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STAFF REPORT

Revised Analysis of Computers, Computer Monitors, and Signage Displays

2016 Appliance Efficiency Pre-Rulemaking

Docket Number 14-AAER-2

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 electric and/or natural gas-fueled energy and/or water. The goal of this pre-rulemaking is to develop the proposed appliance efficiency standards and measures to realize these energy savings opportunities.

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 a staff report, *Analysis of Computers, Computer Monitor, and Signage Displays*. Energy Commission staff conducted a workshop on April 15, 2015, to solicit feedback and discuss the proposed efficiency levels presented in the staff report. The Energy Commission also received written comments from industry, energy efficiency advocates, and other stakeholders on the staff report.

The computers and displays industries hosted two stakeholder workshops, one in June 2015 and the other 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 of these and received additional comments and data. Stakeholders submitted additional analysis to the docket following these workshops.

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

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, monitor, and display, without affecting the functionality or performance, using available, off-the-shelf technologies. The proposed standards statewide would save more than 588 gigawatt-hours per year in computer monitor and displays and 1913 gigawatt-hours per year in 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 the Title 20 standards. The analysis shows that proposed computer, computer monitor, and signage display standards are technically feasible and cost-effective to consumers and would save a significant amount of energy statewide.

The proposed computer standards will save about 1913 gigawatt-hours per year, resulting in greenhouse gas emission reductions of 0.599 million metric tons of carbon dioxide equivalent per year and will save consumers about $306 million in electricity bills after the stock turnover. Regulating computer monitors and signage displays will save about 588 gigawatt hours per year statewide, will result in greenhouse gas emission reductions of 0.184 million metric ton of carbon dioxide, and will save about $96 million after existing stock is replaced. These regulations combined will benefit businesses and consumers by reducing electricity bills by $400 million per year.

In California, computers, computer monitors, and signage displays use an estimated 8,282 gigawatt hours of electricity and account for 2.5 to 4.4 percent of electricity consumption in the residential sector and 10 percent of electricity consumption in the commercial sector. In the commercial sector, these appliances are concentrated in offices and educational facilities.

Proposed Regulations for Computers

Based on the potential for energy savings and other considerations, staff included desktops, notebooks, workstations, small-scale servers, and thin clients (A thin client is a lightweight computer that is purposely built for remoting into a server) in the proposed regulatory scope. Other servers, tablets, smartphones, set-top boxes, game consoles, handheld video games, and industrial computers were excluded 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 mode (when the computer is on but not being used). Idle mode presents the largest opportunity to reduce energy consumption because computers spend about half of the time in "on mode." 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 still consuming significant amounts of power when not in use – for example, 50 watts in idle mode compared to 2 watts in sleep mode.

The proposed regulations differ for notebooks, desktop computers, and workstations. The notebook proposal requires modest improvements in idle consumption that would affect products manufactured one year after the regulation is adopted. The desktop proposal would reduce energy consumption in idle mode by half, and the proposal for workstations and small-scale servers requires the use of efficient 80 PLUS® power supplies. An 80 Plus is a voluntary certification program intended to promote Efficient energy use in computer power supply units that are more cost-effective than less-efficient power supplies.

These proposals set performance standards for computers that give the industry compliance flexibility. Energy savings are achievable through a combination of hardware and/or software improvements. Manufacturers can choose components that use less energy and are more cost-effective to consumers. Software enhancements can be implemented at low costs and can reduce wasteful energy consumption by implementing hardware idle modes that already exist.

Proposed Regulations for Monitors and Signage Displays

Based on the potential for energy savings and other benefits, staff proposes regulations for computer monitor and commercial signage display, for example, those in airports that show departure and arrival schedules. The regulations for monitors would give the industry a choice of compliance options. Digital picture frames, electronic reader displays, and electronic billboards are excluded.

The proposed regulations are similar to the ENERGY STAR® Version 7.0 standards but are about 30 percent more stringent. About 20 percent of monitors on the market meet the ENERGY STAR standards. The core opportunity for energy savings in computer monitors and signage displays lies in reducing the amount of energy used in “on mode.” Monitors operate about 30 percent of the time in “on mode,” and most would only need to reduce power consumption by 3 to 5 watts to comply with the proposed standard. This goal could easily be met by replacing inefficient light-emitting diode lighting, drivers and power supplies with efficient light-emitting diode lights, light-emitting diode drivers, and power supplies that are available at comparable prices. Staff analysis shows that about 14 percent of current models already meet the proposed regulations.

Signage displays are subject to current television standards. A television is an analog or digital device designed primarily to display and receive terrestrial, satellite, cable, Internet Protocol televisions, or other broadcast or recorded transmission of analog or digital video and audio signals. Television standards do apply to signage displays, but not to signage displays greater than 1,400 square inches or to signage displays composed of multiple displays of diagonal screen size greater than 12 inches. These displays are designed to be used in outdoor stadiums and are controlled by a data controller and a support structure connected to either a single or multiple power supplies.

CHAPTER 1: Legislative Criteria

Section 25402(c)(1) of the California Public Resources Code[1] mandates that the California Energy Commission reduces the inefficient consumption of energy and water by prescribing efficiency standards and other cost-effective measures[2] 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

The Warren-Alquist Act[3] establishes the Energy Commission as California's primary energy policy and planning agency and mandates the Commission to reduce the wasteful and inefficient consumption of energy and water in the state by prescribing standards for the minimum levels of operating efficiency for appliances that consume a significant amount of energy or water statewide.

For nearly four decades, California's appliance efficiency standards have shifted the market toward more efficient products and practices, reaping large benefits for consumers. 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 consumers.[5] Since the mid-1970s, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed. In the 1990s, the

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

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

3 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.

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.

California Public Utilities Commission (CPUC) decoupled the utilities' financial results from their direct energy sales, aiding utility support for efficiency programs. These efforts have reduced peak loads by more than 12,000 megawatts (MW) and have saved about 40,000 GWh per year of electricity.[6] The Energy Commission's recently adopted standards for battery chargers are expected to save 2,200 GWh annually, which is enough energy to power 350,000 California households each year.[7] Still, the potential remains for savings by increasing the energy efficiency of and improving the function 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)[8], as well as the recommendations in the California Air Resources Board's (ARB, *Climate Change Scoping Plan*.[9] 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)[10] and the CPUC's 2011 *Energy Efficiency* Strategic *Plan* update.[11]

Loading Order for Meeting the State's Energy Needs

California's loading order describes a priority sequence of actions to address future energy needs and places energy efficiency as the top priority for meeting those needs. The *Energy Action Plan II* (EAP II) [12] is the coordinated implementation plan for state energy policies that have been articulated through the Governor's executive orders, instructions to agencies, public positions, and appointees' statements; the IEPR; CPUC and Energy Commission processes; agencies' policy forums; and legislative direction. EAP II strongly supports the loading order.

For the past 30 years, per capita electricity consumption in the United States has increased by nearly 50 percent; however, 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 *Staff Analysis of Battery Chargers and Self-Contained Lighting Controls*, available at http://www.energy.ca.gov/2011publications/CEC-400-2011-001/CEC-400-2011-001-SF.pdf, page iii; California Energy Commission, *Energy Efficiency Standards for Battery Charger Systems Frequently Asked Questions*, January 2012, available at http://www.energy.ca.gov/appliances/battery_chargers/documents/Chargers_FAQ.pdf.

8 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.

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

10 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.

11 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.

12 *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.[13]

Zero-Net-Energy Goals

The *California Long Term Energy Efficiency Strategic Plan*,14 developed with the Energy Commission, the California ARB, the state's utilities, and other key stakeholders and adopted in 2008 by the CPUC, is California's roadmap to achieving maximum energy savings in the state from 2009 to 2020, and beyond. The following four "big bold strategies" act as cornerstones for significant energy savings that benefit all Californians:[15]

- 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 to the market.

On April 25, 2012, Governor Edmund G. Brown Jr. targeted zero-net-energy consumption for state-owned buildings. Executive Order B-18-12[16] 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 the design process after 2025.

To achieve these zero-net-energy goals, the Energy Commission 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.[17] It also calls for expanding the scope of appliance standards to plug loads, process

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

14 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.

15 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.

16 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.

17 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 *Integrated Energy Policy Report* (IEPR).[18]

Governor's Clean Energy Jobs Plan

On June 15, 2010, Governor Brown proposed the *Clean Energy Jobs Plan*,19 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. Today's appliances are not only more efficient, but they are less expensive and very versatile.

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

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

Part A – Computers

CHAPTER 2: Background

Computers consume a significant amount of energy and have one of the largest plug loads[20] of any appliance. 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 investigates energy efficiency opportunities in five computer form factors: desktops, notebooks, small-scale servers, thin clients,[21] and workstations.

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

This report does not include analysis of tablet computers. The number of tablets in homes is increasing, but the energy use for tablets is relatively low due to the form factors. The opportunity for energy savings is minimal due to battery charger regulations and market pressure to achieve high efficiency to enhance battery life.

20 Plug load is the energy used by products that are powered by means of an ordinary AC plug (e.g., 110 Volt). This term generally excludes building energy that is attributed to major end uses Heating Ventilation Air Conditioning, lighting,water heating etc.

21 Thin clients function as regular PCs, but lack hard drives and typically do not have extra input/output ports or other unnecessary features. Since they do not have hard drives, thin clients do not have any software installed on them. Instead, they run programs and access data from a server.

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

Study	Representative Year	Computer Type	Number of Units (Millions, Scaled to CA[22])	Energy Use Per Unit (kWh/yr)	Total Energy Use (GWh/yr)	Percentage of Residential Electricity[23]
EIA MELS Analysis[24]	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[25]	2013	Desktop	11	186	2,046	2.2%
		Notebook	11.6	53	615	0.7%
		Total	**22.6**	**-**	**2661**	**2.9%**
ITI Comment[26]	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

Most small-scale servers, thin clients, and workstations are found in businesses. The total energy consumption of computers and monitors in the commercial sector can make up more than 10 percent of the overall electricity consumption of a building. Computers are also a major contributor to energy consumption in schools. The U.S. Energy Information Administration[27] suggests that 70 percent of all commercial notebook and desktop consumption occurred in these types of buildings in 2011. This figure does not include the consumption of data centers, which are outside the scope of this report.

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

In May 2013, the Energy Commission solicited stakeholder information, data, and proposals for improving computer energy consumption. Comments on general aspects of computer usage, sales, and so forth were collected; as were details on achieving improved efficiency from the computer industry, utility companies, and nongovernment organizations.

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

23 All compared to 2012, the latest year available, home 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.

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

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

26 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.

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

On March 12, 2015, the Energy Commission released a draft staff report outlining minimum performance requirements for energy efficiency in computers. A workshop was held on April 15, 2015, to discuss the proposal, and public comments were due May 15, 2015 (which was then extended to May 29, 2015). Stakeholders submitted comments regarding the framework, technical feasibility, and potential costs, and staff attended stakeholder-hosted meetings in June and September 2015 to discuss and gather further details and information.

This report compiles and analyzes all the reviewed materials, as well as offers an updated appliance efficiency regulation proposal.

CHAPTER 3:
Product Description

As stated in Chapter 2, the five form factors considered in this report are desktop computers, notebooks, small-scale servers, workstations, and thin clients. Tablets, large-scale servers, game consoles, and industrial computers/controllers are not included.

Of the form factors, desktops have the greatest potential energy savings from technological improvements. There has been a slow, steady decrease in shipments of desktop computers, but sales remain significant. Desktop computers are generally paired with one or more monitors, displays, and/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 other accessories, such as printers. They provide enhanced performance levels per dollar over notebook computers but are more energy-intensive; they also are more configurable, durable, and easily upgraded, which all contribute to longevity and usefulness. Staff investigated the efficiency of some subcomponents of desktops that are available but sold separately from a computer, such as video cards, power supplies, and volatile memory.

Notebook computers are characterized by their small size and ability to run on a battery. A computer screen is integrated in the unit, and upgrades and configurability are limited. Although they can offer similar functionality to a desktop computer, notebooks 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 over desktops due to battery runtime. That is, the more efficient the notebook, the longer the battery will last. Due to smaller size, limited functionality, and efficiency related to long battery life, notebooks use significantly less energy than desktop computers.

Small-scale servers, thin clients, and workstations are all special versions of desktop computers. A small-scale server is a desktop 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 desktops. A thin client contains bare-bones interface hardware that may rely on separate equipment (that is, a server or networked virtual machine) to provide full functionality, such as data storage and computational power. A workstation is a task-oriented computer designed for constant and abnormally high workload and durability.

For the proposed regulations, computer operation is characterized in five modes: active, short-idle, long-idle, sleep, and off. In active mode, the computer is in use by an operator or is running programs and computations at the direct request of the operator. 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; the monitor may have been put to sleep in long-idle. Sleep mode is a low power state that can resume operation by maintaining power to volatile memory. Off mode is the lowest power state; volatile memory is not powered. More detailed definitions for these modes, except for active mode, are contained within the regulatory proposal.

CHAPTER 4: Regulatory Approaches

Energy Commission staff considered and studied regulatory pathways to achieve energy savings in computers. Staff evaluated ENERGY STAR and international computer efficiency standards, including those of Australia, China, and the European Union as potential standards for California. The 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 are a wide range of approaches and requirements for computers, most jurisdictions use the testing method pioneered by ENERGY STAR, which is used domestically and internationally. Staff has proposed to use the testing method in ENERGY STAR Version 6.1, which measures four operation modes: long-idle, short-idle, sleep, and off modes. These modes are typically combined into estimated energy consumption through assumptions about 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 International's ECMA 393 standards for computer network connectivity.[28]

Energy Commission staff was inclined to align with the ENERGY STAR testing methods above; however, stakeholders raised several key concerns about the proposal that must be addressed by the test method. These concerns prompted staff to propose a modified version of the ENERGY STAR test method.

Through discussions with stakeholders, it became clear that the resolution of a display attached to a desktop can affect power consumption. The resolution determines the amount of data necessary to render each pixel on the screen. Higher resolution (therefore, 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 has proposed that attached monitors have a native resolution of 1920 x 1080 pixels—known as full high-definition (full HD) or 1080p.

