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THE SECRET COSTS OF MANUFACTURERS EXPLOITING LOOPHOLES IN THE GOVERNMENT'S TV ENERGY TEST: $1.2 BILLION FOR CONSUMERS & MILLIONS OF TONS OF POLLUTION

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Executive Summary

New televisions purchased over the past few years may cost consumers at least $1.2 billion more on their electricity bills than anticipated, according to a new NRDC study. These lifetime costs for TVs with 32-inch and larger screens are due to deficiencies in the U.S. Department of Energy (DOE) method for testing the energy use of all new television models, which some manufacturers may be exploiting to achieve lower energy usage during testing than in real-world viewing. In addition, TVs from the leading manufacturers—Samsung, Vizio, and LG (which together make up half of the market)—are designed to disable key energy-saving features, often without adequate on-screen warning, whenever a user changes the default picture setting.

Generating this extra electricity over the lifetimes of these new televisions—enough to power all of the homes in the city of Los Angeles for a year—will create an additional five million metric tons of the dangerous carbon dioxide pollution fueling climate change.

JUST A FEW INNOCENT CLICKS ON A TV'S REMOTE CONTROL CAN DRAMATICALLY INCREASE ITS ENERGY USE

Changing the main picture setting on certain TVs can cause their energy use to

DOUBLE

Viewing HDR content may increase energy use by roughly

30 to 50%

If just one-third of the owners of Samsung, LG, and Vizio TVs purchased in 2015 and 2016 in the United States changed the main picture setting, the next 10 years could see:

More than

$1.2 BILLION

extra in electricity bills nationwide

More than

5 MILLION

metric tons of extra carbon dioxide emissions

In addition, testing conducted by our consultant Ecos Research shows that television energy use is poised to grow even more should the recently introduced video format, UHD (ultra high-definition) with high dynamic range (HDR), achieve broad market adoption as expected. Manufacturers have indicated the energy-saving features on their televisions are automatically disabled whenever UHD + HDR content is played, and our testing confirms this.

With millions of televisions purchased annually across America today, all of this extra energy use has a major impact on national energy consumption, consumer utility bills, and the environment. In some cases, a TV's annual energy use will be twice the level that a manufacturer reported. Steps must be taken to ensure televisions are as energy efficient as possible during actual use and not just during government testing.

POSSIBLE ENERGY TESTING ABUSE

In 2015, NRDC and Ecos Research conducted the first comprehensive independent testing of the energy use of new ultra high-definition (UHD) televisions—also known as 4K TVs because they have a horizontal resolution of 4,000 pixels. We observed inexplicable dramatic and sustained drops in energy use in TVs from certain manufacturers, beginning within the first minute of the video test loop used in the DOE test method for new TV models.

Not long afterward, European energy agencies reported similar results. A subsequent article in the U.K.'s *Guardian*[1] suggested the behavior was due to a Samsung television motion-detection feature that reduces energy use when certain content is viewed.[2] (LG TVs have a similar feature.) To better understand the impact of these and other features on TV energy use, we performed follow-up testing in 2015 and 2016 as detailed in this report. It included comprehensive laboratory testing of selected televisions, as well as additional in-store testing to observe the persistence of key energy-saving features on other makes and models.

We concluded that while TV manufacturers appear to measure the energy use of their products in accordance with the government test method—which we do not believe reflects the characteristics of TV content typically viewed by most people—some have taken questionable actions that run counter to the spirit of the law.

The 10-minute video loop used in the test method for measuring and reporting average TV power contains a collection of unusually short scenes that is not representative of most real-world content. It is possible that some manufacturers have designed their TVs to detect the continuous occurrence of short scenes and frequent scene cuts and to "optimize" their performance to reduce power when content with these characteristics is displayed. This would allow a manufacturer to publish a very low average power use (and gain a competitive advantage), even though the TV will draw considerably more power when consumers get it home and watch their broadcast and streamed content the way they prefer. This is mainly because some of the leading manufacturers—including Samsung, LG, and Vizio, which together represent half of all the new televisions sold in the United States—have designed their TVs to disable energy-saving features whenever users change the main picture setting.

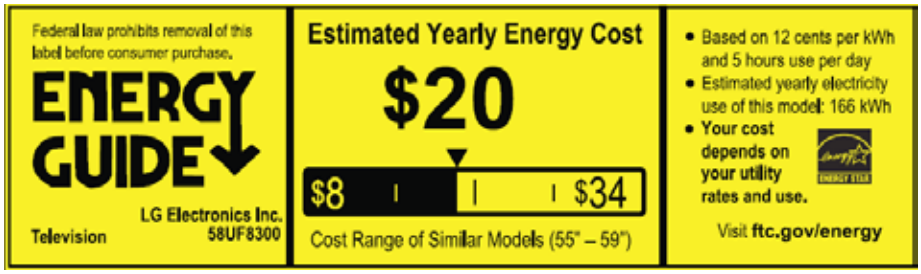
Manufacturers are likely doing this as a means to increase the brightness of the television screen in an attempt to increase perceived owner satisfaction, but the resulting extra energy use is not accounted for in the DOE test.

These "under the hood" changes dramatically increase a TV's energy use and environmental impact, usually without the user's knowledge. While this may not be illegal, it smacks of bad-faith conduct that falls outside the intent of the DOE test method designed to accurately measure TV energy use.

TESTING TVS IN THE LAB AND IN STORES

A television's energy use is highly dependent on the picture settings selected, the screen brightness, and the content on display. The DOE requires that energy use of new TV models be tested while playing a 10-minute video of assorted content developed by the International Electrotechnical Commission (IEC) standards organization and meant to represent typical viewing. This testing is conducted with the television in its default settings.

The results are used to determine the annual energy use listed on yellow EnergyGuide labels (see example below), which are mandated by the Federal Trade Commission (FTC) to appear on every television sold in stores. This allows consumers to compare the TV's energy use against the energy use of similar-size models before purchase.



The test results also are used when manufacturers seek approval to display the ENERGY STAR® label to indicate that the model is among the more energy efficient on the market.

Televisions with lower energy use have greater appeal to consumers concerned about their energy bills and/or the pollution that can be avoided because not as much fossil fuel—generated electricity will be needed to run these models. Achieving sufficiently low energy use levels from the test is also necessary to comply with mandatory television energy efficiency standards in California, Oregon, and Connecticut. There are no national energy efficiency standards for televisions at this time.

To gauge the impact on energy use of the latest television features, and to determine whether this energy consumption is reflected in the DOE testing, NRDC and Ecos Research performed laboratory testing under a range of conditions on recent 55-inch and larger models—two Samsung, one LG, and one Vizio. Our testing used the 10-minute IEC video specified by the DOE protocol, and we tested the TVs both with their default (as-shipped) settings and after switching to a different setting. We also tested the televisions with two alternatives to the DOE test loop video: real-world content we created to reflect typical viewing, and UHD + HDR movies. The latter is important as HDR-ready TVs are expected to become popular, offering a superior viewing experience with more saturated colors, brighter highlights, and deeper shadows.

We were only able to test a limited number of TVs in the lab due to the complexity and cost of doing the testing. We shared the testing results with each manufacturer, and none of them disputed the accuracy of our results or claimed they were limited to a subset of models.

Separately, we conducted testing on 21 different 2015 and 2016 TVs models from Samsung, Sony, LG, Vizio, Panasonic, and Philips in retail stores to assess the persistence, or lack thereof, of the default energy-saving features. In particular, we examined whether changes to the main picture setting (switching from the default Normal setting to the Vivid or Cinema setting) or sub-settings (such as contrast or backlight) caused the energy-saving features to become disabled.

SOME MANUFACTURERS MAY BE EXPLOITING TEST CLIP ANOMALIES

Almost all Samsung and LG TVs have a motion-detection dimming (MDD) feature, which dims or briefly turns off the screen's backlight when the content on display has rapid motion and frequent scene changes, as is common in commercials and music videos. (Samsung calls its MDD feature Motion Lighting; LG terms it Motion Eye Care.)

Our analysis shows the test clip developed by the IEC and used by the DOE contains much shorter scenes and more frequent cuts between them than typical real-world content from sports, dramas, and news programs.

While MDD caused on-mode power to drop by 58 percent in the DOE test on the LG TV, it dropped by only 13 percent when playing the real-world content video loop we created. (This effect was smaller for the Samsung TVs; Vizio TVs do not have this feature.) Put simply, the MDD feature saves more energy during the official government testing than it does when users view most programming that people typically watch.

Therefore, it's conceivable that some manufacturers might be exploiting the abnormally high frequency of scene changes in the IEC test clip to maximize the effect of MDD and obtain a better energy efficiency score, thereby gaining a competitive advantage.

A FEW CLICKS AND ENERGY USE CAN SKYROCKET

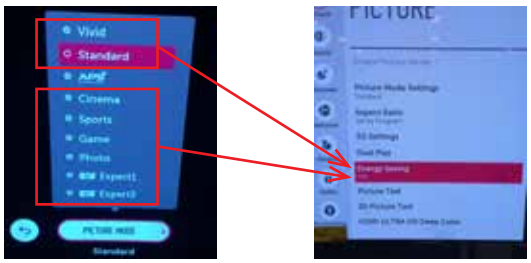
The TVs produced by Samsung, LG, and Vizio also disable key energy-saving features when the user changes the default picture setting (e.g., from Normal to Cinema, Sports, or Vivid) to modify the viewing experience. The disabled features may include MDD and automatic brightness control (ABC), which automatically adjusts the TV screen's brightness and power level according to the amount of ambient light in the room. The manufacturers have an incentive to design their TVs this way as a means to provide a brighter TV image without having the extra energy counted during the official energy use testing by the DOE. If the MDD feature truly was intended to deliver energy savings and potentially reduce eye fatigue when content with certain characteristics is viewed, why would LG and Samsung design their TVs to disable this feature when the user selects a different picture setting?

A few seemingly innocuous clicks on the remote control can as much as double the cost to operate a TV over its 10-year lifetime, costing owners an extra $100 to $200 in energy bills.

For example, in the LG TV shown in Figure ES-1, the default picture setting Auto Power Save (APS) is the only one in which the energy-saving feature remains enabled. Even selecting Standard, the setting that would likely appeal to most users, disables the energy-saving feature. The manufacturers we've spoken with have agreed, to varying degrees, to update the software on their new TVs so the energy-saving features are more likely to remain enabled over the TV's lifetime. Thus far, LG has been the most responsive to our concerns.

Figure ES-I: Screen shots for an LG TV

Shots demonstrate how selection of Standard picture mode disables energy-saving feature on an LG TV. Selection of any picture setting other than APS also disables the energy-saving feature.



Energy Saving (ABC) Off

The Samsung and Vizio TVs behaved similarly. We also found:

- A simple change to the contrast or brightness settings on many Samsung TVs disabled MDD and changes to the backlight setting disabled both MDD and ABC. The user is not informed by any type of screen warning when this occurs. This was the most extreme software design we encountered; no other manufacturer went this far to disable energy-saving features. Samsung has since told us it is discontinuing this particular practice.
- The bottom of the Vizio set-up menu screen contained this statement: *"Select from preset picture modes. Standard picture mode meets ENERGY STAR requirements. For the best picture use Calibrated mode."* This language implies that the Standard setting may deliver a suboptimal picture and essentially encourages the user to select Calibrated mode, which causes the TV's backlighting and power usage to increase.

The manufacturers have not disputed the accuracy of our test results.

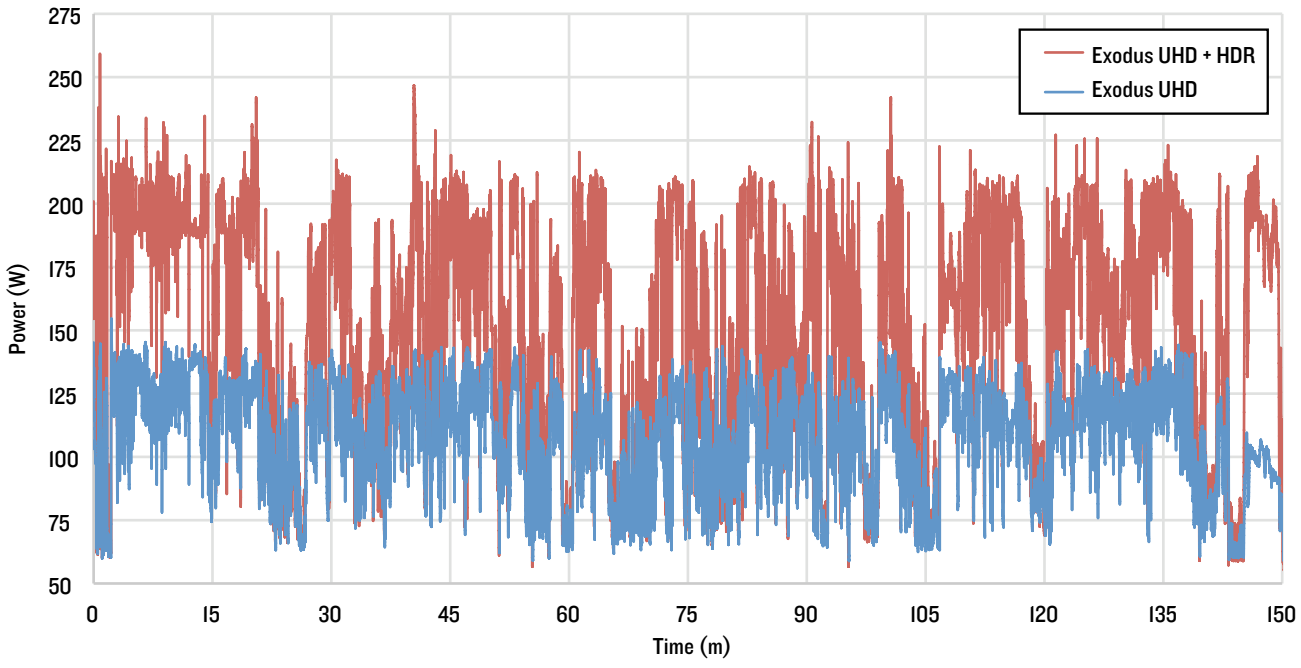
Among those consumers who purchased Samsung, LG, and Vizio televisions 32 inches and larger in 2015 and 2016, if just one-third changed their picture settings—thereby disabling the energy-saving features—the impacts over the 10-year lifetime of these televisions would include:

- A more than $1.2 billion increase in electricity bills nationwide
- More than five million metric tons of additional carbon dioxide emissions, which drive dangerous climate change.

