Australian Government
Department of Climate Change, Energy, the Environment and Water

LED Lamp Performance

Results of in-house testing of lamps sampled from the Australian market

Cataloguing data

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Acknowledgements

This report was prepared with advice and analysis from Light Naturally. Third Party testing provided by Australian Photometry and Radiometry Laboratory.

Acknowledgement of Country

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past and present.

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Executive Summary

To provide a contemporary overview of performance and quality in the Australian LED lamp market, samples of 47 LED lamp models, most commonly used in domestic applications, were purchased from late 2023 and tested against many of the requirements of the proposed LED Minimum Energy Performance Standards (MEPS).

An in-house test facility was developed and used for this market screening.

To improve and understand the accuracy of the testing, several steps were taken, including seeking expert advice, equipment calibration and comparative testing of four LED models by a third-party accredited laboratory. The comparative testing showed a close alignment in the results from in-house testing and accredited laboratory including photometric values between 1-2% variation and electrical values between 0-2.7% variation.

Noting the small sample size (n=47 lamp models), testing found a mixture of product performance, with some models able to meet all the performance and marking requirements, while others performed below MEPS levels and did not provide accurate information on packaging and lamps. Key results include:

- 34% of non-directional and 18% of directional (reflector) lamps tested were found to have an efficacy level (lumens per Watt) **below** the proposed MEPS level for LED lamps.
- Five models were **significantly below** the proposed Colour Rendering Index (CRI) requirement of 80, while several other models were borderline.
- For the Stroboscopic Effect Visibility Measure (SVM), a metric used for the higher frequency stroboscopic effect known to affect human health and productivity, 22% of non-directional and 18% of directional products **would have not met the proposed MEPS level of 0.9**.
- 50% of non-directional and 55% of directional models either had **sufficient variation** between marked and tested luminous flux claims t**o be deemed non-compliant under the proposed MEPS.** or did not provide the information on the package.
- Approximately 20% of models did not include basic product information such as luminous flux and product lifetime on packaging.
- 50% of non-directional and 55% of directional models did not mark luminous flux on the lamp.
- 28% of non-directional and 18% of directional models did not mark colour temperature (CCT) on the lamp.

These results indicate that poorer-quality LED lamp models are available on the market, resulting in unnecessary loss of energy savings, increased difficulties in suitable product selection for consumers, and potential consumer dissatisfaction.

The capacity for delivery of efficient, high quality LED lamps has improved significantly over the last several years, as shown by the high performance of some of the lamps tested.

Background

The development of the proposal for the introduction of minimum energy performance standards (MEPS) for LED lamps under the *Greenhouse and Energy Minimum Standards Act 2012* (GEMS Act) has drawn upon extensive market analysis and product performance testing, as outlined in the draft and final Regulation Impact Statements[1].

Previous testing of LED Lamps has identified a range of product performance, quality, and information accuracy issues. However, some lighting industry stakeholders have recently suggested that LED quality and performance has significantly improved since the last testing of products in the market was done. There is a view expressed by some lighting suppliers that most (80 to 90%) LEDs available to. consumers already meet proposed LED efficacy levels, which would support the case for no regulatory intervention in the market.

If lower quality LED lamps are available on the market, this can result in:

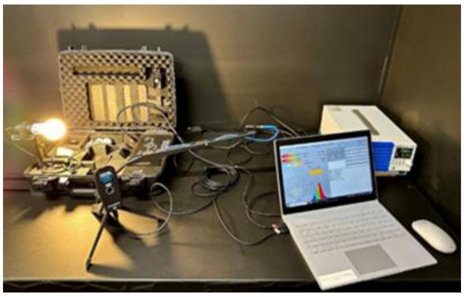
- Lower energy savings.
- Increased difficulty for consumers to select the most suitable LED replacement for their lighting needs.
- Potential consumer dissatisfaction with LED performance, particularly as further incandescent and halogen lamps are being phased out under the GEMS Act.

As a result, it was decided to conduct further market screening to inform regulatory advice about the market.

This also presented an opportunity to trial use of in-house test equipment, some of which is illustrated in Figure 1. Preparation for this exercise included:

- Refitting an available room for lighting testing (e.g. black walls and curtains, partitions, benches, electrical supply), in accordance with advice from technical experts.
- Development of tailored operational manuals for the test equipment.
- Comparison testing of lamps previously tested in third party laboratories.
- Development of tailored data export and analysis spreadsheets.

Figure 1 Some in-house test equipment



[1] Final RIS: https://www.energyrating.gov.au/industry-information/publications/decision-ris-lighting Draft: https://www.energyrating.gov.au/industry-information/publications/consultation-ris-lighting

Market Testing

A range of LED lamps available in Australia and within scope of the proposed determination were selected and ordered online or purchased in-store, commencing in October 2023. This included lamps from:

- Brands known to be sold in physical retail stores.
- Other known brands with an online presence.
- Major online electrical and electronic retailers.
- Lesser-known products sold via eBay and Amazon (with shipment from within Australia).

Figure 2 Non-directional LED Lamp Example

Figure 3 Directional LED Lamp Example

Lamp types tested include non-directional and directional (including GU10, MR16, PAR and R80), as illustrated by examples in Figure 2 and 3. Several smart lamps (controlled by mobile phone apps) and lamps with physical colour temperature switching options were also included. To date, two to three samples of 47 lamp models have been tested, with results averaged for each model.

Lamps were tested using a Viso Systems LightSpion[2] test suitcase and Light Inspector software, capable of a range of photometric and power measurements relevant to the proposed LED MEPS. Samples were stabilised prior to measurement, and a stable power supply was used. A mounted Viso Systems LabFlicker[3] meter was also used to obtain visible flicker (P_{st}^{LM}) and stroboscopic effect (SVM) measurements.

[2] https://www.visosystems.com/products/lightspion/

[3] https://www.visosystems.com/products/labflicker/

Test Accuracy and Constraints

While this in-house testing is not intended to be a complete replacement for the use of accredited photometric laboratories, in this instance it was a useful means of efficiently obtaining an indication of comparative performance across a wide range of brands and products available in the market. The Viso Systems LightSpion test suitcase and software has previously been used for market and product compliance screening by regulators in several EU countries participating in the EEPLIANT program[4].

Several steps have been taken to assist with, and understand the accuracy of this exercise:

- Advice and supervision by technical experts with experience in laboratory operation.
- The LightSpion case was returned to Denmark for calibration over the 2023 Christmas break – a new certificate was received.
- Four of the LED models (two directional and two non-directional) tested in-house were sent to an accredited Australian third-party photometric laboratory (Australian Photometric and Radiometry Laboratory[5] - APRLab) for comparison testing.

The comparative testing showed a close alignment in the results from in-house testing and accredited laboratory:

- Photometric measurement variations of 1 – 2% were within acceptable limits.
- Electrical measurements were within acceptable variations. For example, power was between 0 to 2.7% variation.
- Colour metrics were also accurate. CCT (colour temperature) varied by no more than 55 Kelvin (less than 2% variation for the measured CCTs of 2700K to 3000K), while CRI varied between 0.6 to 0.9 (for measured values near 80 on a scale 0-100).
- Variations in measurement of stroboscopic effect visibility, SVM, were within 0.02 for three of the lamps whereas the fourth lamp (with a complex waveform) varied by 0.11 which is not acceptable and does require some investigation and improvement, however, several of the products had values well outside this uncertainty range and have therefore been included in the results.
- Measurements of short-term flicker, P_{st}^{LM}, were also acceptable, with variations less than 0.01, noting that the MEPS limit is a maximum of 1.0.
- The centre beam intensity measurement was sometimes low. This should be able to be addressed through an adjustment to test procedures and did not have a significant impact upon the uncertainty of the results for MEPS purposes.
- Detailed comparative results are in Annex 1.

Accredited test laboratories will state a laboratory uncertainty (a confidence limit or margin) for each of the test results. These are derived from detailed analysis of the variance of numerous

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[4] https://eepliant.eu/index.php/new-products/wp4-led?id=71

[5] http://www.aprlab.com.au/

measurement factors which contribute to the final confidence limits. This indicates the level of accuracy for each determined quantity and is required as part of their accreditation process. For the key MEPS quantities of power, luminous flux, and luminous efficacy, local accredited laboratories state uncertainties of approximately 1.0%, 3.0% and 3.5% respectively. We are therefore satisfied that the levels of comparative accuracy shown through this comparison indicates that the in-house test data is suitable for use in this market evaluation process and estimated uncertainties of 3.0%, 3.5%, 5.0% respectively for power, luminous flux, and luminous efficacy would be reasonable.

