Measurement of automatic brightness control in televisions – critical for effective policy-making

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Abstract

Display luminance ("brightness") is the largest energy consuming function in televisions and monitors. Subjective research on televisions in households has shown that displays can be dimmed when room ambient light levels are naturally reduced, to achieve lower product power consumption while not diminishing the quality of the viewing experience. This energy-saving feature is most commonly called 'automatic brightness control' (ABC) and works by dimming the display's brightness in relation to the room illuminance.

In Europe, manufacturers are given a small (5 %) power allowance when calculating the energy efficiency index for the energy label class, if the model has enabled and effective ABC under low light conditions. In the United States, the ENERGY STAR® program offers manufacturers a nominal allowance for ABC based on summing 25 % of the on-mode power requirement of the display at four nominal illuminance levels. The stark difference between the power allowances in these two leading economies is due in part to the lack of a good practicable test method and ability to characterize and quantify an optimum energy saving benefit of ABC.

CLASP funded research to develop a novel and repeatable approach to the measurement of television power consumption and display luminance versus controlled ambient illumination under ABC control. This paper describes and illustrates the test setup and data logging equipment to capture the television's power consumption and screen luminance characteristics under a full range of ambient light levels, from <2 lux to >300 lux.

This test method was applied to a small sample of televisions, and test results are provided. The test method provides insight into how the ABC algorithm is written in the television software, with some televisions progressively reducing screen brightness as the ambient lighting levels are lowered, and others simply having one large step reduction at a low level of room illumination. From an energy perspective, the software that progressively reduces screen brightness will achieve more energy savings.

CLASP is submitting this test method to the IEC and CEN/CENELEC for consideration as an update to relevant European and international test standards. Robust test methods like this one help policy-makers design more effective energy-efficiency policies and programs and can catalyse energy efficient design standardisation in the display manufacturing industry.

Introduction and policy context

Automatic brightness control (ABC) is an energy saving feature whereby a television uses a built-in light sensor ("ABC sensor") to detect the ambient level of light in a room, and then adjusts the brightness of the screen to provide a more appropriate and comfortable viewing condition. ABC is based on the principle that as light levels in a room are decreased, the screen does not need to be as bright for the same level of viewing acuity and perceived contrast ratio. Furthermore, in a dark room, a very bright screen can be harsh and uncomfortable for the viewer to watch. The built-in ABC sensor enables the television to adjust the screen brightness (the screen 'luminance') in proportion to the ambient light levels (the room 'illuminance') of the viewing room, enabling both increased viewer comfort and reduced power consumption of the television.

Due to the benefit of reduced energy consumption, televisions that incorporate ABC are given an incentive in policy programmes such as the European energy label and the United States' ENERGY STAR programme. In Europe, manufacturers are given a 5 % bonus on the power consumption in the calculation used to determine energy label class, as set out in the energy labelling regulation for televisions adopted in 2010 [EC, 2010], stating "the on-mode power consumption as established according to the procedure set out in Annex VII is reduced by 5 % if the following conditions are fulfilled".

And in the United States, the ENERGY STAR programme allows products that have ABC incorporated into their products and ship with it enabled to calculate the power consumption in the 'on' mode as the sum of a 25 % weighting the television's power consumption at 100 lux, 35 lux, 12 lux and 3 lux of room light levels. This was found by one study of 55 inch UHD televisions to effectively reduce the power consumption on average by half. [NRDC, 2015].

The United States Department of Energy (DOE) conducted a review of the literature surrounding ABC and issued a report containing an idealised response curve for TV screen luminance relative to the room illuminance [DOE, 2012]. The DOE report notes that the human eye has a logarithmic response curve to light, in other words the eye perceives every doubling of brightness as a subjectively similar degree of increase in lighting levels. Thus, an increase from 10 to 20 lux is perceived as equivalent to an increase from 100 to 200 lux.

Televisions that incorporate ABC ideally would have a luminance response curve that tracks the human eye response curve in order to maintain comfortable viewing conditions under various ambient light levels. And in addition to viewer comfort, the US DOE report notes that a gradual ABC response curve (i.e., one that implements an ideal "S" shape) has the potential to save a significant amount of energy as the television can adjust the screen luminance to a range of different illuminance levels. An ABC system that uses an S-curve response will save more energy than those that implement the screen luminance adjustment in a step or staircase fashion, where energy-savings derived from ABC would be reduced. Figure 1 shows a plot of screen brightness (i.e., a good proxy for power consumption) and ambient levels of room illuminance. The shaded area in this graph shows the opportunity for energy savings from avoided power used to maintain screen brightness.