28 ECMA: European Computer Manufacturers Association.

Another proposed modification is to specify that hard-drive spin down [29]remains in factory default mode. There seems to be some confusion regarding IEC 62623 and the ENERGY STAR test procedure regarding power management setting changes that would be made to measure short-idle and long-idle modes. The proposed language would require that the hard-disk spin-down settings not be altered over the course of testing. The only time power management should be altered is to disable sleep mode, where long-idle measurements would otherwise not be possible.

Staff has proposed a new duty cycle for computers that are sold without the ability to disable power management. This alternate duty cycle would encourage the refinement of operating systems with the ability to meet consumer needs while minimizing idle time when the computer is not in use. The duty cycle shifts time from the long-idle mode into sleep mode, likely yielding to a lower overall annual energy consumption. These computers, while using an alternate duty cycle, would still have to meet the same overall energy consumption targets.

Lastly, the test procedure has been amended to include a method to calculate a newly proposed "expandability score," which is used to calculate an expandability adder[30]. This calculation method is intended to roughly gauge the power requirements of the computer.

Efficiency Standards

ENERGY STAR Frameworks: Comparison of Versions 5.2 and 6.1

ENERGY STAR has a history of voluntary standards development for computers and, in fact, started with these products for its 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.[31] The specification was active between July 1, 2009, and June 2, 2014. The 5.2 specification was replaced with a 6.0 specification that was finalized in September 2013 and was updated to 6.1 in October 2014.[32]

While it is typical for new versions of ENERGY STAR to be more stringent, there have also been structural changes on how the specification handles product categorization and graphics card functional adders. ENERGY STAR Version 5.2 categorizes desktop computers into A-D and notebooks into A-C, with A being lower performance computer types, and C and D being 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"

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29 To conserve energy, hard disk and optical drives are designed to spin-down after a specific period of inactivity. This is usually referred to as hard drive sleep, but the technical term is Standby mode.

30 Computer system characteristic that is the ability to increase capability while retaining or increasing response time and throughput performance. Such a system can accommodate additions to its capacity and capabilities. On hardware, it is adding or increasing or improving hard disks, memory, or video boards.

31 "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.

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

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 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, the speed of those cores, and the power of the graphics card, with emphasis on integrated versus discrete graphics. The changes made in categorization were suggested by the Information Technology Industry Council (ITI) during the ENERGY STAR process where it describes that the ENERGY STAR 5.2 scheme "no longer works"[33] as it focuses on the wrong attributes. This approach, which was also supported by the Japan Electronics and Information Technology Industries Association (JEITA),[34] recognizes growing trends toward integrated graphics.

Energy Commission staff used the ENERGY STAR 6.1 framework as a starting point for standards development over 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.[35] 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 6.1 specification. While the approach differs somewhat from those 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.

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

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33 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.

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

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

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.[36] The Australian standards cover desktops, notebooks, and small-scale servers but do 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 the European Union in design. An interesting "deemed-to-comply" approach for small volume manufacturers to achieve cost-effective compliance is also included. This approach was highlighted in a Collaborative Labeling and Appliance Standards Program (CLASP) study docketed in the Energy Commission's process.[37] These standards are less stringent than the European Tier 2 standards and staff's proposal.

Chinese Standards

Mandatory standards for computers have been in effect in China since September 1, 2012, and are contained in GB 28380 (2011).[38] The standards include desktop and notebook computers, but not workstations or industrial computers. Categorization of desktop and notebook computers are harmonized around the ENERGY STAR 5.2 definitions. The standard levels are less stringent than those in ENERGY STAR 5.2 and include a different graphical adder scheme. They also require certification, and CLASP used resulting data to compare with computers available in the United States to estimate market compliance with ENERGY STAR levels.

European Union Standards

The European Union has effective standards for computers and servers generally referred to as "lot 3" or, more formally, European Commission Regulation No 617 (2013).[39] The regulations apply to all products within the scope of this staff report. Blade servers, server appliances, multinode servers, servers with more than four processor sockets, game consoles, and docking stations are explicitly excluded. Energy Commission staff has incorporated many of these exclusions into its proposed regulations. Staff reviewed the definitions of products in these regulations and found them to be closely linked to the ENERGY STAR 5.2 construct. The requirements are also 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 which became effective on January 1, 2014, and a second, more stringent tier that became effective on January 1, 2016.

The European Union standard also includes disclosures by computer type.

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

37 CLASP Study avaialble at: http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/documents/comments_12-AAER-2A/CLASP_Technical_Report_and_Memo_2014-10-09_TN-73833.pdf

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

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

Stakeholder Proposals

The Energy Commission has received comments and proposals from interested stakeholders regarding the framework and substance of potential computer regulations. These comments were received in context of the draft staff report published on March 12, 2015. This staff report considers the most recent comments submitted by stakeholders. For analysis regarding older, superseded comments, see the March 12, 2015, staff report.[40]

Alternative regulatory proposals to the draft regulations were received from ITI and Technet, the IOUs, and NRDC. A number of comment letters supported levels of stringency proposed in the first draft staff report from the American Council for an Energy-Efficient Economy, Sierra Club, Consumer Federation of America, Consumers Union, Consumer Action, Consumer Federation of California, Northeast Energy Efficiency Partnerships, and the Appliance Standards Awareness Project.

Energy Commission staff adjusted the proposed standards to optimize new data, information, and analysis. The most substantial adjustments to staff's proposal are the additional energy allowances for more powerful computers and incorporation of discrete graphic adders. Some definitional and test procedure adjustments are proposed, upon stakeholder suggestion, to enhance clarity and precision of the standard. The Commission found these adjustments could be made while maintaining the desired level of statewide energy savings.

Staff's Proposal

The proposed regulations combine international experience, stakeholder input, and data analytics to accomplish feasible energy savings for California in both the short and long term. The scope of the regulations includes four categories: desktops, notebooks, small-scale servers, and workstations. Conventional desktops, integrated desktops, and thin clients are included in the desktop category. The categories cover a broad range of applications and form factors. As the standards focus on power consumption in idle mode, however, the products should be conducting relatively few, if any, specialized tasks in the regulated modes. The scope does not include larger-scale servers, blade servers,[41] industrial computers and controllers, video game consoles, tablets, smart appliances, televisions, over-the top boxes, or portable gaming devices.

The requirements for each product type are described below. Beyond the basics of manufacture date, manufacturer name, and model number, Commission staff has not proposed any labels on computers.

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40 Prior 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

41 A balde server is a server chassis housing with multiple thin modular electric circuit boards called a blade server.

Conventional Desktops and Thin Clients

Many stakeholders commented on the global nature of the market. Because the European Union standards taking effect in 2016 are expected to yield benefits for California, the proposed regulations in this report do not take effect until January 1, 2018.

The proposed standards achieve incremental cost-effective and feasible energy efficiency improvements for computers. The largest opportunities for energy savings remain in desktop computers, even post-European Union standards. To set the 2018 proposed standard, staff evaluated the best practices in hardware and software in the market that 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 Addendum.[42] The barrier to achieving these goals is latency—the time it takes for a system to transition from idle to active once a task is prescribed. As latency and power scaling improve over time, 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 effect to performance by putting units to sleep and having rapid transition to full functionality.

The proposed standards set a baseline consumption target of 50 kWh per year based on the test procedure. This target is a performance standard that does not require any specific technology. Staff has also proposed "adders" for discrete graphics cards, integrated displays, RAM, additional hard-disks, and Energy-Efficient Ethernet. These adders are modified or new from the 2015 staff report and are described in detail in the Technical Feasibility chapter.

Staff has proposed an energy adder system for desktop computers based on an expandability score (ES). The ES correlates with the power supply sizing necessary for a unit to power the core system plus potential expansions through externally and internally available ports. An ES less than 200 does not result in an energy adder. A score between 200 and 750 will provide an allowance for energy consumption in a positive linear relationship to the score. A desktop with an ES of more than 750 is considered a workstation and is subject to the standards for workstations.

Finally, staff has retained the proposal to require certain power management default settings when computers are shipped, with an incentive for units with operating systems that prevent power management from being disabled. Units shipped without an operating system at the request of the customer would have to test with power management but would not have to ship with an operating system.

Workstations and Small-Scale Servers

Staff has proposed the Tier 2 standards recommended by the IOUs and NRDC for workstations and small-scale servers. This approach is noninvasive to the functionality of these products by targeting efficiency opportunities that do not affect system performance. Staff has incorporated 80 PLUS Gold program performances and Energy-Efficient Ethernet requirements in a way that

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42 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.

ensures efficiency targets are met without tying the regulations to standards that may change or become defunct over time. Staff has also proposed power management settings consistent with the ENERGY STAR specification Version 6.1. Staff has not proposed additional power supply requirements at 10 percent of load, as some stakeholders suggested. This proposal is substantially the same as it was in the 2015 staff report.

Notebook Computers

In its evaluation of notebook computer data and the design of ENERGY STAR 6.1 limits, staff found that the ENERGY STAR specification provides a narrow difference in allowances versus performance. For notebooks with discrete graphics, the low 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/yr. Proposals by the IOUs and NRDC are even flatter. Staff proposes a single tier of standards for notebooks set at a 30 kWh/year base allowance and includes adders for the same features as desktops. This proposal is substantially the same as it was in the 2015 staff report.

Small Volume Manufacturers Exemption

Unlike most appliance types for which the Energy Commission has proposed regulations, 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 smaller capital and produce smaller volumes of a family of products, which means that the testing and compliance costs may have a larger effect on small businesses. The incremental cost of testing is more significant for smaller volume sales. While not extreme—$600 per test—the cost could be prohibitive for a small entity to perform. According to comments received during the pre-rulemaking proceeding, the testing could put such entities at a competitive cost disadvantage when competing for small information-technology bids and could ultimately place them at risk of failing.[43] Without significant volume, 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 no-cost power management requirements.

To develop the exemption, staff investigated revenue caps, location of assembly and sale, and minimum number of sold systems as the main considerations for exemption. Manufacturers qualify to apply for the exemption if annual gross operations revenues are $750,000 or less, if the manufacturer assembles and sells the computers at the same location, and if no more than 15 units of a similar system are sold. These requirements were modeled after the U.S. Department of Energy exemptions and based on 1) IOUs' estimates of testing costs through outreach to ENERGY STAR-certified laboratories (about $600 for a single test), 2) a combination of assumed overhead costs and net revenue for a small business, and 3) the number of units

43 NASBA comment Aug 29, 2013.

that would need to be sold for the costs of testing to justify the estimated energy savings to the consumer from the proposed standards.[44]

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

44 The net benefit for a desktop computer is estimated to be $40. Therefore, 15 units would have a benefit of $600 and be at a break-even point once testing costs are factored in.

CHAPTER 5:
Technical Feasibility

The proposed standards are deemed feasible due to the array of computers across performance categories that already meet the standards. For small-scale servers and workstations, feasibility is driven primarily by available power supply technologies.

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 use of the 80 PLUS program Gold level of performance. Power supplies are broadly available at 80 PLUS Gold or better efficiencies with more than 1,500 models listed across dozens of manufacturers.[45] Incorporating these efficient power supplies will lead to energy savings in operation 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.[46]

Power supplies in the computer industry are standardized around the “Advanced Technology eXtended” (ATX) specification and tend to have little interaction with the functionality of a computer beyond providing power. Therefore, the proposed efficiency standards should not affect the functionality of small-scale 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 on the market. This functionality is generally enabled in the network interface controller or card (NIC) offered by major chip manufacturers. The 802.3az standard does not have a significant negative effect on the networking functionality of a server or workstation; in fact, it provides enhanced functionality.

Cost

The incremental cost of the proposed standards is driven by the cost of the improved power supply. Estimates from the computer industry, power supply manufacturers, and IOUs provided during pre-rulemaking have varied greatly, with incremental costs ranging from $1.75[47] to

45 1,594 products listed as of November 23, 2015. For a listing of 80 PLUS-certified products, see http://www.plugloadsolutions.com/80pluspowersupplies.aspx.

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

47 Bill of Matirials 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.

$23.85 per unit.[48] The IOUs similarly investigated the incremental cost and included information presented by stakeholders and applied a $1.31 markup from previous DOE work.[49] The IOU incremental cost estimate was $5 to $13, between the two extreme bounds of the ITI and Green Tech Leadership Group estimates. To be conservative, Energy Commission staff incorporated the highest IOU cost in its analysis.

Desktops

There are many ways to reduce the energy consumption of desktop computers. Hardware decisions can yield energy savings in products that offer the same or better performance at lower energy consumption. Chip, motherboard, and other computer component manufacturers can also improve the efficiency of the parts they sell. The market trend is toward lower idle power consumption in individual components. Many software and firmware[50] enhancements can be implemented that would save a lot of energy without changing the components.

The proposed standards require that desktop computers meet a total energy consumption target that is composed of short-idle, long-idle, sleep, and off modes. The relative weightings in the ENERGY STAR 6.1 standard are 35 percent short-idle, 15 percent long-idle, 5 percent sleep, and 45 percent off, for a conventional desktop. These weightings speak to the relative effectiveness of reducing power in any of these modes, with a watt saved in off mode worth seven times a watt saved in sleep mode in terms of meeting the proposed standard. Generally, sleep and off modes are at fairly low power levels, with the majority below 1 watt and nearly all within the 1- to 3-watt range. This means that reductions in off mode and sleep mode represent a small opportunity, and the majority of savings would come from reducing one or both idle-mode consumptions. The remaining feasibility discussion focuses on improvements to these modes.

Components

This section discusses the energy-saving opportunities in each subcomponent of a computer; most component power draws are referred to in watts. These power draws refer to the DC power draw of the component itself, not the AC power draw that would be seen at the outlet. This is necessary to disassociate the power losses that are embodied in the power supply of the computer. However, the power draw for the power supply component refers to the AC power draw that would be seen at the outlet.

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

49 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, p. 35.

50 *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.