It is important to note that the steps taken to evaluate the accuracy as outlined above are not a substitute for establishing formal compliance. This would need to be undertaken by a formally NATA accredited photometric laboratory.

The test results presented need to be considered in light of the sample size differences and test procedure variations to those stated in the relevant Australian Standard (AS/NZS 5321). Some of the differences include:

- The sample size was, for most parameters, less than required in the relevant LED test standards.
- The LightSpion tests lamps mounted in a horizontal position, while the test standard AS/NZS 5341 requires single capped lamps to be tested in a vertical base up orientation. (unless otherwise specified in technical documentation provided at registration). NOTE: Results from the third-party comparison indicates this was not a significant factor.
- Laboratory accreditation is a very involved process requiring considerable documentation of testing and administrative procedure, regular calibrations of all measurement equipment and evidence of suitable proficiency testing results with other competent accredited photometric laboratories.
- Third party accredited laboratories normally use larger test apparatus (enabling more accurate photometric measurements) and employ more experienced staff.

Performance Testing Results

The proposed LED MEPS includes performance requirements, product and package marking requirements, and claim accuracy requirements. Available equipment has enabled testing for:

- Useful luminous flux (accuracy of claim)
- Power (accuracy of claim)
- Energy Efficiency (luminous efficacy calculated from useful luminous flux and Watts, MEPS)
- Standby power (smart lamps, MEPS and accuracy of claim)
- Beam angle (accuracy of claim and input to useful luminous flux)
- Correlated Colour Temperature, CCT (accuracy of claim)
- Colour rendering index, CRI, (MEPS and accuracy of claim)
- Displacement factor (MEPS)
- Flicker: SVM and P_{st}^{LM} (MEPS)

During testing, each sample was also inspected for compliance with regards to proposed mandatory markings on the lamp and package.

Testing found a mixture of products, with some able to meet all the proposed performance and marking requirements, while others performed below proposed MEPS levels and did not provide accurate information on packaging and lamps. Such lamps may not be compliant if the proposed LED MEPS Determination was in place. Some examples of the test results are charted below, while more detailed results can be found in Annex 2.

Energy Efficiency

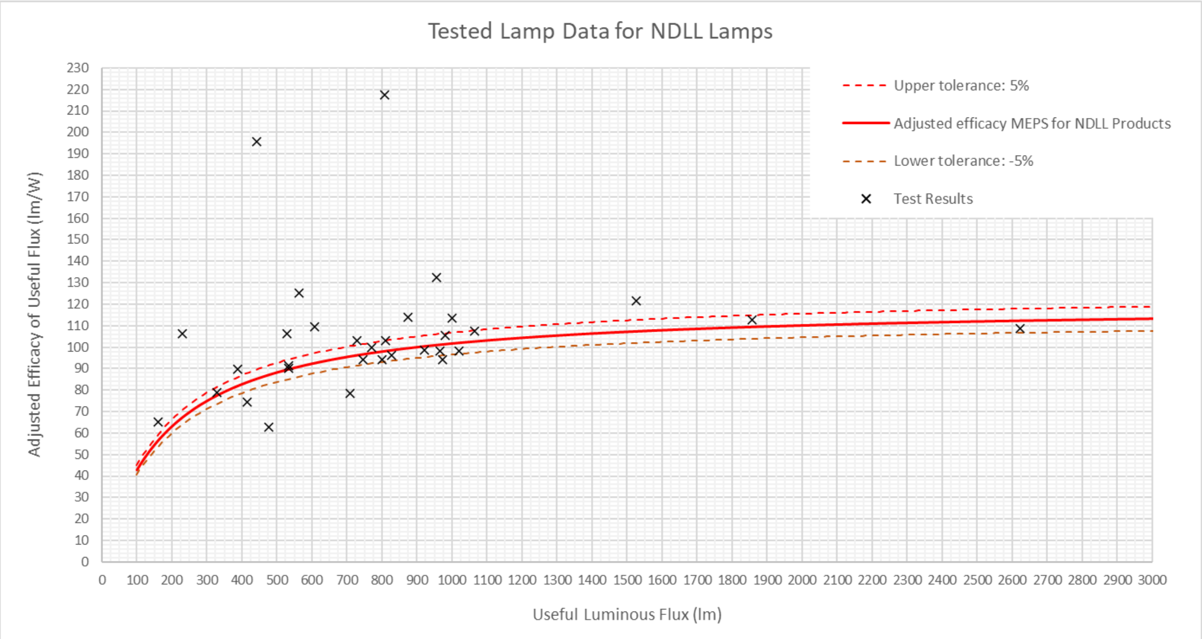
In the most basic form, lighting energy efficiency is referred to as efficacy and is expressed as lumens per Watt. The proposed MEPS require that adjustments are made for a range of product characteristics, including power, directional/non-directional, beam angle, and whether the lamp is colour tuneable.

$$\eta_{\text{lamp.min}} = \left(\frac{F \times \eta}{C \times R}\right) \times \left[1 - \frac{(L \times F \times \eta)}{(L \times F \times \eta) + \Phi_{\text{use}}}\right]$$

In the charts below, adjustments have been made to the equation to allow plotting of multiple types of lamps on the one graph for comparison. This "adjusted efficacy" (vertical axis of graph) is expressed as

$$\eta_{\text{lamp.min}} \times (C \times R) = (F \times \eta) \times \left[1 - \frac{(L \times F \times \eta)}{(L \times F \times \eta) + \Phi_{\text{use}}}\right]$$

Figure 4 Assessment of lamps to proposed MEPS requirement for Energy Efficiency – non directional LED lamps (NDLL)



Test results below the red curve in Figure 4 indicate that the product does not meet the proposed minimum energy efficiency requirements. The area between the red dashed lines designates a 5% measurement uncertainty zone. The results indicate 34% of models tested may not meet this requirement. Note that two products were measured with efficacy levels significantly higher than MEPS. Such products began emerging on the market[6] following policy and regulatory interventions

[6] https://www.signify.com/en-gb/our-company/news/press-releases/2021/20210830-signify-introduces-philips-leds-first-most-energy-efficient-a-class-bulbs

in the EU (Commission Delegated Regulation 2019/2015 (Energy labelling of light sources) entered into force on 1 September 2021) and Dubai and indicate the potential for further improvement and energy savings.

Figure 5 shows the MEPS requirements for energy efficiency for directional lamps based on their light output, useful luminous flux measure in lumens.

Figure 5 Assessment of lamps to proposed MEPS requirement for Energy Efficiency – directional LED lamps (DLL)

