Research Report

Test Results for Incandescent and Tungsten-Halogen Directional Lamps

Prepared in support of the European Commission's regulatory analysis of directional lamps – Ecodesign Lot 19, part 2

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ABOUT CLASP

Established in 1999, CLASP is an independent non-profit organisation serving as a resource and voice for energy efficiency worldwide. CLASP has provided technical assistance on standards and labelling (S&L) in over 50 countries, supporting and promoting energy-efficiency in appliances, lighting and equipment. In 2009, CLASP became a ClimateWorks Foundation (CWF) global Best Practice Network on S&L. CWF funding has enabled CLASP to expand its activities globally to reduce the emission of greenhouse gases that cause climate change. Currently, CLASP has offices or programmes in China, the European Union, India, Latin-American and the United States.

CLASP's primary objective is to identify and respond to the analysis needs of S&L practitioners in targeted countries and regions while making the highest quality technical information on S&L best practice available globally. To this end, CLASP works on the ground providing technical analysis and expertise to national governments and local partners; aggregates resources; assembles project teams from diverse and highly-qualified organizations; oversees projects; partners and collaborates with policy makers and members of industry alike; and disseminates information for maximum impact. This report was prepared for and provided by CLASP's Europe office as part of its effort to strengthen the European Commission's regulatory analysis on directional lamps.

For more information about CLASP, please visit our website: http://www.clasponline.org/index.php

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Acronyms and Abbreviations

CLASP	Collaborative Labelling and Appliance Standards Program
EEI	Energy Efficiency Index
ELC	European Lamp Companies Federation
GLS	General Lighting Service (Incandescent)
HL	Halogen
IRC	Infrared Reflective Coating
MV	Mains Voltage
MV&E	Monitoring, Verification and Enforcement
NMI	National Metrology Institute
PAR	Parabolic Aluminised Reflector
SP	Sveriges Tekniska Forskningsinstitut (SP Technical Research Institute of Sweden)
STEM	Swedish Energy Agency
UBA	Umweltbundesamt (Federal Environment Agency, Germany)
UK	United Kingdom
XEN	Xenon

1 Introduction

1.1 Commission's Work on Directional Lamps

The European Commission is developing minimum energy performance and energy labelling requirements for directional lamps. The Commission's contractors finalised the preparatory study in October 2009, and the Commission held a first meeting of the Consultation Forum in July 2011. A Technical Subcommittee was established in September 2011 to explore specific technical issues relating to the regulations. The Commission has consulted widely throughout this regulatory process, gathering input from stakeholders across Europe.

At the time of this publication, the Commission is preparing for the Regulatory Committee Meeting, which is scheduled for mid-July.

1.2 Disparity of Performance Results

One of the issues discussed in the Consultation Forum was the maximum achievable energy efficiency index (EEI) values for the filament-based directional lamps. The Commission was given two databases – one originating from the European Lamp Companies Federation (ELC) and one from the German Federal Environment Agency or Umweltbundesamt (UBA). ELC states that their database is derived from test data gathered from their members. UBA states that their data are a) values of luminous flux, determined by a laboratory for the consortium that had done the preparatory study[3] for Lot 19-1 and b) derived from photometric reports published by industry for lighting designers that provide information on the light distribution profiles of each lamp type. The UBA calculation method is explained in Annex 1.

Regrettably, the test-based data from ELC and the calculation-based data from UBA are not consistent. For most of the various classes of filament lamp types, the UBA data found that much more ambitious[4] EEI values were achievable than those provided by industry. Figure 1.1 shows the extent of the differences in four key areas, indicated on the diagram. This figure shows the EEI values on the left-hand column, ranging from 2.50 to 0.05. There are five lamp classes shown, which are:

- GLS – general lighting service, which represents incandescent directional lamps. This column includes both blown-reflector shaped blubs and two-part reflectors which are more optically precise.
- HL-MV – halogen-capsule directional lamps that operate on mains voltage (i.e., 220-240 V).
- HL-MV-xen – halogen-capsule directional lamps that operate on mains voltage and have xenon gas-fill to enhance performance.
- HL-LV – halogen-capsule directional lamps that operate on low voltage (i.e., 12 V).
- HL-LV-IRC – halogen-capsule directional lamps that operate on low voltage and incorporate an infrared reflective coating (IRC) on the halogen capsule to reflect heat back onto the filament and reduce the power requirement to maintain the filament operating temperature.

In the summary table below, "e" designates values taken from the ELC dataset (light blue shading) and "d" designates the ones from the UBA dataset (light yellow shading). Among the ELC data, "R"

[3] "Preparatory Studies for Eco-design Requirements of EuPs, Final report: Lot 19: Domestic lighting", prepared by VITO, BIO Intelligence Service, Energy Piano and Kreios, October 2009."

[4] The EEI is a calculated value that is based on the light output for watts of power consumed by the lamp. As the EEI value gets smaller, the efficacy of the lamp improves – that is, the light output increases relative to the watts consumed. For certain lamp types in the European market, the EEI value is adjusted to account for losses associated with specific optical features, external drivers or other factors influencing the system-level performance of a lamp.

indicates blown-glass reflector MV lamps, and "G" the standard two-part glass bulb (i.e., a common lamp-shape based on fusing together a reflector and a lens, for example a parabolic aluminised reflector (PAR) lamp).

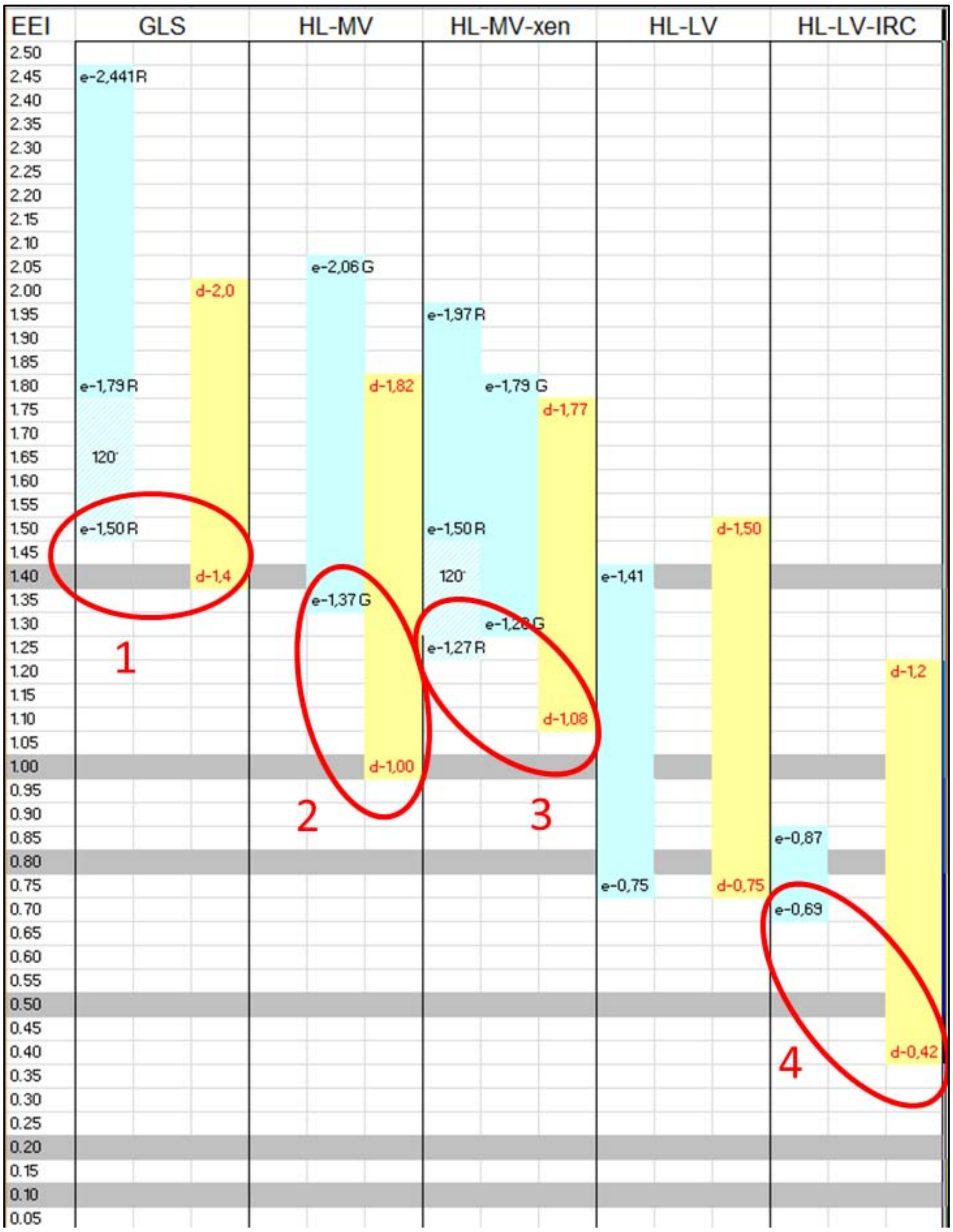

Figure 1-1. Illustration of the Range of EEI values for the Two Datasets

The four red circles highlight the minimum EEI values for the four lamp types that have a numerical difference (i.e., the halogen-low voltage had the same minimum EEI value of 0.75). Table 1.1 summarises the differences between these two datasets for these lamps.

