



**Supporting the Commission with testing
the energy consumption of computer
displays in light of the update of data
for the review of the Ecodesign and
Energy Labelling Regulations on
electronic displays**

Final Report

Task 1 – Testing and Test Results

Task 2 – Results Analysis and Conclusions

Final version

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1 Introduction

Under the requirements of this service agreement the Consortium produced for the Commission:

- An interim report based on tests of twenty-two 2017 monitors that was used to support discussion at the Ecodesign Consultation Forum, in July 2017, for the proposed labelling of Television and Monitor display products;
- An unabridged final laboratory test report delivered in September 2017 on the detailed findings of the testing of a total of 30 monitors from the 2017 European catalogues of monitor manufacturers.
- This final report, analysing the laboratory report results, which is objective, presenting the test results anonymously and providing an analysis and record of discussions of those results particularly in the context of the Commission's proposed Energy Efficiency Index (EEI) equations for electronic displays.

2 Executive Summary

Of the thirty monitors tested for this report twenty fail to meet the Commission's proposed relevant EEI level.

For the eleven monitors which are categorised as "UHD and Above" all have a resolution of UHD and 16:9 aspect ratio (3840 X 2160 pixels) and have flat displays. Seven of these monitors do not meet the Tier 1 EEI proposal and of the three that do, two (ED13 and ED30) have a relatively low but acceptable standard mode peak luminance of 247 and 224 cd/m² respectively however as delivered with a brightest pre-set mode peak luminance of 427 cd/m² ED30 would not meet the luminance ratio requirement of 65% and would not be compliant. A small reduction in peak luminance in the standard mode of UHD samples ED29 and ED32 would allow EEI compliance and not affect luminance ratio compliance. In summary, more detailed attention to factory pre-set luminance levels could allow better EEI compliance for this monitor category.

Of the nineteen monitors categorised as "Below UHD" twelve do not meet the proposed EEI limit but for seven of these samples more detailed attention to factory pre-set luminance levels could allow both EEI and luminance ratio compliance.

The on-mode specific power demand (Watts / unit area of display) of wide aspect ratio and curved display monitors tested is with two exceptions, ED04 and ED16, higher than equivalent flat 16:9 aspect ratio displays. This finding lends some support to the high backlight transmission losses identified by the display manufacturing industries as attributable to the comparatively wide non-transmissive LCD matrix structure of curved displays and to the greater light loss in wider backlight reflector and diffuser panels.

Only two of the test batch of monitors has ABC functionality. In both cases the ABC control characteristic is acceptably progressive but should start control at a much higher ambient light level. The ABC test results support the argument that the ABC characteristic for monitors could mirror that suggested for TVs.

Fourteen of the thirty monitors have external AC to DC power supplies (EPS) with a product specific DC interface connection (i.e. not a standardised DC interface such as USB). All of these monitors have power requirements compatible with USB C power

delivery (PD) Profiles 1 to 5 (10 W to 100 W) and with DC interface modification could operate with a standardised EPS.

Nine of the fourteen monitors with EPS with a product specific DC connection are non-compliant. This number was re-calculated for a hypothetical situation where these monitors were designed with a standardised DC power connection and placed on the market without an EPS. In this situation the measured on-mode power level used for the EEI calculation should be measured at the DC level i.e. excluding the losses in the EPS. The DC power measurement was included as part of the laboratory measurements and it was instead calculated based on assumed efficiencies of the EPSs using the International Efficiency Marking Protocol levels provided in the EPS casings. The new EEI for the DC power level was checked against the EEI_{max} resulting in three more monitors would pass and two are very close. I.e. the number of failing monitors would be reduced from nine to four to six.

3 Task 1. Testing and Test Results

For this task, power demand measurements in on mode and standby modes were conducted under the framework of the test conditions and the test methodology specified in the current versions of IEC/EN 62087 parts 2 & 3: 2015 / 2016 (Methods of measurement for the power consumption of Audio Video and related equipment) and EN 50564: 2011 (Electrical and Electronic household and office equipment - Measurement of low power consumption) respectively.

For automatic brightness control (ABC) testing and characterisation, a new state of the art testing procedure was employed.¹

The following principle test results for each monitor under test are reported:

- On mode power demand and peak white luminance in the mode in which the product is delivered or the mode recommended by the manufacturer for normal use;
- On-mode power demand in delivered mode or recommended usage mode for the product using a dynamic video test sequence of 34% APL other than that provided with IEC 62087 part 2;
- On-mode power demand and peak white luminance of highest peak luminance (brightest) factory pre-set mode or, if this is not available, a laboratory set mode providing an acceptable grey scale and the highest peak white luminance;
- Power demand of standby, network standby and off modes both manually and automatically configured through automatic power down (APD);
- Standby power demand characteristic evaluation (i.e. stable or unstable) and where unstable a graphical analysis of the long duration characteristics for discussion;

¹ Intertek/Harrison et al ECEEE 2017 Paper 7-422-17

- The on-mode power reduction and display luminance reduction of ABC action in response to a high granularity ambient light illumination change from 300 lux to 12 lux, with data fully characterised, in graphical form;
- Where a product features one or more video inputs (Display Port, Thunderbolt, HDMI, VGA, SDI or similar) the response of a main input type (analogue and digital) to the power management protocols of the connected host device (e.g. Computer, Set Top Box or analogous) and the standby power requirement of the modes qualified by those protocols.

These test results, details of test conditions, test equipment identifiers and a basic inventory for each monitor model are detailed in full in a test laboratory report in a file format spread sheet embedded for practicable viewing in Annex 2 and the principal test results are summarised for discussion in Table 1.

Under Task 2 – Results Analysis and Conclusions and in addition to a discussion of principle test results, graphical analysis is made of measured values of on-mode power and measured display area related to the Commissions proposed EEI metrics (see Annex 1). Further graphical analysis is presented for ABC discussion.