Hard Disk

The hard disk is the component used to store data for long-term usage. Power is not needed to maintain those data (unlike volatile memory used for active programs). In the 2015 draft staff report, the estimated "compliant" machine consumed 1 watt average in the hard-disk subcomponents. Hard disks come in various forms and technologies. This report highlights three 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 composed of mostly 2.5- and 3.5-inch drives that are typically rated by revolutions per minute (RPM), related to how fast the platters spin. Typical ratings include 5,400 and 7,200 RPM. The higher the rate of rotation, the higher the read and write speed capabilities. However, 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 run a motor constantly 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 and can consume 0.1 to 0.3 watts. This is achieved by not spinning the platters. While system designers could meet the proposal by implementing this, the amount of time it takes to spin a hard disk back up can be 5 to 20 seconds. The system can be unresponsive during this startup time, causing a short-term delay in user access. It is important to avoid a high frequency of spin-downs and spin-ups, as the spin-up process is power-intensive. Short-idle mode is measured after 15 minutes of inactivity and long-idle mode after 30 minutes of inactivity, outside the range where frequent device state changes would lead to overall energy losses. There is no incremental cost to this approach as it is a standard feature in every hard disk that the Energy Commission evaluated.

There are additional idle states when the disk remains spinning but activity is reduced, or when the read/write heads are removed from the platters. The transition time from these states is typically less than 1 second. However, an idle mode power reduction strategy that temporarily reduces the speed of rotation 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.[51] Substituting a 2.5-inch drive for a 3.5-inch drive can reduce idle power consumption and active power. A 2.5 inch drive can range anywhere from slightly cheaper to $10 more expensive than a

51 This figure is consistent individual hard-drive specification sheets, and presentations given by Seagate in their slide 3 available on line here: http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN206281_20151005T065202_Chris_Hankin_Information_Technology_Industry_Council_Comments_I.pdf and Western Digital's presentation slide 7 available online here: http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN206314_20151009T064443_Chris_Hankin_Information_Technology_Industry_Council_Comments_I.pdf

3.5 inch drive in the most common sizes.[52] The cost for implementing a lower RPM at idle is assumed to be $0 as the feature is already available but not widely used.

The most recent technology to on the data storage market is the solid-state drive. These hard drives do not use moving parts, but instead store the data in flash memory (silicon-based devices). This format 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 much different. Solid-state drives are able to achieve extremely low transition times while consuming minimal power, typically less than 0.5 watts,[53] 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 the power draw, with some systems exceeding the 1-watt level.

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 is not standard. 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, there is 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 can 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.[54] This approach uses a lower-idle technology to store the operating system and critical files of the system, thereby having access to the data without a large idle power. The secondary 3.5-inch storage rotates 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 primary drive is not precise; however, the industry has suggested 64 GB as a level that would

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52 *ITI/Technet Comments on CEC Staff Report,* June 1, 2015, Page 26 available online at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN204797_20150601T093456_ITITechNet_Comments_on_CEC_Staff_Report_for_Draft_Computer_Stan.pdf

53 Staff reviewed product specifications from manufacturers such as this one: http://www.samsung.com/global/business/semiconductor/minisite/SSD/global/html/ssd850evo/specifications.html and also reviewed accumulated data available at Tom's Hardware and presented here: http://www.tomshardware.com/charts/ssd-charts-2014/Power-Requirement-at-Idle,2813.html

54 These are commonly referred to as "hyrbrid drives." Staff found hybrid drives available in the market from Seagate, Toshiba, and Western Digital.

achieve the power performance in idle goals with minimal consumer effect. At a cost of $0.20 [55]per GB of solid-state memory, the incremental cost would be $12.80.

To comply with the standards, a manufacturer should use caution when choosing a hard disk, particularly depending on the 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 ENERGY STAR 6.1 duty cycle. A 1-watt DC variant of storage would consume only 7.3 kWh/year, yielding about $35 in savings over five years. In addition to this example, a typical case is considered later 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 1000 watts.

The conversion efficiency of these power supplies has been the focus of the 80 PLUS program, named after the minimum conversion efficiency of 80 percent or better. 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 more than 90 percent efficient. The testing points generally lie 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 is 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 on the market that use topologies, or configurations, capable of reaching higher efficiency levels. 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 more operational modes to scale power to user needs Power supplies have three modes of operation: on (full), sleep, and off. Without a separate sleep mode in the power supply, current desktop computers would not be able to reach the low sleep mode powers they do (required by the European Union). This allows the power supply to switch from a smaller to a larger supply once the computer wakes from sleep. A similar approach

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55 SSD price per GB has been rapidly decreasing over recent years. Staff consistently found a wide selection of SSDs available at close to $0.25 per gb, and is estimating that prices will continue to fall to $0.20 per GB by 2018. This is a reasonable if not conservative estimate given trends in SSD as detailed in the March 3, 2016 TrendForce article "TrendForce Reports SSD Adoption in Notebooks to Exceed 30% This Year as Price Difference between SSD and HDD Continues to Narrow," available online at http://www.dramexchange.com/WeeklyResearch/Post/2/4309.html

could be taken for idle mode power draw. If a power supply state of some kind is not implemented, the idle mode power of larger systems will be 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 the power supplies. While the fan certainly 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 instead rely on passive cooling to dissipate the few remaining watts of heat.

Central Processing Unit

The *central processing unit* (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 in idle mode between 0.5 watts and 3 watts in comparison to active mode consumptions that can exceed 50 watts.[56] The proposed standards focus on idle, sleep, and off modes, and in every one of these cases, the processor has little to no work to do, as they occur after a period of user inactivity. Therefore, the CPU should be in a deep sleep mode. The proposed standards do not assume any change to the processor, but rather encourage system designers to take advantage of existing features.

The deep sleep power consumption of a CPU can be somewhat disassociated from the processing power and speed as reducing core voltage to zero negates transistor leakage. System design routes most communication through the CPU, and communication controllers often are still powered up during idle mode. 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 small percentage of system power in idle mode 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 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 watts at no incremental cost.[57] This can be driven to 0 watts as

56 Some examples of CPU idle mode power are available in Intel's docketed slide deck "PC Power Management Innovation," slide 12, available online at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205337_20150713T140419_Chris_Hankin_Information_Technology_Industry_Council_Comments_J.pdf

57 The most current versions of the SATA specification, 3.2, embodies several layers of sleep modes that can allow both the SATA controller and device to enter low power modes. Some power is needed to ensure a response to the physical "eject" button, as well as some power to the SATA controller to respond to "wake" events.

is done by zero-power optical disc drives (ZPODD) for notebooks.[58] Stakeholders suggest that this comes at an additional cost for nonslim-style ODDs.[59]

Volatile Memory (RAM)

The energy consumption of this component is decreasing over each generation. [60]In particular, the transition from DDR3 to DDR4 [61]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 desktop market. Further memory energy savings can be achieved by lowering clock speed and supply voltage during idle mode. The proposed standards scale with memory.

Motherboard

This component serves as the link and hub for all other components that route communications through the motherboard. Other than sockets for additional components, the motherboard contains several common and key controllers. Typically included are network interface controllers, Universal Serial Bus (USB) controllers, integrated sound, voltage regulation, and SATA controllers. Energy consumption by the motherboard can be limited through power states of these controllers. Many interface controllers do not have connected devices and may be put into deep sleep states. 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.

Discrete Graphics Card

Discrete graphics cards are used to conduct supplemental graphical calculations usually to support advanced graphics capability. These components are not present in systems where integrated graphics in the CPU or on the motherboard are used instead. Discrete graphics 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 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 over 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, the monitor(s) is generally connected to the card to take

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58 This technology is embodied in SATA specification 3.1.

59 See slides 6 and 7 of "ODD/PSU Idle Reduction," docketed October 5, 2015 and available online at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=14-AAER-02 .

60 "DDR4 White Paper," Corsair, available online at http://www.corsair.com/~/media/Corsair/download-files/manuals/dram/DDR4-White-Paper.pdf

Also "Samsung DDR4 SDRAM: The New Generation of High-Performance, Power-Efficient Memory That Delivers Greater Reliability for Enterprise Applications," Samsung, available online at http://www.samsung.com/global/business/semiconductor/file/media/DDR4_Brochure-0.pdf

61 DDR3 and DDR4: Double data rate 3 and double data rate 4.

advantage of the features and rendering power that not 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 provide information to the still-active monitor. While the computational workload is the same in short idle mode between an integrated graphics card, discrete graphics card, or high-end discrete graphics card, each of these scenarios has varying levels of power overhead derived by the order of magnitude difference in the number of transistors. The proposed adder, therefore, scales proportionally to the bandwidth of the graphics to account for differences in overhead.

For secondary graphics cards or for long idle mode, very low idle mode can be reached consistently across different capability graphics processors. In long idle mode, the computer monitor is not active, and the need to provide and refresh data is not present. This provides an opportunity to power down most of the overhead, leaving minimal controller functionality prepared to wake the graphics on demand. A similar situation exists with secondary graphics cards where low computational demand can allow calculations to be performed on a single card, allowing the secondary card to sleep until needed.

Software

Software 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 increases the effectiveness of lower power states in components.

Example Systems

Computer manufacturers already make desktop computers that reach the proposed efficiency levels. While there were only a few systems in 2014 that could meet the proposed targets, dozens were added to 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 and lower output external power supplies.

Desktop system idle mode 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 disuse or idle mode. Systems, due to powerful components, can easily and quickly exceed the proposed efficiency level if not sufficiently addressed. **Tables 2** and **3** summarize builds that would meet efficiency targets similar to those proposed.

Table 2: Generalized Components, Power Draw, and Cost

Component		Power Draw	Estimated 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
Volatile Memory (RAM)	4 GB DDR3	0.6 watts	$0
	4 GB DDR4	0.4 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 (2018)	2.5 watts	$0

Source: Energy Commission staff

Table 3: Midrange System Short Idle Mode 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 DIMM[62]s, full ATX	8 watts	Same, improved power management, transition to DDR4	6 watts	$3 (DDR cost plus engineering costs)
Power Supply	350 watt, 55% efficiency at loading point	18.8 Watts	350 watt, 75% efficiency at loading point	3 watts	$6
Total		41.8 Watts	-	11.9 watts	$21
Savings	131 kWh/yr, $20.95 per year at a rate of $0.16 per kWh				

Source: Energy Commission staff

Additional Hardware

There are many ways that computer hardware can be expanded beyond typical or basic configurations. In many cases, the 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 referred to as “adders.” It is critical for adders to be sufficiently stringent as to avoid unintended

62 DIMMs: Dual In-Line Memory

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 a decrease in efficacy in computers with increased functionality.

Discrete Graphics Cards

Staff investigated the relationship between graphic cards and system energy consumption. In the initial draft, adders for graphics were not provided, as basic graphics are part of the baseline assumption and advanced graphics are not needed in idle modes. While the rationale is still mostly valid, some systems do not have integrated graphics solutions and, when a graphic card is provided, it is likely that the display will be connected through it, rather than use an integrated solution. This requires such cards to be in a higher level of operation in idle modes.

When considering incorporating graphic card adders to account for correspondingly higher and necessary functionality, staff considered ENERGY STAR 6.1 and European Union adder levels and schemes. Staff has found that these levels were too high compared to modern graphic card idle performance and even worse when future improvements are considered. Staff held a series of meetings with the IOUs, NRDC, ITI, and the largest two graphic card design companies, NVIDIA and AMD, and discussed levels that would be appropriately adjusted from existing frameworks and would incorporate future improvements. The results of these technical discussions are adders that are significantly more stringent than in existing standards, which represent significant technological progress.

Integrated Display

Adders for integrated displays were included in the 2015 proposal. At that time, the adders were aligned 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, this draft staff report proposes to reduce the adder by 20 percent, consistent with efficiency proposals for stand-alone displays presented later in this report.

Random Access Memory

Adders were proposed in the initial draft for random access memory (RAM) that were aligned with ENERGY STAR Version 6.1. This adder scaled by the size of the memory added, giving 0.8 kWh/year per GB incorporated. Further investigation of the contribution of RAM to energy consumption suggests that consumption is connected with the type of RAM and number of physical modules rather than the size of the memory space in idle mode. The Energy Commission proposes to change the adder to 2.5 kWh/year per module. This level is based on observed power consumption levels of DDR3 memory in idle across several sizes and on assumption of 75 percent conversion efficiency.

In addition to properly scaling allowances, the proposal to move to a per-module adder addresses the deterioration of the stringency of the standard over time from the expansion of average memory capacity over time. The Commission is interested in additional feedback on whether to continue to scale memory by capacity, or by number of modules, and if the change is made, what levels to set per module.

Additional Hard Disks

Adders were proposed in the initial draft for 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 and long-idle modes. However, it 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 require the identification of the primary hard-disk drive versus the secondary drive as it could have implications to the allowable maximum energy use. The primary hard-disk drive is the hard-disk drive used to boot the computer.

Energy-Efficient Ethernet

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

$$8.76 \times 0.2 \times (0.15 + 0.35) = 0.876$$

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

Expandability Adder

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. ENERGY STAR 6.1 achieves this is with a “p-score” that is equivalent to the rated maximum clock speed of the processor multiplied by the number of cores. Staff analyzed this score as the basis for differentiating energy consumption targets and found that it did not form a good basis for future 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, power supply sizing, is driven by the expandability of a system through 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 power supply load curve, which typically leads 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 Peripheral Component Interconnect (PCI) controllers. Each controller 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 a driver of idle mode power. Bandwidth is partially solved by frequency scaling in both desktop and notebook computers. It is also related to the type of interfaces in 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 ports available in a computer. The higher the score, the more energy a computer can use. The first 200 watts of power are considered typical of a standard system. Subsequent scores accumulate an energy adjustment that increases the allowable energy consumption for compliance. At 750 watts, a desktop must comply with workstation rather than the desktop requirements.

Notebook Computers

The technical feasibility and efficiency opportunities for notebooks are similar to those of desktops. The frequency and extent to which these features and approaches have been incorporated into notebooks are far greater than in desktops. More than half of the notebooks certified to the ENERGY STAR Version 5 specification already meet the staff proposed notebook standard. In addition, more than 72 percent of models certified to the ENERGY STAR Version 6 specification meet proposed levels as of November 5, 2014. New adders for graphics accelerators are consistent with the discrete graphics card section above and are reflected in the proposed regulations in Chapter 8. The expandability adder does not apply to notebooks, which characteristically have limited expandability, resulting in a smaller range of power supplies.