Table 1-1. Summary of the Lamp Types with the Largest EEI Differences

Lamp Type Group	Corresponding Number in Figure 1-1	ELC Minimum EEI Value	UBA Minimum EEI Value
GLS	1	1.50	1.40
HAL-MV	2	1.37	1.00
HAL-MV-xenon	3	1.27	1.08
HAL-LV-IRC	4	0.69	0.42

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2 Objectives and Lamp Selection and Testing

As the testing project was formulated, several objectives were identified that could help address not only the issue of the discrepancy between the two lamp performance databases, but two other questions about sample size and a correction factor. In preparing the scope of work for the testing project, the following objectives were developed:

1. **Testing the UBA Best Performing Lamps**
   The objective was to work with UBA to identify and then purchase and test the lamps that represent those with the lowest (i.e., best performing) EEI value in the UBA database. The test sample should include GLS, HAL MV, HAL MV xenon and HAL LV IRC lamps that were calculated by UBA to have the lowest EEI values, noting that there may be some uncertainty in the categorisation as to whether xenon gas is present in the lamps or not.

2. **Testing the ELC (and non-ELC) Best Performing Lamps**
   The objective was to work with ELC to identify and then purchase and test the lamp models that represent the best performing EEI lamps in their database. This sample should include GLS, HAL MV, HAL MV xenon and HAL LV IRC lamps – the four categories that experienced the discrepancy with UBA.

3. **Testing of Poor Quality Lamps from Non-ELC Companies**
   Working with UBA, ELC and conducting our own research, the objective of this effort was to identify, purchase and test poor-quality directional lamps from non-ELC companies. With the knowledge of the EEI values from these lamps, the Commission can be sure to adopt a level that will advocate for more efficient lamp designs. The sample of lamps should include models drawn from the four focus categories – GLS, HAL MV, HAL MV xenon and HAL LV IRC. And, when selecting the xenon lamps for testing, we would rely on the manufacturers' packaging to determine whether the lamps contain a sufficient amount of xenon to improve their performance.

4. **Anti-Glare End-Cap Correction Factor Verification Test**
   ELC requested that a correction factor of 1.20 be added to the regulation for directional lamps that incorporate an anti-glare end-cap. Examples of these end-caps can be found on AR-111 directional lamps, which are commonly used in retail, hospitality and other sectors. It was decided to purchase a small sample of these lamps and to make two measurements – one with the anti-glare end-cap in place and one with the end-cap removed. The difference in luminous flux would be compared between the two lamps and the correction factor would be calculated.

5. **Smaller Sample Size for EEI Verification Test**
   Market monitoring, verification and enforcement (MV&E) testing requires the purchase and test of samples of 20 lamps. Two of the lamp properties that require MV&E testing are lamp lifetime and light output (i.e., luminous flux), and according to one national market surveillance authority, the procedures they typically follow involves purchasing a sample of 20 lamps for lifetime testing and a sample of 20 lamps for efficacy testing, resulting in a large volume of lamps for each make and model that they wish to test. The objective of this work

was to determine whether a sample smaller than 20 lamps could be used for the luminous flux measurements.[5]

In order to address these objectives, CLASP and the Swedish Energy Agency (STEM) decided to work together to purchase and test a sample of directional lamps from each of the categories and conduct efficacy measurements on them. CLASP was responsible for coordinating the selection and procurement of the lamps and STEM was responsible for testing. STEM arranged for the national metrology laboratory in Sweden, SP Sveriges Tekniska Forskningsinstitut (SP Technical Research Institute) to do the testing.

2.1 Lamp Selection

The process of lamp selection spanned a period of three weeks and involved telephonic consultations and numerous email exchanges with the ELC, UBA and Kreios BVBA (one of the contractors who participated in the Commission's Preparatory Study). This input was supplemented by CLASP's own research of manufacturer and retail websites, and studying marketing literature and 'premium efficacy' model lamps.

An effort was made to ensure lamps purchased were from both ELC members and non-ELC members. Lamps were purchased from various retail outlets across Europe, including Belgium, France, Germany, the Netherlands, the Slovak Republic and the UK. The retailers in these countries are typical of those that would be used by domestic lighting consumers including two lighting stores in Brussels, an IKEA store in London, and numerous on-line retailers including amazon.de, amazon.co.uk, calex.nl and so on.

The table below presents a summary of the lamps that were purchased and the number of tests that were conducted by SP Technical Research Institute in Sweden.

Table 1. Summary of Lamps Purchased and Tested

Directional Lamp Type	Testing Plan	Number of Lamps	Number of Tests
Incandescent	2 models, 3 units of each, 1 test	6	6
Halogen, mains voltage	9 models, 3 units of each, 1 test	27	26*
Halogen, mains voltage, xenon	8 models, 3 units of each, 1 test	24	24
Halogen, low voltage	4 models, 3 units of each, 1 test	12	12
Halogen – low voltage, xenon	3 models, 3 units of each, 1 test	9	9
Halogen – low voltage, IRC	3 models, 3 units of each, 1 test	9	9
Halogen – low voltage, 20 lamps	1 model, 20 units, 1 test each	20	20
Anti-glare end-cap lamps	4 lamps, 2 tests each	4	8
	Total:	**111**	**114**

*One of the lamps purchased was broken on delivery to CLASP and was not able to be re-ordered in time to be included in the test sample.

[5] Note: the UK National Measurement Office indicated that they believed a sample size of 20 lamps was still needed for the lifetime testing, but that it may be possible to have reasonably accurate measurements for luminous flux with a smaller sample size.

The following series of questions and answers provides an overview of the diversity in performance characteristics and lamps types included in the sample of 111 lamps purchased.

How many lamps were manufactured by ELC Members?

ELC members	82 lamps
Non- ELC	29 lamps

Which nominal lamp voltages were purchased (manufacturer labelled)?

12 volts	55 lamps
230 volts	24 lamps
240 volts	32 lamps

Which base types were purchased?

BA15D	1 lamp
E14	6 lamps
E27	26 lamps
G5.3	54 lamps
GU10	24 lamps

What were the lamp lifetimes (manufacturer labelled)?

1000 hours	3 lamps
2000 hours	44 lamps
2500 hours	9 lamps
3000 hours	9 lamps
4000 hours	28 lamps
5000 hours	9 lamps
Unknown	9 lamps

Which beam angles were purchased (manufacturer labelled)?

24 degrees	6 lamps
25 degrees	9 lamps
30 degrees	21 lamps
35 degrees	3 lamps
36 degrees	36 lamps
38 degrees	3 lamps
40 degrees	10 lamps
50 degrees	3 lamps
60 degrees	3 lamps
“Flood”	3 lamps
Unknown	14 lamps

Which wattages were purchased (manufacturer labelled)?

20 watts	3 lamps

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28 watts	12 lamps
35 watts	48 lamps
40 watts	12 lamps
42 watts	8 lamps
50 watts	15 lamps
60 watts	1 lamp
75 watts	6 lamps
80 watts	3 lamps
120 watts	3 lamps

In which countries were the lamps produced (manufacturer labelled)?

Belgium	12 lamps
China	28 lamps
France	6 lamps
Germany	12 lamps
India	3 lamps
Poland	36 lamps
Slovakia	2 lamps
USA	3 lamps
Unknown	9 lamps

Which lamp shapes were purchased?

AR111	3 lamps
BA15d	1 lamp
MR16	60 lamps
NR63	3 lamps
PAR16	15 lamps
PAR20	6 lamps
PAR30	6 lamps
PAR38	6 lamps
R50	6 lamps
R63	5 lamps

Overall, the sample of lamps purchased for testing represented a broad spectrum of types and performance characteristics.

2.2 Lamp Testing

The team decided that testing of the lamps should be conducted "blind", meaning the laboratory would receive numbered lamps without any of the manufacturer's packaging. Therefore, the lamps were shipped to CLASP where they were prepared for testing by being unpacked, numbered, packed again in bubble-wrap (without branded packaging), and shipped to SP Technical Research Institute in Sweden.

STEM selected the SP Technical Research Institute to conduct the testing of the directional lamps. SP Technical Research Institute is recognised as a leading international research institute and is the national metrology institute (NMI) in Sweden. They are certified by the Swedish Board for Accreditation and Conformity Assessment as complying with ISO/IEC 17025 (laboratories), EN 45011 (certification bodies) and ISO 17020 (inspection bodies). Laboratories accredited for testing and calibration meet at least the requirements of ISO 17025, which means that they also fulfil the relevant requirements of SS-EN ISO 9001. In addition, SP Technical Research Institute operates an ISO 14001 environmental management system, which is integrated with other quality management systems within the SP group.

The test methodology followed by SP Technical Research Institute was provided by ELC, and was as follows:

1. Lamps are operated for 4 hours (a "seasoning" period)
2. The goniophotometer should measure C-planes measured: 4 (x 45°)
3. In each C-Plane, gamma (γ) angles and steps:
   - Step angle between 0° and 5° will be 0.5°
   - Step angle between 5° and 30° will be 1°
   - Step angle between 30° and 90° will be 2°

The measured test data is integrated over the area and the total luminous flux calculated from the test results.

