Executive Summary

The U.S. Department of Energy (DOE), with the support of Pacific Crest Labs (PCL), conducted round robin testing for televisions (TVs) to evaluate within-lab variation (i.e., repeatability) and assess between-lab consistency (i.e., reproducibility) of the new test method developed by PCL on behalf of Northwest Energy Efficiency Alliance (NEEA) to measure dynamic luminance and power consumption in on and standby modes.

Two organizations participated in the round robin: PCL and DOE. PCL conducted testing at its lab facility in Portland, OR, while DOE’s testing was conducted by its contractor, Guidehouse, at its office in Burlington, MA. PCL tested 40 TVs to characterize the requirements of the new test method. These TVs represent a wide array of resolutions, diagonal screen size, and backlight technology. Of these 40 TVs, PCL selected ten units for conducting round robin testing at DOE’s lab. All units were tested in three preset picture settings (PPSs), as available, for on mode power consumption and luminance: default, brightest, and HDR10. Additionally, all units were tested in standby mode.

Both labs conducted testing according to the NEEA test method outlined in Appendix A. This test method is currently in development and is being evaluated by industry associations, such as the Consumer Technology Association (CTA), for potential adoption as the industry standard for measuring TV power consumption and luminance. DOE and the U.S. Environmental Protection Agency (EPA) are also evaluating this test method for potential qualification of TVs in the ENERGY STAR Program.

The key metrics provided by this test method are on mode power consumption (watts) and screen luminance (nits) in the default, brightest, and HDR10 PPSs, and standby mode power consumption (watts). A key update of this test method compared to the existing DOE test procedure to measure TV power and luminance is that screen luminance is measured at the same time as power consumption measurements for the on mode test. A dynamic video test clip specified in the International Electrotechnical Commission (IEC) standard, IEC 62087, “Methods of measurement for the power consumption of audio, video, and related equipment”, Edition 3.0, 2011-04 (i.e., IEC test clip) is played on the TV unit under test and the power consumption and luminance are measured. To measure dynamic luminance, a camera photometer setup is used.

To compare results between both labs, power consumption vs. luminance was plotted and trendlines were drawn for each PPS. These trendlines, referred to as dimming lines, indicate the expected power consumption of the TV for producing a certain amount of light (i.e., screen luminance). Dimming line equations for each test were used to estimate power consumption and luminance, which allowed comparison of the results between labs and within lab. Percent difference in the estimated power consumption and luminance was calculated between DOE and PCL’s dimming lines to assess reproducibility of the test method, while coefficient of variation (COV) was used to evaluate repeatability.

PCL estimated the maximum potential error of the camera photometer dynamic luminance measurement method to be 5 percent. For the nine units tested at DOE and PCL, the percent difference (i.e., reproducibility) was less than 4 percent for both luminance and power consumption for eight of the nine tested units; for the remaining one unit, the percent difference in power consumption was
between 6-9 percent and the percent difference in luminance was between 11-14 percent for the two tested PPSs. It is estimated that the test unit that saw large variation in results is due to the unit being damaged when it was tested at DOE. Additionally, for the four units tested to evaluate repeatability at DOE, the COV was less than 3 percent for both luminance and power consumption for all units. These results indicate that the on mode test method is reproducible and repeatable.

For the standby mode test, a key update in the NEEA test method, compared to the existing procedures, is that an active internet connection is established during the test and network traffic is sent and received over this connection. Additionally, certain features of the TV are enabled that allow it to be turned on from standby mode. These include wake-by-voice (i.e., using voice commands to turn on the TV), wake-by-remote-start (i.e., using an application on a network connected device, such as cellphone or tablet, to turn on the TV), and wake-by-cast (i.e., streaming audio/video content to the TV via an application on a network connected device, such as cellphone or tablet). For the nine units tested for reproducibility, the standby mode power consumption was less than 1 watt for four units. Additionally, repeatability testing on three units indicated that two of the units that exceeded 1 watt did not produce repeatable results. For these TVs, standby power fluctuated between a high power state and low power state, which impacted the average standby power.

Round robin and repeatability testing provide a unique opportunity to critically evaluate the new NEEA test method while still in development. The results of this test program suggest that some alterations to the NEEA test method could be considered to improve the between-lab reproducibility and within-lab repeatability. Specific considerations include the following:

- **Selection of Brightest PPS** – According to the NEEA test method, the brightest PPS for on mode power and luminance measurements is identified by using a spot photometer to measure the static luminance of all PPSs available on the TV using the IEC 3-bar image. The PPS with the highest luminance using this method is identified as the brightest PPS. Two of the nine units tested had a different brightest PPS between DOE and PCL likely due to the inherent variability of the spot photometer measurement method. The test method may need to be updated to improve the reproducibility of the selection of the brightest PPS.

- **Standby Test Duration** – The standby mode power consumption test specified in the NEEA test method requires an active network connection, network traffic to be sent to the TV, and up to three wake features to be enabled during testing. Standby power is measured for 40 minutes after the TV is turned off and the average power consumption of the last 20 minutes is reported. For two of the nine units tested, the 20-minute measurement window was not long enough to capture changes in the TV standby power. Units that cycle between multiple power states likely need a larger measurement period to capture all states repeatably.

- **Standby Test Wake Features** – For the standby mode power consumption test, the NEEA test method instructs test labs to enable all available wake features on the TV, including remote start, wake-by-voice, and wake-by-cast. These wake features can sometimes be difficult to configure and it is possible that some labs may enable certain features that other labs cannot enable. This can have a significant impact on the reproducibility of the test method.

- **Lamp Setup for Tests with Automatic Brightness Control (ABC) Enabled** – The NEEA test method illustrates the position of the lamp angle for on mode tests with ABC enabled by default. The specified lamp angle is 45 degrees, and the lamp must be setup at least 2 meters away from the ABC
sensor and the illuminance meter which is placed orthogonally at the ABC sensor on the TV. DOE’s investigative tests indicated that lamp positioning can have a significant impact on the power and luminance of the TV during on mode testing with ABC enabled. If the test method considers specifying a range of allowable angles (e.g., 30 – 60 degrees) for the lamp setup, this could impact the reproducibility of the test method.
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I. Background
   a. Purpose

   The U.S. Department of Energy (DOE) published the current test procedure for televisions (TVs), which includes methods for measuring active mode (on mode), standby mode, and off mode power consumption and screen luminance as well as calculating annual energy consumption (AEC), in October 2013. Additionally, DOE and the U.S. Environmental Protection Agency (EPA) published the most recent version of the ENERGY STAR TVs Version 8.0 Specification, in February 2018. The ENERGY STAR TVs Version 8.0 Specification includes several testing requirements in addition to those specified in the DOE test procedure. Specifically, these requirements pertain to testing certain TV functionality, such as: HDR upscaling, luminance measurements at different room illuminance levels, and network connectivity in standby mode.

   As part of on mode and luminance testing, DOE adopted the use of the International Electrotechnical Commission (IEC) standard, IEC 62087, “Methods of measurement for the power consumption of audio, video, and related equipment”, Edition 3.0, 2011-04. This standard includes a 10-minute dynamic broadcast-content video signal (i.e., the IEC test clip) on a DVD disc to be used when conducting on mode testing. It also specifies a static, 3-white bar image (i.e., the IEC 3-bar image) to measure screen luminance (i.e., static luminance).

   More recently, in September 2020, DOE and EPA published ENERGY STAR TVs Version 9.0 Draft 1 Specification, which includes additional on mode tests to measure dynamic luminance\(^1\) of the TV at the same time as on mode power consumption and conducted with automatic brightness control (ABC)\(^2\) turned off. The ENERGY STAR TVs Version 9.0 Draft 1 Specification also includes an additional standby mode test, which is conducted with an active internet connection (i.e., connection to wide area network (WAN)), network traffic, and connection to smart device(s). The intent of developing this new test method is to measure TV power consumption and luminance in a representative manner, especially since the Federal test procedure was last updated in 2013 and TV technology has evolved significantly since that time. Pacific Crest Labs (PCL), on behalf of Northwest Energy Efficiency Alliance (NEEA), is leading the effort to develop this new test method (hereafter referred to as the NEEA test method), which is also being considered by standards organizations such as IEC and the Consumer Technology Association (CTA)\(^3\) to update their respective standards for TVs power consumption measurement.

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\(^1\) Dynamic luminance is the term used in this test report to refer to the luminance of a TV when it is playing dynamic video content, such as the IEC test clip. It differs from static luminance, which is the luminance of a TV when a static image, such as the IEC 3-bar image, is displayed on the screen.

\(^2\) ABC is the ability of a TV to alter its luminance automatically in response to the ambient lighting conditions.

\(^3\) The current CTA standard to measure power consumption of TVs is CTA-2037-B. This standard is similar to the current DOE test procedure but includes requirements to ensure TVs are tested with special functions (such as ABC, MDD, etc.) configured such that they are persistent and prevalent. A CTA working group is currently engaged to consider updating this standard to a new version, CTA-2037-C. The working group is using the NEEA test method as the starting point for the development of the CTA-2037-C standard.
DOE, with support of PCL, participated in round robin testing for TVs to evaluate the within-lab variation (i.e., repeatability) and assess between-lab consistency (i.e., reproducibility) of the PCL test method.

b. NEEA Test Method

The NEEA test method is under development and is currently being evaluated by stakeholders. DOE and PCL tested TVs according to the test procedure described in Appendix A, which was the version in development in January 2021. The key metrics provided by this test method are on mode power consumption (watts) and screen luminance (nits) in the default, brightest, and HDR10\(^4\) preset picture settings (PPSs), and standby mode power consumption (watts).

c. Test Plan

PCL tested 40 TVs, representing a wide array of manufacturers, screen technologies, and sizes, to evaluate the requirements of the new NEEA test method. Of these 40 TVs, PCL selected and shipped 10 units for DOE to test to ensure that such round robin testing was conducted on the same units. DOE’s testing was conducted by its contractor, Guidehouse, at its office location in Burlington, MA. Guidehouse conducted testing from January 2021 to March 2021.

Table 1 lists the screen size, lighting technology, HDR10 capabilities, ABC capabilities, and additional features of interest for each tested TV. Unit 1 is an Organic Light Emitting Diode (OLED) TV that does not contain a backlight compared to Light Emitting Diode (LED) TVs. Units 7 and 10 are Quantum Dot LED (QLED) TVs that contain a backlight as well as a quantum dot layer filter. All other units are LED TVs of various sizes ranging from 24 to 55 inches (\(\)\) in diagonal screen length. Unit 10 was damaged during shipping and could not be tested by DOE. Appendix D maps the test units specified in Table 1 to the units listed in the ENERGY STAR Version 9.0 Draft 2 Data Set, which was released along with this test report.

\(^4\) HDR10 is the minimum High Dynamic Range (HDR) specification. HDR allows for brighter images and increased contrast by including a larger range of shades and colors.
Table 1: Features of TVs Selected for Round Robin Testing.

