DOCKETED

Docket Number:	14-AAER-02
Project Title:	Computer, Computer Monitors, and Electronic Displays
TN #:	203854
Document Title:	Staff Report Fnal Draft
Description:	N/A
Filer:	Sabrina Savala
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	3/12/2015 9:43:27 AM
Docketed Date:	3/12/2015

California Energy Commission

STAFF REPORT

ANALYSIS OF COMPUTERS, COMPUTER MONITORS, AND SIGNAGE DISPLAYS

California Energy Commission

2014 Appliance Efficiency Pre-Rulemaking

Docket Number 14-AAER-2

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

MARCH 2015

CEC-400-2015-009-SD

CALIFORNIA ENERGY COMMISSION

Harinder Singh
Ken Rider
Primary Authors

Elliott Bogart
Bogdan Pishtoy
Josh Prather
Anton Rudenko
Research and Technical Support

Harinder Singh
Project Manager

Consuelo Martinez
Office Manager
APPLIANCES AND EXISTING BUILDINGS OFFICE

Dave Ashuckian
Deputy Director
EFFICIENCY DIVISION

Robert P. Oglesby
Executive Director

PREFACE

On March 14, 2012, the California Energy Commission issued an Order Instituting Rulemaking (OIR) 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 1608). In this OIR, 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 (ITP) to provide interested parties the opportunity to inform the Energy Commission about the product, market, and industry characteristics of the appliances identified in the OIR. 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 OIR.

The Energy Commission reviewed all information received to determine which appliances were strong candidates for the development of efficiency standards and measures. Based on its assessment, the Energy Commission will proceed with appliances in phases for the remainder of the rulemaking. The second phase of rulemaking commences with the development of staff reports and proposed regulations for computers, computer monitors and signage displays.

ABSTRACT

This staff report focuses on computers, computer monitors, and signage displays. This report includes analyses of 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, there are no federal or state regulations to provide incentives for implementing cost-effective, readily available technologies to improve the performance of these 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 585 gigawatt-hours (GWh) per year statewide in computer monitor and displays and 2,117.GWh per year in computers after stock turnover.

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

Keywords: Appliance Efficiency Regulations, energy efficiency, computer, computer monitors, signage displays.

Singh, Harinder, Ken Rider. 2015. *Staff Analysis of Computer, Computer Monitors, and Signage Displays.* California Energy Commission. CEC-400-2015-009-SD

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

The California Energy Commission's Appliance Efficiency Program has analyzed computers, computer monitors, and signage displays and has devised proposals that address energy efficiency opportunities through Title 20 standards. Staff's 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 computer standards will save about 2,117.GWh/year resulting in greenhouse gas (GHG) emission reductions of 0.634 million metric tons of carbon dioxide equivalent per year ($MMTCO_2e$/yr). Regulating computer monitors and signage displays will save about 585 GWh/year statewide and will result in GHG emission reductions of 0.183 $MMTCO_2e$, and save about $94 million after the inefficient existing stock is replaced. The computer regulations will benefit businesses and consumers by reducing electricity bills by $340 million leading to a combined savings of $434 million.

In California computers, monitors, and displays use an estimated 8,282 GWh of electricity, accounting for about 5 percent of electricity consumption in both the commercial and the residential sectors. In the commercial sector, these devices are concentrated in offices and educational facilities. For the proposed desktop computer regulations, industry would have to implement existing efficient technologies to meet the proposed regulations that would take effect in 2018.

In 2013, staff invited stakeholders to provide available data and feedback prior to proposing draft regulations.

Proposed Regulations for Computers

Based on the potential for energy savings and other considerations, staff proposes to include desktops, notebooks, workstations, small-scale servers, and thin clients in the regulatory scope. Workstations are heavy-duty computers for a myriad of complex uses, such as three-dimensional graphics for movies. Thin clients are like "terminals" where most of the computing is done in a separate location. Staff has excluded other servers, tablets, Smartphones, set-top boxes, game consoles, handheld video game devices, and industrial computers for this report.

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

The proposed regulations are different for notebook and desktop computers. The notebook proposal requires modest improvements in computer idle consumption that would affect products manufactured one year after the adoption of a regulation. The proposed desktop standard reduces by half the energy wasted in idle mode for desktop computers manufactured in 2018 and beyond.

Proposed regulations for workstations and small-scale servers only require the use of efficient "80 PLUS®" power supplies that are cost-effective relative to less-efficient power supplies. 80 PLUS®" power supplies are a voluntary certification program intended to promote efficient energy use in computer power supply units (PSUs). This program was launched by Ecos Consulting in 2004, it certifies products that have more than 80% energy efficiency and a power factor of 0.9 or greater at 100% load. These power supplies are available in the market and have been in use for number of years.

Staff's proposal sets performance standards for computers that are not prescriptive and allow the industry flexibility to choose how to comply. The energy savings are achievable through a combination of hardware and/or software improvements. Computer manufacturers can choose components that use less energy and are 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.

Desktop computers are expected to improve in efficiency due to standards that will come into effect in Europe in 2016. However the European standards leave large amounts of the cost-effective energy efficiency untapped. Commission staff proposes to close that gap with a more stringent desktop standard in 2018. If California were to adopt the proposed standards, they would be more stringent than existing and yet outdated computer standards, such as those in Australia and China. The U.S. Department of Energy is also considering computer standards at the national level, and the California regulations would likely influence the federal process.

Proposed Regulations for Monitors and Signage Displays

Based on the potential for energy savings and other considerations, staff proposes to regulate computer monitors and commercial signage displays, such as those seen in airports for airplane schedules. Staff has excluded other digital picture frames and electronic billboards.

The core opportunity for energy savings regarding computer monitors and signage displays is to reduce the amount of energy used in "on mode." Reducing the amount of energy used in "on mode" is the largest energy-saving opportunity because computer monitors spend about 30 percent of the time in this mode. About 20 percent of the computer monitors in the market today meet the draft ENERGY STAR Version 7.0 standards. Staff's proposed regulations roughly match the new draft ENERGY STAR Version 7.0, and staff's analysis of the ENERGY STAR data shows that only about 14 percent of the current models meet the staff's proposed standards. However, monitors would only need to reduce their power consumption by 3 to 5 watts to comply. This goal would be easy to meet by replacing inefficient light-emitting diode (LED) lighting with efficient LED lights, LED drivers, and power supplies that are currently available in the market at comparable prices.

The proposed regulations are about 30 percent more stringent than ENERGY STAR Specification Version 6.0. The proposed performance standards for monitors would allow industry to choose how to comply with the regulation.

Staff also clarifies that signage displays are already covered under the previously adopted television standards.

CHAPTER 1:

Legislative Criteria

Section 25402 (c)(1) of the California Public Resources Code[1] mandates that the California Energy Commission reduce 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 Energy 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 California 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, such appliance efficiency standards have shifted the marketplace toward more efficient products and practices, reaping large benefits for California's consumers. The state's appliance efficiency regulations saved an estimated 22,923 gigawatt hours (GWh) of electricity and 1,626 million therms of natural gas in 2012[4] alone, resulting in about $5.24 billion

---

1 Cal. Pub. Resources Code § 25402(c)(1), available at http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25402; Warren-Alquist State Energy Resources Conservation and Development Act, Division 15 of the Public Resources Code, § 25000 et seq., available at http://www.energy.ca.gov/2014publications/CEC-140-2014-001/CEC-140-2014-001.pdf.

2 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.

in savings to California consumers.[5] Since the mid-1970s, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. In addition, the California Public Utilities Commission in the 1990s decoupled the utilities' financial results from their direct energy sales, facilitating utility support for efficiency programs. These efforts have reduced peak load needs by more than 12,000 megawatts (MW) and continue to save about 40,000 gigawatt-hours (GWh) per year of electricity.[6] The Energy Commission's recently adopted appliance 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, there remains huge potential for additional savings by increasing the energy efficiency and improving the use 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] (AB 32), as well as the recommendations contained in the California Air Resources Board's *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 California Public Utilities Commission's (CPUC) 2011 update to its *Energy Efficiency Strategic Plan.*[11]

---

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.

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

Loading Order for Meeting the State's Energy Needs

California's loading order places energy efficiency as the top priority for meeting the state's energy needs. The *Energy Action Plan II*[12] continues the strong support for the loading order, which describes the priority sequence of actions to address increasing energy needs. The loading order identifies energy efficiency and demand response as the state's preferred means of meeting growing energy needs.

For the past 30 years, while per capita electricity consumption in the United States has increased by nearly 50 percent, California's electricity use per capita has been nearly flat. Continued progress in cost-effective building and appliance standards – and ongoing 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] adopted in 2008 by the CPUC and developed with the Energy Commission, the California Air Resource Board, the state's utilities, and other key stakeholders, is California's roadmap to achieving maximum energy savings in the state between 2009 and 2020, and beyond. It includes four "big bold strategies" as cornerstones for significant energy savings with widespread benefit for all Californians:[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.
- Heating, ventilation, and air conditioning (HVAC) will be transformed to ensure that the energy performance is optimal for California's climate.
- All eligible low-income customers will be given the opportunity to participate in the low-income energy efficiency program by 2020.

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

---

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

13 *Energy Action Plan II*, available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, page 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, page 1.

On April 25, 2012, Governor Edmund G. Brown Jr. further 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 their design after 2025.

To achieve these zero-net-energy goals, the Energy Commission has committed to adopting and implementing building and appliance regulations that reduce wasteful power and water consumption. The *Long-Term Energy Efficiency Strategic Plan* calls on the Energy 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 loads, and water use. The Energy Commission adopted its detailed plan for fulfilling these zero-net-energy objectives in its 2013 *Integrated Energy Policy Report* IEPR.[18]

Governor's Clean Energy Jobs Plan

On June 15, 2010, Governor Brown proposed a *Clean Energy Jobs Plan*,[19] which called on the Energy Commission to strengthen appliance efficiency standards for lighting, consumer electronics, and other products. Governor Brown noted that energy efficiency is the cheapest, fastest, and most reliable way to create jobs, save consumers money, and cut pollution from the power sector. He stated that California's efficiency standards and programs have triggered innovation and creativity in the market place. Today's appliances are not only more efficient, but they are cheaper and more versatile than ever.

---

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.

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.

CHAPTER 2: Background

Part A - Computers

Computers consume a significant portion of energy in California buildings and are one of the largest known plug-loads. In a broad sense, computers are everywhere and consist of both very specialized and generic systems. This report focuses on computers that constitute significant loads in buildings and specifically investigates energy efficiency opportunities in five broad computer form factors: desktops, notebooks, small-scale servers, thin-clients and workstations. While there are increasingly more tablets in homes, the energy use of these products are relatively small due to their form factors and the opportunities for savings are minimal due to existing battery charger regulations and market pressure to achieve high efficiency to enhance battery life. This staff report does not address or propose improvement for tablet computers.

In homes, the most common form factors are by far notebooks and desktops. While generally there are more notebooks, the energy consumption of a desktop is more than double that of notebooks. This energy consumption increases if one includes computer monitor energy use, which is necessary for desktop computer functionality. Table 1 shows estimates of residential computer energy consumption with estimates ranging between 2.5 percent and 4.4 percent of residential electricity use, not accounting for computer monitor consumption.

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

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

Source: Energy Commission Staff

Computers contribute significantly to the energy consumption in the commercial sector, particularly in office buildings and educational facilities. In fact, Navigant's analysis suggests that 70 percent of commercial notebook and desktop energy consumption occurred in these types of buildings in 2011. In commercial buildings, computers and monitors can make up more than 10 percent of overall electricity consumption of a building. In addition, the vast majority of small-scale servers, workstations, and thin clients are found in businesses. The total energy

---

20 Simplified scaling was applied as 12.5 percent of national units based on population.
21 All compared to 2012, the latest year available, residential electricity consumption according to the Energy Commission's Energy Consumption Data Management System (ECDMS) http://www.ecdms.energy.ca.gov/. Residential electricity consumption for that year was 91,450 GWh.
22 http://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf.
23 http://www.ce.org/getattachment/Government-Affairs/Issues-Pages/Advancing-Energy-Efficiency-Programs-and-Initiativ/EnergyConsumption2013.pdf.aspx
24 A range of values are shown here based on a case where power management is enabled 100 percent of the time and 0 percent of the time.
http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/Information_Technology_Industry_Council_Proposal_for_Standards_Consumer_Electronics_Computers_2013-07-29_TN-71728.pdf.

consumption of computers in the commercial sector is greater than that in the residential sector. This consumption does not include the energy consumption of data centers, which are outside the scope of this report but certainly contribute additional computer energy consumption to the commercial sector.

