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California Energy Commission

STAFF REPORT

Final Analysis of Computers, Computer Monitors, and Signage Displays

2016 Appliance Efficiency Rulemaking
Docket Number 16-AAER-02

California Energy Commission

Edmund G. Brown Jr., Governor

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California Energy Commission

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PREFACE

On March 14, 2012, the California Energy Commission issued an order instituting rulemaking to begin considering standards, test procedures, labeling requirements, and other efficiency measures to amend the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through Section 1609). In this order instituting rulemaking, the Energy Commission identified a variety of appliances with the potential to save energy and/or water.

On March 25, 2013, the Energy Commission released an invitation to participate to provide interested parties the opportunity to inform the Energy Commission about the product, market, and industry characteristics of the appliances identified in the Order Instituting Rulemaking. The Energy Commission reviewed the information and data received in the docket and hosted staff workshops on May 28 through 31, 2013, to vet this information publicly.

On June 13, 2013, the Energy Commission released an invitation to submit proposals to seek proposals for standards, test procedures, labeling requirements, and other measures to improve the efficiency and reduce the energy or water consumption of the appliances identified in the order instituting rulemaking.

On March 12, 2015, the Energy Commission published its first draft staff report, *Analysis of Computers, Computer Monitor, and Signage Displays.* Energy Commission staff conducted a workshop on April 15, 2015, to solicit written and oral feedback and to discuss the proposed efficiency levels presented in the staff report.

The computers and displays industries hosted two stakeholder workshops, in June 2015 and in September 2015, to promote additional discussion on the cost-effectiveness and technical feasibility of proposed efficiency standards for computers, computer monitors, and signage displays. Energy Commission staff attended both workshops. Stakeholders submitted additional analyses to the docket following these workshops.

On March 30, 2016, the Energy Commission published its second draft staff report *Revised Analysis of Computers, Computer Monitors, and Signage Displays.* The publication was followed by a workshop on April 26, 2016, to discuss the revised proposed efficiency levels in the staff report and to solicit feedback.

The Energy Commission reviewed all information received to determine appropriate adjustments to its proposed efficiency standards and measures. Based on that assessment, this final staff report and the proposed regulations for computers, computer monitors, and signage displays were developed.

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ABSTRACT

This staff report focuses on computers, computer monitors, and signage displays. This report analyzes proposed standards, feasibility, cost analysis and effectiveness, energy use, and regulatory approaches. The electricity consumption of computers, computer monitors, and signage displays varies greatly, even within models of similar sizes and feature sets. To date, no federal or state regulations provide incentives for implementing cost-effective, readily available technologies to improve the performance of less efficient models.

The proposed standards would reduce the average energy use for a typical computer and computer monitor without affecting the functionality or performance, using available, off-the-shelf technologies. The proposed standards would save more than 696 gigawatt-hours per year statewide for computer monitors and 1,636 gigawatt-hours per year for computers after stock turnover.

Staff proposes that signage displays meet the existing California Energy Commission efficiency regulations for televisions.

Keywords: Appliance Efficiency Regulations, energy efficiency, computer, desktop, notebook, workstation, thin-client, small-scale server, computer monitor, enhanced performance display, signage display

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EXECUTIVE SUMMARY

The California Energy Commission's Appliance Efficiency Program has analyzed efficiency opportunities in computers, computer monitors, and signage displays and has developed proposals that address energy efficiency opportunities through Title 20 appliance efficiency regulations. Staff analysis shows that proposed computer and computer monitor standards are technically feasible and cost-effective to consumers and would save a significant amount of energy statewide. The computer standards will save about 1,636 gigawatt-hours per year calculated using the Energy Star dataset as a baseline, resulting in greenhouse gas emission reductions of 0.513 million metric tons of carbon dioxide equivalent per year. Regulating computer monitors will save about 696 gigawatt-hours per year statewide and will result in greenhouse gas emission reductions of 0.218 million metric tons of carbon dioxide and save about $111 million after the existing stock is replaced. The computer regulations will benefit businesses and consumers by reducing electricity bills by $261 million using the Energy Star dataset as a baseline. Combined savings from the computer and computer monitor regulations is $372 million. This proposal would clarify existing standards for signage displays, potentially improving compliance but not affecting energy savings.

In California, computers and computer monitors use an estimated 5,610 gigawatt-hours of electricity, and account for about 1.7 to 2.9 percent of electricity consumption in the residential sector and 7 percent of electricity consumption in the commercial sector. In the commercial sector, these appliances are concentrated in offices and schools.

Proposed Regulations for Computers

Based on the potential for energy savings and other considerations, staff has included desktop computers (including integrated desktops and portable all-in-ones), notebooks (including mobile gaming systems, two-in-one notebooks, and mobile workstations), small-scale servers, thin clients (including mobile thin clients), and workstations (including rack-mounted workstations) in the proposed regulations. A thin client is a type of desktop computer that relies on a server or networked virtual machine to provide full functionality, such as data storage and computational power. Staff has excluded other servers, tablets, smartphones, set-top boxes, game consoles, handheld video game devices, small computer devices, smart televisions, and industrial computers from the scope of this report.

The core opportunity for energy savings in computers is found in reducing the amount of energy consumed in idle modes; that is, when the computer is on but not being used. Idle modes are the largest opportunity to reduce energy consumption because computers spend roughly half of the time in this "on mode." In addition, high idle-mode consumption greatly increases the effectiveness of power management settings to reduce overall computer energy consumption. Automatic power management settings are often disabled, which means computers are constantly consuming significant amounts of power when not in use (for example, 50 watts in idle mode compared to 2 watts in sleep mode).

Proposed Regulations for Monitors and Signage Displays

Based on the potential for energy savings and other considerations, staff proposes to regulate computer monitors. Staff has excluded digital picture frames, electronic reader displays, and electronic billboards.

The core opportunity for energy savings regarding computer monitors is to reduce the amount of energy used in active (on) mode. Reducing the amount of energy used in on mode is the largest energy-saving opportunity because computer monitors spend about 30 percent of the time in this mode. About 20 percent of the computer monitors in the market today meet the ENERGY STAR® Version 7.0 standards. The proposed regulations for mainstream computer monitors are slightly more stringent than the ENERGY STAR Version 7.0 specification and about 30 percent more stringent than ENERGY STAR Version 6.0. About 14 percent of current models would meet the proposed standards. Most monitors would need to reduce only their power consumption by 3 to 5 watts to comply. This goal can be met by replacing components with efficient light-emitting diode lights, light-emitting diode drivers, and power supplies that are available in the market at prices comparable to the inefficient technologies. The proposed performance standards for monitors would allow industry to choose how to comply with the regulation.

Signage displays, such as those seen in airports for airplane schedules, are already subject to the adopted television standards. A television means an analog or digital device designed primarily for the display and reception of a terrestrial, satellite, cable, Internet Protocol Television, or other broadcast or recorded transmission of analog or digital video and audio signal. This proposal clarifies that television standards apply to signage displays but do not apply to signage displays greater than 1,400 square inches or to signage displays that are composed of several displays of diagonal screen size of greater than 12 inches. These latter types of displays are designed to be used in outdoor stadiums and are controlled by a single data controller and support structure connected to either a single power supply or multiple power supplies.

CHAPTER 1: Legislative Criteria

The Warren-Alquist Act[1] establishes the California Energy Commission as California's primary energy policy and planning agency. Section 25402(c)(1) of the California Public Resources Code[2] mandates that the Energy Commission reduce the inefficient consumption of energy and water by prescribing efficiency standards and other cost-effective measures[3] for appliances that require a significant amount of energy and water to operate on a statewide basis. Such standards must be technologically feasible and attainable and must not result in any added total cost to the consumer over the designed life of the appliance.

In determining cost-effectiveness, the Energy Commission considers the value of the water or energy saved, the effect on product efficacy for the consumer, and the life-cycle cost to the consumer of complying with the standard. The Commission also considers other relevant factors, including, but not limited to, the effect on housing costs, the total statewide costs and benefits of the standard over the lifetime of the standard, the economic effect on California businesses, and alternative approaches and the associated costs.

Efficiency Policy

For nearly four decades, appliance efficiency standards have shifted the marketplace toward more efficient products and practices, reaping large benefits for California's consumers. The state's appliance efficiency regulations saved an estimated 22,923 gigawatt-hours (GWh) of electricity and 1,626 million therms of natural gas in 2012[4] alone, resulting in about $5.24 billion in savings to California consumers.[5] Since the mid-1970s, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. In addition, the California Public Utilities Commission (CPUC) in the 1990s decoupled the utilities' financial results from their direct energy sales, promoting utility

1 The Warren-Alquist State Energy Resources Conservation and Development Act, Division 15 of the Public Resources Code, § 25000 et seq., available at http://www.energy.ca.gov/2014publications/CEC-140-2014-001/CEC-140-2014-001.pdf.

2 Cal. Pub. Resources Code § 25402(c)(1), available at http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25402.

3 These include energy and water consumption labeling, fleet averaging, incentive programs, and consumer education programs.

4 California Energy Commission. *California Energy Demand 2014-2024 Revised Forecast, September 2013*, available at http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC_200-2013-004-SD-V1-REV.pdf.

5 Using current average electric power and natural gas rates of residential electric rate of $0.164 per kilowatt-hour, commercial electric rate of $0.147 per kilowatt-hour, residential gas rate of $0.98 per therm and commercial gas rate of $0.75 per therm. This estimate does not incorporate any costs associated with developing or complying with appliance standards.

support for efficiency programs. These efforts have reduced peak load needs by more than 12,000 megawatts (MW) and continue to save about 40,000 GWh per year of electricity.[6], there remains huge potential for additional savings by increasing the energy efficiency of appliances.

Reducing Electrical Energy Consumption to Address Climate Change

Appliance energy efficiency is identified as a key to achieving the greenhouse gas (GHG) emission reduction goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006)[7] (AB 32), as well as the recommendations contained in the California Air Resources Board's (ARB) *Climate Change Scoping Plan.*[8] Energy efficiency regulations are also identified as key components in reducing electrical energy consumption in the Energy Commission's *2013 Integrated Energy Policy Report (IEPR)*[9] and the CPUC's 2011 update to its *Energy Efficiency* Strategic Plan.[10]

Senate Bill 350 (De León, Chapter 547, Statutes 2015) requires the Energy Commission to establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings by January 1, 2030. The bill specifies that the targets may be achieved through energy efficiency savings and demand reduction from a variety of programs, including appliance and building energy efficiency standards developed under Public Resources Code Section 25402.

Loading Order for Meeting the State's Energy Needs

California's loading order places energy efficiency as the top priority for meeting the state's energy needs. The *Energy Action Plan II*[11] continues the strong support for the loading order, which describes the priority sequence of actions to address increasing energy needs. The loading order identifies energy efficiency and demand response as the state's preferred means of meeting growing energy needs.

For the past 30 years, while per capita electricity consumption in the United States has increased by nearly 50 percent, California's electricity use per capita has been nearly flat. Continued progress in cost-effective building and appliance standards and ongoing

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6 *Energy Action Plan II*, available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p 3.

7 Assembly Bill 32, California Global Warming Solutions Act of 2006, available at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.html.

8 California Air Resources Board, *Climate Change Scoping Plan*, December 2008, available at http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf.

9 California Energy Commission, *2013 Integrated Energy Policy Report*, January 2014, available at http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.pdf.

10 California Public Utilities Commission, *Energy Efficiency Strategic Plan,* updated January 2011, available at http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

11 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, page 2.

enhancements to efficiency programs implemented by investor-owned utilities (IOUs), customer-owned utilities, and other entities have significantly contributed to this achievement.[12]

Zero-Net-Energy Goals

The *California Long Term Energy Efficiency Strategic Plan*,[13] adopted in 2008 by the CPUC and developed with the Energy Commission, the ARB, the state's utilities, and other key stakeholders, is California's roadmap to achieving maximum energy savings in the state between 2009 and 2020, and beyond. It includes four "big, bold strategies" as cornerstones for significant energy savings with widespread benefit for all Californians:[14]

- All new home construction in California will be zero-net energy by 2020.
- All new commercial construction in California will be zero-net energy by 2030.
- HVAC will be transformed to ensure that the energy performance is optimal for California's climate.
- All eligible low-income customers will be given the opportunity to participate in the low-income energy efficiency program by 2020.

These strategies were selected based on the ability to achieve significant energy efficiency savings and to bring energy-efficient technologies and products into the market.

On April 25, 2012, Governor Edmund G. Brown Jr. further targeted zero-net-energy consumption for state-owned buildings. Executive Order B-18-12[15] requires zero-net-energy consumption for 50 percent of the square footage of existing state-owned buildings by 2025 and zero-net-energy consumption from all new or renovated state buildings beginning design after 2025.

To achieve these zero-net-energy goals, the Energy Commission has committed to adopting and implementing building and appliance regulations that reduce wasteful power and water consumption. The *Long-Term Energy Efficiency Strategic Plan* calls on the Commission to develop a phased and accelerated "top-down" approach to more stringent codes and standards.[16] It also calls for expanding the scope of appliance standards to plug loads, process

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12 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p. 3.

13 California Energy Commission and California Public Utilities Commission, *Long-Term Energy Efficiency Strategic Plan,* updated January 2011, available at http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

14 California Energy Commission and California Public Utilities Commission, *Long-Term Energy Efficiency Strategic Plan*, available at http://www.cpuc.ca.gov/NR/rdonlyres/14D34133-4741-4EBC-85EA-8AE8CF69D36F/0/EESP_onepager.pdf, p. 1.

15 Office of Governor Edmund G. Brown Jr., Executive Order B-18-12, April 25, 2012, available at http://gov.ca.gov/news.php?id=17506.

16 California Energy Commission and California Public Utilities Commission, *Long-Term Energy Efficiency Strategic Plan*, p. 64.

loads, and water use. The Commission adopted its detailed plan for fulfilling these zero-net-energy objectives in the 2013 *IEPR*.[17]

Governor's Clean Energy Jobs Plan

On June 15, 2010, Governor Brown proposed the *Clean Energy Jobs Plan*,[18] which called on the Energy Commission to strengthen appliance efficiency standards for lighting, consumer electronics, and other products. The Governor noted that energy efficiency is the cheapest, fastest, and most reliable way to create jobs, save consumers money, and cut pollution from the power sector. He stated that California's efficiency standards and programs have triggered innovation and creativity in the market place. Today's appliances are not only more efficient, but they are less expensive and more versatile than ever.

Improving Energy Efficiency in Existing Buildings

Assembly Bill 758 (Skinner, Chapter 470, Statutes 2009) requires the Energy Commission, in collaboration with the CPUC and stakeholders, to develop a comprehensive program to achieve greater energy efficiency in California's existing buildings. The Energy Commission adopted the *Existing Buildings Energy Efficiency Action Plan* on September 9, 2015, setting out a complementary portfolio of programs, projects, and practices that would achieve improved energy efficiency in existing buildings.[19] The action plan highlights the increase in the energy consumption and number of plug-in appliances, or "plug loads," and the increasing share of the overall energy consumption of a building. As a result, a key strategy in the action plan is to set appliance efficiency standards for plug loads to improve the energy efficiency of these appliances.

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17 California Energy Commission, *2013 IEPR*, pp. 21-26.

18 Office of Edmund G. Brown Jr., *Clean Energy Jobs Plan,* available at http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

19 *Existing Buildings Energy Efficiency Action Plan*, available at https://efiling.energy.ca.gov/getdocument.aspx?tn=206015.

Part A – Computers

CHAPTER 2: Background

Computers consume a significant amount of energy and have one of the largest plug loads in California. In a broad sense, computers are everywhere and consist of both specialized and generic systems. This report focuses on computers that constitute significant loads in buildings and specifically investigates energy-efficiency opportunities in five broad computer form factors: desktops, notebooks, small-scale servers, thin clients, and workstations. While the number of tablets in homes is increasing, the energy use of these products is relatively low, and the opportunity for savings is minimal due to existing battery charger regulations and market pressure to achieve high efficiency to enhance battery life. Therefore, this staff report does not include analysis on tablet computers.

In homes, the most common form factors are notebooks and desktops. While there are more notebooks than desktops in California, the energy consumption of a desktop is more than double that of a notebook. This energy consumption increases when computer monitor energy use is included, which is necessary for functionality. **Table 1** shows estimates of home computer energy consumption with estimates ranging between 2.5 percent and 4.4 percent of all home electricity use, not accounting for computer monitor consumption.

Table 1: Various Estimates of Residential Computer Energy Consumption in California

Study	Representative Year	Computer Type	Number of Units (Millions, Scaled to CA[20])	Energy Use Per Unit (kWh/yr)	Total Energy Use (GWh/yr)	Percentage of Residential Electricity[21]
EIA MELS Analysis[22]	2011	Desktop	12.8	220	2,816	3.1%
		Notebook	20.6	60	1,236	1.4%
		Total	**33.4**	-	**4,052**	**4.4%**
CEA 2013 Residential Study[23]	2013	Desktop	11	186	2,046	2.2%
		Notebook	11.6	53	615	0.7%
		Total	**22.6**	-	**2661**	**2.9%**
ITI Comment[24]	2013	Desktop	9.6	187.3-296.4	1,800-2,800	2.0 – 3.1%
		Notebook	8.6	58.3-144.7	500-1,200	0.6 – 1.3%
		Total	**18.2**	-	**2,300-4,000**	**2.5 – 4.4%**

Source: Energy Commission staff

Computers contribute significantly to energy consumption in the commercial sector, particularly in office buildings and schools. In fact, the U.S. Energy Information Administration's analysis of miscellaneous loads suggests that 70 percent of commercial notebook and desktop energy consumption occurred in these types of buildings in 2011.[25] In commercial buildings, computers and monitors can make up more than 10 percent of overall electricity consumption of a building. In addition, the vast majority of small-scale servers, workstations, and thin clients are found in businesses. The total energy consumption of computers in the commercial sector is greater than that in the residential sector. This does not include the energy consumption of data centers, which are outside the scope of this report.

20 Simplified scaling was applied as 12.5 percent of national units based on population.

21 All compared to 2012, the latest year available, residential electricity consumption according to the Energy Commission's Energy Consumption Data Management System (ECDMS) http://www.ecdms.energy.ca.gov/. Residential electricity consumption for that year was 91,450 GWh.

22 https://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf.

23 http://www.ce.org/getattachment/Government-Affairs/Issues-Pages/Advancing-Energy-Efficiency-Programs-and-Initiativ/EnergyConsumption2013.pdf.aspx.

24 A range of values are shown here based on a case where power management is enabled 100 percent of the time and 0 percent of the time. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/Information_Technology_Industry_Council_Proposal_for_Standards_Consumer_Electronics_Computers_2013-07-29_TN-71728.pdf.

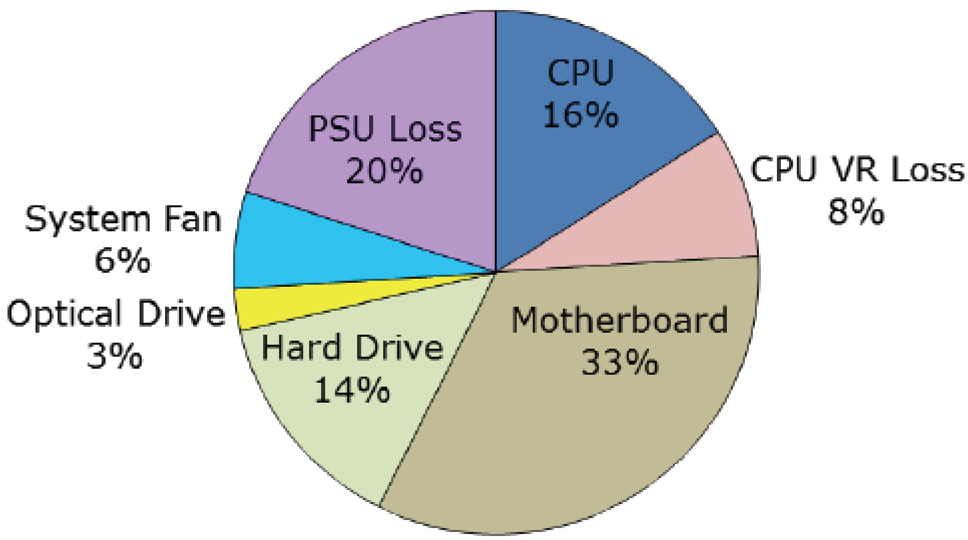
25 https://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf, p. 42.

Computers consume a significant amount of energy in California and were identified and proposed for inclusion in the Energy Commission's 2012 order instituting rulemaking for appliance efficiency regulations. A large number of available technologies and design methods can improve the energy consumption of computers cost-effectively and without a decrease in product efficacy. In fact, significant energy savings can be obtained through low-cost software improvements that use existing hardware more efficiently.

The Energy Commission solicited information, data, and proposals for improving computer energy consumption from stakeholders. Comments and input on general aspects of computer usage, sales, and efficiency opportunities were collected in May 2013. More details about improved efficiency and how to achieve it were gathered in comments from the computer industry, utility companies, and various nongovernment organizations.

The most significant opportunity for improving energy efficiency in computers is reducing idle-mode energy consumption. **Figure 1** shows a breakdown of the idle consumption of a typical desktop. While this chart does not represent every type or vintage of computer, it is an interesting scenario to consider relative to the energy consumption targets of the standard.

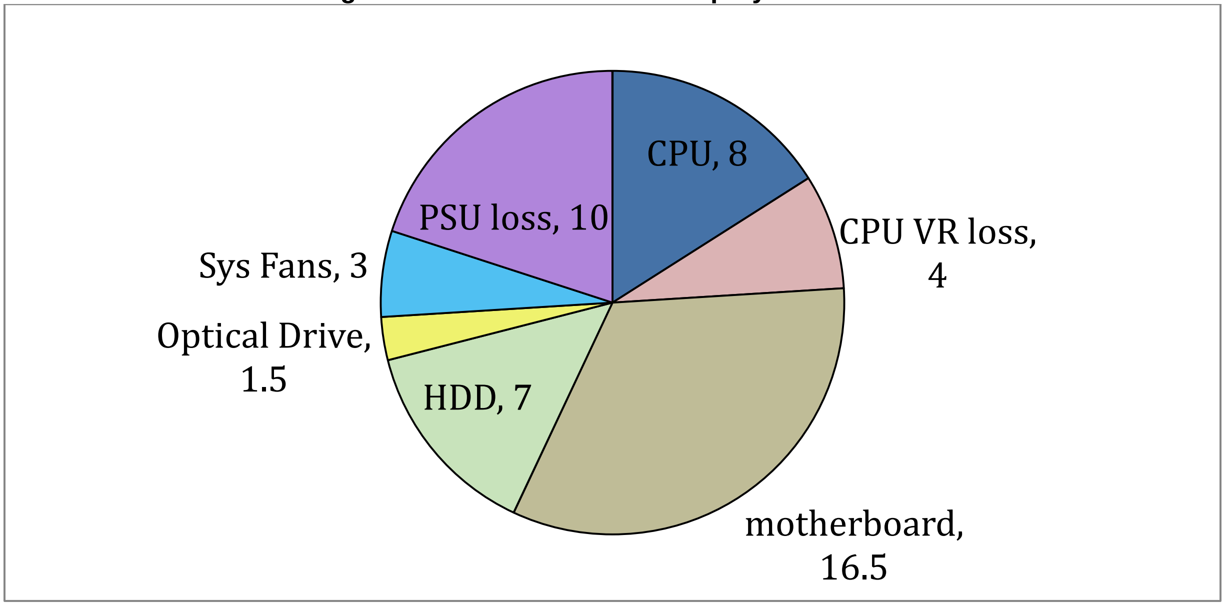
Figure 1: Typical PC Idle Consumption by Percentage



Source: ITI

Figure 2 translates the ITI breakdown for a typical computer with an idle of about 50 watts.