<table>
<thead>
<tr>
<th>TV #</th>
<th>Model Year</th>
<th>Size</th>
<th>Lighting</th>
<th>Resolution</th>
<th>HDR10?</th>
<th>ABC Enabled?*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2020</td>
<td>54.6&quot;</td>
<td>OLED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>2020</td>
<td>49.5&quot;</td>
<td>LED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>2020</td>
<td>49.5&quot;</td>
<td>LED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>2020</td>
<td>48.5&quot;</td>
<td>LED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>2020</td>
<td>54.5&quot;</td>
<td>LED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>2020</td>
<td>42.5&quot;</td>
<td>LED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>2020</td>
<td>54.5&quot;</td>
<td>QLED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>2020</td>
<td>31.5&quot;</td>
<td>LED</td>
<td>1366 x 768</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>2020</td>
<td>23.5&quot;</td>
<td>LED</td>
<td>1366 x 768</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>10**</td>
<td>2020</td>
<td>54.6&quot;</td>
<td>QLED</td>
<td>3840 x 2160</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* ‘ABC Enabled?’ indicates that at least one PPS had ABC enabled by default.
** Unit 10 was damaged during shipping and was not tested.

In addition to the round robin testing conducted to assess reproducibility between labs, DOE also tested a subset of units to evaluate repeatability of on mode and standby mode, and to investigate the impact of lamp angle for TVs tested with ABC enabled by default. The test plan comprised the following test series:

- **Round robin testing.** Conducted by PCL and DOE and included testing each unit once to compare results to those obtained by PCL to determine reproducibility of the NEEA test method.
- **Repeatability testing.** Conducted by DOE and included testing Units 2, 7, 8, and 9 three times each in on mode to evaluate repeatability of the on mode test. Also included testing Units 2, 3, and 5 at least three times each to evaluate repeatability of the standby mode test.
- **Lamp angle investigative testing.** Conducted by DOE and included testing Unit 2 three times, each with a different ABC lamp angle and position, to evaluate the impact of allowing a range of acceptable lamp angles in the test method.

On mode repeatability testing units were selected if DOE’s test results deviated from PCL’s by more than 3 percent in at least one PPS. Standby mode repeatability testing units were selected if (a) the power consumption in standby mode exceeded 2 watts; (b) the TV was capable of implementing at least two of the three wake features; and, (c) there was significant variation between the DOE and PCL standby mode results.

The lamp angle investigative test unit was selected because it was a 49.5" LED unit with ABC enabled in at least two PPSs by default. For PPSs with ABC enabled by default, the NEEA test method specifies that the on mode test must be performed with the lamp setup such that it shines light on the TV’s ABC sensor at an angle of 45 degrees, with the possibility of specifying a range for the allowable lamp angle in the future. DOE conducted investigative testing to determine the impact of light angle on measured power and luminance. DOE conducted on mode testing on Unit 2 according to the NEEA test method.
method three times, once each at a lamp angle of 35, 45, and 60 degrees. As specified in the NEEA test method, power and luminance were measured for the default and HDR10 PPS (the PPSs with ABC enabled by default) at 100 lux, 35 lux, 12 lux, and 3 lux room illuminance levels as measured at the ABC sensor.

DOE tested TVs using the test kit developed by PCL on behalf of NEEA (i.e., the NEEA test kit). All equipment used by DOE and PCL met the requirements specified in the NEEA test method. DOE and PCL used mostly the same equipment and setup the test similarly, with a few exceptions that are outlined in more detail in Appendix B. Specifically, DOE and PCL used different models of Blue-ray player, AC power source, and network equipment. In DOE testing, the AC power source was used to power the camera photometer, ABC Lamp, and TV. To dim the LED lamp for ABC testing, DOE used a variable transformer while PCL used a dimmer switch. PCL did not power the camera photometer with an AC power source. Additionally, PCL tested two units on a single power source. The PCL illuminance meter was calibrated using an LED source, while the DOE illuminance meter was calibrated using an incandescent source. Another difference between the two labs was the network equipment used for testing. DOE implemented a dedicated modem and router that was used exclusively for testing TVs. PCL had a dedicated router but used the building’s modem rather than having a dedicated modem exclusively for testing. Other differences in testing equipment include the smart speaker and mobile device models used for the standby test; these are not expected to have any significant impact on the measured standby power consumption.

d. Statistical Analysis

The key metrics of the PCL test method are on mode power and luminance in up to three PPSs (default, brightest, and HDR10), and standby mode power. For the tests conducted as part of this test program, repeatability and reproducibility were individually assessed for on mode and standby mode.

To evaluate the repeatability and reproducibility of the on mode tests, PCL developed an approach to evaluate power consumption as a function of luminance. This approach plots the measured power consumption vs. luminance for a given TV in each PPS and draws trendlines, called dimming lines, for each PPS, allowing a TV’s efficiency (as indicated by its power consumption) to be evaluated as a function of its ability to produce light (as measured by its luminance).

The power consumption and luminance as determined by the dimming lines are then compared to evaluate the repeatability and reproducibility of the test method. For reproducibility, there are only two values for each TV in each PPS. Therefore, a percent difference was calculated to determine variation in results. For repeatability, there are three results for each TV. Therefore, the coefficient of variation (COV) was calculated for each test to evaluate variation in results.

5 Additional details can be found on PCL’s website: https://www.pacificcrestlabs.com/documents
In its Camera Technical Writeup⁶, PCL estimated the maximum potential error from the camera photometer dynamic luminance measurement method to be 5 percent. Therefore, any variation greater than 5 percent in results for the on mode power consumption or luminance dimming lines is considered a significant difference when evaluating the repeatability and reproducibility of the on mode test method. In addition to the potential variation of the camera photometer setup, additional sources of variation include the ABC lamp setup and room illuminance measurement for tests with ABC enabled by default.

For standby mode tests, test method repeatability and reproducibility was primarily evaluated for units whose power consumption exceeded 1 watt. For such units, the test was not considered repeatable or reproducible if the measured power consumption fluctuated significantly between two or more power levels, indicating that the TV was either in multiple standby states rather than stabilizing at a lower standby state over the duration of the test or the standby power was cyclic.

⁶The camera Technical Writeup can be found on PCL’s website here: https://www.pacificcrestlabs.com/documents
II. Summary of Results

a. On Mode

Round Robin Reproducibility Comparison

To assess reproducibility of the NEEA on mode test method, both PCL and DOE measured on mode power consumption and luminance for the nine TVs specified in section I.c. These TVs were tested at PCL first and then shipped to DOE to ensure that tests were conducted on the same units. Table 2 shows the power consumption and luminance for all nine units in the tested PPSs as well as the average power consumption and luminance for each unit, which is the average of the tested PPSs for a given unit. If a unit had ABC enabled by default in any of the three tested PPSs, the test in that PPS was conducted with ABC on, as specified in the test method. This is noted in the column titled ‘ABC Enabled?’.
Table 2: Measured Power Consumption and Luminance in each PPS at PCL and DOE.

<table>
<thead>
<tr>
<th>UUT Number</th>
<th>PPS</th>
<th>ABC Enabled?</th>
<th>Power Consumption (W)</th>
<th>Luminance (Nits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCL</td>
<td>DOE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCL</td>
<td>DOE</td>
</tr>
<tr>
<td>1</td>
<td>Default</td>
<td>Yes</td>
<td>104.7</td>
<td>107.4</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>167.1</td>
<td>171.3</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>145.3</td>
<td>149.2</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>139.1</td>
<td>142.6</td>
</tr>
<tr>
<td>2</td>
<td>Default</td>
<td>Yes</td>
<td>94.4</td>
<td>89.4</td>
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<td></td>
<td>Brightest</td>
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<td>148.4</td>
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<tr>
<td></td>
<td>HDR10</td>
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<td>85.3</td>
<td>80.6</td>
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<td>Average</td>
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<td>106.2</td>
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<td>96.6</td>
<td>94.9</td>
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<td></td>
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<td></td>
<td>Brightest</td>
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<td>104.3</td>
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<tr>
<td></td>
<td>HDR10</td>
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</tr>
<tr>
<td></td>
<td>Average</td>
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<td>85.4</td>
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<tr>
<td></td>
<td>Brightest</td>
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<td>140.9</td>
<td>140.6</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
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<tr>
<td></td>
<td>Brightest</td>
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<td></td>
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<td></td>
<td>124.4</td>
<td>133.1</td>
</tr>
<tr>
<td>8</td>
<td>Default</td>
<td>No</td>
<td>29.2</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>32.8</td>
<td>32.9</td>
</tr>
<tr>
<td>9</td>
<td>Default</td>
<td>No</td>
<td>19.1</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>21.9</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td></td>
<td>20.5</td>
<td>19.7</td>
</tr>
</tbody>
</table>

* DOE and PCL tested different brightest PPS for Unit 2 and Unit 4.
** Unit 4’s brightest PPS tested at PCL had ABC disabled by default and the brightest PPS tested at DOE had ABC enabled by default.
Differences in the PPS power consumption between PCL and DOE were generally attributed to the differences in TV luminance. TV luminance has a direct proportional impact on the power consumption of TVs. Additionally, for Units 2 and 4, the brightest PPS, as determined via the spot luminance measurement check, at the DOE and PCL labs was different. While the measured luminance (as measured via the camera photometer) and power consumption of the tested brightest PPS was similar between the two labs for Unit 2, Unit 4 had significant difference between to two labs, primarily because the PPS tested at DOE had ABC on while that tested at PCL had ABC off. When DOE tested the same brightest PPS as PCL for Units 2 and 4, the results demonstrated much closer agreement for both power consumption and luminance, as shown in Table 3.

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>ABC?</th>
<th>Power Consumption (W)</th>
<th>Luminance (Nits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PCL</td>
<td>DOE</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>148.4</td>
<td>147.9</td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td>104.3</td>
<td>103.9</td>
</tr>
</tbody>
</table>

To better compare reproducibility between DOE and PCL data, dimming lines were plotted for each TV’s test results in each PPS. Dimming lines are trendlines, one each for each PPS tested at each lab, that define the relationship between power consumption and dynamic luminance for a given TV in a given PPS. To compare the power consumption results between DOE and PCL, the measured luminance at PCL for a given PPS was used to estimate the power consumption for that PPS using the PCL and DOE dimming line equations. These power consumption values were then compared to each other to determine the percent difference between the two values. The same approach was also used to compare the luminance values between DOE and PCL. The resulting percent differences in the measured power consumption and luminance at DOE relative to the PCL values is shown in Table 4.
Table 4: Percent Difference in Measured Power Consumption and Luminance at DOE Versus PCL.

<table>
<thead>
<tr>
<th>UUT Number</th>
<th>PPS</th>
<th>ABC Enabled?</th>
<th>Power Consumption</th>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Default</td>
<td>Yes</td>
<td>0.8%</td>
<td>1.7%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>1.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>0.8%</td>
<td>1.2%</td>
</tr>
<tr>
<td>2</td>
<td>Default</td>
<td>Yes</td>
<td>2.3%</td>
<td>3.1%</td>
</tr>
<tr>
<td></td>
<td>Brightest*</td>
<td>No</td>
<td>2.3%</td>
<td>3.0%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>2.4%</td>
<td>3.4%</td>
</tr>
<tr>
<td>3</td>
<td>Default</td>
<td>No</td>
<td>2.7%</td>
<td>3.7%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>2.4%</td>
<td>3.3%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>2.4%</td>
<td>3.3%</td>
</tr>
<tr>
<td>4</td>
<td>Default</td>
<td>Yes</td>
<td>0.6%</td>
<td>0.9%</td>
</tr>
<tr>
<td></td>
<td>Brightest*</td>
<td>No/Yes**</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>5</td>
<td>Default</td>
<td>No</td>
<td>1.2%</td>
<td>1.4%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>0.6%</td>
<td>0.7%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>0.7%</td>
<td>0.8%</td>
</tr>
<tr>
<td>6</td>
<td>Default</td>
<td>No</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>No</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>7</td>
<td>Default</td>
<td>Yes</td>
<td>1.2%</td>
<td>1.9%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>2.5%</td>
<td>3.1%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>1.8%</td>
<td>2.6%</td>
</tr>
<tr>
<td>8</td>
<td>Default</td>
<td>No</td>
<td>2.5%</td>
<td>3.9%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>2.8%</td>
<td>3.8%</td>
</tr>
<tr>
<td>9</td>
<td>Default</td>
<td>No</td>
<td>6.1%</td>
<td>11.5%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>8.4%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

* DOE and PCL tested different brightest PPS for Unit 2 and Unit 4.
** Unit 4’s brightest PPS tested at PCL had ABC disabled by default and the brightest PPS tested at DOE had ABC enabled by default.