Other key findings include:

1. Playing movies produced in HDR on an HDR-capable TV is likely to significantly increase future TV energy use. In our limited testing with a few different movies on a couple of televisions, we found that TV energy use increased by approximately 30 percent to 50 percent

Figure ES-2: Power usage for *Exodus: Gods and Kings* in UHD + HDR format versus UHD-only format

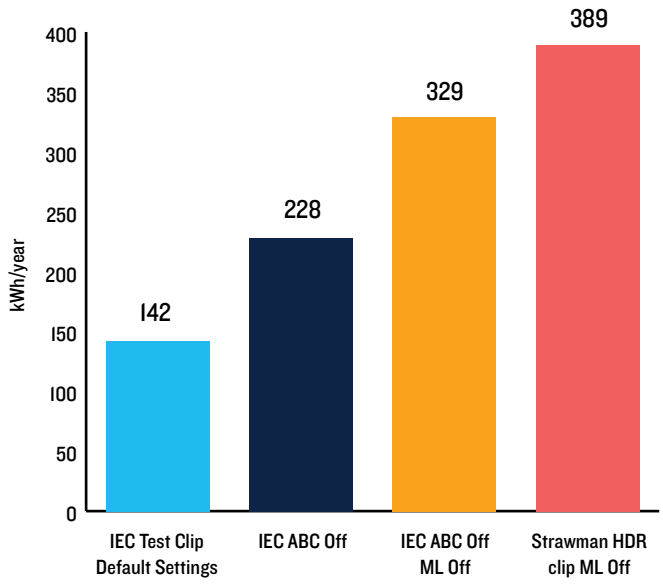


while playing the UHD + HDR version of a movie compared with the one produced in UHD. Figure ES-2 shows how power use varied during the movie *Exodus: Gods and Kings* in these two formats. Average power usage increased by 40 percent, from 106.9 watts to 149.4 watts, during the UHD + HDR version. (Note: Manufacturers have indicated that their HDR-ready TVs temporarily disable energy-saving features whenever UHD + HDR content is being played in order to optimize picture quality, in particular super-bright highlights such as fireworks and reflections of sunlight on water.) This incremental power use is not reflected in the current DOE test method, as the test loop used is only high definition (HD) content, which lags behind both the increasingly common UHD and UHD + HDR formats.

2. There are numerous ways a TV's annual energy use can double, without the user's knowledge, from the published values. As noted earlier, energy-saving features including MDD and ABC are automatically disabled on certain manufacturers' TVs when users change one or more picture settings. According to the DOE testing method, for example, the Samsung 9000 model TV's annual energy use is 142 kilowatt-hours (kWh) per year. However, this changes in actual usage to 228 kWh/yr when ABC is disabled, to 329 kWh/yr when both ABC and MDD are disabled, and all the way up to 389 kWh/yr when a representative clip of HDR content created by European efficiency experts is played, as shown in Figure ES-3. These huge increases are not currently captured by the DOE test method. (Note: These results are meant to be illustrative and are specific to this TV; results for other TVs will vary.)

Figure ES-3: Energy usage of Samsung 9000

Testing was done for IEC test clip (the 10-minute video used during DOE testing); with ABC (automatic brightness control) disabled; with ABC and ML (Motion Lighting) disabled; and for the strawman HDR clip, a new test clip shot in UHD + HDR.



RECOMMENDATIONS

To help avoid major increases in television energy consumption, and to ensure that the U.S. government's TV energy use testing method yields results that better represent real-world usage:

- **Certain manufacturers should discontinue their inappropriate practice of deploying software that automatically disables energy-saving features—mostly without consumer knowledge—whenever certain picture settings are changed.** NRDC met with LG, Samsung, and Vizio to discuss our findings, and each company said it is considering changing its TV software to increase the persistence of energy-saving features. To date, LG has been the most responsive, and its proposed solution will address many of our concerns.
- **The DOE should update its test method to include: (a) content with scene lengths that are more representative of typical content and less susceptible to detection by the TV to activate a TV's energy-saving features during the test, and (b) content produced in UHD + HDR to ensure that this format's incremental energy use is captured. The DOE also should provide clear guidance on how to address the lack of persistence of energy-saving features.** The DOE recently issued a Request for Information (RFI) as part of a formal investigation of the limitations of the current test method.[3] We responded to the RFI and are optimistic the agency will make the necessary improvements to the testing protocol informed by the data it collects.
- **The U.S. Environmental Protection Agency (EPA) should update its ENERGY STAR® specifications for TVs and continue its verification and enforcement efforts.** These actions will preserve the well-deserved integrity and value of this trusted brand, which is used to distinguish the more energy-efficient models on the market. In August 2016, the EPA launched its process to revise its ENERGY STAR specification and intends to produce Version 8.0 that is meant to address many of the issues raised in this report.
- **In anticipation of the likely future popularization of HDR technology, the TV industry should get ahead of this issue and pay greater attention to limiting the energy consumed when playing HDR content on HDR-ready TV models.** Manufacturers are encouraged to incorporate advanced but available energy-saving technologies, such as quantum dots, and should ensure that features like ABC remain enabled while HDR content is played.

- **Consumers should restore the energy-saving features on their TVs, especially ABC, and should avoid overly bright and energy-intensive picture settings like Vivid or Dynamic.** Consumers will see some energy savings, although not nearly as high as advertised, by enabling motion-detection dimming (MDD) and should leave it enabled unless they find it objectionable. Consumers should look for the following terms when scrolling through the menus on Samsung, LG, and Vizio TVs:

TV Manufacturer	Automatic Brightness Control	Motion-Detection Dimming
Samsung	Eco Sensor	Motion Lighting
LG	Energy Saving—auto	Motion Eye Care
Vizio	Auto Brightness Control	n/a

Adopting these recommendations will help ensure that America's new televisions do not continue to waste energy, increasing consumer bills and the harmful carbon pollution driving climate change.

1. Introduction

A new type of more capable, high-performance television has entered the U.S. market over the past few years. These TVs were initially described as 4K models because they have a horizontal resolution of 4,000 pixels. Today these higher-resolution TVs are marketed as ultra high-definition (UHD) TVs. More recently, some of these UHD TVs have begun incorporating additional features designed to improve picture quality even more dramatically, such as wide color gamut and high frame rate. Much of the news media focus on UHD technology has centered on its image quality and performance, with little coverage of the associated energy or environmental impacts.

Much of UHD TV energy consumption depends on what fraction of the screen's area is illuminated and the brightness of those illuminated pixels. Therefore, the easiest way to reduce TV power consumption is for its backlight to be programmed to dynamically produce less light depending on the content at a given time. This can be done through local dimming (turning off the portion of the backlight to pixels that are supposed to be dark), automatic brightness control (dimming the whole screen in proportion to the brightness of ambient light in the room), or motion-detection dimming (temporarily reducing the brightness of the entire screen when scenes change rapidly enough that such dimming is less likely to be noticed by the user).

At the same time, TV power use is being pushed upward due to new technologies like high dynamic range (HDR)—the newest video format that offers more colors, brighter images, and darker shadows—as well as wide color gamut, and by manufacturer competition to claim ever-higher measured screen brightness levels.

In 2015, NRDC and its consultant Ecos Research conducted the first-ever in-depth study of the energy use of UHD TVs entering the market in 2014 and 2015.[4] One of our key findings was that new UHD TVs used 30 percent more power on average than similar-size HD TVs when playing HD video content. The testing also revealed inexplicable sudden and extended drops in power use while certain TVs were being tested in accordance with the official U.S. Department of Energy (DOE) test procedure for measuring a TV's average on-mode power use. Independently, some European researchers observed similar behavior while conducting their own testing using a comparable methodology, which also includes playing a test loop of content developed by the International Electrotechnical Commission (IEC), an international standards organization.

A fall 2015 article in the U.K.'s *Guardian*[5] reported that European independent lab tests had found that some Samsung TVs appeared to use less energy during official testing conditions than during real-world use, "raising questions about whether they are set up to game energy efficiency tests."[6] In response, Samsung issued a statement that its motion-detection dimming (MDD) feature, which it calls Motion Lighting, is an "out-of-the-box" feature that "reduces power whenever motion on the screen is detected."[7] "Out-of-the-box" refers to a television's configurations the first time the user turns it on, including settings and features already enabled without the user having to take any action.

In the absence of publicly available data on the energy impacts of potential energy-saving features like MDD, NRDC and Ecos Research collaborated on a follow-up study to investigate the following questions:

- What impact does MDD—which may have a different name, depending on the manufacturer—have on the energy use of new TVs?
- Does the IEC test loop used by the DOE to measure TV power use contain any unusual characteristics not found in (or less common in) real-world content (RWC)—characteristics that might allow TVs to appear more energy efficient when tested than during typical use?
- Do energy-saving features such as automatic brightness control (ABC) and MDD remain enabled when the user makes changes to the picture setting or adjusts other settings, such as brightness or contrast?
- What is a new TV's incremental energy use when playing a movie in UHD with HDR compared with the same movie that is just UHD? Does MDD impact power use when playing UHD + HDR content?
- What are the per-television and national impacts if a significant percentage of TVs have their energy-saving features disabled due to settings changes made by the user?
- How can consumers restore the energy-saving features of their TVs?

We studied two energy-saving features: automatic brightness control and motion-detection dimming.

AUTOMATIC BRIGHTNESS CONTROL

Televisions with the ABC feature have an external sensor designed to measure the amount of ambient light in the room. The TV then adjusts its backlight in response to the room's light level, causing the TV's energy use to increase or decrease accordingly. For example, when a TV with ABC is viewed during the evening in a dimly lit room, the screen does not need to be as bright and the TV automatically reduces its brightness. This not only saves energy, it also provides the viewer with a more satisfactory viewing experience. Conversely, the screen's brightness automatically increases in daylight in response to high levels of ambient light. As TV viewing more commonly occurs during the evening amid low ambient light levels, the ABC feature tends to be a net energy saver for most locations. In terms of both user experience and energy efficiency, this approach is far superior to always having the TV's brightness/backlight settings turned way up in anticipation of the less common viewing that takes place when ambient light levels are high.

The DOE test procedure requires that TVs be tested with ABC enabled if this is how they ship, and that power measurements be taken at four specified ambient light levels. The on-mode power level reported to DOE is the simple average of the four values.

MOTION-DETECTION DIMMING (MDD)

Many Samsung and LG TV models are also shipped with an MDD feature (referred to as Motion Lighting and Motion Eye Care by the manufacturers, respectively). This feature temporarily reduces screen brightness during periods of rapid onscreen motion, particularly if scenes change abruptly and frequently (as in commercials and music videos). According to the manufacturers, this feature is intended to reduce TV power use and can also reduce viewer eye fatigue. MDD scales either the amplitude or duration of the backlight's illumination during each frame to the desired dimming level. This form of dynamic dimming is designed to be largely imperceptible to the viewer.

We are not aware of any other manufacturer that sells TVs in the United States with MDD technology. Prior to our study, little was known about the impact of MDD on TV power usage when video content is being displayed.

2. Methodology

For this follow-up research, we partnered again with Ecos Research, a Portland, Oregon–based public policy consulting firm. Ecos has extensive experience measuring the energy use of various consumer electronics and a deep understanding of test methods used by government agencies. Ecos performed laboratory testing on four television models purchased for this study as well as additional qualitative testing on the user interface and software of 21 models on the sales floor of two retailers. Our lab testing focused on the three leading TV manufacturers: Samsung, Vizio, and LG. Together these companies account for more than half of all new U.S. TV sales (see Appendix 1).

Table 1 provides information on the four purchased models. These models were selected to represent the range of TVs currently on the market from the leading manufacturers. The two Samsung models represent a mid-level and higher-end TV and both of which have ABC and MDD and are capable of displaying UHD + HDR content. The LG TV has Motion Eye Care (LG's version of MDD), and the Vizio TV is a high-end model that plays the Dolby Vision version of UHD + HDR content. Our results are meant to be illustrative of the behaviors that would be observed for various TVs on the market. Generally most, but not all, TVs from a single manufacturer are configured to behave similarly. The magnitude of measured energy savings from specific features will, of course, vary from television to television.

Table I: Information on the four TV models tested

Manufacturer	Samsung	Samsung	LG	Vizio
Model Number	UN55JU7100	UN55JS9000	58UF8300	RS65-B2
Screen Size (inches)	55	55	58	65
Panel Technology	LED Direct Array	LED Edge Lit (Quantum Dot)	LED Edge Lit	LED Full Array
Type of HDR	HDR 10	HDR 10	No	Dolby Vision
ABC Sensor	Yes	Yes	No	No
Motion-Detection Dimming	Yes	Yes	Yes	No

Our initial testing was performed in accordance with the official DOE test method, which utilizes a Blu-Ray disc from the IEC that contains a 10-minute video of numerous short clips edited together and intended to represent the overall brightness (average picture level) of typical viewing content. These tests were done with the TVs' out-of-the box settings. Per the test method instructions, no adjustments were made to any of the default settings, including the main picture setting and sub-settings such as contrast, brightness, and backlight levels. Ecos Research used a Yokogawa WT310 calibrated power analyzer and Chroma 61602 calibrated power supply to perform all tests. For testing performed with a TV's automatic brightness control (ABC) feature on, we measured power at the four ambient room light levels specified in the DOE test method: 3, 12, 35, and 100 lux. Per the DOE, the average of the power levels at each light level is the reported on-mode power level.

On the four purchased televisions, we went beyond the DOE test method and also measured:

- Average power use with the IEC test loop and with ABC turned off.
- Average power use with the IEC test loop with MDD disabled and with ABC on and ABC off.
- Average power use while playing a real-world content (RWC) test loop created by Ecos Research, with MDD on and off, and with ABC on and off.
- Average power use when playing a movie created in UHD and in UHD + HDR. This testing was done with ABC off.
- Average power use while playing a UHD + HDR movie with MDD on and off. Both tests were done with ABC off.