CHAPTER 6: 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 programs such as ENERGY STAR are also likely to continue to exert pressure on the market to improve efficiency. The savings do not attempt to separate credits 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. Overall energy savings estimates have been reduced, primarily from decreased stringency in the proposed standards from the inclusion of graphics and expandability adders. **Table 4** below compares the energy savings and cost-effectiveness per unit of a product under the proposed standards. **Table 5** analyzes the statewide savings after the first year of the standards and after all existing stock is replaced by compliant products (stock turnover).

Table 4: Unit Energy Savings and Cost-Effectiveness

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 ($)[63]	Incremental Cost ($)	Net Benefit (ratio benefit: cost)
Desktop	143.2	65.8	5	391	$61.92	$18.00	$43.92 (3.44: 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 (2.3: 1)

Source: Energy Commission staff

63 Using $0.16 per kWh.

Table 5: Potential Energy Savings for One Year of Sales and Future Stock

Product Type	Unit Savings (kWh/yr)	Unit Sales (million)[64]	Unit Stock (million)[65]	1-Year Sales Savings (GWh/yr)	Stock Savings (GWh/yr)	Reduced Electricity Cost ($M/yr)
Desktop	77.4	2.9	23.4	224.5	1,811.2	$289.8
Notebook	3.6	5.2	21.0	18.7	75.6	$12.1
Small-Scale Server	24.0	0.06	0.3	1.44	7.2	$1.2
Workstation	37.4	0.15	0.53	5.61	19.8	$3.2
Total	142.4	8.31	45.23	250.25	1,913.8	$306.3

Source: Energy Commission staff

During the rulemaking, the Commission has 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. However, the Commission does not expect this to affect the cost-effectiveness of the regulations. Manufacturers would systematically choose improvements that provided benefit only in idle mode (and not active mode) only if those improvements were significantly less expensive. In that sense, savings would be decreased, but cost would also be decreased.

64 Shipment figures for desktops and notebooks are taken from the ITI July 23, 2013, comments, which are 2017 projections based on the IDC 2011 shipment figures. Figures for small-scale server and workstation shipments were taken from the August 6, 2013, IOU comment letter projections on shipments in 2017, p. 24.

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

CHAPTER 7: 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. Some efficiency approaches to reducing idle power can lead to reductions in active mode power and can save material and reduce disposal impacts. Therefore, 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 them. Lower electricity consumption results in reduced GHG 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 0.599 $MMTCO_2e$.[66]

66 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.

CHAPTER 8: Proposed Regulatory Language

All language that would be new to the appliance efficiency regulations is underlined with the exception of section headers.

1601 Scope.

…

(v) Computers, computer monitors, enhanced-performance display (EPD) monitors, televisions, and consumer audio and video equipment, which are compact audio products, digital versatile disc players, and digital versatile disc recorders.

…

1602 Definitions.

(a) General.

…

"Basic model" of a computer means a group of models of computers that are made by a single manufacturer and that have the same chassis, power supply, and motherboard. Models within the basic model all contain the same expandability score.

…

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

"Computer" means a device that performs logical operations and processes data. A computer includes both stationary and portable units and includes desktop computers, integrated desktop computers, notebook computers, small-scale servers, thin clients, and workstations. Although computers are capable of using input devices and displays, such devices are not required to be included with the computer upon shipment. Computers are composed of, at a minimum:

a) A central processing unit (CPU) to perform operations or, if no CPU is present, then the device must function as a client gateway to a server, which acts as a computational CPU.

b) Ability to support user input devices such as a keyboard, mouse, or touchpad.

c) An integrated display screen or the ability to support an external display screen to output information.

A computer does not include a tablet, a game console, a handheld gaming device, a server other than a small-scale server, or an industrial computer.

"Desktop computer" means a computer whose main unit is designed to be located in a fixed location, often on a desk or on the A desktop computer includes computers that may be sold with a display integrated into the unit or a display that is powered through the power supply of the desktop computer. A workstation or small-scale server is not a desktop computer. A computer that has both an integrated display and integrated energy storage capable of operating the computer for more than 30 minutes in short-idle mode is not a desktop computer.

"Energy-Efficient Ethernet capability" means Ethernet interfaces that are capable of reducing power consumption during times of low data throughput, as specified in IEEE 802.3az (2010).

"Expandability score" means the results of a calculation designed to estimate a computer's power supply capacity based on the power draw if each slot and port present in the system were occupied by a device.

"Game console" means a device that is designed and marketed for video game usage and that does not have the ability to expand volatile memory.

"Industrial computer" means a process controller that is designed specifically to automate an industrial process or a computer integrated into the chassis of industrial equipment that contains more than a computer.

"Integrated desktop computer" means a desktop computer in which the computing hardware and display are integrated into a single housing, and which is connected to AC power through a single cable. Integrated desktop computers come in one of two forms: (1) a system where the display and computer are physically combined into a single unit; or (2) a system packaged as a single system where the display is separate but is connected to the main chassis by a DC power cord, and both the computer and display are powered from a single power supply.

"Long-idle mode" means a state where the computer has reached an idle condition 15 minutes after operating system boot, after completing an active workload or after resuming from sleep mode, and the main computer display has entered a low-power state where screen contents cannot be observed (for example, backlight has been turned off) but remains in the working mode ACPI G0.

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

"Off mode" means ACPI System Level S5 state.

"Short-idle mode" means a state where the computer has reached an idle condition five minutes after operating system boot, after completing an active workload, or after resuming from sleep mode, and the screen is on and the computer remains in the working mode ACPI G0.

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

“Small-scale server” means a computer that uses desktop components in a desktop form factor but that is designed to be a storage host for other computers. Small-scale servers are designed to perform functions such as providing network infrastructure services (for example, archiving) and hosting data and media. These products are not designed to process information for other systems or run Web servers as a primary function. A small-scale server has the following characteristics:

a) Designed in a pedestal, tower, or other form factor similar to those of desktop computers such that all data processing, storage, and network interfacing is contained within one box/product;

b) Designed to operate continuously, with minimal unscheduled downtime.

c) Capable of operating in a simultaneous multi-user environment serving several users through networked client units; and

d) Designed for an industry-accepted operating system for home or low-end server applications (e.g., Windows Home Server, Mac OS X Server, Linux, UNIX, Solaris).

“Small Volume Manufacturer” means a manufacturer that meets all of the following criteria:

a) The manufacturer’s gross revenues from the preceding 12-month period from all of the entity’s operations, including operations of any other person or business entity that controls, is controlled by, or is under common control of the entity, is $750,000 or less; and

b) The manufacturer assembles and sells the computers at the same location.

To be considered a small volume manufacturer, the business must submit an application to the Energy Commission under Section 1606(a)(2)(D).

“Similar systems” means computers with the same motherboard size and power supply unit size.

a) “Motherboard size” means the length and width of the motherboard in inches.

b) “Power supply size” means the maximum output power of the power supply unit in watts.

“Workstation” means a high-performance computer used for graphics, computer aided design, software development, financial, and scientific applications, among other computation intensive tasks. Workstations covered by this specification

a) Do not support altering frequency or voltage beyond the CPU and GPU manufacturers’ operating specifications; and

b) Have system hardware that supports error-correcting code (ECC) that detects and corrects errors with dedicated circuitry on and across the CPU, interconnect, and system memory.

A workstation is a computer that has an expandability score greater than 750 or that meets three or more of the following criteria:

a) Provides support for one or more graphic or compute accelerators;

b) Is wired for > x4 PCI-E on the motherboard in addition to the graphic slot and/or PCI-X support;

c) Contains five or more logical expansion ports (PCI, PCI-Express, PCI-X, Thunderbolt, >USB3.1, or equivalent);

d) Provides multi-processor support for two or more processors (shall support physically separate processor packages or sockets; this requirement cannot be met with support for a single multi-core processor); or

e) Has received qualification from two or more independent software vendor (ISV) product certifications.

"Thin client" means an independently powered computer that relies on a connection to remote computing resources (for example, a computer server or a remote workstation) to obtain primary functionality. Main computing functions (program execution, data storage, interaction with other Internet resources) are provided by remote computing resources. Thin clients are devices with no integral rotational storage media and are designed for use in a fixed location during operation.

…

Section 1604 Test Methods for Specific Appliances.

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

…

(4) Computers shall be tested using the *ENERGY STAR Test Method for Computers, Rev. August 2014*, with the following modifications:

A) Settings regarding hard-disk spinning shall not be altered from the default as-shipped settings.

B) The total energy consumption of a desktop computer, notebook computer, or thin-client computer shall be calculated using Equation 1 and the appropriate mode weighting of **Table 3** contained within the *ENERGY STAR Program Requirements Product Specification for Computers Eligibility Criteria Version 6.1 Rev. Oct. 2014.*

i. A computer that does not provide a user interface to disable power management settings may choose the applicable alternative mode weightings below.

Criteria	**Short Idle**	**Long Idle**	**Sleep**	**Off**
Cannot disable display power management	30%	15%	10%	45%
Cannot disable computer power management	30%	5%	20%	45%

ii. A computer with an operating system that does not incorporate power management shall use the following weighting:

Criteria	**Short Idle**	**Long Idle**	**Sleep**	**Off**
Cannot disable display power management	20%	30%	0%	50%

C) The expandability score shall be calculated as follows:

i. Sum the product of each port score multiplied by the number of such ports present in the system as sold or offered for sale.

ii. Add 100 to the score.

Port Type	***Port Score***
USB 2.0 or less	5
USB 3.0	10
USB C	15
USB-PD	100
PCI slot other than PCIe x16	25
PCIe x16 or higher	75
Thunderbolt 2.0 or less	20
Thunderbolt 3.0 or greater	100
M.2	10
IDE, SATA	15

D) A computer monitor used in the testing of computers shall have a native resolution of 1920x1080 pixels and use progressive scanning. The computer operating system shall be set to operate at 1920x1080 pixels and progressive scanning.

…

1605.3 State Standards for Non-Federally Regulated Appliances.

…

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

…

(4)A desktop computer or notebook computer manufactured on or after January 1, 2018, shall:

(A) Comply with **Table V-3**; and

(B) Be shipped with power management settings that:

(1) Transition the computer into either the sleep mode or off mode measured in 1604(v)(4) within 30 minutes of user inactivity and;

(2) Transition connected displays into sleep mode within 15 minutes of user inactivity.

(3) If the model is shipped without an operating system per the purchaser's request, the model is not required to comply with 1605.3(v)(4)(B)(1) and 1605.3(v)(4)(B)(2).

Table V-3
Energy Consumption Standards for Computers

Computer Type	Maximum total energy consumption on or after January 1, 2018
Desktops and Thin-Clients	*50 kWh/yr + applicable adders in Table V-4*
Notebook	*30 kWh/yr + applicable adders in Table V-4*

Table V-4
List of Potentially Applicable Adders

Function	Desktop and Thin-Client Adder (kWh/yr)	Notebook Adder (kWh/yr)
Memory (per module)	2.5	2.5
Energy-Efficient Ethernet	0.9	0.9
Storage	3.5-inch Drive: 26 2.5-inch Drive: 4.5 Solid-State Memory: 0.5 Other: 26	2.6
Expandability Score	For ES <200: 0 For ES >= 200: (ES-200)/20	N/A

Integrated Display Where: “r” is the megapixel resolution of the display “A” is the viewable screen area in square inches EP = 0 for standard displays EP = 0.3 for enhanced displays less than 27 inches in diagonal length EP = 0.75 for enhanced displays of 27 inches or greater in diagonal length	$8.76 \times 0.35 \times (1+EP) \times (4\times r + 0.05\times A)$	$8.76 \times 0.30 \times (1+EP) \times (2\times r + 0.02\times A)$
Discrete Graphics (before January 1, 2019) Where “B” is frame buffer bandwidth measured in GB/s	66.8*TanH(0.0038*B+0.2)+2.67	33.4*TanH(0.0038*B+0.2)+1.34
Discrete Graphics (after January 1, 2019) Where “B” is frame buffer bandwidth measured in GB/s	32.9*TanH(0.007*B-0.1)+10.68	16.5*TanH(0.007*B-0.1)+5.34
Additional Discrete Graphics	11	5.5

(5) Small scale servers and workstation computers manufactured on or after January 1, 2018 shall:

(A) Be powered by a power supply that meets the 80 PLUS Gold performance standards;

(B) Incorporate Energy Efficient Ethernet functionality;

(C) Transition connected displays into sleep mode within 15 minutes of user inactivity.

(D) Transition into a sleep mode within 30 minutes of user inactivity.

(6) Computers manufactured by businesses qualified as “small volume manufacturers”. A computer manufactured on or after January 1, 2018, by a small volume manufacturer must comply with the power management settings identified in Section 1605.3(v)(4)(B) and 1605.3(5)(C) and (D). Small volume manufacturers are exempt from all other requirements for computers unless they manufacture more than 15 units of a similar system. If a small volume manufacturer produces more than 15 units of a similar system, the manufacturer must certify that those models meet the requirements in Sections 1603, 1604(v), 1605.3(v)(4) or (v)(5), 1606, and 1607.

…

1606. Filing by Manufacturers; Listing of Appliances in Database.

…

Table X
Data Submittal Requirements

	Appliance	*Required Information*	*Permissible Answers*
V	Computers	Computer Type	Desktop, Notebook, Small-Scale Server, Workstation, Thin Client
		Operating System	
		Core Speed (gigahertz)	
		Number of Cores	
		Amount of RAM (gigabytes)	
		Discrete Graphics	Bandwidth in gigahertz
		Does the computer have an integrated display?	Yes, No
		Diagonal screen size (inches)	
		Viewable screen area (square inches)	
		Resolution (megapixels)	
		Enhanced Performance	Yes, No
		Length of time of user inactivity before entering sleep (minutes)	Do not report a number if the model does not enter sleep
		Length of time of user inactivity before placing display into sleep (minutes)	Do not report a number if the model does not enter sleep
		Energy Efficient Ethernet Capability	Yes, No
		Off-mode power (watts)	
		Sleep-mode power (watts)	
		Long-idle power (watts)	
		Short-idle power (watts)	
		Expandability Score	
		Total Annual Energy Consumption (kilowatt hours per year)	
		Small Volume Manufacturer	Yes, No
		Motherboard Size (inches) (if small volume manufacturer)	
		Power Supply Size (Watt) (if small volume manufacturer)	

…

(a)(2)(D) Small Volume Manufacturers.