2.3 Calculating EEI

The Energy Efficiency Index (EEI) of the lamp is calculated according to the approach presented in the Commission's draft working document for directional lamps. The EEI is calculated and rounded to two decimal places from the following formula:

$$EEI = P_{cor} / P_{ref}$$

Where:

P_{cor} is the corrected power, calculated from the measured power at nominal input voltage and corrected (if necessary) according to the values shown below. If more than one correction factor is applicable, then the correction factors are cumulative.

lamps operating on external halogen lamp control gear	$P_{measured}$ x 1.06
lamps with anti-glare cap	$P_{measured}$ x 0.80

P_{ref} is the reference power, obtained by measuring the lamp's useful luminous flux (Φ_{use}) and plugging it into the formula (only applicable for lamps with Φ_{use} < 1300 lumens):

$$P_{ref} = 0.88 \times (\Phi_{use})^{0.5} + 0.049 \times \Phi_{use}$$

Note: there are other correction factors that the Commission is considering and there is a P_{ref} equation for lamps with useful luminous flux higher than 1300 lumens, however these aspects of the draft Regulation are not discussed here because they are not applicable to this test report.

3 Test Results

The test results were provided by SP Technical Research Institute in an Excel spreadsheet, listed according to the numbers attributed to the lamps tested. The following data were reported for each lamp tested:

- Lamp Number
- Luminous Flux (lumens) in a 90 degree cone (i.e., Φ_{use})
- Voltage
- Current
- Power (product of voltage and current)
- Base type

From this data and our own records about each lamp submitted for testing, the equations and correction factors from section 2.3 were applied and the EEI values were calculated for each lamp individually. Then, averages were calculated for each sample of three lamps (or 20 lamps for the model that had 20 units) and these sample average EEI values were compared to the ELC and UBA datasets. This section of the report presents these results.

3.1 Incandescent

The sample size of incandescent lamps tested was very small – only two models were purchased, an 80 W PAR38 flood lamp and a 120 W PAR38 lamp with a 30 degree beam angle. In selecting these two lamps, the team was not expecting to find poor performing incandescent directional lamps. Instead, these two lamp types were selected because it was thought they would represent better performing models as they were both PAR lamps, so there would be better optical design and they were both relatively higher wattage (tungsten filaments tend to be more efficacious at higher wattages). The purpose in selecting these two lamps was to try and provide some data that would address difference observed between ELC (EEI_{min} = 1.79) and UBA (EEI_{min} = 1.40).

Table 3-1 shows that the two lamps purchased and tested by CLASP/STEM had sample average EEI values of 1.965 and 1.894. One lamp was produced by an ELC member and the other one was not.

Table 3-1. Test Results for Incandescent Lamps

Incandescent Lamp	ELC Database	UBA Database	CLASP/STEM Test Data
EEI_{max} (low efficacy)	2.441	2.000	1.965
EEI_{min} (high efficacy)	1.790	1.400	1.894

Thus, the results of the two incandescent lamp models that were tested appear to validate the EEI_{min} values provided by ELC, which extend to slightly better EEI values of 1.79. We find, therefore that the ELC performance claims are reasonable.

3.2 Halogen – Mains Voltage

The sample size of halogen mains voltage lamps tested consisted of nine different lamp models. These lamps were all either 230 V or 240 V, and have various base types including E14, E27 and GU10. There were several lamp shapes, including R50, R63, MR16, PAR16, PAR20 and PAR30. There was a range of nominal wattages, extending from 28 to 75 watts with the majority between 40 and

50 watts. The lamp lifetimes ranged from 1000 to 2500 hours, with 8 out of the 9 models tested having 2000 or 2500 hours of life.

In selecting these lamps, we had received recommendations from several parties and due to the importance of this particular lamp type (one of the fastest growing filament directional lamps in Europe) we purchased most of the recommended models. For this lamp type, the ELC and UBA datasets also had a significant difference, with ELC estimating the EEI_{min} at 1.370 and UBA calculating that the EEI_{min} is 1.000.

Table 3-2 shows that the average EEI values for the nine lamps purchased and tested by CLASP/STEM had a range from 1.647 to 1.275. Individually, the nine lamps tested had the following average EEI values: 1.275, 1.381, 1.420, 1.426, 1.434, 1.443, 1.539, 1.541, and 1.647. Of these nine lamps, five were produced by ELC members and four were not. The lamp with the 1.275 EEI value, the best of this group, was manufactured by an ELC member.

Table 3-2. Test Results for Halogen – Mains Voltage Lamps

Halogen MV Lamp	ELC Database	UBA Database	CLASP/STEM Test Data
EEI_{max} (low efficacy)	2.080	1.820	1.647
EEI_{min} (high efficacy)	1.370	1.000	1.275

The results from our test sample of mains voltage halogen lamps found a minimum value that was lower than the EEI_{min} values provided by ELC, but which was not as low as the value calculated by UBA. Our findings indicate that the EEI_{min} for mains voltage lamps is actually lower than that reported by ELC. As discussed in Chapter 4, our sample size for this lamp type was small (n=3), however if we apply two standard deviations from the lamp type thathad 20 units tested (n=20), the range around our finding does not coincide with ELC.[6] ELC's reported value of 1.370 appears to omit a better performing lamp from this category.

3.3 Halogen – Mains Voltage Xenon

The sample size of halogen mains voltage xenon lamps tested consisted of eight different lamp models. These lamps were all either 230 V or 240 V, and have various base types including E14, E27 and GU10. There were several lamp shapes, including R50, R63, MR16 and PAR16. There was a narrow range of nominal wattages, extending from 30 to 50 W with the majority being either 30 or 40 W. The lamp lifetimes ranged from 2000 to 3000 hours, with the majority being rated as 2000 hours of life.

In a similar way to the halogen mains voltage discussed in the previous section, we had received recommendations for several parties for these lamp types and due to the importance of this lamp type, we purchased most of the recommended models. ELC differentiated the lamps in its database according to the lamp construction. Blown-glass reflectors were grouped together (with a range of EEI_{max} = 1.970 and EEI_{min} = 1.500) and lamps having a shaped reflector fused to a lens were reported to have a range of EEI_{max} = 1.790 and EEI_{min} = 1.280. For this group of lamps, UBA did not differentiate

[6] We sampled 20 lamps of a low-voltage halogen lamp manufactured by an ELC member. The sample had a mean EEI of 0.926 and a standard deviation of 0.021. If we apply two stand deviations to the mean for the mains voltage halogen lamp which we found to have a mean EEI of 1.275, the range would be between 1.233 and 1.317. ELC's value of 1.370 therefore appears to omit a lamp with better performance characteristics in this category. The more efficacious lamp may have been introduced to the market subsequent to the ELC database being provided to the Commission in early 2011.

between blown glass reflector or not, but instead provided one range spanning from an EEI_{max} = 1.770 to EEI_{min} = 1.080.

Table 3-3 shows that the average EEI values for the eight lamp models purchased and tested by CLASP/STEM had a range from EEI_{max} = 1.815 to EEI_{min} = 1.333. Individually, the eight lamps tested had the following average EEI values: 1.333, 1.337, 1.358, 1.380, 1.434, 1.440, 1.659 and 1.815. Of these eight lamps, six were produced by ELC members and two were not.

Table 3-3. Test Results for Halogen – Mains Voltage Xenon Lamps

Halogen MV Xenon	ELC Database	UBA Database	CLASP/STEM Test Data
EEI_{max} (low efficacy)	Blown glass reflector: 1.970 Standard reflector: 1.790	1.770	1.815
EEI_{min} (high efficacy)	Blown glass reflector: 1.500 Standard reflector: 1.280	1.080	1.333

The results from our test sample of mains voltage halogen xenon lamps found a minimum value that was very close to the EEI_{min} value provided by ELC, but which was not as low as the value calculated by UBA. Our findings indicate, therefore, that the EEI_{min} for halogen mains voltage xenon lamps by ELC is a reasonable value to use for this category of lamp.

3.4 Halogen - Low Voltage

Low voltage halogen lamps were not one of the categories where there was a discrepancy between ELC and UBA, however in the process of purchasing and testing lamps, it was decided that we should purchase a few models to verify the EEI values reported. The sample size of low voltage halogen lamps was eight models, however one of these eight models was the one for which we purchased 20 units – thus, a total of 32 lamps were tested in this category. The sample of lamps tested was relatively homogeneous compared to the previous lamp categories – all the lamps were MR16 lamp shapes, rated at 12 volts and having a 36 degree beam angle. They ranged from 20 to 40 W with the majority being 35 W. The lamp lifetime was either 2000 hours (5 models) or 4000 hours (3 models).

ELC's database reported a broad range of EEI values for this lamp category, spanning from EEI_{max} = 1.410 to EEI_{min} = 0.750. The UBA database aligns very well with these data, spanning from EEI_{max} = 1.500 and EEI_{min} = 0.750.