Table 1. Test results summary table

Row	Sample	ED01	ED02	ED03	ED04	ED05	ED06	ED07	ED08	ED09	ED12
1	Display Technology	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD
2	Nominal Diagonal ins/cms	28/71	24/61	28/71	29/74	24/61	29/74	24/61	27/68	27/68	14/36
3	Nominal Aspect Ratio	16:9	16:9	16:9	2.4:1	16:9	2.4:1	16:9	16:9	16:9	16:9
4	Display Form	Flat	Flat	Flat	Curved Wide	Flat	Flat Wide	Flat	Flat	Flat	Flat
5	Measured Image Area (dm ²)	21.24	15.91	21.24	19.08	15.91	19.11	15.68	19.76	19.97	5.39
6	Res. pixels Horiz. X Vert.	3840 2160	1920 1080	3840 2160	2560 1080	1920 1080	2560 1080	1920 1080	3840 2160	3840 2160	1600 900
7	Max. Peak Lum. (cd/m ²)	267.2	234.1	292.0	302.0	288.5	312.3	141.4	327.8	301.2	155.8
8	Default Peak Lum. (cd/m ²)	266.1	234.1	292.0	272.0	288.5	312.3	141.4	327.8	300.3	155.8
9	On-Mode Power (W)	45.1	23.1	44.7	24.7	23.1	37.0	17.7	35.9	52.4	4.5
10	Manual Standby or Off (W) S=stable	0.26 S	0.17 S	0.31 S	0.24 S	0.15 S	0.24 S	0.13 S	0.28 S	0.35 S	0.52 S
11	APD-Standby (networked) (W) S=Stable	0.47 S	0.26 S	0.39 S	0.78 S	0.18 S	0.29 S	0.19 S	0.30 S	0.35 S	0.46 S
12	HDMI CEC Y / N	N	N	N	N	N	N	N	N	N	N
13	EDID Active all video inputs Y / N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
14	EEl (EEl _{max} for Tier) FAIL/PASS Tier	1.466 (1.10) FAIL Tier 1	0.938 (0.90) FAIL Tier 1	1.454 (1.10) FAIL Tier 1	0.883 (1.10) PASS Tier 1	0.938 (0.90) FAIL Tier 1	1.302 (1.10) FAIL Tier 1	0.735 (0.75) PASS Tier 2	1.236 (1.10) FAIL Tier 1	1.776 (1.10) FAIL Tier 1	0.384 (0.60) PASS Tier 3
15	EPS Y / N	Y	N	N	Y	N	Y	N	N	N	DC 5 V USB
16	Modifiable to standardised DC Power Y/N	Y	n/a	n/a	Y	n/a	Y	n/a	n/a	n/a	Type A

Table 1. continued.

Row	Sample	ED13	ED14	ED15	ED16	ED17	ED18	ED19	ED20	ED21	ED22
1	Display Technology	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD
2	Nominal Diagonal Ins/cms	32/81	34/86	34/86	38/96	34/86	34/86	24/61	43/110	24/61	22/56
3	Nominal Aspect Ratio	16:9	2.4:1	2.4:1	2.4:1	2.4:1	2.4:1	16:9	16:9	16:9	16:9
4	Display Form	Flat	Curved Wide	Curved Wide	Curved Wide	Curved Wide	Curved Wide	Flat	Flat	Curved	Flat
5	Measured Image Area (dm ²)	27.43	26.80	26.80	26.77	26.77	26.77	15.85	49.87	15.32	12.86
6	Res. pixels Horiz. X Vert.	3840 2160	3440 1440	2560 1080	3840 1600	3440 1440	3440 1440	1920 1080	3840 2160	1920 1080	1920 1080
7	Max. Peak Lum. (cdl/m ²)	247.0	301.6	247.0	294.0	347.9	273.0	299.3	342.1	350.8	256.8
8	Default Peak Lum. (cdl/m ²)	247.0	301.6	247.0	294.0	343.0	272.7	299.3	342.1	256.8	256.8
9	On-Mode Power (W)	35.6	50.2	36.2	45.6	44.5	46.0	21.1	56.3	34.1	22.3
10	Manual Standby or Off (W) S=Stable	0.15 S	0.28 S	0.16 S	0.26 S	0.24 S	0.26 S	0.20 S	0.21 S	0.19 S	0.00 S
11	APD-Standby (networked) (W) S=Stable	0.22 S	1.33 S	0.30 S	0.74 S	0.59 S	0.57 S	0.30 S	0.32 S	0.26 S	0.16 S
12	HDMI CEC Y / N	N	N	N	N	N	N	N	N	N	N
13	EDID Active all video inputs Y / N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
14	EEI (EEI _{max} for Tier) FAIL/PASS Tier	0.962 (1.10) PASS TIER 1	1.369 (1.10) FAIL Tier 1	0.994 (1.10) PASS Tier 1	1.077 (1.10) PASS Tier 1	1.217 (1.10) FAIL Tier 1	1.257 (1.10) FAIL Tier 1	0.863 (0.90) PASS Tier 1	0.926 (1.10) PASS Tier 1	1.401 (0.90) FAIL Tier 1	1.039 (0.90) FAIL Tier 1
15	EPS Y / N	Y	Y	Y	Y	Y	Y	N	N	Y	N
16	Modifiable to standardised DC Power Y/N	Y	Y	Y	Y	Y	Y	n/a	n/a	Y	n/a