For Units 2 and 4, Table 5 shows the percent difference in power consumption as determined by plotting the dimming lines, when comparing the results from the same brightest PPS.

Table 5: Percent Difference in Power and Luminance of Units 2 and 4 for the Same Brightest PPS.

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>ABC?</th>
<th>Power Consumption</th>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>No</td>
<td>0.3%</td>
<td>3.1%</td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td>0.4%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Additionally, Figure 2 shows nine plots, one for each unit, that includes the measured power consumption vs. luminance for each PPS tested at DOE and PCL. For PPSs with ABC disabled by default there are two points on the graph – the measured power consumption and luminance as measured in
the default settings and the measured power consumption and luminance as measured at the lowest backlight level. For PPSs with ABC enabled by default, there are five points on the graph – the measured power consumption and luminance at 100 lux, 35 lux, 12 lux, and 3 lux and the fifth point corresponds to the measured values with ABC off. Figure 1 shows the legend for each of the nine plots in Figure 2.

---

**Figure 1: Legend Describing the Plotted Series and Dimming Lines for On Mode Reproducibility Testing.**
Figure 2: Measured Power Consumption, Luminance, and Dimming Lines in Reproducibility Tests for each TV in each Tested PPS.

As seen in Table 4 and the graphs in Figure 2, the percent difference in power consumption and luminance is less than 5 percent, which is the maximum potential error estimated by PCL when designing the test to measure dynamic luminance using the camera photometer, for all units except Unit 9. Large variation was observed in the measurements for Unit 9, including its dimming lines which were
different for the two labs and intersected each other, which is unusual compared to the other units tested at both labs. It is speculated that this may be because the TV screen was damaged (potentially while shipping), which lowered the overall brightness of the TV in DOE testing. Reviewing the luminance profile of the DOE tests to PCL tests revealed a difference in the luminance profile of the TV between the two labs as well as an overall difference in the brightness of the unit, as shown in Appendix C. PCL notes that it would retest this unit when it receives it back from DOE’s lab.

**Repeatability Testing**

To test the repeatability of the NEEA test method, DOE conducted three on mode tests each for four units (Units 2, 7, 8, and 9). Table 6 shows the power consumption and luminance for the four units in the tested PPSs as well as the average power consumption and luminance, which is the average of the tested PPSs for a given unit. If a unit had ABC enabled by default in any of the three tested PPSs, the test in that PPS was conducted with ABC on, as specified in the test method. This is noted in the column titled ‘ABC Enabled?’.

**Table 6: Measured Power and Luminance Results for Repeatability Testing on Four Units.**

<table>
<thead>
<tr>
<th>UUT Model</th>
<th>PPS</th>
<th>ABC Enabled?</th>
<th>Power Consumption (W)</th>
<th>Luminance (Nits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test 1</td>
<td>Test 2</td>
</tr>
<tr>
<td>2</td>
<td>Default</td>
<td>Yes</td>
<td>89.4</td>
<td>90.1</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>148.6</td>
<td>148.2</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>80.6</td>
<td>81.6</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>106.2</td>
<td>106.6</td>
<td>105.7</td>
</tr>
<tr>
<td>7</td>
<td>Default</td>
<td>Yes</td>
<td>101.9</td>
<td>98.8</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>179.9</td>
<td>179.7</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>117.6</td>
<td>113.8</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>133.1</td>
<td>130.7</td>
<td>128.5</td>
</tr>
<tr>
<td>8</td>
<td>Default</td>
<td>No</td>
<td>29.2</td>
<td>29.2</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>36.4</td>
<td>36.4</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>32.8</td>
<td>32.8</td>
<td>32.8</td>
</tr>
<tr>
<td>9</td>
<td>Default</td>
<td>No</td>
<td>18.3</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>21.1</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>19.7</td>
<td>19.7</td>
<td>19.7</td>
</tr>
</tbody>
</table>

For these repeatability tests, DOE selected the brightest PPS as determined via the spot luminance photometer check during each test run. The brightest PPS for all units was the same in each run. For Unit 2, the brightest PPS was the same that DOE observed during reproducibility testing (i.e., it is different from the PPS tested by PCL, as discussed previously).

Similar to the reproducibility testing comparison, DOE first plotted dimming lines for each test run. Next, to compare the power consumption results for each test run, DOE calculated an estimated power consumption value for each test run using the dimming line equation for each test run and the luminance value from the first test. DOE then calculated the COV of these three values. This same
approach was also used to compare the luminance results from the three test runs for each TV. The resulting COVs, expressed as a percentage, are shown in Table 7.

**Table 7: COV in Power Consumption and Luminance for On Mode Repeatability Tests.**

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>PPS</th>
<th>ABC Enabled</th>
<th>Power Consumption</th>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Default</td>
<td>Yes</td>
<td>0.6%</td>
<td>0.8%</td>
</tr>
<tr>
<td>2</td>
<td>Brightest</td>
<td>No</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>1.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>7</td>
<td>Default</td>
<td>Yes</td>
<td>0.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>0.8%</td>
<td>1.0%</td>
</tr>
<tr>
<td></td>
<td>HDR10</td>
<td>Yes</td>
<td>1.0%</td>
<td>1.3%</td>
</tr>
<tr>
<td>8</td>
<td>Default</td>
<td>No</td>
<td>0.6%</td>
<td>1.0%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>0.8%</td>
<td>1.1%</td>
</tr>
<tr>
<td>9</td>
<td>Default</td>
<td>No</td>
<td>0.4%</td>
<td>0.8%</td>
</tr>
<tr>
<td></td>
<td>Brightest</td>
<td>No</td>
<td>0.4%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

Figure 4 shows the plots for the tests conducted on the four units, along with the dimming lines for each test and Figure 3 shows the legend for all the plots in Figure 4.

**Figure 3: Legend Describing the Plotted Series and Dimming Lines for On Mode Repeatability Testing.**
As seen in Table 7, the COV for power consumption did not exceed 2 percent for any of the four tested units and the COV for luminance did not exceed 2.5 percent for any of these units. The graphs in Figure 4 additionally show that the measured power consumption and luminance values were very close to each other, as exhibited by the closely overlapping dimming lines. These results show that the relative test-to-test variability in a given lab is very low for the NEEA test method, and it is significantly below the 5 percent potential error of the camera photometer measurement method estimated by PCL.

Additionally, while Unit 9’s reproducibility results between PCL and DOE showed variability, the repeatability results for this unit had a COV less than 1 percent for both power consumption and luminance. These results further suggest that the difference between PCL and DOE could be due to damage of the unit when tested by DOE. It would be important to further investigate the reason for the differences in the measured values of Unit 9 and determine if the differences were due to a damaged unit or a difference in the implementation of the test method. More detail regarding the variability in Unit 9 can be found in Appendix C.
b. Standby Mode

**Round Robin Reproducibility Comparison**

To assess the reproducibility of the NEEA standby mode test method, both PCL and DOE measured standby mode power consumption for all nine units. Figure 5 shows the result of the standby tests where the measured average power consumption value is specified above each bar in the chart.

![Comparison of Standby Power between PCL and DOE](image)

**Figure 5: Comparison of Standby Mode Power Consumption between PCL and DOE.**

Four of the nine units achieved standby power below 1 watt at both labs. For Unit 5, while PCL’s measurement was below 1 watt, DOE measured 5.4 watts average power in standby mode. This difference is attributed to DOE being able to test the unit with wake-by-voice features enabled, which was not turned on when the unit was tested at PCL. The NEEA test method requires this wake feature to be enabled, if available. PCL intends to retest this unit when the unit is shipped back to its lab to attain a direct comparison of standby power to DOE’s results. For the remaining four units, the standby power consumption was above 1 watt at both labs, and, except for Unit 2, the measured values were within 0.2 watts of each other. Information regarding the likely source of the discrepancy for Unit 2 is described in the next section, as ascertained from repeatability testing on this unit.

**Repeatability Testing**

To further investigate the differences in standby power consumption measurement, DOE selected three units for repeatability testing. These units were selected because the measured standby

---

7 DOE was able to replicate PCL’s measured standby power when it turned off the wake-by-voice feature.
power was greater than 1 watt, and for two of them, the values were significantly different between the two labs (Units 2 and 5); Unit 3 was selected for standby testing because it had the highest measured standby power consumption. DOE conducted three tests on Units 3 and 5 and four tests on Unit 2 as shown in Figure 6. The measured average power consumption value for each test is specified above each bar in the chart.

![Figure 6: Comparison of Standby Mode Power between Multiple Tests on Three Units.](Image)

As seen in Figure 6, Unit 3’s results were within 0.1 watt of each other for the three tests (which is similar to the results seen between the DOE and PCL labs). This indicates that Unit 3’s standby power consumption, while high, is repeatable and reproducible.

However, Units 2 and 5 exhibited low test-to-test repeatability. The power consumption for these units fluctuated between less than 1 watt and greater than 20 watts for Unit 2, and between 1 watt and 15 watts for Unit 5 over the duration of the test, as shown in the power traces in Figure 7 and Figure 8, respectively.
According to the NEEA test method, the standby mode test is conducted with an active internet connection (i.e., the TV is connected to a wide area network (WAN)), and network traffic is sent and received over this network connection). While network connectivity and network traffic may cause variability, it is unlikely that its impact would be as significant as that seen in the measured values for Units 2 and 5, especially since all the other TVs did not show any variation in results when using the same network connection and network traffic. Therefore, it is more likely that the fluctuation in power consumption for Units 2 and 5 is due to the inherent design of the TVs and the manner in which they consume power in standby mode.

Additionally, the standby mode test duration, as specified in the NEEA test method, is 40 minutes, and the power consumed over the last 20 minutes only is averaged to determine standby power. Therefore, for TVs known to have cyclic power consumption or those that fluctuate between a high standby state and low standby state, standby power can vary depending on which state of the TV is represented in the final 20 minutes of the standby mode test as seen in Figure 9 and Figure 10 for two tests of Unit 5.
Overall, the proposed standby mode test method is repeatable and reproducible for units that are stable in standby mode. Units that have unstable or cyclical power consumption in standby mode would likely benefit if the test is run over a longer duration or as specified in the IEC standard, IEC 62301, “Household electrical appliances – Measurement of standby power”, Edition 2.0, 2011:01 (hereafter referred to as IEC 62301 Ed. 2.0).

### c. Lamp Setup Investigation for Tests with ABC Enabled

As specified in section I.c, DOE investigated the impact of varying the lamp angle at which light is directed on the ABC sensor of TVs. DOE conducted the on mode test on Unit 2 at three different lamp angles – 35, 45, and 60 degrees. These results are shown in Table 8.