Table 3-4 shows the range of average EEI values for the eight lamp models that were purchased and tested by CLASP/STEM. The range was much narrower than the range presented by ELC and UBA, spanning from EEI_{max} = 0.993 to EEI_{min} = 0.885. Individually, the eight lamps tested had the following average EEI values: 0.885, 0.912, 0.926, 0.927, 0.939, 0.981, 0.985 and 0.993. Of these eight lamps, seven were produced by ELC members and one was not.

Table 3-4. Test Results for Halogen – Low Voltage Lamps

Halogen LV	ELC Database	UBA Database	CLASP/STEM Test Data
EEI_{max} (low efficacy)	1.410	1.500	0.993
EEI_{min} (high efficacy)	0.750	0.750	0.885

The results from our test sample of low voltage halogen lamps did not span the same range of EEI values as those presented by ELC and UBA, most likely because our sample size was small. It is also probably for this reason that we did not find any models with an EEI value as low (i.e., energy-efficient) as those shown by ELC and UBA. Overall, the lamps we tested do not lead us to question the values shown in the ELC and UBA databases for EEI_{min}. We consider 0.750 to be a reasonable and appropriate minimum EEI for this category of lamps.

3.5 Halogen – Low Voltage Infrared Reflective Coating

Low voltage halogen IRC lamps were one of the categories where there was a discrepancy between ELC and UBA. For this category of lamps, we purchased three different models for testing. The sample of lamps tested was relatively homogeneous – all the lamps were MR16 lamp shapes, rated at 12 volts and having 5000 hours of life. The lamps had very different beam angles, however – 24 degrees, 36 degrees and 60 degrees.

ELC's database reported a range of EEI values for this lamp category, spanning from EEI_{max} = 0.870 to EEI_{min} = 0.690. The UBA database aligns very well with these data, spanning from EEI_{max} = 1.200 and EEI_{min} = 0.420.

Table 3-5 shows that range of average EEI values for the three lamp models that were purchased and tested by CLASP/STEM. Perhaps due in part to the limited size of the sample purchased, the range was much narrower than the range presented by ELC and UBA, spanning from EEI_{max} = 0.733 to EEI_{min} = 0.669. Individually, the three lamps tested had the following average EEI values: 0.669, 0.689 and 0.733. All three of these lamps were produced by ELC members.

Table 3-5. Test Results for Halogen – Low Voltage Infrared Reflective Coating Lamps

Halogen LV IRC	ELC Database	UBA Database	CLASP/STEM Test Data
EEI_{max} (low efficacy)	0.870	1.200	0.733
EEI_{min} (high efficacy)	0.690	0.420	0.669

The measured EEI_{min} results from our test sample of low voltage halogen IRC lamps are similar to those of the ELC, although the CLASP/STEM test results indicate that the EEI_{min} could be lower than that shown by ELC. For example, it is feasible that a new, better performing lamp was introduced to the market after the ELC database was submitted to the Commission. We did not find, however, any lamps with a performance as ambitious as the 0.420 value calculated by UBA. From our sample of data therefore, we find that the EEI_{min} value for low voltage halogen IRC lamps to be 0.669.

3.6 End-cap AR-111 Halogen Lamps

As discussed in Chapter 2, one of the objectives of this testing work was to independently verify the magnitude of the correction factor applied for anti-glare end-cap reflector lamps. This is important to verify because this correction factor is one of the largest requested by industry for the Commission's Regulation.

CLASP/STEM purchased four lamps with anti-glare end-caps from four different manufacturers. SP Technical Research Institute measured each lamp as it was shipped (i.e., with the anti-glare end-cap in place), and then removed the anti-glare baffle and conducted a second measurement of luminous flux. The difference between these two measurements represents the light adsorbed by the anti-glare baffle. Industry's request for this correction factor is to off-set against the losses associated with the baffle. All four of these lamps were produced by ELC members.

Table 3-6. Test Results for Halogen – Low Voltage Infrared Reflective Coating Lamps

Lamps from Different Manufacturers	Lumens with Anti-Glare End-Cap	Lumens without Anti-Glare End-Cap	Percentage Difference
AR-111	459	553	- 20%
AR-111	460	553	- 20%
AR-111	843	973	- 15%
BA15d	393	527	- 34%

Overall, the percentage change in luminous flux was 20%, 20%, 15% and 34% for the lamps tested with and without the anti-glare end-cap in place. Thus, it would appear that the correction factor requested by ELC for anti-glare end-caps is reasonable.

4 Sample Size for Testing

As discussed in Chapter 2, the sample size purchased for each of the lamps selected for this study was three lamps. Although it would have been more accurate to purchase and test more lamps (ideally, n=20 as per the industry testing standards), due to budget and schedule constraints, it was agreed that using smaller sample sizes would give us an indication of performance for the models tested. This smaller sample size also enabled the team to select and test more lamps than would have otherwise been possible.

That said, for one lamp, the team purchased twenty units to look at the lamp-to-lamp variance between units of the same model. As per the fifth objective identified in Chapter 2, in addition to testing EEI values of certain categories of directional lamps, this project also sought to answer the question of whether a sample size smaller than 20 units could be used to determine the EEI value. The measurement of the EEI was reported by several testing experts to be a more consistent and reliable measurement, and thus a smaller sample size for this lamp attribute may be acceptable. Indeed, if this were the case, it would lower the MV&E costs across Europe for ensuring compliance with the directional lamp ecodesign regulation.

4.1 European Sample Size

In the draft Regulation, the Commission has included language that requires market surveillance authorities to purchase and test samples of 20 lamps for the performance requirements of covered lamps. The draft regulation reads as follows:

ANNEX IV

Verification procedure for market surveillance purposes

When performing the market surveillance checks referred to in Article 3(2) of Directive 2009/125/EC, the Member States' authorities shall apply the verification procedures listed in this Annex. The market surveillance authorities shall provide the information of the testing results to other Member States and to the Commission.

Member State authorities shall use reliable, accurate and reproducible measurement procedures, which take into account the generally recognised state-of-the-art measurement methods, including methods set out in documents the reference numbers of which have been published for that purpose in the Official Journal of the European Union.

1. VERIFICATION PROCEDURE FOR LAMPS OTHER THAN LED LAMPS AND FOR LED LAMPS THAT ARE MEANT TO BE REPLACED IN THE LUMINAIRE BY THE END-USER

Member State authorities shall test a sample batch of minimum twenty lamps of the same model from the same manufacturer, where possible obtained in equal proportion from four randomly selected sources, unless specified otherwise in Table 9.

The model shall be considered to comply with the requirements laid down in this Regulation if:

(a) the lamps in the batch are accompanied by the required and correct product information, and

(b) *the lamps in the batch are found to comply with the compatibility provisions of points 2.1 and 2.2 of Annex III, applying state-of-the-art methods and criteria for assessing compatibility, including those set out in documents whose reference numbers have been published for that purpose in the Official Journal of the European Union, and*

(c) *testing of the parameters of the lamps in the batch listed in Table 9 shows no noncompliance for any of the parameters.*

Table 9

(...)

Otherwise, the model shall be considered not to comply.

The draft Regulation establishes a "minimum" sample size of "twenty lamps" of the same model from the same manufacturer, selected at random.

4.2 Lamp Tested for this Study

For one of the lamps tested, the team purchased twenty units from two different vendors. The team selected a low-voltage MR-16 halogen lamp due to the fact that this is a very popular lamp in Europe and can be commonly found in retail stores throughout the Member States. These lamps were manufactured by an ELC member company. Luminous flux and power measurements were made by SP Technical Research Institute, and the results are shown in the following table.

Table 4-1. EEI Values Measured for Sample of 20 Low-Voltage Halogen MR-16 Lamps

EEI Values for all 20 Lamps	
0.882	0.929
0.895	0.932
0.899	0.939
0.899	0.940
0.901	0.941
0.920	0.945
0.923	0.946
0.926	0.948
0.927	0.950
0.928	0.956

The lamps were found to have a mean EEI value of 0.926 and a standard deviation of 0.021. The minimum (0.882) and maximum (0.956) values were themselves 4.8% below the mean and 3.2% above the mean, respectively. The standard deviation for this sample represents 2.3% of the value of the mean.

In order to determine the sample size necessary for an accurate estimate, it is necessary to determine the maximum error of the estimate, the population standard deviation and the desired degree of confidence (e.g., 95%, 98%, 99%, etc.). If we assume that the test results from our sample of 20 lamps is representative of the population, we then say that the population average EEI is 0.926 and the population standard deviation is 0.021.

The formula for sample size is derived from the maximum error of estimate formula, solved for the sample size (n), which is given as:

$$n = \left(\frac{z_{\alpha/2}}{E} \times \sigma\right)^2$$

Where:

E	is the maximum error estimate
$z_{\alpha/2}$	represents the degree of confidence (confidence interval = 1 – α)
σ	is the standard deviation

In this calculation, we allow the maximum error estimate to vary from 0% to 2.5%. If we assume the degree of confidence is 99%, thus α = (1.00-0.99) = 0.01/2, therefore α/2 = 0.005 and $z_{\alpha/2} = 2.576$. Given these assumptions and the aforementioned equation, the following table can be calculated that shows the necessary sample sizes for having 99% confidence that the sample mean will have a maximum error (E) of the values shown. We have also added columns to show sample sizes necessary for a confidence interval of 98% and of 95%.