Table 1. continued

	Sample	ED23a	ED24	ED25	ED26	ED27	ED28	ED29	ED30	ED31	ED32
1	Display Technology	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD	LCD
2	Nominal Diagonal Ins/cms	34 86	27 68	23 58	34 86	27 68	28 71	28 71	27 68	27 68	27 68
3	Nominal Aspect Ratio	2.4:1	16:9	16:9	2.4:1	16:9	16:9	16:9	16:9	16:9	16:9
4	Display Form	Curved Wide	Curved	Flat	Flat Wide	Flat	Flat	Flat	Flat	Flat	Flat
5	Measured Image Area (dm ²)	26.62	20.06	14.35	26.77	20.06	21.18	21.18	20.06	20.06	20.06
6	Res. pixels Horiz. X Vert.	3440 1440	2560 1440	1920 1080	3440 1440	2560 1440	3840 2160	3840 2160	3840 2160	3840 2160	3840 2160
7	Max. Peak Lum. (cdl/m ²)	309.1	424.1	214.4	271.9	234.2	317.8	303.7	427.2	485.4	303.3
8	Default Peak Lum. (cdl/m ²)	309.1	398.6	163.4	219.5	201.1	209.3	277.0	223.9	276.7	275.6
9	On-Mode Power (W)	50.6	57.3	17.3	45.4	31.6	39.0	36.1	31.4	64.0	34.8
10	Manual Standby or Off (W) S=Stable	0.26 S	0.30 S	0.11 S	0.39 S	0.27 S	0.24 S	0.15 S	0.28 S	0.20 S	0.26 S
11	APD-Standby (networked) (W) S=Stable	0.26 S	0.82 S	2.24 S	0.41 S	0.3* S	0.27 S	0.22 S	0.30 S	0.24 S	0.33 S
12	HDMI CEC Y / N	N	N	N	N	N	N	N	N	N	N
13	EDID Active all video inputs Y / N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
14	EEl (EEl _{max} for Tier) FAIL/PASS Tier	1.386 (1.10) FAIL Tier 1	1.932 (1.10) FAIL Tier 1	0.762 (0.90) PASS Tier 1	1.241 (1.10) FAIL Tier 1	1.081 (1.10) PASS Tier 1	1.275 (1.10) FAIL Tier 1	1.182 (1.10) FAIL Tier 1	1.074 (1.10) PASS Tier 1	2.155 (1.10) FAIL Tier 1	1.187 (1.10) FAIL Tier 1
15	EPS Y / N	N	Y	Y	N	N	N	Y	N	N	Y
16	Modifiable to standardised DC Power Y/N	n/a	Y	Y	n/a	n/a	n/a	Y	n/a	n/a	Y

*14 W for 12 minutes falling to 0.3 W stable characteristic

4 Task 2. Results Analysis and Conclusions

4.1 Graphical analysis of test results based on Annex 1 metrics

In the following Figure 1 to Figure 6 an analysis of the data in the previous section based on Annex 1 metrics is presented together with the threshold curves for the proposed EEI requirements.

Figure 1. All monitor test data results: Average power and display area coordinates vs EEI requirements

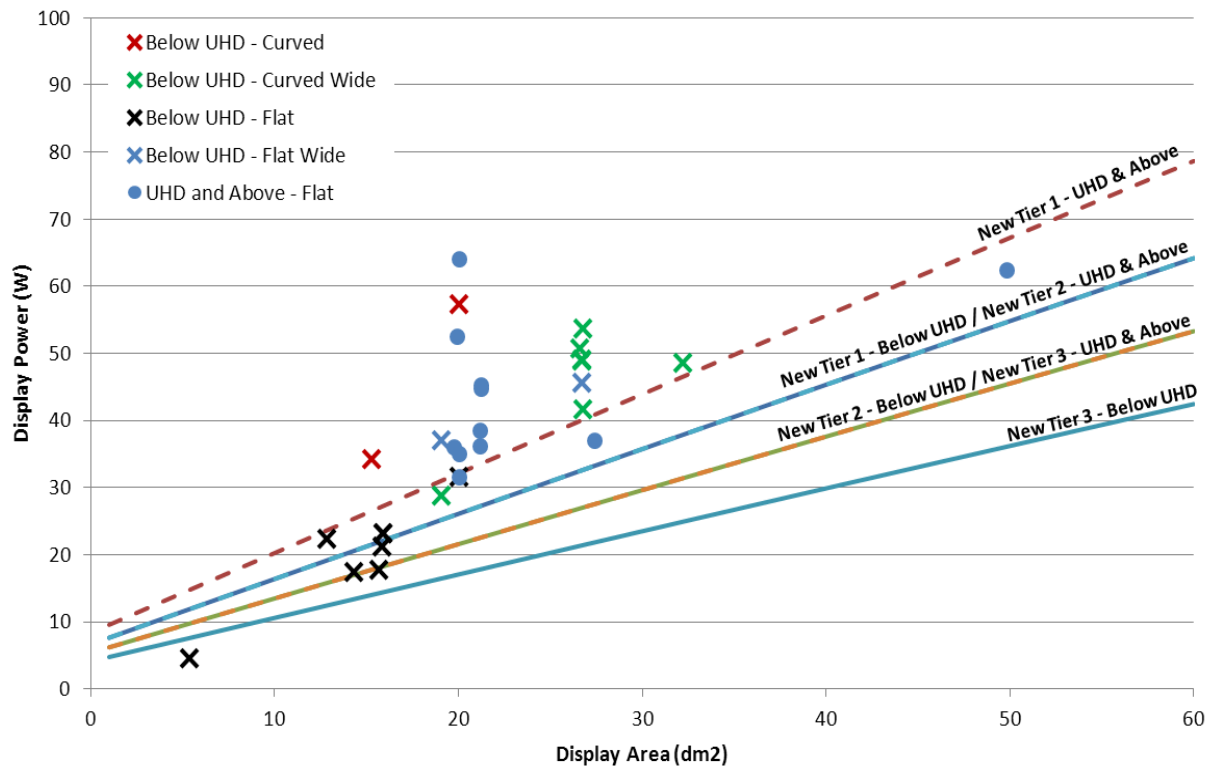


Figure 2. All monitor test data results: Specific power and display area coordinates vs EEI requirements