Entities seeking to be designated as a “small volume manufacturer” for purposes of Section 1605.3(v) and 1608(a)(5) shall submit the following information:

1. Gross revenue from the preceding 12-month period from all of the entity's operations, including operations of any other person or business entity that controls, is controlled by, or is under common control of the entity,

2. Location where entity assembles product, and

3. Motherboard size and power supply size for all models of computers manufactured, where 15 units or less of similar systems are manufactured.

4. If more than 15 units of a similar system are manufactured, then the small volume manufacturer must certify that those similar systems meet the full requirements in Sections 1601-1608.

Manufacturers certifying their models through this alternative method shall, as part of the declaration required in Section 1606, make a statement under penalty of perjury that they meet all criteria for small volume manufacture and keep records supporting their certification.

…

Part B – Computer Monitors and Signage Displays

CHAPTER 9: Background

More than 21 million computer monitors are installed in residential and commercial settings in California.[67] Statewide, computer monitors consume about 1,284 gigawatt hours (GWh) of electricity per year. Computer monitors contribute to a peak demand of almost 200 megawatts (MW).[68]

Computer monitors use energy in three primary power modes: on, sleep, and off. On mode occurs when the display is on and an image is displayed. Sleep mode is a temporary low power state entered after a period of inactivity (for example, for a monitor, a period when power management is enabled). Off mode is the lowest power mode and is reached when the user powers down the display by manually switching it off. Power draws for display on mode depend on display technology, screen size, and resolution. Power consumption for all three modes is measured in watts (W).

Staff evaluated the test data and found that energy consumption of computer monitors is directly related to the brightness of the screen. As the brightness of the display increases, it consumes more energy. User-controlled and automatic dimming techniques have the potential to decrease energy consumption by decreasing screen brightness. Automatic brightness control scales screen brightness to ambient lighting conditions, dimming the screen in low light conditions. Similar to automatic brightness control, global dimming controls light output based on image content; the backlight is turned down for dark scenes and turned up for bright or white images. Even without automatic control, screen brightness can be manually controlled on most computer monitors using buttons on the display or a software menu. Manufacturers of LED-backlit computer monitors have significantly improved the efficiency.

Even though computer monitor shipments have decreased slightly in recent years due to increased notebook and tablet sales, monitor sales are projected to stabilize and grow in the coming years, driven by monitor upgrades, increased adoption of larger screen sizes and resolutions, use with notebook computers, and multiple monitor set-ups. Energy consumption by computer monitors is projected to grow accordingly.

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. DOE or the Federal Trade Commission.

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67 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.

68 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.

The U.S. 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.[69] Many manufacturers have computer monitor models that meet Version 6.0 specifications.[70] U.S. EPA finalized its Version 7.0 specification in October 2015, which is scheduled to take effect July 1, 2016.[71] U.S. EPA has stated that data analysis of ENERGY STAR-compliant monitors shows that 20 percent of computer monitors sold meet ENERGY STAR specification Version 7.0.[72]

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 remainder of this report describes the efficiency opportunities and potential savings for computer monitors and displays.

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

70 88% 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

71 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.

72 “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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CHAPTER 10: Product Description

Scope

Three types of computer monitors and displays are analyzed in this report: computer monitors, enhanced performance displays (EPDs), and signage displays.

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

1. Electronic reader displays (for example, smog analyzers)
2. Digital picture frames
3. Computer monitors classified by the United States Food and Drug Administration for use as medical devices
4. Electronic billboards
5. Professional 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
6. Televisions
7. Integrated displays (for example, those built into laptop computers or all-in-one personal computers, and multimedia projectors); integrated displays may be covered in the computer standard (see Part A)

Computer Monitors

A computer monitor displays graphical information and is intended for use by one person at a desk. The 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 liquid crystal display (LCD), although other technologies such as organic light-emitting diodes and quantum dot displays may come to market in the future.[73] 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, and DC voltage stepdown components. The scope of this proposal 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 monitors less than 17 inches are not considered here, as sales volumes of these displays are low and are estimated to decrease.[74]

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73 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.

74 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.

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. The backlight for the display is provided by LEDs. Until recently, cold cathode fluorescent lamps (CCFLs) [75]were a less expensive light source, but today LEDs are not only more efficient, but are 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 LEDs along the edge of the screen; light from LEDs is redirected from the edge of the monitor toward the viewer through the use of a light guide plate to spread the light evenly behind the LCD panel.

- In a full-array configuration the LEDs cover the entire backside of the backlight unit.[76] 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, computer displays have a contrast ratio of about 1000:1. However with DCR, these numbers vary from 4000:1 to 10,000:1, and higher.[77]

Optical Film Stack

Once light is produced, another key component of the monitor is the optical film stack, which acts to spread light evenly across the display area and also 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

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

76 "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.

77 "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/.

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, for example, 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 the 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.[78],[79] 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 of 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.

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

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78 "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/.

79 "What Is Sharp Aquos Quattron, Quadpixel, and Quadcolor LED TV Technology?" Available at http://lcdtvbuyingguide.com/hdtv/sharp-quadcolor.html.

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 lowest 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, OLEDs have become available in the market. OLED monitors have the potential to be much more efficient than LCD displays, but are also more expensive than LCD displays. 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 to it. 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 smart phones 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.[80] 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-

80 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.

eXtended Graphics Array (WUXGA). Out of the standard graphics arrays, WUXGA have the highest resolution at 1,920 pixels wide by 1,080 pixels high (also expressed as 1920X1080 or 2.07 MP). Recently, Quad High Definition (QHD) entered the monitor market with resolution of (2560X1440 or 3.69MP). **Table 6** describes resolution bins for computer monitors.

Table 6: 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

Source: IOU CASE Report (2013) and Dell

In recent years, 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, panel technology, and so forth). 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.

Modes

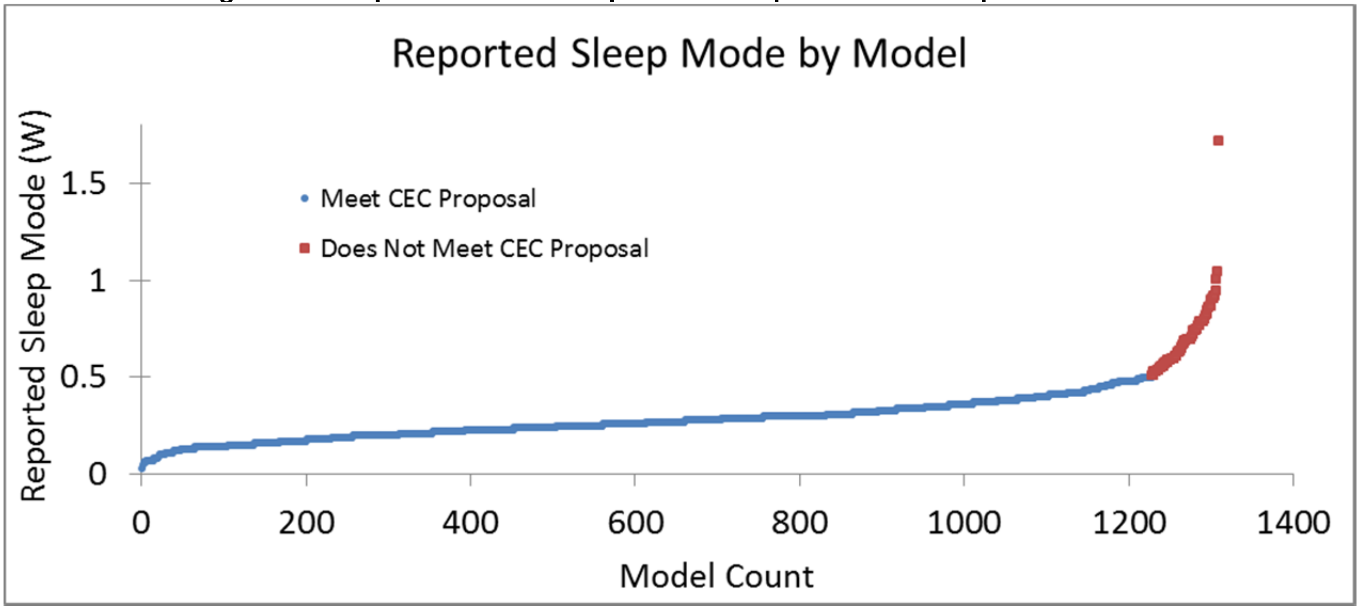
A computer monitor can operate in three primary power modes: on, sleep, and off. Power consumption in all three power modes is described in watts (W).

On Mode: The mode in which the display has been activated and is providing 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 may serve the following functions: ease 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 1** shows reported sleep modes from models from the ENERGY STAR-certified products list.

Figure 1: Computer Monitor Sleep Mode: Sleep Mode Consumption[81]

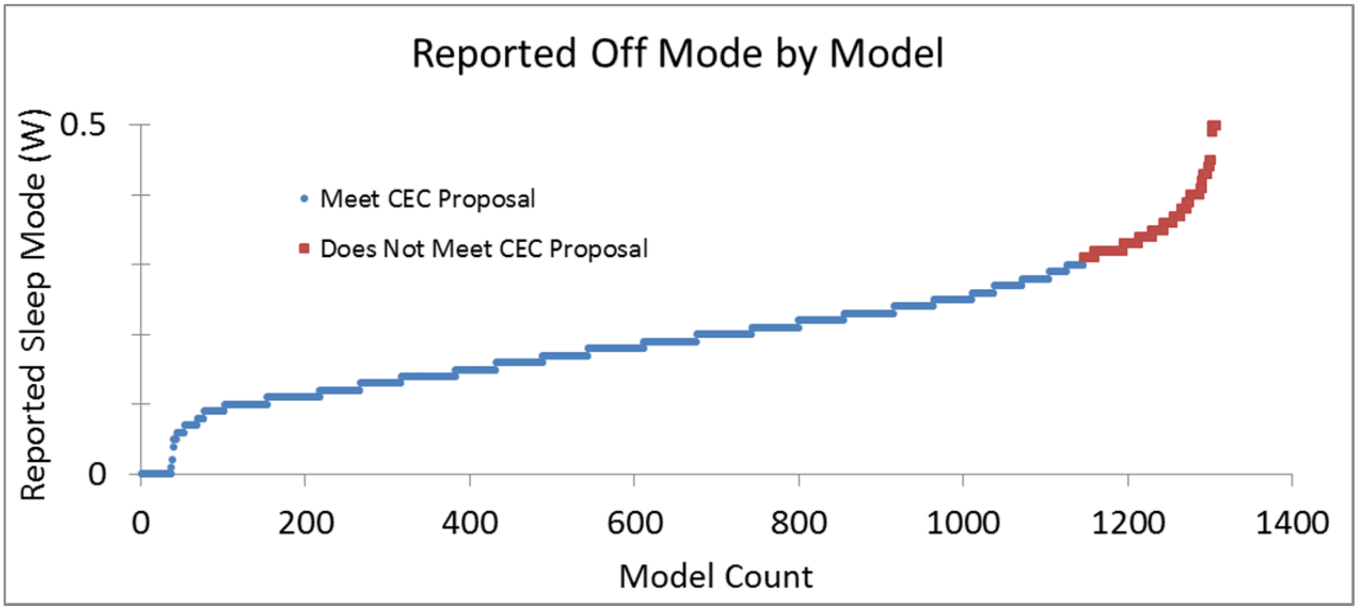


Source: IOU CASE Response (2015), p. 16.

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 2** below 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.

81 IOU CASE Response: Electronic Displays, May 29, 2015, available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN204782_20150529T154245_Bijit_Kundu_Energy_Solutions_on_behalf_of_California_IOUs_Comme.pdf, p.15.

Figure 2: Computer Monitor: Off Mode Consumption



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

Most monitors (more than 80 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 data (**Table 7**). 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 (QPL), and both have a sleep-mode power greater than 1W and off-mode power greater than 0.3W. A Gigabit Ethernet controller managed with Energy-Efficient Ethernet (EEE), however, can idle at less than 0.2W.[82]

82 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.