Table 4-2. Estimated Sample Size to Accurately Estimate the Population EEI

Case	Percent Deviation from Population Mean EEI	Sample Size (n) for a Confidence Interval of 99%	Sample Size (n) for a Confidence Interval of 98%	Sample Size (n) for a Confidence Interval of 95%
1	0.08%	5,979	4,875	3,462
2	0.15%	1,495	1,219	865
3	0.23%	664	542	385
4	0.30%	374	305	216
5	0.38%	239	195	138
6	0.45%	166	135	96
7	0.53%	122	99	71
8	0.60%	93	76	54
9	0.68%	74	60	43
10	0.76%	60	49	35
11	0.83%	49	40	29
12	0.91%	42	34	24
13	0.98%	35	29	20
14	1.06%	31	25	18
15	1.13%	27	22	15
16	1.21%	23	19	14

Case	Percent Deviation from Population Mean EEI	Sample Size (n) for a Confidence Interval of 99%	Sample Size (n) for a Confidence Interval of 98%	Sample Size (n) for a Confidence Interval of 95%
17	1.28%	21	17	12
18	1.36%	18	15	11
19	1.44%	17	14	10
20	1.51%	15	12	9
21	1.59%	14	11	8
22	1.66%	12	10	7
23	1.74%	11	9	7
24	1.81%	10	8	6
25	1.89%	10	8	6
26	1.97%	9	7	5
27	2.04%	8	7	5
28	2.12%	8	6	4
29	2.19%	7	6	4
30	2.27%	7	5	4

4.3 Discussion of Sample Size

The findings indicate that for this lamp type, it would be possible to use a smaller sample size such as n=15 or n=10 for measuring and calculating the EEI.

At a sample size of n=15, we could be 99% confident that the sample mean would not differ more than 1.51% from the true population mean. For this directional lamp, that represents at most a numeric deviation of 0.014 from the population mean of 0.926. This deviation is approximately half the level that was observed in the sample tested.

At a sample size of n=10, we could be 99% confident that the sample mean would not differ more than 1.81% different from the true population mean. For this directional lamp, that represents at most a numeric deviation of 0.0168 from the population mean. This deviation is still well within one standard deviation of the population, estimated at 0.021.

However, the results of this analysis cannot be used as a basis for determining the appropriate sample size for all directional lamps because the testing of the model tested does not represent an exhaustive review of the lamp types and performance characteristics that will be observed in the market. In particular, there are two areas where this sample may not provide a good representation of the normal unit-to-unit variation in lamp manufacturing: (1) mains voltage lamps and (2) blown-glass lamps. For mains voltage lamps, the filament is longer than the low voltage lamps, and therefore the optical performance may not be as consistent from one lamp to the next due to the challenges associated with manufacturing this lamp. For blown-glass lamps, the optical performance is not as precise as it is for heavier glass lamps that have their reflector and lens manufactured separately and later fused together to form the finished lamp.

Thus, while indications are that the sample size could reasonably be reduced for the measurement of EEI by market surveillance authorities, there is uncertainty around whether the same may be true for other lamp types that operate at different voltages or which have different construction techniques. The Commission may wish to work with the surveillance authorities who are sampling and testing larger quantities of directional lamp data and conduct a statistical analysis to ascertain whether the sample size requirement of n=20 can be reduced for EEI measurements.

Alternatively, the Commission may wish to suggest to market surveillance authorities that they can follow an approach similar to that used for washing machines. The surveillance authorities could start by purchasing a smaller sample of lamps (e.g., n=5) for initial screening testing and through these tests, calculate sample mean EEI values and compare them to the regulations. If a lamp is found to be in violation of the ecodesign or energy labelling Regulation, additional lamps would be purchased and tested such that the sample size totals 20 lamps. In this way, the market surveillance authorities would be able to maximise the market coverage of their testing budgets and laboratory capacity, and only conduct full sample testing on certain lamps where the initial screening tests indicated they may be problematic.

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Annex A. UBA Calculation Method

This Annex was written by Christoph Mordziol to provide an explanation for the differences observed between the UBA calculated data for certain lamps and the test results provided by SP Technical Research Institute. In particular, this Annex focuses on some lamps that were common to both the calculated data set (i.e., a manufacturer had posted the photometric profile of that particular lamp) and the test dataset.

As discussed in Chapter 1 of this report, ELC presented a database listing ranges of the EEI for a number of directional lamps. Separately, Germany submitted a comment to the Commission which also provided a range of EEI values which had lower (i.e., more energy-efficient) values for some of the lamp groups. The figure below shows a comparison of the two ranges.

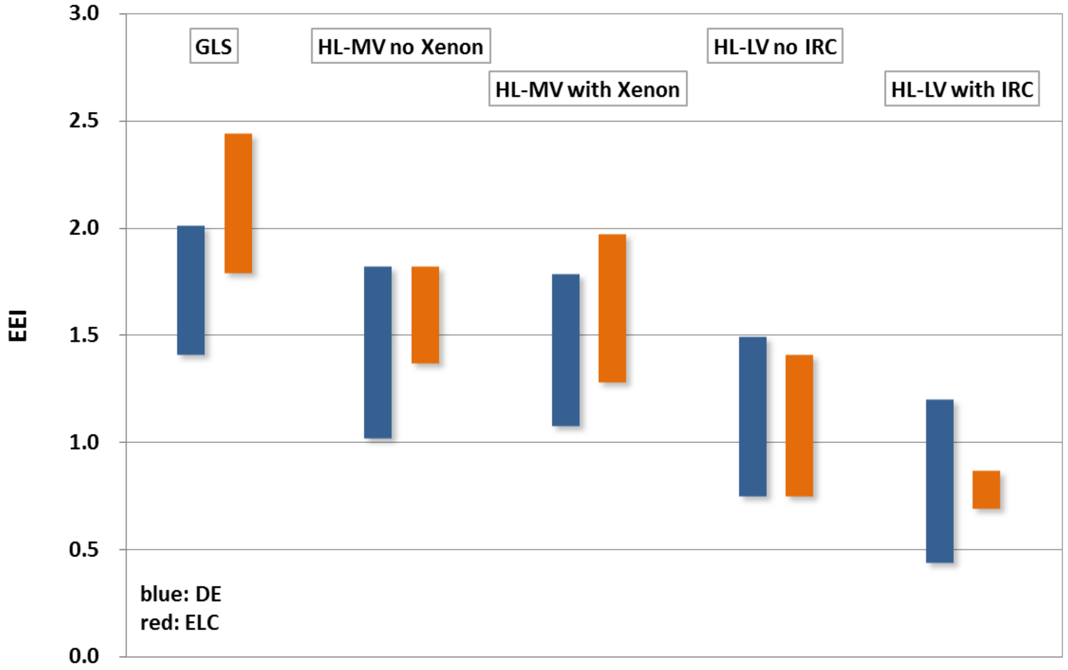


Figure A-1. EEI ranges of data from ELC and UBA, July 2011

The provided in the German comment were developed by the Umweltbundesamt (UBA, Federal Environment Agency, Germany) based on two sources:

- Values of luminous flux, determined by a laboratory for the consortium which had done the preparatory study[7] 19-1 (i. a. 111 data sets for incandescent lamps) and
- Values of luminous flux, calculated by UBA on base of photometric data, published on the Internet[8] (i. a. 65 data sets for filament lamps). Most of these data are published by manufacturers.

Due to the difference between the two datasets, the question arose as to whether the calculation method used by UBA was reliable.

[7] "Preparatory Studies for Eco-design Requirements of EuPs, Final report: Lot 19: Domestic lighting", prepared by VITO, BIO Intelligence Service, Energy Piano and Kreios, October 2009."

[8] This data can be found as "ies" or "ldt" (Eulumdat) files in most cases. Normally they are published to provide lighting designers with data which they need to create lighting designs and run their lighting simulation models.

A.1 Testing the UBA Calculation Method

Efficacy refers to the power of a lamp (at the mains) and the luminous flux[9] (unit lumen, lm) of the lamp. The reflector lamps requirements proposed by the Commission refer to the luminous flux of the lamp within a certain beam angle[10], i.e., 90°, for filament reflector lamps. The luminous flux of a lamp within a certain beam angle generally not measured directly. Instead, laboratories normally measure the luminous intensity[11] in candelas (cd) and use these measurements to calculate luminous flux. This calculation is normally performed by the software integrated into measurement equipment or through the use of a spreadsheet program or software such as *photometric viewer*[12].

Determining luminous flux in this way needs a number of luminous intensity values. These values are measured for a number of angular positions on. These angular positions can be described by values of C-planes and γ-angles. The figure below shows some of these planes and angles. For some additional detail on these measurements, please see Annex B.