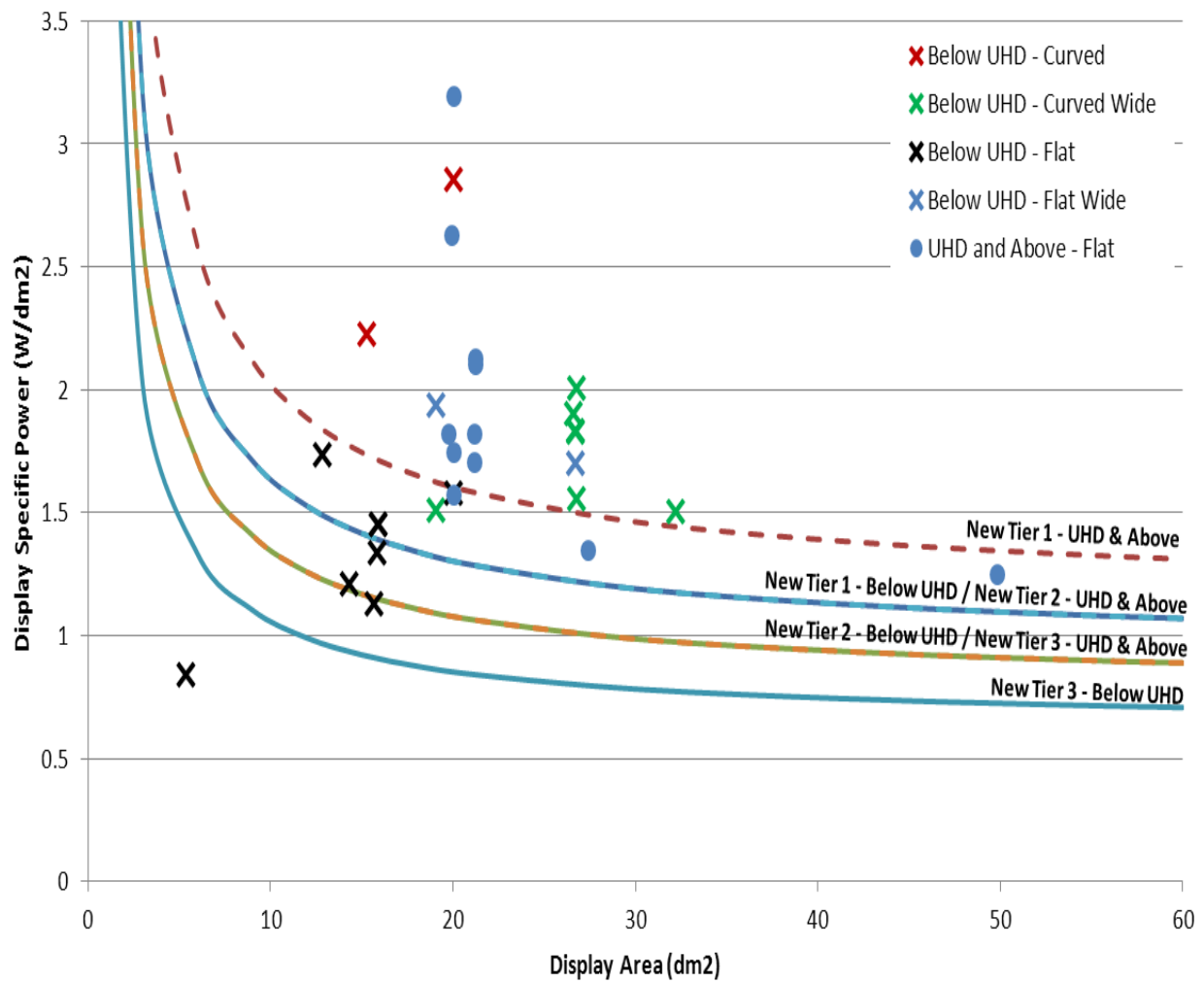


Figure 3. UHD and above monitor test data results: Average power and display area coordinates vs EEI requirements

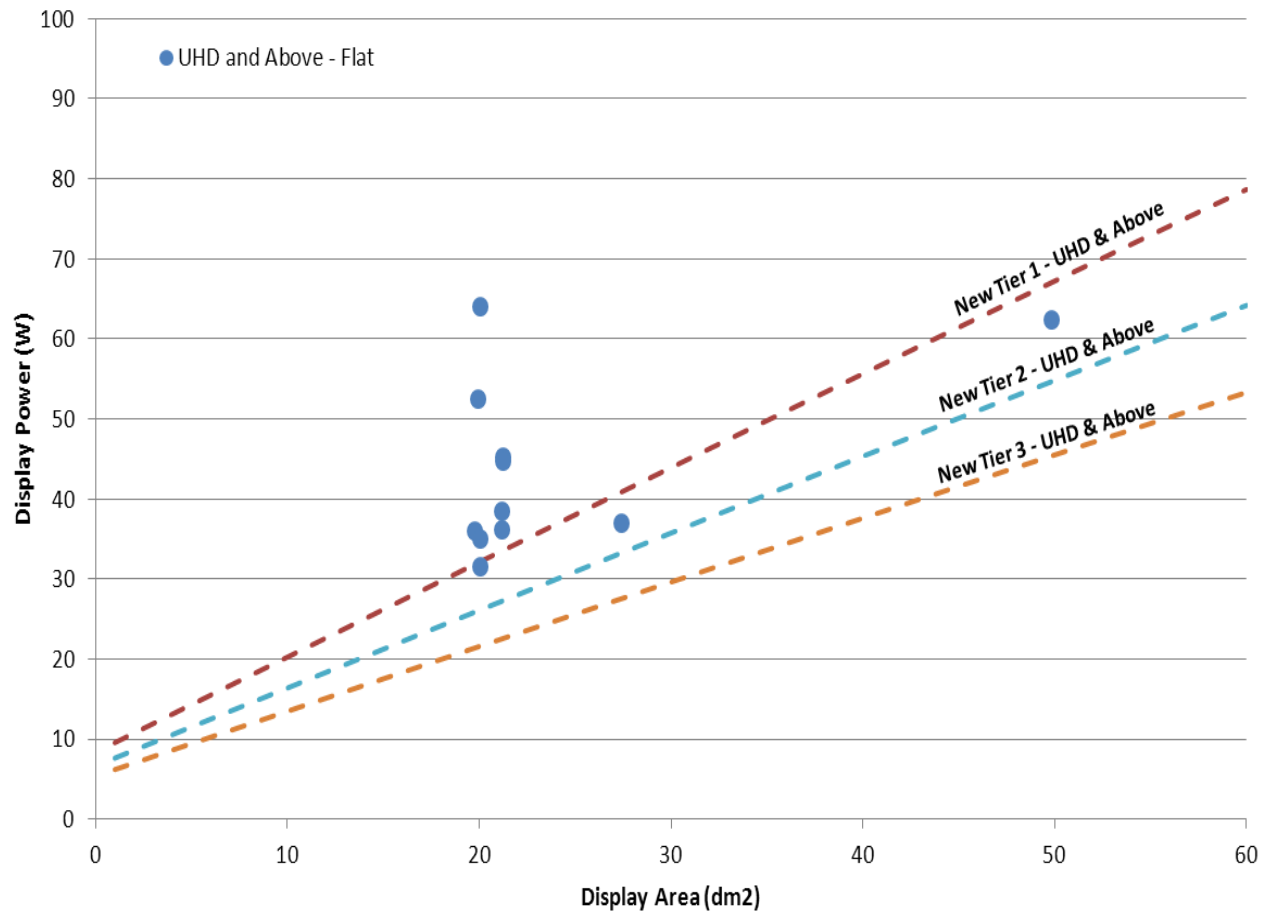


Figure 4. UHD and above monitor test data results: Specific power and display area coordinates vs EEI requirements