Thus, while overall the benefit to viewers both in terms of comfort and energy savings is well understood, there has been, until now, no practicable test for measuring a television's performance using an ABC feature that provides sufficient granularity of data points to fully characterise the ABC control curve. This paper introduces a newly developed test method for ABC that would fill this gap, and enable policy-makers to develop more effective policies that take into account ABC performance.

New ABC test methodology

Harrison and testing laboratory colleagues developed a new test methodology for measuring a television's power and display luminance response with ABC enabled. This new ABC test methodology has the following important advantages:

- Easily controllable levels of illuminance simply and accurately targeted onto the television's ABC sensor via projector;

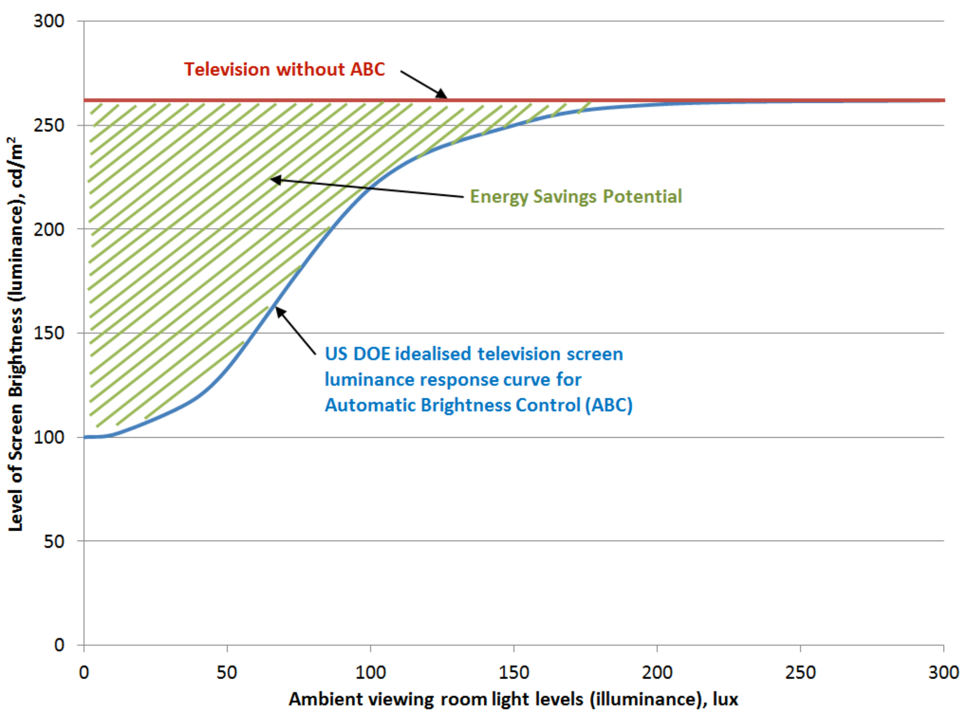

Figure 1. Energy Savings Potential of Automatic Brightness Control (ABC).