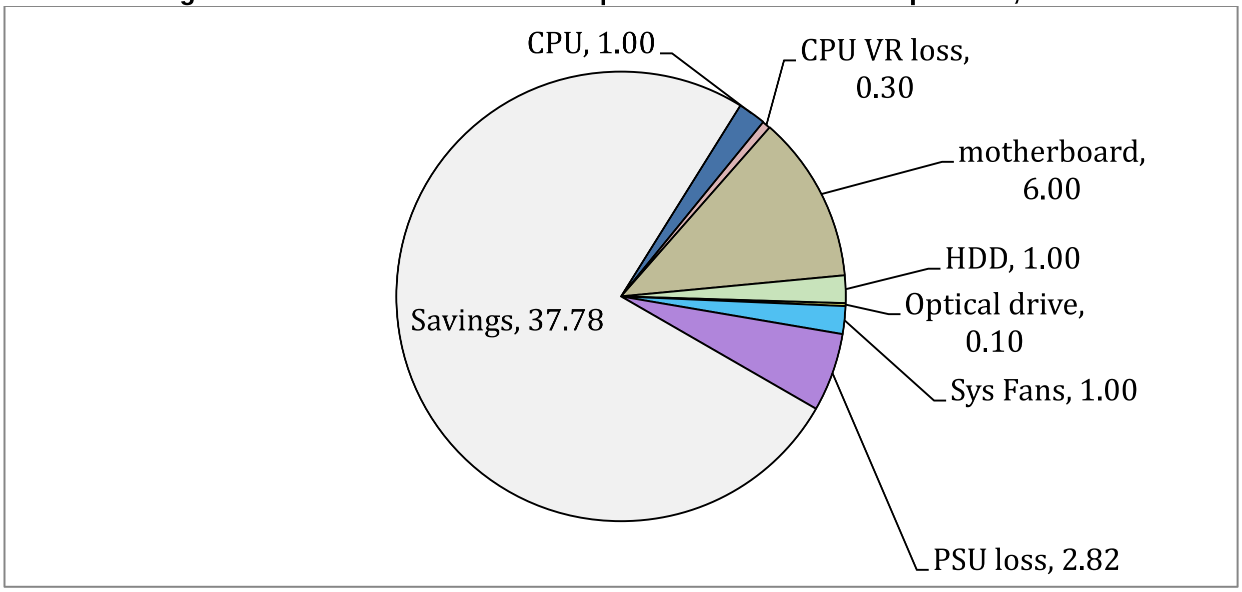
Figure 2: Idle Mode of a Desktop System in Watts



Source: ITI

Given current technologies, the profile in idle mode can look much more like **Figure 3**, using only slightly more than one-third the power:

Figure 3: Idle Mode Power Consumption With Efficient Components, Watts



Source: Energy Commission staff

On March 12, 2015, the Energy Commission released its first staff draft report outlining a proposal for minimum performance requirements for energy efficiency in computers, followed by a workshop on April 15, 2015. In addition, staff attended stakeholder-hosted meetings on June 10, 2015, and September 29, 2015, to discuss details and information. In response to the comments received, the Energy Commission updated the proposed requirements, published its second draft report on March 31, 2016, and held a workshop on April 26, 2016, to discuss the proposed revisions. The Commission received a number of comments both at the workshop and in writing regarding the framework, technical feasibility, and effective date. Subsequently, Commission staff worked with industry stakeholders and efficiency advocates to identify solutions for issues identified during the comment period. This report represents a final compilation and analysis of all the reviewed materials to support the proposed appliance efficiency regulation.

CHAPTER 3: Product Description

The five form factors considered in this report are desktops, notebooks, small-scale servers, workstations, and thin clients. The scope of this analysis does not include tablets, larger-scale servers, game consoles, or industrial computers/controllers. Products are placed out of scope because either the opportunity for energy savings is minimal such as tablets or they spend majority of the time in active mode such as large-scale servers.

Of these forms, desktop computers use the most amount of energy and have the greatest potential energy savings from technological improvements. While there has been a steady but slow decrease in shipments of desktop computers, sales remain significant. Desktop computers are generally paired with one or more computer monitors, displays, or televisions. Less commonly, the computer is integrated with a screen that is referred to as an “integrated desktop.” Desktop computers are generally responsible for the power management of these devices and can have power management responsibilities for accessories as well, such as printers. Desktops generally provide enhanced performance levels per dollar in comparison to notebook computers but are much more energy-intensive. Desktop computers are also more configurable, durable, and easily upgraded, features that contribute to longevity and usefulness. Staff has also investigated the efficiency of subcomponents of some desktops, such as graphics cards, power supplies, and system memory.

Notebook computers are characterized by the small size and ability to run on a battery. A computer screen is integrated in the unit, and upgrades and configurability are generally limited. Although they can offer similar functionality to a desktop computer, they are somewhat constrained by space and power dissipation. Thermal management is important as people tend to touch these computers more often than desktop computers and the orientation and placement of notebooks can lead to fan blockage and poor air flow. While typically plugged in, efficiency and conservation add more consumer value to notebooks than desktops due to battery runtime. That is, the more efficient the notebook, the longer the battery will last. As a result of smaller size and efficiency related to long battery life, this form factor uses significantly less energy than desktop computers.

Workstations, thin clients, and small-scale servers are all special-case versions of desktop computers. A *workstation* is a task-oriented computer designed for abnormally constant and high workload and durability. On the opposite side of the spectrum, a *thin client* contains bare-bones interface hardware that may rely on separate equipment (generally a server or networked virtual machine) to provide full functionality, such as data storage and computational power. A *small-scale server* is a desktop computer configured to run as a server. While most modern desktops can be used as servers, small-scale servers generally have atypical hardware features and different operating systems than generic desktop computers.

There are several niche types of computers that are not adequately described by any of these five form factors. For example, mobile workstations look like notebooks, but the associated energy consumption and configurability are more like a desktop. Other special cases of computers are mobile gaming systems, mobile thin clients, portable all-in-ones, notebook two-in-ones, and rack-mounted workstations. Staff investigated these special cases to determine the appropriate efficiency standards for each type.

For the proposed efficiency standards, the operation of computers is characterized in five modes: active, short-idle, long-idle, sleep, and off. In *active mode*, an operator is running programs and computations on the computer. In *short-idle mode*, the computer has finished requested operations and has not received input for a short period, around 15 minutes. *Long-idle mode* is similar to short-idle *mode,* but the computer has not received input for a longer period, such as 30 minutes, and the monitor may have been put to sleep. *Sleep mode* is a low power state that can resume operation by maintaining power to volatile (or system) memory. It is conventionally consistent with ACPI (Advanced Configuration and Power Interface) system level S3 (suspend to random access memory [RAM]) state. Some computers may use alternative sleep states to provide desired functionality to consumers. *Off mode* is the lowest power state; system memory is not powered. More detailed definitions for these modes, except for active mode, are contained within the regulatory proposal.

CHAPTER 4: Regulatory Approaches and Alternatives

Energy Commission staff studied several regulatory pathways to achieve energy savings in computers. Staff evaluated ENERGY STAR and international computer efficiency standards, including those in Australia, China, and the European Union, as potential standards for California. The Energy Commission also looked at harmonization with other federal or North American test methods but did not find any outside the ENERGY STAR program.

Test Method

While there is a wide range of approaches and requirements for computers, generally all jurisdictions have a fairly harmonized testing method. ENERGY STAR pioneered this method, which is used both domestically and internationally. Energy Commission staff proposes to use the current ENERGY STAR Version 6.1 testing method (revised March 2016). The test method measures four modes of operation: long-idle, short-idle, sleep, and off modes. These modes are typically combined into estimated annual energy consumption through incorporated assumptions about how long the computer operates in each mode (known as the *duty cycle*).

The core of the ENERGY STAR method is the International Electrotechnical Commission (IEC) Standard 62623, *Desktop and Notebook Computers – Measurement of Energy Consumption Edition 1.0, 2012-10* for computers. ENERGY STAR also incorporated IEC 62301, *Household Electrical Appliances – Measurement of Standby Power, Edition 2.0, 2011-01* for general setup. Separately, ENERGY STAR identifies *Generalized Internal Power Supply Efficiency Test Protocol, Rev. 6.6* as the test procedure for internal power supplies. In addition, ENERGY STAR references Ecma Industry's ECMA 393 standards for computer network connectivity.

Two particular mode weightings that are considered for this rulemaking are conventional and full capability duty cycles. *Full capability mode weighting* is used for operating modes that require computer systems to wake upon receiving a command instantly and intelligently. These systems transition from idle modes into sleep or low power mode faster. However, they are required to keep network connectivity at all times. Therefore, the duty cycle for these systems has larger weighting in sleep or low power mode than in short- or long-idle modes. Although full capability mode weighting as stated is intuitively logical, unlike conventional mode weighting, the exact weights are not scientifically or empirically studied. Therefore, staff proposes to allow the use of this duty cycle use for qualified operating systems during Tier 1 while requiring conventional mode weighting for other operating systems during Tier 1 and for all cases in Tier 2.

Efficiency Standards

ENERGY STAR Frameworks: Comparison of Versions 5.2 and 6.1

ENERGY STAR has a long history of voluntary standards development for computers. In fact, ENERGY STAR started with these products for the first specification in 1992. Industry input and existing international regulations focus on ENERGY STAR computer Specification Version 5.2, which started development in 2007 and was finalized in November 2008.[26] The specification was active between July 1, 2009, and June 2, 2014. The Version 5.2 specification was replaced with a Version 6.0 specification that was finalized in September 2013 and updated to Version 6.1 in October 2014.[27]

While it is standard practice for a new version of ENERGY STAR to be more stringent than the old one, there were also some structural changes in how the specification handles product categorization and graphics card functional adders. Adders are additional energy consumption allowance beyond the baseline allowance intended to approximate the power requirements for the added part. ENERGY STAR Version 5.2 categorizes desktop computers into A-D and notebooks into A-C, with A being the lower performance computer types and C and D being the higher performance types. ENERGY STAR Version 6.0 categorizes desktops and notebooks into 0, I1, I2, I3, D1, and D2 categories, with "0" representing the lowest functioning computers. The "I" categories represent computers that have only integrated graphics. The "D" category represents computers that have discrete graphics cards.

Each version categorizes computers from "low performance" to "high performance" to vary the allowances given relative to performance. The ENERGY STAR 5.2 scheme categorizes computers based on two factors: how many cores it has and how much memory it has, with some differentiation for the graphics card bandwidth. The ENERGY STAR 6.1 scheme categorizes computers by the number of cores, speed of those cores, and power of the graphics card, with additional emphasis on integrated versus discrete graphics. The changes made in categorization were from suggestions by the Information Technology Industry Council (ITI) in the ENERGY STAR process where it describes that the ENERGY STAR 5.2 scheme "no longer works"[28] as it focuses on the wrong attributes. This approach, which was also supported by the Japan Electronics and Information Technology Industries Association (JEITA),[29] recognizes growing trends toward integrated graphics.

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26 "Cover Memo for ENERGY STAR Computer Specification version 5.0," US EPA, November 14, 2008, http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/V5.0_CoverMemo.pdf?3e1a-c82f.

27 See "external power supply requirement update" dated October 31, 2014, on the ENERGY STAR product development Web page http://www.energystar.gov/products/spec/computers_specification_version_6_1_pdf.

28 ITI presentation to ENERGY STAR, May 23, 2012, http://www.energystar.gov/sites/default/files/specs//private/V6_D2_ITI-Stakeholder_Presentation.pdf, slide 15.

29 Comments to ENERGY STAR from JEITA, January 9, 2013, http://www.energystar.gov/sites/default/files/specs//JEITA_Comments_Public.pdf, p. 2.

Energy Commission staff used the ENERGY STAR 6.1 framework as a starting point for standards development instead of the 5.2 framework for the same reasons given by ITI in its development and by the IOUs and the Natural Resources Defense Council (NRDC) in their comments to the Commission.[30] More stringent or less stringent standards can be made using either framework, but based on the rationale behind the Version 6.1 changes, staff believes that this specification is more suited to scale energy consumption with performance and, therefore, better characterizes efficiency. This approach also allows clearer evaluation of today's market, as data on the latest computer efficiency from ENERGY STAR are provided only in context of the Version 6.1 specification. While the approach differs somewhat from the approaches taken in Australia, China, and the European Union, it follows the evolution of computer characterization pioneered in ENERGY STAR and the direction China and the European Union were headed in their supplemental inclusion of ECMA 383 standard on top of the ENERGY STAR 5.2 framework.

While the Energy Commission staff started with the ENERGY STAR 6.1 framework, it found that the use of the "p-score" was inappropriate for continued use in differentiating computer allowances. The p-score used in ENERGY STAR is a calculation of processor speed in gigahertz multiplied by the number of cores. However, many of the factors driving idle power consumption are completely unrelated to the computational power of the processor. For example, mini- and microdesktop computers use high p-score processors while consuming far less idle power than lower p-score processors in larger desktops. Staff proposes to use an expandability score to better scale requirements with drivers of idle power.

Australian Standards

Computer efficiency standards came into effect in Australia on April 1, 2013, and in New Zealand on October 1, 2013. The details of the regulations are contained within AS/NZS 5813.2:2012.[31] The scope of the Australian standards covers desktops, notebooks, and small-scale servers but does not cover workstations, thin clients, and "high-end category D desktops" (a reference to ENERGY STAR 5.2 categories). The Australian standards are closely aligned with ENERGY STAR 5.2 and European Union in design. The Australian approach also includes an interesting "deemed-to-comply" approach for small-volume manufacturers to achieve cost-effective compliance. This approach was also highlighted in a Collaborative Labeling and Appliance Standards Program (CLASP) study docketed in the Energy Commission's process. These standards are less stringent than the European Tier 2 standards and this proposal.

30 IOU/NRDC CASE report to Energy Commission, August 6, 2013, p. 28.

31 The Australian standards are available at http://www.standards.org.au/SearchandBuyAStandard/Pages/default.aspx.

Chinese Standards

Mandatory standards for computers have been in effect in China since September 1, 2012, and are contained in GB 28380 (2011).[32] The scope of the standards includes desktop and notebook computers but does not include workstations and industrial computers. The Chinese standards harmonize categorization of desktop and notebook computers around the ENERGY STAR 5.2 definitions. The standard levels chosen is less stringent than those levels in ENERGY STAR 5.2 and includes a different graphical adder scheme. The Chinese standard also requires certification, and CLASP used resulting data to compare with computers available in the United States to estimate marketplace compliance with various ENERGY STAR levels.

European Union Standards

The European Union has standards for computers and servers generally referred to as "lot 3" or, more formally, European Commission Regulation No. 617 (2013).[33] The regulation applies to all products within the scope of this staff report. The regulation explicitly excludes blade servers, server appliances, multinode servers, servers with more than four processor sockets, game consoles, and docking stations. Energy Commission staff incorporated many of these exclusions into the proposed regulations. Both the definitions of the products and the requirements are strongly correlated with the ENERGY STAR 5.2 construct, consisting of baseline energy allowances supplemented with functional "adders." The standards consist of two tiers. The first became effective on January 1, 2014, and the second, more stringent tier became effective on January 1, 2016.

The European Union standard also includes disclosures by computer type.

Alternatives Considered

The Energy Commission has received many comments and proposals from interested stakeholders regarding the framework and substance of potential computer regulations. These comments were received in the context of prior drafts of the staff report published on March 12, 2015, and March 30, 2016. This final staff report considers the most recent comments submitted by stakeholders. For analysis regarding older and superseded comments, see the prior staff reports.[34,35]

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32 The standard, in Chinese, is available at https://law.resource.org/pub/cn/ibr/gb.28380.c.2011.pdf.

33 The European Union standard is available here: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:175:0013:0033:EN:PDF.

34 First draft staff report is available on the Energy Commission's website at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN203854_20150312T094326_Staff_Report__FINAL.pdf

35 Second draft staff report is available on the Energy Commission's website at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN210913_20160330T161602_Final_Draft_Staff_Report_for_Computers_Computer_Monitors_and_Si.pdf.

ITI Proposal

ITI's proposed alternative[36] would incorporate the expandability score as a way to define four discrete product categories and total energy consumption (TEC) levels for those categories:

Table 2: ITI Proposal

System Type	Proposed TEC	Expandability Score Criteria
Base, Entry	50	< 250
Mainstream	80	250-425
Performance	100	425-650
Exempt	N/A	> 650

Source: ITI

ITI proposes a large number of additional adders for both desktops and notebooks, and recommends adjusting the allowances for some of the staff-proposed adders. ITI further proposes to exempt certain systems, such as mobile workstations and mobile gaming systems, from the TEC requirements in the regulations and to remove other systems, such as mobile thin clients, from the scope entirely. Finally, ITI proposes to exempt nontraditional operating systems, such as FreeDOS, Linux, Android, and Chrome, from the power management requirements in the proposed standards.

ITI generally supported staff's proposal for notebooks and workstations in the second draft staff report.[37]

ITI's proposed standards would save nearly 290 GWh in energy annually after stock turnover compared to staff's proposal. Staff incorporates the ITI-proposed TEC levels for its Tier 1 requirement but proposes more stringent Tier 2 requirements to achieve additional cost-effective and technically feasible energy savings.

California IOU Proposal

The California IOUs generally supported the proposal in the second draft staff report. The Codes and Standards Enhancement (CASE) team recommended some modifications, however, to increase energy savings or to improve compliance rates. Specifically, the California IOUs recommended using a new framework for determining appropriate categories for TECs. This new framework would combine power supply nameplate rating and a simplified expandability

36 http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211618_20160523T170836_Christopher_Hankin_Comments_ITITechNet_Comments_on_Computers.pdf.

37 ITI and Technet, Comments on CEC Staff Report (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211618_20160523T170836_Christopher_Hankin_Comments_ITITechNet_Comments_on_Computers.pdf.

score. The CASE team also recommended tightening the stringency of various adders that staff proposed and refining definitions to minimize loopholes.

For notebooks, the CASE team recommended increasing the base TEC stringency from 30 kilowatt-hours (kWh)/year to 16 kWh/year. Implementing the IOUs' recommendation for notebooks would have potentially increased energy savings by about 311 GWh/year. Finally, the CASE team recommended adding a power factor requirement at lower loads, in addition to a 100 percent load requirement.[38]

Staff proposes to incorporate some of the CASE team's recommendations, especially those designed to minimize loopholes and gaming. Other recommendations would require additional technical support to demonstrate technical feasibility and cost-effectiveness that were not available at the time of this effort.

Natural Resources Defense Council Proposal

The Natural Resources Defense Council (NRDC) also generally supported the Commission's proposed standards in the second draft staff report. However, it recommended some changes to increase energy savings and minimize loopholes and gaming in the standard. NRDC proposed a two-tier approach to the standards to achieve early energy savings while providing the computer industry additional time to implement deeper energy efficiency improvements. These tiers would take effect one and two years after adoption, respectively.

NRDC recommends that product categories be based on the hybrid power supply size and simplified expandability score approach put forward by the California IOUs, that adders be made more stringent, that power supplies be required to meet a power factor requirement at lower loads, and that computers get tested with monitor brightness set as shipped with minimum luminance.[39] Finally, NRDC recommends modifications to definitions and weighting to minimize or eliminate loopholes. Staff was not able to estimate the energy savings that would have resulted from implementing all these recommendations.

A two-tiered approach to the standards is proposed, although on a different time frame than recommended by NRDC to account for manufacturer design cycles. Staff also incorporates recommendations regarding definitions to minimize loopholes. Other recommendations would require additional technical support to demonstrate technical feasibility and cost-effectiveness that was not available at the time of this effort.

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38 California IOUs, California IOUs, Response to Final Draft CEC Staff Report for Computers, pp. 11-12 (May 23, 2016), http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211614_20160523T163525_California_Investor_Owned_Utilities_Comments_California_Investo.pdf.

39 NRDC, Comments on CEC March 2016 staff report (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211600_20160523T103042_Pierre_Delforge_Comments_NRDC_comments_on_CEC_March_2016_staff.pdf.

No Standard Alternative

Although the Energy Commission did not receive any comments suggesting that it maintain the status quo and adopt no standards for computers, staff considered the effect of not setting standards for computers. In its *Standardized Regulatory Impact Assessment* submitted to the Department of Finance, the “baseline” represents the economy without computer regulations. As that analysis demonstrates, forgoing regulations means forgoing significant energy savings, greenhouse gas reductions, and monetary benefits from the standards. There were no positive benefits to forgoing regulations. As a result, this alternative was not chosen.

CHAPTER 5: Proposed Standards for Computers

Energy Commission staff reviewed stakeholder comments and adjusted the proposed standards to the new data, information, and analysis.

Test Procedure

The proposal generally aligns with ENERGY STAR testing methods, which align with international testing requirements. However, stakeholders raised several key concerns regarding the regulatory proposal that must be addressed in the test method. Therefore, a modified version of the ENERGY STAR test method is proposed.

Through discussions with stakeholders, it was clear that the resolution of a display attached to a desktop can affect the power consumption of the desktop. The resolution determines the amount of data necessary to render each pixel on the screen. Higher resolution (more pixels) requires higher bandwidth from the desktop and correspondingly more energy. It is critical to define a standard resolution for attached monitors to obtain repeatable test results. To achieve this, staff proposes that attached monitors have a native, or maximum, resolution of 1920 x 1080 pixels, also known as full high-definition (full HD) or 1080p.

Another proposed modification is to specify that hard-drive spin-down remain in factory default mode. There seems to be some confusion under IEC 62623 and the ENERGY STAR test procedure regarding power management setting changes that would measure short-idle and long-idle modes. The proposed language would require that the hard-disk spin-down settings not be altered throughout testing. The only time power management should be altered is to disable sleep mode where long-idle measurements would not be possible otherwise.

One of the major changes from the proposed test method of the previous draft is the way sleep mode power is measured. This change is in response to concern over systems that may not have traditional sleep mode. Instead of measuring the power after manually entering sleep mode, staff proposes to measure the power 30 minutes after long-idle mode, with no user interaction or user-prescribed tasks during this waiting period. This is consistent with the related power management requirements that computers go to sleep within 30 minutes of user interaction.

In the second draft report, staff proposed a new duty cycle for computers that are sold without the ability to disable power management. This alternate duty cycle was to encourage the refinement of operating systems with the ability to meet consumer needs while minimizing idle time when the computer is not in use. However, the computer industry raised concerns about the potential unintended consequences of removing end-user capability to disable power management.[40] Therefore, staff has removed this duty cycle.

The second draft staff report also included a method to calculate a proposed "expandability score," which is used to calculate an expandability adder. Expandability adder is the additional energy consumption allowance beyond the baseline allowance intended to approximate the power requirements for the added parts. This calculation method is intended to approximate the power requirements of the computer. Staff updated the expandability score table to account for configurable aspects of a computer, such as Universal Serial Bus (USB) ports of different vintages, by providing different power allowances. Staff also identified a score for future generations of known interfaces.

To reduce the burden on utilities for poor power factor, the final staff report adds a minimum requirement and a new test procedure for power factor. Staff proposes a minimum power factor requirement of 0.9 measured at full load, consistent with ENERGY STAR. Additional measurements are taken and required to be reported to inform future power factor discussions.

The final report also addresses several test procedure issues that were raised in comments on the second draft staff report. To resolve these issues, staff worked with stakeholders and efficiency advocates to ensure that test procedures would be replicable and could not be manipulated or gamed. These additional issues include:

- How to choose a consistent connection where computers have multiple display connections or discrete graphics cards.
- How to configure automatic brightness control and luminous emittance for notebooks, portable all-in-ones, and integrated desktops.
- How many configurations of a model computer need to be tested and reported.

Efficiency Standards

The most substantial adjustments to the Energy Commission's draft staff report include dividing desktop computers into four categories with different efficiency levels rather than three categories with a smooth function, adjusting the levels of energy allowances for each category, and modifying the effective dates for the standards. These adjustments could be made while maintaining the magnitude of statewide energy savings.

Staff's proposal is an effort to take international experience, stakeholder input, and data analytics and accomplish feasible and attainable energy savings for California in both the short and long term. The proposed regulations are divided into three primary categories: desktops and thin clients, notebooks, and small-scale servers and workstations.

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40 ITI and Technet, Comments on CEC Staff Report (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211618_20160523T170836_Christopher_Hankin_Comments_ITITechNet_Comments_on_Computers.pdf.

Table 3: Products Included in Categories

Category	Products Included
Desktops and thin-clients	Conventional desktops, thin clients, integrated desktops mobile gaming systems
Notebooks	Conventional notebooks, portable all-in-ones (AIOs), mobile thin clients, and two-in-one notebooks
Small-scale servers and workstations	Small-scale servers, high expandability computers (as defined), mobile workstations, rack-mounted workstations, and workstations.