The fact that computers consume a significant amount of energy in California is one of the reasons they were identified and proposed for inclusion in the Energy Commission's OIR for appliance efficiency regulations. There are also a large number of technologies and design methods that can improve the energy consumption of computers without significant cost or decrease in product efficacy. In fact, energy savings can be obtained through software improvements that use existing hardware more efficiently.

The Energy Commission set up a two-step stakeholder process to solicit information, data, and proposals for improving computer energy consumption. Comments and input on general aspects of computer usage, sales, and so forth were collected by May 6, 2013. More details about improved efficiency and proposals to achieve it were gathered in comments due on July 29, 2013. The Energy Commission received input from the computer industry, utility companies, and various nongovernment organizations (NGOs).

In addition, the Energy Commission continues to research computer energy use and efficiency opportunities through the Public Interest Energy Research (PIER) and Electric Program Investment Charge (EPIC) programs. In addition, new studies, reports, and research have been incorporated through staff searches and additional stakeholder submissions to the docket.

This report represents a draft compilation and analysis of all the reviewed materials and an initial proposal for an appliance efficiency regulation.

CHAPTER 3:
Product Description

There are several form factors considered in this staff report including desktops, notebooks, small-scale servers, workstations, and thin-clients. Products not considered in this staff report include tablets, larger scale servers, game consoles, and industrial computers/controllers.

Desktop computers use the most amount of energy of the form factors considered and have the greatest potential energy savings from technological improvements. While there has been a steady but slow decrease in the number of shipments of this form factor, sales remain significant. Desktop computers are generally paired with one or more computer 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 types of devices and can have the power management responsibilities for other attached accessories as well, such as printers. Desktops generally provide enhanced performance levels per dollar in comparison to notebook computers but generally are much more energy-intensive. Desktop computers also are generally more configurable, durable, and easily upgraded, which contribute to longevity and usefulness.

Notebook computers are characterized by the small size and ability to run off of a battery. A computer screen is integrated into a notebook, and upgrades and configurability are generally more limited. These products can offer similar functionality to a desktop computer but are somewhat constrained by space and power dissipation. Thermal management is more important as people tend to touch these computers far more often than desktop computers, and the orientation and placement of these notebooks can lead to fan blockage and poor air flow. While these computers are typically used while plugged in, efficiency and conservation add more consumer value in this form factor than in desktops due to the relationship to battery runtime. This form factor tends to use significantly less energy than desktop computers.

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

In addition, Energy Commission staff has investigated the efficiency of some subcomponents of computers that are frequently available and sold separately from a computer, such as video cards, power supplies, and volatile memory.

.

CHAPTER 4: Regulatory Approaches

Energy Commission staff considered and studied several regulatory pathways to achieve energy savings in computers. Stakeholder suggestions primarily focused on using either the ENERGY STAR 5.2 or 6.1 framework for both testing and product categorization. In addition to ENERGY STAR, Energy Commission staff investigated international computer efficiency standards, including those in Australia, China, and the European Union. The Energy Commission also looked at harmonization with other federal or North American test methods but did not find any outside the ENERGY STAR program.

Test Method

While there are a wide range of approaches and requirements for computers, generally all jurisdictions have a fairly harmonized testing method. This method was pioneered by ENERGY STAR and is used both domestically and internationally. Energy Commission staff proposes to use the ENERGY STAR testing method. The test method measures four modes of operation: long idle, short idle, sleep mode, and off modes. These modes are typically combined into an estimated energy consumption through incorporated assumptions about duty cycle.

The core of the ENREGY 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 393 standards for computer network connectivity.

Energy Commission staff proposes to align with these ENERGY STAR testing methods, which also generally aligns with international testing requirements.

ENERGY STAR Frameworks: Comparison of Versions 5.2 and 6.1

ENERGY STAR has a long 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's computer Specification Version 5.2, which started development in 2007 and was finalized in November 2008. 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 subsequently was updated to 6.1 in October 2014. The California IOUs and Natural Resources Defense Council (NRDC) recommend aligning with Version 6.1 rather than the Version 5.2 specification.

While it is standard practice for a new version of ENERGY STAR to be more stringent than the old one, there were also some structural changes 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 the lower performance computer types and C and D being the higher performance types. ENERGY STAR Version 6.0 categorizes desktops and notebooks into 0, I1, I2, I3, D1, and D2 categories with "0" representing the lowest functioning computers. The "I" categories represent computers that have only integrated graphics. The "D" category represents computers that have discrete graphics cards.

Each version categorizes computers from "low performance" to "high performance" to vary the allowances given relative to performance. The ENERGY STAR 5.2 scheme categorizes computers based on two factors: how many cores it has and how much memory it has, with some differentiation for the graphics card bandwidth. The ENERGY STAR 6.1 scheme categorizes computers by the number of cores, speed of those cores, and power of the graphics card, with additional emphasis on integrated versus discrete graphics. The changes made in categorization were from suggestions by the Information Technology Industry Council (ITI) in the ENERGY STAR process where they describe that the ENERGY STAR 5.2 scheme "no longer works"[25] as it focuses on the wrong attributes. This approach, which was also supported by the Japan Electronics and Information Technology Industries Association (JEITA),[26] recognizes growing trends toward integrated graphics.

Energy Commission staff is using the ENERGY STAR 6.1 framework over the 5.2 framework for the same reasons given by ITI in its development and by the IOUs and the NRDC in their comments to the Commission.[27] 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 the approaches taken in Australia, China, and the European Union, it follows the evolution of computer characterization pioneered in ENERGY STAR and the direction China and the EU were headed in their supplemental inclusion of ECMA 383 standard on top of the ENERGY STAR 5.2 framework.

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. The scope of the Australian standards covers desktops, notebooks, and small-scale servers but does not cover workstations, thin-clients, and "high-end category D desktops" (a reference to ENERGY STAR 5.2 categories). The Australian standards are closely aligned with

---

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

26 Page 2 of comments to ENERGY STAR from JEITA, January 9, 2013, http://www.energystar.gov/sites/default/files/specs//JEITA_Comments_Public.pdf.

27 Page 28 of IOU/NRDC CASE report to Energy Commission, August 6, 2013.

ENERGY STAR 5.2 and European Union in design. The Australian approach also includes an interesting "deemed-to-comply" approach for small volume manufacturers to achieve cost-effective compliance. This approach was also highlighted in a collaborative labeling and appliance standards program (CLASP) study docketed in the Energy Commission's process. These standards are less stringent than the European Tier 2 standards and the staff proposal.

Chinese Standards

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

European Union Standards

The European Union has effective standards for computers and servers generally referred to as "lot 3" or, more formally, European Commission Regulation No 617 (2013). The regulations apply to all products within the scope of products considered in this staff report. The regulations explicitly exclude blade servers, server appliances, multinode servers, and servers with more than four processor sockets, game consoles, and docking stations. Energy Commission staff has incorporated many of these exclusions into the proposed regulations. Energy Commission staff also reviewed the definitions of products in this regulation 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 will become effective on January 1, 2016.

The European standard also includes disclosures by computer type. Beyond the basics of manufacture date, manufacturer name, and model number, Energy Commission staff does not propose any physical labels on computers.

ITI and NASBA Proposal

ITI, in its comments submitted on June 29, 2013, proposed a standard that would set ENERGY STAR 5.2 framework standards for desktops, notebooks, and all-in-one computers. The proposal would exclude workstations, thin-clients, and "high-end" computers. The ITI proposal recommends aligning with ENERGY STAR 5.2 levels or a total energy consumption level that would have current market compliance of 75 percent. The ITI proposal also specifically opposed internal power supply requirements which are included in ENERGY STAR 6.1 and the IOU proposals.

NASBA, "The Association of Channel Resellers," submitted a proposal that fundamentally aligns with the ITI proposal, suggesting ENERGY STAR 5.0 levels and no requirements on power supplies. NASBA also recommends not requiring third-party test laboratories, which ENERGY STAR requires. The Energy Commission's testing requirements for current regulations do not require third-party testing, and staff does not propose to start such a requirement for computers.

Staff's proposal aligns with aspects of comments submitted by NASBA. Exemptions for special-use products are included in the staff proposal. Staff recognizes a manufacturer's ability to optimize performance and cost depending on the specifics of the application. Furthermore, the power supply requirements for external power supplies will be largely realized by DOE external power supply regulations that become effective in 2016. However staff is recommending power supply requirements for products where a total energy consumption (TEC) approach is not taken by proposed regulations

Staff did not choose to align with the ITI proposal regarding the use of the ENERGY STAR 5.2 framework for reasons described in the section "ENERGY STAR Frameworks: Comparison of Versions 5.2 and 6.1." Staff is proposing levels more stringent than ENERGY STAR 5.2 because data and market information suggested that such a standard would only lead to minor, if any, implementation of the cost-effective and feasible improvements available in the market. However, the "incremental improvement" concept inherent in ITI's suggestion to target 75 percent compliance was incorporated into the analysis and staff proposal.

IOU and NRDC Proposal

The original proposal from the IOUs and NRDC was received July 29, 2013, and was subsequently updated on August 6, 2013. The proposal was supplemented with additional testing and analysis on January 21, 2014. Most recently, it was updated on October 27, 2014, to take into account changes in the marketplace since August 2013. The scope of recommended coverage includes conventional desktops, notebooks, and integrated desktops, as well as workstations, small-scale servers, and thin clients. The proposal is generally based on the framework of ENERGYTAR 6.1 with unique and more stringent levels that would be implemented in two tiers: one that would come into effect in 2016 and another in 2018. The 2018 standard would require computers to use about half of the power they use today in standby, sleep, and off modes.

The proposal does not propose any power or energy limitations on workstations, small-scale servers, and thin clients. Instead the IOUs and NRDC proposed power management and

Energy-Efficient Ethernet for all three and 80 PLUS®[28]+ silver-level power supply requirements just for workstations and small-scale servers.

Staff proposal aligns with the IOU and NRDC proposal in a few ways. The staff proposal aligns with the framework of ENERGY STAR 6.1. Staff's proposal sets a slightly different longer-term efficiency goal. Staff's proposal aligns with the IOU and NRDC proposed requirements for workstations and small-scale servers, but differs for notebooks and desktops.

Staff Proposal

Staff's proposal is an effort to take international experience, stakeholder input, and data analytics and accomplish feasible and attainable energy savings for California in both the short and longer term. The scope of the proposed regulations includes four primary categories: desktops, notebooks, small-scale servers, workstations. Conventional desktops, integrated desktops, and thin clients are included in the desktop category. The products included in the scope cover a broad range of applications and form factors, however as the standards focus on the power consumption in idle-mode the products should be conducting relatively few if any specialized tasks. The scope of the proposal does not include larger-scale servers, blade servers, industrial computers and controllers, video game consoles, tablets, smart appliances, televisions, over-the top boxes, and portable gaming devices. The requirements for each product type are described below.

Desktop Computers

Conventional Desktops and Thin-Clients

The standards coming into effect in the European Union in 2016 are expected to yield benefits for California. Many stakeholders commented on the global nature of the marketplace, and therefore the proposed standards do not come into effect until 2 years after the European Union standard: January 1, 2018. The staff proposed standard achieves the major cost-effective and feasible energy efficiency outlined in this report.

The largest opportunities for energy savings remain in the desktop computers, even post-European Union standards. To set the 2018 proposed standard, staff evaluated the best practices in hardware and software in today's market that also provide higher-end functionality. In effect, staff looked at best practices in power scaling along the lines discussed in Appendix C of the IOU Case Addendum.[29] The barrier to achieving these goals is defined by latency, or the time it takes for a system to transition from the idle state into the correct active state once a task is prescribed. As latency and power scaling improves with time, peak performance and innovative features matter less and less to a standard that focuses on idle states.

