DOCKETED

Docket Number:	14-AAER-02
Project Title:	Computer, Computer Monitors, and Electronic Displays
TN #:	204782
Document Title:	Bijit Kundu, Energy Solutions, on behalf of California IOUs Comments: Response to CEC Standards Proposal for Computer Monitors and Signage Displays
Description:	N/A
Filer:	System
Organization:	Bijit Kundu, Energy Solutions, on behalf of California IOUs
Submitter Role:	Other Interested Person
Submission Date:	5/29/2015 3:42:47 PM
Docketed Date:	5/29/2015

Comment Received From: Bijit Kundu, Energy Solutions, on behalf of California IOUs
Submitted On: 5/29/2015
Docket Number: 14-AAER-02

Response to CEC Standards Proposal for Computer Monitors and Signage Displays

Additional submitted attachment is included below.

Electronic Displays

Codes and Standards Enhancement (CASE) Initiative
For PY 2015: Title 20 Standards Development

Response to CEC Standards Proposal for
Computer Monitors and Signage Displays

Docket #14-AAER-2

May 29, 2015

Prepared for:

PACIFIC GAS & ELECTRIC COMPANY

SOUTHERN CALIFORNIA EDISON

SAN DIEGO GAS AND ELECTRIC

SOUTHERN CALIFORNIA GAS COMPANY

Prepared by:
Bijit Kundu, ENERGY SOLUTIONS
Clancy Donnelly, ECOVA

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Table *of* Contents

1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. This document provides recommendations and supporting analysis in response to the CEC's Displays Staff Report.

Energy use in California from electronic displays – computer monitors and signage displays – is significant and has been growing in some sectors. Computer monitors are ubiquitous in homes, offices, and other commercial settings. They are increasingly used as second screens with notebooks and in extended desktop display setups in home and office environments. Monitors account for a significant portion of electricity consumed in computing use. Signage displays are a growing presence in commercial settings, such as retail, restaurant, transit, and hospitality. The California Investor Owned Utilities (CA IOUs) generally support the energy efficiency standards for electronic displays proposed by the California Energy Commission (CEC). Specifically, we strongly support CEC's proposal regarding the On Mode power requirements for computer monitors. We believe these On Mode limits are cost effective and technically feasible across the wide range of computer monitor screen sizes and resolutions.

Regarding signage displays, we support the comment made by CEC staff at the public workshop on April 15, 2015 that they are re-considering more stringent On Mode power requirements for signage displays. More details are provided below on testing the Codes and Standards Enhancement (CASE) Team has done to show more stringent On Mode levels for signage displays than proposed in the staff report and inclusion of large-sized models are cost effective and technically feasible and result in significant energy savings. Based on our testing, we recommend CEC apply power requirements to all screen sizes of signage displays, including models equal to and greater than 1,400 inches-squared (in-sq) – or currently unregulated products.

The comments below outline recommendations for improving proposed standards for electronic displays by capturing additional cost effective energy savings. Electronic display standards if adopted as outlined in this letter would address some of the statewide policy objectives of Zero Net Energy California Long Term Energy Efficiency Strategic Plan and AB32 energy efficiency goals. We appreciate careful consideration of the following comments.

2 Computer Monitors

2.1 Energy Consumption

2.1.1 Growing Sales

As first presented in the CASE Report submitted on July 29, 2013, sales in the residential sector have been declining while sales in the commercial sector have been growing. Figure 2.1 shows the growth in the commercial sector has been among all categories of larger screen sizes: 21-inches and larger.

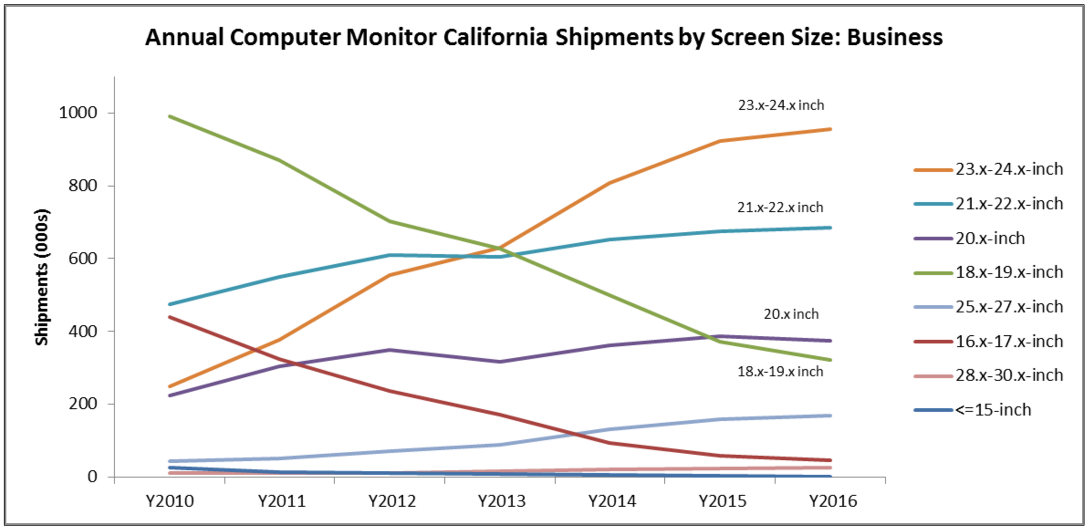


Figure 2.1 Annual Computer Monitor California Shipments by Screen Size: Business
Source: IHS iSuppli 2012a

There are many different resolutions for computer monitors. Table 2.1 below lists most of the resolution types for monitors considered in this report. Also listed in the table is the total native resolution in megapixels (MP).

Table 2.1 Resolution Bins for Computer Monitors
Source: IHS iSuppli 2012a

Resolution Bin	Total Native Resolution (MP)
<=XGA	0 – 0.786
>=UXGA	1.920
>=WUXGA	2.07 and higher
SXGA	1.311
WSXGA	1.51 – 1.76
WXGA	1.024 – 1.049
WXGA+	1.296

Figure 2.2 shows growth of shipments for higher resolution (WUXGA or 2.07 megapixels and larger) commercial computer monitors.

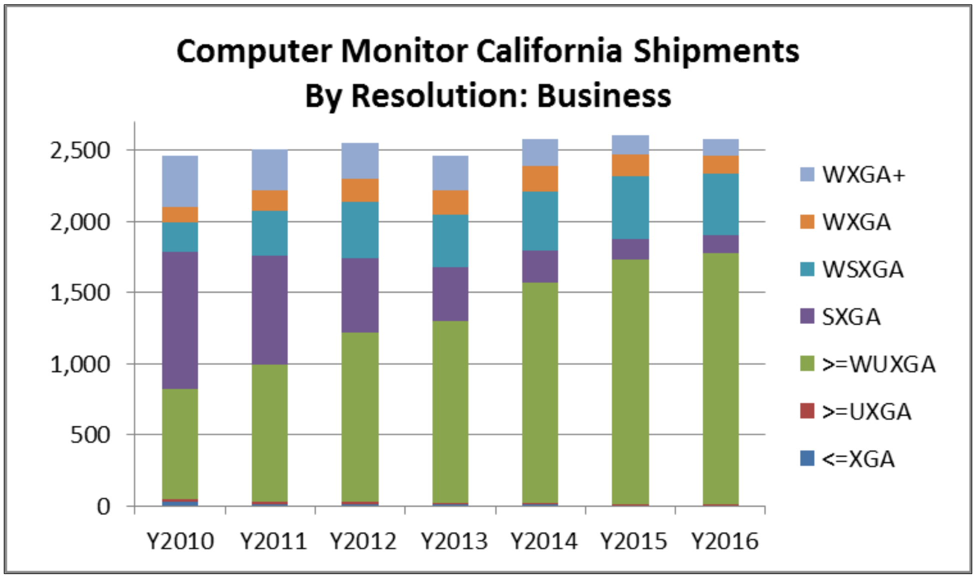


Figure 2.2 Annual Computer Monitor California Shipments by Resolution: Business
Source: IHS iSuppli 2012a

Growth in larger sized, higher resolution computer monitors mean that power draw of monitors in this sector is also increasing as power draw scales with size and resolution. In addition, since a computer monitor in a commercial setting is in On Mode over 60% longer than a monitor in a home setting (Fraunhofer 2014; Navigant 2009), the annual energy consumption for computer monitors overall is likely rising. Computer monitors are a significant contributor to overall plug load energy consumption in California.

2.1.2 Per Unit Energy Use Disparities

As shown previously in the CASE Report, On Mode power draw of computer monitors varies greatly, even within models of similar sizes and feature sets. Differences in some combination of the following components can account for the wide variation: backlighting, panel transmittance, optical films, and electronics (drive circuit, image circuit, and the power supply unit). Figure 2.3 and Table 2.2 below from the CASE Report reflect box plots and associated data to exhibit the wide disparities in On Mode power draw for models with the most popular resolution category >=WUXGA within similar screen size bins. Energy conservation standards could potentially remove the worst performing products (in regards to power consumption) within a size category from the market, while still ensuring a large selection of models that perform the same utility.

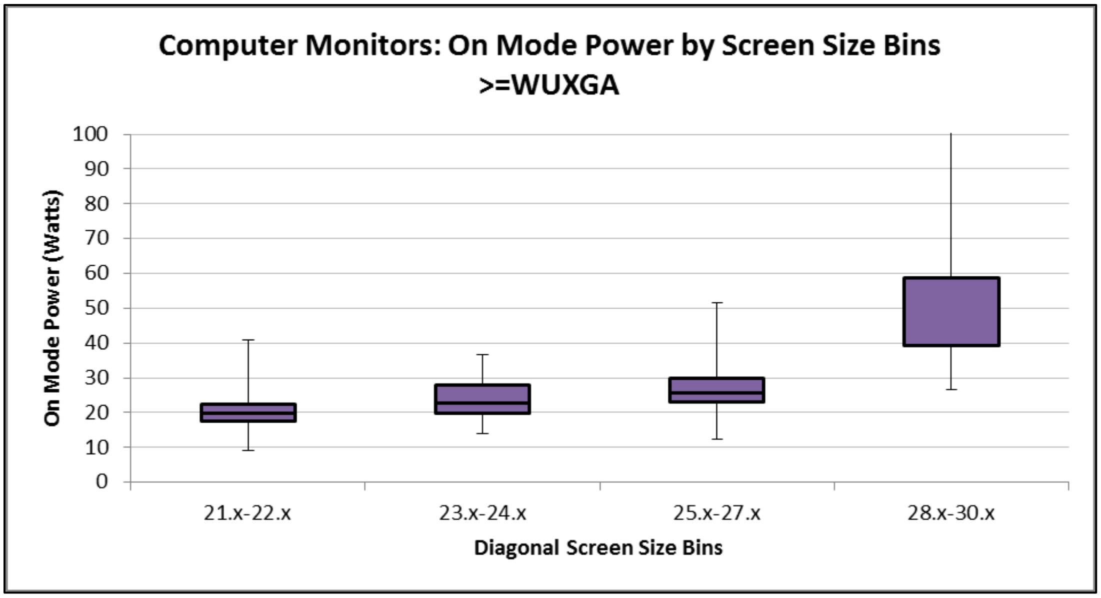


Figure 2.3 Computer Monitor On Mode Power Consumption Box Plot: >=WUXGA Resolution[1]

Source: CASE Team analysis

Table 2.2 Computer Monitor On Mode Power Consumption Box Plot: >=WUXGA Resolution