Table 7: 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 P_{sleep}	0.31	0.27	0.43	0.30	1.37	0.35	0.52	0.41
	% models P_{sleep} <= 0.5W	92%	99%	71%	100%	0%	85%	53%	50%
Off	Average P_{off}	0.20	0.19	0.24	0.22	0.39	0.22	0.25	0.25
	% models P_{off} <= 0.3W	85%	89%	74%	71%	0%	78%	71%	50%

Source: Energy Commission staff

Other Factors

Computer monitors have other features that can consume additional power in on mode and sleep mode. Some of these features 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 available that can limit the wasteful energy consumed by the additional features when not in use. Speakers, cameras, and microphones can be turned off when these functions are is 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

An *enhanced-performance display* (EPD) is a computer monitor display that has a contrast ratio of at least 60:1 measured at a horizontal viewing angle of at least 85°, with or without a screen cover glass. EPDs have a native resolution that is equal to 2.3 MP or greater and a color gamut size of at least sRGB,[83] as defined by International Electrotechnical Commission (IEC) 61966-2-1 (2003-01). Shifts in color space are allowable as long as 99 percent or more of defined sRGB colors are supported.[84]

EPDs are different from standard computer monitors. EPDs provide increased color gamut, greater contrast ratio, better viewing angles, higher resolution, integrated accessories, and expansion potential. EPDs are designed for specialized applications such as engineering, medical, architecture, and graphic design. EPDs have characteristics that are likely to become common in mainstream computer monitors in the future because they have high resolution and accurate color reproduction. IOUs' analysis of EPDs shows that EPDs require additional power

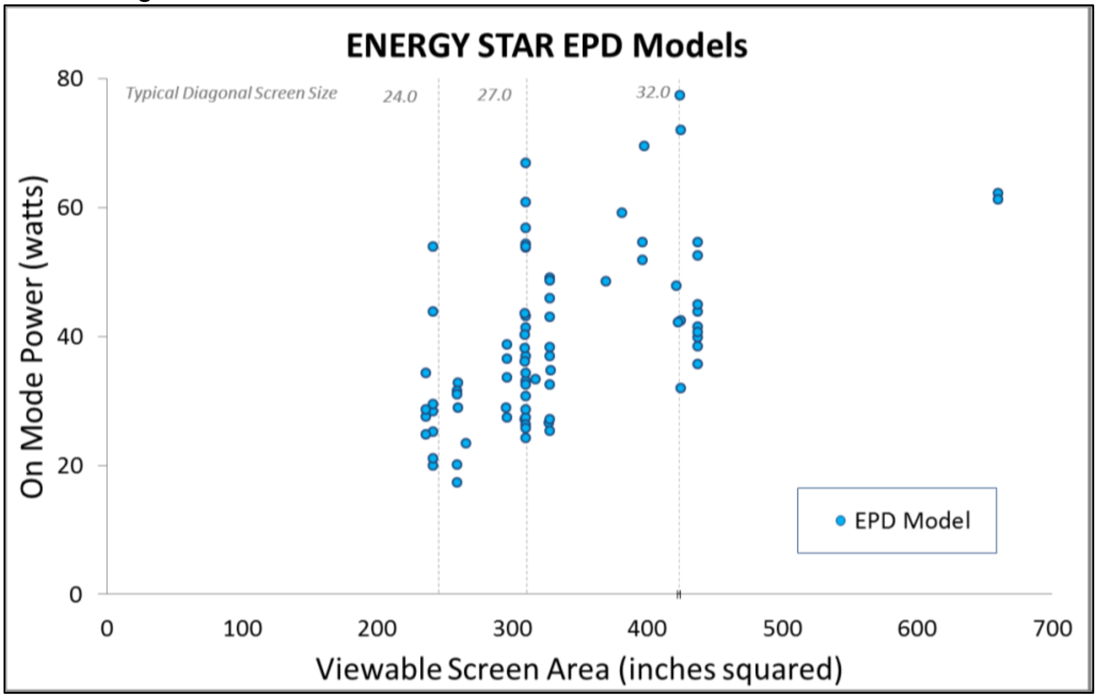
83 sRGB: Standards Red Green Blue.

84 ENERGY STAR Program Requirements Product Specification for Displays Eligibility Criteria Final Draft Version 6.0, available at http://www.energystar.go.jp/document/pdf/disp/150731/FD%20Version%207%20Displays%20Specification.pdf, p 1.

than the standards computer monitors; however, there are opportunities for improvements in the EPDs similar to mainstream computer monitors.[85]

Figure 3 is plotted based on the ENERGY STAR Version 6.0 data for EPDs, and it shows that in the on power consumption mode, there is a wide variation in power consumption among same-size EPDs.

Figure 3: ENERGY STAR Data for EPD: On Mode Versus Screen Area



Source: IOUs CASE Response to Staff Report (2015)

EPDs use two color schemes: standard 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. Adobe RGB covered more of the RGB color space in the 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. 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

85 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.

transmissivity of 3 percent for two EPDs[86] compared to 6 to 11 percent for standard monitors.[87] 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 a higher backlight power to produce the additional light required for a comparably bright screen. The IOUs measured BLU power of two EPDs to be 36 to 50 percent more than that of two standard monitors in the default modes; they IOUs also noted that the power scaling modes of the EPDs cut backlight power to less than that of the standard monitors in equivalent modes (**Table 8**).

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 shows there are about 68 EPD sRGB models available in the market, and 24 meet the proposed standard. Majority of the models with 32.9 percent of International Commission on Illumination CIELUV (99 percent or more of defined sRGB colors) would meet the proposed on mode requirements if an additional power allowance of 10 percent were provided.[88],[89] No models covering at least 38.4 percent of CIELUV (99 percent of Adobe RGB colors) would meet the proposed requirements, indicating that an additional allowance of 50 percent may be required to ensure that this product type remains available. There are six Adobe RGB EPDs on the market, and none meets the proposed standard levels. With additional power allowances, the majority of the EPD products meeting ENERGY STAR version 7.0 will be able to comply with the proposed standards.

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86 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.

87 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.

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

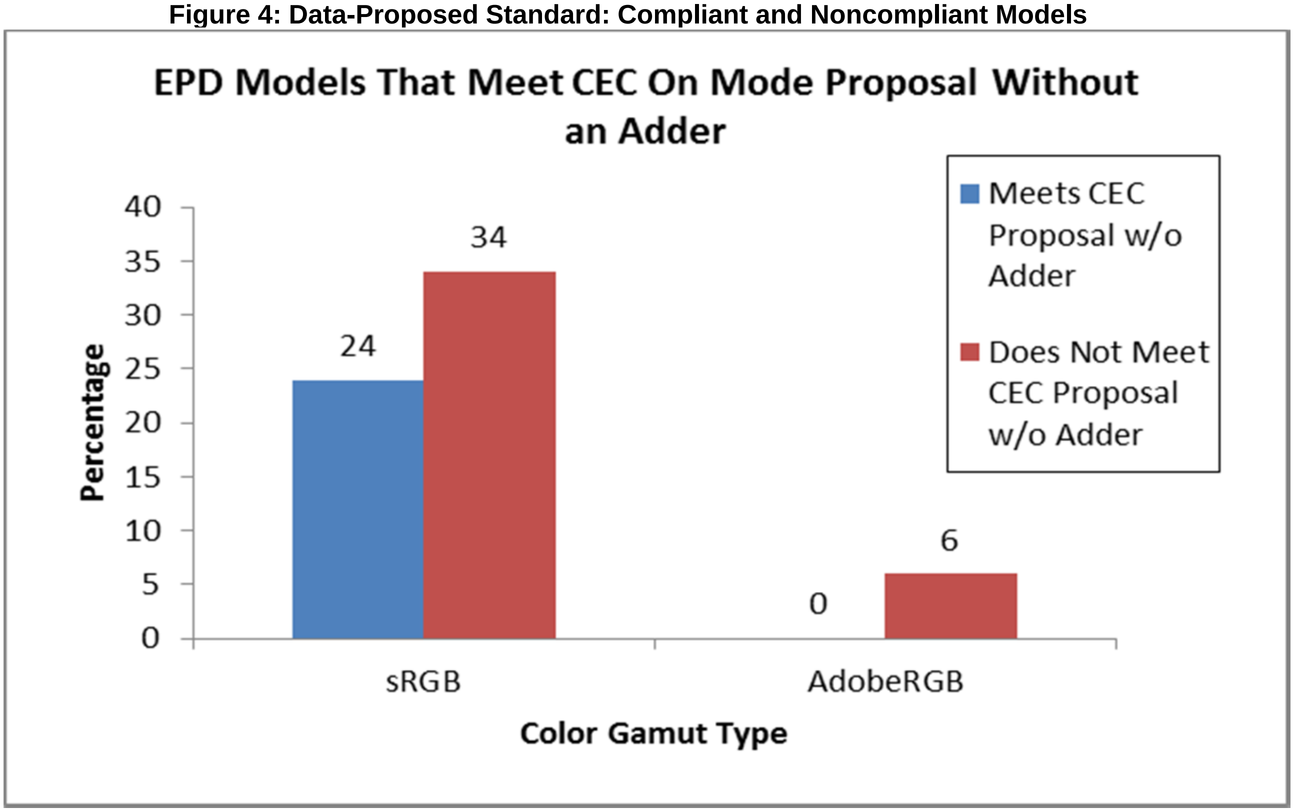
89 A display screen made with thin-film transistor technology is an LCD, common in notebook and laptop computers, that has a transistor for each pixel (that is, for each of the tiny elements that control the illumination of your display). Having a transistor at each pixel means that the current that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

Table 8: Test Data for 27-Inch Baseline and Efficient Monitor Pairs

Mode	Test Unit[90]	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

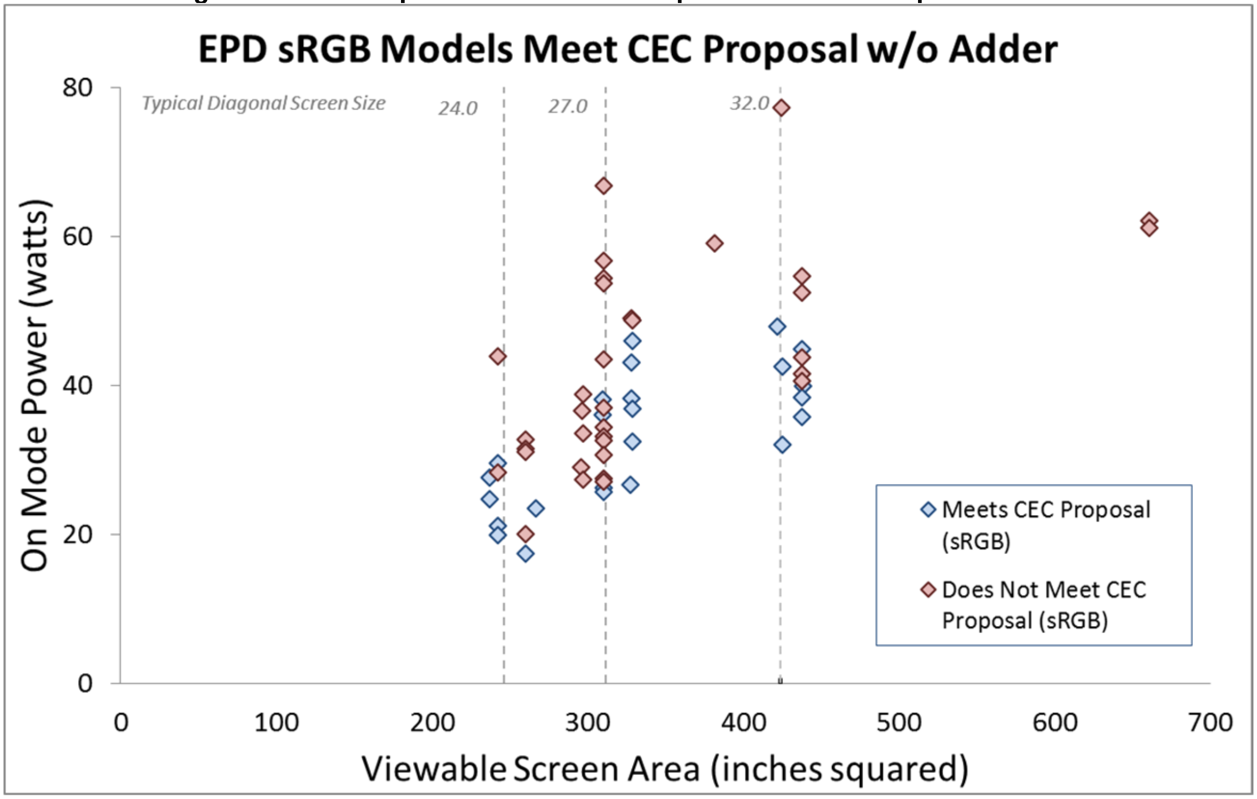
Figure 4: Data-Proposed Standard: Compliant and Noncompliant Models



Source: Energy Commission staff

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

Figure 5: Data Proposed Standard: Compliant and Noncompliant Models



Source: Energy Commission staff

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.[91] 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.[92] However, some manufacturers were not clear as to whether the 2009 television regulations covered signage display units.

91 *2015 Appliance Efficiency Regulations*, available at http://www.energy.ca.gov/2015publications/CEC-400-2015-021/CEC-400-2015-021.pdf, p. 204, 205.

92 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

U.S. DOE has no 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 Energy Guide labels.

ENERGY STAR Maximum On-Mode Power Draw Criteria

Many manufacturers have been participating in ENERGY STAR Version 6.0 specification for computer monitors.[93] Energy allowance requirements are described through ENERGY STAR Version 6.0 equations. These equations apply to diagonal screen size 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, and monitors with automatic brightness control (ABC) 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 watts. Power allowances provide an additional sleep mode allowance up to 0.7 watts for bridging or network or 0.5 watts for additional capabilities. Off mode requires a power draw of less than or equal to 0.5 watts. 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 takes effect July 1, 2016. Version 7.0 requires computer monitors' brightness levels to be tested and calibrated at 200 nits.[94] 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.[95]

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. No other stakeholder proposal

93 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.

94 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.

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.

was received. IOUs recommend on mode maximum requirements based on screen size and resolution. Most models "out of the box" are brighter than 200 nits, and end 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.

Energy Commission Staff's Proposal

Test Procedure

To measure the energy comsumption of computer monitors, staff recommends using the ENERGY STAR test method, published in September 2015, and associated with ENERGY STAR Product Specification for Displays Version 7.0.[96] The proposed test method requires the monitor to be calibrated to a screen luminance of 200 cd/m^2 for the on -mode power measurement. To discourage excess energy use of monitors shipped with overly bright screens, staff also proposes that monitors shall be shipped with screen luminance less than or equal to 200 cd/m^2. In real world use, consumers can easily increase screen brightness, if needed.

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 for on-mode power requirements. Furthermore, staff proposes maximum power for sleep mode (P_{SLEEP_MAX}) and off mode (P_{OFF_MAX}).

The available ENERGY STAR data indicate that the previous staff proposal was too lenient for high-resolution monitors.[97] Staff has reduced the on mode power allowance for monitors with resolutions greater than 5 MPs. If monitor resolution is greater than 5 MP, "*r*" in the power allowance equation is a constant value of 5 MP, so that the first term in the P_{ON_MAX} equation (4.2* r) is a constant 21.

The requirements for low power modes have been updated from the previous staff report since virtually all models in the ENERGY STAR dataset meet the previously proposed 1.0 watt and 0.5 watt requirements for sleep and off modes, respectively. Staff has revised P_{SLEEP_MAX} to 0.5W and P_{OFF_MAX} to 0.3W.

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

96 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.