28 Available at: http://www.plugloadsolutions.com/80pluspowersupplies.aspx#.

29 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.

Staff proposes a standard for desktop computers manufactured on January 1, 2018, and onwards, of 50 kWh per year, while maintaining adders except for graphic adders. The graphic adders as they exist in current voluntary and mandatory standards lead to a near doubling of the idle power consumption of a desktop. To limit this large effect on consumption staff proposes that discrete graphics perform at the same idle levels as integrated and embedded graphics systems.

Workstations and Small-Scale Servers

Staff proposes the tier 2 standards recommended by the IOUs and NRDC for workstations and small-scale servers. This approach is non-invasive 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 into the proposed regulatory text in a way that ensures efficiency targets are met without tying the regulations to standards that may change or become defunct over time. Staff also proposes to require power management settings consistent with the ENERGY STAR specification version 6.1. Staff is not proposing additional power supply requirements at 10% of load as some stakeholders suggested.

Notebook Computers

In evaluating the available notebook computer data and the design of ENERGY STAR 6.1 limits, staff found the standard to provide hardly any allowance that scales with performance score. For notebooks with discrete graphics, the lowest end is given a base allowance of 14 kWh/yr and the high end 18 kWh/yr. For notebooks with integrated graphics, the allowance ranges from 22 to 28 kWh/yr. The most recent proposals by the IOUs and NRDC are even flatter than that. Staff is proposing only a single tier of standards for notebooks set at a 30 kWh/yr base allowance and including all ENERGY STAR 6.1 adders except for the graphic adders. Unlike desktop computers, the European Union's standards for laptops are not likely to require significant changes to design and therefore staff proposes an earlier implementation date than for desktop computers.

CHAPTER 5: Technical Feasibility

The proposed computer standards are feasible as there is an array of computers across performance categories that already meet the standards today. Even the more stringent proposed desktop standards can be met in a straightforward manner. For notebook and desktop computers, there are variety of compliance options that can attain the efficiencies required. For small-scale servers and workstations, the feasibility is driven primarily by readily 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 require the use of 80 PLUS program's silver level of performance. Power supplies are already broadly available at 80 PLUS Silver or better efficiencies with more than 1,700 models listed across dozens of manufacturers.[30] Of those models, more than 1,300 are 80 PLUS Gold. Incorporating these efficient power supplies will lead to energy savings in the operation of these computer types by reducing alternating current (AC) to direct current (DC) conversion losses. In addition to saving energy in the computer itself, the enhanced power factor correction of 80 PLUS will save energy in building wiring distribution and utility infrastructure.[31]

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 necessary power.

Energy-Efficient Ethernet standards specified by the Institute of Electrical and Electronics Engineers (IEEE) 802.3az can be found in many products in the market today. This functionality is generally enabled in the network interface controller or card (NIC), and major chip manufacturers offer this functionality. The 802.3az standard does not have significant negative impact on the networking functionality of a server or workstation and in fact 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 over the pre-rulemaking process have varied greatly, with incremental costs ranging

30 For a listing of 80 PLUS-certified products, see http://www.plugloadsolutions.com/80pluspowersupplies.aspx.
31 http://plugloadsolutions.com/docs/collatrl/print/80plus_power_quality.pdf

per unit from $1.75[32] to $23.85.[33] The IOUs similarly investigated the incremental cost, including those presented by other stakeholders, isuppli, and applied a 1.31 markup from previous DOE work.[34] The IOU incremental cost estimate was $5-$13, decidedly between the two more extreme bounds of the ITI and Green Tech Leadership Group estimates. Staff incorporated the higher cost IOU cost in the small-scale server and workstation cost-effectiveness analysis to be conservative.

Desktops

Technical Feasibility

There is an abundance of ways to reduce the energy consumption of desktop computers. Hardware decisions can yield energy savings where products are available that offer same or better performance at lower energy consumption. Chip, motherboard, and other computer component manufacturers can also improve the efficiencies of the parts they sell beyond what they are today. The trend is toward lower idle power consumption in individual components in the marketplace. There are also many software and firmware[35] enhancements that can be implemented that would save large quantities of energy without changing the components.

The proposed standards require that 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 also speak to the relative effectiveness of reducing power in any one of these modes, with a watt saved in off mode worth seven times a watt saved in sleep mode in terms of meeting any proposed standard. Generally, sleep and off modes are already at fairly low power levels in the range of 1-3 watts. This means that reduction in off-mode and sleep-mode are limited and the majority of savings would necessarily come from reducing one or both of the idle-mode consumptions. The remaining feasibility discussion focuses on improvements to these modes.

---

32 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, page 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

33 Consumer costs of improving from non-80 PLUS power supply. ITI comments submitted to the Energy Commission, May 9, 2013, page 19 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.

34 Marked up BOM figures for upgrading a non-compliant 80 PLUS power supply to 80 PLUS Gold. IOU comments submitted to the Energy Commission, August 6, page 35

35 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.

Hardware Feasibility

The IOUs tested the effects and cost-effectiveness of direct part replacements, primarily focusing on choosing more efficient hard disks and power supplies.[36] This was a simple exercise of choosing one part with the same performance over another. In addition, they investigated the effects of impending improvements in computer CPUs, particularly the introduction of Intel's Haswell product line.

By making different hardware choices, the IOU study was able to reduce energy consumption cost-effectively by 23 kWh/yr for a lower performance computer, 91 kWh/yr for a higher performance computer, and a range of savings for computers in-between generally scale with the overall consumption of the original computer.

There are efficiency opportunities in every component chosen with an array of efficiencies and performances. While the power consumption of some components show positive relationships between performance and power, there are some where these are not so directly proportional. This is particularly true when considering the energy consumption of hardware components, as that consideration allows tradeoff of higher active power in exchange for lower power idle states. The proposed standards particularly emphasize and would encourage this tradeoff as the computer is tested in idle modes.

These standards are feasible with a combination of hardware and software improvements to desktop computers. Technologies that must be implemented are power scaling, low-power idle modes, efficient displays, efficient power supplies, and better state awareness. There is a strong trend toward compliance for desktops using micro-ATX motherboards. While the performance of a computer as manufactured for micro-ATX is generally the same as a full-size ATX motherboard, the number of unused expansion slots and ports is far fewer. This leads to significant reduction in the contribution of a motherboard to system idle power. Most of the expansion slots and associated controllers could be disabled in the larger ATX boards during boot, as Peripheral Component Interconnect (PCI), Integrated Drive Electronics (IDE), and Serial Advanced Technology Attachment (SATA) hardware are generally not installed after boot. If the motherboard is designed accordingly, the basic input-output system (BIOS) can optimize motherboard power by turning off unused controllers post-boot. The median short and idle-mode power consumption of desktops listed in the ENERGY STAR 6.1 database is about 25 watts. To meet the target energy requirement, this idle would need to be reduced to about 13watts. More detail regarding the technical feasibility is available in Appendix A of this report. The engineering work to implement and coordinate existing hardware and software features is likely more difficult than the levels targeted by the IOUs in their work with Aggios, and so staff estimates a doubling of the $1 incremental cost per unit estimate.

---

36 IOU comment submitted to the Energy Commission, *Computers: Technical Report-– Supplemental Analysis and Test Results*, January 21, 2014.

Hardware Cost

ITI also offered some scenarios where a series of part swaps are not overall cost-effective.[37] The IOU study also discusses some part changes that would save energy but would not be cost-effective. It is certainly possible to exceed cost-effectiveness to gain additional energy savings; however, that decision would be at the manufacturer's discretion. Manufacturers may also choose a hybrid approach of software/firmware improvements to accomplish deeper savings. Staff expects that manufacturers will choose the least-cost or at least a cost-effective series of improvements because they are widely available.

Software and Firmware Feasibility

Energy savings can be gained through implementing or enabling energy saving capabilities of hardware. For example, many CPU, GPU, and discrete graphic cards have frequency scaling features that can adjust power consumption relative to demand. In addition, some of these devices have halt commands or alternative lower power resources that can be used to allow realization of very low power levels. Motherboard and basic input-output system (BIOS) operations that enable hardware states effectively for sleep modes can be implemented for idle modes as well. There are few significant differences in power consumption of long-idle and short idle in desktop computers where such differences are commonplace in notebook. This is despite the fact that the computer monitor is guaranteed to be off, allowing the GPU to enter the lowest power mode available and even enter a sleep rather than idle state. Hard-disks can be set to idle, and optical drives can be set to idle. In turn, the cooling requirements are reduced, and fan speeds can be lowered.

Software and Firmware Costs

The incremental costs as a result of these efforts would come from passed on engineering and research and development (R&D) costs and not to production or bill of materials (BOM) costs. It is likely that the cost of implementing this energy optimization work would decrease over time as industry develops tools and shortcuts to optimize and compete. The Aggios work done under contract to the IOUs estimated that the resulting incremental costs at retail could be around one dollar.[38]

Notebook Computers

The technical feasibility and efficiency opportunities for notebooks are similar to those available in desktops. The frequency and extent to which these features and approaches have been incorporated into notebook computers is far greater than in desktop computers. Over half of the notebook computers certified to the older ENERGY STAR version 5 specification already meet the proposed notebook standard. In addition over 72% of models certified to ENERGY STAR version 6 specification meet the proposed levels as of November 5, 2014.

---

37 ITI and Technet comments submitted to Energy Commission, July 29, 2013, pages 29-30.

38 Comment submitted to Energy Commission by IOUs and NRDC, *Computers Codes and Standards Enhancement (CASE) Initiative,* October 27, 2014, page C-27.

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 towards better efficiency and other programs such as ENERGY STAR are likely to continue to exert market pressure to improve efficiency as well. The savings do not attempt to disaggregate credit for the transition to the improved efficiencies; instead, they characterize the value of making the market transition regardless of market driver. Staff used the ENERGY STAR Version 5.2 final qualification product listing to characterize the efficiency of current computers.

Table 2: 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 ($)[39]	Incremental Cost ($)	Net Benefit (ratio benefit: cost)
Desktop	143.2	56.8	5	432	$69.12	$2.00	$67.12 34.56: 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

39 Using $0.16 per kWh.

Table 3: Potential Energy Savings for One Year of Sales and Future Stock

Product Type	Unit Savings (kWh/yr)	Unit Sales (million)[40]	Unit Stock (million)[41]	1 Year Sales Savings (GWh/yr)	Stock Savings (GWh/yr)	Reduced Electricity Cost ($M/yr)
Desktop	86.4	2.9	23.4	250.6	2,021.8	$323.4
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	-	8.31	45.23	-	2,117.2	$339.9

Source: Energy Commission staff

[40] 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 an August 6, 2013 IOU comment letter projections on shipments in 2017 on page 24.

[41] Stock figures for desktops and notebooks are taken from ITI July 23, 2013 comments, which specifically cite KEMA 2010 as its source on page 22. Figures for small-scale servers and workstations were taken from August 6, 2013 IOU comment letter projections on shipments in 2017 on page 24. Stock of small-scale servers was corrected to be equal to the annual shipments multiplied by the 5-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, it targets only idle, sleep, and off mode power. However, some efficiency approaches to reducing idle power can lead to reductions in active mode power and, therefore, save some potential material and disposal impacts. That being said, the proposed regulations are not expected to have any major impact on e-waste within the state.

The proposed standards will, however, lead to improved environmental quality in California. Saved energy translates to fewer power plants built and less pressure on the limited energy resources, land, and water use associated with it. In addition, lower electricity consumption results in reduced greenhouse gas and criteria pollutant emissions, primarily from lower generation in hydrocarbon-burning power plants, such as natural gas power plants. The energy saved by this proposal would reduce greenhouse gas emissions by 0.634 $MMTCO_2e$.[42]

---

42 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, page 5.

CHAPTER 8: 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, televisions, and consumer audio and video equipment, which are compact audio products, digital versatile disc players, and digital versatile disc recorders.

…

(v) Computer monitors and signage displays that are of size greater than 12" and pixel density of greater than 5000 pixel per square inch, 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" means a desktop computer, notebook computer, small-scale server, workstation, or thin-client computer. A computer does not include tablets, game console, handheld gaming device, servers other than a small-scale server, and industrial process controllers.