#### Table 8: Unit 2’s Measured Power and Luminance at Three Different Lamp Angles.

<table>
<thead>
<tr>
<th>PPS</th>
<th>Power Consumption (W)</th>
<th>Luminance (Nits)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35 degrees</td>
<td>45 degrees</td>
</tr>
<tr>
<td>Default</td>
<td>68.2</td>
<td>89.4</td>
</tr>
<tr>
<td>HDR10</td>
<td>63.7</td>
<td>80.6</td>
</tr>
</tbody>
</table>

Additionally, as seen in Figure 11, the dimming lines for each PPS are comparable across the different lamp angles, which is also seen in the COV calculation seen in Table 9.
Table 9: COV in Power Consumption and Luminance for Unit 2’s Lamp Angle Test.

<table>
<thead>
<tr>
<th>PPS</th>
<th>Power Consumption</th>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>0.7%</td>
<td>1.7%</td>
</tr>
<tr>
<td>HDR10</td>
<td>0.9%</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

Figure 11: Dimming Lines for Lamp Angle Testing at 35, 45, and 60 degrees for Unit 2.

The lamp angle investigative testing indicates that lamp angle can have a significant impact on the measured luminance and power draw of a TV, even though the measured ambient light level at the ABC sensor does not change. Additionally, for the unit tested, the TV maintained its ability to produce light (i.e., luminance) at the same efficiency (i.e., power consumption) at the three different lamp angles. Further, for the tests conducted on Unit 2, measured luminance and power consumption was greatest at 45 degrees and these measured values decreased on either side of this angle (i.e., at 35 and 60 degrees). Additional investigative testing is required at different lamp angles and across multiple TVs to fully assess the impact of lamp angle on measured luminance and power consumption.

III. Key Takeaways and Next Steps

a. Selection of Brightest PPS

According to the NEEA test method, the brightest PPS for on mode power and luminance measurements is identified by using a spot photometer to measure the luminance of all PPSs available on the TV using the IEC 3-bar image. The PPS with the highest luminance using this method is the one that is tested for dynamic luminance and power consumption measurements. When following this methodology, DOE and PCL identified different PPS as the brightest for two out of the nine tested units.
While the difference in selection of the brightest PPS did not have a significant impact in the measured luminance and power consumption for Unit 2, for Unit 4, the brightest PPS selected for testing by DOE had ABC enabled by default whereas the brightest PPS selected for testing by PCL did not have ABC enabled, and this difference has a significant impact on the measured values (see Table 2 for results). Additionally, when the results for these two TVs were compared using the dimming lines, the percent difference was within the 5-percent error associated with the camera photometer setup. Although the dimming line comparison does not show a significant difference (because it characterizes the ability of the TV to product light efficiently, which can generally be maintained across PPSs), the measured values can vary significantly.

Given the difference in selection of the brightest PPS for two out of nine units, round robin testing indicates that a difference in identifying the brightest PPS is possible between labs using the IEC 3-bar image. These results indicate that the test method needs a more robust approach to identify the brightest PPS that is selected for measuring dynamic luminance and on mode power consumption.

b. Standby Test Duration

The standby mode power consumption test specified in the NEEA test method requires network connection (WAN), network traffic to be sent to the TV, and up to three wake features to be enabled during testing. Standby power is measured for 40 minutes after the TV is turned off and the average power consumption of only the last 20 minutes is reported.

Reproducibility and repeatability results, as shown in section II.b, indicate that some TVs have consistent, stable power consumption in standby mode whereas a few TVs produced variable results. For TVs that do not have stable power consumption in standby mode, i.e., the power consumption alternates between two or more different power states, the 40-minute test duration for standby tests is likely insufficient because the average power consumption can vary based on which power state is predominantly present in the last 20 minutes of the test. For such TVs, a longer duration that captures the multiple power states effectively, would be necessary to ensure that the reported average power consumption value is representative, repeatable, and reproducible. IEC 62301 Ed. 2.0 provides detailed requirements for the measurement of standby mode power that may be stable, unstable, cyclic, or of a limited duration. The requirements specified in this industry standard should be considered for measuring the standby power of TVs.

c. Standby Test Wake Features

For the standby mode power consumption test, the NEEA test method instructs test labs to enable all available wake features on the TV, including remote start, wake-by-voice, and wake-by-cast. It is often challenging to enable these settings, which can take many hours; frequently, it is difficult to enable these settings even after making multiple attempts, reviewing technical forums, or communicating with the TV manufacturer’s technical service members. The NEEA test method instructs labs to record the features that were enabled during testing. However, if different labs enable different wake features, it can impact standby power results significantly.

Round robin testing between PCL and DOE showed that Unit 5’s average standby power was 0.4 watts at PCL while the same unit’s standby power measurement was 5.4 watts at DOE. This unit was also
tested for repeatability measurements at DOE, and while the results were still variable, DOE did not measure standby power lower than 5.4 watts in any test.

This difference in measured standby power between PCL and DOE is thought to be due to the differences in the enabled wake features between the two labs while testing Unit 5. While DOE was able to configure the TV to enable the wake-by-voice feature, PCL did not test with this feature enabled. DOE was able to confirm this feature impacted the measured power consumption; upon turning off this feature, DOE measured the standby power to be less than 1 watt.

The possibility that different labs may be successful in enabling different wake methods will have significant impact on the measured standby power depending on the unit. The test method needs to address the best path forward to ensure all available wake methods are implemented consistently across labs. Some approaches to ensure repeatable implementation of standby wake features are to require manufacturers instructions be used to setup the wake features for standby testing. Additionally, manufacturers could be required to specify: (a) compatible applications that are available on all devices for remote start; and (b) compatible devices for wake-by-voice. Further, the test method could specify the application that should be used for wake-by-cast, since this may impact the time it takes the TV to wake from standby mode.

d. Lamp Setup for Tests with ABC Enabled

The NEEA test method illustrates the position of the lamp angle for on mode tests with ABC enabled by default, depending on the width of the TV. The specified lamp angle is 45 degrees and the lamp must be setup at least 2 meters away from the ABC sensor and the illuminance meter which is placed orthogonally at the ABC sensor on the TV.

DOE's investigative tests that altered the angle at which light was directed on the ABC sensor indicated that variations in the lamp positioning, angle, and power have a large effect on the power consumption and luminance of the TV. Lamp angle testing of Unit 2 showed a COV of approximately 14 percent in measured power consumption and 20 percent in measured luminance when the lamp angle was varied from 35 to 60 degrees, even though the room illuminance was maintained at the same four values (3, 12, 35, 100 lux). This indicates that the luminance and power consumption of the TV are sensitive to lamp angle and positioning. Additionally, luminance and power consumption was greatest at a lamp angle of 45 degrees.

However, when determining the efficiency of the TV as a function of its luminance (i.e., how much power does a TV consume to brighten its screen), as determined via the dimming lines, Unit 2 showed comparable results at each of the three lamp angles. For DOE repeatability tests with ABC enabled, Unit 2 had a max relative dimming line power difference of 2.4 percent and a max relative dimming line luminance difference of 3.3 percent in the HDR10 PPS. When the same test was conducted at different lamp angles, the COV for dimming line power was 0.9 percent and COV for dimming line luminance was 2.1 percent, well within the repeatability results of this test.

These results indicate that while changing the lamp angle may not alter the efficiency of the TV to produce light, it does impact the measured power consumption and dynamic luminance. If industry is interested in allowing a range of angles at which the lamp can be positioned, additional testing would be
required to determine if different TVs behave similarly at different lamp angles, or if the dimming lines at one lamp angle can be used to estimate the power consumption and dynamic luminance at a different lamp angle. Additionally, a tolerance should be specified on the allowable lamp angle, regardless of whether the test method specifies a range of angles at which the lamp is positioned.
NEEA Test Method

Version 8

January 2021
Determination of Television Set Power Consumption and Average Luminance

1 SCOPE

This standard defines a method for measuring television set power consumption and luminance. It is intended for television sets powered from an external source. Television sets with a non-removable main battery are excluded.

2 REVISION HISTORY

The purpose of this revision is to add requirements to:

- measure screen-average dynamic-luminance with a camera photometer in SDR default, SDR brightest, and HDR10 preset picture settings,
- perform ABC tests using an overhead, LED ambient light source,
- measure standby power in an environment where streaming apps are polling for devices capable of receiving audio or video casting content, and
- measure standby power with leading smart speakers configured to wake the UUT.

<table>
<thead>
<tr>
<th>Revisions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>v1 – Dave Wilson, 11/2/20</td>
<td>Initial draft sent to PCL</td>
</tr>
<tr>
<td>v4 – Gregg Hardy, 11/14/20</td>
<td>Initial PCL revision</td>
</tr>
<tr>
<td>v5 – Gregg Hardy, 11/19/20</td>
<td>Updated cam distance reqmt.</td>
</tr>
<tr>
<td></td>
<td>Added note about HDR10 PPS.</td>
</tr>
<tr>
<td>v6 – Gregg Hardy, 11/22/20</td>
<td>Updated notes.</td>
</tr>
<tr>
<td></td>
<td>Changed to require same</td>
</tr>
<tr>
<td></td>
<td>LAN/WAN/casting/speaker conditions for On and</td>
</tr>
<tr>
<td></td>
<td>Standby tests.</td>
</tr>
<tr>
<td></td>
<td>Removed unused definitions and acronyms.</td>
</tr>
<tr>
<td>v7 – Gregg Hardy, 12/2/20</td>
<td>Removed manual settings check.</td>
</tr>
<tr>
<td></td>
<td>Updated network requirements to require WAN/LAN for all testing.</td>
</tr>
<tr>
<td></td>
<td>Reorganized a bit.</td>
</tr>
</tbody>
</table>
3 REFERENCES

3.1 Normative References
The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed here.

3.1.1 Normative Reference List

- CIE (1932) proceedings, CIE 1931 luminosity function
- IEC 62087-1: 2015, Audio, video, and related equipment - Determination of power consumption - Part 1: General
- IEC 62087-2: 2015, Audio, video, and related equipment - Determination of power consumption - Part 2: Signals and media
- IEC 62087-3: 2015, Audio, video, and related equipment - Determination of power consumption – Part 3: Television sets

3.1.2 Normative Reference Acquisition

- IEC Standards:
  - Global Engineering Documents, World Headquarters, 15 Inverness Way East, Englewood, CO USA 80112-5776; Phone 800-854-7179; Fax 303-397-2740; Internet http://global.ihs.com; Email global@ihs.com
  - IEC Central Office, 3, rue de Varembe, PO Box 131, CH-1211 Geneva 20, Switzerland; Phone +41 22 919 02 11; Fax +41 22 919 03 00; Internet http://www.iec.ch; Email pubinfor@iec.ch

- Commission Internationale de l'Eclairage (CIE) proceedings, Cambridge: Cambridge University Press
3.2 Informative References

The following references contain provisions that, through reference in this text, constitute informative provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

3.2.1 Informative Reference List

- HDMI Specification

3.2.2 Informative Reference Acquisition


4 COMPLIANCE NOTATION

The following compliance terms used in this document are defined as:

shall This word indicates specific provisions that are to be followed strictly (no deviation is permitted).

shall not This phrase indicates specific provisions that are absolutely prohibited.

should This word indicates that a certain course of action is preferred but not necessarily required.

should not This phrase means a certain possibility or course of action is undesirable but not prohibited.

May This phrase indicates that a certain course of action is optional.

5 DEFINITIONS, SYMBOLS AND ABBREVIATIONS

5.1 Definitions

Automatic brightness control – Feature that senses ambient light conditions and changes display brightness accordingly, possibly reducing power consumption.