We supplemented our laboratory measurements with in-store testing that consisted of a qualitative review of 21 different TVs from six manufacturers: LG, Samsung, Vizio, Sony, Panasonic, and Philips. While in the store, the Ecos Research technician used each TV's remote control to assess the impact on the default energy-saving features when changing the default picture setting from Normal/Standard to a different setting. Screen shots were taken and notes were recorded to document this work. (See Appendix 2 for information on the models tested and the results.) These models consisted of both 2015 and 2016 TVs.

IMPACT OF MOTION-DETECTION DIMMING FEATURE ON TV POWER USE

Prior to our study, there were no public data on the impact of MDD on the on-mode (active) power use of new TVs. The DOE recently published the results of testing it performed on this feature across different types of video content, and its findings were consistent with ours.[8] Of the major TV manufacturers, it appears that only Samsung and LG TVs contain a MDD feature. Per NRDC's discussions with these manufacturers, we confirmed that the majority of their models have this feature already enabled when the consumer receives the television.

We tested the power use of two Samsung models and one LG model with the MDD feature enabled. The first set of tests measured each model's energy use as per the official DOE test method, which requires testing the TV as it is received. For example, if the energy-saving features such as MDD or ABC were enabled by default and the user was not given a choice to disable them during initial setup of the TV, the test was conducted with these features on. We then tested the television with MDD off to determine the impact of this feature on power use during the full 10-minute IEC test loop specified by DOE.

LG Televisions

Figure 1 shows how the on-mode power use of the LG television varied over the 10-minute test. The average on-mode power with Motion Eye Care (LG's term for MDD) on was 75 watts but jumped to 119 watts, an increase of 58 percent, when the same test was conducted with MDD off. (Note: The effect of MDD on LG TVs will likely be smaller on models that also have automatic brightness control enabled.)

We also saw an unexpected, dramatic dip in power use within the first minute of the test, when the TV's power dropped from around 120 watts to 60 watts and then stayed near that level for extended portions of the test. This dramatic and sustained level of lower power use was not observed when MDD was disabled, as shown by the blue line in Figure 1. It is also evident from the upward and downward slopes of the orange line that LG TVs gradually engage and disengage MDD over a period of approximately 30 to 60 seconds in order to make the resulting change in screen brightness less abrupt or noticeable to the viewer.

Samsung Televisions

We performed similar testing on the two Samsung TVs, which had the MDD and ABC features enabled when shipped. We took measurements at each of the four ABC

Figure I: LG model 58UF8300: Impact of MDD (Motion Eye Care) on on-mode power use

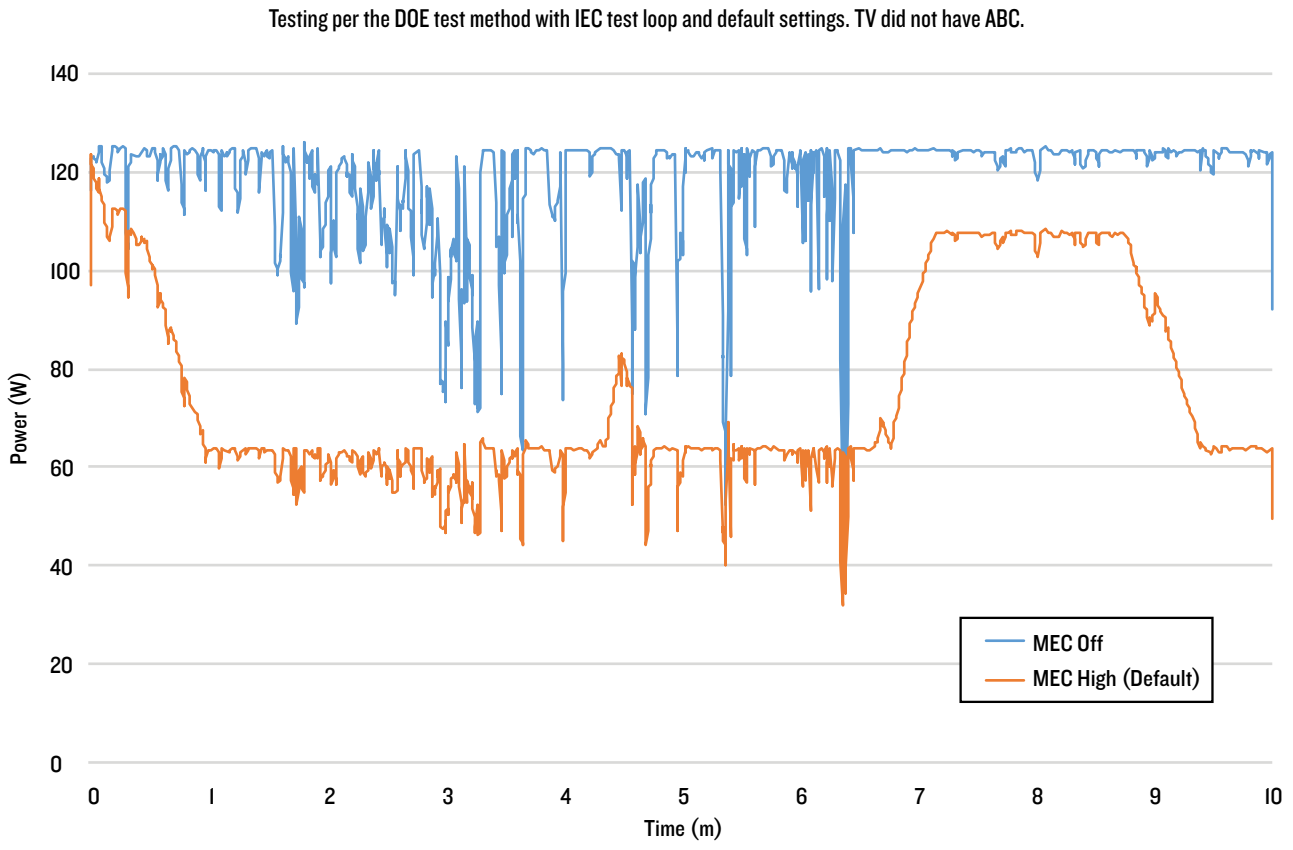


Table 2: Testing results for two Samsung TVs with and without MDD (Motion Lighting) and with ABC on and off. DOE test method with IEC test loop and default picture settings					
		SAM 7100		SAM 9000	
	Motion Lighting	Average Power (W)	Power Increase When ML Off	Average Power (W)	Power Increase When ML Off
ABC Off	Off	124.91	25%	180.50	45%
	On	99.68		124.89	
ABC On*	Off	67.66	13%	87.91	16%
	On	60.10		76.12	

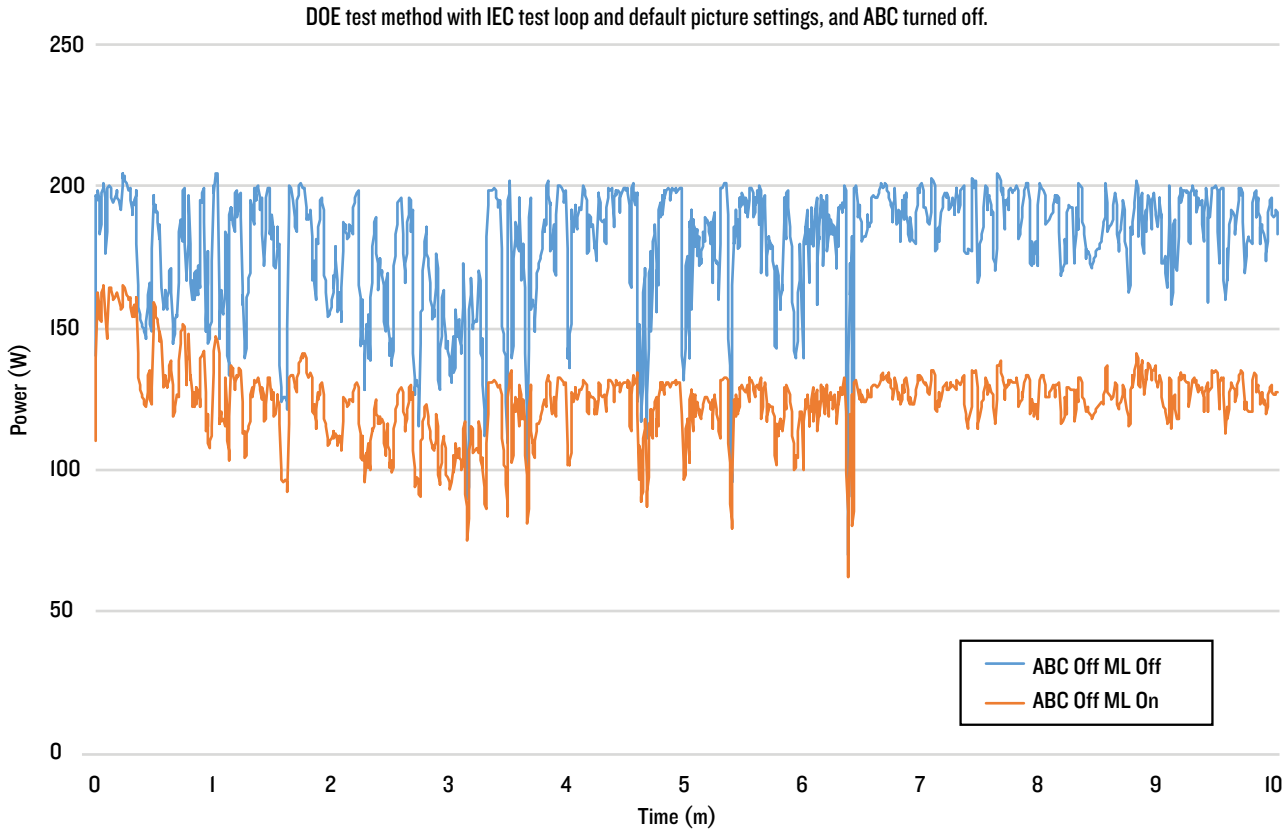
*Highlighted yellow power values are averages of four illuminance levels and what would be reported per the DOE test method.

test levels and with ABC off. The results are shown in Table 2. Disabling the MDD feature (Samsung terms it Motion Lighting) increased average on-mode power use by 13 percent for the SAM 7100 and 16 percent for the SAM 9000. When ABC was also disabled prior to the test, power use increased by 25 percent and by 45 percent, respectively, when MDD was disabled.

When both ABC and MDD were disabled, the Samsung televisions' on-mode power use was more than double the usage levels with out-of-the-box settings (125 watts instead of 60 watts for one TV, and 180 watts instead of 76 watts for the other). As discussed later in this report, there is a considerable likelihood that these two energy-saving features could both be automatically disabled at a time after the TV is first set up.

Like the LG TV, the Samsung models showed a substantial drop in power use during the first minute or so of the test when MDD was on, although power levels remained low throughout the test clip instead of rising later in the 10-minute period, as illustrated in Figure 2. The data also suggest that Samsung and LG TVs utilize different algorithms to achieve the power reductions with their MDD feature.

Figure 2: Samsung model UN55JS9000: Impact of MDD (Motion Lighting) on on-mode power use



TV ON-MODE POWER USE WHEN PLAYING THE IEC TEST LOOP VERSUS REAL-WORLD CONTENT

Unable to fully explain the sudden drop in power use observed when MDD was enabled, we were curious whether there was something unique about the IEC test loop used during laboratory testing under the DOE protocol. We created our own test loop of real-world content and tested the TVs with and without MDD features enabled to see whether similar energy use profiles were observed.

At NRDC's request, Ecos Research constructed a 12-minute test loop of real-world content meant to represent a cross-section of commonly viewed types of video material. This loop consisted of comedy (*Silicon Valley*), sports (2015 Rose Bowl football game), drama (*Breaking Bad*), and news (CNN), followed by a few minutes of commercials. The commercials, two minutes in total length, were deliberately put at the end of a 10-minute loop because this type of content typically has much shorter scenes and more frequent scene changes than most other content, and we were concerned that putting it at the beginning could bias the MDD response.

Figure 3 shows a plot of measured power versus time for the LG television using the real-world test loop. The test was conducted with all of the television's default settings on, including MDD.

The power use profile for the LG TV when playing real-world content (RWC) was substantially different from the IEC test clip. The TV did not show the significant and sustained drop in power use for any content except commercials, as observed in Figure 1.

Figure 4 superimposes plots of the Samsung power use profiles during testing conducted with the IEC test loop and the real-world test loop. Note that the energy use differences were sizable, and that the TV consumed more power when playing the real-world clip than when playing the IEC clip used during DOE testing.

Figure 3: Plot of on-mode power as a function of time for the LG 58UF8300 model when playing the real-world test clip

DOE test method using the real-world test loop, default picture settings. Model did not have ABC.