Source: Energy Commission staff

Products included in the scope cover a broad range of applications and form factors. However, as the standards focus on the power consumption in idle mode, the products should be conducting relatively few, if any, specialized tasks in the regulated modes. The scope of the proposal does not include large-scale servers, blade servers, industrial computers and controllers, video game consoles, tablets, smart appliances, televisions, set-top boxes, portable gaming devices, game consoles, or small computer devices. A *small computer device* is defined for this rulemaking as a computer system with an integrated display that has a screen size of less than 20 square inches, such as calculators and handheld barcode readers.

The requirements for each product type are described below. Beyond the basics of manufacture date, manufacturer name, and model number, physical labels are not proposed.

Conventional Desktops and Thin Clients

Effective Date

Staff received comments from industry regarding the effective date of the proposed standards. Several members of ITI presented information at the workshop indicating that the product design period for desktop computers is roughly 24 months.[41] As a result, an effective date of one year from adoption would not have provided sufficient time for manufacturers to redesign their products to meet the applicable standards.

Staff looked carefully at how to balance near-term and longer-term efficiency savings. Some stakeholders commented on the importance of ensuring a competitive marketplace for more efficient components, which could be satisfied by providing additional time to achieve higher

41 ITI and Technet, Comments on CEC Staff Report (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211618_20160523T170836_Christopher_Hankin_Comments_ITITechNet_Comments_on_Computers.pdf.

efficiencies.[42] Industry stakeholders also noted that longer-term efficiencies could be achieved with at least two design cycles rather than only one.[43] Overall energy savings are affected by both the stringency of the proposed standards and the effective dates.

In response to these comments, staff has proposed to implement the desktop standards in two tiers. The first tier would be effective January 1, 2019, and the second tier would be effective July 1, 2021. This approach will maximize energy savings and provide a smoother supply chain transition. The largest opportunities for energy savings remain in the desktop computers, even post-European Union standards. To set the proposed standard, staff evaluated the best practices in hardware and software in today's market that also provide higher-end functionality. In effect, staff looked at best practices in power scaling along the lines discussed in Appendix C of the IOU CASE Initiative Addendum.[44] The barrier to achieving these goals is defined by latency, or the time it takes for a system to transition from the idle state into the correct active state once a task is prescribed. As latency and power scaling improve, peak performance and innovative features matter less to a standard that focuses on idle states. In other words, the power consumption of new and faster features can be reduced without significant impact to performance by putting them to sleep and having rapid transition to full functionality.

The proposed standard sets a baseline total energy consumption (TEC) target for each category. Each category is determined based on the expandability score. The TEC target is a performance standard and does not explicitly require any specific technology. Staff further proposes a number of adders for graphics cards, integrated displays, system memory, additional hard-disks, energy-efficient ethernet, add-in cards, video surveillance cards, wired Ethernet or fiber cards, and high bandwidth system memory. These adders are modified or new from the second draft staff report and described in greater detail in the Technical Feasibility chapter.

Staff proposes to determine the appropriate category, and therefore the energy consumption allowance, for desktop computers based on an expandability score, or ES. The ES correlates with the power supply sizing necessary for a system to be able to power the core system plus potential expansions through externally and internally available ports and interfaces. In the second draft staff report, desktop computers were divided into three categories based on ES score, with a baseline energy consumption allowance of 50 kWh per year and an allowance based on an expandability adder for each category. While this framework was technically feasible to achieve and proportional to the actual energy usage of the computer, ITI and its members raised concerns about the linear TEC limit and how it would relate to standards adopted around the globe that used a category approach. Industry members also pointed out

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42 See, for example, AMD Comments; Appliance Efficiency Rulemaking (May 20, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211590_20160520T162027_Donna_Sadowy_Comments_14AAER_2_Appliance_Efficiency_Rulemaking.pdf.

43 NRDC, Comments on CEC March 2016 staff report (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211600_20160523T103042_Pierre_Delforge_Comments_NRDC_comments_on_CEC_March_2016_staff.pdf

44 Available at http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/documents/comments_12-AAER-2A/California_IOUs_Standards_Proposal_Addendum_Computers_2014-10-27_TN-73899.pdf.

that the linear TEC limit would decrease the flexibility of engineers to design a desktop model that would meet the efficiency levels at any given level of configurability.

In response to these comments, staff proposes to replace the TEC line with two categories and to modify the efficiency levels for each category. Increasing the number of categories should help reduce the size of the step jump between adjacent categories.

To set the TEC level for each category, a combination of a baseline energy limit and additional energy adders is proposed. The baseline energy consumption allowance is different for each category of computers and is determined based on the ES. For Tier 1, staff proposes TEC levels that achieve roughly 70 percent of the savings from the second staff report. For Tier 2, staff proposes levels that achieve approximately 94 percent of the savings identified in the second draft staff report. For both tiers, a desktop with an ES score of greater than 690 is considered a high expandability computer and would be subject to the standards for workstations rather than the desktop standards. **Table 4** shows the proposed standards.

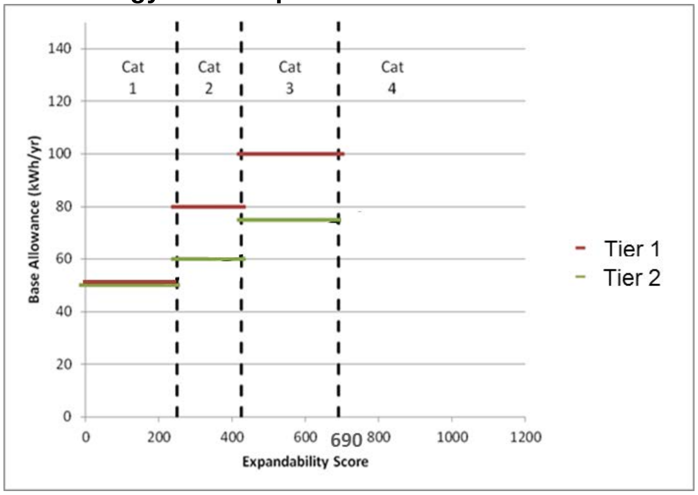
Table 4: Proposed Standards for Desktop Computers

Expandability Score	Annual Energy Consumption on or After January 1, 2019	Annual Energy Consumption on or After July 1, 2021
ES ≤ 250	50 kWh/year + applicable adders	50 kWh/year + applicable adders
250 < ES ≤ 425	80 kWh/year + applicable adders	60 kWh/year + applicable adders
425 < ES ≤ 690	100 kWh/year + applicable adders	75 kWh/year + applicable adders
ES > 690	None, must meet workstation requirements	None, must meet workstation requirements

Source: Energy Commission staff

Efficiency levels for each tier are shown in **Figure 4**.

Figure 4: Total Energy Consumption Limits for Tier 1 and Tier 2 Standards



Source: Energy Commission staff

Table V-7 in the Express Terms includes a list of all adders with the associated energy allowance. A justification for these adders is included in Chapter 6 with the discussion on technical feasibility.

Power Management

The proposal to require certain power management default settings when computers are shipped was retained. A system shipped at the customer's request without an operating system or with a limited capability operating system, such as Free DOS, would have to test with power management. The system would not be required to be shipped with it. Desktop and thin client computers assembled entirely from parts that are manufactured before September 1, 2018, are exempted from TEC requirements in Tier 1 but must still comply with the power management requirements.

High Expandability (HE) Desktops

In the second draft staff report, very high-performing desktops, meaning those with an ES of more than 750, were exempted from the TEC levels for desktops and instead were required to meet the proposed standards for workstations. To provide clarity between these two products, staff has added a new definition for high expandability desktops. These high-end computers are used typically as workstations or for gaming and, therefore, are in active mode more often than typical desktop computers. This means that efficiency opportunities are primarily in the power supply, which is a main factor in driving the energy consumption in active mode. Requiring these products to meet the standards for workstations would yield significant energy savings.

Staff also proposes to reduce the threshold for high-expandability desktops from 750 to 690. Since more technologically advanced components and interfaces typically require more power, and because a larger power supply is analogous to a higher expandability score, high-expandability desktops may also be those that have a power supply of 600 watts or greater and have high-end discrete graphics as described in terms of frame buffer bandwidth.

To account for future efficiency improvements in achieving higher buffer speeds and to prevent a loophole for mainstream desktops, staff proposes a two-tier approach for such graphics, as described below.

Table 5: Minimum Frame Buffer Bandwidth for High-Expandability Computers With Discrete Graphic Cards and Power Supply 600 Watts or Larger

Effective Date	Minimum Frame Buffer Bandwidth
Before 1/1/2020	400 GB/S
On or After 1/1/2020	600 GB/S

Source: Energy Commission staff

The effective date of standards for high-expandability computers is January 1, 2018, the same as for workstations, small-scale servers, and mobile workstations, as these they are subject to the same standards.

Workstations and Small-Scale Servers

The original proposal for workstations and small-scale servers was retained. This proposal incorporates 80 PLUS Gold program named after the minimum conversion efficiency of 80 percent or better, performances and energy-efficient Ethernet requirements into the proposed regulatory text in a way that ensures efficiency targets are met without tying the regulations to standards that may change or become defunct over time. Staff also maintains the proposal to require power management settings consistent with the ENERGY STAR specification Version 6.1. As neither requirement calls for significant redesign or implicate supply chain concerns, it is proposed that these standards take effect for products manufactured on or after January 1, 2018.

Notebook Computers

In evaluating the available notebook computer data and the design of ENERGY STAR 6.1 limits, staff found the ENERGY STAR specification to provide a very narrow difference in allowances versus performance. For notebooks with discrete graphics, the lowest end is given a base allowance of 14 kWh/year and the high end 18 kWh/year. For notebooks with integrated graphics, the allowance ranges from 22 to 28 kWh/year. Proposals by the IOUs and NRDC are even flatter than that. A single tier of standards is proposed for notebooks set at a 30 kWh/year base allowance, including adders for the same set of features as desktops. Although this proposal is substantially the same as the March 2016 staff report, staff proposes a January 1, 2019, effective date.

Special-Case Computers

In response to the second draft staff report, industry members identified several products that did not fit neatly into the desktop, notebook, or workstation categories. These products include mobile gaming systems, mobile workstations, mobile thin clients, two-in-one notebooks, portable all-in-ones, and rack-mounted workstations. Staff investigated the current efficiency levels and efficiency opportunities for these products and proposes to fold them into the category where the product's power consumption most closely aligns. As a result, mobile gaming systems are treated as integrated desktops for the efficiency standards, two-in-one notebook and portable all-in-ones are treated as notebooks, mobile workstations are treated like workstations, and rack-mounted workstations are treated as workstations with exemptions for power management.

Power Factor

Power factor correction is important to power supply efficiency. The California IOUs proposed to include testing and minimum standards for power factor at full load to achieve energy savings on both the consumer side of the meter as well as on the utility side. NRDC further recommended power factor correction at lower load points, including sleep and off, to increase energy savings. Staff proposes a minimum power factor requirement at full load for computers with non-federally regulated power supplies to ensure consistency with other power supply standards, including the federal external power supply standards and the 80 PLUS® program. However, requiring minimum power factor at low loads demands additional technical support to demonstrate technical feasibility and cost-effectiveness that was not available at the time of this effort. Staff proposes to collect and report power factor at low loads to monitor it and incorporate it into future rulemakings, if needed.

Small Volume Manufacturers Exemption

Unlike most appliance types for which the Energy Commission has proposed regulation, computer manufacturing of desktop computers is feasible even at a very small scale. This results in a significant number of manufacturers producing small volumes of the appliance. However, small businesses have less capital and produce much smaller volumes of a family of products, which means that the testing costs and costs of compliance may have a larger effect on these small businesses. While the testing costs are not extreme, roughly $600 per test, it could be cost-prohibitive for a small entity to perform. According to comments received during the pre-rulemaking, the testing alone could put such entities at a cost disadvantage to larger manufacturers in competing for small information-technology bids and ultimately place them at risk of failing.[45] The incremental cost of testing is more significant for smaller volume sales. Without significant volume, the testing costs can outweigh the benefit of improved energy efficiency.

Therefore, staff proposes to exempt small businesses from complying with most manufacturing aspects of the proposed computer standards, with the exception of following no-cost power management requirements.

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45 NASBA comment August 29, 2013.

To develop the exemption, staff investigated revenue caps, location of assembly and sale, and minimum number of sold systems as main factors to consider for the exemption. Originally, the Energy Commission considered $750,000 for the revenue cap but proposes to increase it in response to the comments it received.[46] Under the current proposal, manufacturers qualify to apply for the exemption if their annual gross revenues from all operations are $2 million or less, the manufacturer assembles and sells the computers at the same location, and no more than 40 units of a similar system are sold. These requirements were modeled after the U.S. Department of Energy exemptions and based on:

- IOUs' estimates of testing costs through outreach to ENERGY STAR-certified laboratories (roughly $600 per test).
- A combination of assumed overhead costs and net revenue for a small business.
- The number of units that would need to be sold for the costs of testing to justify the estimated energy savings to the consumer from the proposed standards.[47]

Preassembled products that are repackaged or offered for resale through small businesses are not eligible for this exemption.

46 http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211848_20160616T163227_Erik_Stromquist_Comments_Local_OEM_Computer_Manufacturers_Comme.pdf

47 The Tier 1 net benefit for a desktop computer is estimated to be $14.77. Therefore, 40 units would have a benefit of $600 and be at a break-even point once testing costs are factored in.

CHAPTER 6: Technical Feasibility

The proposed computer standards are feasible as there is an array of computers or computer components across performance categories that meet or exceed the proposed efficiency standards today. For desktop computers, the feasibility is demonstrated through available components that can be readily procured to meet the Tier 1 and Tier 2 efficiency levels. For notebooks, there are a significant number of products today that already meet the proposed efficiency standards. For small-scale servers and workstations, the feasibility is driven primarily by readily available power supply technologies and Energy-Efficient Ethernet devices. Each of these is discussed in depth below.

Desktops

There are many ways to reduce the energy consumption of desktop computers. Hardware decisions can yield energy savings where products are available that offer same or better performance at lower energy consumption. Chip, motherboard, and other computer component manufacturers can also improve the efficiencies of the parts they sell beyond what they are today. Current trends are toward lower idle power consumption in individual components in the marketplace. There are also many software and firmware[48] enhancements that can be implemented that would save large quantities of energy without changing the components.

Staff developed the total energy consumption (TEC) targets for each of the tiers by looking at a database of product performance, provided by ITI, and identified the TEC that could be achieved through subcomponent upgrades. This database was then used to identify the energy savings associated with the various TECs.

The proposed standards require that desktop computers meet a total energy consumption target that is composed of short-idle, long-idle, sleep mode, and off mode. To obtain the TEC, staff proposes to use the relative weightings in the ENERGY STAR 6.1 standard, which are 35 percent short-idle mode, 15 percent long-idle mode, 5 percent sleep mode, and 45 percent off mode for a conventional desktop.[49] Although as mentioned earlier, some computers may use a "full capability" weighting to demonstrate compliance with Tier 1.

Generally, sleep and off modes are already at low power levels, with the majority below 1 watt and nearly all within the 1- to 3-watt range. This means that reduction in off mode and sleep mode represents a small opportunity, and the majority of savings would necessarily come from reducing one or both idle-mode consumptions.

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48 *Firmware* is a software program or set of instructions programmed on a hardware device. It provides the necessary instructions for how the device communicates with the other computer hardware.

49 *ENERGY STAR Program Requirements for Computers*, Version 6.1 (March 2016), at Table 3 and Table 4.

Expandability Framework

The Energy Commission's basic approach to computer standards is to provide a base TEC level and then allow applicable adders to increase the total annual energy consumption of the computer. This section discusses the technical underpinnings of the expandability framework.

The workshop on the 2015 staff report, follow-up meetings, and comments from the computer industry emphasized the need to provide a larger allowance for more "powerful" computers. In ENERGY STAR 6.1, this is achieved by a "p-score" which is equivalent to the rated maximum clock speed of the processor multiplied by the number of cores. Commission staff analyzed this score as the basis for differentiating energy consumption targets and found that it would not form a good basis for forward-looking regulations. This is because a processor varies only slightly in idle power regardless of clock frequency and cores when holding the rest of the hardware constant.

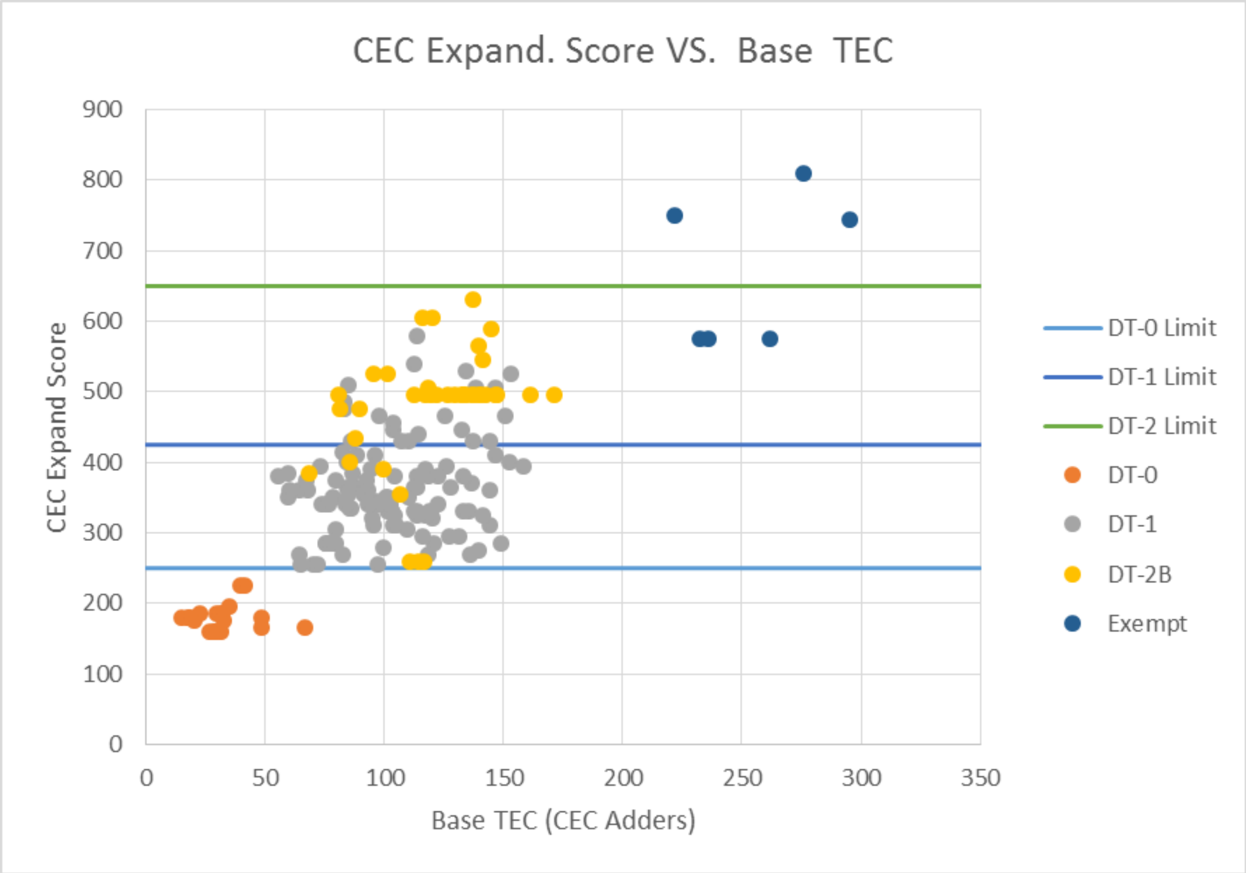
Additional factors that drive idle power consumption were raised through stakeholder interaction. The first is power supply sizing, as it is driven by the expandability of a system through the interface ports. The larger a power supply is, the larger the power overhead of the related components. Also, the idle mode will be on a lower point in the load curve of the power supply, typically leading to diminished conversion efficiency.

The second is the idle mode power draw by an increased number of communication controllers for those interface ports, such as additional USB and PCI controllers. Each of these controllers has a power draw in idle as it awaits connection to a device, awaits a wake-up signal, or conducts minor status and maintenance communications.

Stakeholders also raised increasing bandwidth as driver of idle mode power. However, bandwidth is partially solved by frequency scaling that is implemented in both desktop and notebook computers. It is also related to the type of interfaces present on the motherboard. Staff considered various BUS bandwidths as an adjustment for power consumption, but ultimately could not find a practical way to identify this information in off-the-shelf products. While motherboard manufacturers publish some of these numbers for do-it-yourself motherboards, desktop and notebook systems typically do not.

To adjust for the effects of expandability, staff proposes to calculate an expandability score, which emulates power supply sizing. This approach appears in industry, IOU, and NRDC proposals and is calculated by the number of interfaces available in a computer. However, in response to industry stakeholders' concerns about the effect of the new framework on global markets that use a different framework, staff proposes to use the score to determine which category a desktop falls into and to create a flat base TEC for each category. The score has been adjusted for each category to require standard, less expandable computers to meet more stringent standards while exempting some of the higher end computers from the TEC levels. The remaining feasibility discussion focuses on improvements in short- and long-idle modes.

Figure 5: Measured TEC Versus Expandability Score for Desktop Computers



Source: Energy Commission staff

Components

This section discusses the energy saving opportunities in each subcomponent of a computer. The section discusses most component power draws in watts. These power draws are referring to direct current (DC) power draw of the component itself, not the true alternating current (AC) power draw that would be seen at the outlet. This is necessary to disassociate the power losses that are embodied in the computer power supply. However, the power draw for the power supply component refers to the AC power draw that would be seen at the outlet.

Hard Disk

The hard disk is the component a computer uses to store data for long term usage, and power is not needed to maintain that data (unlike volatile memory used for active programs). In the last draft staff report, the estimated "compliant" machine consumed 1 watt average in the hard-disk subcomponents. Hard disks come in a variety of forms and technologies. This staff report highlights three basic types of technologies: magnetic storage, solid-state, and hybrid systems.

The oldest and least expensive of these technologies uses magnetic platters to store data. The market for these products is almost entirely composed of 2.5- and 3.5-inch drives. In addition, these drives are typically rated by revolutions per minute (RPM) related to how fast the platters spin. Typical modern ratings include 5,400 and 7,200 RPM. The higher the rate of rotation, the higher the read and write speed capabilities of the hard disk. The faster speeds also create additional power demand and greater frictional losses. The idle power consumption of the magnetic hard drive is caused primarily by the need to constantly run a motor to maintain a precise speed of rotation. However, there is some amount of power drawn by the control and interface electronics as well.

The magnetic hard disks on the market include several power states. The lowest power states on a typical hard-drive, referred to as "standby mode," consume far less than the 1 watt level assumed in the 2015 staff report's assumed budget and can consume 0.1 to 0.3 watts. However, this is achieved by no longer spinning the platters. While system designers could meet the proposal by implementing this aggressively, the amount of time it takes to spin a hard disk back up can be 5 to 20 seconds. The system will typically be unresponsive during this time, causing a short-term delay in user access. It is also important to avoid a high frequency of spin-downs and spin-ups as the spin-up process is power intensive. However, short-idle mode is measured after 15 minutes of inactivity and long-idle after 30 minutes of inactivity, outside the range where frequent state changes would lead to overall energy losses. The incremental cost of this approach is $0 as it is a feature already in every hard disk that the Energy Commission evaluated.

There are additional idle states other than standby mode where the disk remains spinning but activity is reduced, or where the read/write heads are removed from the platters. The transition time from these idle states is typically less than 1 second. However, an idle mode power reduction strategy that involves temporarily reducing the speed of rotation in idle mode may exceed this time to transition. These idle states can consume significant amounts of power, particularly in 3.5-inch drives where 3 to 7 watts are common, making it one of the largest component contributors to desktop idle mode power. Smaller 2.5-inch drives have a much lower power draw in idle mode, typically between 0.5 and 1 watt. Substitution of a 2.5-inch drive for a 3.5-inch drive is, therefore, an option for reducing idle power consumption (and active power as well). The incremental cost can range from $0 for a 500 gigabyte (GB) drive to $10 for a 1 terabyte (TB) drive. The hardware incremental cost for implementing a lower RPM at idle is assumed to be $0 as the feature is widely available, although not widely used, in desktop hard disks.