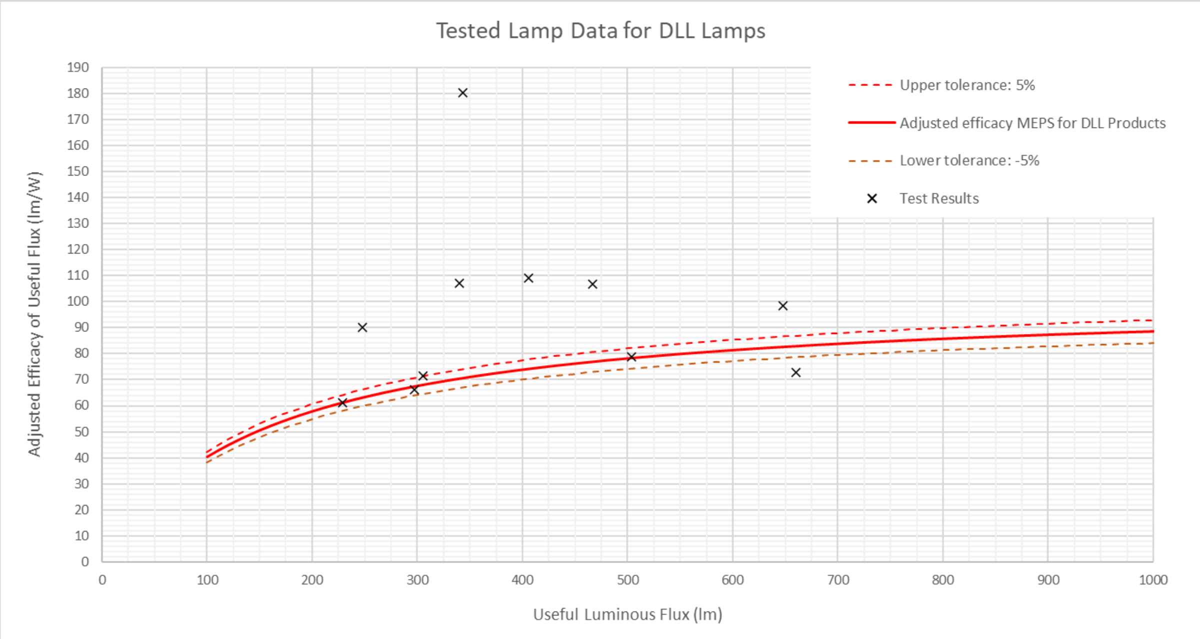
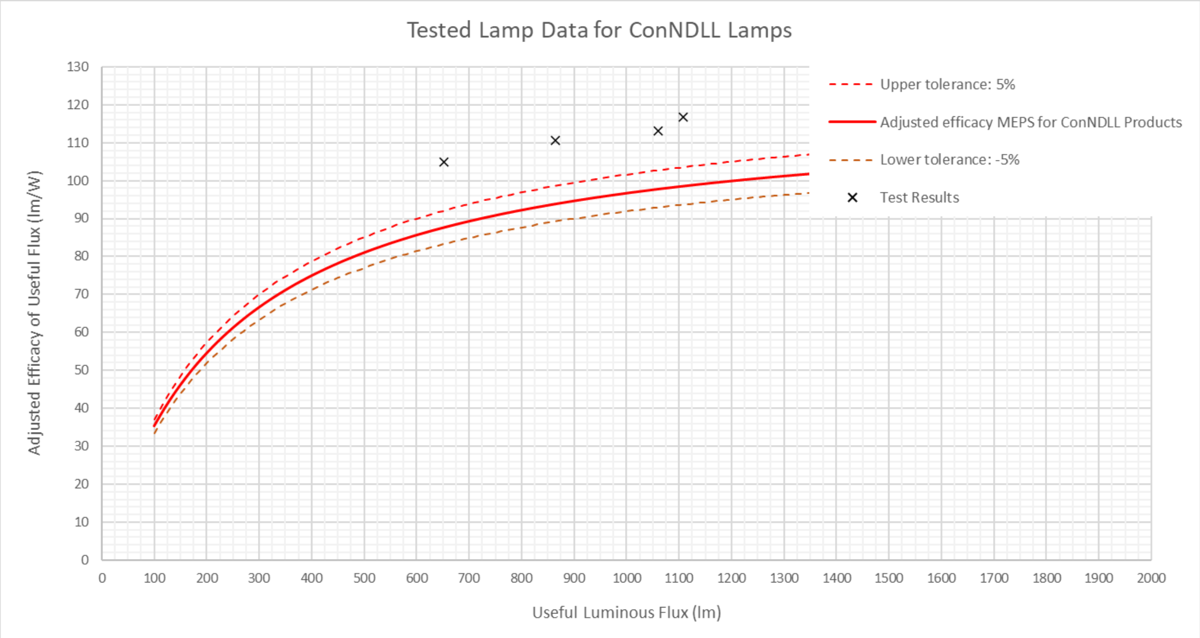


Figure 5 shows that approximately 18% of directional lamps did not meet the proposed MEPS efficacy level. The directional lamp MEPS curve is less stringent than non-directional due to included adjustment factors for the inherently lower light output ratio of directional lamps and the limiting of "useful" luminous flux to that in a restricted angular cone of light output from the lamp.

Additional adjustment factors are also applied to smart (connected) lamps that allow tuning of luminous flux and/or colour temperature. Figure 6 shows that all three such models tested (including two additional tests in different CCT states) would pass the proposed MEPS efficacy requirement.

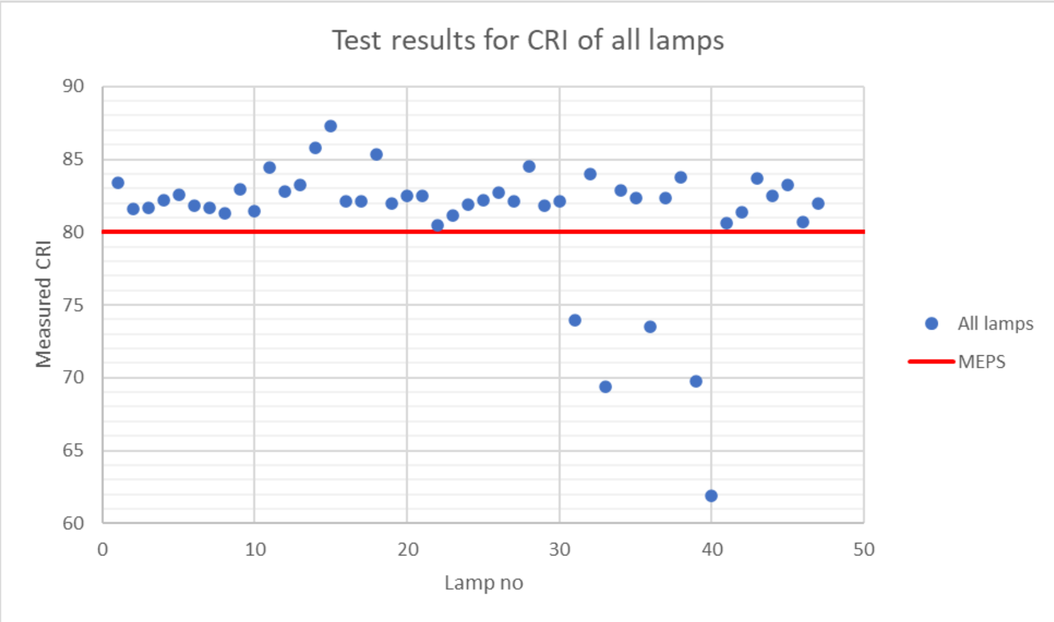
Figure 6 Assessment of lamps to proposed MEPS requirement for Energy Efficiency – smart non-directional lamps (ConNDLL)



Colour Rendering Index

The colour rendering index (CRI) compares the ability of different light sources to render colours accurately, with the measurement of 100 considered to be excellent. A value of 80 (proposed MEPS level for most lamps, including all indoor use) and above is good and appropriate for most situations where people are present. Where colour identification is important, a value of 90 or above should be considered. Figure 7 shows the test results for colour rendering index for all lamp types. It indicates that five models were significantly below CRI 80, while several other models were borderline.

Figure 7 Test Results for Colour Rendering Index (CRI) - all lamp types



Flicker

Temporal light modulation (TLM, known colloquially as “flicker”) of light sources has visual, neurobiological, and performance and cognition effects on viewers. The two main forms of perception of TLM from light sources are flicker and stroboscopic visibility effect both of which can have negative impacts upon people occupying the illuminated area. Under most lighting conditions, the stroboscopic visibility effect is undesirable. It is a source of distraction and may modify task performance. Some individuals also find it can contribute to headaches and migraines. As well as being distracting and annoying visible flicker can produce photosensitive seizures amongst susceptible people. Limiting exposure to these risks is important to people’s health.

Figure 8 is a comparison of measured visible flicker levels of tested models against the proposed MEPS levels. It shows that no models exceeded the proposed MEPS level for visible flicker (measured in P_{st}^{LM} metric), although one was very close to the proposed MEPS limit. The chart shows that most other products were able to operate with levels well below the proposed MEPS level.