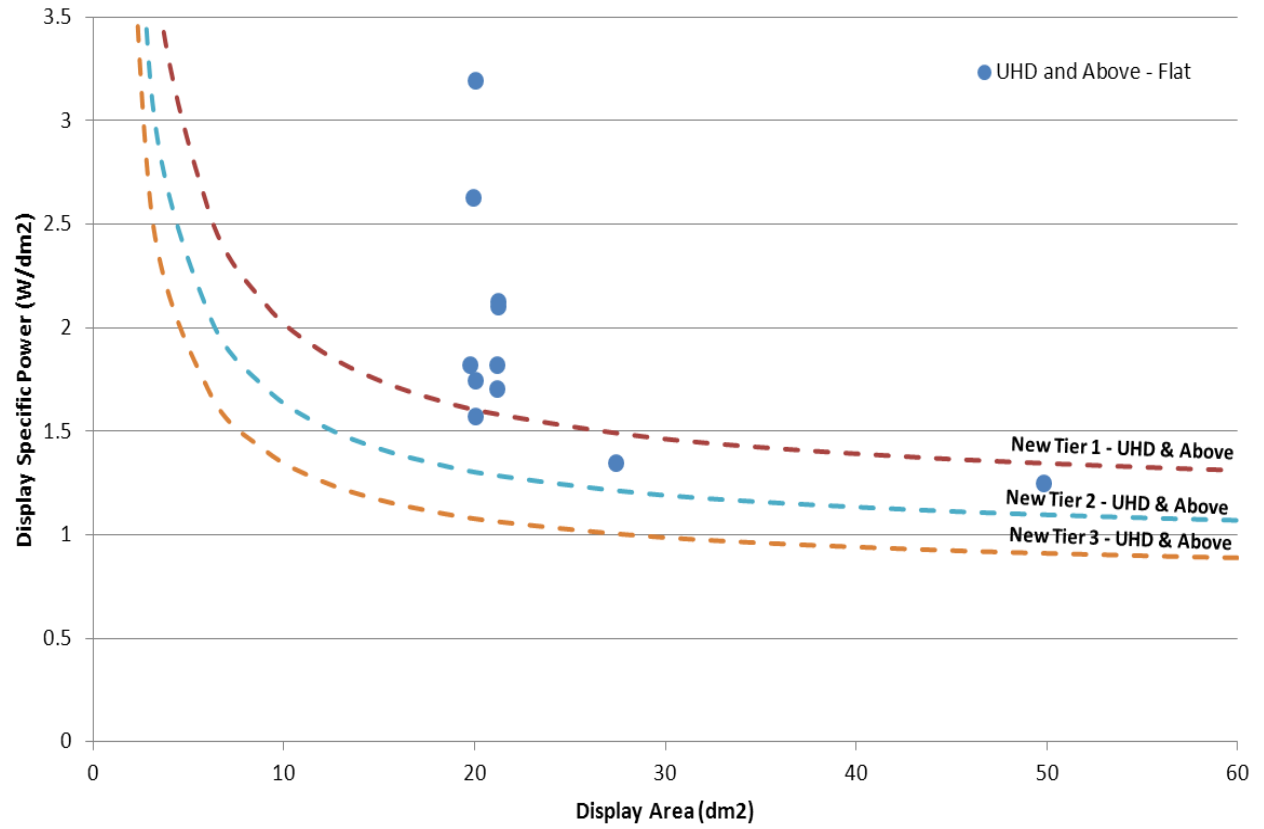


Figure 5. Below UHD monitor test data: Average power and display area coordinates vs EEI requirements