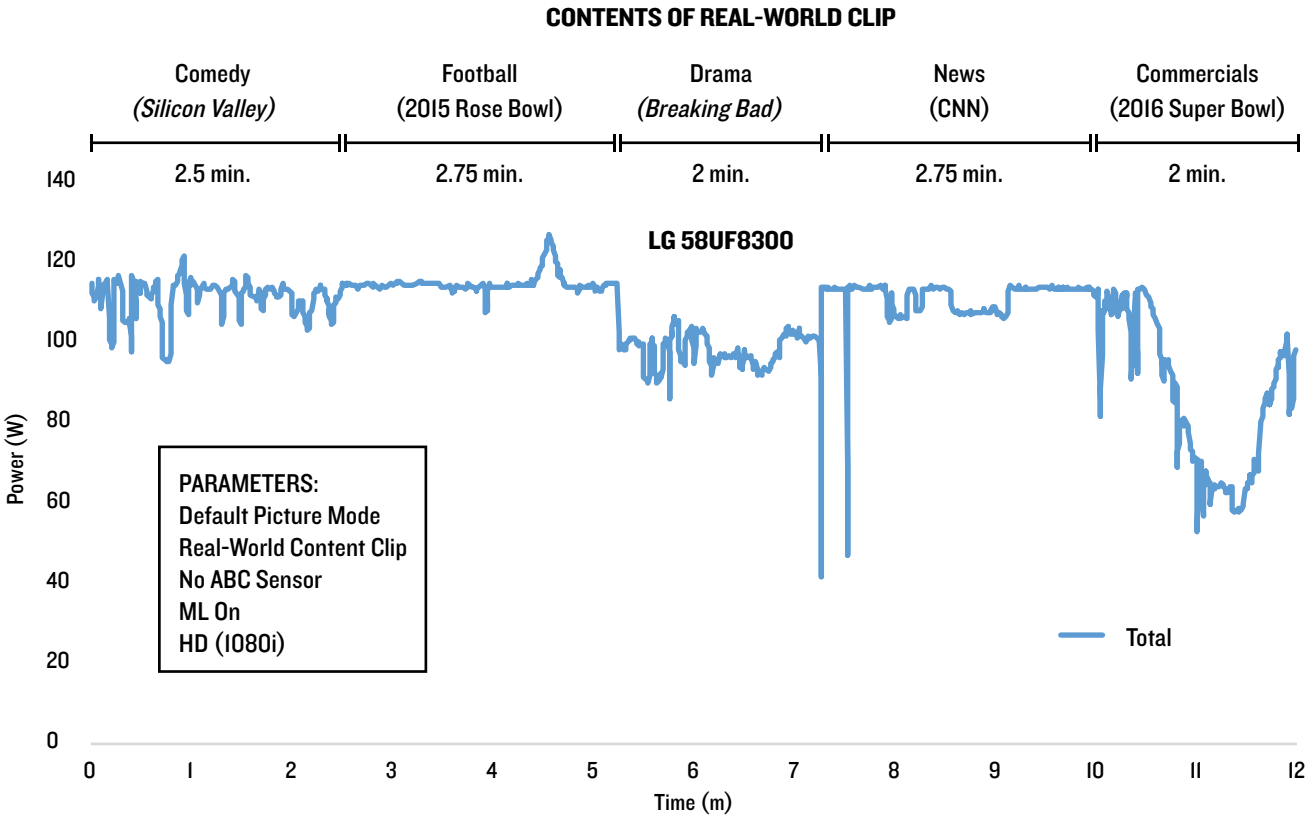
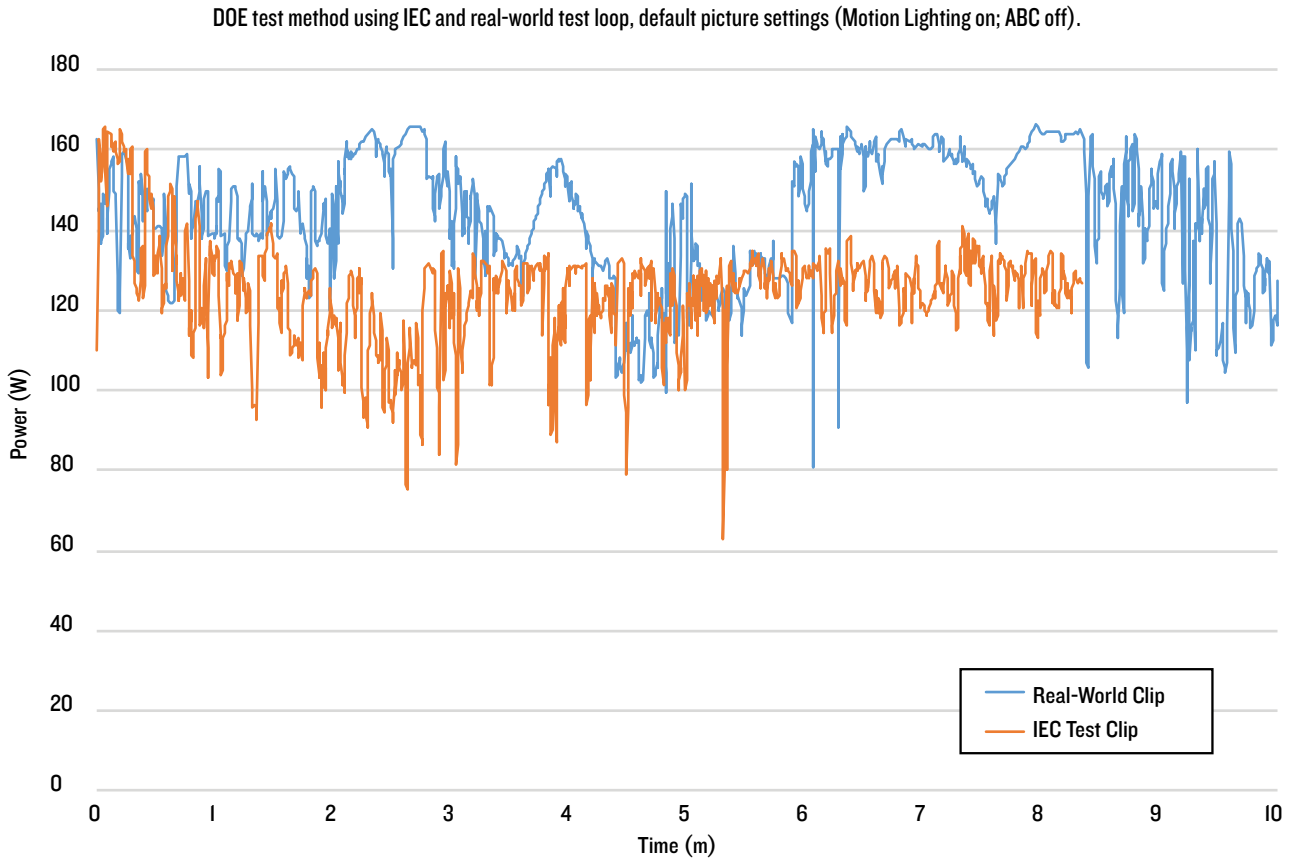


Figure 4: Samsung UN55JS9000 power use for the IEC and RWC test loops



We then compared the average power levels for the 10-minute IEC test loop and the 12-minute RWC test loop with the televisions' energy-saving ABC and MDD features switched off. Table 3 shows virtually no difference in the reported power measurements between the two test loops with the energy-saving features disabled. Note: The IEC test loop was carefully constructed in 2008 to represent the average picture levels (APLs) based on analysis of more than 100 hours of global TV content.[9] Given the similar power use results when playing the IEC test clip and our RWC test clip, one could presume similar APLs.

After confirming that our test loop was sufficiently representative of real-world content, we then used the RWC loop to retest the TVs with their energy-saving features enabled. This was intended to help answer the important question of whether MDD and ABC had a similar effect when viewing the real-world content as when viewing the IEC test loop.

Table 3: Comparison of average power use when playing real-world test loop versus IEC test loop with ABC and MDD turned off, where applicable (LG 8300, no ABC; VIZ RS65-B2, no ABC or MDD)

	SAM 7100		SAM 9000		LG8300		VIZ RS65-B2	
	Average Power (W)	Average Power Difference (Real-World—IEC)/IEC	Average Power (W)	Average Power Difference (Real-World—IEC)/IEC	Average Power (W)	Average Power Difference (Real-World—IEC)/IEC	Average Power (W)	Average Power Difference (Real-World—IEC)/IEC
Real World	124.21	-0.6%	178.17	-1.3%	118.89	-0.2%	242.82	-0.8%
IEC	124.91		180.50		119.10		244.73	

Table 4: Impact of motion-detection dimming on average power use when playing the IEC and RWC test loops. DOE test method, default settings. Positive number indicates reduced power use with MDD

Content Played	SAM 7100	SAM 9000	LG 8300
IEC Test Loop	13%	16%	58%
Real-World Test Loop	–1% (1% higher with MDD on)	9%	13%

Key findings from these measurements:

1. MDD did not save nearly as much energy when playing the RWC test loop as during the IEC test loop. This was particularly true of the LG TV tested, where disabling MDD resulted in a reported on-mode power increase of 58 percent with the IEC test loop, compared with only a 13 percent increase with the RWC test loop. Stated another way, the average power level for the LG TV was 75 watts when playing the IEC test loop but increased to 105 watts when playing the RWC test loop. These are very different outcomes, even though the TV's settings remained the same during both tests.
2. The impact of Samsung's MDD feature on power use for the TVs we tested was not as large.

See Appendix 3 for the raw data used to generate Table 4.

SHORT SCENES AND FREQUENT SCENE CUTS: POTENTIAL CAUSE FOR MDD ACTIVATION

To better understand why some TVs use less energy when playing the IEC test clip, and to illuminate possible differences between the IEC clip and the RWC clip, Ecos Research measured the average scene length in both loops and observed that:

- The average scene length of the IEC test loop was 2.29 seconds. Over the entire 10-minute loop there were 26 scene cuts (changes) per minute.
- In comparison, the average length of the scenes in the RWC test loop was 3.89 seconds, about 70 percent longer. The commercials that were part of the RWC test loop had frequent scene cuts, and their average scene length was only 1.56 seconds. Without the commercials, the average scene length in the real-world test loop jumps to 5.56 seconds.
- Based on these data, it became clear that the MDD technology, while designed to monitor the degree of pixel changes from one frame to the next to detect motion, will be engaged even more extensively by rapid scene cuts because the percentage of pixels changing in that situation is so high. The only sustained drop in power use during playback of the RWC loop occurred when commercials were played and the average scene length during commercials was even lower than the average scene in the IEC test loop.

A deeper analysis of each component of the real-world content test loop is provided in Table 6.

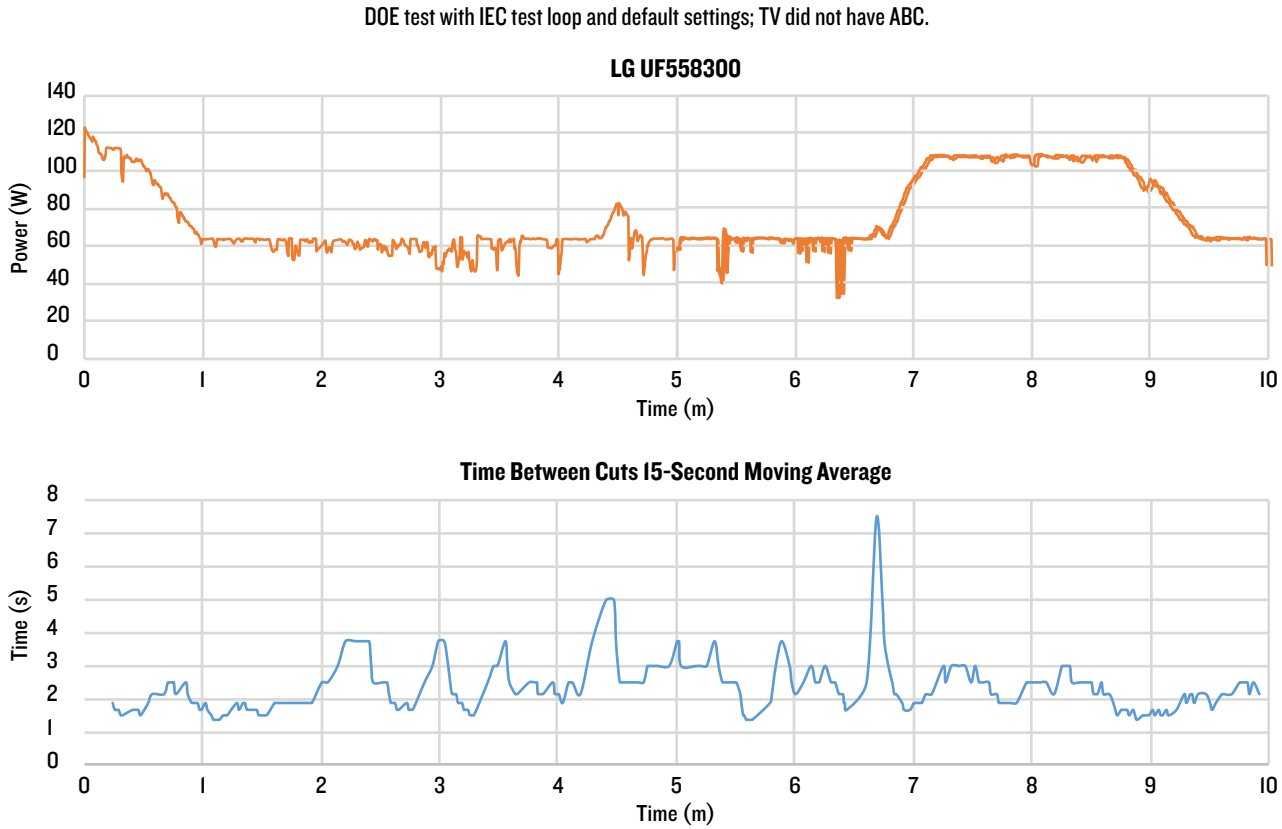
Table 5: Average scene length and number of scenes in IEC and real-world test loops

	IEC Test Clip	Real-World Content	Real-World Content Without Commercials	Real-World Content Commercials
Clip Length (min.)	10	12	10	2
Total Cuts	261	184	107	76
Cuts/min.	26.1	15.33	10.7	38
Total Scenes	262	185	108	77
Average Scene Length (sec.)	2.29	3.89	5.56	1.56

Table 6: Detailed statistics of the real-world content clip

	Silicon Valley	Rose Bowl Football	CNN	*Breaking Bad*	Commercials
Clip Length (min.)	2.5	2.75	2.75	2	2
Total Cuts	50	20	16	18	76
Cuts/min.	20	7.27	5.82	9	38
Total Scenes	51	21	17	19	77
Average Scene Length (sec.)	2.94	7.86	9.71	6.32	1.56

Figures 5a and 5b: Average power and moving average of time between scene cuts for the LG UF558300 for minutes 0–10



Ecos Research combined the test data on power use while playing the IEC test loop and the time in the test loop when scene cuts occurred. These plots for the first and second halves of the test loop are shown in Figures 5a and 5b.

In reviewing these plots we observed:

- There was a sudden and sustained drop in power use during the first minute of testing. Power dropped from approximately 120 watts to 60 watts and remained near that level for an extended period.
- During this first minute, the average scene length was around 2 seconds.
- Just after 6.5 minutes, the average scene length jumped to 7 seconds and the power ramped up with a slope similar to that of the initial drop.
- The power returned to the original levels of near 120 watts for a few minutes and then ramped back down toward about 60 watts and remained there. This is likely because the average scene length again became very short, and the TV's backlight was responding to the resulting dramatic differences from frame to frame.

In developing the MDD algorithms, TV manufacturers' designers may have chosen to reduce the TV's power usage by dimming or briefly turning off the backlight during an extended period of frequent scene cuts and short scenes.

