TESTING FOR QUALITY

Benchmarking Energy-Saving Lamps in Asia

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ACRONYMS

ALC	Asia Lighting Compact
APP	Asia-Pacific Partnership on Clean Development and Climate
ASEAN	Association of Southeast Asian Nations
AS/NZS	Australian/New Zealand Standard
BIS	Bureau of Indian Standards
CCT	correlated color temperature
CFL	compact fluorescent lamp
CISPR	Comité International Spécial des Perturbations Radioélectriques
CRI	color rendering index
DEWHA	Department of Environment, Water, Heritage, and the Arts (Australia)
EC	European Commission
ECO-Asia	Environmental Cooperation-Asia
ELI	Efficient Lighting Initiative
EMC	electromagnetic compatibility
ERDA	Electrical Research and Development Association (India)
EST	Energy Saving Trust (UK)
GEF	Global Environment Facility
GLS	general lighting service
HPF	high power factor
hrs	hours
IEC	International Electrotechnical Commission
lm	lumen
mg	milligram
NGO	non-governmental organization
NLTC	National Lighting Test Center (China)
NPL	National Physical Laboratory (India)
NSW	New South Wales (Australia)
RDMA USAID	Regional Development Mission for Asia
SDCM	Standard Deviation of Color Matching
THD	total harmonic distortion
UK	United Kingdom
US	United States
USAID	United States Agency for International Development
W	watt
WEEE	Waste Electrical and Electronic Equipment

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EXECUTIVE SUMMARY

OVERVIEW

National and local efforts to promote lighting energy efficiency have been gathering strength in Asia. Many of these programs feature the compact fluorescent lamp (CFL), as adoption of CFLs is one of the quickest and easiest means of delivering energy conservation in the residential and commercial sectors. More than forty countries, many of them in Asia, have announced plans to phase out the use of incandescent lamps as part of their efforts to address climate change, with the CFL being promoted as a replacement.[1]

The increasing focus on CFLs has significantly accelerated the global demand for the lamps. Worldwide CFL production has increased six-fold in the last decade, from 500 million lamps in 2000 to more than 3 billion lamps in 2008.[2] This is expected to accelerate, as the phaseout of incandescent lamps could boost demand of CFLs to as many as 10 billion units per year.[3]

Countries in Asia face serious challenges when it comes to adoption of CFLs, including purchase cost, sub-standard quality, a lack of common standards for CFLs, and a lack of consumer awareness about CFL quality. In addition, although CFLs are being sold across Asia, the lack of a common standard makes it difficult for data sharing across the region, or establishment of a regional testing program. Since CFLs are being promoted as a direct replacement for incandescent lamps, CFLs that do not outperform incandescent lamps can result in serious consumer dissatisfaction with the product category as a whole. Thus, the terms "low-quality," "lower-quality," "sub-standard," "poor," or "shoddy" are now being used by experts, program managers, and regulators to describe the poor-performing CFLs that are being produced in large quantities and sold in many markets in the Asia region.

PURPOSE AND SCOPE OF THIS REPORT

In order to assess and address these CFL product quality and standards harmonization issues, the ECO-Asia Clean Development and Climate Program (ECO-Asia) partnered with the Australian Department of Environment, Water, Heritage and the Arts (DEWHA) in 2008 under the aegis of the Asia-Pacific Partnership on Clean Development and Climate (APP) to initiate a substantial regional CFL quality and performance benchmark testing program. The primary objectives of this CFL benchmark testing program were:

- To assess the overall quality of CFLs currently being sold in various Asian markets.
- To assess the opportunities for harmonization of CFL standards based on test results.
- To gain insight into the possibility of implementing a regional product testing program and its complexity.
- To make a first-order examination of lamp mercury content.