Source: CASE Team analysis

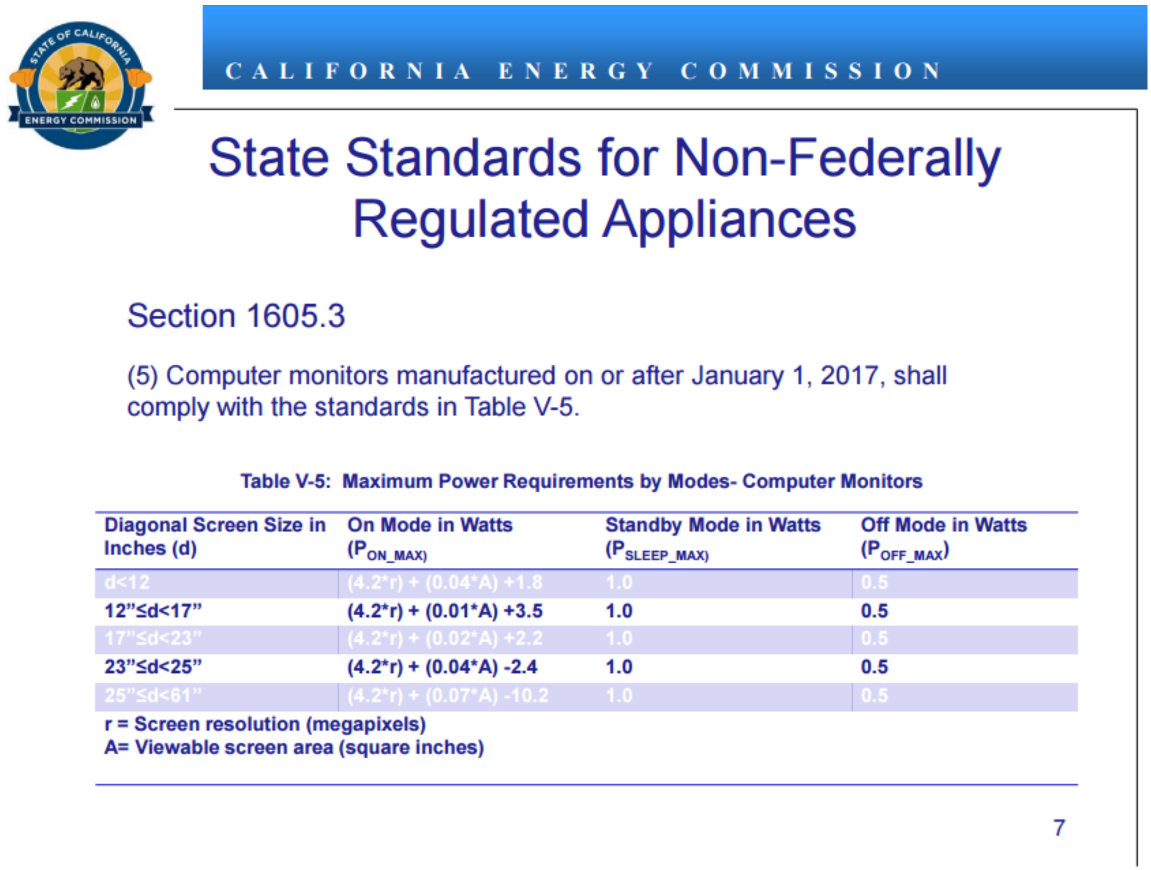
	Screen Size Bin			
	21.x-22.x	**23.x-24.x**	**25.x-27.x**	**28.x-30.x**
Minimum	9	14	13	27
First Quartile	18	20	23	39
Median	20	23	26	59
Third Quartile	22	28	30	59
Maximum	41	37	52	112
Mean	20.8	24.0	27.4	56.1
Count	621	897	215	20

2.2 On Mode Proposal

2.2.1 Cost Effective

Based on extensive testing conducted by the CASE Team and presented in both the docketed CASE and Supplemental Technical Reports (Docket #12-AAER-2A), the On Mode proposal outlined by CEC staff during the April 15th workshop shown in Figure 2.4 is cost effective using widely available technology options.

[1] Black lines in the middle of the boxes indicate the median value. The median value for the 28.x-30.x size bin is the same as the third quartile, so it overlaps with the top border and does not appear on the plot.



CALIFORNIA ENERGY COMMISSION

State Standards for Non-Federally Regulated Appliances

Section 1605.3

(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)

7

Figure 2.4 CEC Proposal on Computer Monitor Maximum Power Requirements by Mode
Source: CEC Staff Presentation (CEC 2015)

Through the testing and teardown analysis of a series of representative computer monitors across a range of screen sizes, the CASE Team was able to demonstrate multiple paths to cost effectively reduce energy use to meet the proposed On Mode levels. The multiple paths include some combination of more efficient film stacks, improved lamp efficacy, reducing default screen brightness, improved power supply efficiency, more common implementation of automatic brightness control, and dimming screen brightness to video content. Section 7.4 of the CASE Report outlines the technical feasibility to meet the proposed On Mode requirements. Table 2.3 below from the CASE Report summarizes the cost effective strategies to meet the On Mode requirements. More detailed information on the efficiency improvements to meet the proposed levels was included in Section 5 of the Technical Report.

Further efficiency opportunities from emerging technology scenarios, such as the use of quantum dots, organic LEDs, and other strategies that are being implemented in televisions and displays now, remain. However, the CASE Team did not include these options as pathways to meet the On Mode requirements given some uncertainty with the costs at the time. These strategies have the potential to be combined for even **greater** improvements to a display's overall efficiency. The conclusion of the initial cost-efficiency analysis is that there are opportunities to improve the overall efficiency of displays at relatively low incremental cost using off-the-shelf technologies.

Table 2.3 Description of Cost Effective Strategies to Meet On Mode Requirements – Computer Monitors

Source: Table 7.5 of CASE Report

Diagonal Screen Size	Representative Display (Measured)	Cost Effective Strategy 1	Cost Effective Strategy 2	Cost Effective Strategy 3	Cost Effective Strategy 4
19"	On Mode: 20.01W PSU: 80% Reflective Polarizer: None Lamp Efficacy (CCFL): 47lm/W Screen Brightness: 255 nits Global Dimming: None ABC: None	On Mode: 5.9W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 110lm/W Screen Brightness: 200 nits Global Dimming: Yes ABC: Yes	On Mode: 9.44W PSU: 88% Reflective Polarizer: None Lamp Efficacy (LED): 110lm/W Screen Brightness: 255 nits Global Dimming: Yes ABC: None	On Mode: 9.16W PSU: 88% Reflective Polarizer: None Lamp Efficacy (LED): 110lm/W Screen Brightness: 200 nits Global Dimming: None ABC: None	On Mode: 8.55W PSU: 83% Reflective Polarizer: Yes Lamp Efficacy (LED): 125lm/W Screen Brightness: 255 nits Global Dimming: None ABC: None
22"	On Mode: 29.42W PSU: 87% Reflective Polarizer: None Lamp Efficacy (LED): 105lm/W Screen Brightness: 275 nits Global Dimming: Not enabled by default ABC: None	On Mode: 13.78W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 110lm/W Screen Brightness: 200 nits Global Dimming: Enabled by default ABC: Yes	On Mode: 14.34W PSU: 87% Reflective Polarizer: None Lamp Efficacy (LED): 110lm/W Screen Brightness: 241 nits Global Dimming: Enabled by default ABC: None	On Mode: 13.33W PSU: 87% Reflective Polarizer: Yes Lamp Efficacy (LED): 105lm/W Screen Brightness: 241 nits Global Dimming: Enabled by default ABC: None	On Mode: 14.73W PSU: 87% Reflective Polarizer: None Lamp Efficacy (LED): 125lm/W Screen Brightness: 241 nits Global Dimming: Not enabled by default ABC: None
27"	On Mode: 38.38W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 87lm/W Screen Brightness: 400 nits Global Dimming: None ABC: None	On Mode: 17.25W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 110lm/W Screen Brightness: 170 nits* Global Dimming: Yes ABC: None Improved TFT (low)	On Mode: 20.04W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 107lm/W Screen Brightness: 170 nits Global Dimming: None ABC: Yes	On Mode: 19.36W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 110lm/W Screen Brightness: 170 nits Global Dimming: Yes ABC: None	On Mode: 19.62W PSU: 88% Reflective Polarizer: Yes Lamp Efficacy (LED): 107lm/W Screen Brightness: 170 nits Global Dimming: Yes ABC: None

2.2.2 Model Availability

A range of currently available models from various manufacturers already meet the proposed On Mode limits across all the major screen sizes between a diagonal screen size of 10 to 32 inches. Figure 2.5 shows computer monitor models 2 megapixels (MP) and lower available today that would meet the CEC On Mode proposal with no other modifications.[2]

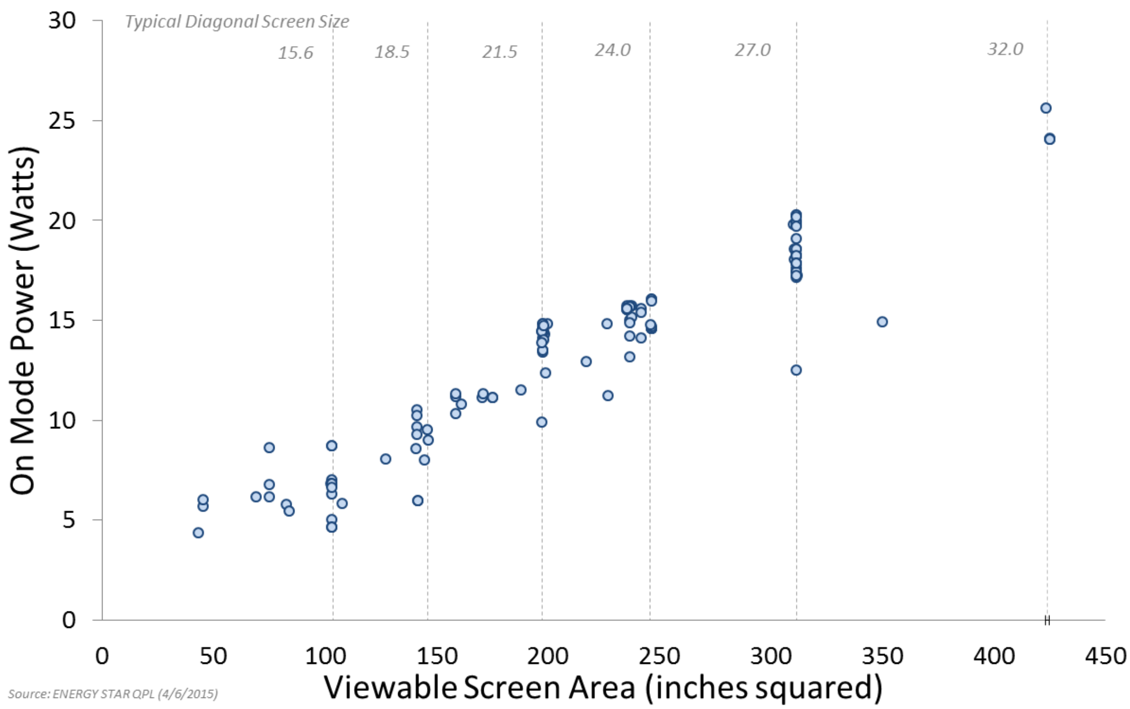


Figure 2.5 Computer Monitors 2.07 MP and Lower That Meet On Mode Requirements
Source: ENERGY STAR Qualified Products List (April 6, 2015)

[2] Since the On Mode power limits are dependent on two variables, they are specific to each model and are not shown in this figure.

2.2.3 Highly Featured Models

A wide range of currently available models meet the CEC proposed On Mode levels even across larger resolutions beyond 2 MP.

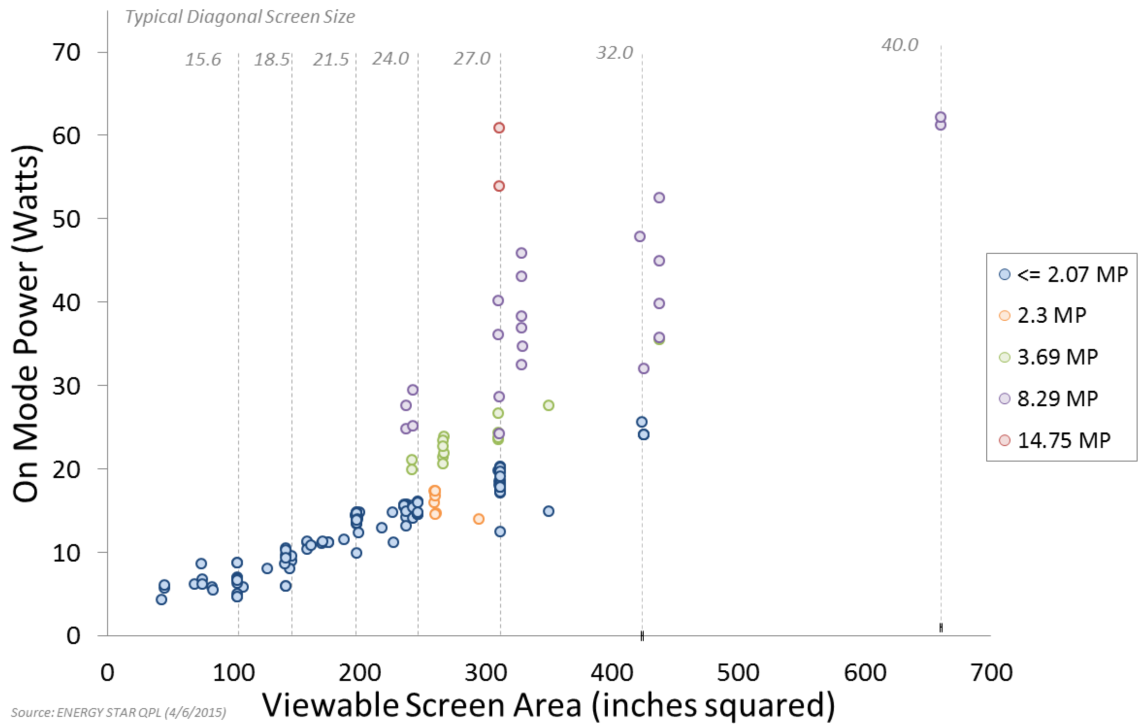


Figure 2.6 shows all the models at multiple resolutions available today from multiple manufacturers that would meet the CEC proposal. In addition to the standard 2 MP models, some of the newest, highly featured 4K and 5K models (noted as 8.29 MP and 14.75 MP) are able to meet the CEC On Mode proposal. These models, some of the newest on the market today, would not have to make any modifications to meet the proposed requirements.