"Desktop computer" means a computer that is not designed for portability and are designed for use with an external display, keyboard, and mouse. Desktop computers are intended for a broad range of home and office applications, including point of sale applications. A desktop computer includes computers that may be sold with a display integrated into the unit or that is meant to be powered through the power supply of the 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).

"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 include an integrated display and are always sold with a mechanical keyboard (using physical, movable keys).

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

"Short-idle mode" means a state where the computer has reached an idle condition 5 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 5 seconds from initiation of wake event to system becoming fully usable, including rendering of display. For systems where ACPI standards are applicable, sleep mode most commonly correlates to ACPI System Level S3 (suspend to RAM) state.

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

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

b) Designed to operate 24 hours/day, 7 days/week, with minimal unscheduled downtime (on the order of hours/year)

c) Capable of operating in a simultaneous multiuser environment serving several users through networked client units

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).

"Workstation" means a high-performance, single-user computer typically used for graphics, computer-assisted design (CAD), software development, and financial and scientific applications among other computer-intensive tasks. Workstations covered by this specification (a) are marketed as a workstation, (b) provide mean time between failures (MTBF) of at least 15,000 hours (based on either Bellcore TR-NWT000332, Issue 6, 12/97 or field collected data), and (c) support error-correcting code (ECC) and/or buffered memory. In addition, a workstation meets three or more of the following criteria:

a) Provides supplemental power support for high-end graphics (for example, PCI-E 6-pin 12V supplemental power feed)

b) Is wired for greater than x4 PCI-E on the motherboard in addition to the graphics slot(s) and/or PCI-X support

c) Does not provide support for uniform memory access (UMA) graphics

d) Provides five or more PCI, PCI-E, or PCI-X slots

e) Provides multiprocessor support for two or more processors (shall support physically separate processor packages/sockets, that is, requirement cannot be met with support for a single multicore processor)

f) Qualified by 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 (for example, program execution, data storage, interaction with other Internet resources) are provided by the remote computing resources. Thin clients covered by this specification are (1) limited to devices with no rotational storage media integral to the computer and (2) designed for use in a permanent location (for example, on a desk) and not for portability.

…

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.* 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.*

…

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 the effective date shall comply with the Table V-3 and be shipped with power management settings that:

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

(B) Transitions connected displays into sleep mode within 15 minutes of user inactivity.

Table V-3

Energy Consumption Standards for Computers

Computer Type	*Maximum total energy consumption on or after January 1, 2017*	*Maximum total energy consumption on or after January 1, 2018*
Desktops and Thin-Clients	*none*	*50 kWh/yr + applicable adders in Table V-4*
Notebook	*30 kWh/yr + applicable adders in Table V-4*	*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 GB RAM)	0.8	0.8
Energy Efficient Ethernet	8.76 × 0.2 × (0.15 + 0.35)	8.76 × 0.2 × (0.10 + 0.30)
Storage	26	2.6
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	$8.76 \times 0.35 \times (1+EP) \times (4 \times r + 0.05 \times A)$	$8.76 \times 0.30 \times (1+EP) \times (2 \times r + 0.02 \times A)$

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		

(5) Small scale servers and workstation computers manufactured on or after January 1, 2017 must comply with the following:

(A) Shall be powered by a power supply that meets the 80 plus "gold" performance standards;

(B) Shall incorporate Energy Efficient Ethernet functionality;

(C) Shall transition connected displays into sleep mode within 15 minutes of user inactivity. In addition workstation computers shall transition into a sleep mode within 30 minutes of user inactivity.

…

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	Specify
		Core Speed (giga-hertz)	
		Number of Cores	
		Amount of RAM (gigabytes)	
		Discrete Graphics	None, G1, G2, G3, G4, G5, G6, G7, G8+
		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)	
		Length of time of user inactivity before placing display into sleep (minutes)	
		Energy Efficient Ethernet Capability	Yes, No
		Off mode power (watts)	
		Sleep mode power (watts)	
		Long-idle power (watts)	
		Short-idle power (watts)	
		Total Annual Energy Consumption (kilowatt hours per year)	

CHAPTER 9:
Part B: Displays

Background

A computer monitor and a signage display are products with a display screen and associated electronics encased in a single housing. A computer monitor is an electronic device, typically with a diagonal screen size of greater than 12 inches and a pixel density greater than 5,000 pixels per square inch (pixels/in^2), which displays the user interface and open programs of a computer, allowing the user to interact with the computer, typically using a keyboard and mouse. A signage displays is an electronic device typically with a diagonal screen size of greater than 12 inches and a pixel density less than or equal to 5,000 pixels/in^2. It is typically marketed as commercial signage for use in areas where it is intended to be viewed by people in nondesk-based environments, such as retail or department stores, restaurants, museums, hotels, outdoor venues, airports, conference rooms, or classrooms.

The primary function of these products is to display visual information from a computer, workstation, or server via one or more inputs for example, video graphics array (VGA), digital visual interface (DVI), high-definition multimedia interface (HDMI), display port (Institute of Electrical and Electronics Engineers), IEEE 1394, and universal serial bus (USB). These devices are also used to display information from external storage (for example, USB flash drive, memory card) or a network connection.

Staff's analysis shows that the proposed computer monitor and signage display standards are technically feasible and cost-effective. Proposed standards would save significant amounts of energy. Specifically, computer monitors and signage displays will save roughly 585 GWh/year statewide after the complete stock turnover.

Based on various published studies of existing stock in the United States, staff estimates that that there are about 21 million computer monitors[43] installed in California homes, offices, and commercial settings, most of which do not comply with the proposed standards and are inefficient. Computer monitors and signage displays also have a growing presence in commercial settings, such as retail and hospitality. Statewide, computer monitors and signage displays consume about 1,282 gigawatt hours (GWh) of electricity per year and create a peak demand of almost 200 megawatts (MW).[44]

There are no federal standards for computer monitors and signage displays. However, many computer monitor manufacturers produce monitors that comply with the ENERGY STAR Specification Version 6.0.[45]

---

43 Fraunhofer 2014; Navigant 2009.

44 2013 CASE study: *Analysis of Standards Proposal for Electronic Displays.*

45http://www.energystar.gov/sites/default/files/specs//Final_Version_6.0_Displays_Program_Requirements.pdf.

ENERGY STAR also provides a test method, published in September 2012, to measure the energy consumption of computer monitors. The ENERGY STAR test method defines formulas for energy efficiency within six bins that are based on monitor size. In the current market, about 70 percent of monitors claim ENERGY STAR compliance.[46]

California adopted television standards in 2009, and signage displays were included in the scope of those regulations.[47] Because there was some confusion among manufacturers as to whether the 2009 standards covered signage display units, Energy Commission staff is clarifying the definition of televisions to ensure that signage displays are specifically included in the scope and covered, ensuring full compliance of signage displays with existing television standards.

Evaluation of the test data shows that energy consumption in computer monitors and signage displays is directly related to the brightness of the screen. As the brightness of the display increases, it uses more energy. Some monitors also have automated brightness control (ABC), which varies the brightness automatically depending on the ambient lighting conditions in the user area. Automated brightness controls help reduce computer monitor and signage display energy consumption by reducing the brightness. Some computer monitors come with manual settings that allow the user to vary the brightness and contrast with either a hardware or a software menu.

User-controlled brightness and ABC have the potential to decrease energy consumption by controlling the brightness of computer monitors and signage displays. Similar to ABC, backlight dimming based on image content also reduces the light output and, therefore, power of a display.

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

Manufacturers of LED computer monitor and signage display screens have significantly improved the efficiency, but the manufacturers provide little information to consumers about the energy consumption by these products. The manufacturer can set the default brightness at the highest brightness settings and, therefore, the largest energy consumption level for retail stores. Display manufacturers are not required to report energy consumption information, such as brightness levels, for their products to the (DOE) or the Federal Trade Commission (FTC).

---

46 Energy Commission staff market study.

[47] 2014 *California Energy Commission Appliance Efficiency Regulations.*

CHAPTER 10:
Product Description

An electronic display is a product that has a display screen and associated electronics encased in a single housing. Computer monitors are designed to display electronic images from a source. The primary function of a computer monitor is to display visual information from (1) a computer, workstation, or server via one or more inputs (for example, VGA, DVI, HDMI, display port, IEEE 1394, USB); (2) external storage (for example, USB flash drive, memory card); or (3) a network connection.

Computer Monitors

A computer monitor is an electronic device, typically with a diagonal screen size of greater than 12 inches and a pixel density greater than 5,000 pixels/in^2 that displays the user interface and open programs of a computer, allowing the user to interact with the computer, typically using a keyboard and mouse. Computer monitors are used both in homes and businesses.

Signage Displays

A signage display is an electronic device typically with a diagonal screen size of greater than 12 inches and a pixel density less than or equal to 5,000 pixels/in^2. It is typically marketed as commercial signage for use in areas where it is intended to be viewed by people in nondesk-based environments, such as retail or department stores, restaurants, museums, hotels, outdoor venues, airports, conference rooms, or classrooms.

Modes

A computer monitor has three primary power modes: on, sleep, and off. On mode occurs when the display is powered and displays an image. Power consumption in all three power modes is described in watts (W). The power mode descriptions are the same as the ENERGY STAR Version 6.0 specifications.

The on mode is the power mode in which the product is activated and is providing one or more of the primary functions. 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 typically greater than the power draw in sleep and off modes. Power draws for displays in on mode depend most strongly on display technology, screen size, and resolution.

Sleep mode is the power mode the product enters 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 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.

Off mode is the lowest power mode, consumes the least amount of power, and 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.

Some computer monitors do not have an off mode, while other displays refer to off mode as standby mode.

Resolution

A key characteristic of monitors and displays is resolution. Resolution of a computer monitor or signage display describes the number of pixels that occupy the viewable screen area. The maximum resolution of the comptuer monitors has increased over time and will most 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. A pixel is a combination of a red, green, and blue filter in most applications. A new pixel technology that is available has a fourth filter of yellow that provides a vivid color picture.[48] Different amounts of light passing through liquid crystal display (LCD) openings provide a pixel-specific color. White light passes through the opening provided by the crystals that create a color pixel and make up the picture display on a screen. Display resolution is measured in megapixels (MP). Some common resolutions are Super eXtended Graphics Array (SXGA), wide extended graphics array (WXGA), wide extended graphics array plus (WXGA+), and wide ultra-extended graphics array (WUXGA). Of these standard graphics arrays, WUXGA has the highest resolution at 1,920 pixels wide by 1,080 pixels tall (also expressed as 1920X1080), or 2.07 MP. In recent years, displays have come on the market with even greater resolution such as "4K" or ultra-high-definition (UHD) designs that incorporate 8.3 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.

Other Factors

Computer monitors are advertised by the features that make them unique. Some monitors include built-in speakers that can convert audio signals received from a computer. Some monitors have USB ports or other ports to provide additional functionalities. All these features usually add to the energy consumption and price of the monitor. There are technologies available, when these features are not in use, that can limit the wasteful energy consumed by the additional features.

48 http://www.cnet.com/news/sharp-intros-industry-firsts-four-color-filter-68-inch-led-tv/.

Enhanced Performance Displays

IOUs have proposed that a subcategory of computer monitors be defined as "enhanced-performance displays" (EPDs). According to ENERGY STAR, EPDs are defined as:

"A computer monitor that has all of the following features and functionalities:

- 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
- A native resolution greater than or equal to 2.3 megapixels (MP)
- 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.[49]"

Display Panels

The most common electronic display panel type is the LCD. There are various LCD structure technologies available in the market that use thin-film transistor (TFT) technology to operate the opening and closing of individual LCD openings. All the technologies rely on an electric stimulation of the LCD structure. Depending on the panel type, 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 consumers care about are response times, viewing angles, color accuracy, and price.

LCD displays require backlighting to form and project an image and to allow the display to function. The light is provided by LEDs or cold cathode fluorescent lighting (CCFLs). LEDs are much more efficient and dominate the current display market. LEDs can be arranged in either a full-array or an edge-lit configuration. Edge-lit configurations use LEDs only along the edge of the screen, and light are redirected from the edge of the monitor toward the viewer through the use of light guide plates.