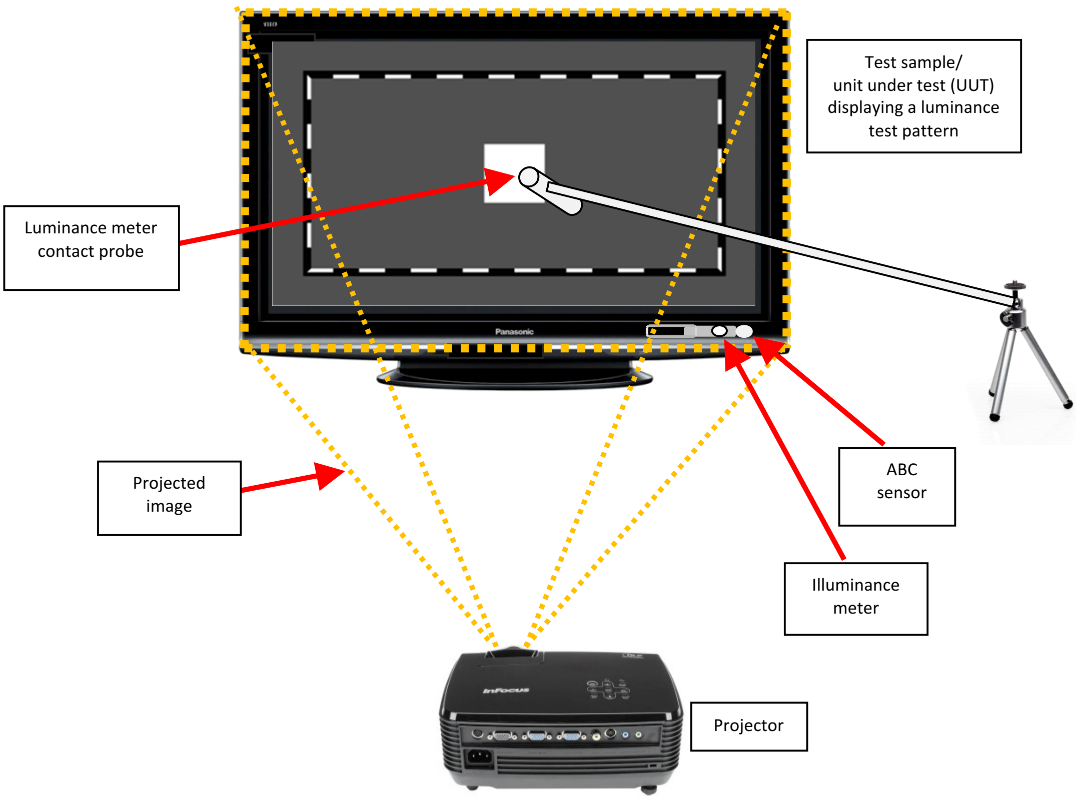

Figure 2. Graphical illustration of the test setup.

- Provides excellent granularity in terms of light levels as the projector's light output is cycled from full brightness to black and then back up again;
- Methodology is very efficient from lab technician time perspective; and
- Results are highly accurate and repeatable.

The test set-up is depicted in Figure 2, with labels to indicate the key pieces of equipment and components. The television under test is called the "test sample", and two light measuring instruments are used – one contact luminance meter that is mounted perpendicular to and at the centre of the display, and one illuminance meter next to the ABC sensor itself. The projector beam is directed onto the test sample and the illuminance adjacent to the ABC sensor is measured. Simultaneously, the resultant luminance of the white portion at the centre of the displayed test pattern is also measured. A further simultaneous measurement is made of the power consumption of the unit under test. When the projector's light output is varied, by means of projecting various greyscale images sequentially, this provides the relationship data recorded on a common timescale between ambient light level, screen brightness and power consumption.

Figure 3 provides a photograph of a power meter, luminance meter and data logging computers which are used in the test setup for measuring ABC. A summary of the test methodology followed for measuring ABC is outlined below:

1. **Test Setup** – a television, projector and light meters are set-up as shown in Figure 2 in a dark room, and connected to the metering equipment. The television (unit under test, or UUT) is then connected to its standard AC input voltage via a data logging power meter. A data logging contact colour analyser for display luminance measurements is mounted in a fixed position at the centre of the screen, within the boundaries of a luminance test pattern (or suggested modified pattern with motion – Figure 4) peak white box (see Figure 2). The projector should be positioned approximately perpendicular from the UUT, although this is not critical (unlike the current DOE lamp methodology) and the only precise alignment required is one to ensure that the illuminance meter is registering an illuminance value at the fixed test position very close to the value immediately in front of the ABC detector within 2 lux at approx. 100 lux illuminance).
2. **Adjust illuminance to >300 lux** – the distance between the projector and the UUT is then adjusted to provide an illuminance reading of more than 300 lux on a data logging illuminance meter that is mounted next to (but not blocking) the ABC sensor of the UUT. Any reflective surfaces from trim or plastic that are part of the UUT are not masked, but all other surfaces between the projector and the UUT are dark and non-reflective.
3. **Vary illuminance and record data** – the projector is fed a slide show which consists of 39 slides that vary the light output of the projector from white (255, 255, 255) to black (0, 0, 0). These slides are played in an automated presentation mode with a five-second duration for each slide in forward and then in reverse order. These slides are projected at the UUT in a dark room (i.e., <1 lux measured at the ABC sensor), and this has the effect of adjusting the illuminance measured by the television's ABC sensor. The black slide