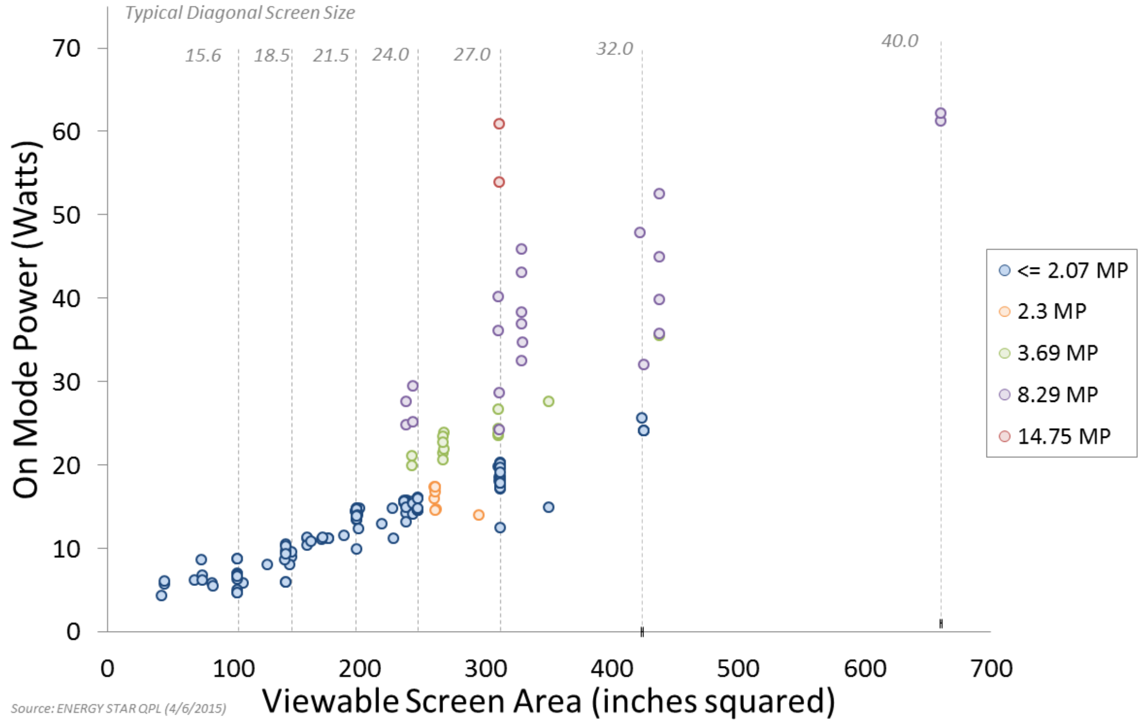


Figure 2.6 Computer Monitors 2.07 MP and Greater That Meet On Mode Requirements
Source: ENERGY STAR Qualified Products List (April 6, 2015)

For LCD, higher resolution to increase power draw is expected. 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. However, based on the CASE Team's analysis, resolution does not necessarily scale with linearly with size. This was the rationale for including a power adder based on resolution into any On Mode requirements. While we continue to support a resolution adder given the availability of very large resolution Mode ls, we are continuing to investigate the appropriateness of the

currently proposed adder. In one case shown in

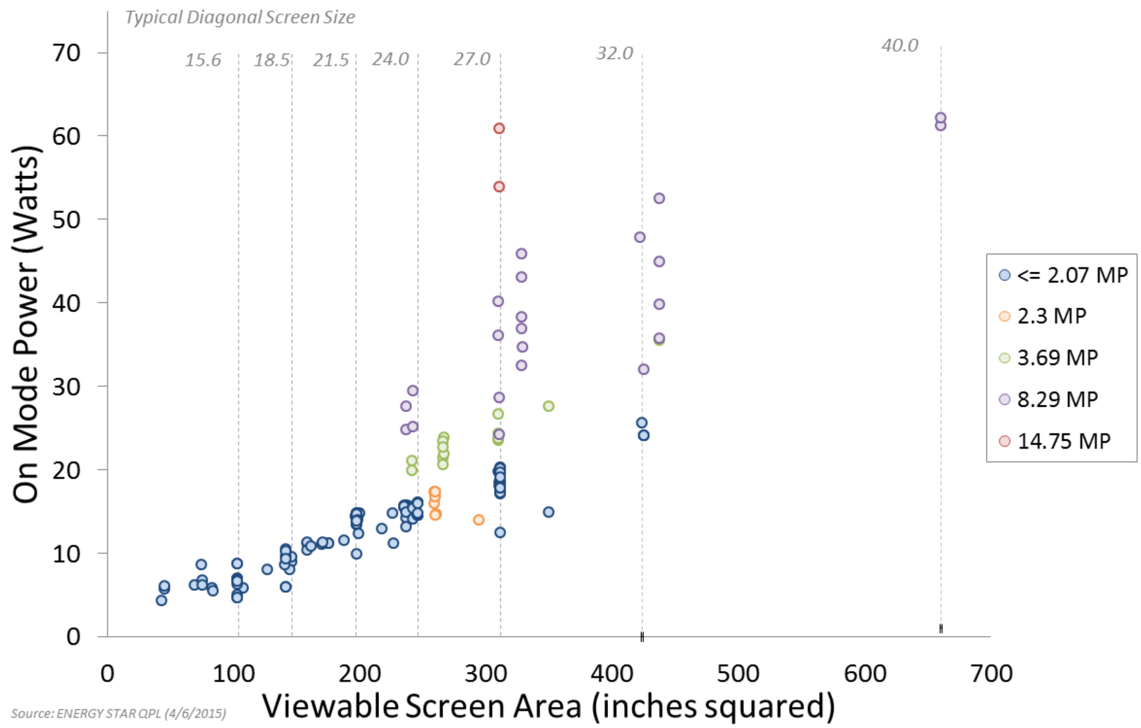
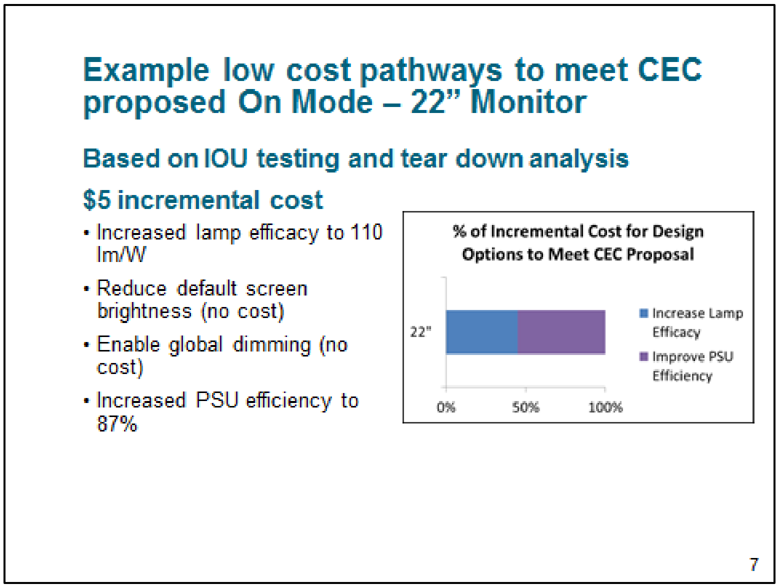


Figure 2.6, a 27-inch model can consume almost five times as much power as the most efficient 27-inch model and still meet the On Mode requirements. While that may be justified given the larger resolution, further analysis will be conducted to ensure On Mode requirements account for future trends to the extent possible.

2.2.4 Incremental Cost

Section 5 of Technical Report outlines the CASE Team's analysis of the incremental cost for meeting the On Mode requirements. At the time of the testing and analysis, cold cathode fluorescent lamps (CCFLs) were still being used in some backlight units and a CCFL backlit model was assumed to be representative for 19-inch models. Currently, there are no projected shipments of CCFL backlit models; therefore, results for the 19-inch models (Section 5.1 of the Technical Report) should be excluded from consideration. Sections 5.2 to 5.7 of the Technical Report outline incremental costs associated with meeting the On Mode requirements.

The CASE Team obtained cost information from discussions with industry experts and DisplaySearch, a research company that analyzes the electronic display market and interviews manufacturers to develop quarterly cost estimates of typical display models by technology and size. Using results from the teardown analysis, we tailored these costs to each test unit to develop a specific bill of materials cost. We then applied a retail markup factor to determine retail costs. In some cases these incremental costs for some efficiency improvements can be $5 or less, as shown in Figures 5.2 and 5.3 of the Technical Report. Some of these low cost pathways were also described by the CASE Team during the April 15th workshop and displayed below in Figure 2.7.



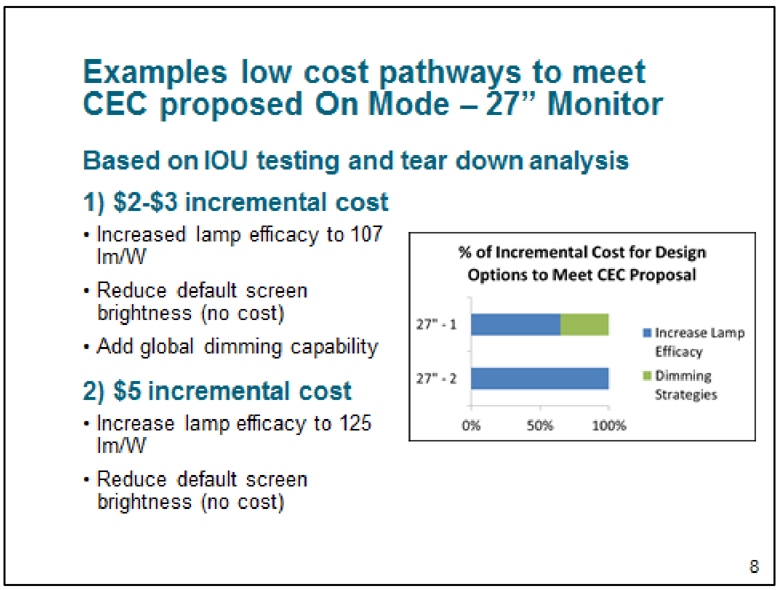


Figure 2.7 Incremental Cost Examples to Meet On Mode Requirements: 22- and 27-inch Models

Source: CASE Team Presentation

From additional analysis conducted subsequently, in a review of retail price data of models that would qualify versus comparable models that would not qualify, the CASE Team found little to no differences in cost to the consumer of models of similar size and features. In some cases the qualifying model is actually less expensive than a similarly sized and featured model that would not qualify to the proposed On Mode requirement. In another case, the model that would be able to meet the CEC proposal is a few dollars more expensive than the model that would not meet the CEC On Mode proposal. However, when factoring the cost of energy consumption over a product's lifetime, the model that would be able to meet CEC's proposal is less expensive for consumers over the lifetime of the product.

The CASE Team is continuing to track price information for models that would and would not meet the CEC proposed requirements. Further analysis will be conducted and provided to the CEC at a later date.

2.3 Sleep and Off Modes

Of the 1,235 models reviewed in the ENERGY STAR Qualified Products List downloaded on April 6, 2015, only six models had a reported Sleep Mode value of over one watt, the CEC proposed Sleep Mode requirement as shown in Figure 2.8. In the ENERGY STAR Version 7 Draft 1, a Sleep Mode requirement of 0.5 watts was proposed with additional adders for network connectivity and other features. The CASE Team will be evaluating a similar 0.5 watt level given virtually all models in the current dataset meet the current one watt Sleep Mode proposal.

Regarding adders, the CASE Team conducted laboratory testing on ten computer monitors, however, none of the units tested had occupancy sensors or network internet connectivity, the two features recognized by ENERGY STAR as needing a power allowance. We recommend collecting more data on Sleep Mode power draw for monitors with these features.