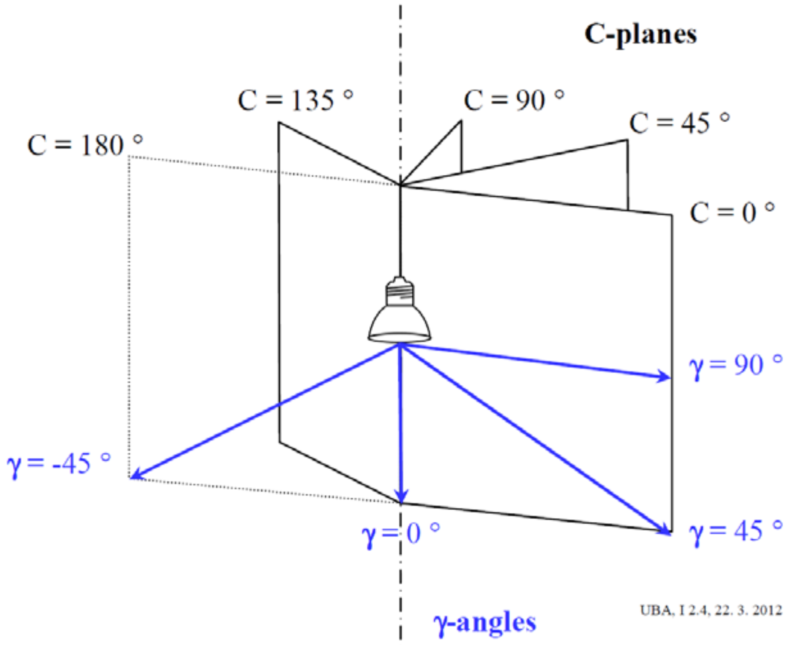


Figure A-2. An Illustration of Selected C-planes and Gamma (γ) Angles [13]

Source: UBA, derived from DIN EN 13032-3

Thus lighting laboratories measure luminous intensity and then integrate over those measurements to calculate the luminous flux. The Swedish laboratory that conducted the testing for CLASP/STEM measured the luminous intensity for a batch of over 100 lamps. During measurement the increment of γ-angles was 0.5 °. However, to be consistent with the test methodology that was requested by

[9] While radiant flux is the measure of the total power of light emitted, the luminous flux or luminous power (German: *Lichtstrom* French: *flux lumineux*, Polish: *strumień świetlny*) is the measure of the perceived power of light. The luminous flux is derived from radiant flux by weighting the power at each wavelength with the varying sensitivity of the human eye to different wavelengths of light.

[10] German: *Kegelwinkel*

[11] The luminous intensity (German: *Lichtstärke* French: *intensité lumineuse*, Polish: *światłość*) is the luminous flux per solid angle (German: *Raumwinkel* French: *angle solide*, Polish: *kąt bryłowy*).

[12] http://www.photometricviewer.com/

[13] A γ-angle of 45 ° stands for a cone angle of 90 °.

ELC (see Section 2.2 of this report), the calculation of luminous flux was based on a larger gamma angle increment. In order to compare the UBA calculation methodology with the SP Technical Research Institute test method, the raw (luminous intensity) measurement data from SP at the small gamma angle increments (0.5) were provided to UBA. UBA used the same γ-angle increment as SP Technical Research Institute has used for calculation, and UBA calculation method[14] was applied to for each of the lamps resulting in a calculated luminous flux values within a 90 degree cone. Upon comparing these results with those from SP Technical Research Institute, it was confirmed that the UBA calculation method is correct.

A.2 Checking the UBA Dataset

The SP Technical Research Institute had measured with an γ-angle increment of 0.5 °, and the data used by UBA has a range of γ-angles, in increments from 1° up to 10°. That leads to the next question – 'what influence does the γ-angle increment have on efficiency values?' The figure below shows the deviation of luminous intensity values for differing γ-angle increments. This example is for a lamp with a narrow beam angle (18.5°).

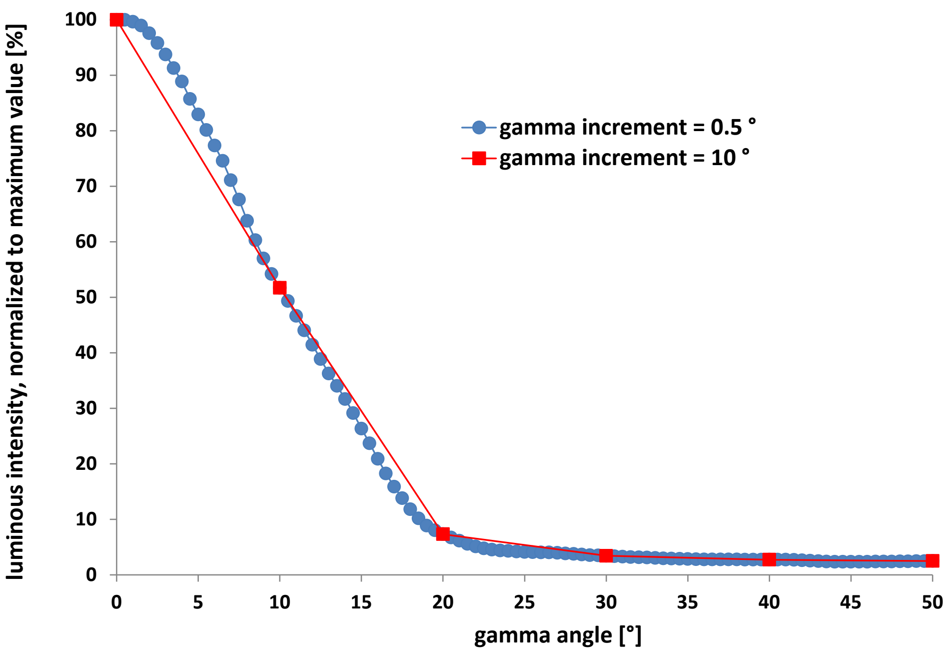


Figure A-3. Luminous Intensity Deviation for Different Gamma Angle Increments
Source: UBA

In order to determine the influence of the γ-angle increment, raw data from SP Technical Research Institute (luminous intensity) was used. For each of the lamps, the UBA calculation method was applied with different γ-angle increments 0.5, 1.0, 2.5, 5 and 10 ° and luminous flux was calculated. In order to use the 10 °-steps too, the calculation has been done up to gamma angle of 50 ° instead of 45 ° as before, i.e. luminous flux within a cone angle of 100 °. The results for a γ-angle increment

[14] The calculation method used by UBA is derived from them method describes by Olino (Netherlands) with a modification concerning averaging values of luminous intensity within the area of a spherical zone (German: *Kugelzone*;) UBA takes the arithmetic average The Olino-method is described at http://www.olino.org/us/articles/2008/09/29/background-light-measurements#l_v_2_PHI.

of 0.5 ° were also taken as reference (the smallest gamma angle increment). The following table presents the results.

Table A-1. Difference in Luminous Flux within a Cone Angle of 100

γ-angle Increment	Luminous Flux Difference		
	Minimum	Average	Maximum
1.0 °	0.0%	0.06%	0.2%
2.5 °	0.0%	0.46%	1.5%
5.0 °	0.4%	1.9%	6.5%
10.0 °	1.6%	7.5%	25.8%

A closer look on these results shows that the difference is increasing with smaller beam angle, thus we can conclude that the accuracy of the calculation method decreases with higher γ-angle increment and smaller beam angles.

Due to the fact that some of the input data used by UBA for calculating the EEI was too coarse (i.e., the gamma angle increments were too large) a number of photometric data sets had to be excluded from the analysis. Due to the removal of these data, the efficiency ranges become less broad – however, for most lamp groups, UBA data sets still showed better EEI values than ELC.

UBA considered whether there are other reasons to exclude lamp datasets. Some data sets used for calculation do not come from manufacturers or from the measurements made for the preparatory study. There were not very many of these datasets, but they were excluded anyway to eliminate any doubt in the quality of the input data. Excluding these data sets did not change efficiency ranges.

After making these adjustments to the UBA database, the resulting EEI ranges were as shown in the table below.

Table A-2. Comparison of EEI Ranges in the UBA Dataset

Lamp Type	UBA Dataset, July 2011		UBA Dataset with Adjustments	
	Worst EEI	Best EEI	Worst EEI	Best EEI
Incandescent (GLS)	2.00	1.40	1.87	1.41
HL-MV without Xenon	1.82	1.00	1.82	1.02
HL-MV with Xenon	1.77	1.08	1.68	1.36
HL-LV without IRC	1.50	0.75	1.34	0.79
HL-LV with IRC	1.20	0.42	0.93	0.47

There were six lamps that were in the batch tested by SP Technical Research Institute and also appear in the UBA database. This raises the question as to whether there is a difference between the efficacy value calculated for a particular lamp (based on candela values measured by SP Technical Research Institute) and calculated by UBA on the basis of candela values published by manufacturers.

It was found that for one lamp, SP Technical Research Institute calculated a higher luminous flux than UBA, by 6 percent. For the other five lamps, UBA's calculation method resulted in a higher luminous flux, with differences compared to the SP Technical Research Institute test data of between 4 and 51 percent. As an example, the figure below shows the luminous intensity versus gamma (γ)-angle plot for a lamp where the photometric data and the measured luminous intensity data resulted in a difference of about 48 %. The figure shows lamps that had been tested by SP Technical Research Institute (blue curve as average for three lamps and different C-Planes) and for which values of luminous intensity have been published by the lamp's manufacturer (red curve).