Figure 8 Test Results for Flicker - measurement of P_{st}^{LM} metric

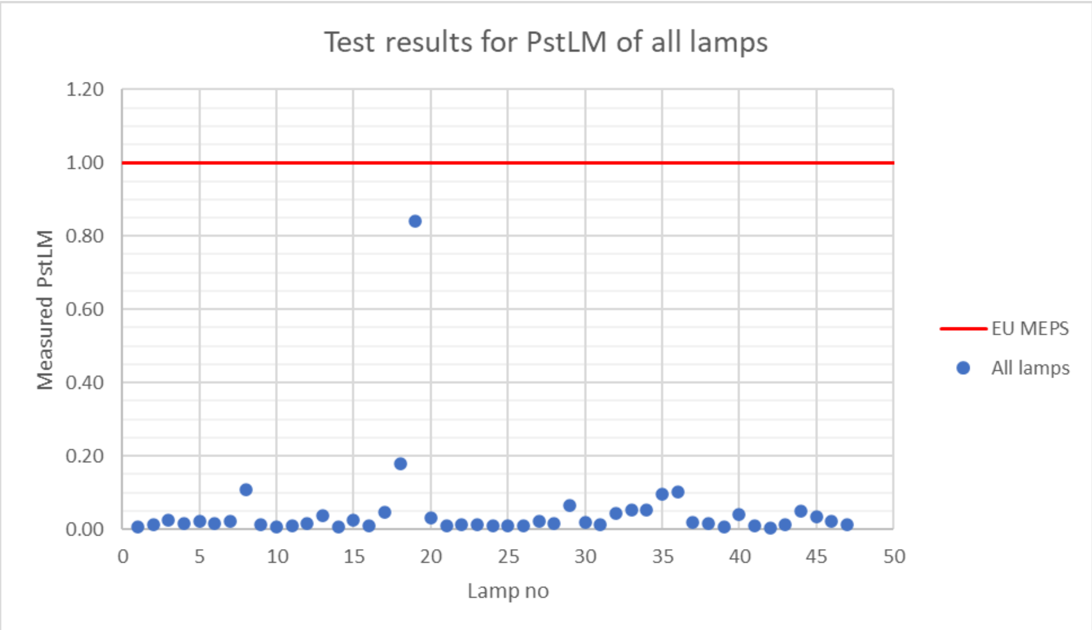


Figure 9 highlights testing of a lamp that is equipped with a physical switch to select between three CCT settings. Testing found significant differences in visible flicker between these settings, with one setting not meeting the proposed P_{st}^{LM} MEPS.

Figure 9 Variations in Flicker, P_{st}^{LM} - same lamp with three manual CCT settings

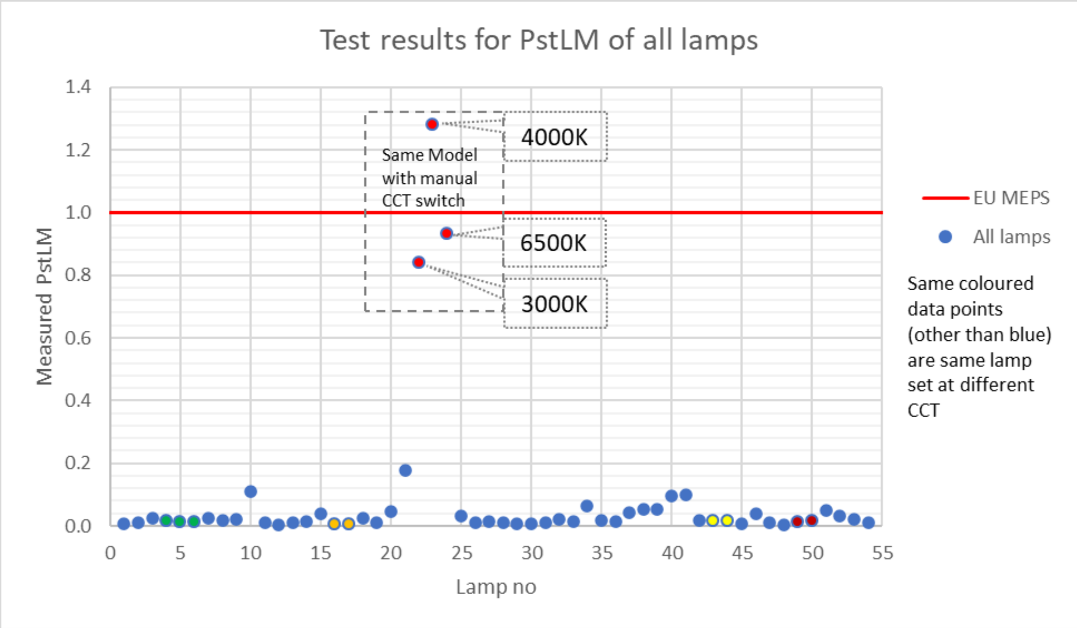


Figure 10 charts all lamps against the SVM metric used for stroboscopic effect visibility. Here 22% of non-directional and 18% of directional lamps would not meet the proposed MEPS level of 0.9. The graph also shows the 0.4 level which has come into effect in EU regulations on 1 September 2024.

Figure 10 Test Results for Stroboscopic effect Visibility - SVM metric.

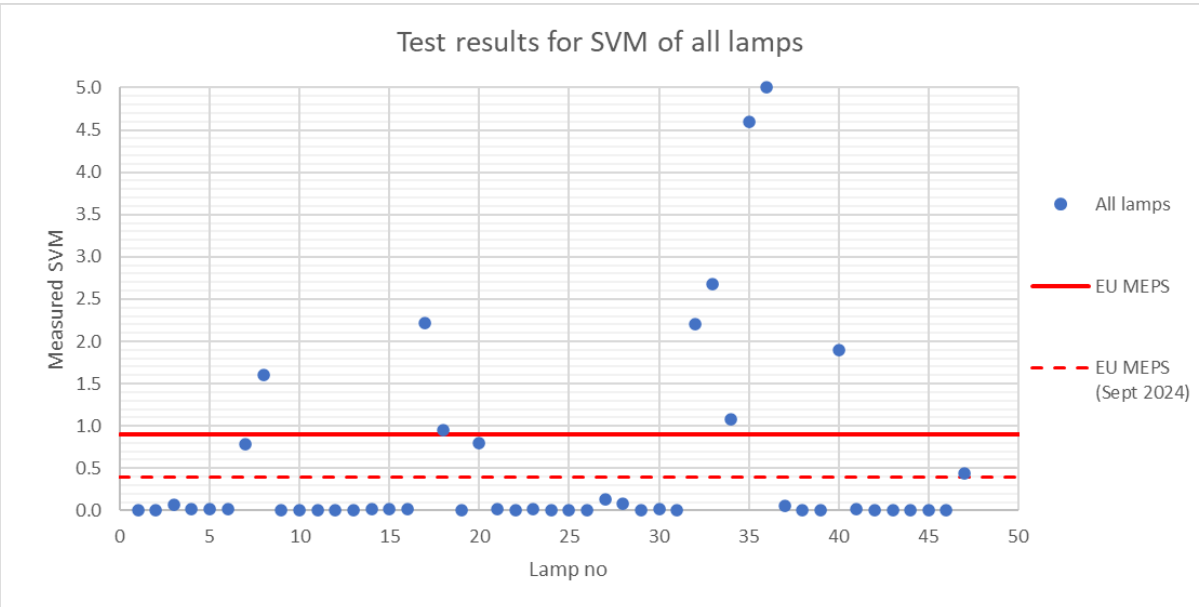
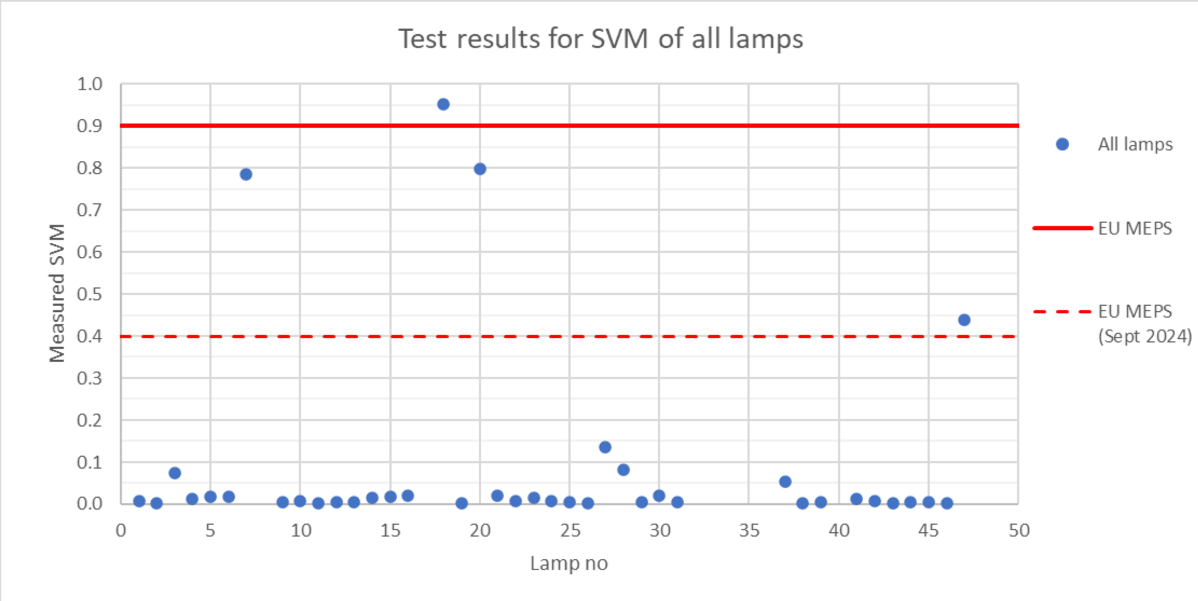