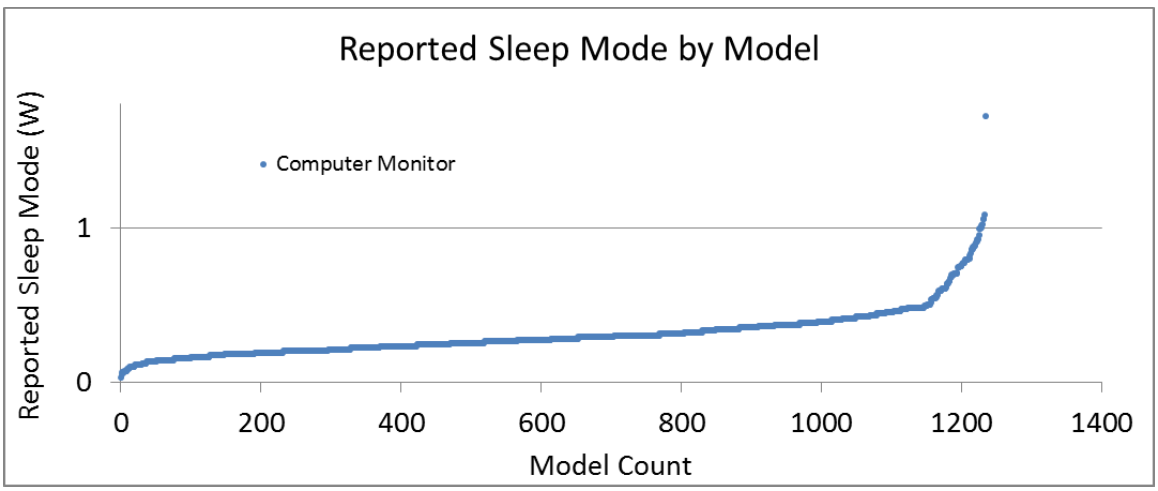


Figure 2.8 Reported Sleep Mode Wattage by Model Count
Source: ENERGY STAR Qualified Products List (April 6, 2015)

Similar to Sleep Mode, of the 1,224 models with a reported Off Mode value in the ENERGY STAR QPL, all models draw 0.5 Watts or less in Off Mode and would meet the CEC proposed requirements. The CASE Team is investigating Off Mode requirements that are cost effective and feasible and result in energy savings.

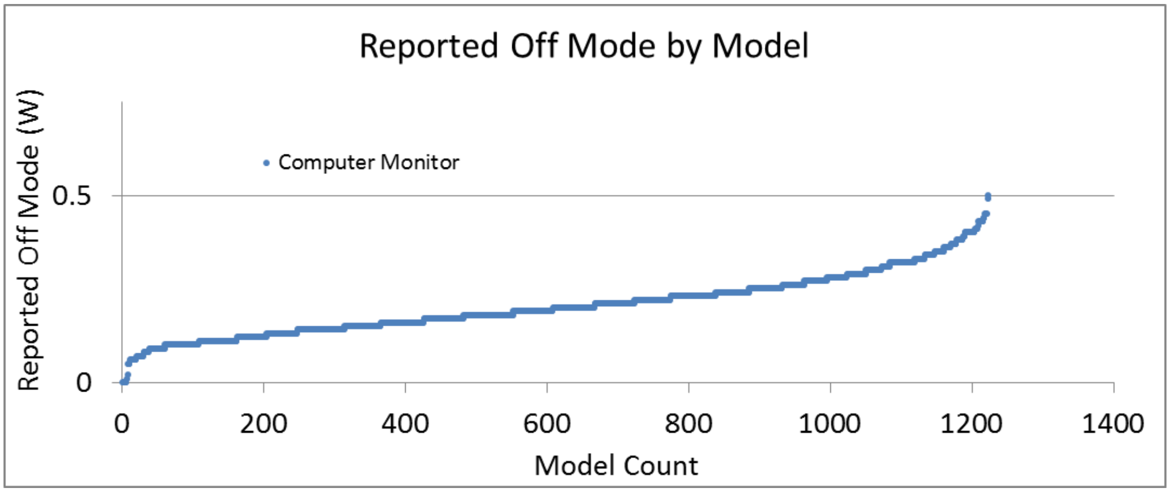


Figure 2.9 Reported Off Mode Wattage by Model Count

Source: ENERGY STAR Qualified Products List (April 6, 2015)

2.4 Test Procedure

We recommend On Mode testing for monitors without adjusting luminance or other settings from their default settings. Since most users likely do not adjust brightness settings from "out of the box" settings, this method is likely to be more representative of real world power usage than by calibrating the screen brightness to a certain level. By testing default settings, the state of California will be able to more accurately measure monitor energy usage that is more reflective of real-world conditions.

In order to prevent manufacturers setting the default picture setting to an unacceptably low level in order to achieve a lower On Mode power measurement, the CASE Team suggests that the ratio of the default picture setting to the brightest picture setting be greater than or equal to 65 percent. This is a similar approach as outlined in the ENERGY STAR Television Specification, which also requires On Mode testing to be conducted in the default setting. The CASE Team will continue to investigate alternative requirements to close any potential loopholes to the test procedure.

The CASE Team will be reviewing the updated ENERGY STAR test procedure once it becomes final later this year to identify any other modifications to the proposed test procedure for this rulemaking.

2.5 Power Management

The CASE Team recommends the following power management requirement to align with the ENERGY STAR Version 7 Draft 2 specification:

- Computer monitors shall automatically enter Sleep Mode or Off Mode within 5 minutes of being disconnected from a host computer.

In addition to time-based power management, we encourage CEC to examine the opportunity for power management requirements based on the presence of the user in proximity of the monitor. Proximity-based power management could require occupancy sensors on monitors, so that when no one is in the room, the display is off ready to respond and turn back on within a millisecond once someone activates the proximity sensor.

2.6 Enhanced Performance Displays

The CASE Team believes enhanced performance displays have characteristics that are likely to become more common in mainstream computer monitors in the near future such as high resolution and accurate color reproduction and therefore recommends the CEC include them in the scope of this rulemaking. In our testing and analysis of enhanced performance displays the CASE Team found that they require more power than standard computer monitors, but that there are similar opportunities for improvement – improved LED efficacy, addition of global dimming, reduction of default luminance. The CASE Team is continuing to study enhanced performance displays in order to determine whether a power allowance is necessary for these products' enhanced capabilities.

3 Signage Displays

3.1 Definition

Based on guidance provided by the CEC to the Consumer Electronics Association (CEA) in a letter dated March 29, 2010, products that would today be considered signage displays, such as monitors installed in public places, are referred to in Title 20 as television monitors and are subject to the standards for televisions. Since television monitors can no longer be referenced as a "television,"[3] we proposed to update the definition of "television monitor" to instead refer to them as "signage displays." This is a clear way for the CEC to distinguish signage displays from the television standard and update the current energy efficiency regulation to realize significant, cost-effective energy savings for signage displays given the technology advancements since the last standards for televisions were adopted in 2009.

3.2 Per Unit Power Draw

Despite their close similarities, the energy use of a signage display is significantly higher as compared to a television. Unlike televisions, signage displays are typically larger – and therefore draw more power – for installations in open, commercial spaces. Signage displays are typically also set at higher brightness settings to draw attention and to differentiate their images from bright surroundings. Figure 3.1 shows the On Mode power draw comparisons between signage displays and televisions. At a given size, signage displays can draw four times or greater more power than similar-sized televisions in On Mode.

[3] Based on our understanding of a Federal Communication Commission (FCC) ruling in 2007, TVs without tuners, what would fall under the current Title 20 definition of a "television monitor" are not able to be sold or marketed as a television in the U.S.

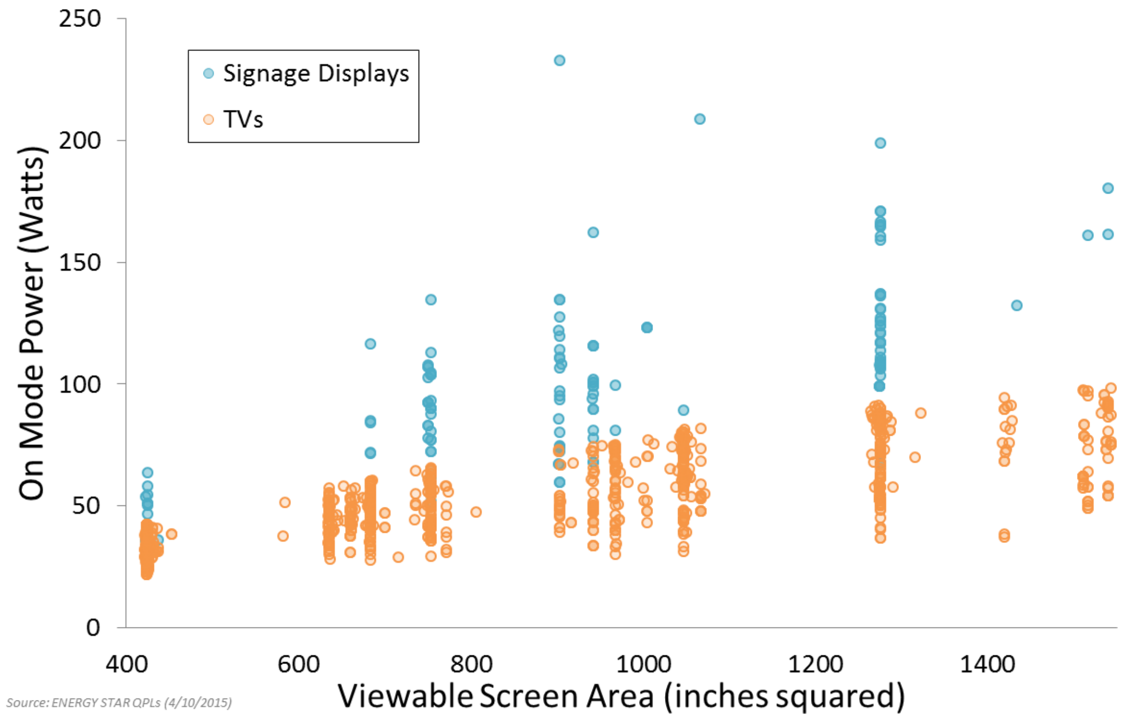


Figure 3.1 On Mode Power Draw Differences: Televisions and Signage Displays
Source: ENERGY STAR Qualified Product Lists 2015

Many signage displays promote themselves as being able to withstand "heavy" usage for commercial applications capable of a duty cycle of 24/7 operation. While some signage displays may run 24 hours a day in applications such as hospitals, hospitality, and transportation, other commercial applications may not require around the clock operation (e.g., retail, restaurants, and education settings). For signage displays, we estimated a general average of 18 hours per day in On Mode and the remainder of the day (i.e., 6 hours) in Sleep Mode. We estimate that a majority of signage displays are used 365 days of the year.

Not only is there greater power draw for signage displays, but given that signage displays are typically operating 18 to 24 hours a day (compared to televisions which are typically on 5 hours a day), **the energy consumed by a signage display can be <u>nine times or more</u> than a similar sized television**. Table 3.1 shows the duty cycle differences, conservatively assuming a signage display is operating 18 hours a day for 365 days a year and a television is operating 5 hours a day for 365 days a year.

Table 3.1 Annual Duty Cycle Differences: Televisions and Signage Displays
Source: CASE Team analysis

	On (hrs/yr)	Sleep (hrs/yr)
Televisions	1,825	6,935
Signage Displays	6,570	2,190

3.3 Growing Sales

Figure 3.2 shows 2012-2018 California shipment trends for signage displays by size bin based on a market report published by IHS iSuppli in 2014 entitled Signage and Professional Displays Market Tracker (IHS iSuppli 2014). This information includes historical and projected shipments of signage displays to North America. U.S. shipments were estimated by assuming 90 percent of North American shipments were to the U.S. Finally, shipments to California were calculated by multiplying the U.S. shipments by 13 percent, the percentage of California's share of the total U.S. gross domestic product (GDP). Overall, there is projected to be an average annual increase in shipments of 10% from 2012 to 2018.