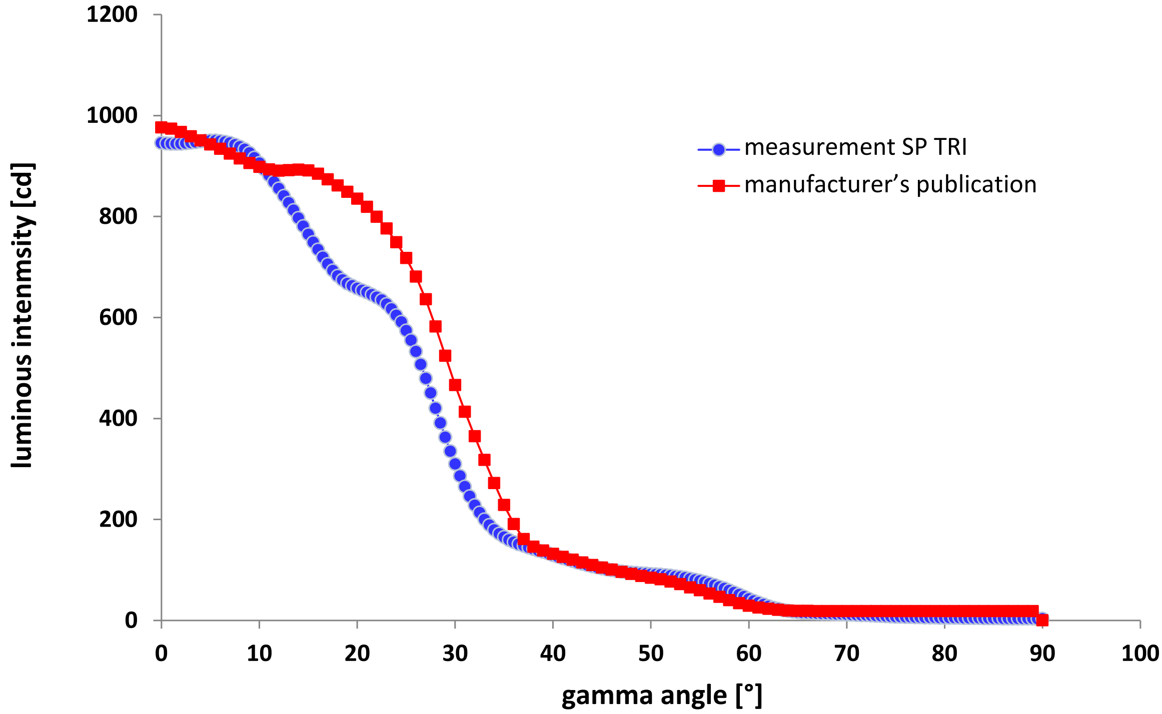


Figure A-4. Luminous Intensity Comparison between Published and Test Data for the Same Lamp

The figure above shows that the luminous intensity following photometric data published by the manufacturer is significantly different from the average measured for three lamps of the same model by SP Technical Research Institute.

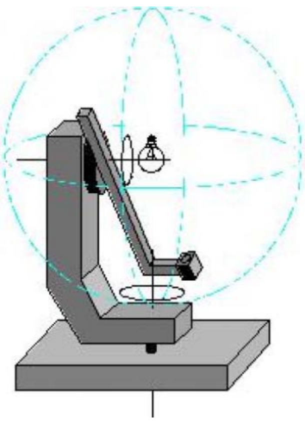
UBA contacted one of the manufacturers who had published the luminous intensity data for one of their lamps which had a very low (i.e., highly efficacious) EEI value. This lamp was calculated to have an EEI of 0.47 in the low-voltage halogen IRC lamps. The manufacturer responded by saying that he believed the information about the lamp must have been incorrectly entered, as the luminous flux was much too high for a 35 watt lamp, and that must be a 50 watt lamp. UBA adjusted its calculation for this lamp and now has a minimum EEI for low-voltage halogen IRC of 0.67, which is very close to the values for ELC (0.69) and CLASP/STEM (0.669).

Annex B: Methods of measuring luminous flux

The following text has been taken from "Task 1. International Directional Lamp Regulatory Review – A report prepared in support of the European Commission's work evaluating Directional Lamps under the Energy Using Products Directive"; A report prepared for Defra, eceee and STEM by Navigant Consulting Europe, Ltd.; May 2010[15].

Goniophotometer

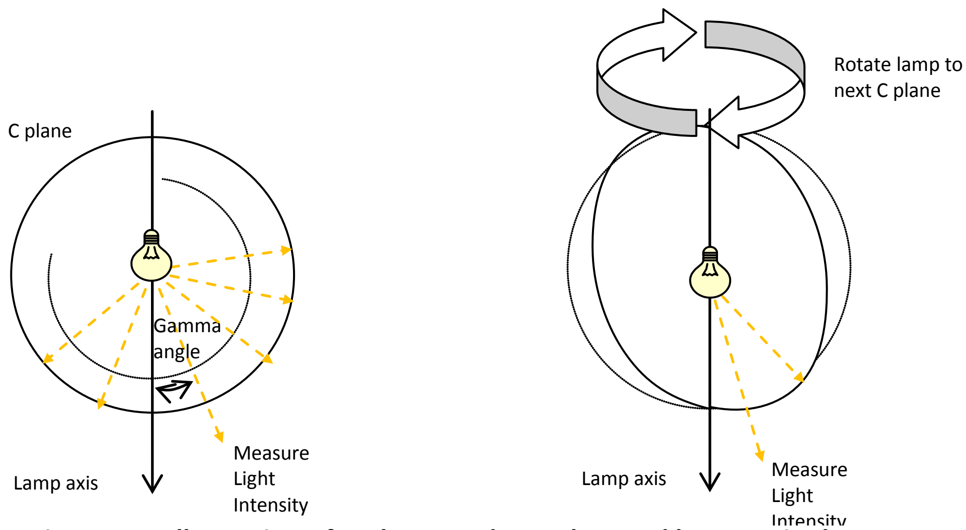
The most precise way of measuring the light output of a directional lamp is through the use of a goniophotometer, pictured on the right. A goniophotometer is a device that measures the spatial distribution patterns of the intensity of a light source and displays the photometric properties of visible light to the human eye in relation to defined angular positions. Through the rotation of the light sensor (or a mirror directed to a sensor) and the rotation of the lamp under test, measurements can be gathered in all directions from an operating lamp. These measurements can then be integrated to accurately determine the light output from the lamp under test.



Source: National Physical Laboratory, UK. 2010

There are three angular systems used when conducting measurements with a goniophotometer: the A-Alpha, the B-Beta and the C-Gamma systems. The A-Alpha system is used for automobile headlights; the B-beta system is often used for floodlights and roadway lighting; and the C-Gamma system is the most commonly used system, applied to measurements of both lamps and luminaires. Conversion between these three systems is a simple matter of geometry and interpolation of data.

Focusing on the C-Gamma system, there are two variables that must be defined when taking a measurement – the number of C-planes and Gamma (γ) angles. The C-plane represents the plane in azimuth, around which the γ-angles describe points where readings are taken. The lamp is located in the centre of the C-plane and the γ-angles are measured from the optical axis (nadir).



Source: Steven Coyne, Australia. 2010

Figure B-1. Illustration of C-planes and γ-angles used by a Goniophotometer

[15] http://efficient-products.defra.gov.uk/assets/Uploads/Defra-Report-Directional-Lamps-Task-1-v.10a.pdf

A highly accurate lamp measurement may involve twelve C-planes (each 15° apart) and with measurements taken at one degree γ-angles, ranging from zero through to 360° on that plane. A more common measurement may involve four C-planes (each 45° apart), with measurements taken at every γ-angle.

With an adequate number of C-planes and γ-angles, goniophotometric measurement is considered the most accurate means of quantifying light output from a test lamp. However, it is time consuming in the setup, measurement and data analysis/reporting, which can make it expensive for manufacturers and regulating authorities when a large number of samples from a particular model must be tested for statistical robustness.

Annex C: Measured Luminous Flux from the Lamps Tested

The following are the test data for each of the lamps tested. This is provided to illustrate the variance that was observed in the small samples (n=3) of each lamp model tested.