The TV's processor also would be smart enough to detect when the scenes were longer and to ramp up and maintain screen brightness (and power) accordingly, to ensure a positive consumer viewing experience.

This strategy could also allow a TV designer to exploit the apparent anomaly in the test loop whereby the scenes are much shorter than in most typical viewing experiences. The manufacturer could then publish average power levels and operating costs that are very low under the test but are likely to be higher during actual viewing.

The first 60 seconds of testing on the Samsung TV also revealed a sudden drop in power use, but the magnitude was not as large. This is partially because the LG TV we tested did not have ABC (it used its MDD feature, Motion Eye Care, to achieve all of the screen dimming needed to meet ENERGY STAR® energy efficiency levels), whereas the Samsung TVs did (they used some screen dimming from ABC and some from its MDD, Motion Lighting). As the screen brightness and resultant power levels are already reduced dramatically by ABC, it makes sense that we observed a smaller official impact for Motion Lighting on the Samsung TVs. As seen earlier in Table 2, Motion Lighting had a much bigger impact when ABC was off: a 45 percent increase when compared with the DOE test result for the Samsung UN55JS9000.

3. Results of Persistence Testing of Energy-Saving Features

Because we saw dramatic differences in measured power use depending on whether the ABC or MDD feature was on, we surveyed a cross-section of televisions in retail stores to assess the persistence of these features. In particular, we investigated the following questions:

- Did these features persist or "stick" if the default picture setting was changed?
- Did other settings changes affect the persistence of these energy-saving features?

Each television we assessed was first configured with all of its default settings. We then scrolled through the different menus and documented the impacts of settings changes we made. Our results are summarized in Appendix 2.

Each manufacturer has its own set of names for its various picture settings. Even the default or standard settings go by different names, some of which are not intuitive. For example, the default setting for LG TVs is termed Auto Power Save (APS). This yields a power usage completely different from its option called Standard, as will be discussed later.

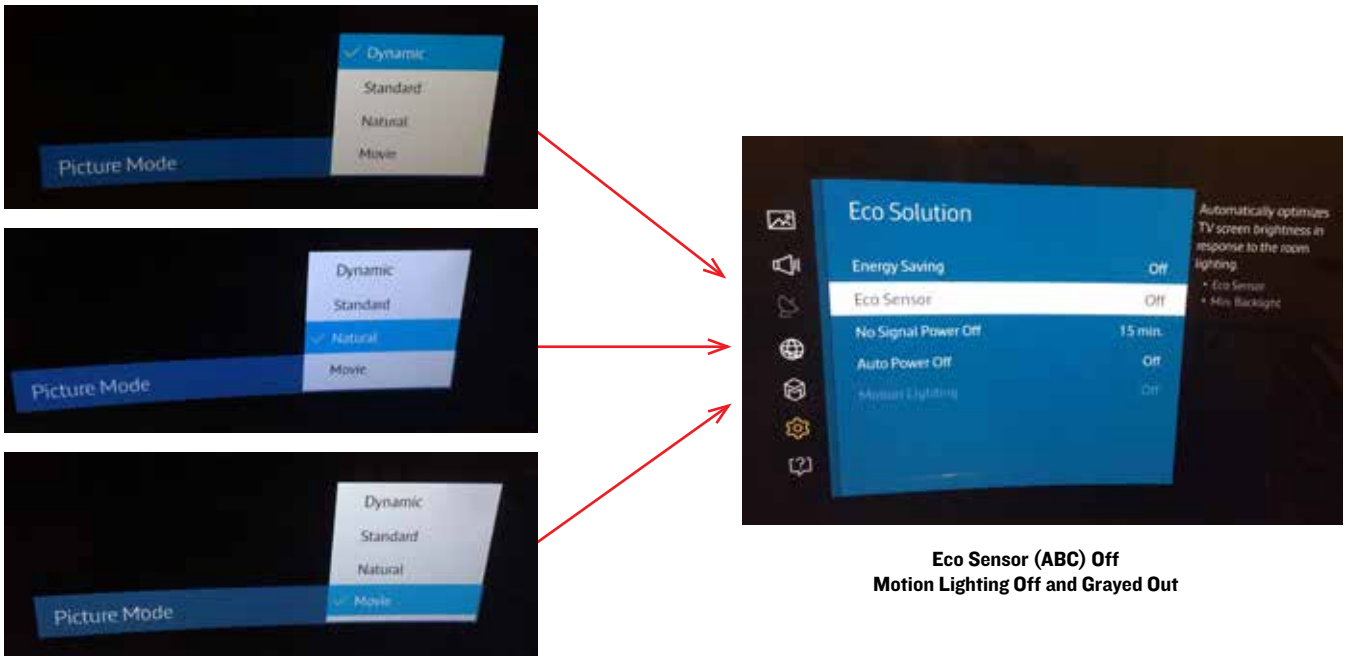
Our first set of tests examined what happens to ABC and MDD (if present) when the user changes the preset picture setting. Much to our surprise, energy-saving features were, as a result, automatically disabled on almost all of the Samsung, LG, and Vizio TVs we tested. In addition, the user was neither notified of these changes nor given an adequate and effective on-screen warning that energy use would increase if he or she proceeded with the change to the picture mode setting. The only type of warning language we encountered during our testing was text on the bottom of Vizio's picture setting page stating that Standard, the default picture setting, meets ENERGY STAR requirements.

Following are sample screen shots intended to illustrate each manufacturer's user interface and how its software design affects the persistence of its energy-saving features.

The images for Samsung's TV (Figure 6) show that both Eco Sensor (the manufacturer's term for ABC) and Motion Lighting (its term for MDD) are enabled in the TV's default picture setting, called Standard. However, once the picture setting is changed to another option—Dynamic, Natural, or Movie—both of these energy-saving features are automatically disabled.

Figure 6: Screen shots of Samsung's user interface

These demonstrate how Eco Sensor (Samsung's term for Automatic Brightness Control [ABC]) is disabled when the main picture setting is changed from Standard.



Eco Sensor (ABC) Off
Motion Lighting Off and Grayed Out

When these changes are made, there is no warning prompt, nor is the user offered the option to keep the energy-saving feature enabled. The MDD setting is grayed out and, for some models, the user is unable to reselect this feature from this screen. Instead, the message "This function isn't available" appears, as shown in Figure 7.

Of perhaps even greater concern is the way the software in some Samsung models was designed so that a single click to adjust the contrast, brightness, or backlight levels in the menu causes MDD to be automatically disabled, as shown in Figure 8, again without adequate notification to the user. ABC was also disabled when any change was made to the backlight setting.

Figure 7: Screen shot of Samsung TV showing inability to reselect Motion Lighting

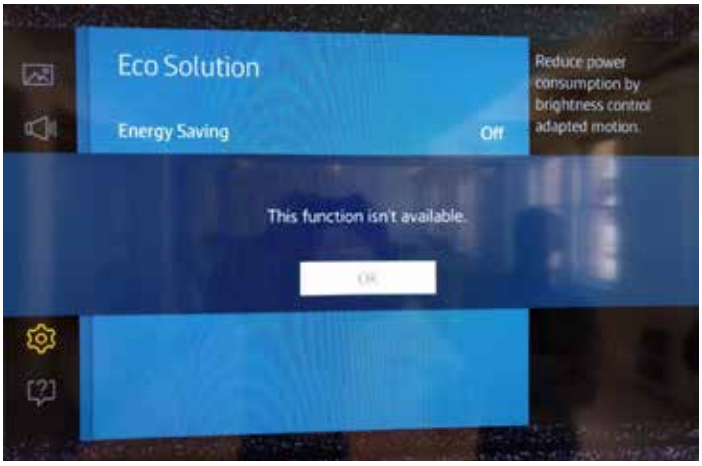


Figure 8: Screen shot showing Samsung TV default settings

Changing the contrast, brightness, or backlight setting caused the energy-saving features on some Samsung TVs to be automatically disabled.

The Vizio TVs we surveyed did not have the MDD feature, but some had ABC. When present, ABC was enabled by default and was often set at medium. These TVs displayed this text at the bottom of the screen, as shown in Figure 9:

"Select from preset picture modes. Standard picture mode meets ENERGY STAR® requirements. For the best picture, use Calibrated mode."

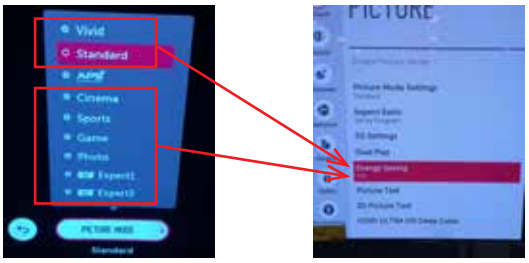
Given the likely preference for best picture quality, the average user will be tempted to select the Calibrated mode, which automatically disables ABC, as our qualitative testing showed. The backlight level then jumps from 75 to 100, which tends to push power consumption higher.

Figure 9: Screen shots of Vizio TV language encouraging selection of Calibrated mode, disabling ABC

The screen shot at the top shows how the TV is received, in Standard picture mode and with ABC enabled and set at Medium. When Calibrated picture mode is selected (bottom), ABC is automatically disabled.

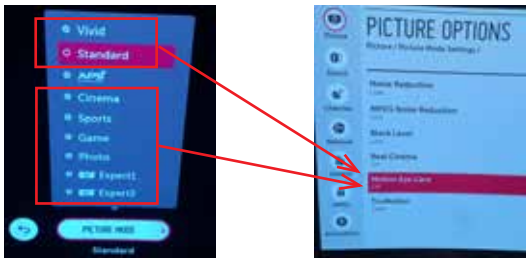
Figure 10: Screen shots demonstrating how selection of LG's Standard picture mode disables both Energy Saving (ABC) and Motion Eye Care (MDD)

All Picture Modes Beside APS (Auto Power Save) Disable ABC



Energy-Saving (ABC) Off

All Picture Modes Beside APS (Auto Power Save) Disable Motion Eye Care



Motion Eye Care Off

LG TVs had a large selection of picture modes and used the unique term Auto Power Save (APS) to designate their default picture setting. Selecting any other picture setting disabled both ABC (called Energy Saving) and MDD (called Motion Eye Care), if present. Even Sports mode, which often has the type of fast-changing content that MDD was designed for, causes this feature to be disabled.

Curiously, choosing the setting called Standard also caused both energy-saving features to be disabled, as shown in Figure 10. However, changes made to sub-settings like backlight or contrast did not.

We also collected information on how easy (or difficult) it is for the user to re-enable the energy-saving features after they have been turned off due to setting changes. The results varied by manufacturer, and in some cases it was not possible to re-enable an energy-saving feature without completely resetting the TV. (See Appendix 2 for details.)

It's possible these manufacturers designed their TVs this way in order to achieve a low energy use result in the DOE test. Further, some manufacturers may have assumed—perhaps incorrectly—that if a user acted to change a picture setting, this meant the user wanted the screen to be brighter; thus they decided to always disable the energy-saving features so the TV could provide a brighter picture, regardless of the ambient light level or the content being shown. The resulting additional power use is not captured by the DOE test method as currently written.

The Sony and Philips TV models we tested retained their energy-saving features even when the picture setting or a sub-setting was changed. This is best practice and one we hope other manufacturers will follow.

4. Energy Impact of Playing Content with Latest Format: HD (4K) with High Dynamic Range

TV manufacturers, studios, and content distributors (like Netflix) have begun to heavily promote UHD + HDR content, which is intended to deliver an enhanced consumer experience. When video content encoded in HDR is played on TVs with HDR playback capability, the brightest parts of the image can be much brighter and the darkest parts can be darker, while still retaining detail. Color vividness and saturation can also be improved. There are two competing HDR formats: HDR 10 and Dolby Vision.

Because we could not find any publicly available data on the incremental power use of HDR-ready TVs when playing HDR content, we looked into this issue further and took our own measurements. In our prior study, we accessed two movies that were available both in UHD and in UHD + HDR versions and played them on the Samsung UN55JS9000 TV.[10] (Recall that UHD TVs have a horizontal resolution of 4,000 pixels and that 4K is synonymous with UHD.) We found that playing the UHD + HDR version of the two movies increased the power use of this TV by 40 percent and 54 percent compared with the UHD versions. The details of our testing (completed with ABC off) are shown in Table 7.

Table 7: Comparison of Samsung UN55JS9000 measured average power use while playing movies in UHD and UHD + HDR. Default picture settings, ABC turned off, movie viewed during testing

Movie Title	Average Power (Watts) UHD Version	Average Power (Watts) UHD + HDR Version	Percent Increase in Power Use
Exodus: Gods and Kings	106.9	149.4	40%
Maze Runner	94.2	145.4	54%

Figure 11 shows how on-mode power compares for the two versions of the movie *Exodus: Gods and Kings*.

