RAM DIMMS filled
3. The units for discrete GPUs framebuffer bandwidth are listed as "gigahertz". This should be GB/s.
4. "Enhanced Performance" should read "Enhanced Performance Display" for clarity.
5. Details about the number and type of storage devices need to be included so that allowances can be calculated.
6. Details about the expandability score need to be added so that overall allowance can be checked.

Appendix A: Desktop Demonstration Project

The purpose of the desktop demonstration at the April 26, 2016 workshop was to demonstrate how a highly efficient desktop computer can be assembled using off-the-shelf components, while at the same time demonstrating that even when not carefully selecting all components, one may end up with a much lower energy efficiency for an otherwise very similar computer.

Two desktop computer systems were presented, both using readily available hardware components to build an upper-tier Windows PC. Both systems were built around the latest generation Intel Skylake CPUs.

	System A	**System B**
Item Type	**Model**	**Model**
Motherboard	MSI B150M ECO	ASUS H170-PLUS D3
Processor	i7-6700k	i7-6700k
Memory	HyperX FURY 2133MHz DDR4 16GB (2x8GB)	Crucial Ballistix Sport DDR3 16GB (2x8GB)
HDD	WD Green 1TB (WD10EZRX)	WD Blue 1TB (WD10EZEX)
PSU	Reference Design (2-Stage)	Seasonic X-400 Fanless 400W PSU 80PLUS Platinum rated

Both systems were running a standard installation of Windows 8, with all Windows updates performed as well as motherboard specific drivers installed. No 3rd party anti-virus software was installed, however all default Windows security settings were left in place, i.e. Windows Defender remained enabled.

To monitor their power demand, both systems were connected to AC power meters.

A.1 The PSU Reference Design

The PSU reference design was based on the idea of using separate circuits for the low-load use-case, with the full load circuit being activated above a certain threshold.

The reference design consists of a dual-stage 300W AC/DC converter from Power Integrations, producing 12V, connected to DC-DC converters for the 5V and 3.3V rails from Rohm Semiconductor. This PSU reference design achieves 80 PLUS Silver-level efficiency, while also achieving a low-load efficiency of 65% at 6 watts and 70% at 8 watts DC, which is significantly better than the low-load efficiency we've observed for any 300W ATX power supply we've analyzed so far.

While all lab measurements were performed using the setup described above, a slightly different configuration was used during the live demo, due to technical difficulties onsite with the original setup. During the demo the Power Integrations 300W AC/DC converter was connected to a 160W HDPLEX ATX converter.

A.2 Demo Flow

The primary focus of the demo was to compare the power draw while idle, covering both the short and long idle states as defined in Energy Star 6.1.

Both desktop computers were booted into Windows, and the idle state was entered by simply moving the mouse, without any application windows open. In order to make it easier to demonstrate the long idle power draw, the Windows power management settings were adjusted to allow the display to turn off after only one minute of inactivity, instead of having to wait 15 minutes, which is the Windows default.

A.3 Results

The power draw seen for the two different desktop computers was below 10.5 watts for System A, while System B drew around 21 watts.

The power draw of System A seen during the demo was nearly 1W lower than what had been measured in the lab tests, due to the lower-wattage ATX converter used during the demo.

State	**System A**	**System B**
Short Idle	10.5W (11.4 W)	22.4 W
Long Idle	9.8 W (10.5 W)	21.7 W

The numbers in parenthesis refer to the measurements obtained in the lab using the complete 300W reference design.

A.4 Cost Analysis

System A and B were built from off-the-shelf parts, except the prototype PSU of System A, which is based on the reference design developed by AGGIOS, Power Integrations and Rohm Semiconductors. The prices provided in the table below are walk-in store or web prices from March to April 2016 for single unit purchases without tax or shipping costs.

	System A		System B	
Item Type	Model	Price	Model	Price
Mother-board	MSI B150M ECO	$69.99	ASUS H170-PLUS D3	$96.99
Processor	i7-6700k	$399.00	i7-6700k	$399.00
Memory	HyperX FURY 2133MHz DDR4 16GB (2x8GB)	$79.00	Crucial Ballistix Sport DDR3 16GB (2x8GB)	$52.99
HDD	WD Green 1TB , 5400 RPM (WD10EZRX)	$49.99*	WD Blue 1TB, 7200 RPM (WD10EZEX)	$53.99
PSU	Reference Design (2-Stage)	See note	Seasonic 400W Platinum	$109.99
Total retail cost		**See note**		**$712.96**

*As of May 2016, the price difference (e.g. on Amazon.com) between the WD Green 1TB 5400RPM ($51.99) and the 7200RPM version ($53.99) is ~$2.

Note: The 2-stage PSU reference design was developed using selected components of Power Integrations and Rohm Semiconductors for the AC/DC and DC/DC parts, respectively. The initial analysis of the feasibility of the two-stage AC/DC conversion conducted by Power Integrations indicated an increase in the bill of material (BOM) of only $.11, which once gone through multiple layers of OEMs and retail would result in ~$.50 for the customer. We estimate similar cost increases for the DC/DC part, resulting in the total price increase of around $1 for the new two-stage PSU compared to a standard 300W PSU. Power Integrations has prepared a detailed BoM and schematics of the reference design which is available from their representatives. According to Power Integrations, the estimated total BOM for the AC/DC part of the reference design PSU is $14.66. Typical BOM for standard desktop PSUs of the same wattage is between $13 and $15. Based on these numbers, assuming the reference design PSU is the same cost as the Seasonic 400W Platinum PSU, the total retail cost would be $707.97.

A.5 Conclusions

The power numbers seen during the demonstration, as well as measured during our lab tests, show that it is possible to assemble a desktop PC which can easily meet the proposed targets as defined in the CEC Staff Report. At the same time, the demonstration also reveals that low power draw is not guaranteed. Using slightly different components centered around the same latest generation CPU and yielding the same benchmark performance, System B exhibited an idle-state power draw approximately twice as high as that of System A.