Brightest selectable Preset Picture Setting – This is the user-selectable, Preset Picture Setting that produces the highest luminance picture in Home configuration.
Forced menu – Configuration selections required of the user when a television set is turned on for the first time that forces the user to make several set-up configuration decisions when prompted.

High definition multimedia interface (HDMI) – Audio-visual interface that is capable of carrying uncompressed video data, compressed or uncompressed digital audio data, and other information. For reference, see HDMI specification.

Home configuration – Forced menu selection most likely to be chosen for home use. This configuration selection is sometimes named “home”.

Illuminance – Photometric measure of the total luminous flux incident on a surface, per unit area, expressed in lux.

Luminance – Photometric measure of the luminous intensity per unit area of light traveling in a given direction, expressed in units of candelas per square meter (cd/m²).

Main battery – Power storage device capable of powering equipment such that the equipment can provide its primary functions.

Neutral density filter (ND filter) – Optical device that reduces the light intensity in the visible wavelength region.

Partial On mode – A collection of power sub-modes, including Standby-passive, Standby-active, low, and Standby-active, high.

Quick start – Function that reduces the television’s resume time, which is the length of time required for the television to display content when switching from Partial On mode to On mode after pressing the “power” button on the remote control.

Retail configuration – Forced menu selection most likely to be chosen for use in a retail environment. This configuration selection is generally recommended by the manufacturer for presentation in a public space when the television set is offered for sale and might be named “retail”, “store”, “shop”, or equivalent.
Retail picture setting – Out-of-the-box picture setting for television sets with a forced menu in the retail configuration. (See Figure 1.)

Remote Start – The ability to wake a TV using any network-connected device not physically connected to TV.

Special functions – Functions that are related to, but not required for, the basic operation of the device.

Preset Picture Setting – TV picture setting that is selectable by a user from a set of manufacturer defined picture settings.

Television set (TV) – Commercially available electronic product designed primarily for the display and reception of audio-visual signals from terrestrial, cable, satellite, Internet Protocol TV (IPTV), or other transmission of analog and/or digital signals, consisting of a tuner/receiver and a display encased in a single housing. The product usually relies upon a liquid crystal display (LCD), organic light emitted diode (OLED) display, or other display device.

Wake-on-Cast – The ability to wake a TV by choosing to cast streaming audio or video from a mobile device.

Wake-by-Voice – The ability to wake a TV by voice command to a smart speaker.

### 5.2 Symbols and Abbreviations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Automatic Brightness Control</td>
</tr>
<tr>
<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>cd/m²</td>
<td>candela per square meter</td>
</tr>
<tr>
<td>cm</td>
<td>centimeters</td>
</tr>
<tr>
<td>CLASP</td>
<td>Collaborative Labeling &amp; Appliance Standards Program</td>
</tr>
<tr>
<td>DAM</td>
<td>Download Acquisition Mode</td>
</tr>
<tr>
<td>EPG</td>
<td>Electronic Program Guide</td>
</tr>
<tr>
<td>fps</td>
<td>frames per second</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>----------</td>
<td>-----------------------------------------------------</td>
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<tr>
<td>HDMI®</td>
<td>High Definition Multimedia Interface</td>
</tr>
<tr>
<td>HDR</td>
<td>high dynamic range</td>
</tr>
<tr>
<td>HEVC</td>
<td>High Efficiency Video Codec</td>
</tr>
<tr>
<td>Hz</td>
<td>Hertz</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>IPTV</td>
<td>Internet Protocol TV</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>ITU-R</td>
<td>ITU Radiocommunication Sector</td>
</tr>
<tr>
<td>jpg</td>
<td>digital image format developed by Joint Photographic Experts Group</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LED</td>
<td>light-emitting diode</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>lx</td>
<td>symbol for lux, the SI derived unit of illuminance</td>
</tr>
<tr>
<td>ND</td>
<td>Neutral Density</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>PAR</td>
<td>parabolic aluminized reflector</td>
</tr>
<tr>
<td>QS</td>
<td>Quick Start</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>SDR</td>
<td>standard dynamic range</td>
</tr>
<tr>
<td>SMPTE</td>
<td>Society of Motion Picture and Television Engineers</td>
</tr>
<tr>
<td>TV</td>
<td>Television Set</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>UUT</td>
<td>Unit Under Test</td>
</tr>
<tr>
<td>V</td>
<td>volts</td>
</tr>
<tr>
<td>W</td>
<td>Watts</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
</tbody>
</table>

8 HDMI® is a registered trademark of HDMI Licensing, LLC.
6 GENERAL OVERVIEW OF TEST METHOD

This TV test procedure is organized into three sections:

- General requirements
- Unit Under Test (UUT) set-up and plan development
- Test sequence

7 GENERAL REQUIREMENTS

7.1 Lab equipment

The test shall be conducted using test and measurement equipment that meets the following requirements.

**Note:** There are new requirements for Spot (i.e. Luminance) and Illuminance photometers. We propose to call the illuminance meter a spot photometer to distinguish it from the newly introduced camera photometer.

7.1.1 AC power supply

In On mode, the following requirements apply:

The fluctuation of the voltage supplied shall not exceed ±2 %. The frequency fluctuation and the harmonic components of the supplied power shall not exceed ±2 % and 5 % respectively.

In the Partial On and Off modes, the following requirements apply:

The test voltage shall be the declared voltage ±1 % and the test frequency shall be the rated frequency ±1 %. Where a number of models of equipment are being tested and compared for use in the same country, the declared voltage ±1 % and declared frequency ±1 % may be used for all tests. Where the test voltage and frequency are not defined by an external standard, the test voltage and the test frequency shall be the declared voltage and the declared frequency of the country for which the power consumption is being determined ±1 %.

The total harmonic content of the source voltage when supplying the UUT in the specified mode shall not exceed 2 % (up to and including the 13th harmonic); harmonic content is defined as the root-meansquare (r.m.s.) summation of the individual components using the fundamental as 100 %.

The ratio of peak value to r.m.s. value of the test voltage (i.e. crest factor) shall be between 1.34 and 1.49.
The power supply shall be capable of delivering the voltage and current defined in 8.5.

### 7.1.2 Power meter

Power measurement shall be carried out directly by means of a wattmeter, a wattmeter with an averaging function, or a watthour meter by dividing the reading by the measuring time. For measurements where the input video signal varies over time, a wattmeter with an averaging function shall be used to carry out the measurement.

**Note:** I don’t understand what the averaging function is [GHardy]. To my knowledge labs log 1 second data and calculate the average power using Excel. The meter does not do the averaging. This appears to be the best approach because one retains a record of the 1 second interval readings, which can provide valuable insights.

The power measuring instrument used shall measure the real power consumed regardless of the power factor of the device under test.

The test instrument used to measure power consumption shall have the following attributes:

- An available current crest factor of 3 or more at its rated range value, and lower bound on the current range of 10 mA or less.

- The power measurement instrument shall have a resolution of 0.01 W or better for power measurements of 10 W or less; 0.1 W or better for power measurements of greater than 10 W up to 100 W; and 1 W or better for power measurements of greater than 100 W.

In addition, the test instrument should have these following attributes:

- Calibrations with a standard that is traceable to the U.S. National Institute of Standards and Technology (NIST) or equivalent.

- The sampling rate of the watt-hour meter or wattmeter with averaging function shall be one measurement per second or more frequent.

Measurements of power of 0.5 W or greater shall be made with an uncertainty of less than or equal to 2% at the 95% confidence level. Measurements of power of less than 0.5 W shall be made with an uncertainty of less than or equal to 0.01 W at the 95% confidence level.

**NOTE:** For more information about the determination of uncertainty of measurement, refer to IEC 62301:2011, Annex D.

For loads less than 10 W, power figures shall be reported in watts and rounded to the second decimal place. For loads greater than or equal to 10 W, three significant figures shall be reported.
7.1.3 Spot photometer [AKA Luminance Meter]

When directed to measure display luminance, a spot photometer luminance measuring device, which may be of either the contact or non-contact type, shall be used. The spot photometer shall have an acceptance (or measuring) angle in the range of 1° to 3°, inclusive. For contact spot photometers, the measuring area shall have a diameter of 25 mm or more.

The spot photometer shall have an accuracy of ± 2 % ± 2 digits of the digitally displayed value or better. If the luminance measuring device is neither a spectroradiometer nor calibrated against an illuminant replicating the spectral emission of LEDs, and relies on filters to match the CIE 1931 luminosity function, it shall additionally have a <2% spectral mismatch index f1' against its calibration illuminant as defined in ISO/CIE 19476:2014: "Characterization of the performance of illuminance meters and luminance meters"

Note: NEEA research indicates that because older spot photometers like the Konica-Minolta LS-100 have higher spectral mismatch than newer spot photometers like the KM LS-150, they can have significant (up to 9%) error when measuring the luminance of LED -backlit TVs or OLED TVs. They are calibrated against and their specified accuracy is assessed against incandescent standard illuminant A, which does not guarantee accuracy when measuring other light sources. Some luminance meters are calibrated against LED sources (e.g. KM CA 410 with CA P427 probe). Spectroradiometers are not dependent on filter match and are therefore fit for use with modern TVs.

7.1.4 Illuminance photometer

When directed to illuminate one or more ABC sensors, an illuminance photometer shall be used to adjust the light level to the specified value.

The illuminance photometer shall have an accuracy of ± 2 % ± 2 digits or better. If the illuminance photometer is neither a spectroradiometer nor calibrated against an illuminant replicating the spectral emission of LEDs, and relies on filters to match the CIE 1931 luminosity function, it shall additionally either have a <2% spectral mismatch index f1' against its calibration illuminant as defined in ISO/CIE 19476:2014: "Characterization of the performance of illuminance meters and luminance meters", or be adjusted using the manufacturer recommended method against a traceable reference device not requiring such an adjustment.

Note: The rationale for these requirements is similar to that for the spot photometer.

7.1.5 Camera photometer

Dynamic Luminance shall be measured with a monochrome camera photometer system that meets the following requirements:

- Must be capable of measuring screen-average luminance (in cd/m2) during video test clip play with ± 5% accuracy
Must be able to sample luminance and log images at 6 fps without dropping data between frames and to log data averaged from samples at 1 second intervals

Must have minimum resolution of 720 x 540 pixels

Must have 12-bit dynamic range

Must be capable of TV screen border identification and geometry correction

Should be capable of master black correction

Should be capable of vignette correction

7.1.6 **USB thumb drive**
USB thumb drives shall be used as the primary means of playing test patterns and video files as specified in section 8.7.

7.1.7 **Blu-ray player**
BRPs shall be used as a secondary means of playing test patterns and video files as specified in section 8.7.

7.1.8 **Network**

7.1.8.1 **Internet Service and Modem**
The internet service provider and modem combination used to provide network connectivity must support confirmed download speeds of 25 Mbps and upload speeds of 10 Mbps.

7.1.8.2 **Router**
The router used to provide LAN connectivity must comply with the 802.11ac standard and must be a stand-alone router (i.e. not be part of a mesh network).

7.1.8.3 **Smart speaker**
The smart speaker used to conduct wake-by-voice testing must be from the one of the following product families: Amazon Echo, Google Home, or Google Nest. Any model and generation of these devices is sufficient.