The most recent technology to enter the data storage market is the solid-state drive. These hard drives do not use moving parts but store the data in flash memory, which is a silicon-based device. This format of data storage is much faster in idle mode transition and data transfer than magnetic storage and is used in computers where performance is paramount. Because there are no moving parts, the idle state characteristics are also much different. Solid-state drives are able to achieve extremely low transition times while consuming minimal power, typically less than 0.5 watt, although some achieve much lower levels. This power consumption is associated with the controller and interface system of the solid-state drive. There is some variance in this power draw, with some systems exceeding 1 watt. Solid-state drives that consume more power could transition to lower power controller technologies at little, if any, incremental cost to help a computer system comply with the proposed standards. However, solid-state drives are significantly more expensive than magnetic storage, which is the primary reason the technology has not become standard in most computers. Solid-state drive costs are decreasing, but so are the costs of magnetic storage devices. As a result, while replacing magnetic storage devices with solid-state drives is a way to reduce computer energy consumption, it has a high incremental cost. On the other hand, computers using solid-state drives will have maximized the storage opportunity to further reduce idle energy consumption while achieving maximum performance.

In addition to using the various power states of hard drives and swapping one technology for another, manufacturers have the option to take a two-technology approach. This approach involves combining a 2.5-inch magnetic or solid-state drive with a 3.5-inch magnetic drive. In fact, manufacturers make hybrid drives that combine solid-state storage and a 3.5-inch drive into a single housing. This approach uses a lower-idle technology to store the operating system and critical files of the computer system, thereby always having access to these data without a large idle power. The 3.5-inch storage is not rotating most of the time, except when less frequent access to bulk storage is necessary. Small capacity 2.5-inch drives and solid-state drives are relatively inexpensive. Adding solid-state memory also benefits system performance. The exact amount of storage necessary for the higher performance drive is not precise; however, industry participants in discussions have suggested 64 GB as a level that would achieve the power performance in idle goals with minimal consumer impact. At a cost of $0.20 per GB of solid-state memory, this would lead to an incremental cost of $12.80.

To comply with the standards, a manufacturer will have to be cautious with hard-disk choice, particularly depending on the level of efficiency of the power supply. A 7-watt idle power hard disk combined with a 60 percent efficient power supply contributes a total of 11.7 AC watts to idle, or the equivalent of 51 kWh/year when applying the conventional ENERGY STAR 6.1 duty cycle. A watt idle power variant of storage would consume only 7.3 kWh/year, yielding about $35 in savings over five years. While this is just an example, a typical case is considered later in the analysis in the discussion of system approaches.

Power Supplies

The computer power supply converts AC power to DC power for use by the motherboard and subcomponents. Historically, most desktop computers have used an internal power supply with multiple output voltages. These internal power supplies are rated for output power from 150 watts to more than 1,000 watts.

The conversion efficiency of these power supplies has been the focus of the 80 PLUS program. Beyond a basic 80 PLUS level, there is a tiered system of ratings ranging from “bronze,” which is slightly better than 80 percent efficient, to “titanium,” which is better than 90 percent efficient. The testing points lie generally at 20, 50, and 100 percent of maximum load, with the exception of the titanium rating, which also includes a requirement at the 10 percent loading point.

Unfortunately, the efficiencies achieved at higher loading points do not translate into similar efficiencies at lower loading points. The DC idle power levels achievable in desktop computer systems are significantly below the 10 percent loading point. The conversion efficiency at low-loading points can be extremely poor, with efficiencies below 60 percent at a 10-watt DC load.

For power supplies with a rated output of 350 watts or less, there are products in the market today that use circuit designs capable of reaching higher efficiency levels, even at low-loading points. The use of single voltage output external power supplies is increasing, generally paired with all-in-one computers and smaller form factor desktops. These power supplies can improve low-load efficiency by reducing fixed losses and by re-engineering to a load that better matches the load profile of higher-efficiency desktops.

Larger power supplies can incorporate a greater number of operational modes to scale power to the needs of the user. Power supplies have three modes of operation: on (full), sleep, and off. Without a separate sleep mode in the power supply, desktop computers would not be able to reach the low sleep mode powers they do today and that are required in the European Union. This allows the power supply to switch from a smaller supply to the larger one once the computer wakes from sleep. A similar approach could be taken for idle-mode power draw. If a power supply sleep state of some kind is not implemented, the idle mode power of larger more powerful systems will be strongly dominated by power supply losses.

In both cases reducing fixed losses in idle operation is the key opportunity. A simple way to reduce fixed loss would be to turn off the fan that is integrated into these power supplies. While the fan serves a purpose at higher loads, at the idle load, it can make up a significant percentage of the power supply losses. The power supply can rely instead on passive cooling to dissipate the remaining few watts of heat.

The 80 PLUS program requires power factor correction for certification,[50] demonstrating that power factor correction at full load is technically feasible to achieve, as there are a significant number of power supplies in the 80 PLUS program.[51] Moreover, minimum power factor requirements are already a feature of the U.S. Department of Energy's external power supply standards.

50 California IOUs, Response to Final Draft CEC Staff Report for Computers, pp. 11-12 (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211614_20160523T163525_California_Investor_Owned_Utilities_Comments_California_Investo.pdf.

51 http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN210102_20160130T110353_Douglas_McIlvoy_Comments_Results_from_laboratory_testing_for_th.pdf

Central Processing Unit (CPU)

The CPU is the primary and core computational power for a system, providing a generic platform to execute programming commands. Impressive improvements have been made in desktop CPUs over the last decade with the introduction of deeper "C" states, which are active processor states designed to reduce energy consumption during idle mode. Most modern processors have deep sleep states that allow for very low power consumption idle mode between 0.5 watt and 3 watts in comparison to active mode consumptions that can exceed 50 watts. The proposed standards focus on idle, sleep, and off modes, and in every case, the processor has little to no work to do, as these modes occur after a period of user inactivity. The system CPU should, therefore, be in a deep sleep. The proposed standards do not assume any change to the architecture or infrastructure of the processor, but rather that system designers take full advantage of existing features in CPUs today.

The deep sleep power consumption of a CPU can be somewhat disassociated from processing power and speed as reducing core voltage to zero negates transistor leakage altogether. System design routes most communication through the CPU, and communication controllers are often still powered up during idle. This accounts for the bulk of remaining idle power and does scale to the overall speed and performance of a system. However, this variance makes up a very small percentage of system power in idle and is somewhat handled by the expandability score modifier.

Optical Disk Drive

Optical disk drives (ODDs) are the Blu-ray and compact disc players found in many desktops. While the popularity of these players is diminishing in favor of flash memory, cloud storage, and streaming services, a significant number of units still ship with ODDs. The idle mode power consumption of an ODD can vary depending on manufacturer, system power management, and software power management. Power can be reduced by triggering advanced power management modes that allow ODDs to idle near 0.1 watt at no incremental cost. Alternatively, this can be driven even further to 0 watt as is done by zero-power optical disc drives (ZPODD) for notebooks. Stakeholders suggest that this comes at some additional cost for nonslim-style ODDs.

Volatile (System) Memory (RAM)

The energy consumption of this component is generally decreasing over time. In particular, the transition from double data rate Type 3 (DDR3) to DDR4 is expected to reduce energy consumption as well as increase performance. Although DDR4 has been available for some years now, the uptake has been slow in the mainstream desktop market. Further memory energy savings can be achieved by lowering clock speed and supply voltage during idle. The proposed standards scale with memory.

Motherboard

This component serves as the link and hub of all other components, which route communications through the motherboard. Other than sockets for additional components, the motherboard also contains several common and key controllers. Typically, these include network interface controllers, USB controllers, integrated sound, voltage regulation, and serial advanced technology attachment (SATA) controllers. Energy consumption by the motherboard can be limited through power states of these related controllers. Many interface controllers do not have connected devices, and these may be put into a deep sleep. For more powerful motherboards, incorporating multiphase voltage regulation can also provide energy savings. To some extent, the motherboard characteristics strongly drive the expandability score and, therefore, the standards scale by motherboard capacity.

Software

Software is not a physical component, but it usually determines whether the computer is in active mode, idle modes, or off. In idle modes, the demand on system resources is dictated by maintenance and background data tasks. Further, the operating system manages these tasks and requests, as well as transitions to large power state changes. Software management and organization of system resource requests into timed groupings increase the effectiveness of lower power states in components.

During the workshop on the second draft staff report and in written comments submitted afterward, industry members pointed out operating systems that did not use conventional sleep states or power management features. Chrome or Android operating systems, for example, do not enter the ACPI S3 sleep mode, although they do enter a low power state similar to sleep mode. In addition, computers are increasingly using “modern standby” to allow for a quick or remote wake feature for the product. To accommodate these types of alternative sleep modes, staff have proposed power consumption limits for these modes to ensure that they achieve the same efficiencies as conventional sleep modes and to retain incentives for power management. These power consumption levels are based on what these operating systems are able to achieve today after incorporating the same efficiency improvements expected of computers that use traditional sleep modes.

FreeDOS is an example of a limited functionality operating system without any power management capability. These types of operating systems are typically used by commercial customers to boot up the system one time so that users (typically information technology departments) can upload their own licensed operating system onto the computer. To address these limited functionality operating systems, staff has proposed exempting them from having to meet the power management requirements, although computers will still need to be tested with operating systems that have power management enabled.

Example Systems

Computer manufacturers make desktop computers that reach the proposed efficiency levels today. While there were only a few systems in 2014 that could meet the proposed targets, dozens were added in the ENERGY STAR Version 6.1 qualified product list in 2015. While these systems are available across ENERGY STAR performance levels, they tend to be small form factor computers with lower wattage output external power supplies.

Desktop system idle mode power consumption can vary greatly and is, at least in part, due to the versatility and computational power of the systems. However, nearly all components have the ability to enter lower power states when in idle. High performance systems, due to their powerful components, can easily and quickly exceed the proposed efficiency level if not sufficiently addressed. **Tables 6** and **7** below summarize some generalized builds that would meet efficiency targets similar to those proposed.

Table 6: Generalized Components, Power Draw, and Cost

Component		Power Draw	Incremental Cost
Hard Drive	3.5” 1 TB	6 watts (DC)	$0
	2.5” 1 TB	1 watt (DC)	$0
	Solid-state 1 TB	0.05 watts (DC)	$200
	Hybrid 1 TB	0.05 watts (DC)	$12
	2.5” + 3.5” 1 TB	1 watt (DC)	$20
Power Supply Unit	300 watt standard	9 watts (internal loss)	$0
	300 watt external power supply	3 watts (internal loss)	$10
	300 watt 80+ Gold	6 watts (internal loss)	$8
	Re-engineered idle mode	2 Watts (internal loss)	$14
Volatile Memory (RAM)	4 GB DDR3	3 watts	$0
	4 GB DDR4	2.5 Watts	$2
Motherboard	Standard	12 watts	$0
	Improved efficiency	9 watts	$3
	Best efficiency	6 watts	$10
Optical Disk	Standard	1 watt	$0
	Improved	0.1 watts	$0
	Zero power	0 watts	$2
CPU	Standard (C3 state)	9-10 watts	$0
	Standard (deeper state)	3-4 watts	$0
	Improved (Standard 2018)	2.5 watts	$0

Source: Energy Commission staff

Table 7: Midrange System Short-idle Comparison

Part	Standard Build	Standard Power	Efficient Build	Efficient Power	Incremental Parts Cost
CPU	Midrange CPU operating at C3	8 watts	Midrange CPU operating at C7	2.5 Watts	$0
Hard Disk	1 TB 3.5" drive	6 watts	1 TB 3.5" Drive 64 GB SSD, integrated	0.3 watts	$12
Optical Drive	1 Full size DVD player RW	1 watt	Power managed DVD Player	0.1 watts	$0
Motherboard	4 SATA, 2 USB 3.0, 6 USB 2.0, integrated sound, 1 PCIx16, 1 PCI x1, 4 DDR3 slots with 2, 1GB DIMMs, full ATX	8 watts	Same, improved power management, transition to DDR4	6 watts	$3
Power Supply	350 watt, 55% efficiency at loading point	18.8 Watts	350 watt, 75% efficiency at loading point	3 watts	$10
Total	-	41.8 Watts	-	11.9 watts	$25

Source: Energy Commission staff

Additional Hardware

There are many ways that the hardware of a computer can be expanded beyond typical or basic configurations. In many cases, this expansion will cause a corresponding increase in idle load consumption. Some examples include additional hard drives, integrated display, and discrete graphics cards. To account for these, the proposal includes specific energy allowances, commonly referred to as "adders." It is critical for adders to be sufficiently stringent as to avoid unintended incentives to add energy-consuming features for sake of compliance, potentially reversing some energy savings. It is also important that sufficient energy be allowed for these features to avoid unintentionally reducing the utility of a highly functional computer to the consumer.

Discrete Graphics Cards

Discrete graphics cards are used in computers to conduct supplemental graphical calculations, usually to support advanced graphics capability. These components are not present in all systems. Some systems rely on integrated graphics in the CPU or on the motherboard. These cards, given the computational power, can consume the majority of power in a system and can have direct connection to the power supply outside of power supplied through the motherboard. The idle mode power consumption of these cards has historically been significant, comprising the largest adders in the ENERGY STAR and European Union specifications.

Significant improvements have been made by graphics card designers and manufacturers in recent years. These improvements allow for large modification of these adders from the ENERGY STAR and European Union levels to the levels proposed in this staff report. When a discrete graphics card is present, generally the computer monitor(s) will be connected to that card to take advantage of the features and rendering power that would not be available through the on-motherboard video port. This has implications for short-idle mode, as the graphics card will need to be in some form of active mode to continue providing information to the still-active computer monitor. While the computational workload is the same in short-idle mode among an integrated graphics card, discrete graphics card, or high-end discrete graphics card, each scenario has varying levels of power overhead due to the potentially order of magnitude difference in the number of transistors. The proposed adder scales proportionally to the bandwidth of the graphics to account for differences in overhead.

However, for secondary graphics cards or for long-idle, very low idle power can be reached consistently across different capability graphics processors. In long-idle mode, the computer monitor is no longer active, and there is no need to provide and refresh data. This provides an opportunity to power down most of the overhead, leaving minimal controller functionality prepared to wake the graphics upon demand. A similar situation exists with secondary graphics cards where low computational demand means calculations can be performed on a single card, allowing the secondary card to sleep until needed.

Staff held a series of meetings with IOUs, NRDC, ITI, and the largest two graphic card design companies, NVIDIA and AMD, to discuss levels that would be appropriately adjusted from existing frameworks and to incorporate some future improvements as well. The results of these technical discussions are adders that are significantly more stringent than in existing standards and that represent significant technological progress. The adders were slightly modified from the second draft staff report to better reflect the anticipated energy savings that could be achieved from these components.

Integrated Display

Adders for integrated displays were proposed in the initial proposal. At that time, staff proposed to align the adder with ENERGY STAR Version 6.1. As discussed in the display section of this report, display efficiency has significantly advanced since the inception of adders in 2012 and was based on computers manufactured before that date. To adjust for improvements in technology, staff proposes to align the adder with the levels proposed for stand-alone displays presented later in this report with minor modification to simplify and smooth out the transition between different sizes.

Memory

Random access memory (RAM) temporarily stores data for CPUs and graphics. The speed of a computer is limited often by the speed of the memory rather than the CPU speed because a computer constantly reads and writes large amounts of data into the RAM when executing a program or displaying a graphic. Therefore, computer manufacturers are driven to increase the speed or bandwidth of system memories. High-bandwidth memories, however, normally lack efficiency and waste energy. High-bandwidth memories are often used in discrete graphics to support high-resolution screen data. These products can be paired with more efficient regular system memories that can handle most of the data used in idle modes. Staff proposes a high-bandwidth memory (HBM) adder for integrated desktops and notebooks with high-speed graphics and high-resolution displays that don't have sufficient RAM. This adder would also be applied to any computer where a majority of its memory is high bandwidth memory, regardless of the type of display.

System memory is typically directly connected on the motherboard and can be configured in different ways. For a given size, it can be configured as a single memory device, also called a *module*, or multiple modules. In the second draft, adders were proposed for memory devices that were scaled by the number of physical modules rather than the size of the memory space in idle. Further investigation of the contribution of RAM to energy consumption suggests that the energy consumption is connected more with the type of RAM and the size of the memory space rather than the number of physical modules in idle. After further discussion with both industry and efficiency advocates, the Energy Commission proposes to change the adder to a formula that combines the two approaches and includes a factor that is proportional to the memory size. This level is extrapolated from observed power consumption levels of DDR3 and DDR4 memories in sleep across several sizes and an assumption of 75 percent conversion efficiency.

Additional Hard Disks

Adders were proposed in the initial draft for additional hard disks that are aligned with ENERGY STAR 6.1. This level is appropriate for a typical 3.5-inch hard-disk drive if it is spinning in both short-idle mode and long-idle mode. However, the adder is excessive for smaller form-factor hard-disk drives and particularly excessive for solid-state drives. Introducing different adders for different hard-drive parts would also require the identification of the primary hard-disk drive versus the secondary as it could have implications to the allowable maximum energy use. The primary hard-disk drive is the hard-disk drive that has the largest capacity.

Ethernet

The Commission originally proposed an adder for Energy-Efficient Ethernet that was taken from the ENERGY STAR Version 6.1 specification and modified to a single number. This adder was presented as a calculation to be consistent with ENERGY STAR. However, the calculation does not contain any variables and, therefore, could be collapsed into a single number.

$$8.76 \times 0.2 \times 0.5 = 0.876$$

To simplify the adder, the Commission proposes to use 0.9 kWh per year for Energy-Efficient Ethernet. Both changes will reduce the potential for error and complexity of certification.

Add-In Cards

An *add-in card* is a type of expansion card that can be added to a desktop to increase functionality. All add-in cards consume some additional energy, and the amount varies depending on the feature. An add-in card would be used, for example, for a legacy port, a television tuner, wired Ethernet, redundant array of independent disks (RAID), SATA and USB add-ins, video surveillance, Wi-Fi, or discrete audio. To address add-in cards, staff has separated add-in cards that require more than 10 watts of energy from those that require 10 watts or less.

Both wired Ethernet and fiber cards with a transmission rate of 10 GB/second or greater, as well as video surveillance cards, require more power than other add-in cards. Staff proposes adders for these cards of 25 watts each. For all other add-in cards, staff proposes a flat 10-watt adder. These adders are roughly aligned with ITI's proposed adders in its comments on the second draft staff report.[52]

Notebook Computers

The technical feasibility and efficiency opportunities for notebooks are similar to those available in desktops. The frequency and extent to which these features and approaches have been incorporated into notebook computers is far greater than in desktop computers. More than half of the notebook computers certified to the older ENERGY STAR Version 5 specification meet the staff proposed notebook standard. In addition, more than 72 percent of models certified to the ENERGY STAR Version 6 specification meet the proposed levels as of November 5, 2014. New adders for graphics accelerators have been added consistent with the discrete graphics card section above and reflected in the proposed regulations. Additional adders that were considered and added for desktops were also added for notebooks, with levels consistent with the energy consumption expected in a notebook application. The expandability

52 ITI and Technet, Comments on CEC Staff Report, pp. 12-13 (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211618_20160523T170836_Christopher_Hankin_Comments_ITITechNet_Comments_on_Computers.pdf.

adder does not apply to notebook computers, which characteristically have very little expandability, resulting in a much smaller range of power supplies.

Small-Scale Servers and Workstations

Technical Feasibility

The requirements for these products have two hardware implications regarding power supply and network interface. The proposed regulations require the use of 80 PLUS program Gold level of performance. Power supplies are already broadly available at 80 PLUS Gold or better efficiencies, with more than 1,500 models listed across dozens of manufacturers.[53] Incorporating these efficient power supplies will lead to energy savings in the operation of these computer types by reducing alternating current (AC) to direct current (DC) conversion losses. In addition to saving energy in the computer itself, the enhanced power factor correction of 80 PLUS power supplies will save energy in building wiring distribution and utility infrastructure.[54]

Power supplies in the computer industry are standardized around the "Advanced Technology eXtended" (ATX) specification[55] and tend to have little interaction with the functionality of a computer beyond providing necessary power. Therefore, the proposed efficiency standards should not affect the functionality of these servers and workstations other than to reduce overall system heat, which should increase system performance.

Energy-Efficient Ethernet standards specified by the Institute of Electrical and Electronics Engineers (IEEE) 802.3az can be found in many products in the market. This functionality is generally enabled in the network interface controller or card (NIC), and major chip manufacturers offer this functionality. The 802.3az standard does not have a significant negative effect on the networking functionality of a server or workstation and, in fact, provides enhanced functionality.

Cost

The incremental cost of the proposed workstation standards is driven by the cost of the improved power supply. Estimates from the computer industry, power supply manufacturers, and IOUs provided over the pre-rulemaking have varied greatly, with incremental costs ranging per unit from \$1.75[56] to \$23.85.[57] The IOUs similarly investigated the incremental cost,

53 1,594 products listed as of November 23, 2015. For a listing of 80 PLUS-certified products, see http://www.plugloadsolutions.com/80pluspowersupplies.aspx.

54 http://plugloadsolutions.com/docs/collatrl/print/80plus_power_quality.pdf.

55 http://www.formfactors.org/developer/specs/Power_Supply_Design_Guide_Desktop_Platform_Rev_1_2.pdf

56 BOM cost of improving from baseline 80 compliant to 80 PLUS Gold. Comments submitted to the Energy Commission by the Green Tech Leadership Group, May 9, 2013, p. 5. http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Consumer_Electronics_12-AAER-2A/Green_Technology_Leadership_Group_Letter-Consumer_Electronics_2013-05-09.pdf

57 Consumer costs of improving from non-80 PLUS power supply. ITI comments submitted to the Energy Commission, May 9, 2013, available at

including those presented by other stakeholders, and applied a $1.31 markup from previous DOE work.[58] The IOU incremental cost estimate was $5 to $13, decidedly between the two more extreme bounds of the ITI and Green Tech Leadership Group estimates. Staff incorporated the highest IOU cost in its analysis.

Future Technologies

During the comment period on the second draft staff report, both industry and efficiency advocates expressed concern about "future-proofing" the standard, that is, making sure that the standard would still achieve energy savings during the lifetime of the standard while providing a way for new technologies or innovations to be incorporated into the standard. Because this issue arises with respect to technologies that do not yet exist, it is difficult to address in existing regulatory text.

The Energy Commission's petition for a rulemaking can address this issue. For an interface type or adder that is not listed in the regulatory text and that did not exist at the time of the adoption hearing for the regulation, any person(s) may petition the Commission to request a rulemaking hearing under Section 1221 of Title 20 to consider adding an interface score (for calculating expandability) or functionality adder. The Commission also has a process to handle trade secrets or confidential business information. Such confidential information must be submitted under Section 2505(a) of Title 20 to protect the confidentiality of the information.

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http://www.energy.ca.gov/appliances/2013rulemaking/documents/responses/Consumer_Electronics_12-AAER-2A/Information_Technology_Industry_Council_Comment_Letter_2013-05-09_TN-70709.pdf, p. 19.

58 Marked up bill-of-materials figures for upgrading a noncompliant 80 PLUS power supply to 80 PLUS Gold. IOU comments submitted to the Energy Commission, August 6, 2015, p. 35.

CHAPTER 7: Energy Savings and Cost-Effectiveness

The energy savings for computers are characterized by the difference in efficiency between what computers consume today and what they would consume if they complied with the proposed regulation. The computer industry is making progress toward better efficiency, and other programs such as ENERGY STAR are likely to continue to exert market pressure to improve efficiency as well. The savings do not attempt to separate credit among ENERGY STAR, consumer demand, mandatory standards, and other market drivers for the transition to the improved efficiencies; instead, they characterize the value of making the market transition regardless of market driver. Since the second draft staff report, overall energy savings estimates have been reduced, primarily from decreased stringency in the proposed standards from the inclusion of new adders and the new effective dates for desktops. **Tables 8** and **9** compares the energy savings and cost-effectiveness per unit of a product under the proposed standards. The energy savings and incremental costs are calculated given that some products are already compliant and, therefore, the associated energy savings and incremental cost are zero.

Table 10 provides an analysis of the statewide savings after the first year of the standards and after all existing stock is replaced by compliant products (stock turnover).