97 CA IOU CASE Response (May 2015). Docket #14-AAER-2 available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf.

Table 9: Maximum Power Allowances by Modes – Computer Monitors

Diagonal Screen Size in inches (d)	On Mode in Watts ($_{PON\_MaX}$)	Sleep Mode in Watts (P_{SLEEP_MAX})	Off Mode in Watts (P_{OFF_MAX})
Resolution (*r*) Less Than or Equal to 5.0 MP			
17”≤d<23”	(4.2*r) + (0.02*A) +2.2	0.5	0.3
23”≤d<25”	(4.2*r) + (0.04*A) – 2.4	0.5	0.3
25”≤d	(4.2*r)+(0.07*A)– 10.2	0.5	0.3
Resolution (*r*) Greater Than 5.0 MP			
17”≤d<23”	21 + (0.02*A) +2.2	0.5	0.3
23”≤d<25”	21 + (0.04*A) – 2.4	0.5	0.3
25”≤d	21 + (0.07*A) – 10.2	0.5	0.3
Touch Screen (All)	1 Watt		

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 mode power maximum as proposed in **Table 9**. This was based on information submitted by the IOUs regarding touch-screen monitors.[98]

Default Settings

To discourage excess energy use of monitors shipped with overly bright screens, staff also proposes that monitors be shipped with screen luminance less than or equal to 200 cd/m^2. In real world use or retail settings, consumers can easily increase screen brightness, if needed.

Enhanced Performance Displays

Based on the ENERGY STAR data, almost half of the computer monitors available today with 32.9 percent of CIELUV (99 percent or more of defined sRGB colors) need additional power allowance of 10 percent to comply with the proposed on mode allowances. (See **Figure 4.**) Models covering at least 38.4 percent of CIELUV (99 percent of Adobe RGB) need a power allowance of 50 percent to comply with the staff proposal. For products meeting the definition of an EPD with a color gamut specified in **Table 10**, a power allowance adder (P_{EP}) shall be added to the on mode power maximum as proposed in **Table 10.** In these cases, measured on mode power (P_{ON}) shall be less than or equal to the sum of P_{EP} and $_{PON\_MAX.}$

98 *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 10: On Mode Power Allowance Adder for EPDs

Color Gamut Criteria	On Mode Power Allowance Adder in Watts (P_{EP})
Color Gamut support is 32.9% of CIELUV or greater (99% or more of defined sRGB colors)	$0.10*P_{ON\_MAX}$
Color Gamut support is 38.4% of CIELUV or greater (99% of Adobe RGB)	$0.50*P_{ON\_MAX}$

Source: Energy Commission staff

Signage Displays

Staff has included a definition of signage displays and clarifies that signage displays are included 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)
$d<1400^2$ inches	(0.12*A) +25	1	0.9

Where A is a viewable screen area (Square Inches). Staff Report for Proposed Efficiency Standards for Televisions [99]

99 *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 12: 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, 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 (UEC) in computer monitors.

The use of more efficient LED backlights in LCD monitors over the less efficient LEDs or CCFL backlights can reduce power consumption. 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 that decrease the energy consumption by increasing the energy efficiency of their products. Some of the technological options available are shown in **Table 11**.

Table 11: 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	Trade-offs in material cost, ease of manufacture, and efficiency
		Reflective polarizer	Slight cost increase[100]
LCD Panel		Improvement in panel transmittance by optimizing pixel design, functional layers, e.g., polarizer, color filter, and data line	Re-design 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 lamps and increasing the light production efficiency, or efficacy, is a major opportunity to reduce display power. As discussed above, 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 lamps 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 or more.[101] Improving efficiency of backlight unit is one pathway to comply with the proposed standard. The cost to improve the efficiency of inefficient monitors is between $1 and $5.

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

101 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.

LED backlights are generally brighter and cost less than CCFL technology. LED lights have increased energy efficiency of the monitors compared to CCFL backlights.

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.[102] 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.[103] This film allows properly polarized light to pass through to the back of the LCD panel and reflects the remaining light back into the BLU 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. [104,105]

Reflective films and reflective polarizing films are inexpensive and widely available. They are one of 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 and staff agrees,[106] 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 the energy consumption.

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102 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.

103 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.

104 Managing light to increase efficiency in LCDs , available at http://www.photonics.com/Article.aspx?AID=30097

105 "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.

106 *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 cd/m^2 showed significant differences.[107] 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.[108]

The Lawrence Berkeley National Laboratory (LBNL) 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.[109]

Improved Power Supply Unit

Using an efficient power supply unit (PSU) 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.[110] 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.

The proposed standard levels are cost-effective and technically feasible. Manufacturers have the option of using various approaches that includes using efficient film stacks, improving LED backlights and LED drivers, reducing default screen brightness, improving power supply efficiency, and implementing ABC and global dimming.

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107 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.

108 *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.

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

110 *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.

CHAPTER 13: Energy Savings and Cost Analysis

Staff conducted an energy savings and cost analysis to establish that the proposed standard for computer monitors and signage displays is feasible and cost-effective, 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 12.** 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 12: 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. Staff agrees with the IOUs' report that assumes an average workweek of five days. Assumption also accounts for 20 days of time off. On average, a worker is at work 240 days a year. 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 13.** 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 13: 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

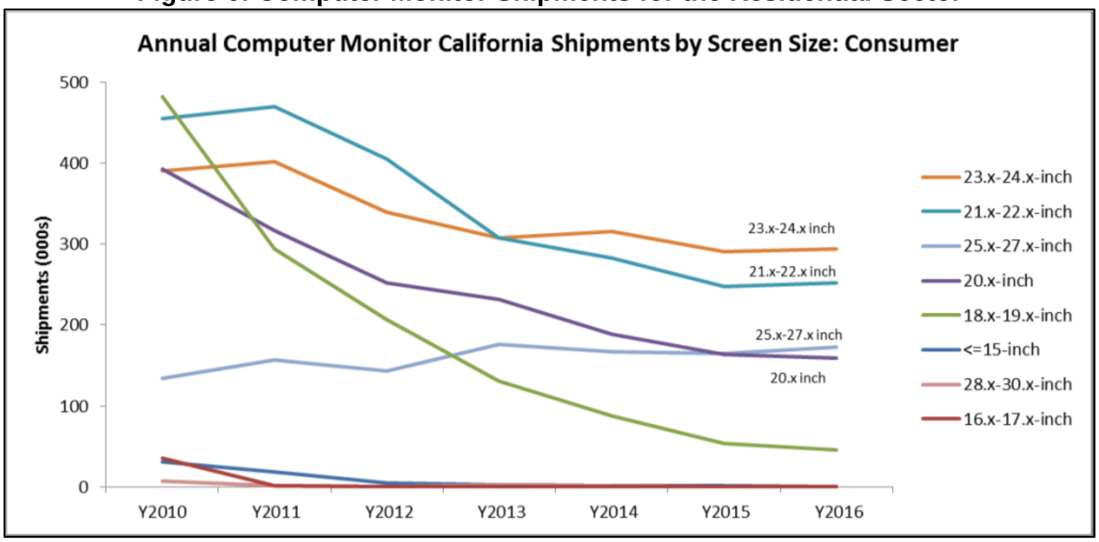
Source: IOUs CASE Response (August 2015)

Based on usage hours, staff estimates the current computer monitor stock consumes more than 1,284 GWh of electricity per year. Based on market trends in **Figure 6** and **Figure 7**, 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 in place, 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 residential sector are illustrated below.

Figure 6: Computer Monitor Shipments for the Residential Sector

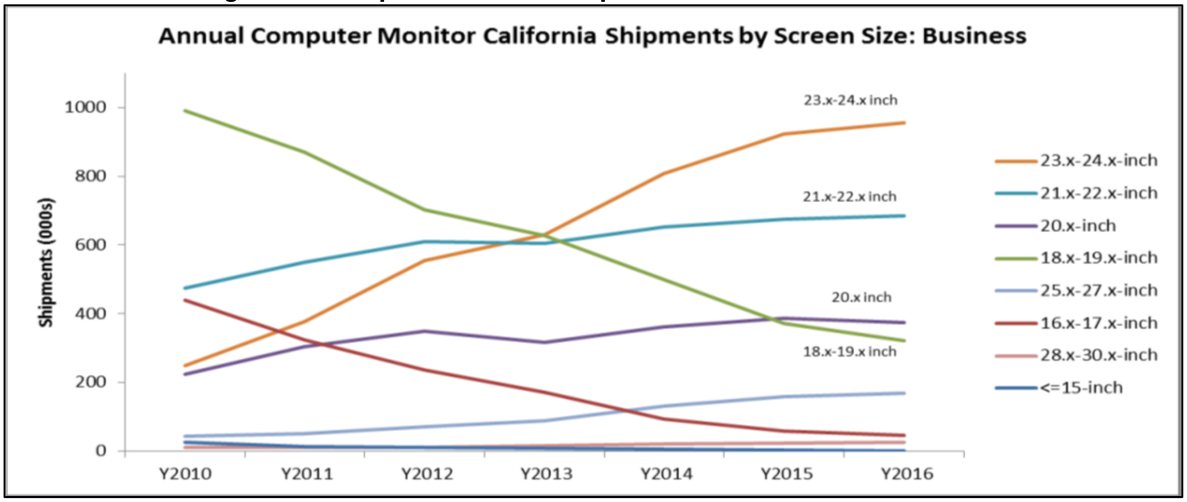


Source: IOUs, *2013 CASE Study, Analysis of Standards Proposal for Electronic Displays*

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 7: 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.

Categorization of sizes in bins 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 modifications to the two largest screen size bins. The proposed computer monitor size bins are listed in **Table 14**.

Table 14: Computer Monitors Screen Size Bins for Maximum Power Requirements

Diagonal Screen Size in Inches (*d*)	
1	$d < 12”$
2	$12” \leq d < 17”$
3	$17” \leq d < 23”$
4	$23” \leq d < 25”$
5*	$25” \leq d < 29”$
6*	$29” \leq d \leq 61”$

*Screen Size Bins 5 and 6 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-

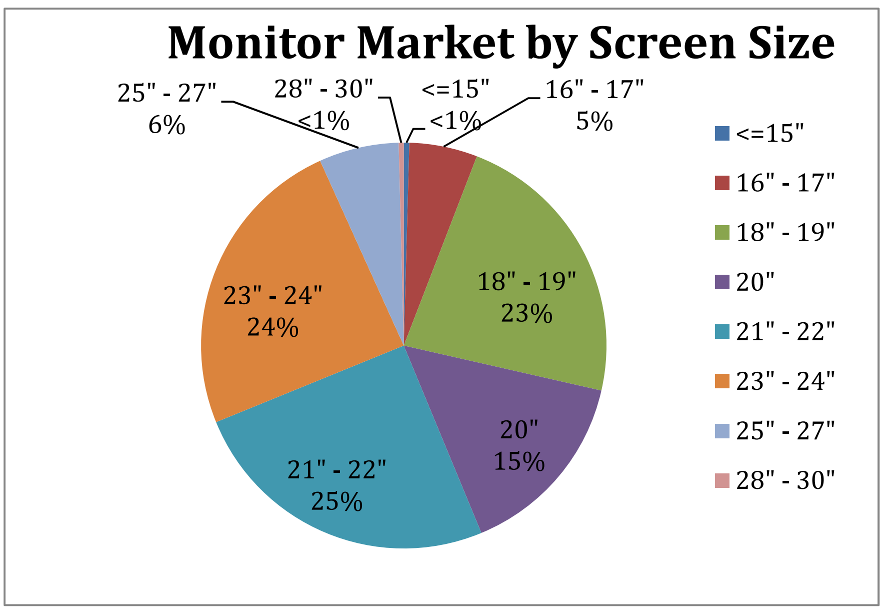
Table 15: Screen Size Categorizations for Market Analysis

Size Bin	Included Diagonal Screen Sizes (*d*)	Approximate Market Distribution
<=15.x-inch	d < 16-inch	< 1 Percent
16.x-17.x-inch	16-inch <= d < 18-inch	5 percent
18.x-19.x-inch	18-inch <= d < 20-inch	25 percent
20.x-inch	20-inch <= d < 21-inch	15 percent
21.x-22.x-inch	21-inch <= d < 23-inch	25 percent
23.x-24.x-inch	23-inch <= d < 25-inch	25 percent
25.x-27.x-inch	25-inch <= d < 28-inch	5 Percent
28.x-30.x-inch	28-inch <= d < 31-inch	< 1 Percent

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

To align with the ENERGY STAR framework, this report is using screen size bins that are outlined in the ENERGY STAR specification with the two exceptions noted. (See **Table 15** above.) These screen size bins are broader than the bin sizes used in staff's market analysis to group screen size categories based on likely purchasing decisions.

Figure 8: Computer Monitor Market Distribution by Screen Size



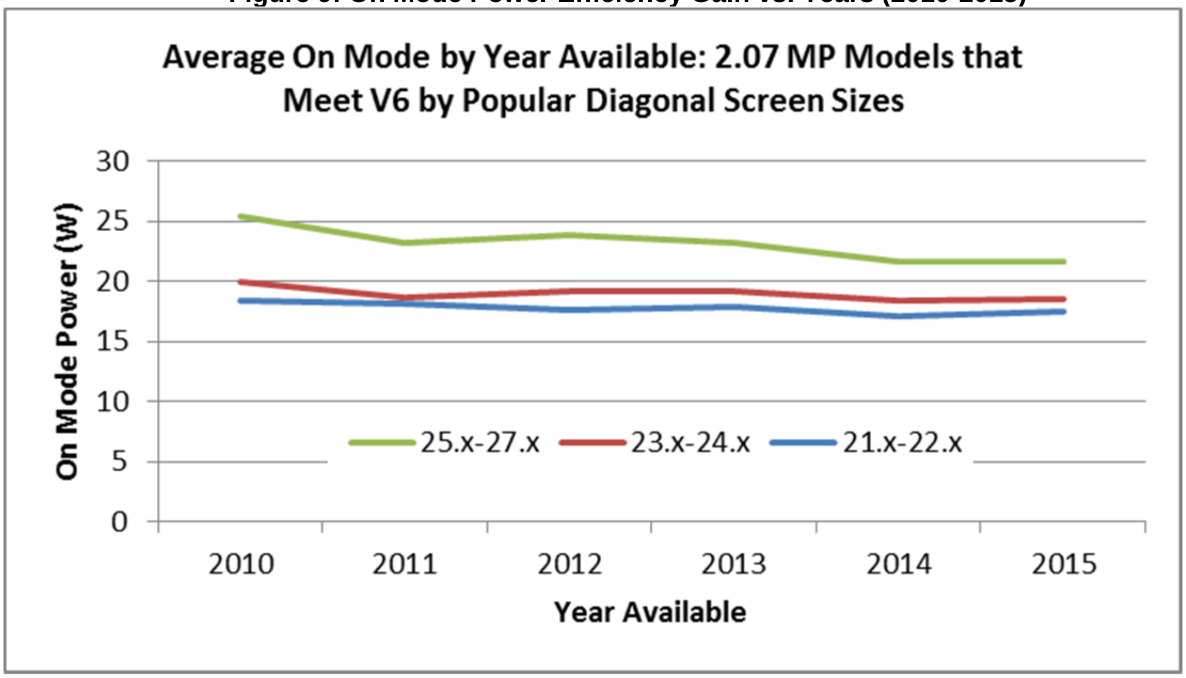
Source: Energy Commission staff market study

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.