The table below presents the test results for all of the lamps from SP Technical Research Institute. The explanations of the table headings are provided here:

Lamp: number of the lamp in testing
Flux: calculated luminous flux from SP Technical Research Institute using ELC Test Method
Volt: measured voltage at the time of test measurement
Current: measured wattage at the time of test measurement
Watts: calculated resultant wattage for each lamp
Base: base type for the lamp
Corr1: Correction factor for voltage, 1.06 for 12 V, 1.00 for mains voltage
Corr2: Correction factor for anti-glare end-cap, 0.80 for lamps with the end-cap
EEI: calculated energy efficiency index, including correction factors

Table C-1. Test Results for the Halogen Directional Lamps Tested by SP Technical Research Institute

Lamp	Flux (lm)	Volt	Current	Watts	Base	Corr1	Corr2	EEI
1	482	11.986	2.9347	35.2	GU5.3	1.06	1.00	0.869
2	452	11.998	2.9142	35.0	GU5.3	1.06	1.00	0.907
3	475	11.998	2.9376	35.2	GU5.3	1.06	1.00	0.880
4	259	240.231	0.1508	36.2	GU10	1.00	1.00	1.348
5	253	240.209	0.1504	36.1	GU10	1.00	1.00	1.367
6	257	240.254	0.1510	36.3	GU10	1.00	1.00	1.358
7a	459	12.010	4.2527	51.1	G53	1.06	0.80	1.047
8a	460	12.001	4.1623	50.0	G53	1.06	0.80	1.023
9	400	240.214	0.2161	51.9	E27	1.00	1.00	1.396
10	391	240.259	0.2183	52.4	E27	1.00	1.00	1.433
11	388	240.306	0.2164	52.0	E27	1.00	1.00	1.430
12	427	12.005	2.9144	35.0	GU5.3	1.06	1.00	0.948
13	466	11.998	2.9542	35.4	GU5.3	1.06	1.00	0.899
14	428	12.010	2.9123	35.0	GU5.3	1.06	1.00	0.946
15	468	12.006	2.9633	35.6	GU5.3	1.06	1.00	0.899
16	427	12.003	2.9207	35.1	GU5.3	1.06	1.00	0.950
17	441	12.011	2.9236	35.1	GU5.3	1.06	1.00	0.928
18	433	12.009	2.9137	35.0	GU5.3	1.06	1.00	0.939
19	442	12.007	2.9378	35.3	GU5.3	1.06	1.00	0.932
20	443	12.011	2.9291	35.2	GU5.3	1.06	1.00	0.927
21	469	11.987	2.9602	35.5	GU5.3	1.06	1.00	0.895
22	449	12.013	2.9351	35.3	GU5.3	1.06	1.00	0.920
23	424	12.006	2.9208	35.1	GU5.3	1.06	1.00	0.956
24	479	12.001	2.9617	35.5	GU5.3	1.06	1.00	0.882

Lamp	Flux (lm)	Volt	Current	Watts	Base	Corr1	Corr2	EEI
25	442	12.010	2.9318	35.2	GU5.3	1.06	1.00	0.929
26	430	12.011	2.9185	35.1	GU5.3	1.06	1.00	0.945
27	464	12.003	2.9501	35.4	GU5.3	1.06	1.00	0.901
28	444	12.017	2.9293	35.2	GU5.3	1.06	1.00	0.926
29	451	12.002	2.9580	35.5	GU5.3	1.06	1.00	0.923
30	433	12.011	2.9231	35.1	GU5.3	1.06	1.00	0.941
31	Failed							
32	251	239.917	0.1534	36.8	GU10	1.00	1.00	1.403
33	246	239.917	0.1521	36.5	GU10	1.00	1.00	1.412
34	261	239.901	0.1491	35.8	GU10	1.00	1.00	1.324
35	689	11.983	3.0375	36.4	GU5.3	1.06	1.00	0.679
36	717	11.991	3.0302	36.3	GU5.3	1.06	1.00	0.656
37	704	11.990	3.0563	36.6	GU5.3	1.06	1.00	0.671
38a	843	11.999	5.1095	61.3	G53	1.06	0.80	0.777
39	183	11.996	1.6762	20.1	GU5.3	1.06	1.00	1.022
40	191	11.991	1.6772	20.1	GU5.3	1.06	1.00	0.991
41	203	11.994	1.7084	20.5	GU5.3	1.06	1.00	0.965
42	208	239.910	0.1446	34.7	GU10	1.00	1.00	1.515
43	204	239.922	0.1440	34.5	GU10	1.00	1.00	1.533
44	198	239.932	0.1449	34.8	GU10	1.00	1.00	1.576
45	148	239.992	0.1234	29.6	E27	1.00	1.00	1.651
46	140	239.837	0.1226	29.4	E27	1.00	1.00	1.700
47	156	239.888	0.1236	29.6	E27	1.00	1.00	1.588
48	358	229.937	0.2169	49.9	E27	1.00	1.00	1.460
49	369	229.793	0.2204	50.6	E27	1.00	1.00	1.448
50	385	229.945	0.2188	50.3	E27	1.00	1.00	1.393
51	696	229.721	0.3410	78.3	E27	1.00	1.00	1.367
52	704	229.868	0.3419	78.6	E27	1.00	1.00	1.358
53	663	229.859	0.3403	78.2	E27	1.00	1.00	1.419
54	657	12.019	2.9283	35.2	GU5.3	1.06	1.00	0.682
55	646	12.024	2.9292	35.2	GU5.3	1.06	1.00	0.691
56	645	12.023	2.9472	35.4	GU5.3	1.06	1.00	0.696
57	451	12.014	2.9633	35.6	GU5.3	1.06	1.00	0.926
58	440	12.013	2.9371	35.3	GU5.3	1.06	1.00	0.935
59	449	12.018	2.9372	35.3	GU5.3	1.06	1.00	0.921
60	757	229.780	0.3311	76.1	E27	1.00	1.00	1.242
61	750	229.747	0.3288	75.5	E27	1.00	1.00	1.242
62	688	229.748	0.3322	76.3	E27	1.00	1.00	1.343
63	143	229.809	0.1250	28.7	E14	1.00	1.00	1.642

Lamp	Flux (lm)	Volt	Current	Watts	Base	Corr1	Corr2	EEI
64	140	229.796	0.1254	28.8	E14	1.00	1.00	1.672
65	143	229.804	0.1269	29.1	E14	1.00	1.00	1.663
66	620	11.986	3.0805	36.9	GU5.3	1.06	1.00	0.748
67	637	11.991	3.0617	36.7	GU5.3	1.06	1.00	0.728
68	641	11.995	3.0467	36.5	GU5.3	1.06	1.00	0.722
69	271	229.858	0.1742	40.0	GU10	1.00	1.00	1.443
70	273	229.911	0.1747	40.2	GU10	1.00	1.00	1.440
71	274	229.886	0.1759	40.4	GU10	1.00	1.00	1.445
72	214	229.770	0.1908	43.8	E27	1.00	1.00	1.877
73	226	229.772	0.1909	43.8	E27	1.00	1.00	1.805
74	456	240.227	0.3314	79.6	E27	1.00	1.00	1.934
75	426	240.163	0.3308	79.4	E27	1.00	1.00	2.036
76	470	240.248	0.3373	81.0	E27	1.00	1.00	1.924
77	893	240.141	0.5071	121.8	E27	1.00	1.00	1.738
78	818	240.175	0.5124	123.1	E27	1.00	1.00	1.885
79	713	240.205	0.5005	120.2	E27	1.00	1.00	2.058
80a	393	12.001	4.2143	50.6	Ba15d	1.06	0.80	1.170
81	422	240.130	0.2135	51.3	GU10	1.00	1.00	1.324
82	413	240.134	0.2147	51.5	GU10	1.00	1.00	1.352
83	418	240.130	0.2122	51.0	GU10	1.00	1.00	1.324
84	435	12.015	2.9304	35.2	GU5.3	1.06	1.00	0.940
85	478	11.999	3.3395	40.1	GU5.3	1.06	1.00	0.996
86	499	12.001	3.3258	39.9	GU5.3	1.06	1.00	0.959
87	481	12.006	3.3340	40.0	GU5.3	1.06	1.00	0.989
88	255	240.145	0.1950	46.8	E27	1.00	1.00	1.762
89	278	229.784	0.1875	43.1	E14	1.00	1.00	1.522
90	265	229.791	0.1851	42.5	E14	1.00	1.00	1.558
91	271	229.798	0.1856	42.6	E14	1.00	1.00	1.535
92	521	12.024	3.2631	39.2	GU5.3	1.06	1.00	0.911
93	541	12.017	3.2979	39.6	GU5.3	1.06	1.00	0.894
94	504	12.035	3.2384	39.0	GU5.3	1.06	1.00	0.930
95	269	229.803	0.1731	39.8	GU10	1.00	1.00	1.441
96	266	229.809	0.1722	39.6	GU10	1.00	1.00	1.445
97	279	229.802	0.1746	40.1	GU10	1.00	1.00	1.415
98	669	12.009	4.1686	50.1	GU5.3	1.06	1.00	0.955
99	695	12.021	4.1673	50.1	GU5.3	1.06	1.00	0.927
100	688	12.019	4.1637	50.0	GU5.3	1.06	1.00	0.934
101	172	229.875	0.1239	28.5	GU10	1.00	1.00	1.429
102	173	229.879	0.1249	28.7	GU10	1.00	1.00	1.434

Lamp	Flux (lm)	Volt	Current	Watts	Base	Corr1	Corr2	EEI
103	168	229.849	0.1249	28.7	GU10	1.00	1.00	1.458
104	331	240.144	0.1899	45.6	E27	1.00	1.00	1.415
105	326	240.143	0.1908	45.8	E27	1.00	1.00	1.436
106	224	240.198	0.1309	31.4	GU10	1.00	1.00	1.300
107	223	240.191	0.1359	32.6	GU10	1.00	1.00	1.355
108	214	240.187	0.1320	31.7	GU10	1.00	1.00	1.355
109	428	12.022	2.9141	35.0	GU5.3	1.06	1.00	0.947
110	410	12.016	2.9514	35.5	GU5.3	1.06	1.00	0.992
111	402	12.004	2.9804	35.8	GU5.3	1.06	1.00	1.015