Table 8: Unit Energy Savings and Cost-Effectiveness (Tier 1), ITI Dataset

Product Type	Average Energy Use – Baseline (kWh/yr)	Average Energy Use – Tier 1 Compliant (kWh/yr)	Design Life (yr)	Life-Cycle Savings (kWh/yr)	Life-Cycle Savings ($)[59]	Incremental Cost ($) Tier 1	Net Benefit (ratio benefit: cost)
Desktop	133.7	103.3	5	152	$24.32	$9.55	$14.77 (2.55: 1)
Notebook	33.4	29.8	4	14.4	$2.30	$1.00	$1.3 (2.30: 1)
Small-Scale Server	302.0	278.0	5	120	$19.20	$13.00	$6.20 (1.48: 1)
Workstation	469.3	431.9	5	187	$29.92	$13.00	$16.92 (2.30: 1)

Sources: Energy Commission staff

59 Using $0.16 per kWh.

Table 9: Unit Energy Savings and Cost-Effectiveness (Tier 2), ITI Dataset

Product Type	Average Energy Use – Baseline (kWh/yr)	Average Energy Use – Tier 2 Compliant (kWh/yr)	Design Life (yr)	Life-Cycle Savings (kWh/yr)	Life-Cycle Savings ($)[60]	Incremental Cost ($) Tier 2	Net Benefit (ratio benefit: cost)
Desktop	133.7	84.6	5	245.5	$39.28	$14.00	$25.28 (2.81: 1)
Notebook	33.4	29.8	4	14.4	$2.30	$1.00	$1.3 (2.30: 1)
Small-Scale Server	302.0	278.0	5	120	$19.20	$13.00	$6.20 (1.48: 1)
Workstation	469.3	431.9	5	187	$29.92	$13.00	$16.92 (2.30: 1)

Sources: Energy Commission staff

Table 10: First-Year and Stock Turnover Savings (Tier 2), ITI Dataset

Product Type	Unit Savings (kWh/yr)	Unit Sales (million)[61]	Unit Stock (million)[62]	1 Year Sales Savings (GWh/yr)	Stock Savings (GWh/yr)	Reduced Electricity Cost ($M/yr)
Desktop	49.1	4.12	20.91	202.3	1,026.7	$164.27
Notebook	3.6	5.83	23.12	20.99	83.23	$13.32
Small-Scale Server	24.0	0.06	0.3	1.44	7.2	$1.15
Workstation	37.4	0.106	0.53	3.97	19.82	$3.17
Total	-	10.12	44.86	-	1136.96	$181.91

Source: Energy Commission staff

The stock numbers in **Table 10** are projected for 2027 when the entire stock is turned over and all computers are assumed to be Tier 2-compliant. The shipments are calculated based on the design life of each product and the associated stock numbers.

The savings calculations for desktops presented in **Tables 8, 9** and **10** used a different dataset than the first and second draft staff reports. Therefore, the savings estimates between the two

60 Using $0.16 per kWh.

61 Shipment figures for desktops and notebooks are calculated based on design life and stock numbers taken from the ITI July 23, 2013, comments. Figures for small-scale server and workstation shipments were taken from an August 6, 2013, IOU comment letter projections on shipments in 2017, on p. 24.

62 Stock figures for desktops and notebooks are taken from ITI July 23, 2013, comments, which specifically cite KEMA 2010 as the source on page 22. Figures for small-scale servers and workstations were taken from August 6, 2013, IOU comment letter projections on shipments in 2017, on p. 24. Stock of small-scale servers was corrected to be equal to the annual shipments multiplied by the five-year life span.

reports are not directly comparable. The first and second draft staff reports used the ENERGY STAR dataset for desktop computers, whereas this staff report relies on a dataset prepared by ITI that included computer models that were not certified to ENERGY STAR. Staff initially calculated the expected energy savings from its previous proposal using the new dataset, then worked from there to identify the effects of changes to the TEC levels on the expected energy savings. The ITI dataset is available for review in the Energy Commission's docket for this proceeding.

To provide a basis for comparing energy savings with previous staff reports, staff applied the approximate savings to the ENERGY STAR database to calculate Tier 1 and Tier 2 energy savings for desktop computers. The results are shown in **Tables 11** and **12**.

Incremental cost is also different from previous draft staff reports. It has been adjusted proportional to the energy savings for each tier compared to the original energy savings from the second draft staff report. The cost is also adjusted to calculate the average cost considering the fact that some computers are already compliant. This factor was not accounted for in the previous staff report.

Table 11: Unit Energy Savings and Cost-Effectiveness for Noncompliant Desktop Computers, ENERGY STAR Dataset

Product Type	Average Energy Use – Baseline (kWh/yr)	Average Energy Use Compliant (kWh/yr)	Design Life (yr)	Life-Cycle Savings (kWh/yr)	Life-Cycle Savings ($)	Incremental Cost ($)	Net Benefit (ratio benefit: cost)
Tier 1	143.20	88.73	5	272.37	$43.58	$9.55	$34.03 (4.56:1)
Tier 2	143.20	70.21	5	364.95	$58.39	$14.00	$44.39 (4.17: 1)

Source: Energy Commission staff

Table 12: First-Year and Stock Turnover Energy Savings (Tier 2), ENERGY STAR Dataset

Product Type	Unit Savings (kWh/yr)	Unit Sales (million)[63]	Unit Stock (million)[64]	1-Year Sales Savings (GWh/yr)	Stock Savings (GWh/yr)	Reduced Electricity Cost ($M/yr)
Desktop	72.99	4.12	20.91	300.72	1,526.22	$244.20
Notebook	3.6	5.83	23.12	20.99	83.23	$13.32
Small-Scale Server	24.0	0.06	0.3	1.44	7.2	$1.15
Workstation	37.4	0.106	0.53	3.97	19.82	$3.17
Total	-	10.12	44.86	-	1,636.47	$261.84

Source: Energy Commission staff

During the rulemaking, the Commission received comments regarding the accuracy of the estimated energy savings from not including "active" modes in the duty cycle. The IOUs and NRDC estimate that the savings would be even larger than estimated because savings would scale with the higher power use in active mode. ITI and Intel estimate that the savings would be smaller than estimated because certain improvements that save energy in idle mode would yield little to no energy savings in active modes. Both concepts are correct, and the extent depends on which improvement options a manufacturer chooses. The Commission does not expect this to affect the cost-effectiveness of the regulations. Manufacturers would systematically choose improvements that only provided benefit in idle mode if those improvements were significantly less expensive than others. In that sense, savings would be decreased but cost would also be decreased.

63 Shipment figures for desktops and notebooks are calculated based on design life and stock numbers taken from the ITI July 23, 2013, comments. Figures for small-scale server and workstation shipments were taken from an August 6, 2013, IOU comment letter projections on shipments in 2017, on page 24.

64 Stock figures for desktops and notebooks are taken from ITI July 23, 2013, comments, which specifically cite KEMA 2010 as the source on page 22. Figures for small-scale servers and workstations were taken from August 6, 2013, IOU comment letter projections on shipments in 2017, on page 24. Stock of small-scale servers was corrected to be equal to the annual shipments multiplied by the five-year lifespan.

CHAPTER 8: Environmental Impacts

The improvement in energy efficiency in computing is not likely to change the material composition of computers. In many cases, lower power consumption will lead to smaller computers and even less material use. Generally, the regulations are not designed to reduce maximum power; instead, they target only idle, sleep, and off mode power. However, some efficiency approaches to reducing idle power can lead to reductions in active mode power and, therefore, save some potential material and disposal impacts. That being said, the proposed regulations are not expected to have any major impact on electronic waste within the state.

The proposed standards will, however, lead to improved environmental quality in California. Saved energy translates to fewer power plants built, and less pressure on the limited energy resources, land, and water use associated with it. In addition, lower electricity consumption results in reduced greenhouse gas and criteria pollutant emissions, primarily from lower generation in hydrocarbon-burning power plants, such as natural gas power plants. The energy saved by this proposal is estimated to avoid direct greenhouse gas emissions associated with electricity production by 0.513 $MMTCO_2e$.[65]

65 Million metric tons of carbon dioxide equivalents are calculated by using conversion of 690 pounds per MWh to metric scale, using the rate estimated by the *Energy Aware Planning Guide,* CEC-600-2009-013, February 2011, Section II: Overview, p. 5.

Part B – Computer Monitors and Signage Displays

CHAPTER 9: Background

More than 25.2 million computer monitors are installed in homes and businesses in California.[66] Statewide, computer monitors consume about 1,527 gigawatt hours (GWh) of electricity per year. Computer monitors contribute to a peak demand of almost 206 megawatts (MW).[67]

There are no state or federal standards for computer monitors. Computer monitor manufacturers are not required to report energy consumption information, such as brightness levels, for their products to the U.S. Department of Energy (DOE) or the Federal Trade Commission.

The U.S. Environmental Protection Agency (EPA) ENERGY STAR program has voluntary specifications for computer monitors. ENERGY STAR Version 6.0 for computer monitors has been in effect since January 2013.[68] Many manufacturers have computer monitor models that meet Version 6.0 specifications.[69] According to data reported to the U.S. EPA, Version 6.0 had achieved 93 percent market penetration, meaning that most of the computer monitors market met ENERGY STAR Version 6.0 standards. U.S. EPA finalized its Version 7.0 specification in October 2015, which took effect on July 1, 2016.[70] U.S. EPA has stated that data analysis of ENERGY STAR-compliant monitors shows that more than 20 percent of computer monitors sold meet ENERGY STAR specification Version 7.0.[71]

After analyzing potential energy-saving features in computer monitors and displays and associated costs, Energy Commission staff has determined that the proposed standards are technically feasible and cost-effective and would save significant amounts of energy. The

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66 IOU CASE Response: Electronic Displays available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf. Page 12. Staff confirmed these estimates by researching studies on the existing stock of these products in the United States.

67 2013 CASE study: Analysis of Standards Proposal for Electronic Displays, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf.

68 http://www.energystar.gov/sites/default/files/specs//Final_Version_6%200_Displays_Program_Requirements.pdf.

69 Eighty-eight percent of LCD monitors shipped meet Version 6 from the Unit Shipment Data Report CY 2014, available at https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2014_USD_Summary_Report.pdf?6d2e-c6c5

70 Overview of Final Criteria: ENERGY STAR Version 7.0 specifications, available at http://www.energystar.gov/sites/default/files/FINAL_Version7_Displays_CoverMemo_501.pdf.

71 "Over 20% of computer monitor models in the current Version 6.0 Consumption the Total Energy Consumption requirements for computer monitors ENERGY STAR dataset meet the proposed Draft 2 Version 7.0 Total Energy Consumption requirements."
Source: EPA ENERGY STAR 2015
https://www.energystar.gov/sites/default/files/Version7DisplaysDraft2CommentResponses.pdf.
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remainder of this report describes the efficiency opportunities and potential savings for computer monitors and displays.

CHAPTER 10: Product Description

Scope

Three types of computer monitors are analyzed in this report: computer monitors, gaming monitors, and enhanced performance displays (EPDs). This report also discusses signage displays, which are considered a type of television.

The following types of displays are not considered in the proposed regulations:

1. Electronic reader displays (for example, smog analyzers)
2. Digital picture frames
3. Electronic billboards
4. Professional multipanel signage displays that are typically composed of several displays with a diagonal screen size of 12 inches or greater and designed for use in stadiums
5. Televisions (except signage displays)
6. Integrated displays (for example, those built into laptop computers or all-in-one personal computers, and multimedia projectors); integrated displays are covered in the computer standard (Part A)

Computer Monitors

A computer monitor displays graphical information, and the primary function is to produce visual information from a computer, workstation, or server via one or more inputs (for example, Video Graphics Array (VGA), Digital Video Interface (DVI), High-Definition Multimedia Interface (HDMI), DisplayPort, Instiute of Electrical and Electonics Engineers (IEEE) 1394, and USB). Computer monitors are typically intended for one person to view in a desk-based environment. Monitor components include a display device, a backlight unit, electronic circuitry, casing, and a power supply. The display device is typically a thin-film transistor (TFT) liquid crystal display (LCD), although other technologies such as organic light-emitting diodes (OLEDs) and quantum dot displays may come to market.[72] The backlight includes LEDs or other lamps to provide light, an optical film stack to direct the light to the panel, controllers, and drivers. Electronic circuitry includes a main processor and component controllers. The power supply includes a transformer, AC-to-DC rectification (conversion), and DC voltage stepdown components.

The proposal scope includes displays of a diagonal screen size greater than or equal to 17 inches and a pixel density greater than 5,000 pixels per square inch (pixels/in^2). Computer

72 A display screen made with thin-film transistor technology is a liquid crystal display (LCD) that has a transistor for each pixel (that is, for each tiny element that controls the illumination of the display). Having a transistor at each pixel means that the current that triggers pixel illumination can be smaller and can be switched on and off more quickly.

monitors less than 17 inches are not considered here, as sales volumes of these displays are low and are expected to decrease.[73] Curved monitors are included in the scope of this report. Curved monitors have a curved screen and therefore a larger screen area, but are otherwise similar to other computer monitors. They are relatively new to the market, so little information is available about their energy consumption or performance.

Liquid Crystal Display Panels

Most computer monitors contain LCD panels. An LCD is made up of millions of pixels consisting of liquid crystal subpixels that selectively filter light produced behind the panel for the desired color. A wide range of color hues can be produced on the larger display.

Backlighting

LCD displays require backlighting to form and project images and to allow the display to function. LEDs provided the backlight for the display. Until recently, cold cathode fluorescent lamps (CCFLs)[74] were a less expensive light source. Today, LEDs are not only more efficient, but available at low cost. Consequently, they dominate the display market. Backlight-display LEDs can be arranged either in an edge-lit or a full-array configuration.

- Edge-lit configurations use fewer total LEDs and locate them along the edge of the screen; light from LEDs is redirected from the edge of the monitor toward the viewer through a light guide plate to spread the light evenly behind the LCD panel.

- Full-array configurations use LEDs to cover the entire backside of the backlight unit.[75] In this configuration, LEDs are placed behind the screen, and the brightness is globally (rather than individually) controlled.

In either configuration, the lamps are controlled using one of two techniques. The simpler method is *global control*, where all lamps output the same brightness. If the display has global dimming, it has the ability to scale lamp brightness to the brightness of the content being shown or to ambient light conditions. The second method is *dynamic local dimming backlight* or *dynamic contrast ratio (DCR) configuration*, in which lamps are controlled individually or in clusters to control the level of light or color intensity in a given part of the screen. Typically,

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73 *Analysis of Standards Proposal for Electronic Displays available* at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf, pp. 19 and 20.

74 A *cold cathode fluorescent lamp* (CCFL) is a lighting system that uses two phenomena: electron discharge and fluorescence. CCFLs are used mainly as light sources for backlights in televisions, because they are smaller and have longer lifetimes than ordinary fluorescent lamps.

75 "What Is a Direct-Lit LED LCD TV?" *Consumer Reports,* May 8, 2012. Available at http://www.consumerreports.org/cro/news/2012/05/what-is-a-direct-lit-led-lcd-tv/index.htm.

computer displays have a contrast ratio of about 1000:1. With DCR, these numbers vary from 4000:1 to 10,000:1, and higher.[76]

Optical Film Stack

Once light is produced, another key component of the monitor is the optical film stack, which spreads light evenly across the display area and directs light toward the LCD panel. Working from the light guide plate to the LCD panel, a film stack often contains a diffuser film to further spread the light exiting the light guide plate, and one or two prism films that direct the light into the direction(s) useful for the application. For example, a monitor that has a wide viewing angle would use a prism film to spread light horizontally from the screen but limit light spreading vertically since the monitor is not typically viewed from above or below. A monitor designed to have a narrow viewing angle for increased privacy may have two prism films, crossed in opposite orientations to direct light straight out of the screen. Although not standard practice in typical monitors, the inclusion of a reflective polarizer between the prism film and the LCD panel improves efficiency by passing only properly polarized light to the LCD panel and reflecting the rest of the light back into the backlight unit to be recycled.

Types of LCD Display Panels

Liquid crystals in an LCD panel alter their crystalline orientation when voltage is applied, resulting in different transparency levels. The light exiting the film stack first passes through a polarization film and gets modulated by the liquid crystals. Modulated light then passes through a color filter. Most manufacturers use a pixel made up of three subpixels that produce red, green, and blue light. Some manufacturers add a fourth pixel of yellow to enhance the yellow, gold, and brass color renditions by expanding the pixel color gamut.[77,78] Different amounts of light passing through LCD openings provide a pixel-specific color. By selectively illuminating the colors within each pixel, a wide range of hues can be produced on the larger display.

There are various types of LCD structure technologies available in the market that use thin-film transistor technology to operate the opening and closing of LCDs. All the technologies rely on an electric stimulation of the LCD structure. Depending on the panel type, an electric stimulation creates an opening or a closing in the LCD structure to allow the light to pass through. The monitor or display characteristics that are critical for quality operation include response times, viewing angles, and color accuracy.

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76 "Just What's So 'Dynamic' About Contrast Ratio Anyway?" *Cnet*, August 6, 2008. Available at http://www.cnet.com/news/just-whats-so-dynamic-about-contrast-ratio-anyway/.

77 "Sharp Intros 'Industry Firsts' Four-Color Filter, 68-Inch LED TV," *Cnet*, January 6, 2010, available at http://www.cnet.com/news/sharp-intros-industry-firsts-four-color-filter-68-inch-led-tv/.

78 "What Is Sharp Aquos Quattron, Quad pixel, and Quad color LED TV Technology?" Available at http://lcdtvbuyingguide.com/hdtv/sharp-quadcolor.html.

There are three LCD technologies used in display panels.

Twisted Nematic Panels

Twisted nematic (TN) panel LCDs have a relatively fast response time, usually about two milliseconds, and are less expensive to produce than other panel technologies. The disadvantages of TN panels are narrow viewing angles, relatively low brightness, and inaccuracies in color reproduction. Unlike other LCD technologies, when no voltage is applied across a pixel on a TN panel, the pixel is open, and light passes through it. Thus in applications such as word processing or spreadsheets, where a large proportion of the screen is white, TN panels use less power than other technologies. However, monitors are used increasingly for video and other darker content, for which a TN panel would use more power and might not be the best choice.

Vertical Alignment Panels

Vertical alignment (VA) panels have improved viewing angles as compared to TNs. VAs also tend to have better color reproduction and typically have a higher brightness. In addition, they tend to have the darkest black levels of all three panel technologies. However, the response time and input lag of a VA panel are not quite as fast as that of a TN panel.

In-Plane Switching Panels

In-plane switching (IPS) based monitors offer the best viewing angles and produce the most accurate colors of the LCD panel technologies. The black levels are not as deep as VA panels but are better than TN panels. IPS monitors are the slowest of the panel types in both response time and input lag. Wider viewing angle and better contrast of IPS compared to TN make IPS panels popular for video content applications like gaming and watching television.

Organic Light-Emitting Diodes Panels

Recently, organic light-emitting diodes (OLEDs) have become available in the small-screen display market, such as smartphones, although they have not been commercially released for computer monitors. OLED monitors have the potential to be much more efficient than LCD displays but are more expensive. OLED technology emits, rather than filters, light at each subpixel. This emitting electroluminescent layer is a film of organic compounds that emit light when voltage is applied. These emissive displays promise to reduce energy consumption by generating only the light that is needed to show a picture, rather than lose light through filters. In addition, OLED panels have no need to use a backlight to produce an image. Instead, voltage is applied across organic thin films made of a cathode, an anode, and two organic materials. As the current passes through the materials, they produce a light similar to LED technology. This technology is new and is being applied to smartphones and other small-screen applications. It is expected to compete with LCD technology due to superior contrast ratio, viewing angle, color gamut, color accuracy over LCD panels, and low energy consumption, if manufacturers can overcome technical challenges.[79] OLEDs have the potential to be less expensive and more efficient than LCDs since there are fewer components involved in creating an image.

Resolution

A key characteristic of computer monitors is resolution. *Resolution* of a computer monitor describes the number of pixels that occupy the viewable screen area. The maximum resolution available in computer monitors has increased over time and will likely continue to increase with the adoption of newer technologies and the demand and need for higher resolutions to accommodate better picture quality on larger screens.

Display resolution is measured in megapixels (MP), and it is usually quoted as width × height, with the units in pixels. For example, 1024 × 768 means the width is 1024 pixels and the height is 768 pixels. Some common resolutions are Super eXtended Graphics Array (SXGA), Wide eXtended Graphics Array (WXGA), Wide eXtended Graphics Array plus (WXGA+), and Wide Ultra-eXtended Graphics Array (WUXGA). Out of the standard graphics arrays, WUXGA has the highest resolution at 1,920 pixels by 1,080 pixels (1920X1080, or 2.07 MP). Recently, Quad High Definition (QHD) entered the monitor market with resolution of 2560X1440, or 3.69MP. Table 13 describes resolution bins for computer monitors.

Displays have come on the market with even greater resolution such as "4K" and "5K" or Ultra-High-Definition (UHD) designs that incorporate 8.3 MP and 14.75 MP display panels. For LCD displays, an increased power draw for larger resolutions is expected, all other aspects being equal (such as size, brightness, and panel technology). Higher resolution means more pixels, which increase the area of the electronics that control pixel operation, reducing the transmissivity of the panel. To maintain screen luminance, this requires increased output from the backlight, which correlates to increased display power.

79 2013 CASE Study: *Analysis of Standards Proposal for Electronic Displays*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf.

Table 13: Resolution Bins for Computer Monitor Dataset

Resolution Bin	Total Native Resolution (MP)
≤XGA	0 – 0.786
≥UXGA	1.920
≥WUXGA	2.07 and higher
SXGA	1.311
WSXGA	1.51 – 1.76
WXGA	1.024 – 1.049
WXGA+	1.296
QHD	3.686
UHD-4K	8.3
UHD 5K	14.75

Source: IOU CASE Report (2013) and Dell

Power Modes

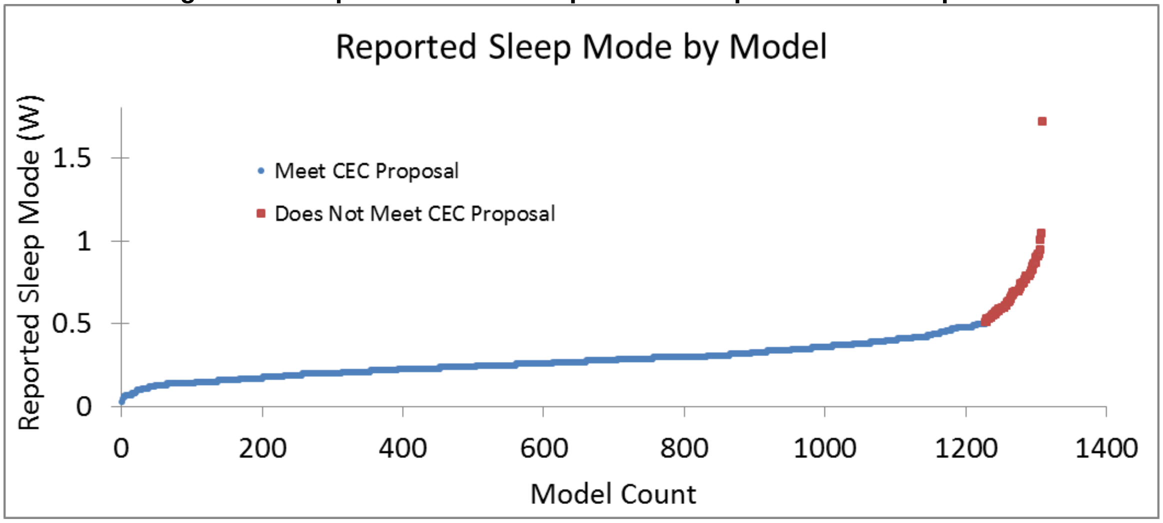
A computer monitor can operate in three primary power modes: on, sleep, and off. Power consumption in all three power modes is described in watts (W).

On Mode: The mode in which the display has been activated and provides the primary function. On mode occurs when the display is powered and displays an image. Primary functions include displaying input whether from a computer, internal memory, or other source. The terms “active,” “in-use,” and “normal operation” also describe this mode. The power draw in this mode is greater than the power draw in sleep and off modes. Power draws for displays in on mode depend on display technology, screen size, and resolution.

Sleep Mode: A low-power mode in which the display provides one or more nonprimary protective functions or continuous functions. Sleep mode eases the activation of on mode via remote switch, touch technology, internal sensor, or timer; provide information or status displays, including clocks; support sensor-based functions; or maintain a network presence.