Organic Light-Emitting Diodes Panels

Recently, organic light-emitting diodes (OLEDs) have become available in the market. OLED monitors are highly efficient due to having fewer layers than LCD displays. These monitors are more expensive than LCD displays. 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, 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 if manufacturers can overcome technical challenges.[50]

49 2013 CASE study: *Analysis of Standards Proposal for Electronic Displays.*

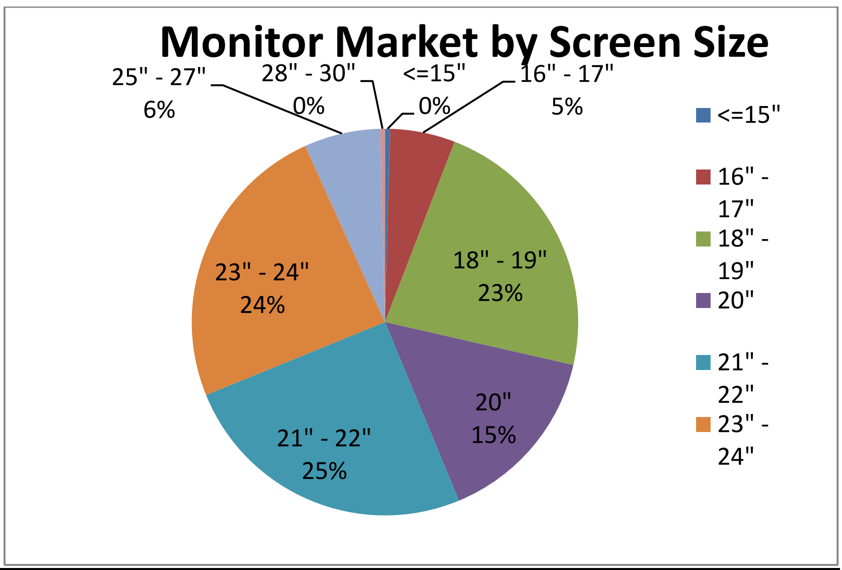
50 2013 CASE Study: *Analysis of Standards Proposal for Electronic Displays.*

CHAPTER 11:
Computer Monitor Sizes and Market

A computer monitor is a digital device designed primarily for the display of computer-generated signals and is not marketed for use as a television.[51] Computer monitors are used primarily in businesses or homes. Recent market data show that monitor sales in homes are declining due to the increased use of notebooks and tablets. In the commercial sector, however, monitor purchases are expected to increase steadily.[52]

One of the most distinguishable characteristics of any monitor is its size. Computer monitor size is measured by the diagonal distance between two opposite corners of the viewable screen. Diagonal sizes can reach all the way up to 34 inches or greater. The following graph shows the size distribution of popular monitors currently sold in the market.

Figure 1: Computer Monitor Market Distribution by Screen Size



Source: Energy Commission staff market study

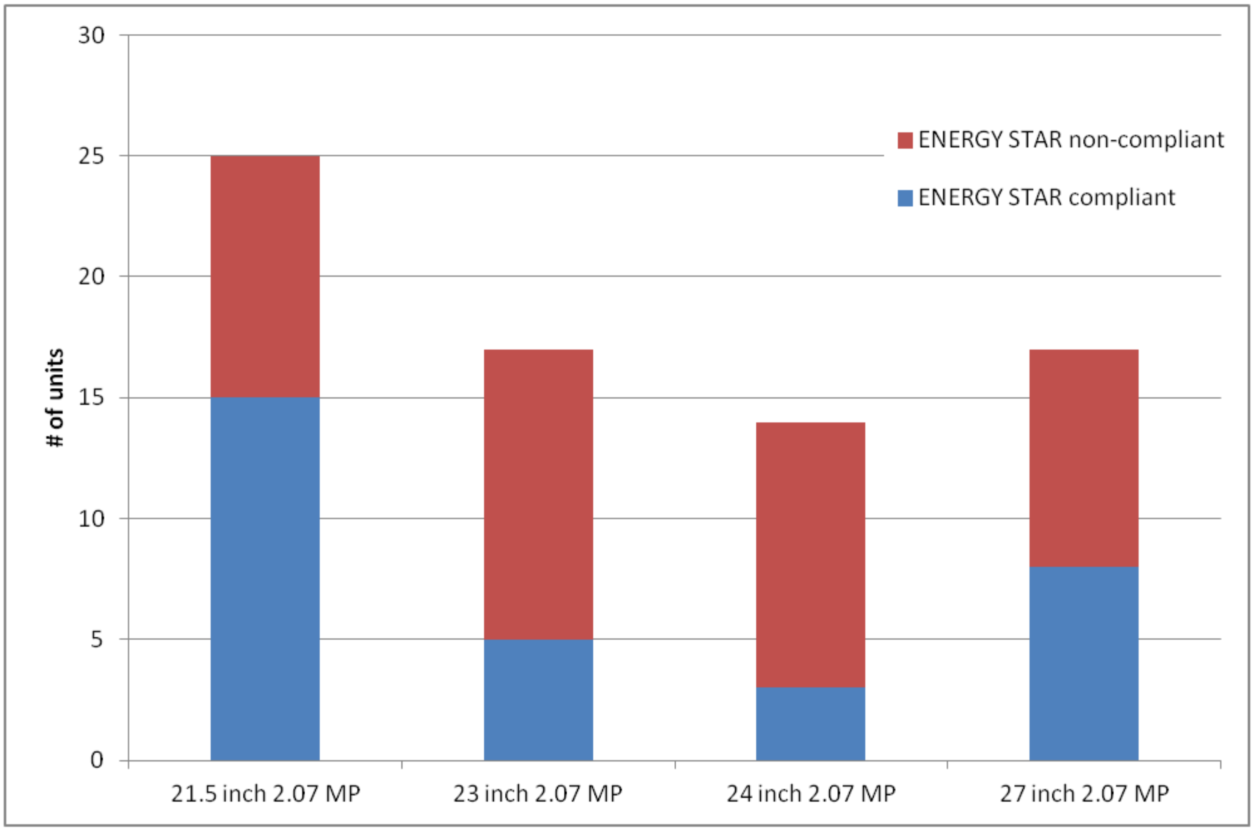
The most popular size bins of monitors in the current market are 21-22 inches, 23-24 inches, and 18-19 inches. In the last few years, sales of large monitors have increased significantly, resulting in increased energy consumption.

ENERGY STAR has been working with the computer monitor manufacturers to reduce energy consumption. This effort has resulted in availability of energy-efficent monitors in the market. However, the large stock of older monitors that are still in use is inefficent. The following graph in Figure 2 below shows the current compliance of the computer monitors with the ENERGY STAR Specifications Version 6.0 based on anecdoctal sampling of the market.

51 2014 *California Energy Commission Appliance Efficiency Regulations*.

52 Fraunhofer, *Energy Consumption of Consumer Electronics in US Homes in 2013*.

Figure 2: ENERGY STAR and Non-ENERGY STAR-Compliant Sample



Source: Energy Commission staff market study

The graph above compares, by size of screen, monitor models that are compliant with Energy Star. Energy Commission staff's proposed energy consumption levels closly match the Energy Star complaint consumption levels.

CHAPTER 12:
Technical Feasibility

Recent technological developments for LEDs and the use of reflective films have lowered unit energy consumption (UEC) substantially. The use of more efficient LED backlights in LCD monitors over the less efficient CCFL backlights contributed to this reduction in consumption. There are many other options that manufacturers can implement into future computer monitor design to further reduce the energy consumption. The Lawrence Berkeley National Laboratory (LBNL) has established several methods for computer monitor manufacturers that decrease the energy consumption and increase the efficiency of their products. Some of the technological options available to the manufacturer are shown in the table below.

Table 4: 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 (i.e., high power LEDs)
	Optical film	Optimized combination of film	Trade-offs in material cost, ease of manufacture, and efficiency
		Reflective polarizer	Cost increase[53]
LCD Panel		Improvement in panel transmittance by optimizing pixel design, functional layers, e.g., polarizer, color filter, and data line	Proprietary technology R&D investment required but driven by cost reduction
Power management		Brightness control based on computer usage patterns Auto brightness control by ambient light condition	Efficiency improvement varies with settings and usage patterns.
Other		USB-powered monitor: video and power over one single USB 3.0 cable	High-efficiency LCD panel required Cost increase for the LCD panel but likely cost-neutral for the monitor set

Backlight Efficacy

The backlight in LCD monitors is the biggest source of power consumption of power in monitors. Therefore, increasing the efficacy of the backlight in an LCD monitor would increase the efficiency of the product. Manufacturers use LED edge-lit LCDs, which use LEDs only along the edges of the monitor instead of covering the entire back of the monitor (array-lit). Light is redirected from the edge of the monitor toward the viewer through light guide plates. Because LED edge-lit LCDs often use fewer LEDs to light the screen than array-lit LCDs, they are frequently more efficient.

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

The majority of monitor manufacturers already use LED backlight technology. Manufacturers can improve the efficiency of monitors by implementing high-efficacy LEDs that are available at a comparable price as low-efficacy LEDs. There are also efficient power supplies and LED drivers that are available at a low incremental cost, but computer monitor manufacturers continue to produce and sell inefficient monitors. LED backlights are generally brighter and have increased efficiency compared to CCFL backlights. In an attempt to decrease manufacturing costs, LED monitor manufacturers have implemented edge-lit monitors.

Reflective Polarizer Technology

Since display manufacturers already use efficient LED technology and edge lighting for backlights, the backlight unit (BLU) is energy-efficient. However, LCDs are considered nonemissive displays. The majority of the light emitted by the BLU is not used to illuminate the display area, is absorbed in the monitor, and is often dissipated as heat in the display.[54]

Many technologies exist that can improve the efficiency of light passing through the film stack and LCD panel, for example, the use of reflective polarizer films.[55] By applying a reflective polarizing film to reflect the unabsorbed, nonpolarized light, the display will recycle the light, instead of it being absorbed and/or remaining unused. A reflective polarizer film results in less light being lost when passing through the polarizing layer of the LCD panel, requiring less light to illuminate the display area altogether. A reflective polarizer would increase the efficiency of the monitor by about 30 percent, with a brightness increase of roughly 55 percent.

Because one manufacturer (3M) dominates the reflective polarizer market, Energy Commission staff in its proposed standard levels used reflective polarizers as only one of several possible paths to compliance.

Default Screen Brightness

Staff agrees with the assumption in the IOU's CASE study that most consumers do not adjust the brightness of their monitor away from the default brightness.[56] The default brightness varies from monitor to monitor as well, giving a wide variance in screen brightness. 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.

Brightness control could greatly increase the efficiency of a monitor. The LBNL report *Efficiency Improvement Opportunities for Personal Computer Monitors* points out that increased brightness control based on usage patterns and ambient light conditions could decrease the energy

---

54 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.

55 2012 LBNL, *Efficiency Improvement Opportunities for Personal Computer Monitors: Implications for Market Transformation Programs.*

56 2013 CASE study: *Analysis of Standards Proposal for Electronic Displays.*

consumption of monitors by 20 percent.[57] Since brightness control is based on usage patterns and ambient light conditions, efficiency of the products that use brightness control to reduce energy consumption would vary greatly based on these factors.

Automatic Brightness Control

Automatic brightness control (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. Furthermore, a dimmer screen in a dark environment provides less eye strain than a brighter screen in a dark environment, providing consumer satisfaction. With ABC installed, monitors can see a 10 percent increase in energy efficiency.[58]

Improved Power Supply Unit

Improving the power supply unit (PSU) of a monitor will increase the efficiency of that monitor. IOUs analyzed a PSU upgrade from 80 percent efficiency to 88 percent efficiency in 19 inches and 22 inches monitors.[59] Both the 19 inches and 22 inches models experienced an overall 8 percent increase in efficiency. Since the majority of the market consists of 19” and 22” monitors, an increase in PSU efficiency would create significant energy savings.