Figure 11: Samsung UN55JS9000 on-mode power vs. time plot for the UHD and UHD + HDR versions of *Exodus: Gods and Kings*

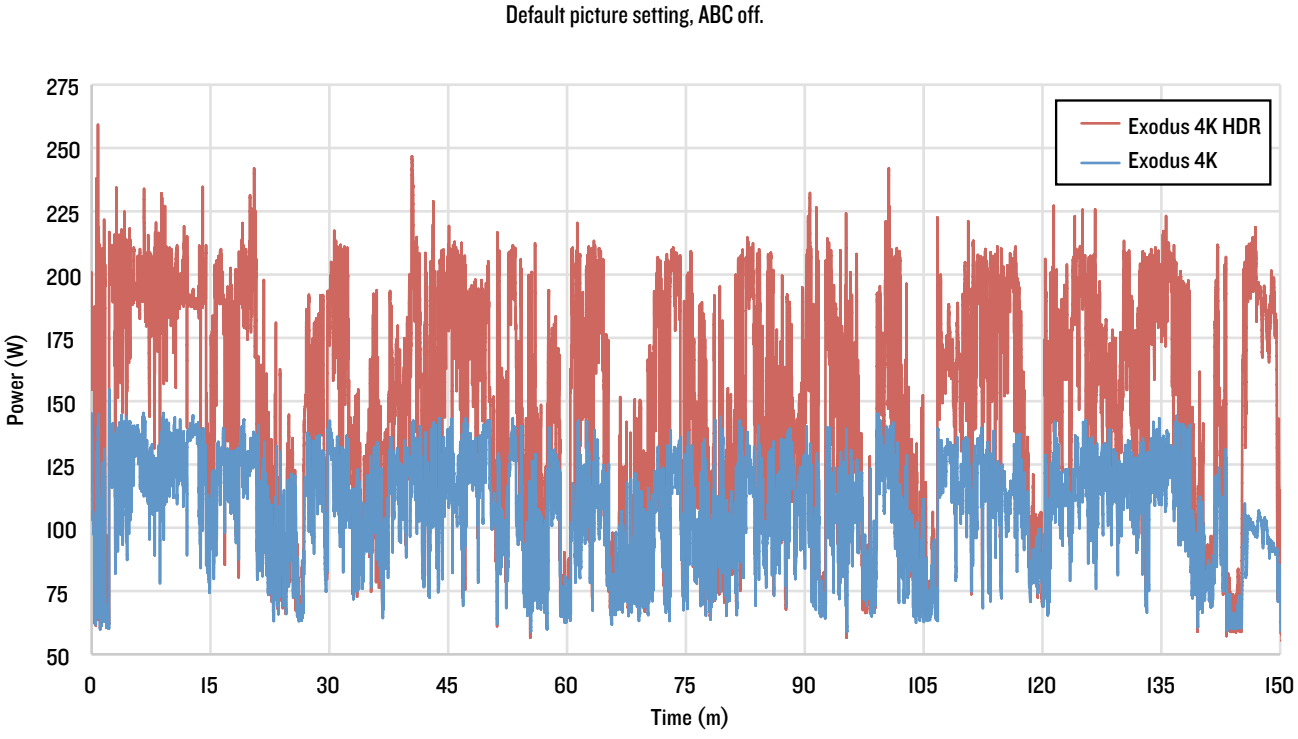
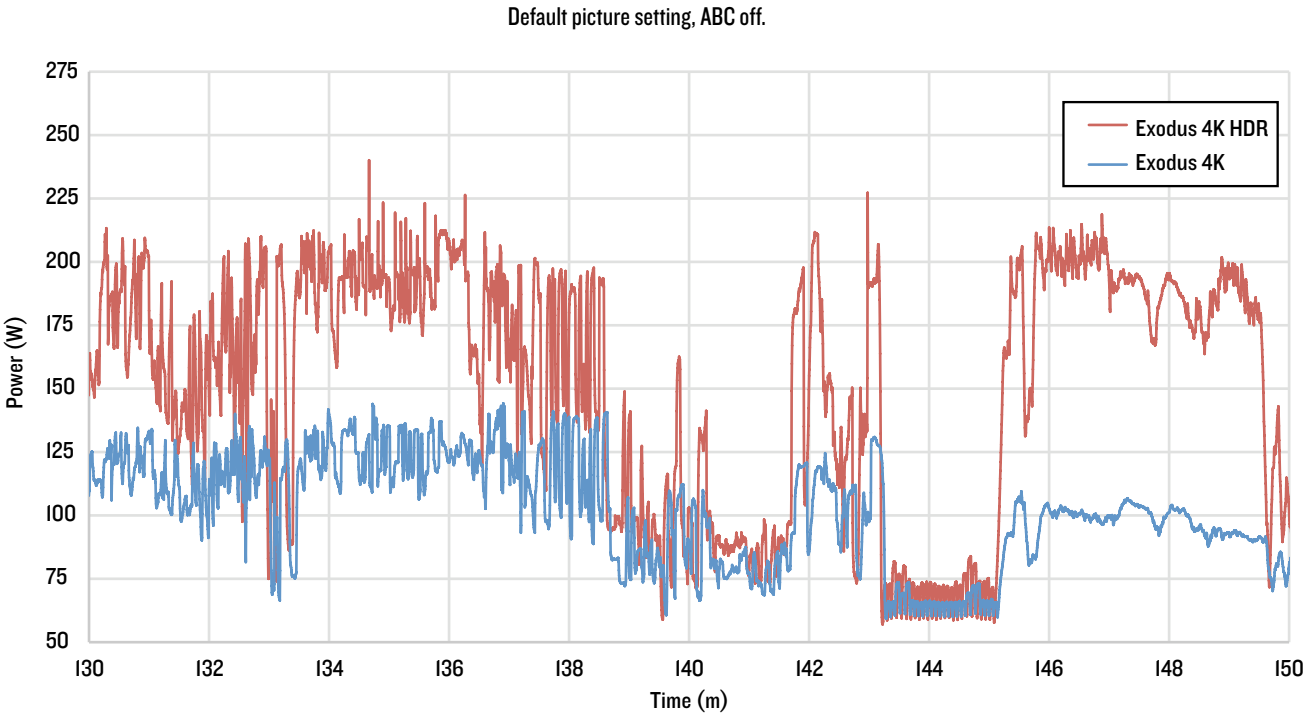


Figure 12: Time slice of Samsung UN55JS9000 on-mode power vs. time for the UHD and UHD + HDR versions of *Exodus: Gods and Kings*



Further darkening the dark portions of scenes has a very modest impact on power use, but brightening the already bright portions can significantly increase power use. This is why the percentage impact on power consumption from HDR differs from one film to the next and even from one portion of a film to another. Figure 12 provides a time slice of the power use during minutes 130 to 150. Note the minimal extra power used by HDR from minutes 142 through 144 (when the scenes were quite dark) and the much greater extra power used immediately thereafter. It is evident that great care must be taken when deciding what content or portion of a movie to use when performing testing.

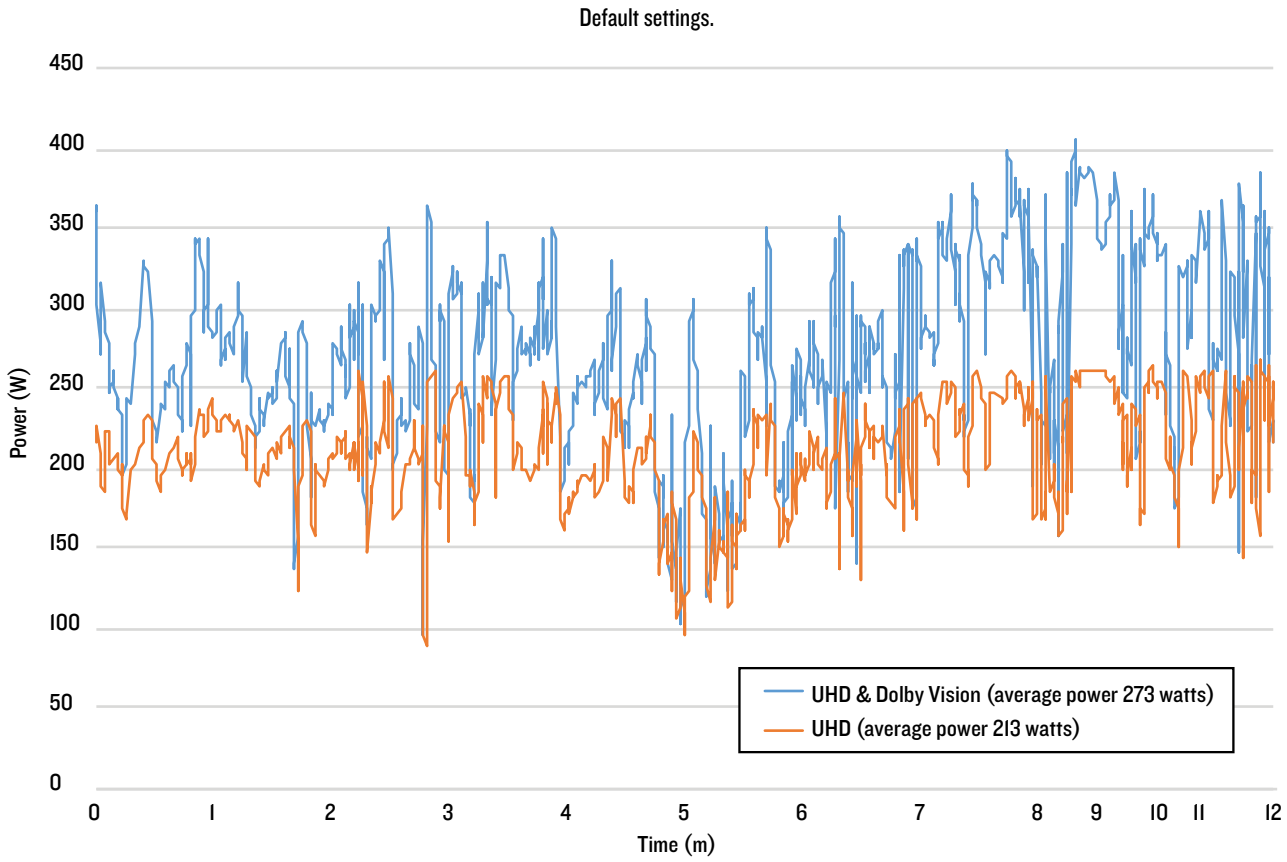
We tested the average on-mode power use for the movie *Mad Max* in both UHD and UHD + Dolby Vision on Vizio's 65-inch Reference Series TV, its highest-performing TV line designed for home theater applications. Figure 13 shows the results of this testing, in which the UHD + Dolby Vision version used 273 watts average power compared with 213 for the UHD version—a 28 percent increase.

In summary, we found that playing UHD + HDR content increased power consumption by roughly 30 to 50 percent compared with the UHD version of the same movie on the same television. These values should be treated as confirmation that UHD + HDR content draws more power than standard UHD content. Recent testing in Europe using a new strawman clip of original UHD content and encoded in standard UHD and UHD + HDR largely confirms these findings, in some cases revealing power consumption increases of more than 100 percent between non-HDR and HDR versions of the same UHD test clip. (We discuss the strawman clip at greater length in the next section.) Regulators and labeling organizations should move to add this type of content to their test methods because this incremental power increase will not otherwise be captured during testing, nor will it be reported.

Last, we tested the effect of motion detection on TV power use when playing a UHD + HDR movie. We played *Maze Runner* on both Samsung TVs, first with MDD on and then with it off. We found that MDD made virtually no difference in the energy use of the TVs we tested.

In follow-up conversations with some leading manufacturers, we learned their energy-saving features are temporarily disabled when the TV plays UHD + HDR content. This is quite significant, as the power levels reported per the DOE test method—based on default TV settings and measured while playing HD content (the most common video format in 2016)—are half the values observed when playing UHD + HDR content, and in some cases even less. This is not represented by the test.

Figure 13: Vizio RS65OB2 on-mode power use while playing UHD and UHD + Dolby Vision HDR versions of *Mad Max*



5. Why All This Matters: The Energy, Economic, and Carbon Impacts

The various examples provided in the energy-savings persistence section illustrate how the user can inadvertently disable key energy-saving features. This has large energy consequences, in some cases doubling a TV's energy use. In addition, playing real-world content instead of the IEC test loop or playing UHD + HDR content can also dramatically increase the measured power levels over those reported under the DOE test method, as illustrated in Figures 14 and 15. For example, the Samsung TVs that would report an on-mode power level of about 60 or 80 watts per the official DOE test may actually be consuming 120 or 181 watts, respectively, in viewers' homes. In such cases, the viewer's TV will use much more energy than the consumer expected from the TV's published energy rating.

The red segment of each bar in Figure 14 shows the TV's power use when playing the UHD + HDR version of the 10-minute strawman test clip, developed in the United Kindgom by the energy efficiency group CLASP and its contractors as part of the European STEP program.[11] This clip was made precisely for the purpose of understanding how much higher TV energy use would be with more realistic content instead of the IEC test clip. This new video clip was produced in HD, UHD, and UHD + HDR versions and contains a variety of custom-filmed clips in HDR of street scenes, sports, advertising, television dramas, and talk shows. The STEP project team is working with the European Commission to replace the IEC 62087 video clip with this new test clip, which retains the same average picture level, a metric indicating video content brightness. Some of the data in Figure 14 were obtained from the Northwest Energy Efficiency Alliance (NEEA) in Portland, Oregon, via personal communication between Ecos Research and NEEA, which is also interested in reducing TV energy use and has commissioned its own testing.

We can look more closely at a single TV and clearly see the effect of settings and content changes. In this case, the TV's annual energy use more than doubles simply when the energy-saving features are disabled. This TV consumes even more energy when playing HDR content. Note that these values represent the TV's annual energy use, expressed in kilowatt-hours per year, and are based on a daily viewing rate of five hours per day, per DOE guidance. If in the future HDR content is played most of the time on big-screen TVs like the Samsung 9000 model, the TV may use as much energy per year as a 2016 energy efficient 18-cubic-foot refrigerator.[12]

Figure 14: Annual energy use levels and 10-year electricity costs when each TV was tested under various conditions

The light blue, dark blue and and orange segments of each bar represent power levels when tested with the IEC test clip; the red segment reflects testing with the strawman HDR clip. Assumed duty cycle of five hours per day and average national electricity cost of 12.6 cents per kWh.