A display enters sleep mode after a period of inactivity, usually triggered by a signal from a connected device or an internal stimulus (such as a timer or occupancy sensor). The product must re-enter on mode upon receiving a signal from a connected device, network, or control device. While the product is in sleep mode, it is not producing a picture. **Figure 6** shows reported sleep modes from models from the ENERGY STAR-certified products list.

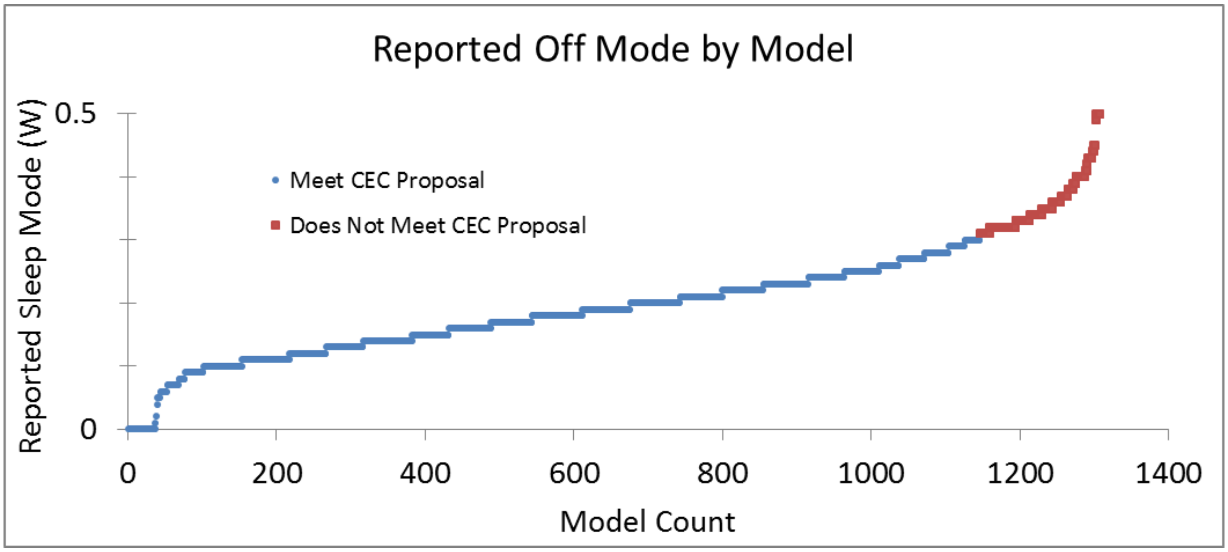
Figure 6: Computer Monitor Sleep Mode: Sleep Mode Consumption



Source: IOU CASE Response (2015), p. 16.

Off Mode: The lowest power mode is reached when the user powers down the display by manually switching it off. In off mode, the product is connected to a power source but is switched off and not performing any function. The display may exit this mode only by direct user actuation of an integrated power switch or control. **Figure 7** shows reported off mode from models from the ENERGY STAR-certified products list. Some computer monitors do not have an off mode, while other displays refer to off mode as standby.

Figure 7: Computer Monitor: Off Mode Consumption



Source: IOU CASE Response (2015), p. 16.

Other Factors

Computer monitors have other features that can consume additional power in on mode and sleep mode. Some of these include built-in speakers, USB ports or high-definition multimedia interface (HDMI), digital visual interface (DVI), and other ports that provide additional functionalities and consume additional energy. Other features include touch screen capability, built-in camera, microphone, and 3D capability. These features may add to the energy consumption when enabled and to the price of the monitor. There are technologies that can limit the energy consumed by the additional features when not in use. Speakers, cameras, and microphones can be turned off when these functions are not requested by the user. USB, HDMI, and DVI ports can be powered down or turned off when the corresponding cables are disconnected.

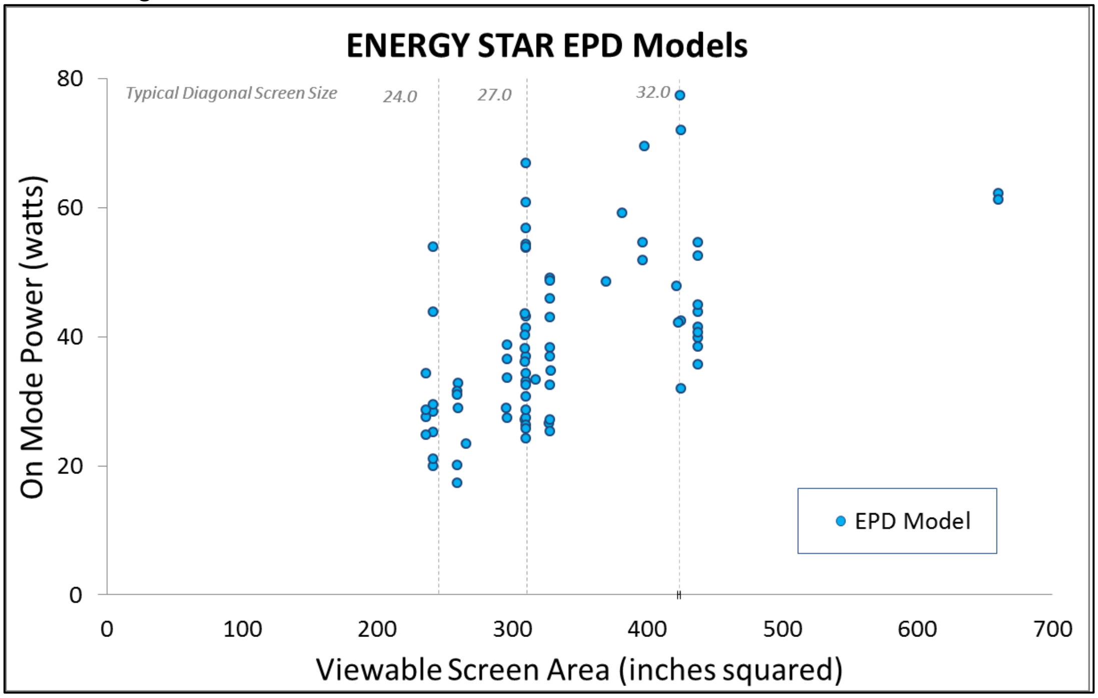
Enhanced-Performance Displays

Enhanced-performance displays (EPDs) are different from standard computer monitors. EPDs provide increased color gamut, greater contrast ratio (at least 60:1), better viewing angles (at least 85° horizontal viewing angle), higher resolution (at least 2.3 MP), integrated accessories, and expansion potential. EPDs are designed for specialized applications such as engineering, medical, architecture, and graphic design. The IOUs' analysis of EPDs shows that EPDs require additional power compared to mainstream computer monitors; however, there are opportunities for improvements in the EPDs similar to mainstream computer monitors.[80]

80 IOU CASE Updated Information on Computer Monitors and Signage Displays, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf, pp. 4-5.

Figure 8 is plotted based on ENERGY STAR Version 6.0 data for EPDs. It shows that there is a wide variation in power consumption among same-size EPDs in on-mode.

Figure 8: ENERGY STAR Data for EPD: On Mode Versus Screen Area



Source: IOUs CASE Response to Staff Report (2015)

EPDs use two color schemes, called for short, sRGB and Adobe RGB. RGB is the color space that encompasses all the visible colors. However, it is not possible to include all visible colors into a digital representation. Because of this, alternative color spaces like sRGB and Adobe RGB were created. Both color spaces can represent up to 16 million colors. The main difference between the two is what colors they cover. SRGB was created first and covered only a fraction of the entire RGB range. An "sRGB" EPD means that it covers 32.9 percent of CIELUV[81] (99 percent or more of defined sRGB colors). Adobe RGB covered more of the RGB color space in shades of green. Adobe RGB has a wider range of colors, and the difference between colors is bigger than in sRGB. As a result, an Adobe RGB EPD uses more power than sRGB. An "Adobe RGB" EPD means that it covers at least 38.4 percent of CIELUV (99 percent of Adobe RGB colors). ENERGY STAR Version 7.0 established power adders to calculate the on mode power limit for EPDs to account for additional power consumption due to the enhanced capabilities of EPDs.

EPDs may draw more power than conventional counterparts for two reasons. First, the LCD panel transmissivity is lower in an EPD than a standard monitor. The IOUs measured panel

81 CIELUV is the common abbreviation to signify a color space adopted by the International Commission on Illumination (CIE) in 1976.

transmissivity of 3 percent for two EPDs[82] compared to 6 to 11 percent for standard monitors.[83] The lower transmissivity in EPDs is likely due to the presence of more color filters and thin-film transistors in the LCD panel and leads to higher backlight power to produce the additional light required for a comparably bright screen. The IOUs measured back light unit (BLU) power of two EPDs to be 36 to 50 percent more than that of two standard monitors in the default modes. The IOUs also noted that the power scaling modes of EPDs cut backlight power to less than that of the standard monitors in equivalent modes (**Table 14**).

Second, additional data processing may be required to drive the LCD panel. The IOUs measured the power of all components except the BLU (but including the LCD driver, PSU losses, and other components) to be 20 to 72 percent larger for EPDs than standard monitor counterparts. This increase likely includes an increased LCD driver power but also may include additional PSU losses and other signal processing power.

Analysis of all market data, including the ENERGY STAR Version 7.0 data models that are in July 2016 database, shows there are about 49 EPD sRGB models available in the market, and 38 meet the proposed standard with the proposed adder.[84,85] There are 21 Adobe RGB EPDs in the dataset, and 12 of these meet the proposed standard with the proposed adder. EPD market share is about 2 to 3 percent of the total computer monitor market. No sales growth estimates are available. Because of the better quality picture, some speculate that EPDs will grow in market share. However, these products cost significantly more than conventional computer monitors, making it unlikely that they will achieve significant market penetration.

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82 IOUs 2015. Response to ECE Staff Report for Computer Monitors and Signage Displays, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf.

83 IOUs 2014. *Electronic Displays Technical Report – Engineering and Cost Analysis*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Supplemental_Technical_Report_Electronic_Displays_2014-01-08_TN-72475.pdf.

84 CIELUV is the CIE 1976 (L^*, u^*, v^*) color space, adopted by the International Commission on Illumination (CIE) in 1976 and is commonly known by the abbreviation CIELUV.

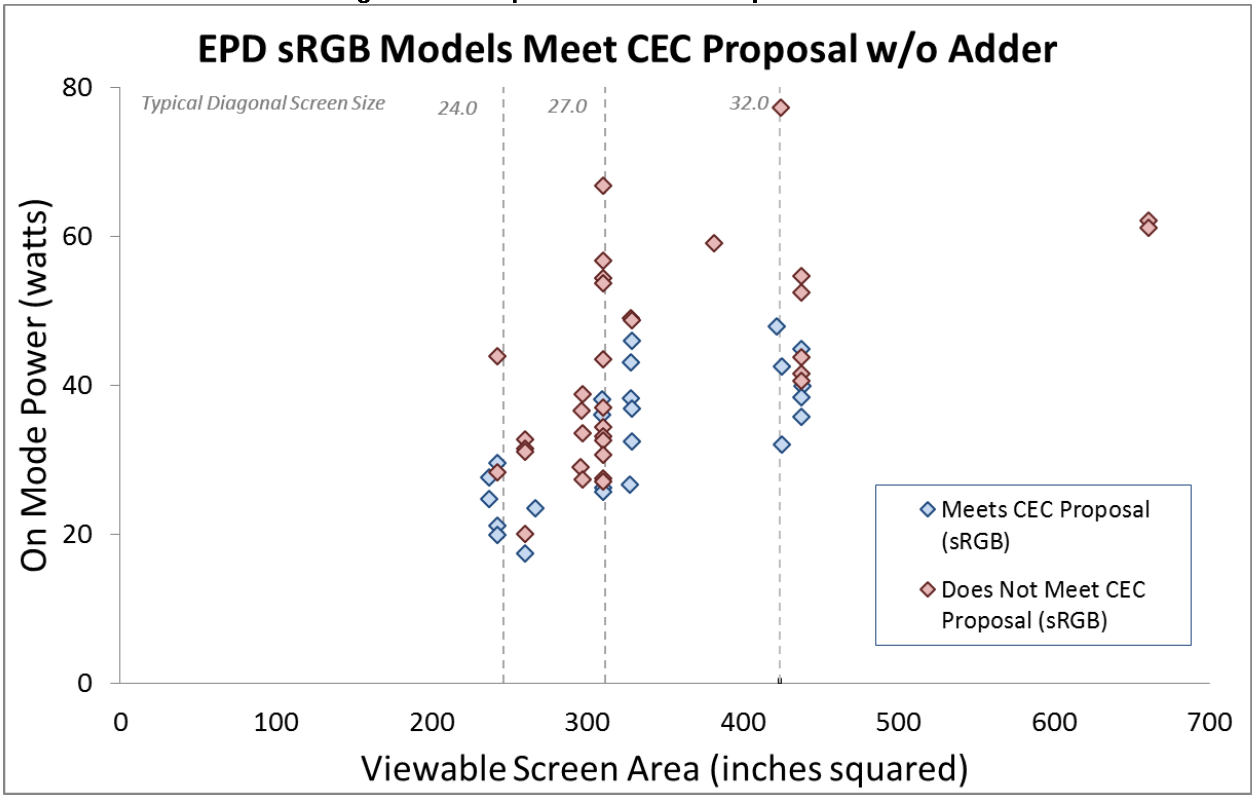
85 A display screen made with thin-film transistor technology is an LCD, common in notebook and laptop computers, that has a transistor for each pixel (that is, for each of the tiny elements that control the illumination of your display). Having a transistor at each pixel means that the current that triggers pixel illumination can be smaller and, therefore, can be switched on and off more quickly.

Table 14: Test Data for 27-Inch Baseline and Efficient Monitor Pairs

Mode	Test Unit[86]	Power (W)			BLU Share of Total Power
		BLU	LCD Driver, PSU Losses, Other	Total	
Default	D27-1	25	14	39	64%
	D27-2	12	10	22	55%
	EPD27-1	34	22	56	60%
	EPD27-2	24	17	41	59%
Power scaling	D27-1	25	14	39	64%
	D27-2	5	8	13	38%
	EPD27-1	5	17	22	23%
	EPD27-2	7	14	21	34%

Source: IOUs CASE Response to Staff Report (2015), p. 6

Figure 9: Compliant and Noncompliant Models



Source: Energy Commission staff

Gaming Monitors

Gaming monitors are a type of computer monitor that incorporates rapid refresh rates to allow for images to change rapidly on the screen in response to direction by user, a desirable quality

86 The D-27 units are standard monitors, and the EPD27 units are EPDs.

for video games. Gaming monitors are either with incremental hardware-based assistance or without incremental hardware assistence to provide a variable refresh rate. Power consumption for these types of technologies in on mode is more akin to EPDs than standard computer monitors.

Signage Displays

A signage display means an analog or digital device designed primarily for the display of computer-generated signals and is not marketed for use as a television. Signage displays were included as "television monitors" in the scope of California television standards that were adopted in 2009.[87] Based on guidance provided by the Energy Commission to the Consumer Electronics Association in a letter dated March 29, 2010, and referenced by a stakeholder in response to the Energy Commission's invitation to participate, electronic public signage displays that do not contain tuners are subject to television regulations.[88] However, some manufacturers were not clear as to whether the 2009 television regulations covered signage display units.

87 *2015 Appliance Efficiency Regulations*, available at http://www.energy.ca.gov/2015publications/CEC-400-2015-021/CEC-400-2015-021.pdf, p. 204, 205.

88 Letter to CEA, available at http://docketpublic.energy.ca.gov/PublicDocuments/Migration-12-22-2015/Non-Regulatory/2000-2011%20Proceedings/09-AAER-1C/TN%2056065%2003-29-10%20Responce%20to%20CEA%203-29-10.pdf.

CHAPTER 11:
Regulatory Approaches

Federal Activity

There are no U.S. DOE standards for computer monitors or signage displays. The Federal Trade Commission, which regulates Energy Guide labeling, does not require computer monitors or signage displays to have EnergyGuide labels.[89]

ENERGY STAR Maximum On-Mode Power Draw Criteria

Many manufacturers have participated in the voluntary ENERGY STAR Version 6.0 specification for computer monitors.[90] Energy allowance requirements are described through ENERGY STAR Version 6.0 equations. These equations apply to diagonal screen sizes of less than 61 inches. On-mode power must be less than or equal to the maximum on-mode power allowance. Products must offer at least one power management feature enabled by default. ENERGY STAR has separate allowances for EPDs. Monitors with automatic brightness control have specific on-mode power calculations.

In ENERGY STAR Version 6.0, the maximum power usage in sleep mode for any monitor is less than or equal to 0.5 watt. Power allowances provide an additional sleep mode allowance up to 0.7 watt for bridging or network or 0.5 watt for additional capabilities. Off mode requires a power draw of less than or equal to 0.5 watt. Specifications require that external power supplies must adhere to Level V requirements under the International Efficiency Marking Protocol.

ENERGY STAR recently released Version 7.0 of its specification for computer monitors that took effect July 1, 2016. Version 7.0 requires the brightness levels of computer monitors be tested and calibrated at 200 nits.[91] Version 7.0 retains the same basic framework as Version 6.0 by scaling maximum power consumption to screen size. However, Version 7.0 sets new power consumption requirements in terms of total energy consumption, which allows manufacturers flexibility to balance power consumption in on mode and sleep mode.[92] The total energy consumption metric uses an assumed duty cycle for monitors to weight the energy used in each mode.

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89 https://www.ftc.gov/tips-advice/business-center/guidance/energyguide-labeling-faqs-appliance-manufacturers.

90 ENERGY STAR Program Requirements Product Specification for Displays Eligibility Criteria Version 6.0, available at http://www.energystar.gov/sites/default/files/specs//Final_Version_6.0_Displays_Program_Requirements.pdf.

91 In lighting terminology, a *nit* is a unit of visible-light intensity, commonly used to specify the brightness of a cathode ray tube or liquid crystal display computer display. For example, a typical active-matrix LCD panel has an output between 200 and 300 nits.

92 ENERGY STAR Program Requirements Product Specification for Displays Eligibility Criteria Version 7.0 available at https://www.energystar.gov/sites/default/files/Version7Displays%28Rev.%20Nov-2015%29.pdf.

Alternatives Considered

In addition to the ENERGY STAR specification, staff considered stakeholder proposals received in comments on the first and second staff reports.

IOUs' 2013 CASE Study Regulatory Proposal

The IOUs and NRDC have proposed that the Energy Commission adopt computer monitor standards based on the ENERGY STAR Version 6.0 construct. IOUs recommend on-mode maximum requirements based on screen size and resolution. Most models “out of the box” are brighter than 200 nits, and users are not likely to calibrate their computer monitors to 200 nits. Therefore, the IOUs propose testing be performed at default (that is, “out of box”) settings.

IOUs proposed to include the sRGB and Adobe RGB EPDs in the scope, out of concern that the market for these products was growing, resulting in additional energy consumption.

IOUs’ 2016 Regulatory Proposal

In comments on the second draft staff report, the IOUs supported the Commission’s proposal but suggested several changes to the proposed standards to increase energy savings and minimize loopholes.[93] Specifically, the IOUs recommended that the Energy Commission cover monitors less than 17 inches, set stringent on-mode requirements for monitors between 30 and 61 inches, use screen area rather than the diagonal to create size bins, reduce the allowance for EPDs, and increase the stringency of requirements for signage displays. The Energy Commission considered each of these opportunities to improve energy savings. However, the Energy Commission focused on those measures likely to have the largest impact on mainstream displays, while ensuring that there were not loopholes for more niche products.

ITI’s 2016 Regulatory Proposal

In comments on the second draft staff report, ITI generally recommended that the Commission reduce the stringency of its proposal for computer monitors in all modes and screen sizes; extend the effective date from January 1, 2018 to July 1, 2019; and exempt certain niche products from the standards entirely.[94] The overall effect of this proposal is to significantly reduce the energy savings achieved from the standard. Energy Commission staff considered these comments and determined that it was appropriate to adjust the effective date to allow manufacturers more time to redesign products to meet the standards. Staff also worked with industry stakeholders to resolve their concerns regarding niche products and the Commission’s concerns with creating compliance gaps in the standards.

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93 California IOUs, Response to Final Draft CEC Staff Report for Computer Monitors and Signage Displays (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211612_20160523T160952_California_Investor_Owned_Utilities_Comments_California_Investo.pdf.

94 ITI/Technet, Comments on CEC Staff Report (Displays) (May 23, 2016), available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211620_20160523T172108_Christopher_Hankin_Comments_ITITechNet_Comments_on_Displays.pdf.

No Standard Alternative

Although the Energy Commission did not receive any comments suggesting that it maintain the status quo and adopt no standards for computer monitors, staff considered the effect of not doing standards for computer monitors and signage displays. In its *Standardized Regulatory Impact Assessment* submitted to the Department of Finance, the "baseline" represents the economy without computer, computer monitor, and signage display regulations. As that analysis demonstrates, forgoing regulations means forgoing significant energy savings, greenhouse gas reductions, and monetary benefits from the standards. There were no positive benefits to forgoing regulations. As a result, Energy Commission staff did not choose this alternative.

CHAPTER 12: Staff Proposal for Computer Monitors

To measure the energy consumption of computer monitors, staff proposes to use the ENERGY STAR test method, published in September 2015, and associated with the ENERGY STAR Product Specification for Displays Version 7.0.[95] The ENERGY STAR Version 7.0 test procedure requires manufacturers to measure and report total energy consumption (TEC) per unit. The total energy consumption matrix requires combining on-, sleep-, and off-mode energy consumption measurements.

Staff's proposed standard requires reporting of on-mode, sleep-mode, and off-mode energy consumption separately. The ENERGY STAR test method has provisions to test the on-sleep-, and off-mode energy consumption separately. Staff has, therefore, included modifications to the test procedure to clearly state how to measure on-, sleep-, and off-mode energy consumption for monitors.

As specified in ENERGY STAR, staff proposes that on-mode measurements be taken using IEC 62087 test method, while sleep-mode and off-mode measurements shall be made using the IEC 62301 test method. Product features and functions not specifically addressed by the test method must be turned off or disconnected during the test. Built-in speakers must be muted or turned down to the lowest volume setting for the on-mode test. Any nonmonitor-specific feature (USB hubs, webcams, speakers, LAN connections, SD card readers, touch sensors, and so forth) must be turned off as part of test preparation, before starting the test procedure for measuring "on" power.

The proposed test method requires the monitor to be calibrated to a screen luminance of 200 nits (cd/m^2) for the on-mode power measurement. Monitors may be shipped with screen luminance of fewer than or equal to 200 nits with a 35 percent allowance higher or lower. EPDs would not be subject to this limitation. This provision will test all monitors at an equal screen luminance to create an apples-to-apples comparison of the monitor energy consumption. Industry members, however, raised concern about the ability to calibrate the monitors to customer specifications, which may require shipping at higher (or lower) brightness levels. Staff's proposal ensures that the monitor is near what it was tested while allowing computer monitor manufacturers to meet customer demand. In real-world use or retail settings, consumers can also increase screen brightness, if needed.

95 ENERGY STAR Program Requirements Product Specification for Displays Eligibility Criteria Version 7.0 available at https://www.energystar.gov/sites/default/files/Version7Displays%28Rev.%20Nov-2015%29.pdf.

Proposed Efficiency Standards
Computer Monitors

Energy Commission staff proposes computer monitor standards to establish maximum on-mode requirements based on screen area and resolution. This approach is similar to the ENERGY STAR Version 6.0 specification, which sets on-mode power requirements. Staff proposes maximum power for sleep mode (P_{SLEEP_MAX}) and off mode (P_{OFF_MAX}).

In the second draft staff report, staff proposed to reduce the on-mode power allowance for high-resolution monitors (with resolutions greater than 5 MPs). Staff proposed a flat adder at higher resolutions as ENERGY STAR data demonstrated that energy consumption did not vary significantly by resolution for monitors with more than 5 MP. Industry members pointed out that this made higher resolution monitors subject to a more stringent standard than some lower-resolution monitors, despite higher resolution monitor requiring more power generally in on mode. As a result, staff added 4 watts of power consumption for high-resolution monitors.