Figure 11 shows an expanded view of products that comply with the 0.9 level, noting that 2 products are close to the proposed MEPS limit but are beyond the uncertainty of the conducted measurements. The majority of modern products compliant with the 0.9 SVM level are able to achieve SVM levels close to zero and would also be able to achieve the new EU level of 0.4 for SVM.

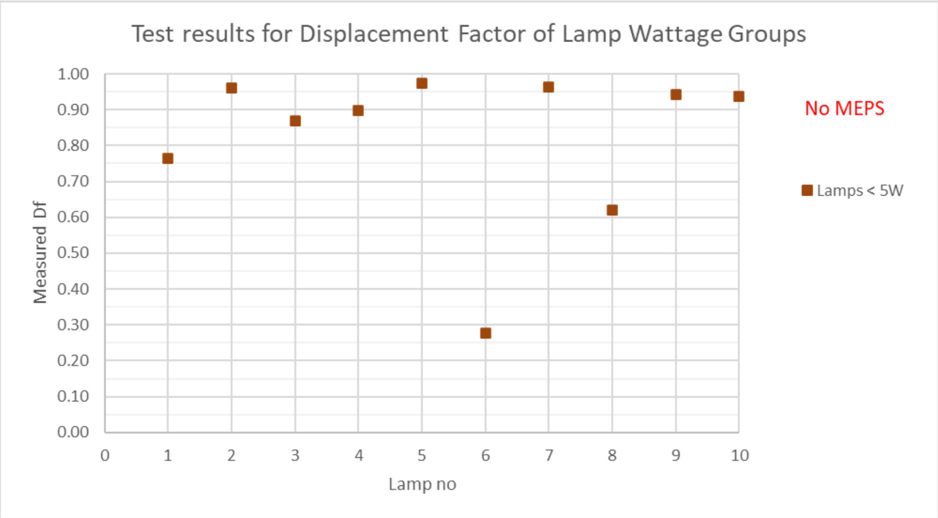
Figure 11 Test Results for Stroboscopic effect Visibility - SVM metric – expanded scale.



Displacement Factor

The lower a product's displacement factor is (scale of 1.0 to 0), the more of a negative impact it may have by contributing to the creation of 'phantom' loads to substations in the grid, thereby unnecessarily increasing overall load demand and increasing network costs. For LED lighting, this is more of an issue with substations dominated by commercial loads. The test results found only one product would not meet the proposed MEPS (results in Annex 2, Figure 18 - Figure 20). Products less than or equal to 5W would not be subject to a MEPS level in the current proposal, alleviating the potential difficulties in fitting additional components in small form lamps. The results of this screening (Figure 12) indicates that most of the products tested in this displacement factor category could comply with other category limits (e.g. proposed MEPS limit is 0.50 for lamps from above five Watts to ten Watts).

Figure 12 Displacement Factor Results for Lamps ≤ 5W (where proposed MEPS does not apply)



Luminous Flux and Efficacy Claims

Accurate package information is important to assist consumers in choosing the correct lighting product for their needs, including light output (luminous flux), and efficiency.

Figure 13 shows accuracy of luminous flux and efficacy claims for tested non-directional lamps. There remain significant variations between claimed and tested values, with some variations over 150 lumens. Figure 14 focuses on those non-directional models likely to have not met the allowed tolerance for proposed efficacy product marking requirements (34%) and luminous flux marking requirements (50%, including those with no marking). In comparison with past testing, more products are underclaiming luminous flux and power, though there are also some significant overclaims.

The non-directional charts (Figure 13 and Figure 14) are marked with zones indicating where products are equivalent to standard incandescent lamps. In some cases, the degree of variation between claim and measured value is enough to shift a model between these equivalence categories, meaning consumers seeking incandescent replacements based on luminous flux will receive a product potentially unsuitable for intended use.

Figure 13 Claimed vs Tested Lamp Data for Non-directional LED Lamps (NDLL)

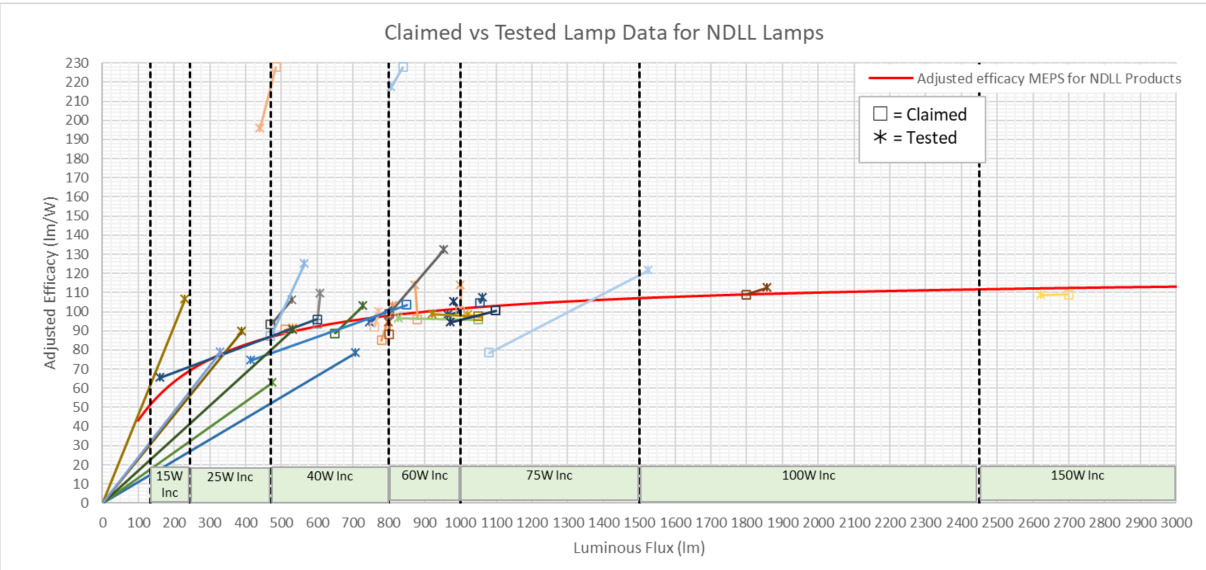


Figure 14 Non directional lamps which were not within the proposed tolerance required for claimed luminous flux and/or efficacy (±10% and -5% respectively)