7.1.8.4 **Network traffic**
Network traffic shall be configured to meet the requirements of (8.11).
### 7.1.9 ABC light source

The light source used for illuminating the ABC sensor to specific illuminance levels shall use a dimmable LED reflector lamp and shall have a diameter of 90 mm ±5mm. The rated beam angle of the lamp shall be 45° ±5°. The rated correlated color temperature (CCT) shall be 2 700 K ± 145 K at all light output levels. In other words, the lamp shall not be specifically designed to achieve warmer color (lower color temperature) when it dims. The lamp shall not be color-tuneable (e.g. RGB). The rated color rendering index (CRI) shall be 80 ± 3. The front surface of the lamp shall be clear (i.e., not colored or coated with spectrum modifying material) and may have a smooth or granular front surface; when shined against a uniform white surface, the diffusion pattern should appear smooth to the naked eye. The lamp assembly shall not modify the spectrum of the LED source, including the IR and UV bands.

**Note:** Intertek recommended that we add a criterion stating that the lamp’s SPD must be within specified limits. I will explore this possibility. All of the lamps we purchased that met the currently stated requirements had similar SPDs, but that’s not a guarantee that they will in the future. Because PCL has a spectroradiometer, PCL could check lamps for test labs and maintain a global qualified lamp list.

To reach the illumination levels specified in 9.1, the lamp must have dimming capability incorporated (e.g. wifi or zigbee dimming) or be wired with a compatible dimming switch capable of dimming it to the lowest level required in 9.1. The lamp shall be capable of providing the highest illumination level when wired with the dimming switch. For illuminance levels below 10 lx, a 2 stop ND filter may be used as a contingency if a lamp/dimmer combination cannot be found for which the lowest setting does not reach the required level below 10 lx. No ND filter shall be used for luminance levels at or above 10 lx. The ND filter shall be large enough to cover the entire surface of the diffusion area of the lamp. The ND filter shall have an average transmission of 25 % ± 2.5 % within the visible range, which is 400 nm to 700 nm, without selectively absorbing light at specific wavelengths.

Specific illuminance levels shall be obtained by adjusting the dimming switch.

The model of the lamp and dimmer (and versions thereof if available) used for illuminating the ABC sensor to specific illuminance levels shall be reported.

The lamp shall be stabilized by setting it to maximum output for at least 10 minutes.

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Dimmer</th>
<th>CCT (K)</th>
<th>CRI</th>
<th>Beam Angle (degrees)</th>
<th>Nominal Rated Lumens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philips</td>
<td>19428L/LED/827/F40/DIM/ULV/120V</td>
<td>Lutron MAOL-153M</td>
<td>2700</td>
<td>83</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>GE Lighting</td>
<td>LED12BP30R82740</td>
<td>Lutron MAOL-153M</td>
<td>2700</td>
<td>83</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>Satco</td>
<td>19415</td>
<td>Leviton D5L06-11Z, Lutron MAOL-153M</td>
<td>2700</td>
<td>83</td>
<td>95</td>
<td>40</td>
</tr>
</tbody>
</table>
7.1.10 ABC table surface
A black cloth and reflective card shall be placed on the table surface when testing according to the requirements in section 8.2.

7.2 Test media
The following video files shall be used for determination of On mode power consumption. The file with the highest resolution supported by the UUT shall be used.

For determination of the brightest PPS, one of the following static pattern video signal shall be used:
IEC_ThreeBar_SD_5994p_SDR_HEVC_AC-3.MP4
IEC_ThreeBar_HD_5994p_SDR_HEVC_AC-3.MP4

For stabilization and determination of On mode power consumption in SDR PPSs, one of the following dynamic broadcast-content video files shall be used:
IEC_Broadcast_SD_5994p_SDR_HEVC_AAC.mp4
IEC_Broadcast_HD_5994p_SDR_HEVC_AAC.mp4

For determination of On mode power consumption in the HDR10 PPS, one of the following dynamic broadcast-content video signal shall be used:
IEC_Broadcast_HD_5994p_HDR10_HEVC_AAC.MP4
IEC_Broadcast_UHD_5994p_HDR10_HEVC_AAC.MP4

In each of the above cases the higher of the two resolution levels shall be used if supported by the UUT.

Note: The camera photometer supplier may provide other test patterns to configure and calibrate the camera photometer.

7.3 Environmental conditions
The ambient temperature of the room used for testing shall be 23°C ± 5°C and the relative humidity shall be between 10% and 80% for the duration of the measurement procedure. The max and min ambient temperature shall be reported.

Note: Ambient temperature requirements from IEC 62087-1: 2015, humidity from 10 CFR 430, Subpart B, Appendix H, Section 4.2.

7.4 Ambient light conditions
For determining On mode power consumption for television sets with ABC enabled, ≤ 1 lx shall be confirmed at the surface of the ABC sensor assembly with the ABC lamp off and the UUT in the Standby, Off or Disconnected mode.
8 UUT TEST SETUP & PLANNING

The UUT shall be tested with ABC enabled or disabled for each PPS consistent with the default state of ABC for that PPS. For tests with ABC enabled, all the test set-up requirements in this section shall be in effect. For tests with ABC disabled, lamp set-up and reflective card requirements do not apply.

8.1 Initial set-up

Configure the UUT and test equipment per Figure 1, the general requirements documented in section 7, and the detailed instructions noted in section 8.

![Figure 1: UUT test set-up for measurements with ABC enabled](image)

**Note:** For the next year or two (e.g. until a possible VA Tier 1 takes effect), all VA-related tests shall be conducted at a lamp angle of 45 degrees. Using this fixed angle means the lamp will be positioned in front of the camera photometer for most TV models. Therefore, a system for placing the lamp in front of the camera photometer without obstructing the TV will be required.

8.2 Table surface

For ABC tests the table used to hold the UUT shall be covered with black, non-reflective cloth and shall have the area immediately in front of and underneath the UUT’s ABC sensor as shown in Figure 4 covered with reflective card having a gloss measurement of 15GU as measured by a
60-degree gloss meter. The material must not alter visible light in the 400 to 700nm range that arrives on or is reflected by the material. The thickness of the ABC sensor reflective card shall be 4mm or less and shall be at least 203mm wide by 177mm deep; shall be printed with a matte finish, with a colour adhering to the M1 lighting standard having CMYK values of (43, 53, 84, 84)+/-2. The card shall not polarize light reflected off its surface. The reflective card shall be placed under the stand of the UUT and centered left-to-right under the ABC sensor and with the back edge of the card aligned with the back of the TV’s bottom bezel. If this placement causes the card to extend beyond the table’s front edge, or if the UUT’s stand covers the table beneath the ABC sensor, align the front of the card with the front edge of the table instead.

Note: see section 10 for further information about the reflective card.

8.3 UUT installation

The UUT shall be installed in accordance with the manufacturer’s instructions.

In order to simplify alignment of the light source, all four corners of the face of the UUT should be equidistant from a vertical reference plane (e.g., wall) and the bottom two corners of the face of the UUT should be equidistant from a horizontal reference plane (e.g., floor). See section 8.1 for test environment setup.

The environmental conditions (7.3) and ambient light conditions (7.4) shall be confirmed.

8.4 Main batteries

Main batteries, if any, shall be removed for the duration of the measurement procedure.

8.5 Power

Provide power to the ABC lamp, camera and UUT from the AC power source per the power quality requirements defined in section 7.1.1 and the geographical requirements defined in Table 1.

Table 1: Typical declared electricity supplies for some regions

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Declared voltage(^1) and frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>115 V, 60 Hz</td>
</tr>
<tr>
<td>Europe</td>
<td>230 V, 50 Hz</td>
</tr>
<tr>
<td>Japan(^2)</td>
<td>100 V, 50/60 Hz</td>
</tr>
<tr>
<td>China</td>
<td>220 V, 50 Hz</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>220 V, 60 Hz</td>
</tr>
</tbody>
</table>
Australia and New Zealand

| 230 V, 50 Hz |

**Note 1:** Values are for single phase only.

**Note 2:** 50 Hz is applicable for the Eastern part; 60 Hz is applicable for the Western part.

### 8.6 Plug-in modules

No user-removable plug-in module, such as a conditional access module, a point of deployment module, a USB or HDMI stick or an external media storage unit, shall be connected to the UUT during the measurement procedure, unless it is installed in the UUT as shipped to the end customer. If the UUT is shipped to the end customer with a user-removable plug-in module which is described in the User Manual as necessary for the product’s primary out-of-box functionalities, that user-removable module shall remain connected during the measurement procedure.

A USB stick that contains media files (video, image, audio) for testing as specified in this document may be connected to the UUT as test media source during the measurement procedure. An HDMI source for standby testing specified in this document may be connected to the UUT as a video source during the stand-by low testing only.

### 8.7 Provision of test media

A USB input port on the UUT shall be selected, using a USB port recommended in the UUT manual for video file playback and one with the highest data rate specified (e.g. USB 3.0 supports higher data rates than USB 2.0). If multiple of the same date port are available, the port with a higher max amperage shall be selected (e.g 0.5A / 1A).

For USB inputs, a single USB 3.0 stick of at least 32GB that holds all the test media shall be inserted directly into the UUT’s USB port. The USB stick should be formatted in either Fat32 or ExFAT format. The UUTs native file player shall be used to play test files located on the USB stick. Before testing, confirm that the UUT remains in the same preset picture setting when switching from HDMI input to USB input. In the unlikely event that it does not, then either test with HDMI input selected, or select the USB input and manually ensure that the UUT is set to the default or specified preset picture setting associated with the HDMI input during all On mode tests.

The manufacturer, model and storage size of the USB stick used shall be reported.

If the UUT does not have a USB port capable of playing the test video files, the test files shall be played from a Blu-ray player with a compatible USB port using the BRP’s default settings. The BRP shall be connected to the UUT using an HDMI cable that meets the HDMI 2.0 standard or more recent update.

**Note:** Should add an anti-defeat clause that reduces that risk that TVs will be designed to perform more efficiently when playing content from USB sticks than via HDMI input for example? For example, the TV could be designed to increase local dimming when playing from USB stick with little customer impact since few people watch content from USB stick.
Note: Simplified relative to 62087 by requiring USB 3.0, which is backward compatible. Plan to comment in 62087 CD review.

8.8 UUT planning

8.8.1 Task overview

Record the information required below to make a test plan for the UUT.

- Record UUT screen width.
- For UUTs with at least one USB port, identify the USB spec level (i.e. 2.0 vs 3.0) of the highest speed port available or the port that is intended for video file playback as required by section 8.7.
  
  Note: We could possibly allow the use of any USB port unless there is a problem with file playback. Maybe just document which port is used.

- For TVs without a USB port, identify the appropriate HDMI port per section 8.7.
- Power on the UUT using the UUT remote control.
- Proceed through initial set-up prompts. When prompted to enable features like location services or crash reporting, or any other feature that has the potential to increase energy consumption, always enable.
- Update the firmware if possible (8.8.2.1), and factory reset the UUT using the above guidance on initial set-up prompts.
- Record SDR default PPS and whether ABC is enabled by default.
- Record HDR10 default PPS and whether ABC is enabled by default. Do this by ensuring that the UUT starts in the SDR default PPS and default ABC setting and then play the HDR10 broadcast dynamic test clip (7.2). Pause the video and check the PPS and ABC settings.
  
  Note: in rare cases, the USB media player closes when one selects the settings menu to check for PPS and ABC settings. In these cases, try again to determine the HDR10 default PPS using HDMI input (e.g. USB stick in BRP). If that also fails, assume that the HDR10 default PPS and ABC setting are the same as the default SDR PPS and ABC setting.