---

57 2012 LBNL: *Efficiency Improvement Opportunities for Personal Computer Monitors: Implications for Market Transformation Programs*

58 2013 CASE study: *Electronic Displays Technical Report – Engineering and Cost Analysis, page 57*

59 2013 CASE study: *Electronic Displays Technical Report – Engineering and Cost Analysis, page 57*

CHAPTER 13: Regulatory Approaches

U.S. Department of Energy

There are no federal standards for computer monitors and signage displays. Many manufacturers are complying with ENERGY STAR Specification Version 6 for computer monitors and signage displays.[60]

ENERGY STAR Maximum On-Mode Power Draw Criteria

ENERGY STAR issued Specification Version 6.0 Rev. in January 2013 to specify the criteria for computer monitors. Requirements are described through ENERGY STAR Specification Version 6.0 equations. These equations apply only to diagonal screen size less than 61 inches. On mode power must be less than or equal to the maximum on mode power. Products must offer at least one power management feature enabled by default. ENERGY STAR has separate allowances for EPDs, and monitors with ABC have specific on mode power calculations.

The maximum power usage in sleep mode for any monitor shall be less than or equal to 0.5 watts. Additional bridging or network options increase sleep mode power maximum, depending on type and number. 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.

In the current market, nearly 70 percent of monitors claim ENERGY STAR Version 6.0 compliance.[61]

IOUs' 2013 CASE Study Criteria

The IOUs and NRDC have proposed that the Energy Commission adopt computer monitor standards based on the construct provided by ENERGY STAR Specification Version 6.0 Rev. IOUs recommend on mode maximum requirements based on screen size and resolutions. Instead of testing at the ENERGY STAR calibrated brightness of 200 units, the IOUs propose testing be performed at default (that is, "out of box") settings.

Energy Commission Staff Proposals

Energy Commission staff proposes monitor standards to establish maximum on mode power (P_{ON_MAX}) for computer monitors based on screen area and resolution, as outlined in Table 5 below. This approach is similar to ENERGY STAR specifications for on mode power

---

60http://www.energystar.gov/sites/default/files/specs//Final_Version_6.0_Displays_Program_Requirements.pdf.

61 Energy Commission staff market study.

requirements. Furthermore, staff proposes maximum power for standby mode (P_{SLEEP_MAX}) and off modes (P_{OFF_MAX}).

Table 5: Maximum Power Requirements by Modes − Computer Monitors

Diagonal Screen Size in inches (d)	On Mode in Watts (P_{ON_MOX})	Standby Mode in Watts (P_{SLEEP_MAX})	Off Mode in Watts (P_{OFF_MAX})
d<12	(4.2*r) + (0.04*A) +1.8	1.0	0.5
12″≤d<17″	(4.2*r) + (0.01*A) +3.5	1.0	0.5
17″≤d<23″	(4.2*r) + (0.02*A) +2.2	1.0	0.5
23″≤d<25″	(4.2*r) + (0.04*A) +2.4	1.0	0.5
25″≤d<61″	(4.2*r) + (0.07*A) +10.2	1.0	0.5

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

Signage Displays – Power Mode Requirements

Signage displays are covered under the television regulations. Many manufacturers are designing and registering applicable products to adhere to these existing regulations. The proposed updates to the definition will provide clarity for the products that are already covered under the television regulations. All manufacturers of signage display would be required to comply with the following regulation.

Table 6: Maximum Power Requirements by Mode – Signage Displays

Screen Size (Area A in Inches Squared)	On Mode (W)	Standby Mode (W)	Minimum Power factor for (P≥ 100 Watts)
d<1400″	(0.12*A) +25	1	0.9

Where A is a viewable screen area (Square Inches)[62]

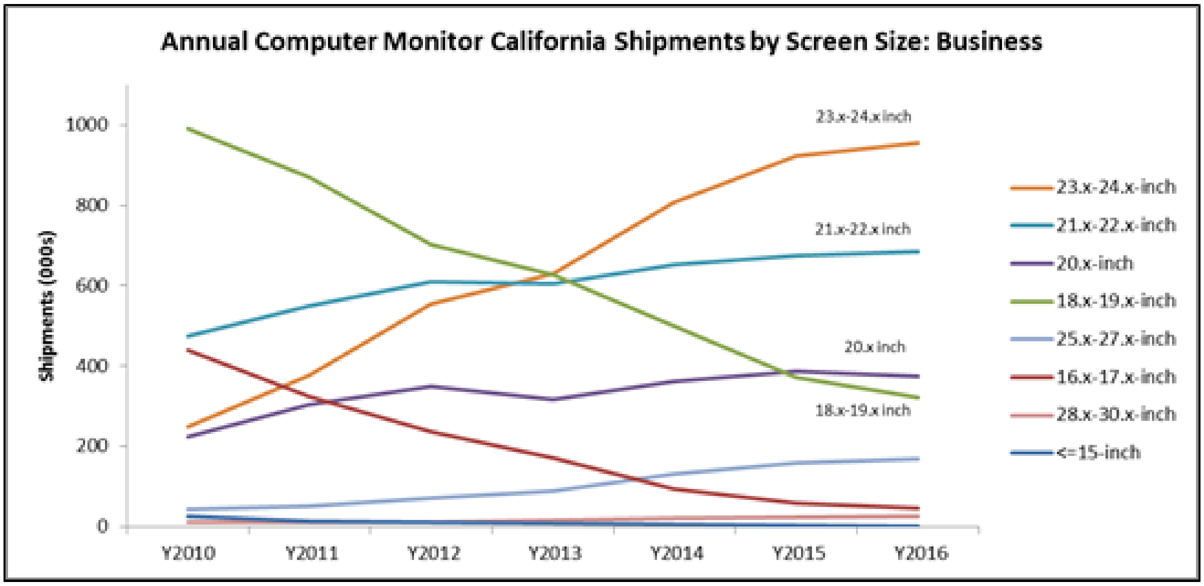
62 Available at http://www.energy.ca.gov/2009publications/CEC-400-2009-024/CEC-400-2009-024.PDF, page 46.

CHAPTER 14: Energy Savings and Cost Analysis

Stock and Sales

Annual shipments of computer monitors show a decline in sales and stock. Most of this decrease has been found in small monitors. However, sales of larger monitors have increased, thereby increasing the energy consumption. This trend is shown in Figure 3.

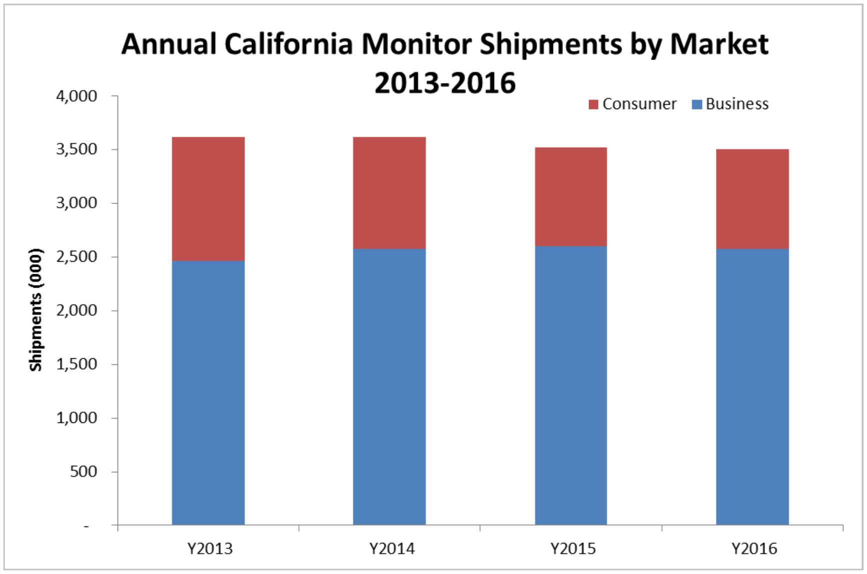
Figure 3: Annual Shipments by Screen Size



Source: IOUs CASE Study 2013

As shown in Figure 4 below, the IOUs estimate that current California annual shipments are 3.6 million.

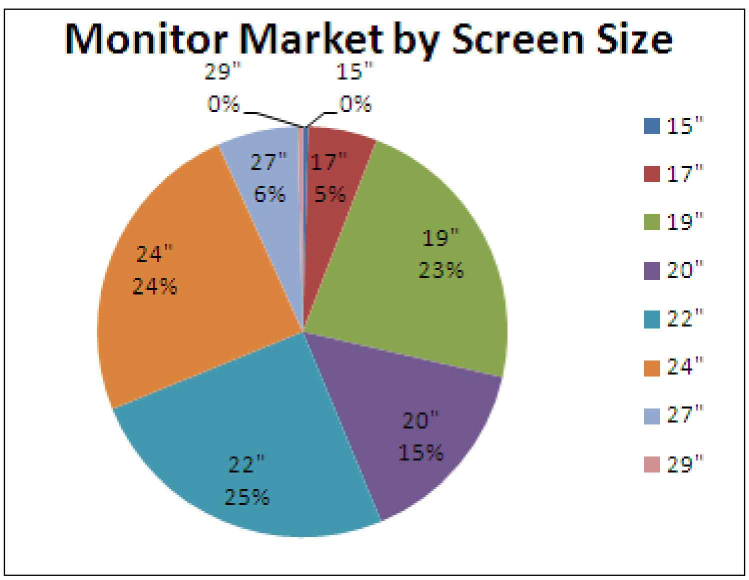
Figure 4: Estimated Annual Shipments



Source: IOUs CASE Study 2013

Figure 5 below shows the CA market distribution for 2013 by screen size.

Figure 5: Screen Size in the Marketplace



Source: IOUs Case Study 2013

Table 7 shows the installed computer monitor base estimates in California by residential and commercial sector.

Table 7: California Noncompliant Stock

Sector	Installed Base in Millions
Residential	12.7
Commercial	8.5
Total	21.2

Source: Fraunhofer 2014;[63] Navigant 2009.[64]

Table 8 below shows the average energy consumption of nonqualifying computer monitors. A *Nonqualifying computer monitor* means that the unit would not comply with the proposed standard and represents the current inefficient stock. Qualifying stock represents unit that would comply with the proposed standard.

Table 8: Energy Consumption per Unit

	On Watts	Standby Watts	Off Watts	Annual Energy KWh/year
Nonqualifying	26.16	0.35	0.27	60.58
Qualifying	13.95	0.30	0.21	32.93

Source: IOUs CASE Study 2013

Duty Cycle

Home and business consumers have very different operating hours, and the duty cycles for the residential and commercial sectors are shown in the Table 9. The residential duty cycle is derived from the Consumer Electronic Association study (Fraunhofer 2011),[65] while the commercial duty cycle is derived from the study conducted by Navigant Consulting (Navigant 2009).

Table 9: Duty Cycle

Sector	On Mode (hrs/day)	Sleep Mode (hrs/day)	Off Mode (hrs/day)
Residential	4.2	12.2	7.7
Commercial	6.8	13.8	3.4

63 [Fraunhofer] Fraunhofer Center for Sustainable Energy Systems. 2014. *Energy Consumptions of Consumer Electronics in U.S. Homes in 2013,*.

64 [Navigant] Navigant Consulting, Inc. 2009. *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances,* final report.

65 Fraunhofer] Fraunhofer Center for Sustainable Energy Systems. 2011. *Energy Consumptions of Consumer Electronics in U.S. Homes in 2010*.

Source: Fraunhofer 2014; Navigant 2009 [66]

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. Their 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 10. 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

Table 10: Annual Hours in Power Mode for Computer Monitors by 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	4,887	1,640

Source: IOUs Case Study 2013 CASE study: "Analysis of Standards Proposal for Electronic Displays"

Staff estimates that current inefficient computer monitor stock consumes more than 1,282 GWh of electricity annually. Monitor purchases are expected to increase steadily in the commercial sector, while sales will decrease in the residential sector.[67] Without standards in place, energy consumption will not change much. Under the proposed standards once all the existing stock is replaced with the efficient computer monitors, there will be significant reduction in energy consumption.