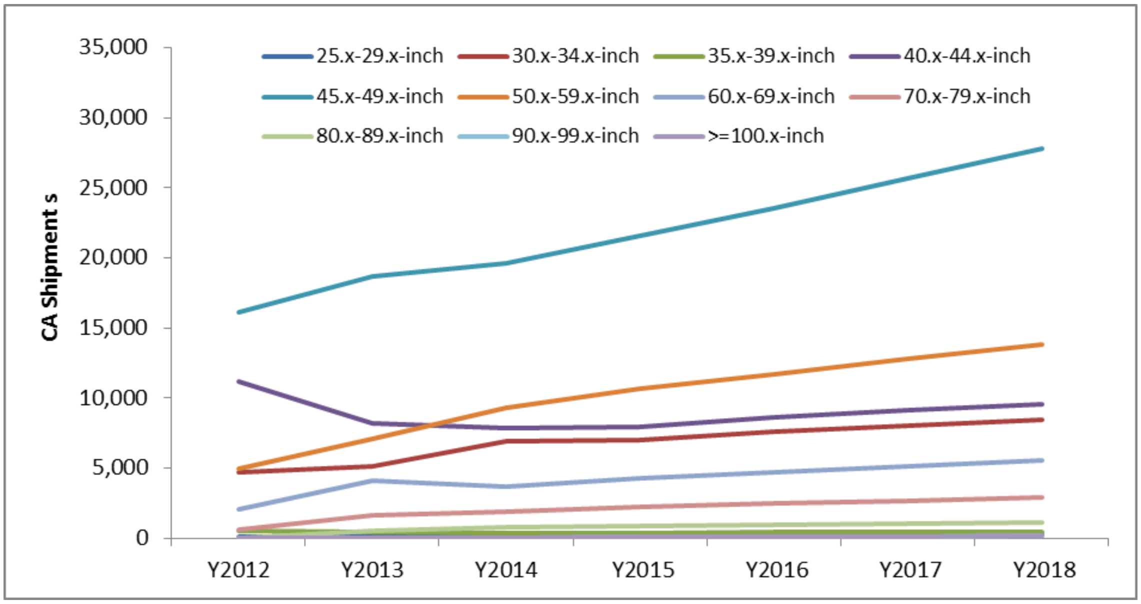


Figure 3.2 Annual Signage Display California Shipments by Screen Size

Source: IHS iSuppli 2014

Typically, signage displays have a diagonal screen size 30-inches and greater. Figure 3.3 shows the market share of each size bin in 2017.

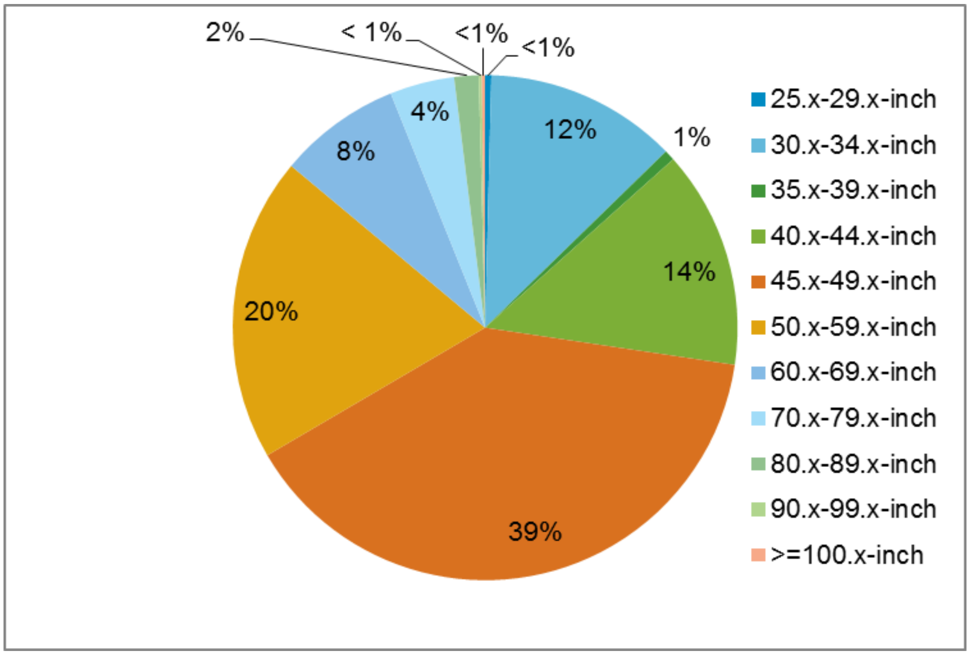


Figure 3.3 Signage Display California 2017 Shipments by Screen Size
Source: IHS iSuppli 2014

With a better understanding of signage displays' significant power draw, heavy duty cycle, and increasing installations in California, the CASE Team recommends **more stringent** On Mode power limits than was initially proposed in the 2013 CASE Report and currently proposed in the CEC staff report. The On Mode requirements should apply across all screen sizes, including currently unregulated models greater than 1400 in-sq.

3.4 Energy Use per Unit for Non-qualifying Signage Display

Based on performance of models in the signage dataset from ENERGY STAR collected since 2013, the below table shows by mode the energy use of signage displays that are considered the non-qualifying products that do not meet the CASE Team proposed standard described in Section 3.11. Unit annual energy consumption was calculated based on determining the average power draw in each mode and multiplying by the assumed annual duty cycle for these products. Finally, shipment-weighted averages were calculated for each size bin based on 2017 shipments to California.

Table 3.2 Average Energy Use for Non-qualifying Products – Signage Displays
Source: CASE Team analysis

On Mode Power Draw (W)	Sleep Mode Power Draw (W)	Unit Energy Consumption (kWh/yr)
169	0.79	1110

3.5 Energy Use per Unit for Qualifying Signage Display

Qualifying products are products that meet the proposed standard described in Section 3.11 and are in Table 3.3. For qualifying products, unit annual energy consumption was calculated based on determining the average power consumption in each mode and multiplying by the assumed annual duty cycle. Finally, shipment-weighted averages were calculated for each size bin based on 2017 shipments to California.

Table 3.3 Average Energy Use for Qualifying Products – Signage Displays

Source: CASE Team analysis

On Mode Power Draw (W)	Sleep Mode Power Draw (W)	Unit Energy Consumption (kWh/yr)
81	0.40	531

It is important to note that both of these energy use estimates for non-qualifying and qualifying products should be considered conservative for a number of reasons:

- There are only a few models in the ENERGY STAR dataset with a diagonal screen size of 60-inches in the dataset and no models with a diagonal screen size greater than 60-inches. Thus, estimates for the energy use for 60-inch models and greater were based on 60-inch models. Models larger than 60-inches will likely consume significantly more power, especially since no standards currently apply to these models.

- Because of the limited available data of 60-inch models, there were no 60-inch models that met the proposed levels. The power draw was conservatively assumed to be minimally compliant to the CASE Team proposed standard. We assume that there are 60-inch models available that draw less power than the CASE Team's proposed standard.

- The dataset conservatively utilizes reported On Mode power. For signage displays (and monitors), the ENERGY STAR test procedure has manufacturers report On Mode at a set luminance (200 candelas per square-meter) regardless of how the units are shipped. Based on our testing, units are typically shipped at a higher brightness. Therefore, we assume the actual installed On Mode power is much higher than the reported, calibrated value.

The CASE Team will continue to collect additional product data on signage displays to ensure the dataset is robust and reasonably reflective of the marketplace.

3.6 Statewide California Energy Savings

These energy use values include signage displays with the following screen areas: < 1400 in-sq (currently regulated) and ≥ 1400 in-sq (currently unregulated). The currently unregulated sizes of signage displays comprise a significant share of the market: 14 % based on shipments and 30% based on total energy consumption.

As our shipment estimates only went through 2018, we assumed a similar rate of increase in shipments through 2024, the year of stock turnover. "Non-Standards Case" noted in this section refers to the situation where the current On Mode standards for models with a screen area of less than 1400 in-sq are not modified. “Standards Case” noted in this section refers to the situation where the current On Mode standards for models less than 1400 in-sq are modified based on the CASE Team recommendations and models with a screen area greater than and equal to 1400 in-sq are included, per the CASE Team proposals outlined in Section 3.11.

Table 3.4: California Statewide Non-Standards Case Energy Use & Peak Demand
Source: CASE Team analysis

Year	Sales Energy Use (GWh/yr)	Sales Peak Demand (MW)	Stock Energy Use (GWh/yr)	Stock Peak Demand (MW)
2015	55.5	13	421.5	96
2016	59.6	14	425.7	97
2017 (standard effective)	63.6	15	433.8	99
2018	67.2	15	445.5	102
2019	70.9	16	460.9	105
2020	74.9	17	480.4	110
2021	79.2	18	504.1	115
2022	83.7	19	554.6	127
2023	88.6	20	587.7	134
2024 (stock turnover)	93.9	21	622.0	142

Table 3.5 California Statewide with Standards Case Energy Use & Peak Demand
Source: CASE Team analysis

Year	Sales Energy Use (GWh/yr)	Sales Peak Demand (MW)	Stock Energy Use (GWh/yr)	Stock Peak Demand (MW)
2015	55.5	13	421.5	96
2016	59.6	14	425.7	97
2017 (standard effective)	34.7	8	405.0	92
2018	37.3	9	386.8	88
2019	40.1	9	371.5	85
2020	43.1	10	359.2	82
2021	46.4	11	350.1	80
2022	49.9	11	366.7	84
2023	53.6	12	364.8	83
2024 (stock turnover)	57.6	13	362.8	83

The difference between the peak demand and annual energy consumption in the non-standards and with standards cases is shown in Table 3.6. The currently unregulated sizes of signage displays (models with a screen area greater than and equal to 1400 in-sq) comprise of 21% of the energy savings outlined in this table.

Table 3.6 Estimated California Statewide Energy Savings and Peak Demand Reduction with Standards Case

Source: CASE Team analysis

	Sales		Stock	
Year	Energy Use (GWh/yr)	Peak Demand (MW)	Energy Use (GWh/yr)	Peak Demand (MW)
2015	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0
2017 (standard effective)	28.8	6.6	28.8	6.6
2018	29.8	6.8	58.6	13.4
2019	30.8	7.0	89.4	20.4
2020	31.8	7.3	121.2	27.7
2021	32.8	7.5	154.0	35.2
2022	33.9	7.7	187.9	42.9
2023	35.0	8.0	222.9	50.9
2024 (stock turnover)	36.3	8.3	259.2	59.2

3.7 Incremental Cost Methodology

To develop an initial cost-efficiency relationship for signage displays, the CASE Team studied the performance of two pairs of models selected to represent the range of energy efficiency of displays currently on the market. The details of the CASE Team testing and analysis are presented in Appendix A.

3.8 Design Life

Typically, signage displays tend to be more durable as compared to computer monitors to accommodate the extended usage patterns of signage displays. Assuming the lifetime hours in On Mode of signage displays is 50,000 hours and given the assumed duty cycle, we calculated a design life for signage displays of 7.6 years.

3.9 Lifecycle Cost / Net Benefit

The lifecycle 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 lifecycle costs and benefits of the proposed standards for signage display per unit are shown in Table 3.7. The overall lifecycle cost/benefit ratio and present value of all costs and benefits of the standard is shown in Table 3.7. The total cost of $356 noted in Table 3.7 is the average of all cost effective approaches based on the testing and analysis outlined in detail in Appendix A.

Table 3.7 Lifecycle Costs and Benefits per Unit for Qualifying Products

		Lifecycle Costs per Unit (Present Value $)			**Lifecycle Benefits per Unit (Present Value $)**		
Year	Design Life (years)	Incremental Costs per Unit	Additional Costs	**Total Costs[a]**	Energy Savings per Unit[c]	Additional Benefits	**Total Benefits**
2015	7.6	$356	n/a	**$356**	$702	n/a	**$702**

[a] Cost calculations include 3% annual discounting from 2015 to account for production experience.
[c] Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2012).

Table 3.8: Lifecycle Cost Benefit Ratio for Qualifying Products and Net Present Values with Standards Cased

	Net Present Value[b]		
Lifecycle Benefit / Cost Ratio[a]	Per Unit	First Year Sales ($)	Stock Turnover ($)[c]
2.09	$346	$ 17,244,410	$ 175,015,645

[a] Total present value benefits per unit divided by total present value costs per unit for the period from the effective date of the tier through the earlier of 1) the stock turnover year (i.e., the NPV of "turning over" the whole stock of less efficient products that were in use at the effective date to more efficient products); or 2) the effective date of the next tier.
[b] Positive value indicates a reduced total cost of ownership over the life.
[c] Stock Turnover NPV is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year (see note a above) , plus any additional non-replacement units due to market growth, if applicable. For example, for a standard effective in 2015 applying to a product with a 6 year design life, the NPV of the products purchased in the 6th year (2020) includes lifecycle cost and benefits through 2025, and therefore, so does the Stock Turnover NPV.
[d] For price of electricity, average annual rates were used, starting in the effective year. It should be noted that while the proposed standard is cost-effective, it may be more cost-effective if using alternative rate structures. For example, marginal utility rates may more accurately reflect what customers save on utility bills as result of the standard.

3.10 Feasibility and Justification

Using the methodology outlined in the Technical Memo attached in Appendix A, we combined individual efficiency measures to generate three cost effective measures for each size analyzed. All scenarios meet the CASE Team proposed On Mode power requirements. To determine if a scenario was cost effective, we calculated the lifetime energy savings of the modeled more efficient display over the representative model and compared that to the incremental cost of the efficiency improvements. Further details are included in the Technical Memo attached in Appendix A.