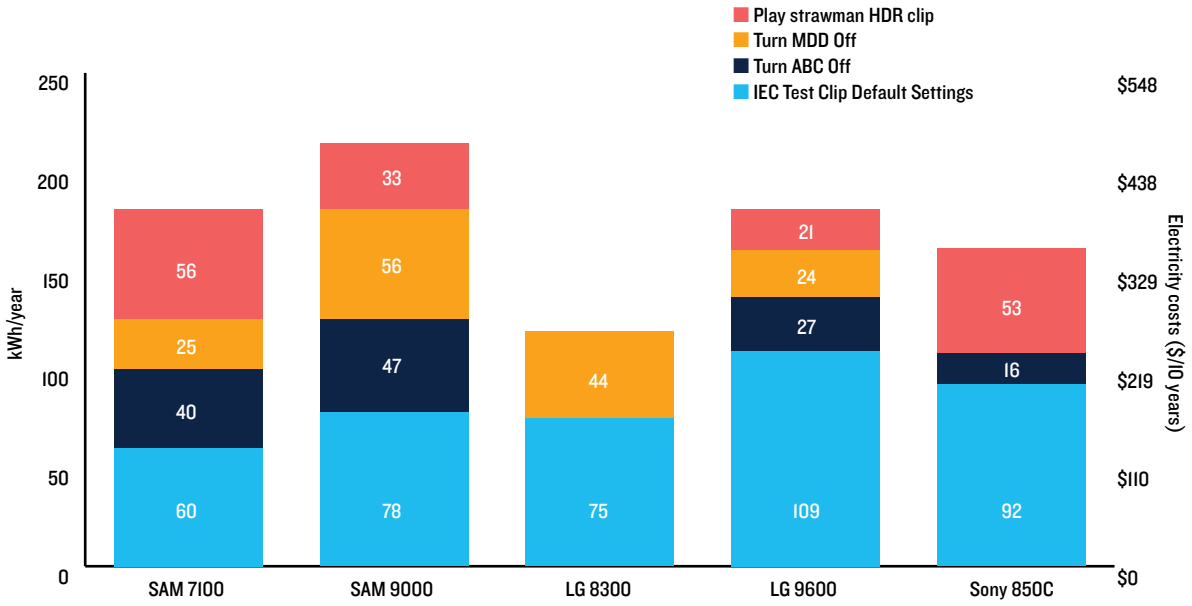
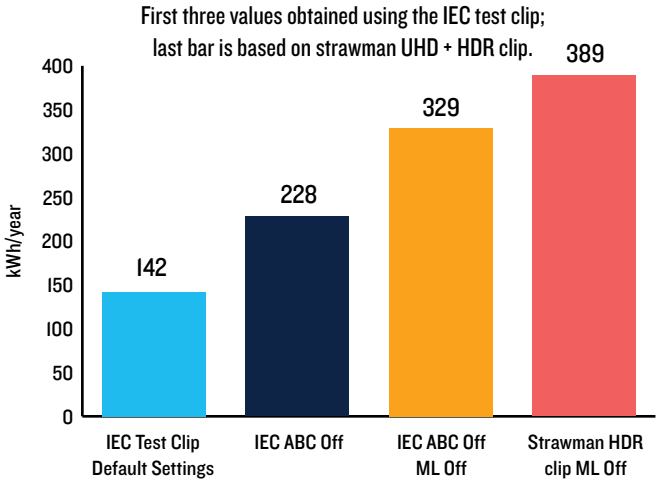


Figure 15: Range of annual energy use for the Samsung 55-inch 9000 TV under various conditions



NATIONAL IMPACTS

In order to put all these findings into perspective, Ecos Research reviewed the results of the testing conducted for our 2015 report and this follow-up study and created a model to estimate how much more energy TVs use in the real world than the reported DOE test results would suggest. These calculations, explained in more detail in Appendix 1, show that a few clicks of the remote control by just one-third of the U.S. consumers who purchased 32-inch or larger Samsung, LG, or Vizio TVs in 2015 will cause more than $600 million of extra electricity costs over the 10-year life of their televisions. This translates to 2.7 million metric tons of additional climate change pollution from power plants across the nation. And this is the impact of just one year of U.S. TV sales.

In reality, the persistence problems surrounding energy-saving features have likely been eroding energy savings from ABC and MDD for the past several years. If we assume two years of new TV sales, the gap between national energy calculations for installed TVs based on DOE test results and how much energy TVs might actually use in real-world use over their lifetime likely exceeds $1.2 billion, creating an additional 5.4 million metric tons of carbon dioxide pollution in the U.S. market alone. To put that into perspective, this is greater than the annual residential electricity consumption for all of Los Angeles. For more information on the calculation method and assumptions, see Appendix 1.

Some consumers may see the cost to operate their new big-screen TV increase by $100 to $200 or more over its 10-year lifetime simply because they unintentionally disabled its energy-saving features, as shown in Table 8.

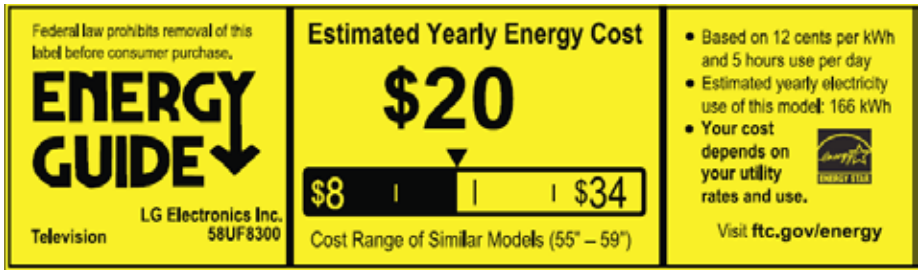
Keep in mind, too, that these numbers are based only on HD content viewing. When we factor in the future prevalence of UHD + HDR content, the impact will be even larger. Early testing suggests that on-mode power consumption increases by 30 to 50 percent when playing UHD + HDR content compared with the UHD version.

As a result, owners of a recent Samsung, LG, or Vizio television who change the default picture setting will experience much higher annual energy levels than those reported on the yellow EnergyGuide label.

Table 8: Impact of disabling default energy-saving features. ABC: automatic brightness control; MDD: motion-detection dimming, called Motion Lighting by Samsung and Motion Eye Care by LG

	SAM 9000 55"	SAM 7100 55"	LG 8300 58"	Vizio RS65-B2 65"
Default Features	ABC and MDD	ABC and MDD	MDD	Neither
On-Mode Power with Default Energy-Saving Features On (watts)	78	60	75	245
On-Mode Power with Default Energy-Saving Features Disabled (watts)	181	125	119	245
Increase	138%	108%	59%	0%
Additional Cost of Electricity over TV Lifetime (10 years)	$232	$136	$101	n/a

Figure 16: Sample EnergyGuide label for the LG TV we studied



6. Conclusions and Recommendations

In summary, we find that for many new televisions, the values derived from DOE testing protocols and shown on the EnergyGuide label may not accurately reflect real-world energy consumption or cost. We have found multiple independent pathways that indicate anywhere from 50 to more than 100 percent higher energy use in the TVs we tested, caused by users taking one or more of the following actions:

- Watching video content that is more typical than the IEC clip used in DOE testing. Typical content may lack enough rapid motion or adequately frequent scene changes to deliver the level of energy savings that MDD achieved during the DOE test.
- Adjusting contrast, brightness, or backlight settings even slightly on one manufacturer's TV and unknowingly switching off MDD and in some cases both MDD and ABC.
- Choosing a picture setting different from the default setting in which the TV was shipped, often boosting backlight brightness and unknowingly switching off ABC and MDD.
- Following onscreen prompts or advice from popular websites encouraging them to manually turn off ABC or switch to a different picture display setting for an even brighter picture all the time.
- Playing UHD + HDR content from streamed or disc-based sources, temporarily switching off energy-saving features and boosting screen brightness and power use (without the user's knowledge).

RECOMMENDATIONS FOR POLICYMAKERS, MANUFACTURERS, AND CONSUMERS

To help ensure that the testing and reporting of TV energy consumption better represent real-world usage, and to preserve the recent gains in TV energy efficiency, we make these recommendations:

1. **Manufacturers should discontinue their practice of automatically disabling energy-saving features when a picture setting is changed.** We have met with some of the leading manufacturers, and they are exploring various options for improving the persistence of their energy-saving features. To date, LG has been the most proactive and responsive in developing software improvements that address our concerns. We understand Samsung is discontinuing its practice of disabling energy-saving features in response to changes to sub-settings like contrast or backlight.
2. **The DOE test method and test loop for measuring average on-mode power should be updated. The agency should provide detailed guidance on the expected persistence of energy-saving features after initial setup.** If the energy-saving features are automatically disabled through some other consumer action, or if the default settings are changed by the TV without any user input, we recommend the television be tested without these energy-saving features turned on. The DOE should be able to make this change relatively quickly. The DOE also should provide explicit guidance on how it will treat future firmware updates to Internet-connected TVs that cause a significant increase to their energy use. Changes to the test loop are critically needed as well but will take more time. A new test loop would: (a) contain content that is more representative of real-world viewing (i.e., uses more typical scene lengths) and (b) include content produced in UHD + HDR to ensure its incremental power use is captured by the test. In addition, the DOE and U.S. Environmental Protection Agency (EPA) should develop a more sophisticated enforcement scheme that utilizes multiple versions of the official test loop during verification testing. These changes would make it harder for manufacturers to design their TVs to produce results during government testing that are superior to those achieved during actual usage.
3. **Consumers should be encouraged to scroll through their settings menus and to restore the energy-saving features in their TVs, particularly automatic brightness control.** (See Table 9 for each manufacturer's term for this feature.) Consumers should specifically avoid the overly bright and most energy-intensive picture mode setting called Vivid or Dynamic. A well-designed TV with ABC will, for example, increase the screen brightness levels when the TV experiences high levels of sunlight but will produce a more appropriate picture and use considerably less energy when ambient light levels are lower.

Table 9: Names used by leading manufacturers to describe energy-saving features

TV Manufacturer	Automatic Brightness Control (ABC)	Motion-Detection Dimming (MDD)
Samsung	Eco Sensor	Motion Lighting
LG	Energy Saving—auto	Motion Eye Care
Vizio	Auto Brightness Control	n/a

4. **The EPA should update its ENERGY STAR specifications for TVs and continue its verification efforts.** We encourage the DOE to work with the EPA to update the test method, and the EPA should update its specification as soon as possible. This work is critical for preserving the hard-earned trust, value, and integrity that the ENERGY STAR brand represents to consumers.

5. **The TV industry should pay greater attention to limiting the increased energy use caused by displaying HDR content on HDR-ready TVs.** Manufacturers are encouraged to incorporate energy-saving features such as ABC during HDR viewing and to incorporate new energy-saving technologies, such as quantum dots. As HDR is still in its infancy, manufacturers who act now can minimize the incremental environmental impacts caused by a shift to HDR technology.

These efforts should result in more accurate energy use disclosures that better represent how a TV is really used. Consumers can use this information with greater confidence as they shop for more energy efficient models and can better assess the operating costs of competing models. This improved set of policies will also help ensure a level playing field for manufacturers so they can fairly compete in the marketplace. And most important, better-designed TVs will use less energy, reducing consumer electricity bills and carbon pollution.

Appendix 1

Calculation of National Energy Impact of Energy-Saving Features

We estimated the national impact of observed setting persistence issues using the following approach. For each of the major U.S. brands, we estimated Pacific Northwest (PNW) 2015 regional market share, unit sales, and total energy consumption for 32-inch and larger televisions based on analysis performed by Energy Solutions on behalf of the Northwest Energy Efficiency Alliance (NEEA) using NPD's market tracking service and publicly available NPD reports. Energy Solutions' analysis included a detailed estimate of average TV unit energy consumption (UEC) by size bin, but not by brand. We used these average UEC values here—instead of UEC values based on power measurements taken during this study—since the TVs tested for this study are not representative of the broader TV market in terms of the mix of sizes and features. As a result, this analysis assumes that all brands have the same average unit energy consumption across their product line. We scaled regional results to national using population count. We then estimated the percent increase in energy when ABC and MDD are disabled for each brand using measurements performed by Ecos Research on behalf of NRDC. To calculate the extra energy used nationally by TVs when energy-saving features are turned off, we assumed that one-third of TV owners changed their TV settings.

Table A-1: Calculation of national energy and environmental impact of disabling energy-saving features of 2015 TVs. National numbers assume energy-saving features are disabled for one-third of all TVs

		Market Share*	U.S. Sales of 32+" TVs (million units)	U.S. Energy Use of 32+" 2015 Sales in Default Config. per DOE Test (GWh)	U.S. Energy Increase if ABC and MDD Disabled (%)**	U.S. Energy Increase if ABC and MDD Disabled on 33% of TVs Sold in 2015 (GWh)	U.S. Cost of Energy Increase ($M)	U.S. Additional CO_2 Emissions (Thousands of Metric Tons)	Average Unit Energy Cons Increase (kWh)	Per Unit Cost of Energy Increase ($)
Annual	Samsung	23%	6.4	713	123%	290	37	162	138	17
	Vizio	20%	5.6	620	66%	135	17	75	74	9
	LG	9%	2.5	279	59%	54	7	30	66	8
	Total	52%		1613		479	60	268		
10-yr Total				16127		4789	603	2677		

*Source: NPD Technology Topline Report, 2016

**Source: Calculated using results of both 2015 and 2016 NRDC studies

Note: This analysis assumes that all brands have the same average unit energy consumption

By these calculations, households that purchased TVs in 2015 will pay an extra $603 million in electric bills over the lifetime of these TVs. If the impact from 2016 sales is approximately the same, then the total cost to households would be around $1.2 billion. Therefore, it is safe to say that if only one-third of owners adjust their TV settings, automatically disabling ABC and MDD, U.S. households will face more than $1 billion in additional electricity costs. This number may be conservative, as these manufacturer practices may go back further than two years and may continue in the future.

Ecos Research's measurement results are noted in Table A-2, which includes results for the major brands cited in Table A-1 and also includes Panasonic and Sony models for additional information only (these models are not included in the national impact calculations). The percent increase figures by brand were calculated by taking a simple average of the percent increase for models we tested made by that brand, except for Vizio. In that case, we gave only 10 percent weighting to the 65-inch Vizio Reference Series model and 45 percent each to the other two Vizio models (both 55-inch), since we estimate that Vizio's Reference Series televisions have relatively lower sales, given their premium sales price. We then calculated the national energy impact in GWh, by major brand, if ABC and MDD were disabled in their models when users made simple changes to their television settings. We converted the national energy consumption value to electricity costs and carbon dioxide emissions using the conversion factors and assumptions in Table A-3.