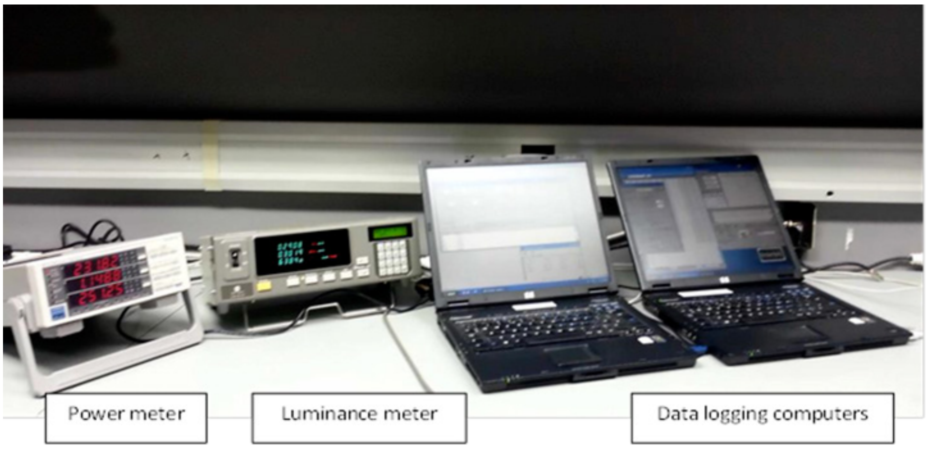

Figure 3. Photograph of the data logging equipment for the ABC Test Methodology.

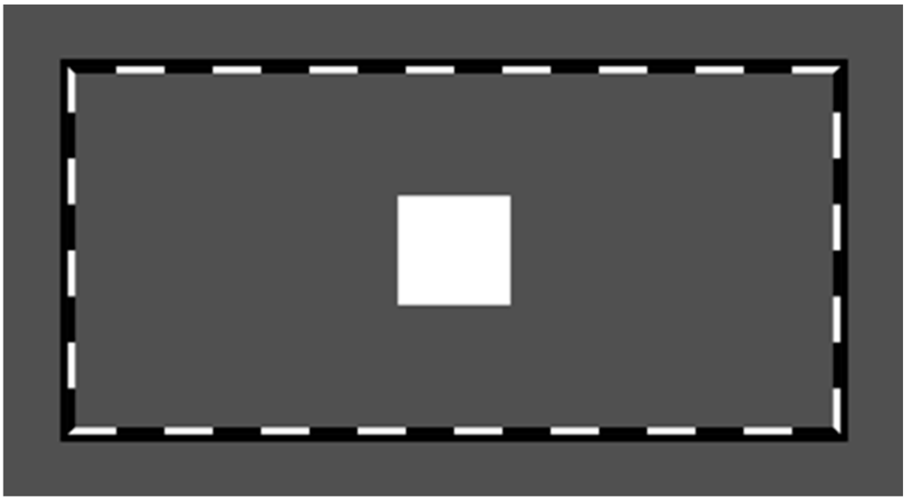

Figure 4. Modified European luminance test pattern (EN 62087) displayed continuously on television during test.

normally provides an illuminance at the ABC sensor of less than 2 lux. During the slide show presentation, the illuminance at the ABC detector, the power of the television and the display luminance are simultaneously logged in Excel with no technician involvement in the process. After reaching the end of the presentation – which ends on a black slide – the presentation is then run in reverse, back to the full white >300 lux white slide.

Applying the new ABC test methodology

The aforementioned test setup and measurement procedure were then applied to a small sample of televisions with ABC to assess the test method and understand more about the ABC feature of the televisions. The following figures present the findings.

Figure 5 presents the results for Model A, a 55-inch television which had a had a relatively smooth power transition that started around 100 lux and reduced down to about 7 lux. Above 100 lux and below 7 lux, the television's luminance was relatively flat, drawing constant power.

Figure 6 presents the screen luminance measurements for model A again, but this time from 0 to 300 lux ambient room illuminance, and with the ideal US DOE curve, to see how it compares to the ideal curve. Model A saves some power but generally has a brighter screen than the ideal reference curve.