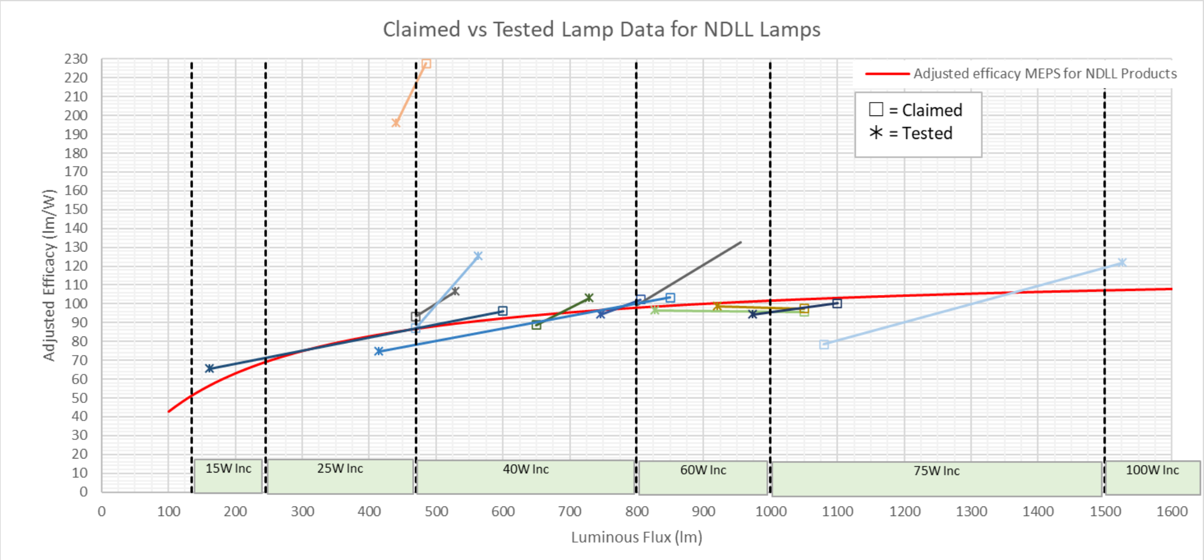


Figure 15 focuses on those lamps that made incorrect incandescent equivalence claims.

Figure 15 Non-directional lamps where the supplier makes an incorrect equivalence claim to an incandescent lamp

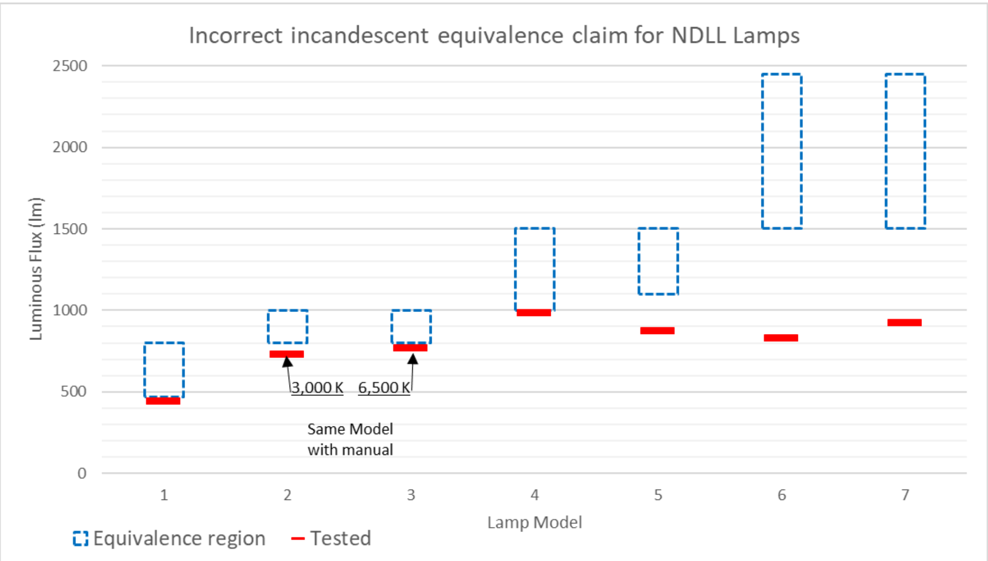


Figure 16 shows results for directional lamps, with more models overclaiming in this category – by up to almost 200 lumens.

Figure 17 focuses on those models likely to have not met proposed efficacy product marking requirements.

Figure 16 Claimed vs Tested Lamp Data for Directional LED Lamps

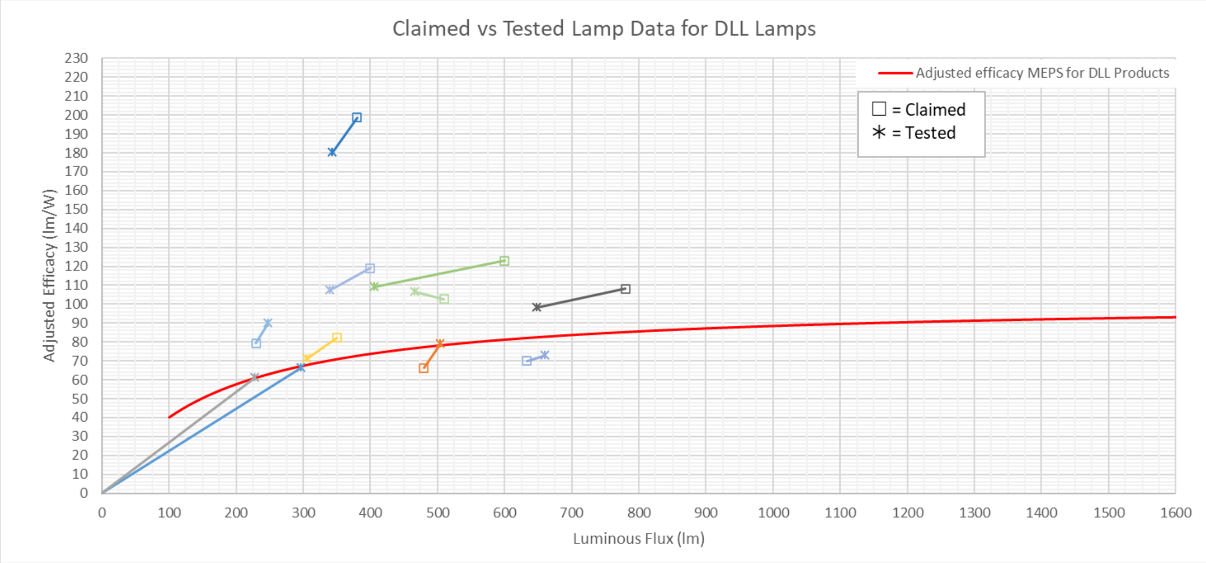
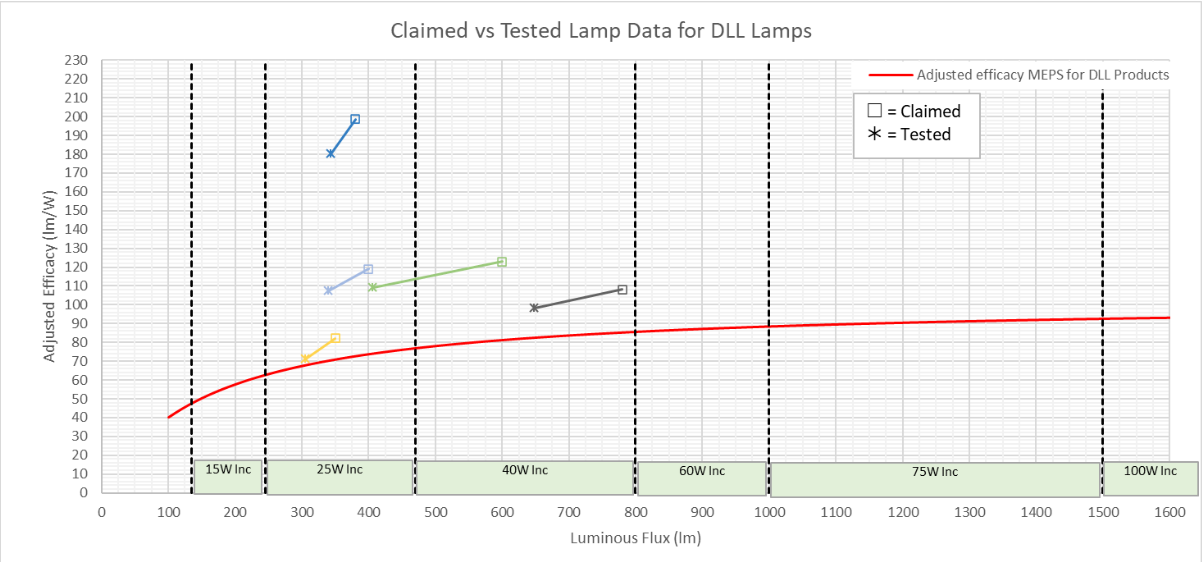


Figure 17 Directional lamps not within the proposed tolerance required for claimed luminous flux and/or efficacy (± 10% and -5% respectively)



Other Product Marking

There was a wide variation in marking of performance and product information on packages and lamps. This ranged from lamps supplied in bubble wrap without a package, lamps in blank boxes, or no marking on the lamps themselves, to well labelled lamps and packages clearly aimed at informing the consumer.