- Identify and record the SDR brightest PPS by following the instructions in section 8.8.2.3.
- Identify whether UUT has Quick Start feature and whether QS is enabled by default in the SDR default PPS (8.8.2.4)
- For TVs with QS disabled by default in the SDR default PPS, measure the wake time per (8.8.2.4).
● Identify if Remote Start is available (7.1.8.4)
● Identify if Wake-by-Voice is available (1.1)

8.8.2 Specific procedures

8.8.2.1 UUT firmware update

If a firmware update for the UUT is available, it shall be updated following the manufacturer’s instructions, e.g., via a USB stick or the UUT’s network connection by connecting it to the Internet. Upon completing any firmware update, disconnect the USB stick containing the firmware update files.

The firmware version of the UUT as tested shall be reported. Firmware version can generally be found in “About” section of TV settings, usually using the name “Software Version” or “Software Update.”

8.8.2.2 Identify the default SDR and HDR10 PPSs

Identify SDR default PPS and whether ABC is enabled by default in that PPS. Then identify the HDR10 default PPS and whether ABC is enabled by default in that PPS by ensuring that the UUT starts in the SDR default PPS and default ABC setting and then play the HDR10 broadcast dynamic test clip (7.2) from USB. Pause the video and check the PPS and ABC settings.

Note: It can be difficult to determine information about the default HDR10 PPS. Typically, the only way to put a TV into an HDR10 PPS is to play HDR10 content. However, on some TVs if one navigates to the settings menu from the USB clip player, it will shut down the USB clip player, presumably returning the TV to SDR settings. For cases like these, please consult the manual or manufacturer tech support to understand what features are enabled in the HDR10 PPS. Or try making the determination using HDMI input.

Make best attempts when testing to ensure that the TV is in fact in an HDR10 PPS. Some TVs temporarily show an HDR badge on the screen when playing HDR content. Others will indicate HDR in the PPS title. Others will indicate ST2084 as the gamma curve or EOTF in the advanced picture settings. The product manual and/or technical support may also be helpful. If one cannot confirm that the TV is in HDR10 mode when playing the HDR10 test clip, then conduct the test with the HDR10 clip anyway starting from the default SDR PPS.

8.8.2.3 Identify brightest PPS

Play the IEC SDR Broadcast Video clip for 5 minutes to stabilize the UUT. Then use the spot photometer to measure the luminance of each of the PPSs orthogonally at screen center while playing the Three Bar test pattern. Move camera photometer if necessary. Trigger the spot photometer after displaying the three-bar pattern in that PPS for 15 seconds. The video, which starts with 10 seconds of black, shall be restarted between each PPS during this determination.
Note: Some spot photometers require a few seconds to record a measurement. This time can be variable depending the luminance level. Therefore, we specify that the measurement shall be stated 15 seconds after the three-bar pattern is displayed, 25 seconds after the start of the test clip.

8.8.2.4 Quick Start

For TVs that have a quick start function, after enabling Remote Start, Wake-by-Cast, and Wake-by-Voice where possible per 8.11.1 plan to test the UUT with quick start in its default state if the UUT’s resume time is less than 10 seconds as measured per 8.8.2.5. Otherwise, test the UUT with quick start adjusted to provide the shortest possible resume time.

8.8.2.5 Measure wake time

When required in this spec, one must use the following procedure to measure wake time.

1. Connect the UUT to a LAN with no other connected devices and no WAN connection.
2. Before each standby test a live SDR video feed should be supplied via HDMI cable (e.g. from a set-top box, DVD or Blu-ray player), and the relevant UUT HDMI input shall be selected such that the SDR video feed is displayed by the UUT. This HDMI video stream should continue throughout the test.
3. All UUT inputs, other than the abovementioned HDMI input, shall be removed.
4. Power down the UUT with the remote-control unit.
5. Leave the UUT in this state for 20 minutes.
6. Measure wake time by recording the time duration between issuing a wake command and when the UUT displays video content. The method of waking the UUT will be determined by setup performed per section 8.11.1.

6.1 If the UUT has Wake-by-Voice configured wake time is determined by recording the time between the smart speaker receiving the voice command to wake the UUT and the UUT displaying the above mentioned HDMI video feed.
6.2 If the UUT does not have Wake-by-Voice capabilities but has Wake-by-Cast configured wake time is determined by measuring the time between casting to the UUT and the UUT displaying the casted content.
6.3 If the UUT has neither Wake-by-Voice nor Wake-by-Cast but has Remote Start wake time is determined by measuring the time between pressing the power button within the Remote Start application and the UUT displaying the video content supplied by the HDMI input.
6.4 If the UUT has no configurable wake settings wake time is determined by measuring the time between pressing the UUT remote control Power button and when the UUT displays the video content supplied by the HDMI input.
8.9 Camera photometer set-up

The camera photometer shall be positioned at a distance of 1.76 - 1.78 times the UUT screen width away from the center of the screen, pointing at the center of the screen.

The camera photometer must be powered with the AC Power Supply configured per section 8.5.

The camera photometer must be stabilized before testing is conducted, requiring a 60-minute warm-up, and it must be set to log data at 1 second intervals.

The camera shall be focused on the screen with the appropriate vignette correction in place for the test.

8.10 Lamp set-up

The lamp must be powered with the AC Power Supply configured per section 8.5. The center of the light source shall be aligned as shown in Figure 1.

Aside from the possible use of a 2 stop ND filter when applying low illuminance levels to the ABC sensor assembly of the UUT, there shall be no obstructions (e.g. diffusing media, IR filters, UV filters, etc.) between the illuminating light source and the UUT’s automatic brightness control (ABC) sensor assembly during power measurements.

If used, the ND filter, shall be positioned immediately in front of the illumination light source assembly with care to not exceed the filter’s operating temperature range. The illumination levels shall be verified with the illuminance measuring instrument positioned immediately in front of the ABC sensor assembly, parallel with the unit’s front frame regardless of the orientation of the ABC sensor (i.e. forward facing or downward facing), as shown in Figure 1.

No test room surface (i.e. floor, ceiling, and wall) shall be within a 0.5 m hemisphere in front of the center of the UUT’s ABC sensor. If the UUT ships with or has a built-in table stand, the UUT shall be setup on a table as shown in Figure 1. The table in front of the UUT’s ABC sensor should be covered with material the Test Table Surface Material as specified in section 8.2.

Note: To improve test repeatability, it is suggested that the lux meter be hung over top of TV with string fixed by tape on the back side of the TV, and two pieces of tape on the TVs top bezel, one on either side of the string during initial placement, to indicate string alignment and improve placement accuracy during subsequent ABC measurements (e.g. to confirm 100, 35, 12 and 3 lux ambient light levels).

For UUTs that are not capable of being positioned on a tabletop, for example TVs without a stand, they should be tested as close as possible to their intended configuration:

a) For wall mounted UUTs that include the ABC sensor [Figure 2] within the display enclosure the UUT should be mounted on a matt white wall at least 1m above floor level with no other objects on the wall within 50cm of all screen edges.
b) In addition, for wall mounted UUTs where the ABC sensor is located externally to the display [Figure 3], e.g. in an external electronics box enclosure or sound bar, the ABC sensor enclosure should be positioned in the same vertical plane as the screen (e.g. fixed to the same wall) at no further than 50cm distance. The ABC sensor enclosure should be fixed with or placed on (right angled) brackets and not on a shelf.

c) For all other TV designs that do fit within the above guidance, for example a rollable display integrated into a furniture-stand supplied by the TV manufacturer, the UUT should be tested with all such furniture on a floor covered with black felt material to a distance of at least 1m away from all such furniture.
The UUT mounting configuration used in Figure 1, Figure 2, or Figure 3 during testing, including details of the exact light source configuration used, shall be reported. NOTE: This standard cannot consider every variation of consumer (or laboratory) test environments (e.g., exact ambient lighting color temperature; lighting angle of incidence with respect to UUT’s ABC sensor; wall, floor, ceiling paint color, texture, reflectivity; specific UUT mounting configuration; etc.). Therefore, this standard provides the two methods most representative of consumer use, i.e., on an entertainment stand/table or wallmounted/manufacturer-supplied furniture stand.

If the UUT includes multiple ABC sensors, each sensor shall be illuminated to the same level, within the rated tolerance limits, and multiple light sources may be used.

8.11 UUT Settings

8.11.1 Network connections and wake

For all On and Partial-On Mode tests, if the UUT is network enabled, connect it to an internet-connected (i.e. WAN connected) LAN that includes no other networking devices besides the modem used for WAN connectivity, a network traffic generator configured to output multicast discovery packets to the LAN every 1 second, a mobile device with remote start application, and smart speaker. Details on the packet contents are in “Informative Annex C: Multicast Network Traffic”. More than one TV may be connected to the LAN used for testing.

If the UUT has multiple network connections (e.g., Wi-Fi and Ethernet), configure the UUT and connect it to a single network source in accordance with the hierarchy of connections listed in Table 2 of this section.

<table>
<thead>
<tr>
<th>Priority</th>
<th>Network Connection Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wi-Fi (Institution of Electrical and Electronics Engineers - IEEE 802.11- 20072)</td>
</tr>
<tr>
<td>2</td>
<td>Ethernet (IEEE 802.3). If the UUT supports Energy Efficient Ethernet (IEEE 802.3az-20103), then it shall be connected to a device that also supports IEEE 802.3az.</td>
</tr>
</tbody>
</table>

Conduct all tests with Remote Start, Wake-on-Cast and smart speaker Wake-by-Voice enabled where possible.

- When the UUT is capable of casting from first-party or third-party applications, this feature along with the ability to power-on remotely with mobile device, when present, shall be enabled. This feature is sometimes called “Remote Start” or “Power-on with Mobile”.
Enabling Remote Start will typically enable Wake-by-Cast. However, if this is not the case, then Wake-by-Cast capability must be separately enabled if possible.

If possible, configure the UUT to connect to a smart speaker with Wake-by-Voice enabled. Current major speaker brands known to support this capability are limited to Amazon and Google per section 7.1.8.3. Before choosing the smart speaker, check the UUT and/or smart speaker manufacturer websites to determine which speaker brand(s) support Wake-by-Voice. Some TVs advertise support for smart speaker Wake-by-Voice, but it is difficult or impossible to successfully configure this feature. If after a reasonable effort, a test lab cannot configure Wakeby-Voice, then try the other smart speaker brand specified in section 7.1.8.3. If neither speaker brand supports Wake-by-Voice, then test without this capability enabled. One or both smart speaker brands may be configured to control the UUT during testing. In other words, if the tester has attempted but failed to configure Wake-by-Voice with one or two brands of smart speaker, the tester does not have to disable speaker connections before testing. This can avoid the need for a UUT factory reset.

Which of these capabilities (Remote Start, Wake-on-Cast and smart speaker Wake-by-Voice) is advertised to work and which ones are confirmed to work (and therefore tested) shall be documented. In addition, the applications used to perform Remote Start (first-party applications, etc…), Wake-by-Cast (Youtube, Netflix, etc…), or Wake-by-Voice shall be documented.

8.11.2 Motion Detection Dimming (MDD)

All tests for On Mode power determination per clause 6.4 shall be performed with MDD disabled. If MDD cannot be disabled, the unit must be tested in the brightest selectable preset picture settings as determined by section 8.8.2.2.

Preset Picture Settings used for testing shall exclude the following:

- Picture setting labeled “PC” or “Computer” or otherwise intended for the use case where the Television Set is to be used as a monitor connected to a computer.
- Picture setting labeled “Game” or “Gaming” or otherwise intended for low-latency use when the Television Set is connected to a gaming console.
- Picture setting labeled “Accessibility” or “Low Vision” or otherwise intended to produce high contrast pictures explicitly for use by viewers with limited vision capabilities.