3.11 On Mode Recommendations

The new requirements for all sizes of signage displays proposed in Table 3.9 are an update to the proposal we presented in the CASE Report. During the development of the CASE Report, we stated that without additional testing, the levels we proposed were intended to be a minimum. As explained in the Technical Memo in Appendix A, we propose an On Mode equation for signage displays that accounts for luminance and screen area which aligns with the approach proposed by ENERGY STAR in the development of the Version 7 specification. The asymptotic curve of the On Mode requirement proposed by the CASE Team reflects that in recent years, very large televisions have achieved dramatic power draw reductions while maintaining and enhancing performance. Given the technological similarities with televisions, signage displays can achieve similar reductions in power draw without sacrificing performance or functionality. If this asymptotic curve factoring luminance and screen area is used, a requirement should also be included to prevent potential backsliding of the current regulation that is based on screen area.

Table 3.9 Maximum Power Requirements– Signage Displays <u>All Screen Areas</u>

On Mode (W)
$(4.5 \times 10^{-5} \times l \times A) + 70 \times \tanh(0.001 \times (A - 200)) + 20$

Where

A = Viewable screen area (square inches);

l = Maximum measured luminance in candelas per square meter

Figure 3.4 depicts the current On Mode power standard and newly proposed On Mode requirement proposed by the CASE Team using the average dataset value of maximum luminance times screen area in order to display the line.

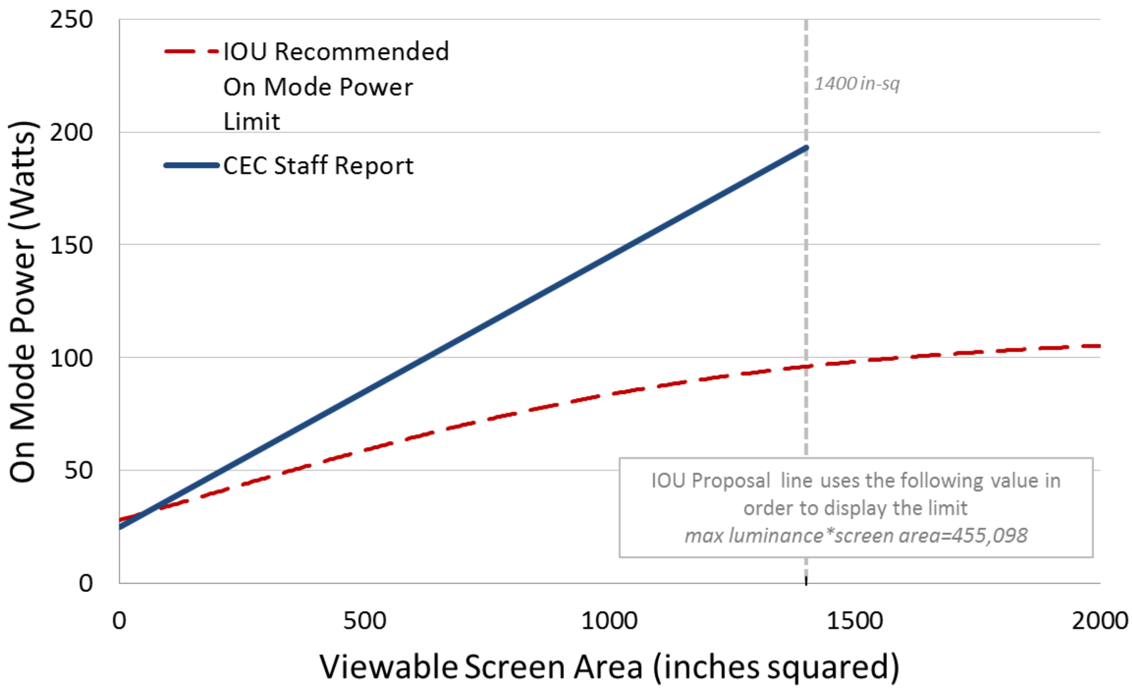


Figure 3.4: On Mode Power Requirements – Signage Displays

4 References

[CA IOUs] California Investor-Owned Utilities. 2014. Response to CEC Invitation to Submit Proposals. Codes and Standards Enhancement (CASE) Initiative: Title 20 Standards Development, Analysis of Standards Proposal for Electronic Displays. CEC Docket #12-AAER-2A. Dated June 29, 2013.

__. 2014. Response to CEC Invitation to Submit Proposals. Codes and Standards Enhancement (CASE) Initiative: Title 20 Standards Development, Supplemental to CASE Report for Electronic Displays. CEC Docket #12-AAER-2A. Dated January 8, 2014.

__. 2015. Response to Standards Proposal. Presentation to the California Energy Commission. CEC Docket #12-AAER-02. Dated April 15, 2015.

[CEC] California Energy Commission. 2015. *Presentation Computer Monitor and Signage Displays.* Staff Workshop: Computer Monitors and Signage Displays. May 16, 2015.

[EPA] United States Environmental Protection Agency. 2015a. ENERGY STAR® Displays Qualified Product List. Dated April 6, 2015.

__. 2015b. ENERGY STAR® Program Requirements for Displays. Draft 2 Version 7.0. Dated April 21, 2015.

__. 2015c. ENERGY STAR Televisions Qualified Product List. Dated April 10, 2015.

[Fraunhofer] Fraunhofer Center for Sustainable Energy Systems. 2014. "Energy Consumption of Consumer Electronics in U.S. Homes in 20130". Dated June 2014.

[IHS iSuppli] IHS iSuppli. 2012. Worldwide Monitor Market Tracker Q3 2012. Market Report. 2012.

__. 2014. Worldwide Signage & Professional Displays Market Tracker. Market Report. 2014.

[Navigant] Navigant Consulting, Inc. 2009. "Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances". Final Report Dated December 21, 2009.

Appendix A Technical Memorandum

1 Background

This memo is intended to supplement the California IOUs' displays CASE report[4] and supplemental technical report[5]. These reports focused primarily on the testing and analysis of computer monitors and presenting cost-effective levels of power draw for On Mode and Sleep Mode. During 2014, the CA IOU technical team had an opportunity to do a similar analysis for signage displays[6] and is using the current comment period as an opportunity to present the findings.

2 Methodology

2.1 Test Unit Selection

The technical team procured four signage displays to test and analyze – one pair of 47" displays and one pair of 65" displays. For each pair, the models were selected to represent the range of energy efficiency of displays currently on the market. To isolate differences in power due to energy efficient designs rather than other features and functionality, the technical team selected a pair of displays that had similar features but drew different amounts of power utilizing the ENERGY STAR® Qualified Product list, the CEC database of qualified TVs and large displays, and online research. The representative models were chosen to represent a display of average energy efficiency; the energy efficient models represented one of the most efficient models available at that time. Consideration was also given to representing a range of major display manufacturers. To represent the market, each display was manufactured by a distinct, major display manufacturer.

2.2 As-Assembled Testing

The technical team performed testing according to the ENERGY STAR Program Requirements for Displays – Test Method (Version 6.0 – Final, Jan-2013) for input power, luminance, illuminance, ambient temperature, relative humidity, power meter specifications and measurement accuracy. To warm up and stabilize each display before testing, the IEC 62087 dynamic broadcast-content video signal was used, which has an average picture level (APL) of 34% for a minimum of one hour. Test signals were generated by a computer then input to the displays using an interface cable such as HDMI, DVI or VGA.

Instantaneous luminance measurements were collected using the IEC 62087 3-bar static test signal in controlled darkroom conditions with the display in its as-shipped condition, with all user

[4] http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Response_to_the_Invitation_for_Standards_Proposals_for_Electronic_Displays_2013-07-29_TN-71760.pdf

[5] 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

[6] From the CA IOU displays CASE report: 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/in^2. 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.

configurable options set to factory settings for default mode. Optional modes were tested in their default settings. Note that instantaneous power associated with each luminance measurement was logged, but integrated power (described below) was used in the following analysis.

The technical team performed On Mode power testing according to the ENERGY STAR test method using guidance from IEC 62087, with the display in its as-shipped condition with all user-configurable options set to factory settings for default mode. Since ENERGY STAR requires signage displays without ABC enabled by default is measured with luminance set at a value greater than or equal to 65% of the manufacturer reported maximum luminance, each display was also tested in its default luminance settings to get a more accurate measurement of real world power draw. Additionally, optional picture modes in default settings and other picture features enabled were tested. Line power was measured every second during the 10-minute IEC 62087 dynamic broadcast-content video signal (IEC test clip) and averaged.

Sleep Mode testing was performed at factory default settings using guidance from IEC 62301: Household Electrical Appliances – Measurement of Standby Power.

2.3 Teardown Analysis

The purpose of the teardown analysis was to investigate power and optical systems to determine which components and designs produce more efficient displays. The technical team targeted the investigation to include light processing components and lamps used in backlight units (BLUs). Although the computer monitor teardown analysis described in the CASE report included power measurement of additional components, we determined that it would be more time and cost effective to focus on the most significant drivers of power draw.

The following information was collected:

- As-assembled and circuitry photographs: Documented the display and its components.
- BLU power draw: Used invasive techniques including modifying circuit boards, for in-circuit power measurements. A multi-channel power meter was spliced into the power distribution circuits of the display under test. Power measurements were made using the 10 minute IEC video test clip and the 10-minute IEC internet test clip.
- Film characterization: Identified film types and the number of films in the stack.
- Optical film stack and LCD panel transmittance: Transmittance as the amount of light normal to the display that passes through each layer was measured. Each film sheet and the LCD panel have a gain or loss. Loss through the entire optical system is assessed by comparing the transmittance of light out of the LCD panel (normal to the display) to the power into the BLU.
- Micrographs of optical films and LCD panel: Identified film and panel types using a 300X digital microscope to view internal structures.
- Lamp count: Recorded number and size of the LEDs in the display.
- Lamp efficacy: Each display's LED strip was removed to test lamp efficacy in an integrating sphere. Lamp efficacy is a measure of the efficiency with which a lamp converts electrical energy into light energy, expressed in lumens per watt (lm/W). All lamp efficacies were determined using a Sphere Optics Model SLM-20 integrating sphere. The lamps were prepared for testing by attaching leads so that four of the lamps could be powered in isolation. Prior to removal, the technical team determined the voltage per lamp that the

display under test used to drive its BLU. The number of lamps energized was limited to prevent overheating with the lamp strip removed from its heat sink. The prepared LED assembly was placed in the integrating sphere with the lamps centered in the chamber. Lamp efficacy data were obtained while driving at the previously determined voltage per lamp and measuring the power input to the lamps being lit. Additional tests at lower driving voltages were also made to estimate what voltage produced the highest efficacy.

2.4 Cost Efficiency Analysis

To focus our efforts on the key components and approaches that most affect display energy use, the technical team utilized lessons learned from testing and analysis completed in the CASE report. We developed incremental costs for cost effective paths to efficiency improvement based largely on BLU power draw measurements and the efficiency with which the LCD panel and BLU manage light. This approach was also directed by the fact that DisplaySearch, whose data we used to develop full bill of material costs for computer monitors in the CASE report, does not have cost estimates for signage displays. We were able to use cost estimates for televisions from DisplaySearch for certain components including LEDs, optical films and backlight configurations since these are expected to be the same. For other efficiency measures, such as implementation of light management approaches, we used industry expert estimates.

The technical team used results from the teardown analysis to identify current technologies that may be used to improve energy efficiency, as well as market research to identify emerging technologies that may be available for future energy efficiency improvements.

3 Test results and Analysis

3.1 As-Assembled Testing

3.1.1 47" Pair

Power and screen luminance test results for the two 47" test units are shown in Table 3.1. The representative model (SD47-1) had a default luminance of 267 cd/m^2 and corresponding power of 75.6 W. The efficient model (SD47-2) had a default luminance of 528 cd/m^2 and power of 101.3 W. The ENERGY STAR test method requires that average power be measured at a luminance greater than or equal to 65% of the reported maximum luminance. We therefore also measured power with the luminance set to as close to 65% of the reported maximum as we could get without going below. In this state, the representative and efficient displays drew less power than in their as-shipped conditions (both about 9% less).

The efficient display had user-selectable features that resulted in significantly lower power draw when enabled. With its "Energy Saving" mode selected, the efficient model drew 18% to 51% less power depending on the exact preset than in its default or as-shipped state. In its "Eco" display mode, the representative model drew the same power as in its as-shipped state.

In Sleep Mode, the representative and efficient displays drew very different amounts of power - 9.1 W and 0.3 W, respectively.