Figure 7 presents the measured test results for model B, a 43-inch television. When tested, Model B was found to have a very different power-illuminance curve compared to model A, it used a step function rather than variable screen brightness. The screen maintained the same level of luminance from >300 lux to approximately 10 lux, and then decreased rapidly to about 4 lux and stayed flat. Although it did not capture all the energy savings possible at the different levels of room illuminance between 300 and 12 lux, the fact that it stepped down at 12 lux enabled the television to earn the benefit of the 5 % power allowance under the existing energy labelling regulation. The regulation states "automatically reduced between an ambient light intensity of at least 20 lux and 0 lux" [EC, 2010], but does not require any adjustment at other illuminance levels.

Figure 8 presents the screen luminance measurements for model B again, but this time from 0 to 300 lux ambient room illuminance, and with the ideal US DOE curve, to see how it compares to the ideal curve. When compared to the US DOE ideal curve, the lost energy savings from the step-function are clearly illustrated – there is no reduction in power between

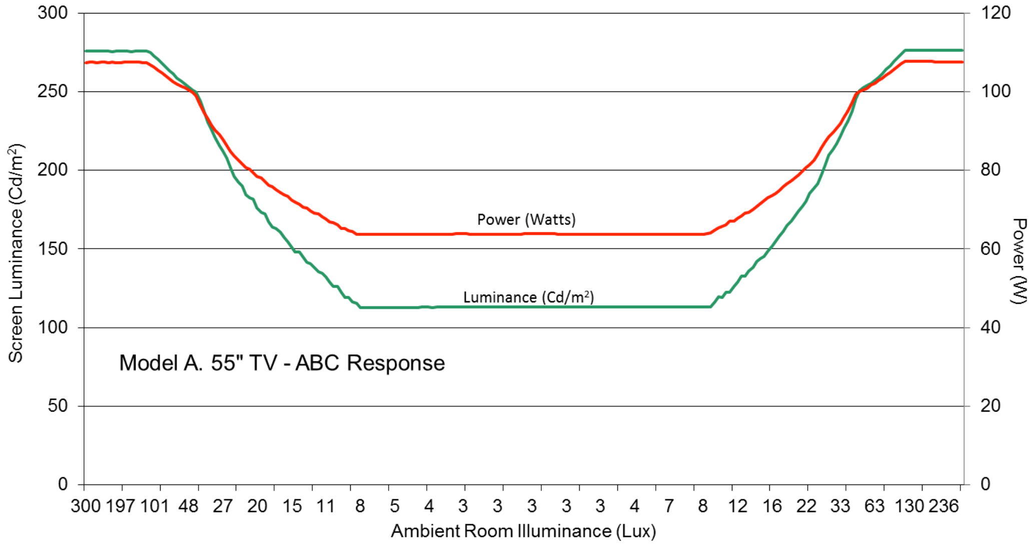

Figure 5. Model A, a 55" TV – ABC Test Results: Power and Screen Luminance Data.

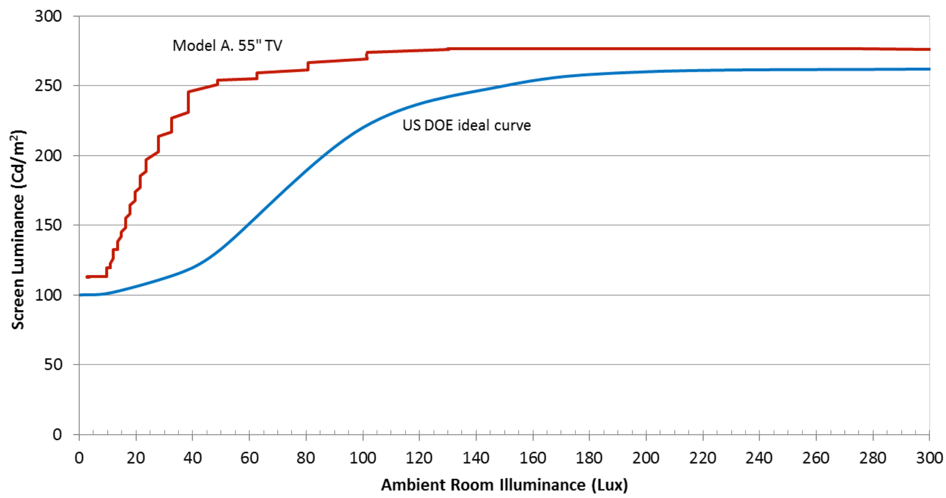

Figure 6. Model A, a 55" TV – ABC Test Results: Room Illuminance vs. Screen Luminance Data.