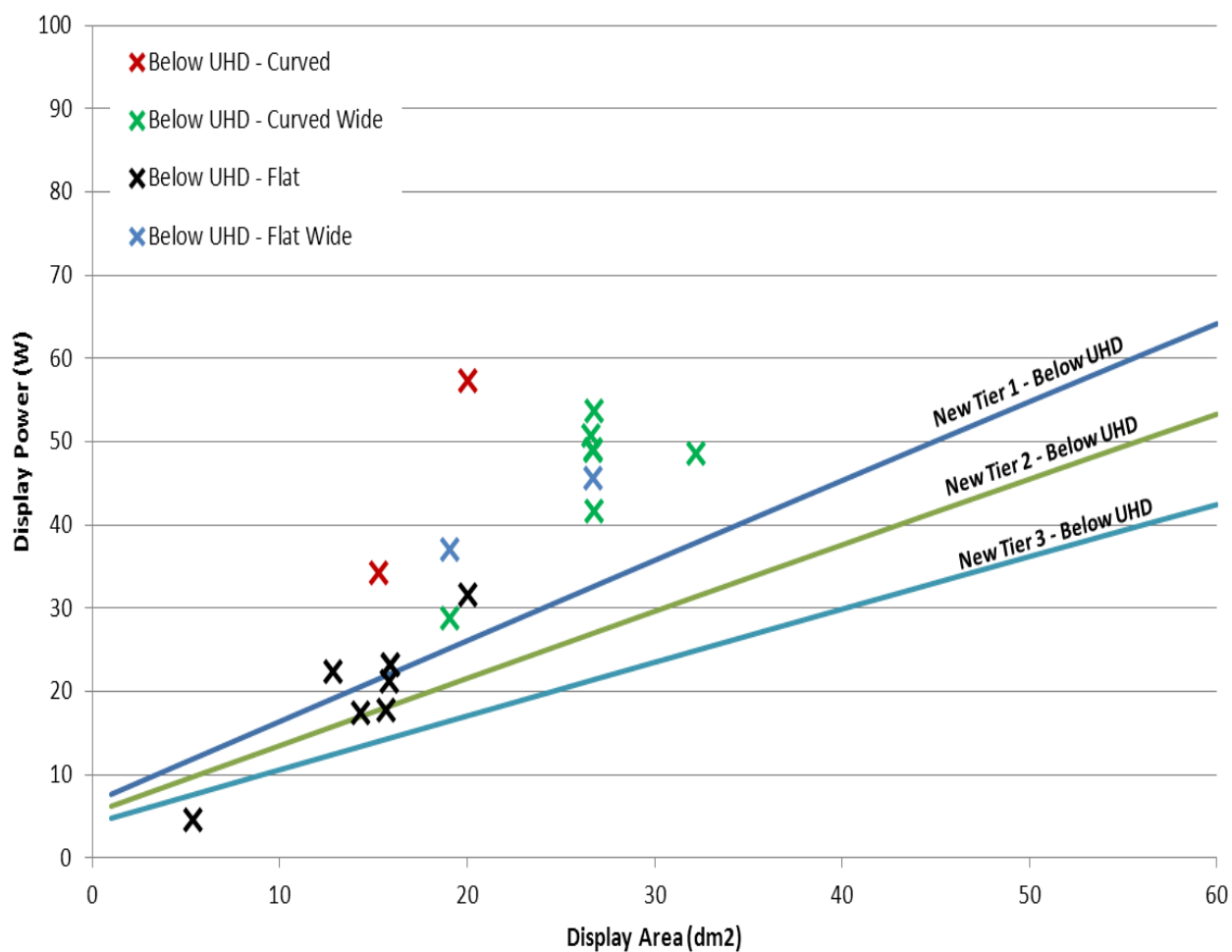
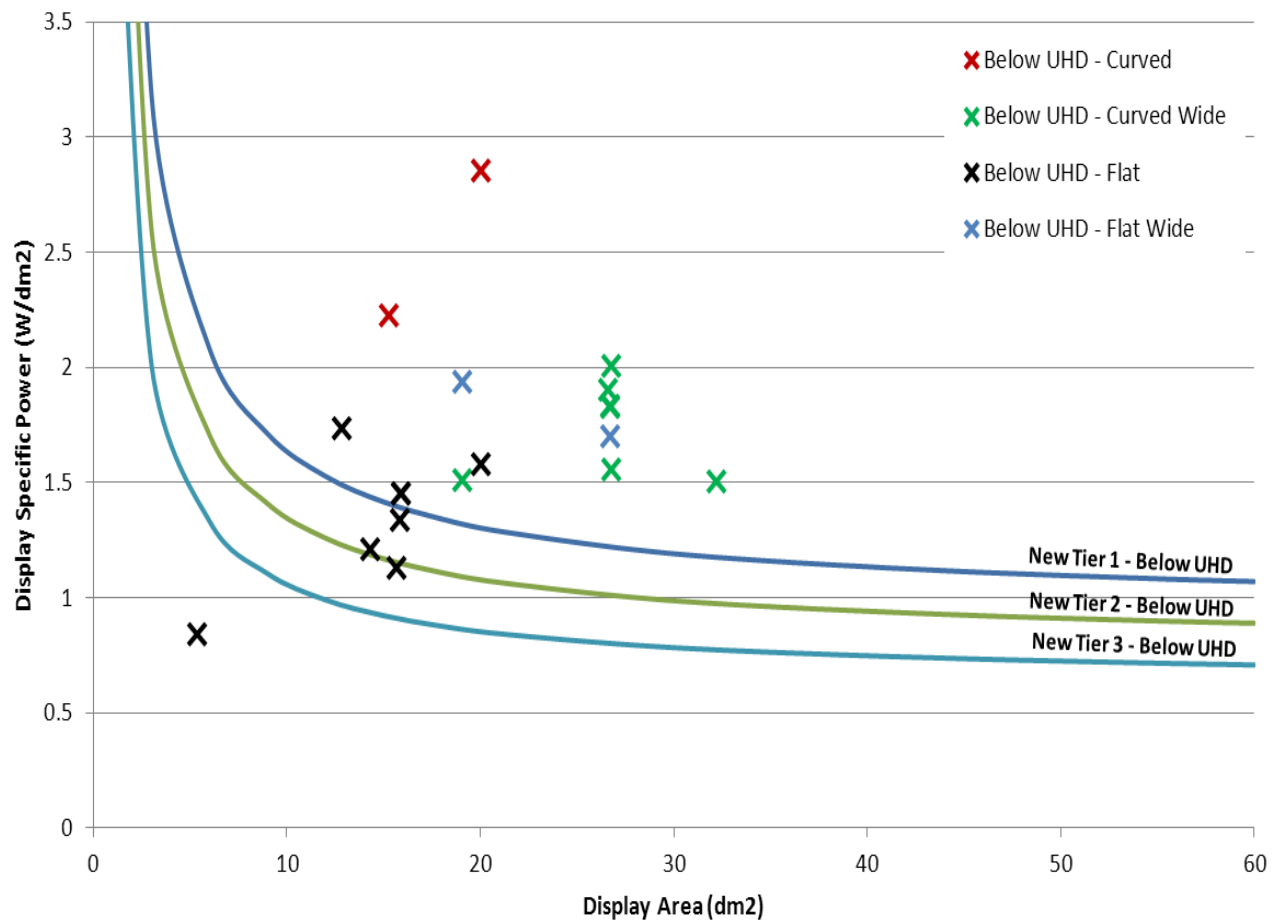


Figure 6. Below UHD monitor test data: Specific power and display area coordinates vs EEI requirements



4.2 Analysis of the key test results summarised in Section 3, Table 1.

4.2.1 Physical and technical characteristics of monitors under test (Table 1, rows 1 to 6 and 15 to 16)

All monitors tested are based on LCD display technology with an edge lit LED backlight. There were no advanced quantum dot (QD) technology filters identified in any product specification.

Nineteen of the thirty monitors tested have a flat display with a 16:9 aspect ratio. Eleven of these are in the "UHD and Above" resolution category with UHD resolution of 3840 X 2160 pixels. Two flat displays have a wide aspect ratio of 2.4:1.

Nine monitors have curved displays with a small curvature radius of 1800 mm typical of that employed for relatively close proximity viewing. Seven of the nine curved display monitors are of 2.4:1 wide format ratio and have gaming viewing modes as options to the standard, as delivered for use, viewing mode. All of the curved monitors are "Below UHD" resolution.

Fourteen of the thirty monitors have external AC to DC power supplies (EPS) with a product specific DC interface connection (i.e. not a standardised DC interface such as USB). All of these monitors have power requirements compatible with USB C power delivery (PD) Profiles 1 to 5 (10W to 100W) and with DC interface modification could operate with a standardised EPS. One small monitor intended for use with portable video signal sources (Sample ED12) has a standardised USB "A" DC and signal interface.