66 [Navigant] Navigant Consulting, Inc. 2009. *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances,* final report December 21, 2009.
67 2013 CASE study: *Analysis of Standards Proposal for Electronic Displays.*

Design Life

The design life of computer monitors varies by application. A recent LNBL study estimated the design life to be six years. ENERGY STAR estimates it to be four years for commercial monitors and five years for residential monitors. In this analysis, staff assumes the average lifetime for computer monitors to be five years, which is a reasonable approximation of the average design life of computer monitors.

Life-Cycle Cost and Net Benefit

The life-cycle costs and benefits represent the sum of the annual benefits and 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 12. The overall life-cycle cost/benefit ratio and present value of all costs and benefits of the standard are shown below in Table 12.

Incremental Cost

Staff has evaluated CASE report analysis for different cost effective strategies to meet the proposed levels. Some of the strategies may not cost anything (calibrating the brightness) while other technologies have an associated cost that is more. The Energy Commission staff evaluated pathways presented in the technical support document and found cost effective energy reducing pathways. Incorporating higher efficiency LEDs, enhanced reflective films, and global dimming presented a compliance pathway at a cost of approximately $5.[68] This incremental cost estimate is based a detailed cost analysis for two sizes of computer monitors using a DisplaySearch component cost survey that is commonly used by the industry.

The proposed standard will save about 28 kWh a year per unit, and at a cost of $0.16 per kWh,[69] it will generate $4.40 in electricity savings per unit per year. Total energy saving over the entire life of the product will be about $26.54. Subtracting the incremental cost of $10.26 per unit from the total energy savings of $26.54 per unit over the life cycle of the product provides savings of $16.28 to the consumer. Using the IOUs incremental cost estimates, the payback period for the improvement is less than 2½ years. Therefore, the proposed standard is cost-effective.

---

68 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 Figure 5.2, page 34, figure 5.3, page 35.

69 Using a residential electric rate of $0.16 per kilowatt-hour.

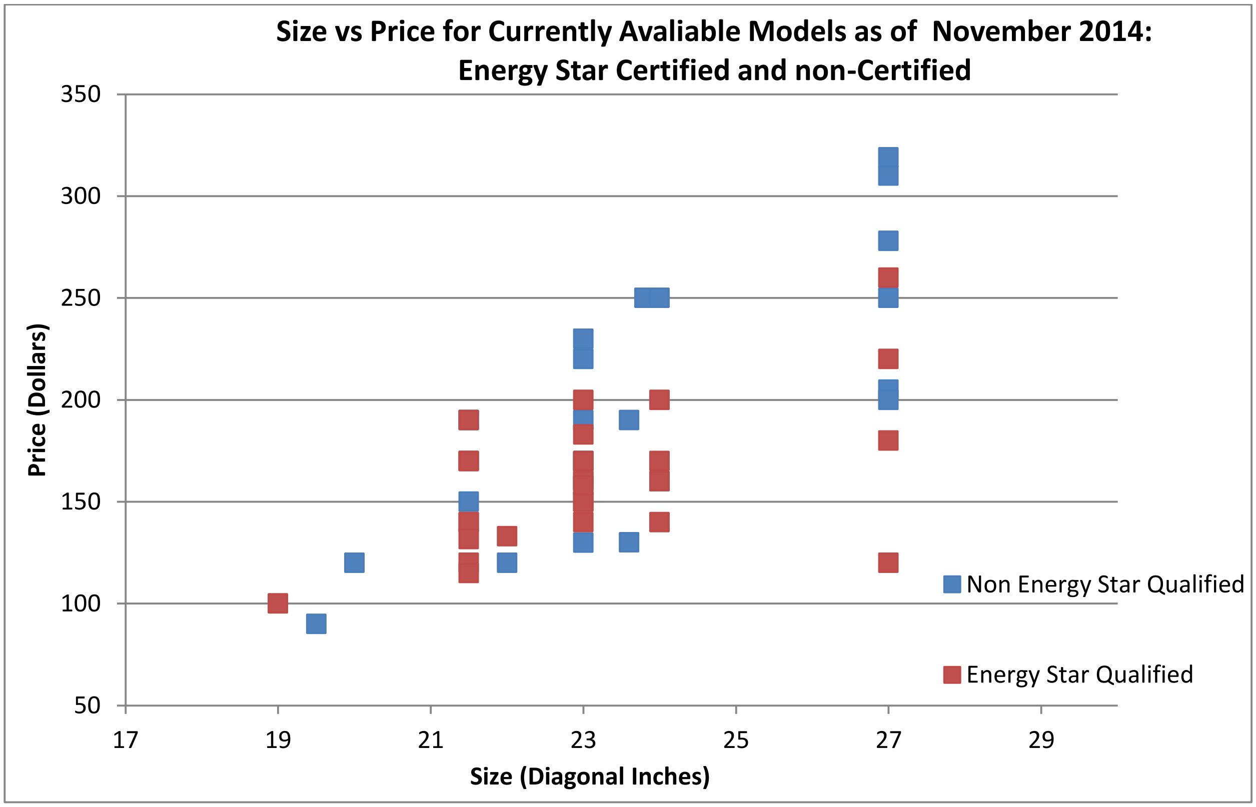
Table 11: Life-Cycle Costs and Benefits per Unit for Qualifying Products

Design Life	Life-Cycle Cost per Unit (Present Value $) Total Incremental Cost per unit	Life-Cycle Benefits per Unit (Present Dollar Value) Energy Savings per unit	Per Unit Savings Over the Life Cycle
6 years	$5.00	$26.54	$21.54

Cost of electricity for the analysis is assumed to be $0.16 per KWh. This assumption is based on present average residential and commercial rates

For illustration, Energy Commission staff has conducted a market survey to evaluate the price differences between ENERGY STAR-compliant and non-ENERGY STAR monitors. Many LED computer monitors that are sold in the market are ENERGY STAR-compliant, but a large number of LED monitor models in the market are not ENERGY STAR-compliant and are inefficient. Staff has conducted a current market price-versus-size survey of ENERGY STAR and non-ENERGY STAR computer monitors. Survey results are plotted in a graph shown in Figure 6 below. The survey shows the ENERGY STAR-compliant monitors sell at the same or lower prices than non-ENERGY STAR compliant monitors.

Figure 6: Size Vs Price



Source: Energy Commission Staff

For this analysis, three sizes of monitors were analyzed: small, medium, and large. A small monitor is considered to be a monitor with a diagonal screen size of 21 inches. A medium-sized monitor is a monitor with a diagonal screen size of 23 inches. A large monitor is a monitor with a diagonal screen size of 27 inches.

Total Energy Savings

Staff calculated the annual energy savings and dollar savings, which are shown in Table 12. First-year energy savings and total lifetime savings are shown in Table 13 below.

Table 12: 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**
Non-Qualifying Unit - Qualifying Unit 60.58-32.93= 27.65	Energy Savings per Unit X Product Life Cycle 27.65*6=165.9	Product Life Cycle Savings X Electricity Rate $26.54

Source: Energy Commission Staff

Table 13: First-Year Statewide Energy Savings and Savings After Stock Turnover

First Year Statewide Energy Savings Based on 2017 Sales	Total Statewide Energy Savings After the Stock Turnover KWh/Year	Total Statewide Savings $ in Net Present Value at a Discount Rate of 3 Percent
First Year Sales X Electricity Rate 3.6 million X0.16¢=$576,000	Current Energy Consumption- Energy Consumption after the Stock Turnover 585 GWh	$11 Million

Source: Energy Commission Staff

CHAPTER 15: Safety and Environmental Issues

Staff could not identify any safety or negative environmental impacts of improving efficacy of computer monitor and signage display efficiency. 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.

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 greenhouse gas emissions by about 0.183 $MMTCO_2e$.[70]

70 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, page 5.

CHAPTER 16:
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) Computer monitors and signage displays that are of size greater than 12" and pixel density of greater than 5000 pixel per square inch, 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.

…

"Electronic display" means a display screen with the primary function of displaying visual information from (1) a computer, workstation, or server via one or more inputs (for example, VGA, DVI, HDMI, DisplayPort, IEEE 1394, USB); (2) external storage (for example, USB flash drive, memory card), or (3) a network connection.

"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 greater than or equal to 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 on mode" means the power mode in which the product is activated and is providing one or more of its principal functions. The common terms "active," "in-use," and "normal operation" also describe this mode.

"Display off mode" means the power mode in which the product is connected to a power source but is not providing any display on mode or display sleep mode functions. This mode may persist for an indefinite period. The product may only exit this mode by direct user actuation of a power switch or control. Some products may not have this mode.

"Signage display" is an electronic device typically with a diagonal screen size greater than 12 inches and a pixel density less than or equal to 5,000 pixels/in2. It is typically marketed as commercial signage for use in areas where it is intended to be viewed by multiple people in non desk-based environments, such as retail or department stores, restaurants, museums, hotels, outdoor venues, airports, conference rooms, or classrooms.

"Display sleep mode" means the power mode the product enters after a period of inactivity, in which a signal from a connected device or an internal stimulus (for example, a timer or occupancy sensor) is received. The product may also enter this mode by virtue of a signal produced by user input. The product must wake on receiving a signal from a connected device, a network, a remote control, and/or an internal stimulus. While the product is in this mode, it is not producing a visible picture, with the possible exception of user-oriented or protective functions such as product information or status displays, or sensor-based functions.

…

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 manufactured on or after April 24, 2014 and signage displays 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 Version 6.0*.

…

1605.3 State Standards for Non-Federally Regulated Appliances

…

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

…

(5) Computer monitors manufactured on or after January 1, 2017 shall comply with the standards in Table V-5.

Table V-5

Maximum Power Requirements by Modes- Computer Monitors

Diagonal Screen Size in Inches (d)	*On Mode in Watts (P_{ON_MAX})*	*Standby Mode in Watts (P_{SLEEP_MAX})*	*Off Mode in Watts (P_{OFF_MAX})*
d<12	*(4.2*r) + (0.04*A) +1.8*	*1.0*	*0.5*
12″≤d<17″	*(4.2*r) + (0.01*A) +3.5*	*1.0*	*0.5*
17″≤d<23″	*(4.2*r) + (0.02*A) +2.2*	*1.0*	*0.5*
23″≤d<25″	*(4.2*r) + (0.04*A) +2.4*	*1.0*	*0.5*
25″≤d<61″	*(4.2*r) + (0.07*A) +10.2*	*1.0*	*0.5*
r = Screen resolution (megapixels) A= Viewable screen area (square inches)			

…

(6) Signage displays manufactured on or after January 1, 2017 shall comply with the standards in table V-6

Table V-6

Maximum Power Requirements by Mode – Signage Displays

Screen Size (Area A in Inches Squared)	**On Mode (W)**	**Standby Mode (W)**	**Minimum Power factor for *(P ≥100W)***
d<1400″	**(0.12*A) +25**	**1**	**0.9**
Where A is a viewable screen area (Square Inches)[71]			

71 Available at http://www.energy.ca.gov/2009publications/CEC-400-2009-024/CEC-400-2009-024.PDF, page 46.

APPENDIX A

The pathways to compliance with a 50 kWh standard are different depending on whether a computer takes additional power saving steps between short-idle and long-idle. Once adders are incorporated to the target, it is likely that the standard will be more along the lines of 55 kWh per year. If short-idle and long-idle are roughly the same as is seen in most desktops today, the target wattage is (assuming 1 watt off, and 2 watt sleep) about 11.5 watts. However, the short idle is likely to consume more power, and the long idle less power. Figure 7 is an estimate of typical PC idle consumption as presented in ITI's July 29, 2013 comments. While staff realizes that this chart does not represent every type or vintage of computer, it is an interesting scenario to consider relative to the standard's energy consumption targets.