The requirements for low-power modes were also updated from the previous staff report. In the second draft staff report, virtually all models in the ENERGY STAR dataset met the proposed 0.5 watt and 0.3 watt requirements for sleep-and off-modes, respectively. However, this dataset did not account for all monitors, especially EPDs, and manufacturers pointed out in comments on the second draft staff report that these levels would be difficult to meet for all monitors. Furthermore, there were not technological solutions for these monitors to achieve those levels, meaning that they would simply be removed from the market rather than redesigned to meet efficiency standards.[96] To resolve this issue, staff proposes a 0.7 watt limit for sleep and 0.5 watt limit for off. In the alternative, manufacturers may comply by demonstrating that sleep mode and off mode together are no greater than 1.2 watts, allowing additional flexibility to achieve technological solutions.

Staff proposes to regulate only computer monitors with a diagonal screen size of 17 inches or greater.

96 ITI and Technet, Comment on Displays, pp. 13-14, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN211620_20160523T172108_Christopher_Hankin_Comments_ITITechNet_Comments_on_Displays.pdf.

Table 15: Maximum Power Allowances by Modes – Computer Monitors

Diagonal Screen Size in Inches (d)	On Mode in Watts (P_{ON_MOX})	Sleep Mode in Watts (P_{SLEEP_MAX})	Off Mode in Watts (P_{OFF_MAX})
Resolution Less Than or Equal to 5.0 MP			
17”≤d≤20”	(6.0*r) + (0.025*A) + 3.7	0.7	0.5
20”<d<23”	(4.2*r) + (0.02*A) + 2.2	0.7	0.5
23”≤d<25”	(4.2*r) + (0.04*A) – 2.4	0.7	0.5
25”≤d<30”	(4.2*r) + (0.07*A) – 10.2	0.7	0.5
30”≤d≤61”	(6.0*r) + (0.1*A) – 14.5	0.7	0.5
Resolution Greater Than 5.0 MP			
17”≤d≤20”	25 + (0.025*A) +3.7	0.7	0.5
20”<d<23”	25 + (0.02*A) +2.2	0.7	0.5
23”≤d<25”	25 + (0.04*A) – 2.4	0.7	0.5
25”≤d<30”	25 + (0.07*A) – 10.2	0.7	0.5
30”≤d≤61”	25 + (0.1*A) – 14.5	0.7	0.5

r = Screen resolution (megapixels)
A= Viewable screen area (square inches)
Source: Energy Commission staff

Touch Screen Monitors

Computer monitors with touch screen capability are allowed a maximum of 1 watt allowance added to the on-, sleep-, and off-mode power limits. This allowance was based on information submitted by the IOUs.[97] This category of monitors has a small number of models in the market. Providing an additional allowance for touch screen monitors will have a small effect on energy consumption and savings, but it is necessary to ensure that these products are able to provide the functionality expected, such as being able to wake from sleep mode upon touch.

Enhanced Performance Displays

Based on the ENERGY STAR data, almost half of the computer monitors available with 32.9 percent of CIELUV (99 percent or more of defined sRGB colors) need an additional power allowance to comply with the proposed on-mode requirements. Models covering at least 38.4 percent of CIELUV (99 percent of Adobe RGB) need an even higher power allowance to comply with the standards. For products meeting the definition of an EPD with a color gamut specified in Table 16, a power allowance adder (P_{EP}) is proposed for maximum on mode power. These power allowances are proposed to be reduced after January 1, 2021, as manufacturers are able to redesign their products to attain additional efficiencies.

97 *Electronic Displays Technical Report -Engineering and Cost Analysis,* available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Supplemental_Technical_Report_Electronic_Displays_2014-01-08_TN-72475.pdf, p. 15.

Table 16 On-Mode Power Allowance for Enhanced Performance Displays

EPDs manufactured on or after July 1, 2019, shall comply with the following standards	
Color Gamut Criteria	On-Mode Power Allowance in Watts (PEP)
Color Gamut support is 32.9% of CIELUV or greater (99% or more of defined sRGB colors)	0.30*PON_MAX*
Color Gamut support is 38.4% of CIE LUV or greater (99% of Adobe RGB)	0.75*PON_MAX*
EPDs manufactured on or after January 1, 2021, shall comply with the following standards	
Color Gamut Criteria	On Mode Power Allowance in Watts (PEP)
Color Gamut support is 32.9% of CIELUV or greater (99% or more of defined sRGB colors)	0.20*PON_MAX*
Color Gamut support is 38.4% of CIE LUV or greater (99% of Adobe RGB)	0.60*PON_MAX*

*The percentage values derived from the formulas in table below are to be added to the On Mode values specified in Table V3

Source: Energy Commission staff

Gaming monitor, Curved Monitors, and OLED Monitors

These three monitor types are special cases of computer monitors: Gaming monitors (with or without incremental hardware-based assistance), curved monitors, and OLED monitors.

Gaming monitors with variable refresh rates use significantly more energy than standard monitors and are more akin in on-mode power consumption to EPDs. Gaming monitiors with incremental hardware bases assiatnace are slightly more power consumptive monitors than the monitors without incremental hardware bases assiatnace. These monitors have a relatively low share of the market, due in large part to cost and limited added functionality, as most computer monitor users do not need their screen to rapidly refresh in response to user input. Staff proposes to provide an adder for these technologies to accommodate additional functionality.

For curved monitors and OLED monitors, because few or none are available in the computer monitor market, staff proposes to treat them as EPDs so that the technology has time to evolve before focusing on efficiency.

Proposed energy standards for these products will help energy consumption low.

Exceptions

Staff proposes to exempt four types of monitors that are highly specialized and in niche markets from the efficiency standard.

(A) A keyboard, video, and mouse (KVM).

(B) Keyboard, mouse, and monitor (KMM).

(C) A very high performance monitor of resolution equal or greater than 8.2 megapixels and that is either greater than 99 percent of AdobeRGB or is greater than 99 percent of DCI-P3.

(D) Products that are classified for use as medical devices by the United States Food and Drug Administration.

Staff proposes that these monitors still be tested and the associated energy consumption data be submitted to the Energy Commission for certification. This provision will help tracking the energy consumption and monitoring market activity.

Signage Displays

A definition of signage displays is included, as is clarification that signage displays are in the scope of the television regulations and are subject to compliance with existing television standards. The power mode requirements in Title 20 are shown in **Table V-2**.

Table V-2: Standards for Television

Screen Size (Area A in Inches Squared)	On Mode (W)	Sleep Mode (W)	Minimum Power factor for (P≥ 100 Watts)
A<1400[2] inches	(0.12*A) +25	1	0.9

Where A is a viewable screen area. *Staff Report for Proposed Efficiency Standards for Televisions*[98]

Professional Multipanel Signage Displays

Professional multipanel signage display are composed of two or more display panels, each with a diagonal size greater than 12 inches, and are operated together by an external data controller to display a single image or video (that is, each display shows one piece of the image/video). They have a size greater than 1,400 square inches and are intended to be viewed by multiple people in public environments, such as stadiums, airports, and convention centers. Professional multipanel signage displays are not included in staff's proposal and are not subject to the power limits of **Table V-2**.

98 *Staff Report for Proposed Efficiency Standards for Televisions,* available at http://www.energy.ca.gov/2009publications/CEC-400-2009-024/CEC-400-2009-024.PDF, p. 46.

CHAPTER 13: Technical Feasibility

Rapid development in LED lighting technologies has drastically increased the efficiency of LED backlights and drivers. Power supply efficiency has also improved. Use of efficient LEDs and drivers over the less efficient LEDs or CCFL backlights, along with an efficient power supply, can improve the overall efficiency of computer monitors. Another cost-effective technology that is prevalent in televisions is reflective polarizing films. Used in the optical film stack behind the LCD panel, these films pass properly polarized light to the LCD panel and reflect the rest of the light back into the optical stack for recycling. Use of reflective polarizers can substantially lower the unit energy consumption in computer monitors.

There are many other technology options available to manufacturers that they can implement to design computer monitors to further reduce the energy consumption. These options are cost-effective when implemented and would save significant energy per unit, and consumers will save money on their utility bills. The Lawrence Berkeley National Laboratory has established several methods for computer monitor manufacturers to decrease the energy consumption by increasing the energy efficiency of their products. Some of the technological options available are shown in **Table 17**.

Table 17: LCD Monitor Efficiency Improvement Options

Components		Improved Options	Notes
Backlight Unit	Backlight Source	High LED efficacy	Cost reduction in the long term; technical barrier in thermal management and short-term cost increase from adoption of higher-efficiency LEDs
	Optical film	Optimized combination of film	Tradeoffs in material cost, ease of manufacture, and efficiency
		Reflective polarizer	Slight cost increase[99]
LCD Panel		Improvement in panel transmittance by optimizing pixel design, functional layers, e.g., polarizer, color filter, and data line	Redesign investment required but driven by cost reduction
Power management		Brightness control based on computer usage patterns. Auto brightness control by ambient light conditions.	Efficiency improvement varies with settings and usage patterns.
Other		USB-powered monitor: video and power over a USB 3.0 cable	High-efficiency LCD panel required. Cost increase for the LCD panel but likely cost-neutral for the monitor set

Source: Energy Commission staff

Backlight Configuration and Efficacy

The biggest source of power consumption in LCD monitors is the backlight. Therefore, reducing the number of LEDs or lamps and increasing the light production efficiency, or efficacy, are major opportunities to reduce display power. As discussed, computer monitors, EPDs, and signage displays are built with either edge-lit LED configurations or full-array backlight configurations. Edge-lit configurations generally use fewer LEDs than full-array lit and thus draw less power.

Another way to reduce the LED count is to use higher-efficacy LEDs that produce more light per watt. Little cost difference exists between high- and low-efficacy LEDs. The IOUs estimate that upgrading 90-100 lumens/watt LEDs to 110-125 lumens/watt LEDs would cost about $1.[100]

99 Although 3M has owned the patent on this technology in the past, the patent has expired.

100 IOUs, 2014, *Electronic Displays Technical Report – Engineering and Cost Analysis*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Supplemental_Technical_Report_Electronic_Displays_2014-01-08_TN-72475.pdf.

Staff estimates that the cost to improve the efficiency of inefficient monitors using more efficient LEDs is between $1 and $5.

Reflective Polarizer Technology

Even if light is produced efficiently, much is lost to heat in the LCD panel. In fact, most light produced by the BLU is not used to illuminate the display area and is absorbed in the monitor, thus dissipated as heat in the display.[101] An optical film stack between the light production area and the panel directs light toward the LCD panel.

A key component of an efficient film stack is a reflective polarizer.[102] This film allows properly polarized light to pass through to the back of the LCD panel and reflects the remaining light back into the back light unit to be redirected and polarized, instead of it being absorbed as heat. Reflective polarizing film also increases the amount of light passing through the LCD panel, thus requiring less light from LED lamps to illuminate the display area. A reflective polarizer can increase the efficiency of the monitor by about 30 percent, with a brightness increase of roughly 55 percent. [103,104]

Reflective films and reflective polarizing films are inexpensive and widely available. They are among several possible paths to compliance. Proposed limits do not require the use of reflective polarizing film.

Default Screen Brightness

The IOUs' CASE study pointed out that most consumers do not adjust the brightness of their monitor away from the default brightness. Staff agrees,[105] although the default brightness varies depending on the monitor model, as there is no standardized default. Decreasing the brightness of a monitor increases the energy efficiency of the monitor. If the default brightness were to be lowered, the monitor would consume less energy unless adjusted by the consumer. Setting a standard for monitor shipment in default mode would help lower energy consumption. There are no technological barriers to decreasing default screen brightness.

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101 Department of Photonics and Display Institute, "Minimization for LED-Backlit TFT-LCDs" http://www.cse.psu.edu/~xydong/files/proceedings/DAC2011/data/1964-2006_papers/PAPERS/2006/DAC06/PDFFILES/P0608.PDF.

102 2012 LBNL, *Efficiency Improvement Opportunities for Personal Computer Monitors: Implications for Market Transformation Programs*, available at http://eetd.lbl.gov/sites/all/files/lbnl-5533e.pdf.

103 "Managing Light to Increase Efficiency in LCDs," available at http://www.photonics.com/Article.aspx?AID=30097.

104 "3M Showcases Energy Efficient Vikuiti™ Optical Films for TVs, Monitors and Notebooks at FPD International 2008," *Photonics Spectra,* available at http://www.businesswire.com/news/home/20081027005235/en/3M-Showcases-Energy-Efficient-Vikuiti-TM-Optical.

105 *2013 CASE Study: Analysis of Standards Proposal for Electronic Display*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf.

The power draw measurements of monitors in default settings versus the ENERGY STAR test method of calibrating screen brightness to 200 candles/meter ^{2} (cd/m ^{2}) showed significant differences.[106] This, in turn, has a significant effect on the backlight unit power and energy consumption.

Automatic Brightness Control

Automatic brightness control (ABC) is a method for adjusting the brightness of a display to increase in bright ambient conditions and decrease in more dimly lit conditions. The goal is to keep a reasonable level of contrast with the ambient light levels. Reducing screen brightness in darker conditions reduces eye strain and reduces backlight power. ABC is a function in which a computer monitor automatically adjusts the brightness of the screen based on ambient light conditions. ABC saves unnecessary energy consumption in low-light conditions. With ABC installed, monitor power can be reduced by 10 percent.[107]

The Lawrence Berkeley National Laboratory study notes that dimming backlights according to dynamically changing pictures can be an effective way to reduce power consumption and enhance dynamic contrast ratio. Dimming strategies are not widely employed with monitors because of the content displayed, typically static word processing or spreadsheet images.[108]

Improved Power Supply Unit

Using an efficient power supply unit is another pathway to increase the efficiency of the monitor. IOUs analyzed a PSU upgrade from 80 percent efficiency to 88 percent efficiency in 19-inch, 22-inch, and 27-inch monitors.[109] These monitors experienced an overall 8 percent increase in efficiency. Since the majority of the market consists of 19-inch, 22-inch, and 27-inch monitors, an increase in PSU efficiency would result in significant energy savings.

Sleep and Off Modes

Most monitors (more than 95 percent) across all screen sizes can comply with both the proposed sleep- and off-mode power levels based on an analysis of ENERGY STAR Version 6.0

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106 Response to CEC Staff Report for Computer Monitors and Signage Displays available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf, p. A-2, A-10.

107 *2013 CASE Study: Electronic Displays Technical Report – Engineering and Cost Analysis,* page 57 available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Display.

108 *Efficiency Improvement Opportunities for Personal Computer Monitors: Implications for Market Transformation Programs* http://eetd.lbl.gov/sites/all/files/lbnl-5533e.pdf.

109 *2013 CASE Study: Electronic Displays Technical Report – Engineering and Cost Analysis,* page 57, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Display.

data (**Table 18**). Staff examined the effect of network and data connections to ensure that the proposed levels are achievable. For all data connections with the exception of Gigabit Ethernet, half or more of the ENERGY STAR-qualifying models would comply with the proposal. Two models with Gigabit Ethernet capability are listed on the ENERGY STAR Qualified Product List, and both have sleep-mode power greater than 1 W and off-mode power greater than 0.3 W. A Gigabit Ethernet controller managed with (EEE), however, can idle at less than 0.2 W.[110]

Table 18: Average Sleep- and Off-Mode Power for the ENERGY STAR QPL

Mode		All QPL Models	Models With No Network or Data Connection	Models with Network or Data Ports					
				All With Network or Data	Fast Ethernet	Gigabit Ethernet	USB 2.x	USB 3.x	Wi-Fi
	Total # of models	1380	1064	316	7	2	165	137	2
Sleep	Average S_{leep}	0.31	0.27	0.43	0.30	1.37	0.35	0.52	0.41
	% models S_{leep} <= 0.7W	92%	99%	71%	100%	0%	85%	53%	50%
Off	Average O_{ff}	0.20	0.19	0.24	0.22	0.39	0.22	0.25	0.25
	% models O_{ff} <= 0.5W	85%	89%	74%	71%	0%	78%	71%	50%

Source: Energy Commission staff

Future Technologies

During the comment period on the second draft staff report, both industry and efficiency advocates expressed concern about "future-proofing" the standard, that is, making sure that the standard would still achieve energy savings during the lifetime of the standard while providing a way for new technologies or innovations to be incorporated into it. Because this issue arises with respect to technologies that do not exist, it is difficult to address in existing regulatory text.

The Energy Commission's petition for rulemaking process can address this issue. For a computer monitor type that is not listed in the regulatory text and that did not exist at the time of the adoption hearing for the regulation, any person may petition the Commission to request a rulemaking hearing under Section 1221 of Title 20 to consider adding an adder or allowance. The Commission also has a confidentiality process to handle trade secrets or confidential business information. Such confidential information must be submitted under Section 2505(a) of Title 20 to protect the confidentiality of the information.

110 IEA 4E Standby Power Annex (September 2013), *Final Report: Power Requirements for Functions*, available at http://standby.iea-4e.org/files/otherfiles/0000/0103/PFF_Final_Report_FINAL_v2_Xergy_17Sep2013.pdf.

CHAPTER 14: Energy Savings and Cost Analysis

Energy Commission staff conducted an energy savings and cost analysis to establish that the proposed standard for computer monitors is cost-effective to the consumer and would save energy statewide. Staff concludes that the proposed standard and requirements would result in significant energy and cost savings.

Duty Cycle

Residential and commercial consumers have very different usage hours. The duty cycles for the residential and commercial sectors are shown in Table 19. The residential duty cycle is derived from the Consumer Electronic Association study (Fraunhofer 2011),[111] while the commercial duty cycle is derived from the study conducted by Navigant Consulting (Navigant 2009).[112]

Table 19: Duty Cycle

Sector	On Mode (hrs./day)	Sleep Mode (hrs./day)	Off Mode (hrs./day)
Residential	4.2	12.2	7.6
Commercial	6.8	13.8	3.4

Source: Fraunhofer 2014; Navigant 2009 [113]

The commercial sector annual duty cycle estimate is based on the number of workdays per year. On average, a worker is at work 240 days a year (assuming a five-day workweek with 20 days off). The average annual operating hours for computer monitors, by mode, in both home and business settings are taken from the IOUs' report and displayed in Table 20. The usage pattern differs depending on the application. Staff agrees with the IOUs' analysis of a shipment-weighted average of total hours a year in each mode based on the 2013 shipments to California.

111 Fraunhofer Center for Sustainable Energy Systems. 2011. *Energy Consumptions of Consumer Electronics in U.S. Homes in 2010*, available at: http://www.cta.tech/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf.

112Navigant Consulting, Inc. 2009. *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances,* final report December 21, 2009. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf.

113 Ibid.

Table 20: Annual Hours in Power Mode for Computer Monitors by Sector

Sector	On (hrs./yr.)	Sleep (hrs./yr.)	Off (hrs./yr.)
Residential	1,533	4,453	2,774
Commercial	2,483	5,043	1,234
Shipment-Weighted Averages	2, 232	4,888	1,640

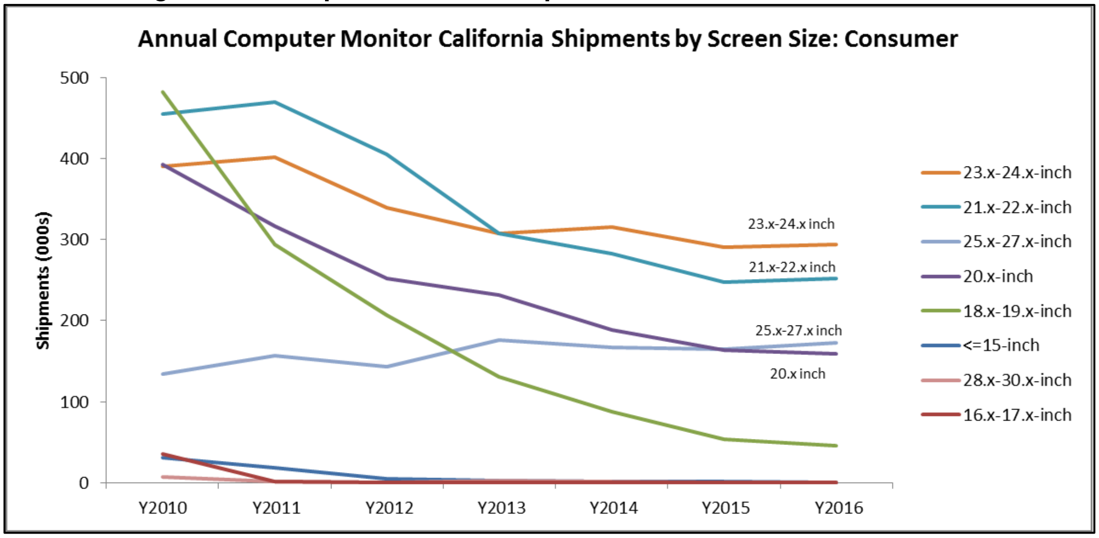
Source: IOUs CASE Response (August 2015)

Based on usage hours, staff estimates the current computer monitor stock consumes more than 1,527 GWh of electricity per year. Based on market trends in Figure 10 and Figure 11, monitor purchases and stock are expected to increase steadily in the commercial sector, while sales and stock will decrease in the residential sector.[114] Without standards, total computer monitor energy consumption is expected to stay roughly level. Under the proposed standards, there will be significant reduction in energy consumption after stock turnover.

Stock and Sales

Market data analysis of computer monitors shows that monitor sales in the residential sector are declining due to the increased use of notebooks and tablets; however, sales have slightly increased in the commercial sector. Annual computer monitor California shipments by screen size for the residential sector are illustrated in **Figure 10**.

Figure 10: Computer Monitor Shipments for the Residential Sector

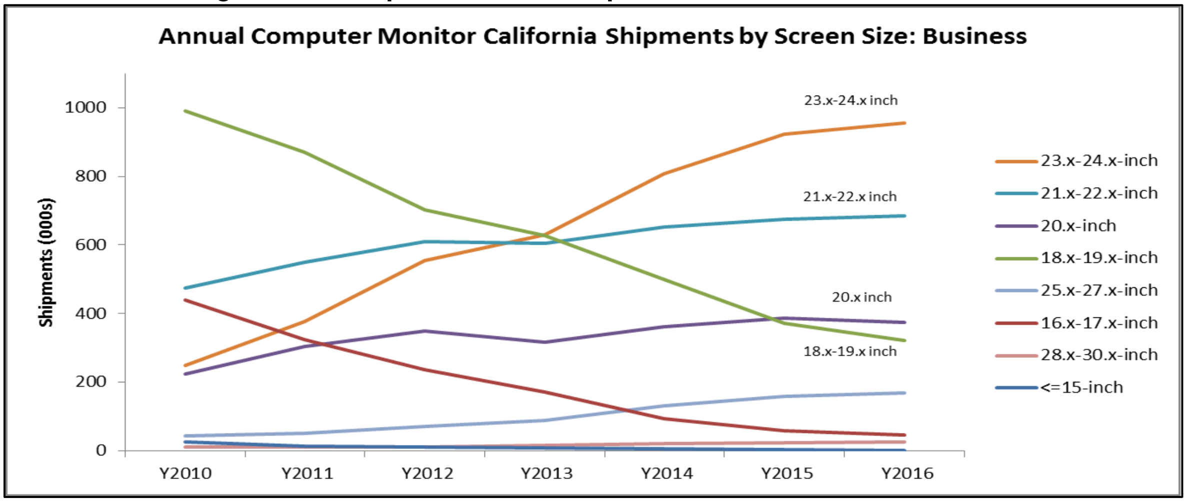


Source: IOUs, *2013 CASE Study, Analysis of Standards Proposal for Electronic Displays*

In the commercial sector, however, monitor purchases are expected to increase steadily.

114 *2013 CASE Study: Analysis of Standards Proposal for Electronic Displays.* http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf.

Figure 11: Computer Monitor Shipments for Commercial Sector



Source: IOUs, *2013 CASE Study, Analysis of Standards Proposal for Electronic Displays*

Size Bins

One of the most distinguishable characteristics of any monitor is size. Monitor size is measured by the diagonal distance between two opposite corners of the viewable screen. Diagonal sizes can reach 61 inches or greater.

Creating bins for categories of sizes provides a better method to allocate energy allowance based on screen size. For this analysis, size bins for up to 25-inch screens were modeled from ENERGY STAR Version 6. Energy Commission staff proposes changes to the two largest screen size bins. The proposed computer monitor size bins are listed in **Table 21**.