Nine of the fourteen monitors with EPS with a product specific DC connection are non-compliant. This number was re-calculated for a hypothetical situation where these monitors were designed with a standardised DC power connection and placed on the market without an EPS. In this situation the measured on-mode power level used for the EEI calculation should be at the DC level i.e. excluding the losses in the EPS. The DC power consumption was not part of the laboratory measurements and it was instead calculated based on assumed efficiencies of the EPSs using the International Efficiency Marking Protocol level. The new EEI for the DC power level was checked against the EEI_{max} resulting in three more monitors would pass and two are very close. I.e. the number of failing monitors would be reduced from nine to four to six.

4.2.2 Luminance and power demand characteristics of monitors under test (Table 1. Rows 7 to 11)

The maximum peak luminance of the monitors under test with a subjectively acceptable image determined with a grey scale test pattern, ranges between 485 cd/m² and 141 cd/m². The latter peak luminance (141 cd/m²) is delivered by an AC powered "Below UHD" monitor (Sample ED 07) which has a commensurately low average power demand in the standard as delivered mode allowing a pass at EEI Tier 2. This peak luminance figure is also the standard viewing mode peak luminance figure.

With the exception of the above sample (ED07) and the USB interfaced sample for portable use (ED12) all monitors can meet the minimum luminance of 200 to 220 cdl/m² considered necessary by this report's testing laboratory for subjective testing by the testing laboratory in average office lighting conditions of up to 100 lux. However, some of the monitors, which fail their respective EEI limits are factory pre-set to a relatively high peak luminance in the standard mode as delivered for use. For example samples ED02, ED03, ED05, ED06, ED08, ED15, ED17, ED18, ED23a, ED29 and ED32

could meet the required EEI limit if adjusted to a lower but subjectively acceptable peak luminance figure in the standard mode, as delivered for use. This has been tested on one monitor as an example, which proved that it is feasible.

The on-mode specific power demand (Watts / unit area of display) of wide aspect ratio and curved display monitors tested is with two exceptions, ED04 and ED16, higher than equivalent flat 16:9 aspect ratio displays. This finding lends some support to the high backlight transmission losses identified by the display manufacturing industries as attributable to the comparatively wide non-transmissive LCD matrix structure of curved displays and to the greater light loss in wider backlight reflector and diffuser panels.

Standby, automatic power down (APD) and off mode power demand characteristics are stable for all test samples. All displays met the network standby requirements but four did not meet the manual standby or off, requirements of proposed draft display regulation. A functional anomaly in sample ED27 delays APD reaching a stable standby power demand of 0.3W for 12 minutes. In that period the power demand falls from an on-mode of 32W to 14W. Without the testing of further samples, no conclusion can be drawn from this observation, however a systematic similar behaviour would be non-compliant.

Extended display identification data functionality (EDID) is active on all monitors for all video inputs including HDMI inputs.

Consumer electronic control (CEC) functionality is not fully implemented on the HDMI inputs of any test sample. The monitor source selection and standby status is therefore not controllable by an external HDMI CEC network.

4.2.3 ABC control characteristics

Just two test samples, ED08 and ED09 of the thirty under test feature ABC control. The control characteristics are shown graphically to a high level of data point granularity in Figure 7 and Figure 8 below.

Figure 7. ABC Test results Sample ED08 represented graphically from high granularity data