Table A-2: Calculation of 10-year TV energy costs for TVs tested in NRDC's 2015 and 2016 studies										
		2016 NRDC Study				2015 NRDC Study				
		SAM 9000 55"	SAM 7100 55"	LG 8300 58"	VIZ RS65-B2 65"	LG UFF7600 55"	VIZ P552ui-P2 55"	VIZ M55-C2 55"	PAN 850U 55"	Sony 850C 55"
	ABC and MD Default Settings	ABC & MD	ABC & MD	MD	Neither	ABC & MD	ABC	ABC	ABC	ABC
Power	Default Configuration (W)	76	60	75	245	48	107	68	114	78
	ABC & MD Off (W)	181	125	119	245	88	166	130	152	78
	Increase (W)	105	65	44	0	40	59	62	38	0
	Increase (%)	138%	108%	59%	0%	83%	55%	91%	33%	0%
Energy	Default Configuration (kWh)	139	110	137	447	88	195	124	208	142
	ABC & MD Off (kWh)	330	228	217	447	161	303	237	277	142
	Increase (kWh)	192	119	80	0	73	108	113	69	0
Cost	10-Year Electricity Cost in Default Configuration ($)	175	138	172	563	110	246	156	262	179
	10-Year Electricity Cost with ABC and MD Off ($)	416	287	274	563	202	382	299	350	179
	10-Year Electricity Cost Increase with ABC and MD Off ($)	241	149	101	0	92	136	143	87	0

ABC = Automatic Brightness Control
MDD = Motion Detection (called Motion Lighting by Samsung and Motion Eye Care by LG)
Motion Eye Care was ON for test results highlighted in yellow since we did not perform MD-off testing in the 2015 study

Table A-3: Assumptions used during energy and economic impact calculations		
PNW % of U.S. Population	4.3%	Source: http://www.census.gov/popest/data/state/totals/2015/
PNW Energy Consumption of 32+" TVs Sold in 2015	134 GWh/yr	Source: Northwest Energy Efficiency Alliance
U.S. Energy Consumption of 32+" TVs Sold in 2015	3.1 TWh/yr	Calculated
PNW Sales 32+" in 2015	1,200,000 Units	Source: Northwest Energy Efficiency Alliance
U.S. Sales 32+" in 2015	27,773,949 Units	Calculated
Average Unit Energy Consumption of Sales in 2015	112 kWh/yr	Calculated
Percent of TVs with ABC and MDD Disabled	33%	Assumed for the purpose of illustration
Retail Cost of Electricity ($)	0.126 $/kWh	Source: https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a
Conversion Factor	2,205 lbs/metric ton	
Emissions Factor	1,232.35 lbs CO_2/MWh	Source: NRDC

We also used publicly available data to convert the incremental energy used by new big-screen TVs, 4,789 GWh per year for two years, to the annual amount of electricity consumed by a certain number of households. This two years' worth of incremental energy use is equivalent to the annual electricity consumed by all the homes in Los Angeles. This conversion was based on an annual household energy use in California of 6,744 kWh/yr.

Appendix 2

Energy-Saving Features Persistence

Ecos Research conducted an informal survey of TVs located in two retail stores to assess the persistence of the MDD and ABC energy-saving features. Using the remote control, the technician documented the default settings and then changed the picture setting from the default value to see whether ABC or MDD was automatically disabled. The technician returned the TV to its out-of-the-box default conditions and then changed one of the sub-settings, such as contrast, brightness, or backlight, to see if that caused ABC or MDD to be disabled. A summary of the results is provided in Table A-4, and more complete information is provided in Table A-5.

Table A-4: Settings persistence summary

	Automatic Brightness Control (ABC)	Details	Motion Detection Dimming (MDD)	Details
Samsung	Disabled by picture setting changes Disabled by certain picture sub-setting changes	True for 6 of 6 models tested	Disabled by picture setting changes Disabled by certain picture sub-setting changes	True for 5 of 6 models tested
LG	Disabled by picture setting changes	True for 3 of 4 models tested	Disabled by picture mode changes	True for 6 of 6 models tested
Vizio	Disabled by picture setting changes	True for 3 of 3 models tested	N/A	N/A
Sony	No automatic disabling	True for 2 of 2 models tested	N/A	N/A
Philips	No automatic disabling	True for 1 of 1 model tested	N/A	N/A
Panasonic	Disabled by picture setting changes	True for the 1 model year 2014 TV; 2015 TV did not have ABC	N/A	N/A

Table A-5: Settings persistence by model

Brand	Model	Year	Resolution	ENERGY STAR Certified	ABC Sensor	ABC Notes	MDD Equivalent	MDD Notes
LG	58UF8300	2015	4K	Y	N		Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes
LG	55EG9600	2015	4K	Y	Y	• ABC defaults to Auto • ABC unaffected by picture mode changes • ABC unaffected by sub-setting changes • Backlight setting grayed out when ABC active	Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes
LG	60UF7700	2015	4K	Y	N		Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes

Table A-5: Settings persistence by model								
Brand	Model	Year	Resolution	ENERGY STAR Certified	ABC Sensor	ABC Notes	MDD Equivalent	MDD Notes
LG	65UH7700	2016	4K	Y	Y	• ABC defaults to Auto • ABC disabled when picture mode changed from APS (Auto Power Save) • Re-enabled when APS reselected • ABC unaffected by sub-setting changes • Backlight setting grayed out when ABC active	Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes
LG	55EG9100	2015	1080	Y	Y	• ABC defaults to Auto • ABC disabled when picture mode changed from APS (Auto Power Save) • Re-enabled when APS reselected • ABC unaffected by sub-setting changes • Backlight setting grayed out when ABC active	Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes
LG	70UF7700	2015	4K	Y	Y	• ABC defaults to Auto • ABC disabled when picture mode changed from APS (Auto Power Save) • Re-enabled when APS reselected • ABC unaffected by sub-setting changes • Backlight setting grayed out when ABC active	Y	• MEC defaults to High • MEC disabled and grayed out (unselectable) when picture mode changed from APS • Re-enabled when APS reselected • MEC unaffected by sub-setting changes
Panasonic	TC55CX850U	2014	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed to anything but Standard or Home Theater • Re-enabled when Standard or Home Theater reselected • ABC unaffected by sub-setting changes	N	
Panasonic	TC55CX420	2015	4K	N	N		N	
Philips	55PFL6900	2015	4K	Y	Y	• ABC defaults to On • ABC unaffected by any picture mode or sub-setting changes	N	
Samsung	UN55KS8000	2016	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	Y	• ML Defaults to On • ML disabled and grayed out (unselectable) when picture mode changed from Standard • Re-enabled when Standard mode reselected • ML unaffected by picture mode sub-setting changes

Table A-5: Settings persistence by model								
Brand	Model	Year	Resolution	ENERGY STAR Certified	ABC Sensor	ABC Notes	MDD Equivalent	MDD Notes
Samsung	UN55JU7100	2014	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	Y	• ML Defaults to On • ML disabled and grayed out (unselectable) when picture mode changed from Standard • Re-enabled when Standard mode reselected • ML disabled by changes to Backlight, contrast, or brightness • Remains disabled when sub-settings returned to default levels
Samsung	UN55JS9000	2015	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	Y	• ML Defaults to On • ML disabled and grayed out (unselectable) when picture mode changed from Standard • Re-enabled when Standard mode reselected • ML disabled by changes to Backlight, contrast, or brightness • Remains disabled when sub-settings returned to default levels
Samsung	UN60JS7000	2015	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	Y	• ML Defaults to On • ML disabled and grayed out (unselectable) when picture mode changed from Standard • Re-enabled when Standard mode reselected • ML disabled by changes to Backlight, contrast, or brightness • Remains disabled when sub-settings returned to default levels
Samsung	UN55JS8500	2015	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	Y	• ML Defaults to On • ML disabled and grayed out (unselectable) when picture mode changed from Standard • Re-enabled when Standard mode reselected • ML disabled by changes to Backlight, contrast, or brightness • Remains disabled when sub-settings returned to default levels
Samsung	UN65J6200	2015	4K	Y	Y	• ABC defaults to On • ABC disabled when picture mode changed from Standard • Re-enabled when Standard mode reselected • ABC disabled when Backlight setting changed • Remains disabled when Backlight setting returned to default level	N	

Table A-5: Settings persistence by model								
Brand	Model	Year	Resolution	ENERGY STAR Certified	ABC Sensor	ABC Notes	MDD Equivalent	MDD Notes
Sony	XBR55X850C	2015	4K	N	Y	• ABC defaults to On • ABC unaffected by any picture mode or sub-setting changes	N	
Sony	XBR55X850D	2016	4K	N	Y	• ABC defaults to On • ABC unaffected by any picture mode or sub-setting changes	N	
Vizio	E60-C3	2015	1080	Y	Y	• ABC Defaults to Medium • Options are Off, Low, Medium, and High • ABC disabled when picture mode changed from Standard • ABC re-enabled when Standard mode reselected • ABC unaffected by changes to sub-settings • Backlight sub-setting grayed out (unselectable) when ABC On	N	
Vizio	E55-C1	2015	1080	Y	Y	• ABC Defaults to Medium • Options are Off, Low, Medium, and High • ABC disabled when picture mode changed from Standard • ABC re-enabled when Standard mode reselected • ABC unaffected by changes to sub-settings • Backlight sub-setting grayed out (unselectable) when ABC On	N	
Vizio	M55-C2	2015	4K	N	Y	• ABC Defaults to Off • Options are Off, Low, Medium, and High • If ABC turned On in Standard mode: ABC disabled when picture mode changed • ABC re-enabled when Standard mode reselected • ABC unaffected by changes to sub-settings • Backlight sub-setting grayed out (unselectable) when ABC On	N	
Vizio	P50-C1	2016	4K	N	Y	• ABC Defaults to Low • Options are Off, Low, Medium, and High • ABC disabled when picture mode changed from Standard • ABC re-enabled when Standard mode reselected • ABC unaffected by changes to sub-settings • Backlight sub-setting grayed out (unselectable) when ABC On	N	

Appendix 3

Original Data from Power Measurements Taken in Ecos Research's Laboratory

The tables below contain more complete versions of the summary data provided in this report.

Table A-6: On-mode power use measurements for the four TVs tested with the IEC test clip

	Motion Lighting	SAM 7100		SAM 9000		LG 8300		VIZ RS65-B2
		Average Power (W)	Power Increase When ML Off	Average Power (W)	Power Increase When ML Off	Average Power (W)	Power Increase When MEC Off	Average Power (W)
ABC Off	Off	124.9	25.3%	180.5	44.5%	119.1	58.1%	244.73
	On	99.7		124.9		75.3		
ABC On*	Off	67.7	12.6%	87.9	15.5%	No ABC Sensor		No ABC Sensor No MDD
	On	60.1		76.1				
100 Lux	Off	107.0	22.6%	137.7	36.4%			
	On	87.3		100.9				
35 Lux	Off	62.9	10.6%	78.5	8.7%			
	On	56.9		72.3				
12 Lux	Off	50.2	4.3%	67.6	3.1%			
	On	48.1		65.6				
3 Lux	Off	50.6	5.0%	67.8	3.2%			
	On	48.1		65.7				

*ABC On calculation per DOE test method (Average of four illuminance levels: (100 lux + 35 lux + 12 lux + 3 lux)/4)

Table A-7: On-mode power use measurements for the four TVs tested with the real-world content test clip

	Motion Lighting	SAM 7100		SAM 9000		LG 8300		VIZ RS65-B2
		Average Power (W)	Power Increase When ML Off	Average Power (W)	Power Increase When ML Off	Average Power (W)	Power Increase When MEC Off	Average Power (W)
ABC Off	Off	124.2	−0.6%	178.2	23.4%	118.9	12.9%	242.8
	On	125.0		144.4		105.3		
ABC On*	Off	65.1	−1.0%	87.6	9.4%	No ABC Sensor		No ABC Sensor No MDD
	On	65.7		80.1				
100 Lux	Off	97.1	−3.8%	137.4	18.6%			
	On	100.9		115.9				
35 Lux	Off	62.8	0.3%	78.6	6.1%			
	On	62.7		74.1				
12 Lux	Off	50.1	1.0%	67.2	3.2%			
	On	49.6		65.1				
3 Lux	Off	50.2	1.2%	67.2	3.0%			
	On	49.6		65.2				

*ABC On calculation per DOE test method (Average of four illuminance levels: (100 lux + 35 lux + 12 lux + 3 lux)/4)

ENDNOTES

1 Arthur Nelsen, "Samsung TVs Appear Less Energy Efficient in Real Life Than in Tests," *The Guardian*, October 1, 2015, www.theguardian.com/environment/2015/oct/01/samsung-tvs-appear-more-energy-efficient-in-tests-than-in-real-life (accessed August 2, 2016).

2 Arthur Nelsen, "Samsung TVs Appear Less Energy Efficient in Real Life Than in Tests".

3 U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy Office, Proposed Rule on Energy Efficiency Program: Test Procedure for Televisions; Request for Information, *Federal Register*, June 25, 2016, www.federalregister.gov/articles/2016/06/24/2016-14982/energy-efficiency-program-test-procedure-for-televisions-request-for-information (accessed August 2, 2016).

4 Natural Resources Defense Council (NRDC) and Ecos Research, *The Big Picture: Ultra High-Definition Televisions Could Add $1 Billion to Viewers' Annual Electric Bills*, November 2015, www.nrdc.org/sites/default/files/uhd-tv-energy-use-report.pdf (accessed August 2, 2016).

5 Arthur Nelsen, "Samsung TVs Appear Less Energy Efficient in Real Life Than in Tests".

6 Arthur Nelsen, "Samsung TVs Appear Less Energy Efficient in Real Life Than in Tests."

7 Samsung, "Samsung Firmly Rejects The *Guardian*'s Article on TV Compliance Testing," Oct. 1, 2015, https://news.samsung.com/global/samsung-firmly-rejects-the-guardians-article-on-tv-compliance-testing (accessed Sept. 9, 2016).

8 U.S. Department of Energy (DOE), Energy Efficiency and Renewable Energy Office, Proposed Rule on Energy Efficiency Program: Test Procedure for Televisions; Request for Information.

9 Average picture level is a measure of the relative lightness or brightness of a particular video clip or frame, where 100 percent represents all pixels displaying their brightest possible value, 0 percent represents all black pixels, and 34 percent represents a typical average for the content procured from around the world and analyzed by video experts more than a decade ago, when the IEC test clip was created.

10 NRDC and Ecos Research, *The Big Picture*.

11 STEP, the Smart Testing of Energy Products, is a one-year focused research project funded by the European Climate Foundation and involving four nonprofit organizations in Europe: CLASP, Topten, EEB, and ECOS. Their goal is to achieve greater CO_2 emission reductions from standards and labeling by (1) identifying issues and potential failures in standardized product testing; (2) quantifying discrepancies between real-life and declared performance; and (3) suggesting improvements to standardization and ways to address any discrepancies or declaration issues.

12 For example, per the EnergyGuide label for a new Whirlpool 18.2-cubic-foot ENERGY STAR–labeled refrigerator, annual energy use is 371 kWh/yr. *See*: i.sears.com/s/d/pdf/mp-tc/spinpdf/spin_prod_1116342112 (accessed August 2, 2016).