- Approximately 20% of models did not include basic product information such as luminous flux and product lifetime on packaging. More than 40% did not include luminous flux on the lamp.
- Over 70% of packages did not include luminous efficacy.
- 16% of non-directional and 9% of directional lamp packages did not include a model number (despite this already being a mandatory requirement of electrical safety regulations).
- Further results are provided in Annex 2.

Conclusion and Next Steps

These results indicate that there are poorer-quality LED lamp models on the market. Acknowledging the limitations of this testing, the results suggest the performance and quality issues could be present in other products available on the market meaning unnecessary loss of energy savings, increased difficulties in suitable product selection for consumers, and potential consumer dissatisfaction.

The proposed introduction of MEPS, along with suitably resourced industry communication, monitoring and enforcement has the potential to assist in addressing this poor performance and quality.

Subject to available resources, some potential next steps for in-house testing include:

- Development of improved test procedures informed by the results of the comparative third party testing.
- Updating of the operating manuals.
- Use of the ageing rack for endurance testing.
- Further LED testing of a broader range of LED lamp types (e.g. linear and small form lamps) and integrated luminaires (not in scope).
- Training of additional staff in lighting testing room operation.

Annex 1 – Viso System Calibration – Comparison of In-house Results to APR Laboratory Results

1.1 Electrical Parameters

Table 1 Electrical Parameters – Lamp 1

Lab	Voltage (V)	Current (A)	Power (W)	Pf	Df	THDc
APR Lab	230.1	0.052	6.24	0.525	0.951	147.8%
DCCEEW	229.2	0.049	6.08	0.540	0.954	145.8%
Variance	99.6%	94.7%	97.4%	102.9%	100.4%	98.7%
Correction Factors =			102.7%		99.6%	

Table 2 Electrical Parameters – Lamp 2

Lab	Voltage (V)	Current (A)	Power (W)	Pf	Df	THDc
APR Lab	230.0	0.057	10.12	0.771	0.985	79.1%
DCCEEW	229.1	0.058	10.12	0.760	0.984	80.8%
Variance	99.6%	101.7%	100.0%	98.6%	100.0%	102.1%
Correction Factors =			100.0%		100.0%	

Table 3 Electrical Parameters – Lamp 3

Lab	Voltage (V)	Current (A)	Power (W)	Pf	Df	THDc
APR Lab	230.1	0.075	9.42	0.546	0.958	143.3%
DCCEEW	229.2	0.073	9.30	0.550	0.960	140.8%
Variance	99.6%	97.3%	98.8%	100.7%	100.2%	98.2%
Correction Factors =			101.2%		99.8%	

Table 4 Electrical Parameters – Lamp 4

Lab	Voltage (V)	Current (A)	Power (W)	Pf	Df	THDc
APR Lab	230.0	0.030	5.13	0.742	0.846	51.6%
DCCEEW	229.1	0.029	5.22	0.780	0.854	43.0%
Variance	99.6%	96.4%	101.8%	105.1%	100.9%	83.3%
Correction Factors =			98.3%		99.1%	

1.2 Photometric Parameters

Table 5 Photometric Parameters – Lamp 1

Lab	Centre Beam Intensity (cd)	Beam Angle (°)	x	y	CCT (K)	CRI	SVM	P_{st}^{LM}
APRLab	91.8	174.4	0.4444	0.4005	2849	81.9	0.670	0.037
DCCEEW	86.1	184.8	0.4413	0.3991	2891	82.7	0.781	0.032
Variance	93.7%	10.4	-0.0031	-0.0014	42	0.83	0.110	-0.005

Table 6 Photometric Parameters – Lamp 2

Lab	Centre Beam Intensity (cd)	Beam Angle (°)	x	y	CCT (K)	CRI	SVM	P_{st}^{LM}
APRLab	91.0	219.5	0.4593	0.4166	2760	80.7	1.593	0.095
DCCEEW	94.1	219.6	0.4564	0.4156	2791	81.3	1.600	0.107
Variance	103.4%	0.1	-0.0029	-0.0010	31	0.59	0.006	-0.012

Table 7 Photometric Parameters – Lamp 3

Lab	Centre Beam Intensity (cd)	Beam Angle (°)	x	y	CCT (K)	CRI	SVM	P_{st}^{LM}
APRLab	246.9	109.2	0.4398	0.4056	2954	81.9	0.006	0.010
DCCEEW	234.5	114.5	0.4376	0.4058	3006	82.8	0.006	0.012
Variance	95.0%	5.3	-0.0022	0.0002	52	0.87	0.000	0.001

Table 8 Photometric Parameters – Lamp 4

Lab	Centre Beam Intensity (cd)	Beam Angle (°)	x	y	CCT (K)	CRI	SVM	P_{st}^{LM}
APRLab	323.4	58.7	0.4409	0.4086	2961	81.5	2.208	0.045
DCCEEW	298.4	64.7	0.4376	0.4070	3016	82.2	2.219	0.050
Variance	92.3%	6.0	-0.0033	-0.0016	55	0.67	0.011	0.005

1.3 Light Distribution – Detailed comparison

Table 9 Light Distribution– Lamp 1 (Total luminous flux determined as the Useful luminous flux)

Lab	Zonal Flux 90° cone	Zonal Flux 120° cone	Zonal Flux 180° cone	Total Luminous flux
APRLab	156.6	251.1	424.2	586.5
DCCEEW	148.3	239.9	412.7	578.5
Variance	94.7%	95.5%	97.3%	98.6%
Correction Factor =	**105.6%**	**104.7%**	**102.8%**	**101.4%**

Table 10 Light Distribution – Lamp 2 (Total luminous flux determined as the Useful luminous flux)

Lab	Zonal Flux 90° cone	Zonal Flux 120° cone	Zonal Flux 180° cone	Total Luminous flux
APRLab	208.4	360.6	674.4	967.1
DCCEEW	206.03	357.8	676.2	973.7
Variance	98.8%	99.2%	100.3%	100.7%
Correction Factor =	101.2%	100.8%	99.7%	99.3%

Table 11 Light Distribution – Lamp 3 (Zonal flux 120° cone determined as the Useful luminous flux)

Lab	Zonal Flux 90° cone	Zonal Flux 120° cone	Zonal Flux 180° cone	Total Luminous flux
APRLab	366.5	535.3	729.2	790.5
DCCEEW	358.3	529.7	732.8	794.5
Variance	97.7%	99.0%	100.5%	100.5%
Correction Factor =	102.3%	101.0%	99.5%	99.5%

Table 12 Light Distribution – Lamp 3 (Zonal flux 90° cone determined as the Useful luminous flux)

Lab	Zonal Flux 90° cone	Zonal Flux 120° cone	Zonal Flux 180° cone	Total Luminous flux
APRLab	303.4	378.6	430.0	429.6
DCCEEW	306.03	388.9	447.3	446.1
Variance	101.1%	102.7%	104.0%	103.8%
Correction Factor =	98.9%	97.4%	96.1%	96.3%

Annex 2 – Detailed Test Results – average results for each model

1.1 Non-Directional Lamps – average results for each model

Table 13 Non-Directional Lamps – Potential compliance outcomes – Markings on the lamps

Parameters	Useful Luminous flux[L]	CCT[L]
Pass	16	23
Not met	16	9
Total	32	32
Percentage not met	50%	28%

Table 14 Non-Directional Lamps – Potential compliance outcomes – Markings on the package

Parameters	Model Identifier	Useful Luminous flux[P]	Luminous Efficacy[P]	CCT[P]	CRI[P]	Intended use for low CRI[C]	Cap Type[P]	$L_{70}B_{50}$ Lifetime[P]	On-mode Power[P]	Dimmability Details[P]
Pass	27	26	7	29	17	0	32	25	31	32
Not met	5	6	25	3	15	0	0	7	1	0
Total	32	32	32	32	32	0	32	32	32	32
Percentage not met	16%	19%	78%	9%	47%	0%	0%	22%	3%	0%

Table 15 Non-Directional Lamps – Potential compliance outcomes – Accuracy of claims