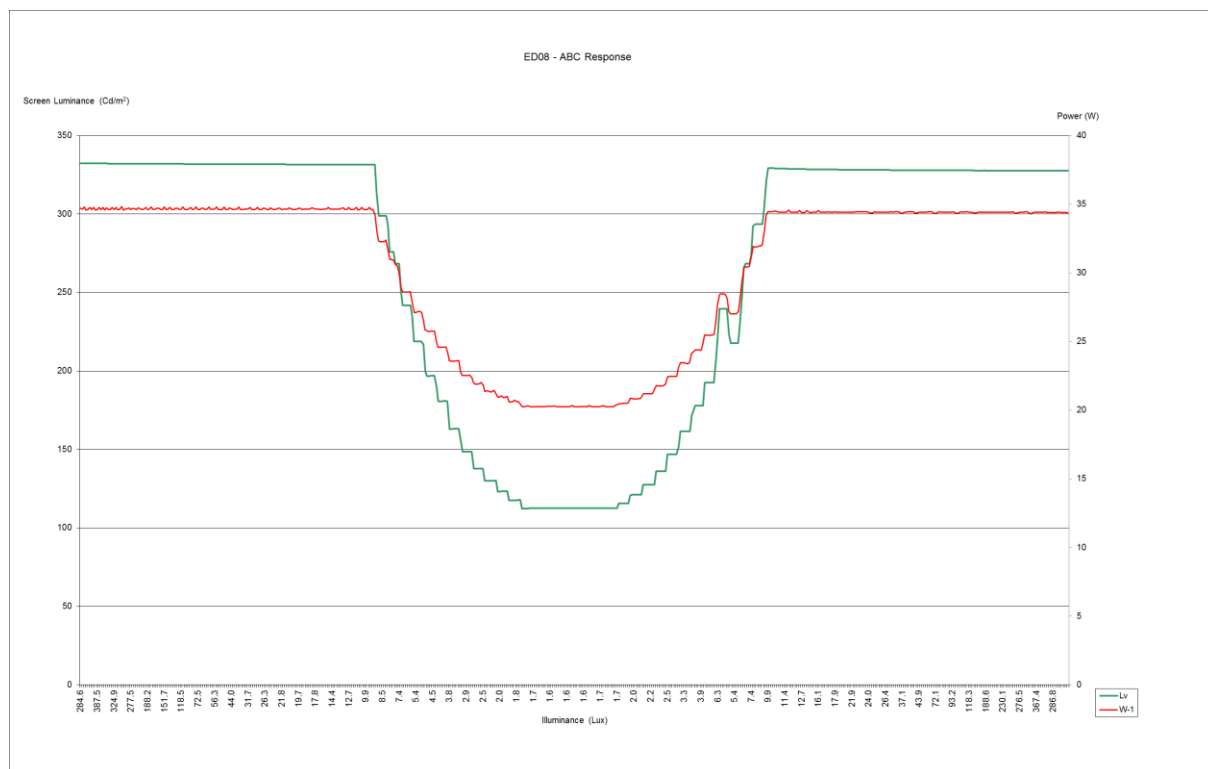
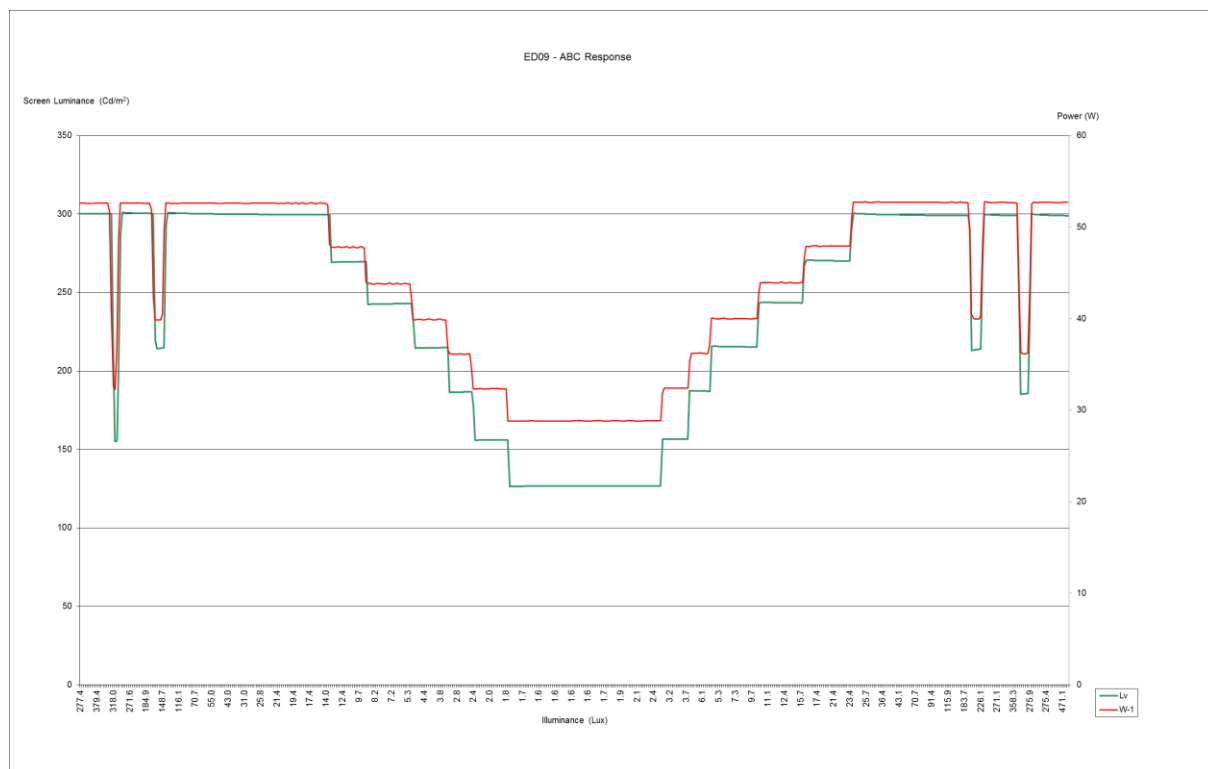


Figure 8. ABC Test results Sample ED09 represented graphically from high granularity data



In the case of ED08 an analysis of Figure 7 shows a rapid progressive reduction in display luminance starting at a very low ambient light level of 8 lux and continuing down to a very dark condition of 2 lux. This control window is considered unrepresentative of a normal ambient light range in a working environment (for test purposes a nominal ambient light range of 100 lux to 12 lux is considered representative) It is noted that at the 2 lux ambient light condition the monitor was still working at a display peak white luminance of 115 cdl/m² which is around the optimum suggested for TV viewing in low ambient light conditions.² Between 8 lux and 2 lux ambient light conditions the monitor power demand is reduced by 50% and the display luminance is reduced by 66%. Given the level of display luminance at full ABC control for a dark room it may be concluded that the control characteristic could be shifted by software reprogramming to cover a more practical ambient light range of 100 lux to 12 lux as currently suggested for TVs.

In the case of ED09, an analysis of Figure 8 shows that the ambient light control range is a more practical 22 lux to 3 lux. The display luminance reduction is 60% ending at 125 cdl/m² with a commensurate power reduction of 43%. Again, it may be concluded that the control characteristic could be shifted by software (i.e. the firmware) reprogramming to cover a more practical ambient light range of 100 lux to 12 lux as currently suggested for TVs. After the reprogramming, the display should be updated with the new firmware.

² US Department of Energy Report 2012 ANALYSIS OF ROOM ILLUMINANCE AND TELEVISIONS WITH AUTOMATIC BRIGHTNESS CONTROL: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS:

Annex 1: Metrics for calculating Ecodesign energy efficiency index (EEI) and EEI limit requirements

The screen area A of an electronic display is calculated by multiplying the viewable image width by the viewable image height. For curved displays, the width and height is measured along the arc of the display. The on-mode power demand ($P_{measured}$) is determined by averaging the power demand of the electronic display for the duration of a standardised broadcast content video test sequence (IEC / EN 62087 Part 2 & 3).

On-mode power demand limits expressed as an EEI

The EEI of an electronic display shall be calculated using the following equation where A represents the screen area in decimetres squared (dm^2):

$$EEI = \frac{(P_{measured} + 1)}{(3 \times [90 \times \tanh(0,02 + 0,004 \times (A - 11)) + 4] + 3)}$$

The declared EEI of an electronic display shall not exceed the maximum EEI (EEI_{max}) calculated using the following limits:

From 1 July 2018:

Displays with resolution up to HD (1980x1080 pixels)	Displays with resolution above HD
$EEI_{max} = 0.90$	$EEI_{max} = 1.10$

From 1 January 2020:

Displays with resolution up to HD (1980x1080 pixels)	Displays with resolution above HD
$EEI_{max} = 0.75$	$EEI_{max} = 0.90$

From 1 January 2022:

Displays with resolution up to HD (1980x1080 pixels)	Displays with resolution above HD
$EEI_{max} = 0.60$	$EEI_{max} = 0.75$

Annex 2. Embedded File: Full Laboratory test report