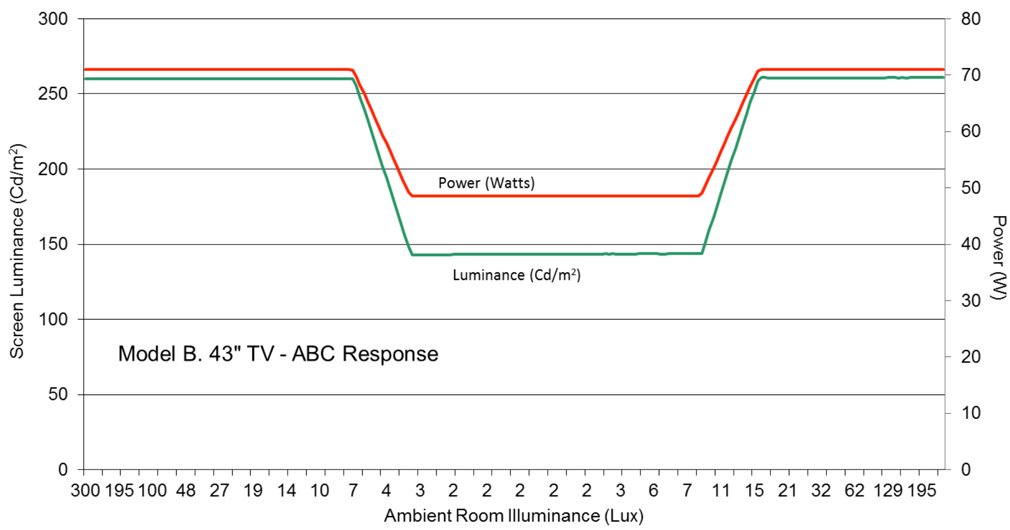

Figure 7. Model B, a 43" TV – ABC Test Results: Power and Screen Luminance Data.

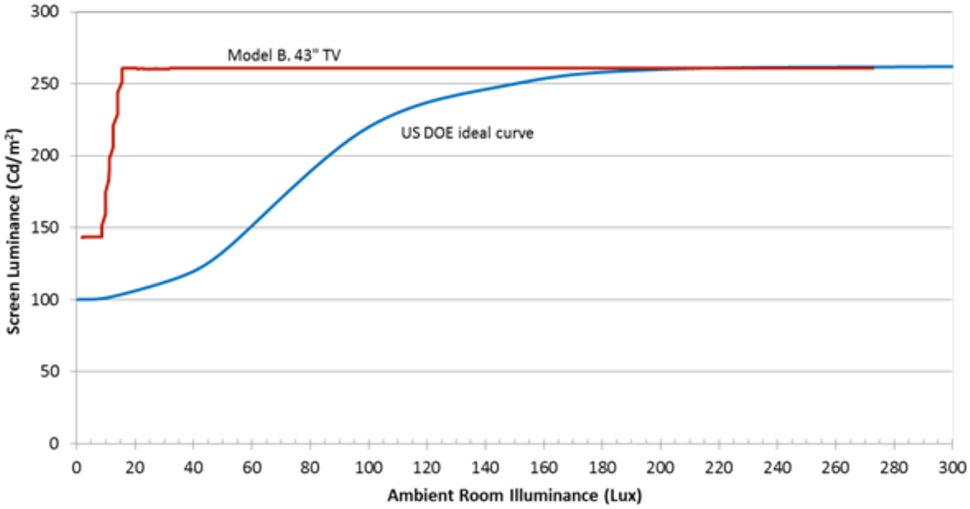

Figure 8. Model B. 43" LED TV – ABC Test Results: Room Illuminance vs. Screen Luminance Data.