Table 3.1 Power and Screen Luminance Testing Results: 47-inch Models

Source: CASE Team analysis

Display ID	Input Port	Test Description	Display Mode	Screen Luminance (cd/m2)	Power (W)
SD47-1 Representative	HDMI	Default	Default	267.4	75.6
		Max contrast and brightness	Default	349.1	80.9
		ENERGY STAR 65% of max luminance	Default	227.5	68.7
		Eco Normal	Default - Eco mode selected	257.1	75.5
		Sleep (Sleep Source)	Default	-	9.1
		Sleep (Disconnect Source)	Default	-	9.1
		Off	Default	-	9.2
SD47-2 Efficient	HDMI	Default	Standard	528.5	101.3
		Max contrast and brightness	Standard	698.5	127.1
		ENERGY STAR 65% of max luminance	Standard	454.6	92.3
		Energy Saving min	Standard	382.0	83.2
		Energy Saving medium	Standard	272.3	67.1
		Energy saving max	Standard	140.0	49.3
		Default	Vivid	348.7	75.5
		Default	Cinema	180.3	56.5
		Default	Sport	340.8	75.4
		Default	Game	254.8	64.3
		Sleep (Sleep Source)	Standard	-	0.3
		Sleep (Disconnect Source)	Standard	-	0.3
		Off	Standard	-	0.3

3.1.2 65” Pair

Power and screen luminance test results for the two 65” test units are shown in Table 3.2. The representative model (SD65-1) had a default luminance of 317 cd/m^2 and corresponding power of 192.1 W. The efficient model (SD65-2) had a default luminance of 273 cd/m^2 and power of 113.7 W. As with the 47” pair, we also measured power with luminance set at 65% of the reported maximum luminance. In this state, the representative and efficient displays drew less power than in their as-shipped conditions (28% and 12% respectively).

Both displays had user-selectable features that resulted in significantly lower power draw when enabled. With its “Energy Saving” mode selected, the representative model drew 7% less power than in its default or as-shipped state. In both its “Eco” and cinema display modes, the efficient model drew significantly less power than in its as-shipped state (40% and 47% respectively). It should be noted that the cinema mode is likely intended for low light conditions as the luminance measurement was a very low 83 cd/m^2.

In Sleep Mode, the representative model used essentially full power when the source computer was put in Sleep Mode, presumably not turning off its backlight. It did, however, reduce its power draw to 0.2 W when the source disconnected or the display was turned off. The efficient display drew between 5 and 6 watts in Sleep Mode and reduced to 0.3 in off mode.

Table 3.2 Power and Screen Luminance Testing Results: 65-inch Models

Source: CASE Team analysis

Display ID	Input Port	Test Description	Display Mode	Screen Luminance (cd/m2)	Power (W)
SD65-1 Representative	HDMI	Default	Standard	317.6	192.1
		Max contrast and brightness	Standard	375.5	224.6
		ENERGY STAR 65% of max luminance	Standard	227.7	139.0
		Default	Dynamic	313.7	216.6
		Default	Energy Savings	229.5	178.0
		Default	Theatre	150.7	179.8
		Default	Game	301.0	180.0
		Default	Custom	231.3	178.2
		Sleep (Sleep Source)	Standard	-	180.8
		Sleep (Disconnect Source)	Standard	-	0.2
		Off	Standard	-	0.2
SD65-2 Efficient	HDMI	Default	Dynamic	273.2	113.7
		Max contrast and brightness	Dynamic	335.2	115.8
		ENERGY STAR 65% of max luminance	Dynamic	226.7	99.5
		Eco Custom Power save on	Dynamic	137.1	67.9
		Eco Custom Power save Sensor	Dynamic	291.2	114.0
		Default	Standard	178.3	78.2
		Default	Cinema	83.4	60.4
		Sleep (Sleep Source)	Dynamic	-	5.7
		Sleep (Disconnect Source)	Dynamic	-	5.6
		Off	Dynamic	-	0.3

As with the computer monitors tested for the CASE report, average power consumption increased approximately linearly with screen luminance (Figure 3.1). This suggests that the majority of power draw variability is related to producing light and generating an image on the screen. Signal processing and other functions draw relatively constant power, as compared to screen brightness, when the display is showing a picture.

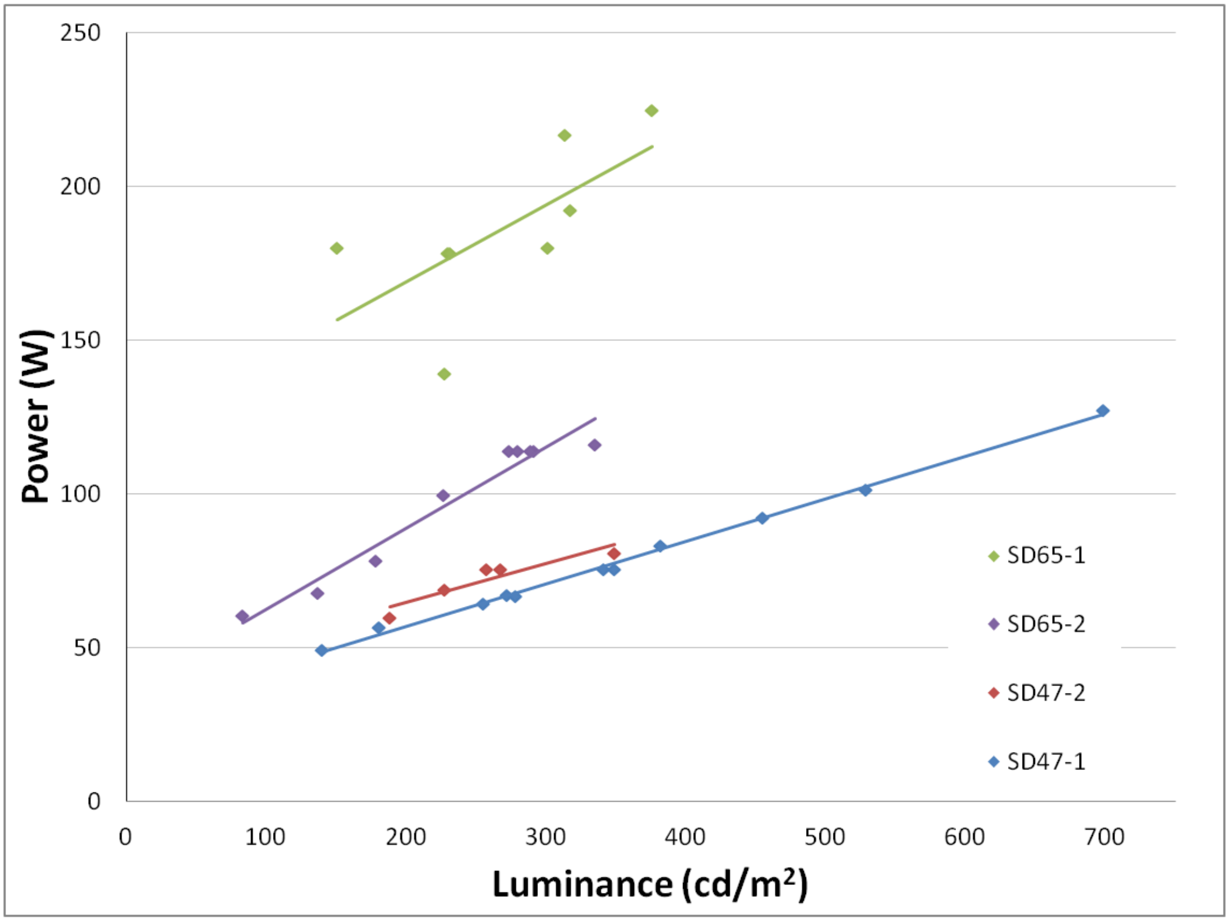


Figure 3.1 Screen Luminance versus Power for the Representative and Efficient Test Units
Source: CASE Team analysis

4 Teardown Analysis

Table 4.1 below presents the details for each signage display model that was included in the teardown analysis.

Table 4.1 Signage Display Tested Model Details
Source: CASE Team analysis

	46/47 inch pair		65 inch pair	
ID	SD47-1	SD47-2	SD65-1	SD65-2
Panel type	TN	TN	A-MVA	VA
Edge-lit or array	Edge-lit	Edge-lit	Array	Edge-lit
Number of LEDs	120	72	72	96
in^2/W default	9.30	11.96	9.43	15.64
LED efficacy (lm/W)*	99.5	99.6	60.3	103.9
Film stack: *diffuser 1*	Y	Y	Y	Y
horizontal prism	Y	Y	Y	Y
vertical prism	N	Y	N	Y
diffuser 2	N	Y	Y	Y
reflective polarizer	Y	N	N	N
BLU efficiency (cd/W)	45.0	88.5	52.4	75.0
Panel transmissivity %	6	4	5	5

* Efficacy for SD65-1 may be low compared to actual operating efficacy. It was connected to a large heat sink which we were not able to include in the sphere for testing. We assumed an average efficacy of 100 lm/W for analysis.

4.1 BLU Power

As part of the testing of signage displays, the IOU technical team measured the power draw of the BLU as well as the total power draw for each display in its default and power saving mode by logging component-level power during the IEC video and internet test clips (Table 4.2 and Figure 4.1). The backlight unit accounts for the majority of a display's power budget with more efficient designs reducing the percent of power draw used by the backlight. For both pairs of displays, the representative and efficient models showed similar BLU percentages in their default modes. However, each efficient model (SD47-2 and SD65-2) measured a slightly lower percentage when measured in its power saving mode.

Table 4.2 Tested Signage Display Backlight Unit Power Draw
Source: CASE Team analysis

Display Mode	ID	BLU (W)	LCD, PS losses, Other (W)	BLU %
Default Mode	SD47-2	67.2	36.6	65%
	SD47-1	45.9	30.1	60%
Power Saving Mode	SD47-2	34.5	33.4	51%
	SD47-1	38.0	21.5	64%
Display Mode	**ID**	**BLU (W)**	**LCD, PS losses, Other (W)**	**BLU %**
Default Mode	SD65-2	86.4	29.2	75%
	SD65-1	137.0	48.2	74%
Power Saving Mode	SD65-2	42.4	25.8	62%
	SD65-1	134.7	48.3	74%

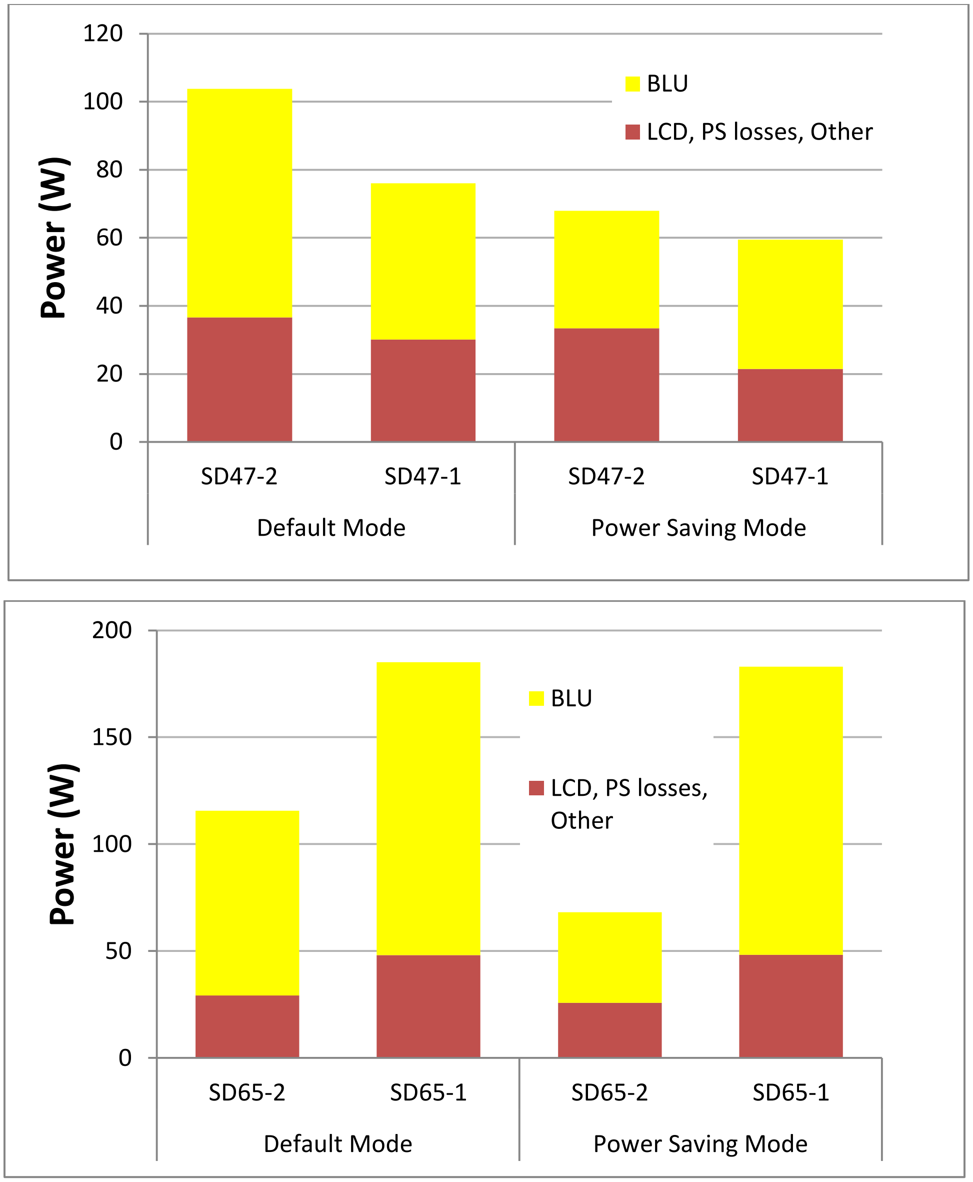


Figure 4.1 Tested Signage Display Backlight Unit Power Draw
Source: CASE Team analysis

To further investigate BLU efficiency, we examined the instantaneous power measured during the test clips which shows how the power of the backlight scales to the content displayed. Displays that scale effectively will show lower power draw during the darker scenes of the test clip and high power draw during brighter scenes, saving energy use overall. In all four cases, there was no scaling of the backlight to content, indicating that power draw reductions are due to dimming of the backlight overall and little else.