The most popular size bins of monitors on the market are 21 to 22 inches, 23 to 24 inches, and 18 to 19 inches. In the last few years, sales of large screen size monitors have increased significantly, resulting in increased energy consumption.

Figure 9 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 16** shows the number of models that meet ENERGY STAR Version 6 on mode levels by year of availability in these popular screen sizes.

Figure 9: On Mode Power Efficiency Gain vs. Years (2010-2015)



Source: Energy Commission staff market study

Table 16: 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

An estimated 21.2 million residential and commercial computer monitors are installed in California.[116] Of these, about 12.7 million monitors are used in homes and about 8.5 million in

116 Response to CEC Staff Report for Computer Monitors and Signage Displays available at http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-

businesses and schools (**Table 17**). Residential stock estimates are based on the 2009 Navigant study, and commercial estimates are based on the 2014 Fraunhofer study. [117] [118]

Table 17: California Installed Base (Stock)

Sector	Installed Base in Millions
Residential	12.7
Commercial	8.5
Total	21.2

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 the computer monitors.[120] **Figure 10** illustrates this decline in small monitor sales and increase in sales of larger monitors and assumes that California annual residential and commercial shipments are about 3.6 million units.

02/TN205649_20150806T165521_California_Investor_Owned_Utilities_Comments_CA_IOU_Updated_Inf.pdf Page 12, Table 7.1.

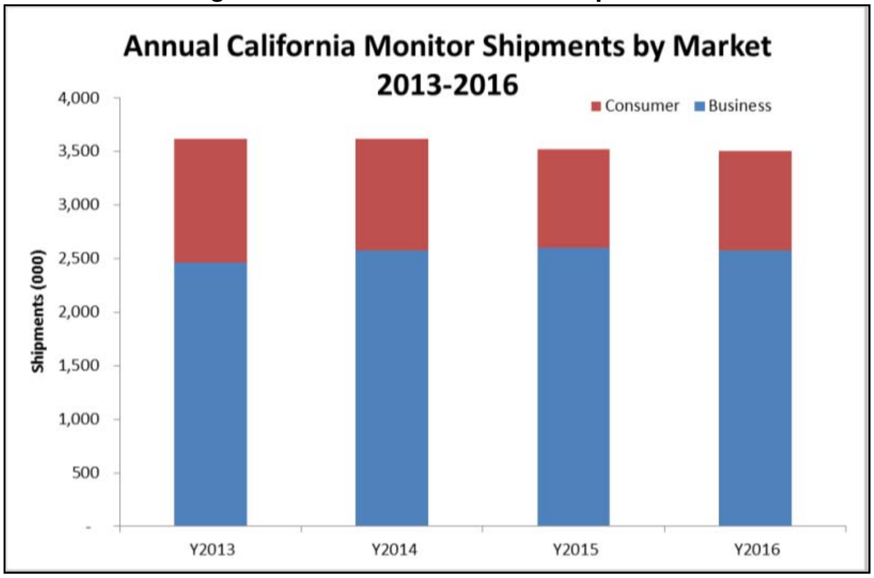
117 Navigant Consulting, Inc. 2009. Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances, final report. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf.

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.

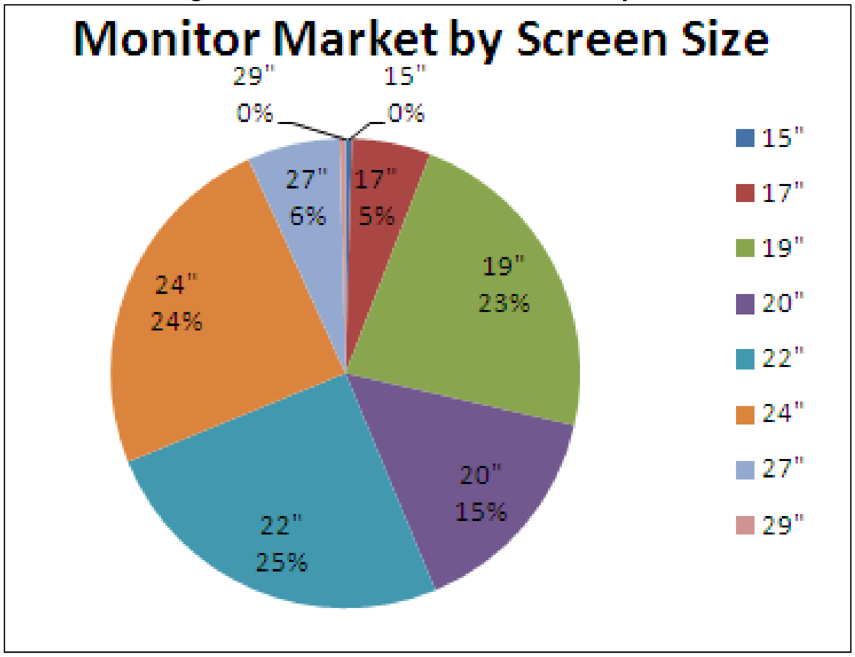
Figure 10: Estimated Annual Shipments



Source: IOUs CASE Study 2013

Figure 11 shows the shipment distribution for 2013 through 2016 by screen size.

Figure 11: Screen Size in the Marketplace



Source: IOUs Case Study 2013

Table 18 shows the average energy consumption of currently 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 18: 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) LNBL 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 commercial monitors and five years for residential monitors.[123] IOUs in their comment letter noted that many monitors can continue to work for 10 years or longer.[124] Based on all the available information, it is reasonable to assume the commercial replacement cycle to be around six years and residential monitor replacement cycle to be about seven years. The weighted average of the installed units across both commercial and residential sectors is about 6.6 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 19.**

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 19: 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-32.83kWh/year = 27.75kWh/year	Energy Savings per Unit X Product Design Life = 27.75*6.6 = 183.15 kWh	Product Life Cycle Savings (183.15 KWh) X Electricity Rate ($0.16/kWh) = $29.30

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 of the strategies may not cost anything at all, such as calibrating the brightness of the monitor, while other strategies 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 128cost 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 20.** Using high-efficiency LEDs in the back light unit of the monitor is one of the pathways identified in the technical feasibility section. The **Table 20** shows a continued decrease in LED prices and simultaneous increase in efficacy.

Table 20: 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

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 19).** At a cost of $0.164 per kWh,[129] the proposed standard will generate $4.55 in electricity savings per unit per year and $29.30 over the lifetime of the unit to the consumer. Subtracting the incremental cost of $5 per unit from the total energy savings of $29.30 per unit over the product life provides life cycle savings of $24.30 to the consumer. Based on the iSuppli and the IOUs' incremental cost data staff estimates, the payback period for the improvement is less than 1.1 years. Therefore, the proposed standard for each unit and model is cost-effective and will save energy.

Table 21: 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
6.6 years	$5.00	$29.30	$24.30

Source: Energy Commission staff

Statewide Energy Savings

First-year energy savings and total lifetime savings are shown in **Table 22** below.

Table 22: 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* $0.164/kWh= $16.38 million	Current Energy Consumption- Energy Consumption after the Stock Turnover = 1284 GWh– 696 GWh = 588 GWh	Total Energy Savings after Stock Turnover * $0.164*$10^9$ = $96 Million[130]

Source: Energy Commission Staff

A summary of the incremental costs, cost-effectiveness, and statewide impacts is provided in **Table 23**.

Table 23: 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	183.15k Wh/year	$4.44	$29.30	1.1 years	588 GWh

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.

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 24** provides the cost benefit and energy savings from these proposed standards.

Table 24: Energy Savings Analysis for Televisions, Including Signage Displays

Tier	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)
I	10	132	0	18.48	164.21	4.0	528
II	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

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 different, 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, 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 would reduce GHG emissions by about 0.184 $MMTCO_2e$.[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.

CHAPTER 15: Proposed Regulatory Language

All language below that would be new to the appliance efficiency regulations are provided in underline with the exception of section headers.

1601 Scope.

…

(v) Computers, computer monitors, enhanced performance display (EPD) monitors, signage displays, televisions, and consumer audio and video equipment, which are compact audio products, digital versatile disc players, and digital versatile disc recorders.

…

1602 Definitions.

…

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

…

"computer monitor" means an analog or digital device of size greater than or equal to 12 inches and less than or equal to 61 inches, a pixel density of greater than 5000 pixels per square inch, and that is designed primarily for the display of computer generated signals and not marketed for use as a television. A computer monitor does not include:

1. Displays with integrated or replaceable batteries designed to support primary operation without AC mains or external DC power, or device mobility (e.g., electronic readers, battery-powered digital picture frames); and

2. Products that are classified for use as medical devices and that either prohibit power management capabilities or do not have a power state meeting the definition of sleep mode.

"enhanced-performance display (EPD)" means a computer monitor that has all of the following features and functionalities:

(1)A contrast ratio of at least 60:1 measured at a horizontal viewing angle of at least 85º, with or without a screen cover glass;

(2) A native resolution of equal to or greater than 2.3 megapixels (MP); and,

(3) A color gamut size of at least sRGB as defined by IEC 61966 2-1. Shifts in color space are allowable as long as 99 percent or more of defined sRGB colors are supported.

"Display off mode" means the display is connected to a power source, produces no visual information, and cannot be switched into any other mode with the remote control unit, an internal signal, or an external signal.

"Display sleep mode" means low-power mode in which the display provides one or more non-primary protective functions or continuous functions.

"electronic display (display) or monitor" means a product with a display screen and associated electronics, often encased in a single housing, that as its primary function produces visual information from:

(1) A computer, workstation, or server via one or more inputs (e.g., VGA, DVI, HDMI, DisplayPort, IEEE 1394, USB)
(2) External storage (e.g., USB flash drive, memory card)
(3) A network connection

electronic display or monitor is intended for one person to view in a desk based environment.

"Professional signage display" means a large sized-display of size greater than 1400 square inches, typically composed of several displays with a diagonal screen size greater than 12 inches. These displays are designed to be operated by an external data controller, operated by a single or multiple power supplies, have a mechanical support structure, and intended to be viewed by multiple people in non-desk based environments such as indoor and outdoor stadiums.

"signage display" means an analog or digital device designed primarily for the display of a computer generated signals and is not marketed for use as a television.

…

Section 1604 Test Methods for Specific Appliances.

…

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

…

(2) The test method for televisions and signage displays manufactured on or after April 24, 2014 is 10 C.F.R. Sections 430.23(h) (Appendix H to Subpart B of part 430).

…

(5) The test method for computer monitors is ENERGY STAR Test Method for Determining Displays Energy Use Rev. Sep-2015, attached to the Version 7.0 Displays Product Specification.

…

1605.3 State Standards for Non-Federally Regulated Appliances.

…

(v) Computers, Computer Monitors, Signage Displays, Televisions, and Consumer Audio and Video Equipment.

…

(4) Computer monitors manufactured on or after January 1, 2018, shall comply with the standards in **Table V-3.**

Table V-3 Maximum Power Requirements 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})**
Resolutions Less Than or Equal to 5.0 MP			
17”≤d<23”	(4.2*r) + (0.02*A) +2.2	0.5	0.3
23”≤d<25”	(4.2*r) + (0.04*A) – 2.4	0.5	0.3
25”≤d≤30	(4.2*r) + (0.07*A) – 10.2	0.5	0.3
Resolutions Greater Than 5.0 MP			
17”≤d<23”	21 + (0.02*A) +2.2	0.5	0.3
23”≤d<25”	21 + (0.04*A) – 2.4	0.5	0.3
25”≤d≤30	21 + (0.07*A) – 10.2	0.5	0.3

r = Screen resolution (megapixels)
A= Viewable screen area (square inches)

(5) Enhanced Performance Displays manufactured on or after January 1, 2018, shall comply with the standards in Table V-4, where PON_MAX is determined by the screen size and resolution of the Enhanced Performance Display in reference to **Table V-3.**

Table V-4 On Mode Power Allowance Adder for Enhanced Performance Displays

Color Gamut Criteria	**On Mode Power Allowance Adder in Watts (PEP)**
Color Gamut support is 32.9% of CIELUV or greater (99% or more of defined sRGB colors)	0.10*PON_MAX
Color Gamut support is 38.4% of CIE LUV or greater (99% of Adobe RGB)	0.50*PON_MAX

(6) Computer monitors with touch screen capability are allowed an additional 1 watt allowance.

(7) A computer monitor manufactured on or after the effective date shall be shipped with a screen luminance less than or equal to 200 cd/m^2.

…

(8) Signage displays manufactured on or after January 1, 2018, shall comply with the standards in **Table V-2.**

…

Section 1606. Filing by Manufacturers; Listing of Appliances

in Database.

… [skipping sections A-U of Table X]

Table X Continued - Data Submittal Requirements

	Appliance	*Required Information*	*Permissible Answers*
V	Computer Monitors	* Manufacturer's Name	
		* Brand Name	
		* Model Number	
		Type	CCCFL, LED, OLED, Quantum Dots
		Viewable Screen area	
		Screen size	
		Automatic Brightness Control	Yes, No
		Automatic Brightness Control Enabled	Yes, No
		Native Resolution	
		On Mode Power (watts)	
		Sleep Mode (watts)	
		Off Mode (watts)	
		Enhanced Performance Display (EPD)	sRGB, Adobe RGB