The state of the MDD feature during testing shall be reported.

8.11.3 Quick start

The Quick Start setting must be set per the determination made in section 8.8.2.4.

8.11.4 Video aspect ratio

The UUT shall be set such that the active area of the video input signal fills the entire display area.
8.11.5 Sound level adjustments
The volume control shall be adjusted to a level greater than zero that is closest to 2% of maximum.

*Note:* For a TV with a maximum level of 50, this would be a setting of 1.

8.11.6 Input selection
The input source chosen in section 8.7 (i.e. USB where possible) shall be selected.

9 TEST SEQUENCE

On Mode tests shall be conducted before Partial On Mode tests.

9.1 On Mode
1) Configure camera: Identify screen border in camera FOV and needed geometry corrections
2) Stabilize UUT: by repeatedly playing the first 5 minutes of the SDR broadcast test clip (a “stabilization run”) in the default PPS with ABC off until a stabilization run has an average power level that is within 2% of the previous run.
3) Calibrate camera if necessary, per manufacturer’s instructions.
4) Conduct ABC off tests with default backlight level for all 3 PPSs listed below.

Backlight shall be in the default setting for all 3 PPS tests listed below. Start each test by 5 minutes after completion of the previous test. Each broadcast test clip has 5 minutes of grey after the broadcast content with a timer that counts-up to 5 minutes. Log power and screenaverage luminance at 1 sec intervals.

a) SDR Default PPS
b) SDR Brightest PPS
c) HDR10 Default PPS

5) Conduct ABC off tests, with backlight level set to its lowest level, only for PPSs where ABC is not enabled by default.

a) SDR Default PPS
b) SDR Brightest PPS
c) HDR10 Default PPS

6) Conduct ABC on tests only for PPSs where ABC is enabled by default.

a) Set ambient light to 100 lux ± 5%
   i) SDR Default PPS  ii) SDR Brightest PPS iii) HDR10 Default PPS
c) Set ambient light to 35 lux ± 5%
   i) SDR Default PPS  ii) SDR Brightest PPS iii) HDR10 Default PPS

d) Set ambient light to 12 lux ± 5%
   i) SDR Default PPS  ii) SDR Brightest PPS iii) HDR10 Default PPS

e) Set ambient light to 3 lux ± 5%
   i) SDR Default PPS  ii) SDR Brightest PPS iii) HDR10 Default PPS

9.2 Partial On Mode

9.2.1 Test Conditions Partial On Mode Test

Standby-active, low power and wake-time measurements shall be conducted by powering down
the UUT from the SDR Default Preset Picture Setting configuration in its default state.

Standby tests must be conducted with updated software and active LAN and WAN connections.
Before the standby test, a live SDR video feed should be supplied via HDMI cable (e.g. from a
set-top box, DVD or Blu-ray player), and the relevant HDMI input shall be selected such that the
SDR video feed is displayed by the UUT. This video stream should continue throughout each
standby test so that wake time can be determined by measuring the time between pressing the
UUT power button to when the SDR video stream is visible on the screen.

All UUT inputs, other than the abovementioned HDMI input, shall be removed, including the
USB stick used to play video files during On mode testing.

For UUTs with a Quick Start (QS) feature that is disabled by default, if the wake time measured
per section 2.4.1 is equal to or greater than 10 seconds, then the standby-active, low test shall be
performed with QS enabled.

9.2.2 Measuring standby-active, low

Measure power at 1 second intervals for 40 minutes and determine the average power by
calculating the average of the power readings taken during the last 20 minutes of the test.
Measure wake time after measuring standby-active, low average power according to section
8.8.2.5.
The following items, while not required by implementers of this standard, met this standard’s specifications and measurement accuracies as used by the IEC 62087 Maintenance Team to confirm the utility and repeatability of this standard:

- Pantone Black 2C SuperSwatch (section 5.6.6 for test table ABC sensor material);
- Photo Research PR655 Spectroradiometer (section 7.1.8 for characterizing LED bulb specifications);
- PCE-GM 60Plus Gloss Meter (60 degree);
- Fing network scanner application (for mobile devices);
- Magic PacketTM network signal used for Wake-on-LAN functions
11 INFORMATIVE ANNEX A: REPORTING

11.1 Items to be reported

The following summarizes the items to be reported:

- Description/identification of the UUT (brand name, model number, etc),
- The date and location of the measurements,
- The name of the person/people who executed the measurements,
- The type of power source used (6.2.2). [Indicate the included external power supply (5.2.2)], mains power (5.2.3), and/or power from other than the mains (5.2.4)],
- The ambient temperature (5.3),
- The voltage and frequency of the power source (5.2.2, 5.2.3, 5.2.4, 6.2.2),
- The model of the lamp used for illuminating the ABC sensor to specific illuminance levels (5.6.5),
- The model of the lamp used for disabling the ABC feature (5.6.6),
- Selected input terminals (6.2.3),
- Selected video resolution and frame rate (6.2.4),
- Automatic brightness control capabilities (6.2.5),
- Network connection capabilities (6.2.6),
- Initial set-up prompt selection(s) (6.3.10.1),
- On mode power consumption, $P_{\text{on\_mode}}$ (W) (6.4.3, 6.4.4),
- Power factor (6.5.2.3),
- The manufacturer’s name or label associated with the brightest selectable Preset Picture Setting Preset Picture Setting (6.5.2.4),
- Whether $L_{\text{brightest\_selectable}}$ or $L_{\text{retail}}$ is greater (6.5.2.7),
- Peak Luminance ratio, $L_{\text{ratio}}$ (6.5.2.8),
- Power consumption in Standby-passive, $P_{\text{standby\_passive}}$ (W) (6.6.4),
- Power consumption in Standby-passive with Quick Start enabled, $P_{\text{standby\_passive\_quick\_start}}$ (W or N/A) (6.6.4),
- The availability of the Standby-active, low sub-mode (6.6.5.2),
- Power consumption in Standby-active, low, $P_{\text{standby\_active\_low}}$ (W or N/A) (6.6.5.3),
- The availability of Off mode (6.7.2),
- Power consumption in Off mode, $P_{\text{off}}$ (W or N/A) (6.7.3).
When directed to broadcast packets to simulate high network traffic home activity, configure a program capable of sending packets to multicast addresses on the LAN to send the following list of packets at the specified interval:

**MDNS (Multicast DNS) Packets (IPV4 address 224.0.0.251:5353)**
- Standard query 0x0000 PTR _googlecast._tcp.local, "QM" question
- Standard query 0x0000 PTR _spotify-connect._tcp.local, "QM" question
- Standard query 0x0000 A wpad.local, "QM" question

**SSDP (Simple Service Discovery Protocol) Packets (IPV4 address 239.255.255.250:1900)**
- HOST: 239.255.255.250:1900\r\nMAN: "ssdp:discover"\r\nMX: 1\r\nST: urn:dial-multiscreenorg:service:dial:1\r\n
- HOST: 239.255.255.250:1900\r\nMAN: "ssdp:discover"\r\nMX: 3\r\nST: urn:schemas-upnporg:device:MediaServer:1\r\n
- HOST: 239.255.255.250:1900\r\nMAN: "ssdp:discover"\r\nMX: 3\r\nST: urn:schemas-upnporg:device:MediaRenderer:1\r\n
**Note:** The PCL Kit Manual contains instructions for using Packet Sender to send these packets.
Appendix B: Equipment Used for Testing

TV Setup
- TV table/stand
- Black tablecloth
- Reflective card (PCL Test Kit)
- **AC power supply source** – DOE and PCL used different models:
  - PCL - Chroma Programmable AC Source Model 61602
  - DOE - California Instruments Model 1251P AC Power Source
- AC Power Wattman HPM-100-A Power Meter (PCL Test Kit)
  - Cords/equipment needed to connect AC power supply source to the power meter
  - Serial to USB cable to connect power meter to test kit laptop
  - **Note:** The laptop in the PCL test kit logs the data using a custom LabView program.
- PCL Test Kit Laptop used to collect and analyze data (PCL Test Kit)
  - Must contain PCL test software
  - PCL USB Thumb drive
  - **Note:** All test clips and images are provided in the USB thumb drive in the PCL test kit.
- **Blue Ray Player for Standby testing** – DOE and PCL used different models:
  - PCL - LG Ultra HD Blu-Ray Disc Player Model UP970
  - DOE – SONY UBP-X700
  - Disc with video more than 40 minutes long
    - PCL used IEC test clip DVD
    - DOE used Planet Earth II DVD

Bulb Setup
- Philips 10W 2700K LED Bulb
- AC outlet plug for bulb
- **Lamp dimmer source** – DOE and PCL used different methods:
  - DOE - Adjustable AC transformer for dimming (Superior Electric L2M126C)
  - PCL – Lutron MACL-153M-WH LED Dimmer Switch
- Stand setup for LED bulb
  - 2x 9 foot stand/tripod
  - Tripod ball head
  - Mounting clamp for mounting bulb onto tripod ball head
  - 5/8” x 36 in wooden dowel
    - Used to prevent tripod from obscuring cameras during ABC testing

Camera/Spectroradiometer Setup
- Basler camera setup (PCL Test Kit)
  - Basler camera
  - Stand for Basler camera
  - PoE injector to connect to laptop for data acquisition
  - Software (included in rental kit)
- Spectroradiometer setup
  - PR-655 spectroradiometer
  - MS-75 Lens
- CR-655 90 degree Cosine Receptor (integrating sphere)
- Data acquisition cables, software
- Stand for spectroradiometer

**Other/Miscellaneous equipment**
- T10-A illuminance meter – difference in calibration
  - PCL – Calibrated using LED light source
  - DOE – Calibrated using incandescent light source (noted to be +/-4% from LED calibrated device by PCL)
  - **Note:** We used the illuminance meter to determine the lux levels during ABC testing.
- Power strip(s) for connecting the laptop, TV, PC, spectroradiometer, camera (powered by PoE injector), LED bulb (connected via transformer), power meter.
- Temperature and humidity meters
- String and tape for positioning illuminance meter over ABC sensor
- String and/or tape measurer for measuring distances and angles
- Mobile app used to measure level and angle of Basler and ABC Lamp

**Network equipment**
- Modem + Router – different network equipment
  - PCL - Netgear N600 Wireless Dual Band Gigabit Router Model WNDR3800
  - DOE – Netgear model LB1120 modem, Linksys AC400 Triband router
  - 18 GB/month plan from AT&T
- Packet sender application to send Multi-Network Traffic
- Mobile app corresponding to TV brand used for wake commands
Appendix C: Unit 9 Reproducibility Investigation

To further investigate the cause of difference in measurement between DOE and PCL’s on mode test results for Unit 9, the luminance profile of the TV between the two labs was compared. The figures below show the luminance profile observed at PCL vs. DOE.

As seen in the figures, the luminance profile at PCL indicates a peak center luminance of about 200 nits with no edge deformity. On the other hand, the luminance profile at DOE indicates a peak center luminance of about 160 nits with large deformity at the right side of the screen. Overall, the luminance profile at DOE was dimmer compared to PCL. One potential reason for this difference may be that the TV was damaged during shipment to DOE.
Appendix D: DOE/PCL Unit Numbers and ENERGY STAR Version 9.0 Draft 2 Data Set Unit Key

<table>
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<th>Unit Number Identified in this Test Report</th>
<th>Unit Designation in the ENERGY STAR Draft 2 Version 9.0 Data Set</th>
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