4.2 Lamp Efficacy

With the exception of the representative test unit, all of the displays' LEDs measured around 100 lm/W in simulated operation. In our prior computer monitor testing, we found instances of slightly higher efficacy LEDs up to 107 lm/W. Market analysts have predicted a continued trend toward higher efficacy, lower cost LEDs.

4.2.1 Backlight Unit On-Axis Efficiency

We calculated backlight unit on-axis efficiency as the screen-normal light output divided by the backlight power input. As explained in the CASE report, usable, screen-normal light is measured as the luminance of light directed normal to the display's screen. As light passes through a display's optical components, it is focused and oriented to be usable once it hits the LCD panel. For the units tested, both of the efficient models demonstrated a higher on-axis efficiency than the representative models. For more explanations of the different film types, please see the IOU displays supplemental Technical Report.

4.2.2 LCD Panel Transmissivity

LCD transmissivity is the ratio of screen-normal light measured out the front of the LCD panel to the screen-normal light measured out the front of the film stack, indicating how efficiently light passes through the LCD panel. The models tested showed a relatively low range in efficiency from 4-6%.

5 Cost-Efficiency Analysis

5.1 Efficiency Improvement Measures

5.1.1 LED Improvements

The technical team performed calculations for two scenarios representing improvements in LED lamp efficacy for each signage display pair: modeling increased lamp efficacy to 110 lumens per watt (lm/W) and 125 lm/W. Improving to 110lm/W is slightly better than current typical display lamp efficacy (95-100 lm/W according to discussions with industry experts). Costs for these lamps were estimated from discussions with industry experts based on DisplaySearch costs for slightly lower performance lamps. Further increasing lamp efficacy to 125lm/W increased total display efficiencies significantly while only moderately increasing costs. The reason for this stems from using more efficacious lamps to produce the same amount of backlight, which allows manufacturers to build displays with fewer lamps. Costs for the 125lm/W lamps were conservatively estimated to be twice the cost of typical lamps found in current displays.

5.1.2 Reflective Polarizing Film

Reflective polarizing film is a low cost means to recycle improperly polarized light rather than letting it be lost as absorbed heat. This improvement increases LCD transmissivity which enables the use of a less powerful BLU. When a reflective polarizer was theoretically added to the efficient models, it increased overall efficiency by 6% (47") and10% (65"). This estimate is based on component manufacturer estimates for BLU improvements (HDTVExpert.com 2012, 3M 2013). Cost estimates are based on data supplied by DisplaySearch's BLU Cost Model for large TVs. We assumed these film costs to be the same as for signage displays.

5.1.3 Backlight Dimming to Video Content

Dimming (also referred to as global dimming) reduces the light output and therefore power of a display. Although all test units contained the necessary hardware to enable global dimming, none of them incorporated this approach to save energy. From the computer monitors study in the CASE report, power reduction with dimming enabled using the IEC video clip were 35% and 40% for the 22" and 27" models respectively. For this analysis, a conservative power reduction of 30% was used and applied to the efficient units.

Through consultation with industry experts, costs for dimming to video content were estimated to be minimal. The need to interpret signal picture levels and apply them to backlight output may require a slightly higher processing capability, so an incremental cost of $1 was used for implementation of dimming to content.

5.1.4 Reduced Sleep Mode power draw

For three of the four units tested, Sleep Mode power draw measured greater than 1 W. The representative 65" model (SD65-1) measured full power with the source device in Sleep. However, with the source disconnected, the power draw was 0.2 W, indicating that it should easily be able to reduce its power draw with the source in Sleep for minimal cost. The representative 47" display (SD65-1) drew more than 9 W in Sleep and Off Modes. This display is a connected display, possible accounting for the high Sleep Mode power draw, however, from an ENERGY STAR QPL pulled 5/13/15, there are 78 instances of Ethernet connected displays between 42 and 60 inches that use less than 1 W, indicating that connected displays do not inherently require higher than average Sleep Mode power draws.

5.2 Cost-Effective Approaches

The select individual efficiency measures described above were combined to generate three cost-effective measures for each size analyzed (Figure 5.1). The On Mode power limit denotes the maximum power draw for the two scenarios within each size group. To determine if a scenario was cost effective, the technical team calculated the lifetime energy savings of more efficient display over the representative model and compared that to the incremental cost of the efficiency improvement. Cost effectiveness was calculated using 2016 costs averaged over all the cost effective approaches. Costs generally decrease over time, making analyses of the same scenarios for future years result in even further cost effectiveness.

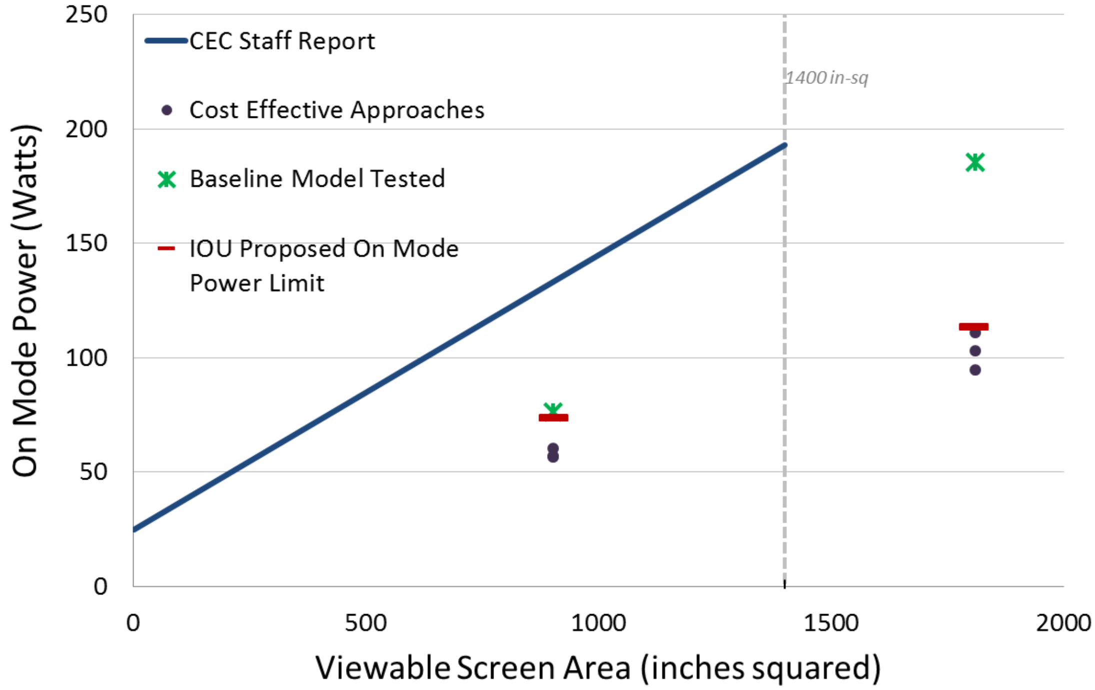


Figure 5.1 Cost Effective Approaches to Meet on Mode Power Limits: Signage Displays
Source: CASE Team analysis

Details regarding which efficiency measures we utilized for each scenario and the impact to On Mode power draw are described in Table 5.1.

Table 5.1 Description of Cost Effective Strategies to Meet On Mode Power Limits – Signage Displays
Source: CASE Team analysis

	Representative Model Attributes	Cost Effective Level 1	Cost Effective Level 2	Cost Effective Level 3
46"/47"	On Mode: 75.9 W Reflective Polarizer: None Lamp Efficacy (LED): 100 lm/W Screen Brightness: 267 nits Global Dimming: None	On Mode: 60.1 W Reflective Polarizer: Yes Lamp Efficacy (LED): 110 lm/W Screen Brightness: 267 nits Global Dimming: No Panel improvement: 20%	On Mode: 56.8 W Reflective Polarizer: None Lamp Efficacy (LED): 110lm/W Screen Brightness: 267 nits Global Dimming: Yes Panel improvement: 20%	On Mode: 56.5 W Reflective Polarizer: Yes Lamp Efficacy (LED): 125 lm/W Screen Brightness: 267 nits Global Dimming: None Panel improvement: 20%
65"	On Mode: 185.2 W Reflective Polarizer: None Lamp Efficacy (LED): 60 lm/W Backlight Configuration: Array Screen Brightness: 318 nits Global Dimming: None	On Mode: 111.0 W Reflective Polarizer: No Lamp Efficacy (LED): 110 lm/W Backlight Configuration: Edge Screen Brightness: 273 nits Global Dimming: None	On Mode: 102.8 W Reflective Polarizer: Yes Lamp Efficacy (LED): 110 lm/W Backlight Configuration: Edge Screen Brightness: 273 nits Global Dimming: None	On Mode: 94.6 W Reflective Polarizer: No Lamp Efficacy (LED): 110 lm/W Backlight Configuration: Edge Screen Brightness: 273 nits Global Dimming: Yes Panel improvement: 20%

Through the testing and teardown analysis of two pairs of representative signage displays, the technical team was able to demonstrate multiple paths to cost effectively reduce energy use.

Approaches include more efficient film stacks, improved lamp efficacy, more efficient LCD panels, and dimming screen brightness to video content.

Because of the broad range of applications for signage displays that require various levels of brightness to account for the relative brightness of the ambient conditions, from dimly lit conference rooms to hotel lobbies to public displays that may receive direct sunlight, we recommend that the CEC consider including screen luminance in any specification for signage displays. The maximum measured luminance in candelas per square meter is proposed in the On Mode power requirement proposed listed in Table 3.9 of the comment letter. This approach aligns with the most recent draft of the ENERGY STAR Version 7 specification update.

Appendix B Opportunity for ENERGY STAR

Some CEC stakeholders had concerns that there would be no opportunity for the ENERGY STAR program for computer monitors if CEC adopts the proposed requirements. The CASE Team compared On Mode power consumption requirements from ENERGY STAR with the CEC proposal and note there is still an opportunity in the market for ENERGY STAR to incentivize the top performing computer monitor models with regards to energy efficiency. Table B.1 below shows for typical monitor sizes and resolutions, the On Mode power limit comparisons between the CEC proposal and ENERGY STAR Version 7 Draft 1 and ENERGY STAR Most Efficient 2015. The limits in red text identify the limits that are more stringent than the CEC proposal.

Table B.1 Computer Monitor on Mode Power Limit Comparisons: CEC Proposal and ENERGY STAR

Source: CASE Team analysis

			On Mode Limits (Watts)		
Diagonal Screen Size (inches)	**Typical Resolution (MP)**	**Typical Screen Area (in-sq)**	**CEC Proposal**	**ENERGY STAR V7 Draft 1**	**ENERGY STAR Most Efficient 2015**
15.6	1.05	103	8.94	8.62	7.73
19.5	1.44	160	11.46	12.48	10.80
21.5	2.07	198	14.85	15.40	13.56
23	2.07	226	15.33	16.45	14.68
27	2.07	312	20.33	18.78	18.12
34	2.07	415	27.54	20.27	22.24
42	2.07	754	51.27	21.45	35.80

In ENERGY STAR Version 7 Draft 2, EPA proposed a total energy consumption (TEC) approach instead of a modal power approach, so the CASE Team was unable to include the ENERGY STAR Draft 2 proposal in this comparison. The TEC approach provides another opportunity for ENERGY STAR to distinguish the top performing models on the market.