Table 21: Computer Monitors Screen Size Bins for Maximum Power Requirements

Diagonal Screen Size in Inches (*d*)	
1	17”≤d≤20”
2	20”≤ *d* < 23”
3	23” ≤ *d* < 25”
4*	25”≤d<30”
5*	30”≤d≤61””

*Screen Size Bins 4 and 5 are modified bins that do not align with ENERGY STAR Version 6.

Source: Energy Commission staff

The IOU CASE analysis provided the distribution of popular monitor sizes that are sold in the market. Distribution of popular sizes sold in the market is different than the ENERGY STAR screen bins but meant to approximate current market shipments.[115]

115 IOUs, *2013 CASE, Analysis of Standards Proposal for Electronic Displays*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf, pp. 18 and 19.

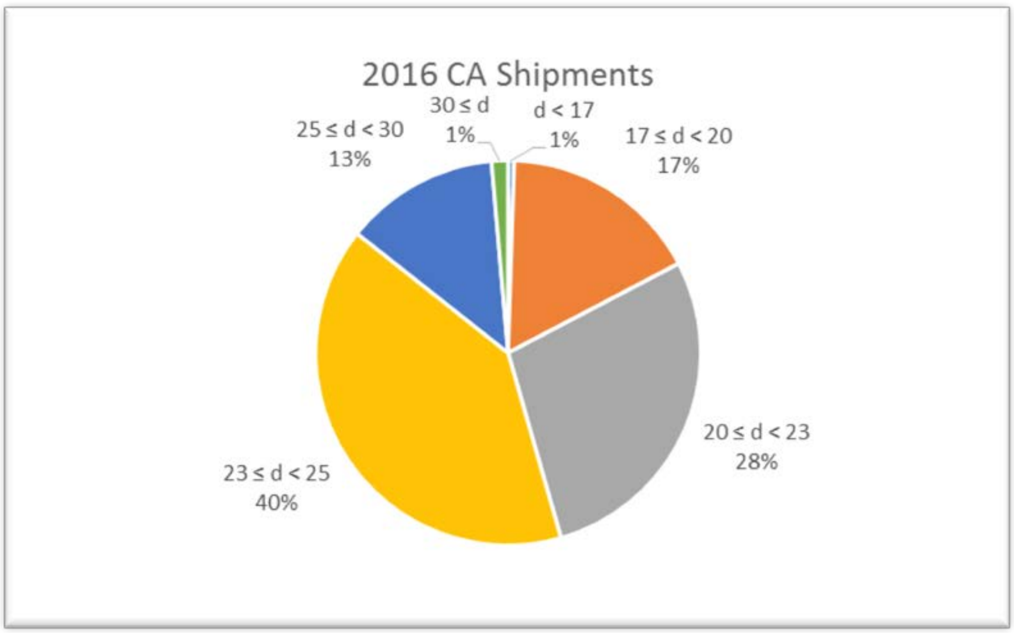
Table 22: Screen Size Categorizations for Market Analysis

Size Bin	Included Diagonal Screen Sizes (*d*)	Approximate Market Distribution
Less than 17.x	<17-inch	≤1 percent
17.x-19.x inch	17-inch ≤ d ≤20-inch	17 percent
20.x-22.x-inch	20-inch < d < 23-inch	28 percent
23.x-24.x-inch	23-inch ≤ d < 25-inch	40 percent
25.x-29.x-inch	25-inch ≤ d < 30-inch	13 Percent
30.x-61.x-inch	30-inch ≤ d < 61-inch	<1 Percent

Source: IOUs, *2013 CASE Study, Analysis of Standards Proposal for Electronic Displays*

Figure 12 shows current computer monitor shipments by bin sizes for California.

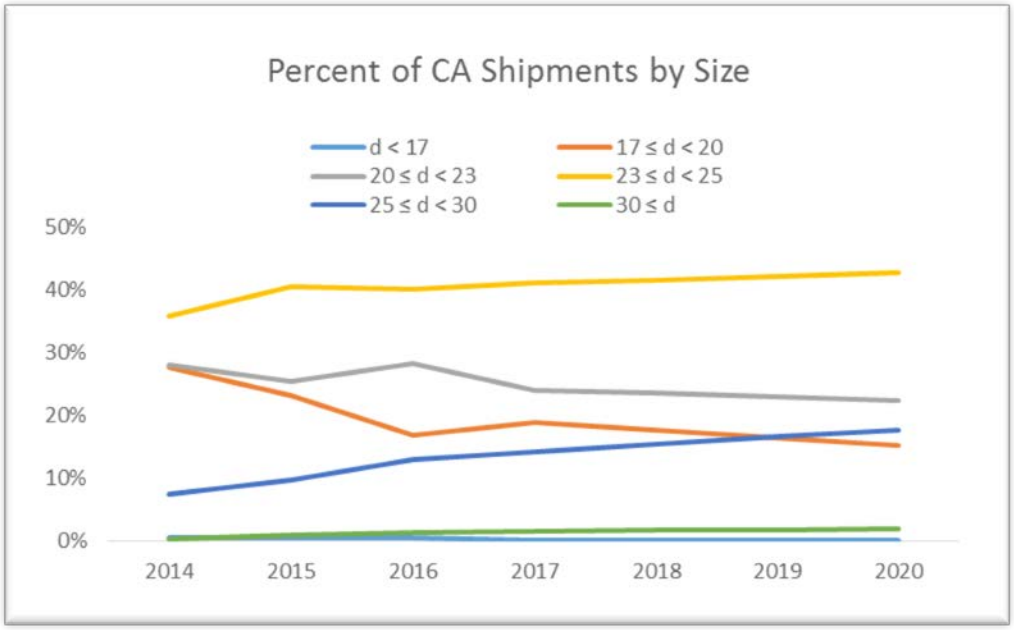
Figure 12: 2016 California Shipment



Source: Energy Commission market study based on the IOUs market data.

Figure 13 shows that the increase in the most popular size bins of monitors on the market are 25 to 29 inches, 23 to 24 inches, and 20 to 22 inches. In the last few years, sales of large screen size monitors have increased significantly, resulting in increased energy consumption.

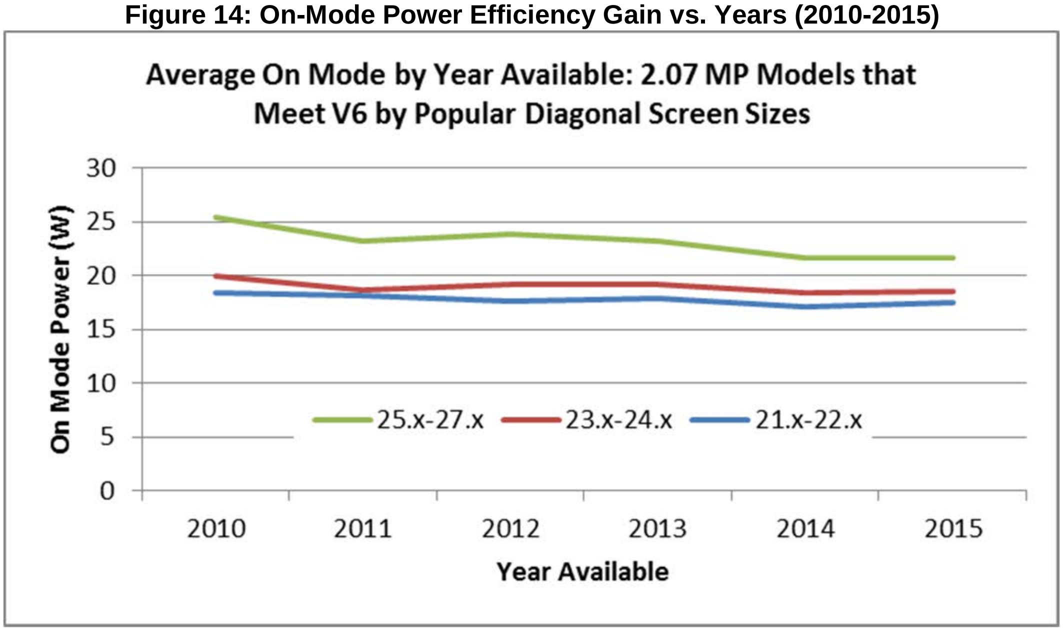
Figure 13: Percent of California Shipments by Size



Source: Energy Commission market study based on the IOUs market data.

Figure 14 shows on mode energy consumption by computer monitors that have been able to meet ENERGY STAR Version 6 on-mode levels from 2010 to 2015. Analysis of market data shows minimal energy improvements over the past five years for more efficient models (that is, models that meet ENERGY STAR Version 6 on mode) in the most popular sizes. **Table 23** shows the number of models that meet ENERGY STAR Version 6 on-mode levels by year of availability in these screen sizes.

Figure 14: On-Mode Power Efficiency Gain vs. Years (2010-2015)



Source: Energy Commission market study based on the IOUs market data.

Table 23: Count of Models That Meet ENERGY STAR Version 6 by Date Available

Screen Size Bin	2010	2011	2012	2013	2014	2015
21.x-22.x	173	92	89	130	34	45
23.x-24.x	82	94	142	155	64	63
25.x-27.x	14	34	51	62	27	25
Total	269	220	282	347	125	133

Source: Energy Commission staff market study

Staff has reevaluated the sales and stock numbers and design life of the computer monitors and has adjusted the stock and design life to harmonize with computer stock and annual monitors sales. Staff estimates that about 25.2 million home and business computer monitors are installed in California.[116] Of these, about 15.1 million monitors are used in homes, and about 10.1 million monitors are used in businesses and schools **(Table 24).** commercial stock estimates are based on the 2009 Navigant study, and residential estimates are based on the 2014 Fraunhofer study.[117, 118]

Table 24: California Installed Base (Stock)

Sector	Installed Base in Millions
Residential	15.1
Commercial	10.1
Total	25.2

Source: Fraunhofer 2014; Navigant 2009.

The IOUs analyzed market sales data for computer monitors and found that annual shipments of monitors less than 17 inches have declined in sales and stock.[119] The IOUs' analysis also found that sales of larger monitor sizes have increased, thereby increasing the overall energy consumed by computer monitors.[120] **Figure 15** illustrates this decline in small monitor sales and increase in sales of larger monitors. **Figure 15** is based on the California annual residential and commercial shipment data of about 3.6 million units.

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116 Response to CEC Staff Report for Computer Monitors and Signage Displays available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf Page 12, Table 7.1.

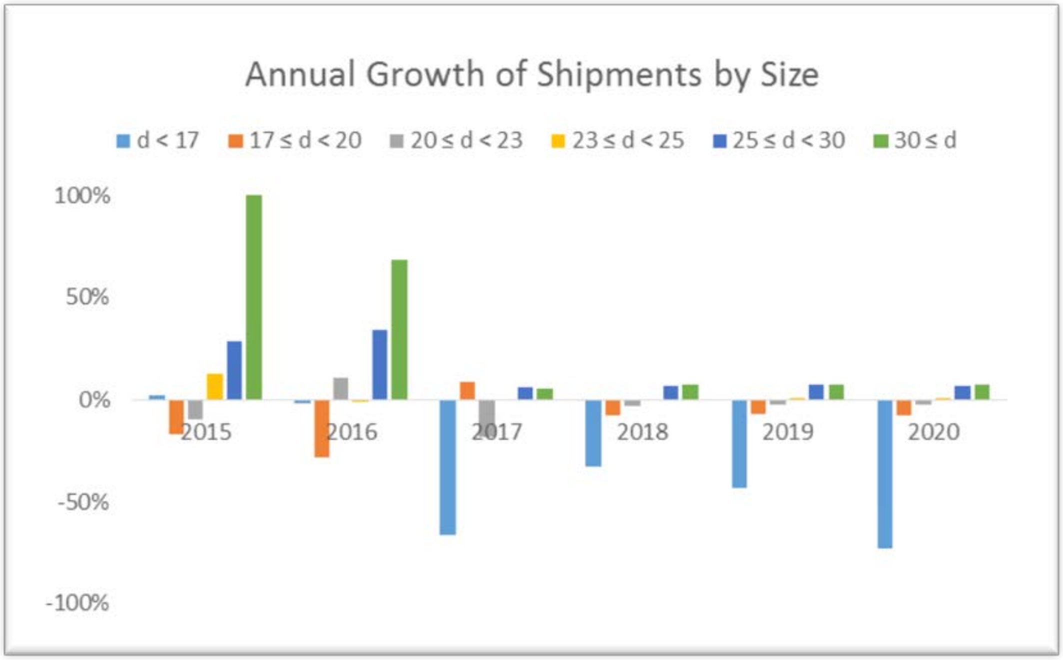
117 Navigant Consulting, Inc. 2009. *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances,* final report. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf.

118 Fraunhofer Center for Sustainable Energy Systems. 2014. *Energy Consumptions of Consumer Electronics in U.S. Homes in 2013*, available at http://www.cta.tech/CorporateSite/media/environment/Energy-Consumption-of-Consumer-Electronics.pdf.

119 *Analysis of Standards Proposal for Electronic Displays* available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf, p. 15.

120 *Analysis of Standards Proposal for Electronic Displays* available at Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf, p. 15.

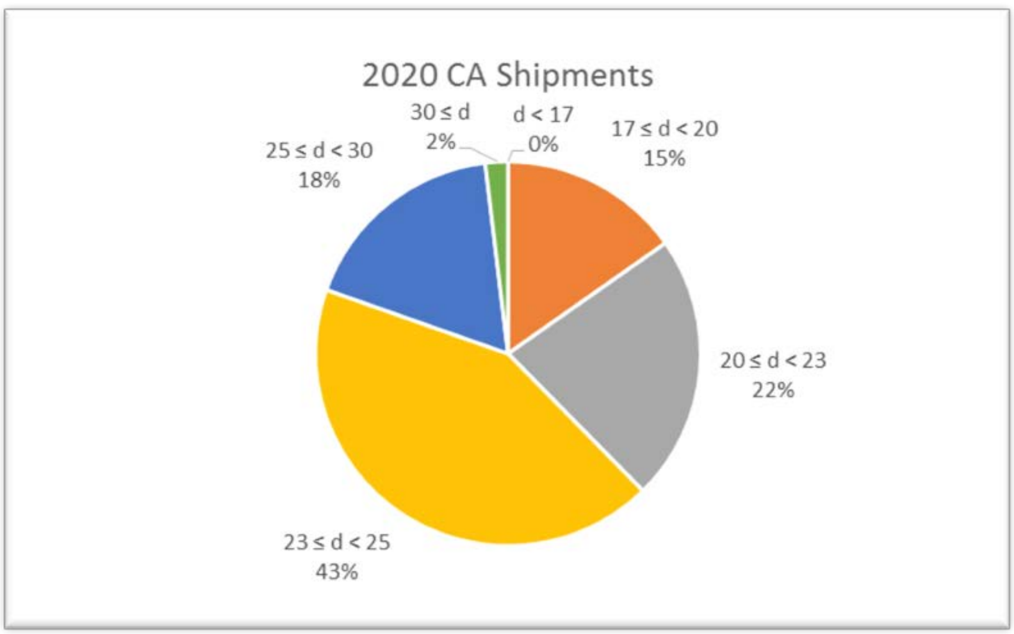
Figure 15: Annual Growth of Shipment by Size



Source: Energy Commission market study based on the IOUs market data.

Figure 16 shows the shipment projected sales distribution for 2020 by screen size.

Figure 16: 2020 California Shipments



Source: Energy Commission market study based on the IOUs market data.

Table 25 shows the average energy consumption of available computer monitors that do not meet the proposed standard. The average energy consumption calculation per unit for these computer monitors is based on the weighted average of energy consumption, average bin size, duty cycle, and annual shipments.[121]

Table 25: Energy Consumption per Unit

Energy Consumption per Unit	On Watts	Sleep Watts	Off Watts	Annual Energy (KWh/year)
Without Standards	26.16	0.35	0.27	60.58
With Standards	13.90	0.30	0.21	32.83

Source: Energy Commission staff

Design Life

The design life of computer monitors varies by application. A recent (Park 2013) LBNL study estimated the design life of a computer monitor to be about six years.[122] ENERGY STAR estimates design life to be about four years for business monitors and five years for household monitors.[123] IOUs in their comment letter noted that many monitors can continue to work for 10 years or longer.[124] Based on this information, staff estimates that the weighted average of the installed units across both commercial and residential sectors is about seven years.[125]

Life-Cycle Cost and Net Benefit

The life-cycle costs and benefits represent the sum of the annual benefits and consumer costs of the proposed standard over the entire design life of the product. The life-cycle costs and benefits of the proposed standards for computer monitors per unit are shown in **Table 26.**

121 *Weighted average* is calculated as per unit annual energy consumption for each size category based on determining the average power consumption in each mode and multiplying by the shipment-weighted average of annual hours in each mode.

122 *Efficiency Improvement Opportunities for Personal Computer Monitors: Implications for Market Transformation Programs,* available at http://eetd.lbl.gov/sites/all/files/lbnl-5533e.pdf, p. 23.

123 *Analysis of Standards Proposal for Electronic Displays*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf, p. 40.

124 Response to CEC Staff Report for Computer Monitors and Signage Displays, August 6, 2015, http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf, p. 12.

125 Response to CEC Staff Report for Computer Monitors and Signage Displays, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf, p 12.

Table 26: Annual Energy Savings per Unit and Life-Cycle Savings per Unit

Annual Energy Savings per Unit (KWh/year)	Savings Over the Life Cycle (KWh)	Dollar Savings Per Unit Over Life Cycle
Unit Energy Consumption Without Standards – Unit Energy Consumption With Standards = 60.58 kWh/year-32.83 kWh/year = 27.75 kWh/year	Energy Savings per Unit X Product Design Life = 27.75*7 = 194.25 kWh	Product Life Cycle Savings (194.25 KWh) X Electricity Rate ($0.16/kWh) = $31.08

Source: Energy Commission staff

Incremental Cost

Staff has evaluated the CASE report analysis for different cost-effective strategies to comply with the proposed standard levels. Some strategies may not cost anything, such as calibrating the brightness of the monitor, while others include implementing technologies that may have some associated cost. Energy Commission staff evaluated all possible pathways that are presented in the technical support document and found most of the pathways to be cost–effective, energy-reducing pathways.[126] Incorporating higher efficiency LEDs, enhanced reflective films, efficient power supplies, and global dimming presented a compliance pathway at a cost of about $5.[127] This estimate is based on a detailed analysis for two sizes of computer monitors using iSuppli[128] cost data to estimate the cost associated with various energy efficiency upgrades.

An estimated cost to improve efficiency of the backlight unit is given in **Table 27.** Using high-efficiency LEDs in the backlight unit of the monitor is one of the pathways identified in the technical feasibility section. **Table 27** shows a continued decrease in LED prices and simultaneous increase in efficacy.

Table 27: Summary of LED Package Price and Performance Projections

Metric	2013	2015	2017	2020
Cool-White Efficacy (lm/W)	166	192	211	231
Cool-White Price ($/klm)*	4	2	1.3	0.7
Warm-White Efficacy (lm/W)	135	169	197	225
Warm-White Price ($/klm)*	5.1	2.3	1.4	0.7

*klm= Per thousand lumens
Source: IOUs Supplemental Technical Report Electronic Displays, January 8, 2014

126 Supplemental to CASE Report submitted on July 29, 2013 available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Supplemental_Technical_Report_Electronic_Displays_2014-01-08_TN-72475.pdf, p. 43.

127 http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Supplemental_Technical_Report_Electronic_Displays_2014-01-08_TN-72475.pdf, pp. 34-35.

128 iSuppli is a global information company.

Energy savings from the proposed standard are about 27.75 kWh a year per unit (**Table 26**). At a cost of $0.16 per kWh,[129] the proposed standard will generate $4.44 in electricity savings per unit per year and $31.08 over the lifetime of the unit to the consumer. Subtracting the incremental cost of $5 per unit from the total energy savings of $31.08 per unit over the product life provides life-cycle savings of $26.08 to the consumer. Based on the iSuppli and the IOUs' incremental cost data staff estimates, the payback period for the improvement is slightly more than one year. Therefore, the proposed standard for each unit and model is cost-effective and will save energy.

Table 28: Life-Cycle Costs and Benefits per Unit for Qualifying Products

Design Life	Incremental Cost (Present Dollar Value)	Life-Cycle Benefits per Unit (Present Dollar Value)	Per Unit Savings Over the Life Cycle
7 years	$5.00	$31.08	$26.08

Source: Energy Commission staff

Statewide Energy Savings

The proposed on-mode standard for 17- to 20-inch monitors and 30- to 61-inch monitors use a formula that is less stringent than 20- to 30-inch monitors. Staff calculated that the proposed standard for 17- to 20-inch and 30- to 61-inch monitors would result in 2.1GWh/year and 0.69 GWh/year less in energy savings, respectively, after stock turnover, compared to the more stringent formula. First-year energy savings and total lifetime savings are shown in **Table 29.**

Table 29: First-Year Statewide Energy Savings and Savings After Stock Turnover

First-Year Statewide Energy Savings	Total Statewide Energy Savings After Stock Turnover	Total Annual Bill Savings After Stock Turnover
Savings per Unit X First Year Sales X Electricity Rate = 27.75 kWh*3.6 million Unit* $0.16/kWh= $15.38 million	Current Energy Consumption-Energy Consumption after the Stock Turnover = (1527 GWh/year– 827 GWh/year =699 GWh/year-2.79 GWh/year)= 696 GWh	Total Energy Savings after Stock Turnover * $0.16*$10^9$ = $111Million[130]

Source: Energy Commission Staff

129 Using an average of residential and commercial electric rate of $0.16 per kilowatt-hour.

130 Total annual bill savings =Total energy savings X electric rate per GWh.

A summary of the statewide energy and cost impacts is provided in **Table 30**.

Table 30: Statewide Energy and Cost Impact

Incremental Cost	Total Unit Savings Over the Lifetime of the Product	First-Year Unit Energy Savings	Total Savings per Unit Over the Design Life	Simple Payback Period	Statewide Energy Savings After Stock Replacement in 2029
$5.00	194.25 kWh/year	$4.44	$31.08	~1 year	696 GWh

Source: Energy Commission staff

The cost-effectiveness of the proposed standards for signage displays is described in the Energy Commission's *2009 Staff Report for Proposed Efficiency Standards for Televisions.*[131] **Table 31** is inserted here from 2009 staff report for proposed efficiency standards for televisions to reiterate that signage display standards are feasible, cost effective, and save energy. No additional energy saving benefits are claimed for signage displays in this report, because energy savings generated from signage displays were included in the 2009 staff analysis for televisions. Staff has included signage display proposal in this rulemaking proceeding to clarify that signage displays are covered under 2009 television regulations.

Table 31: Energy Savings Analysis for Televisions, Including Signage Displays

Design Life (yr.)	Annual Unit Energy Savings (kWh/yr.)	Incremental Cost ($)	First- Year Unit Energy Savings ($)	Reduced Total Cost Over the Design Life ($)	Annual Sales (millions of units)	First-Year Statewide Energy Savings (GWh)
10	84	0	11.76	104.50	4.0	336

Source: Energy Commission staff.

131 *Staff Report for Proposed Efficiency Standards for Televisions.* California Energy Commission, Efficiency and Renewable Energy Division, Appliances and Process Energy Office, available at http://www.energy.ca.gov/2009publications/CEC-400-2009-024/CEC-400-2009-024.pdf.

CHAPTER 14: Safety and Environmental Issues

Energy Commission staff could not identify any safety or negative environmental impacts of improving the efficiency of computer monitors and signage displays. While the technical feasibility section acknowledges the use of more efficient components and perhaps some additional control circuitry, those improvements would not create a particular waste hazard compared with existing components and circuitry.

The proposed standards will lead to improved environmental quality in California. Saved energy translates to fewer power plants built and less pressure on the limited energy resources, land, and water use associated with it. In addition, lower electricity consumption results in reduced greenhouse gas and criteria pollutant emissions, primarily from lower generation in hydrocarbon burning power plants, such as natural gas power plants. The energy saved by this proposal would reduce GHG emissions by about 0.218 $MMTCO_2e$.[132]

132 Million metric tons of carbon dioxide equivalents are calculated by using conversion of 690 pounds per MWh to metric scale, using the rate estimated by the *Energy Aware Planning Guide,* CEC-600-2009-013, February 2011, Section II: Overview, p 5.