Parameters	Useful Luminous flux^C^	Incandescent Equivalence^C^	Halogen Equivalence^C^	Luminous Efficacy^C^	CCT^C^	CRI^C^	On-mode Power^C^	Useful Luminous flux^C^	Incandescent Equivalence^C^	Halogen Equivalence^C^
Pass	16	7	2	21	26	17	31	16	7	2
Not met	16	6	0	11	6	15	1	16	6	0
Total	32	13	2	32	32	32	32	32	13	2
Percentage not met	50%	46%	0%	19%	19%	47%	3%	50%	46%	0%

Table 16 Non-Directional Lamps – Potential compliance outcomes – MEPS performance requirements

Parameters	Efficacy^M^	Displacement Factor^M^	CRI^M^	Colour Consistency^M^	Flicker^M^	Stroboscopic effect^M^
Pass	21	26	28	26	32	25
Not met	11	0	4	6	0	7
Total	32	26	32	32	32	32
Percentage not met	34%	0%	13%	19%	0%	22%

1.2 Directional Lamps – average results for each model

Table 17 Directional Lamps – Potential compliance outcomes – Markings on lamp

Parameters	Useful Luminous flux^L^	CCT^L^	Beam Angle^L^
Pass	5	9	5
Not met	6	2	6
Total	11	11	11
Percentage not met	55%	18%	55%

Table 18 Directional Lamps – Potential compliance outcomes – Markings on package

Parameters	Model Identifier	Useful Luminous flux[P]	Luminous Efficacy[P]	CCT[P]	CRI[P]	Intended use for low CRI[C]	Beam Angle[P]	Cap Type[P]	$L_{70}B_{50}$ Lifetime[P]	On-mode Power[P]	Dimmability Details[P]
Pass	10	9	2	11	10	0	10	11	8	11	11
Not met	1	2	9	0	1	1	1	0	3	0	0
Total	11	11	11	11	11	1	11	11	11	11	11
Percentage not met	9%	18%	82%	0%	9%	100%	9%	0%	27%	0%	0%

Table 19 Directional Lamps – Potential compliance outcomes – Accuracy of claims

Parameters	Useful Luminous flux[C]	Luminous Efficacy[C]	CCT[C]	CRI[C]	Beam Angle[C]	On-mode Power[C]
Pass	5	4	11	10	8	11
Not met	6	7	0	1	2	0
Total	11	11	11	11	10	11
Percentage not met	55%	64%	0%	9%	20%	0%

Table 20 Directional Lamps – Potential compliance outcomes – MEPS performance requirements

Parameters	Efficacy[M]	Displacement Factor[M]	CRI[M]	Colour Consistency[M]	Flicker[M]	Stroboscopic effect[M]
Pass	9	5	10	6	11	9
Not met	2	1	1	3	0	2
Total	11	6	11	9	11	11
Percentage not met	18%	17%	9%	33%	0%	18%

1.3 Connected Non-Directional Lamps – average results for each model

Table 21 Connected Non-Directional Lamps – Potential compliance outcomes – Markings on lamp

Parameters	Useful Luminous flux[L]	CCT[L]
Pass	4	2
Not met	0	2
Total	4	4
Percentage not met	0%	50%

Table 22 Connected Non-Directional Lamps – Potential compliance outcomes – Markings on package

Parameters	Model Identifier	Useful Luminous flux[P]	Luminous Efficacy[P]	CCT[P]	CRI[P]	Intended use for low CRI[C]	Cap Type[P]	$L_{70}B_{50}$ Lifetime[P]	On-mode Power[P]	Standby Power[P]	Networked Standby Power[P]	Dimmability Details[P]
Pass	3	3	1	4	2	0	4	2	4	0	0	4
Not met	1	1	3	0	2	0	0	2	0	0	4	0
Total	4	4	4	4	4	0	4	4	4	0	4	4
Percentage not met	25%	25%	75%	0%	50%	0%	0%	50%	0%	0%	100%	0%

Table 23 Connected Non-Directional Lamps – Potential compliance outcomes – Accuracy of claims

Parameters	Useful Luminous flux[C]	Incandescent Equivalence[C]	Halogen Equivalence[C]	Luminous Efficacy[C]	CCT[C]	CRI[C]	On-mode Power[C]	Standby Power[C]	Networked Standby Power[C]
Pass	2	1	0	3	4	2	4	0	0
Not met	2	0	0	1	0	2	0	0	4
Total	4	1	0	4	4	4	4	0	4
Percentage not met	50%	0%	0%	25%	0%	50%	0%	0%	100%

Table 24 Connected Non-Directional Lamps – Potential compliance outcomes – MEPS performance requirements

Parameters	Efficacy[M]	Displacement Factor[M]	Standby Power[M]	Networked Standby Power[M]	CRI[M]	Colour Consistency[M]	Flicker[M]	Stroboscopic effect[M]
Pass	4	4	0	1	4	1	4	4
Not met	0	0	0	1	0	3	0	0
Total	4	4	0	2	4	4	4	4
Percentage not met	0%	0%	0%	50%	0%	75%	0%	0%

Figure 18 Test Results for Displacement Factor, Lamps > 5W and ≤ 10W

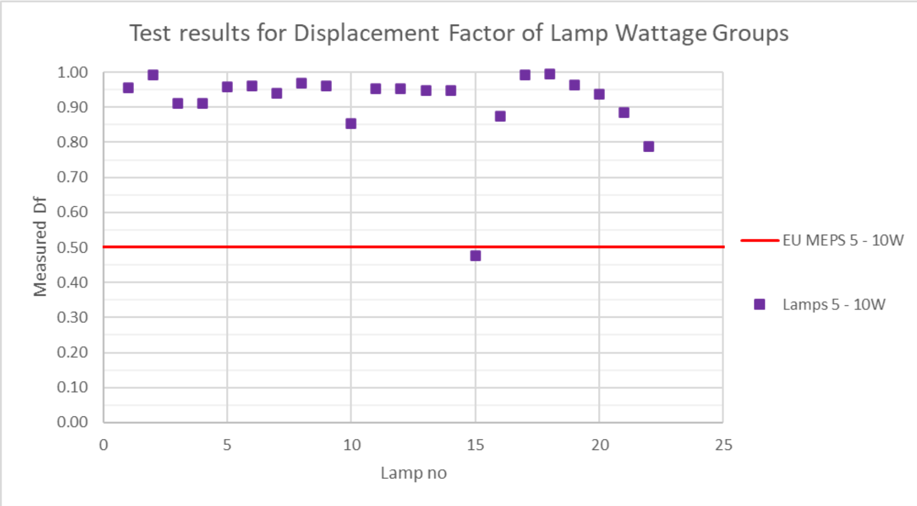


Figure 19 Test Results for Displacement Factor, Lamps > 10W and ≤ 25W

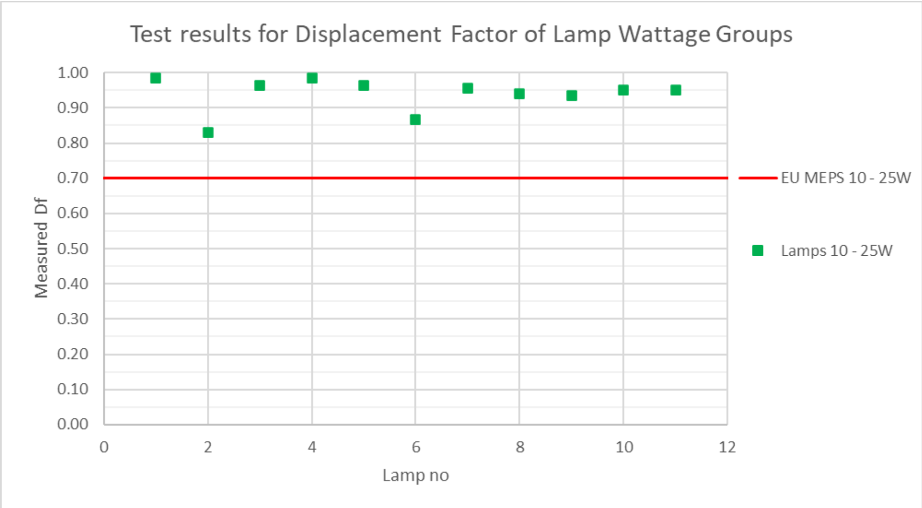


Figure 20 Test Results for Displacement Factor, Lamps > 25W