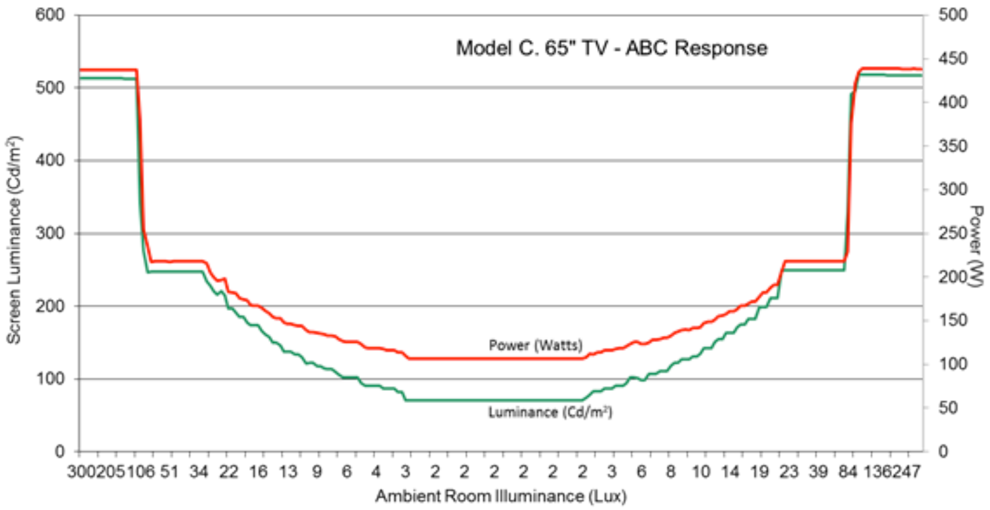

Figure 9. Model C, a 65" TV – ABC Test Results: Power and Screen Luminance Data.

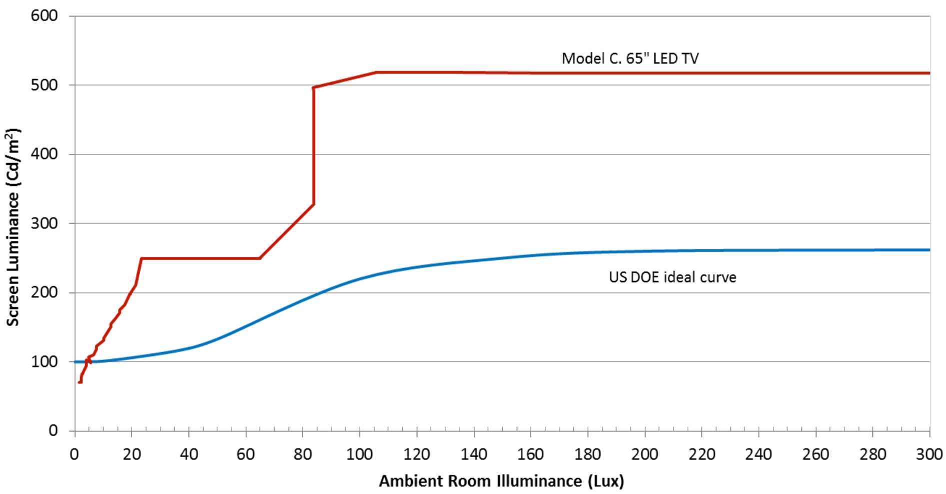

Figure 10. Model C. 65" LED TV – ABC Test Results: Room Illuminance vs. Screen Luminance Data.

10 lux and 150 lux, whereas the US DOE curve recommends adjusting the screen luminance over that illuminance range, which would result in energy savings by the television.

Figure 9 presents the shape of the ABC power profile for model C, a 65-inch television. The graph shows that screen luminance did not change between 300 lux and 100 lux of ambient room illumination, then it dropped significantly, and followed a gradual curve reducing all the way to 3 lux. This shape has characteristics of both the step function and the variable screen brightness.

Figure 10 compares model C, the 65-inch television, to the US DOE ideal curve. This graph shows that model C deviates from the recommended levels of screen brightness, and that the television was brighter than what the US DOE report recommends for screen luminance in all levels of ambient room illuminance. The change in power from the 300 lux to 3 lux was very large for this model, representing more than 70 % of the full brightness screen power consumption.

Overall, applying the new ABC measurement method to three televisions revealed performance data about the ABC software in these models, and how they responded to changes in ambient room illumination. These ABC response curves were compared to the US DOE recommended curve, which establishes a recommended level of screen luminance for a given background ambient room illuminance. In general, the screens were all brighter than the recommended US DOE curve, which corresponds to higher energy consumption. There was, however, a distinct difference between models A and B, in that model A did offer a number of adjustments in the level of screen brightness as the ambient light levels were reduced. Model B, however, only offered one large reduction at a low level of room illuminance (around 12 lux), and at all light levels above that, simply held the screen at full brightness. The approach to ABC followed by Model B will not offer the full energy savings potential of this feature, nor will it offer a comfortable viewing experience for consumers at lower light levels close to, but not less than, the point where ABC dims the screen.