Figure 7: Typical PC Idle Consumption by Percentage

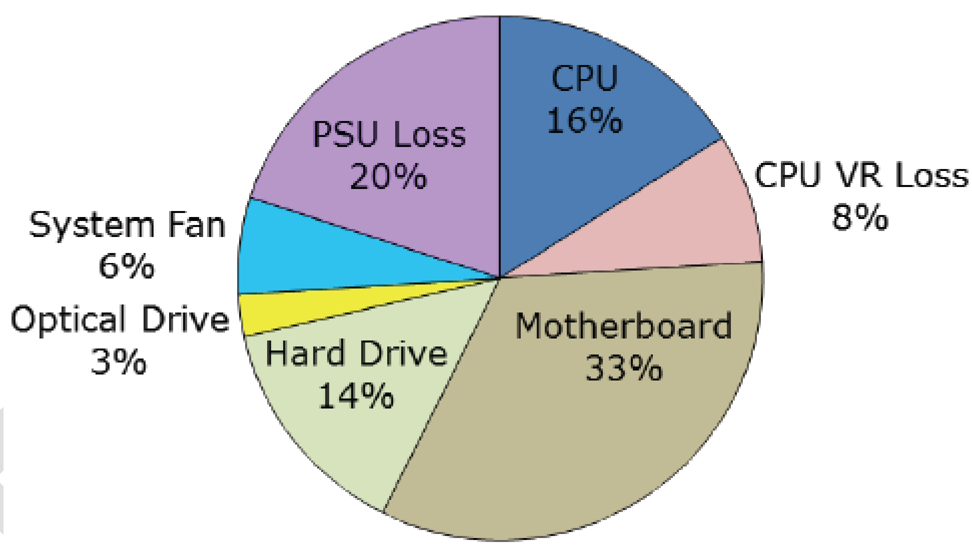
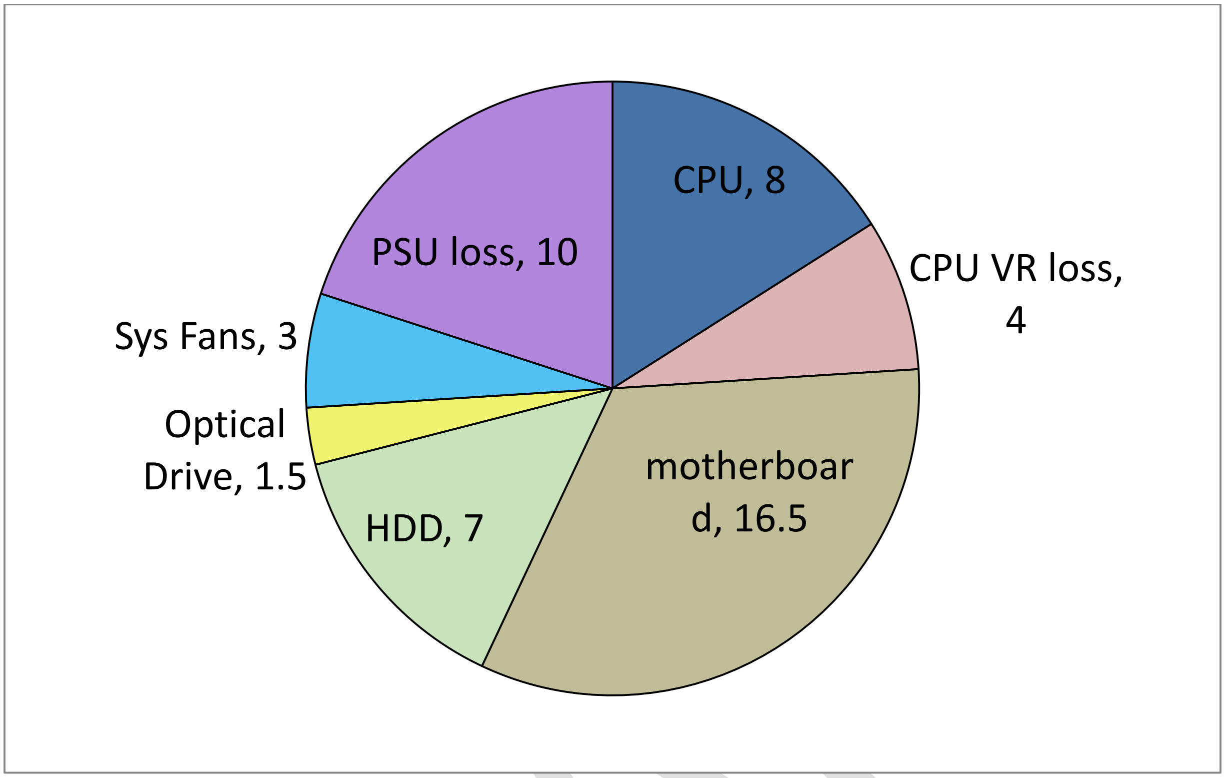


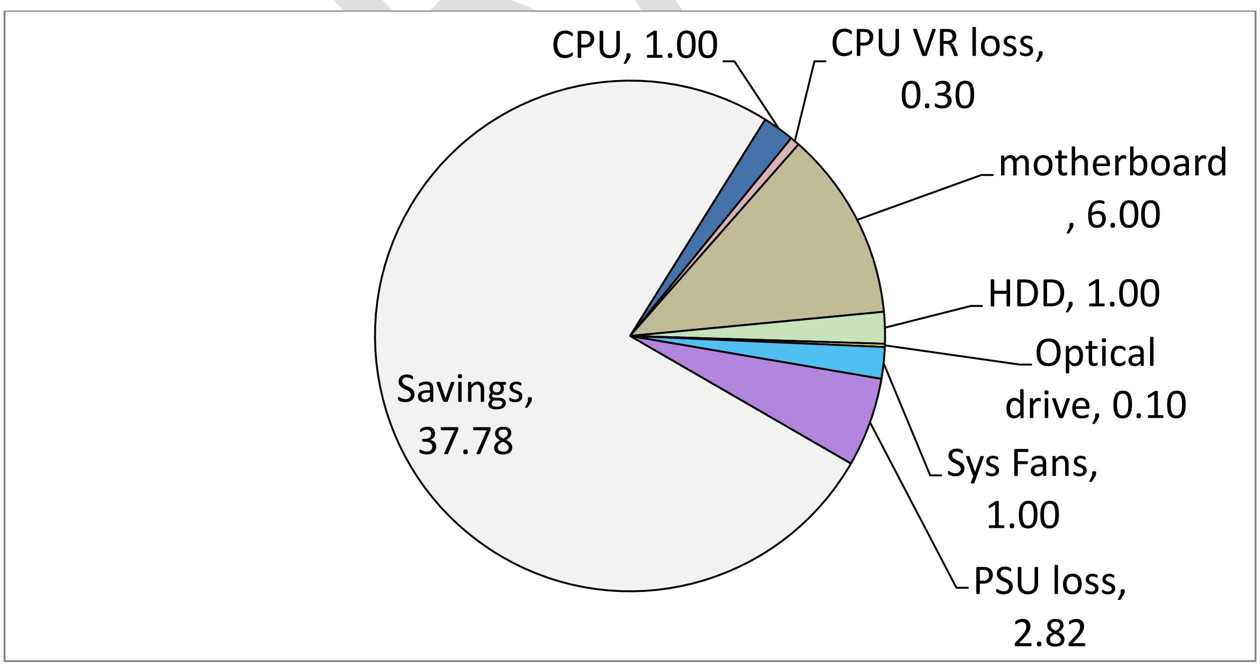
Figure 8 translates the ITI breakdown for a typical PC from the graphic's vintage with an idle of about 50 watts.

Figure 8: Idle Mode of a Desktop System in Watts



However given current technologies the profile in idle mode can look much more like this, using only a bit more than 1/3 the power:

Figure 9: Idle Mode Power Consumption with Efficient Components, Watts



The advancements that enable this are further described in this appendix.

CPU

The introduction of C7 states such as that found in Haswell chips allows lower power consumption states while in idle mode. Figure 9 estimated a current draw of 2/3 of an amp to represent a low level working state. The power to the processor is provided by voltage regulators that translate the 12 volts provided by the power supply to the final CPU voltage. The associated voltage regulator is thereby rendered practically to its standby-state, reducing the conversion losses to essentially the regulator's fixed losses. The voltage regulator fixed losses are estimated at about 0.3 watts.

Hard-Drive

Computer hard drives have a wide range of idle power performances. Historically, low-idle power was only found in 2.5" notebook drives and solid state drives (SSDs). However with new SATA standard power management features even full-sized 3.5" disks are able to achieve idle consumption of less than 1 watt.

Optical Drive

SATA 3.1 specifications allow for zero power optical drive idle consumption. Optical drive idle power can be brought to zero, although staff modeled it at 0.1 watts to be conservative.

System Fans

With the reduced idle power in other components, less heat dissipation is needed. Therefore, fan power can be significantly reduced. In fact, the draw could be low enough where many systems may be able to be sufficiently cooled without active fans in idle. Staff estimated a 1 watt draw for fans, which is roughly equivalent to a single fan running at a low speed.

Motherboard

Many features allow motherboard power consumption to be reduced. DC-DC conversion losses are reduced by lowering overall component loads. Ethernet idle power is reduced by Energy Efficient Ethernet. BUS and other clock can be reduced, thereby lowering the power consumption of associated chips and processes. New SATA and USB standards lower standby. Losses can also be reduced by minimizing the motherboards unused capacity by either using smaller form-factor motherboards or by ensuring that unused expansion capabilities do not yield higher idle mode power.

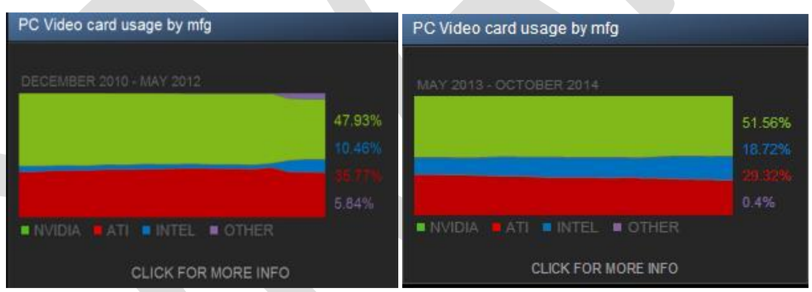
Power Supply Losses

Power supply idle can be reduced to levels considerably lower than 10 watts. The idle is naturally reduced by the reduction of system load, as discussed in previous sections. Reduction of system load will reduce the conversion losses in the power supply as less overall power must be delivered. This number can be further reduced both by increasing the conversion efficiency at small loads and also by addressing standby loads within the power supply itself. Desktops are capable of achieving lower idle power well below 3 watts in sleep modes where the power supply must still provide power along with its fixed losses. The entire computer system is drawing less than 2 or 3 watts while the power supply is providing power to sustain system RAM and other components.

Idle in Graphics Processing Units

The ITI idle mode consumption shown in figure 7 does not include a separate category for graphics processing units. Most computers do not need high-end discrete graphics cards. With the introduction of well performing integrated GPU in chips made by AMD and Intel the standard business desktop does not need additional graphics processing capabilities. The residential sector is where discrete graphics cards are most commonly used, particularly in high-end gaming systems. However these computers are relatively low in shipments in comparison to the bulk of the computer market, and only a small percentage contain the most powerful discrete graphics cards. Casual video gamers are increasingly relying on integrated graphics as can be seen in the Steam graphics profile where Intel integrated graphics made up 18.7 percent of systems in October 2014 and Intel HD Graphics 3000 and 4000 GPUs are the most common GPUs. This is a large increase from May 2012, when intel integrated graphics cards only made up 10.5 percent of system video cards on Steam.

Figure 10: PC Video Card Usage On Steam



This means that even amongst the minority of computers used for gaming, integrated graphics are substantially used. These integrated graphics processors are capable of power scaling along with the overall processor chips, and are able to achieve low power consumption in idle mode.

The workload of a GPU in idle is very low. In the case of short-idle the graphic workload is to render the desktop. In the case of long-idle the screen should be in low power mode and no video is transmitted. The idle power in discrete graphics cards is relatively high, adding large system idle power overhead. This overhead appears to be decreasing as shown by research conducted by NRDC, CLASP, and California IOUs,[72] but still remain very high for the level of performance required in short and long idles modes. Reducing the overhead at very low demand is a large opportunity to reducing idle mode power in discrete graphics cards.

[72] "Comments regarding Version 6.0 Draft 3 Computer Specification," California IOUs and NEEA, January 22, 2013, figure 2 on page 5.