Potential policy measure

It is recognised that there is value in encouraging manufacturers to design their ABC software incorporated into televisions to better track the ideal curve. For this reason, CLASP suggests that the European Commission considers adopting language in the draft ecodesign measure which would reward manufacturers who follow this curve with an extra power allowance. This reward of extra power allowance would be justified on the basis that the energy savings of the television would be recorded at ambient light levels between 300 lux and 12 lux. It is suggested that the US DOE ideal curve is subjected to a curve fit and that this equation is used as a basis for comparison with the actual ABC curves used by television manufacturers. If they are within a small percentage, then the extra power allowance would be granted.

Working from the recent draft of the European Commission's regulation of electronic displays published[1] as part of the World Trade Organisation's review, CLASP identified a possible location and language where this incentive could be incorporated into the regulation. This would require revisions in section 6.3 and bullet 9 in Annex IV for market surveillance authorities. Possible language to incorporate into section 6.3 is presented here:

B) For products supplied with ABC enabled by default, $P_{measured}$ may be reduced by 15 % in the calculation of the EEI provided that:

- $P_{measured}$ is recorded with an ambient light illumination of 300 lux measured at the ABC sensor of the display product;
- $P_{measured}$ is recorded at all light levels (L) from 12 to 300 lux using a published transitional test method, and the screen luminance measured in cd/m^2 is found to be no greater than ±5 % of the recommended luminance level characteristic, defined by the equation: = 95+165 /(1+EXP(-0,05*(L-75))) where L is the ambient light level measured at the ABC sensor of the display ranging from 12 to 300 lux; and
- $P_{measured}$ reduces by at least 20 % when the ambient light illumination measured at the ABC sensor of the display product is reduced from 300 lux to 12 lux.

Conclusions and recommendations

Many televisions placed on the market today offer an energy-saving feature commonly referred to as 'automatic brightness control' (ABC). ABC works by dimming the display's brightness in relation to the room illuminance, thereby reducing the power consumed by the television. CLASP funded research to develop a novel and repeatable test method to enable the continuous measurement of television power consumption and display luminance versus controlled ambient illumination under ABC control. Test methods like this one help policy-makers design more effective energy-efficiency policies and programs and can catalyse energy efficient design standardisation in the display manufacturing industry.

The new test method was developed which offers robust, accurate, fast and repeatable measurements using data loggers, light meters and a projector. A small sample of televisions was tested, and the results were compared to the US DOE's idealised screen luminance vs. room illuminance curve. Several different approaches to ABC were observed through the new test method: model A tended to follow the DOE recommended curve; model B simply dropped screen luminance once at a level <20 lux (a large step change); and model C had significantly higher brightness than the others, but which also had characteristics of a step function and a curve function, tracking the variance in room illuminance.

Table 1 presents the min-max range of on-mode power change for the range of room illuminance levels simulated by projecting light onto the television's ABC sensor. The range of savings potential of ABC is between 32 % and 76 % of the full power. However, the min-max range of savings for each individual television needs to be assessed in the context not only of the power consumption, but also how what the television will

1. The draft ecodesign regulation was published in January 2017 on this webpage: http://ec.europa.eu/info/law/better-regulation/initiatives/ares-2016-7108187_en.

Table 1. Summary of Power Measurements for Automatic Brightness Control Testing.

Television Tested	On-mode wattage consumption at >300 lux and <2 lux	Percentage power reduction between >300 lux and <2 lux	ABC Response Curve Type
Model A. 55″ television	108 watts and 64 watts	41 %	Continuous
Model B. 43″ television	71 watts and 48 watts	32 %	Step
Model C. 65″ television	439 watts and 106 watts	76 %	Step/Continuous

do at room illuminance levels between the min and max. Televisions that have a single step response will not save as much energy as those with a continuous curve because with a single step, the screen is not responding to the variance in the ambient room illuminance.

CLASP is submitting this new methodology to the CEN/CENELEC technical committee for measurement standards of televisions (TC 100X), it is hoped that it can become a European and eventually international standard, and constitute the basis for stronger and more effective policy-making in the future. The ability to look at the power consumption at different levels of room illuminance enables more precise benefit calculations and will enable viewers to enjoy both a better picture and save energy.

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