THE TEST PROCESS AND RESULTS

Sample CFLs were purchased from stores in six countries – Australia, India, Indonesia, the Philippines, Thailand, and Vietnam. Australian lamps were purchased by DEWHA staff, and lamps in India, Indonesia, Philippines, Thailand, and Vietnam were purchased by ECO-Asia staff using a common, consistent procurement methodology. Overall, more than 2,600 samples were collected representing 160 models (the performance results below represent results from 137 models).[4] The results presented focus

1. *Phasing in Quality: Harmonization of CFLs to Help Asia Address Climate Change*. USAID Asia, March 2009.
2. Chen, Yansheng. China Association of Lighting Industry, 2008.
3. *Global Lighting: Phase Out of Incandescent Lamps.* Project Identification Form under the GEF Trust Fund for the Global Environment Facility. July 2007.
4. Additional and supplementary analyses on the test data have been carried out by DEWHA. The methodology and results from these further investigations are available online, and will be available as DEWHA reports separately in 2010.
5. Tested in accordance with *IEC 60969 Ed. 1.3 b:2009. Self-ballasted lamps for general lighting services – Performance requirements.*

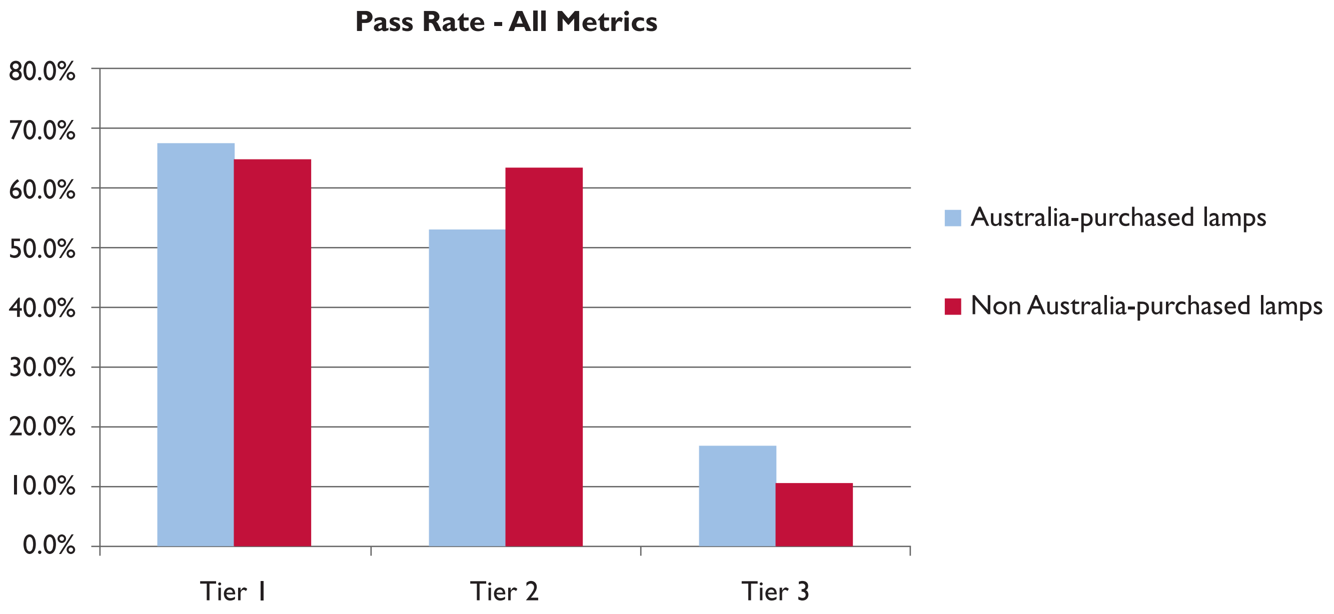
on the following five metrics:[5]

- Efficacy
- Survival Rate
- Lumen Maintenance
- Power factor
- Color Rendering Index (CRI)

Along with the discussion of the numerical results of these five key metrics, these results were compared to the three quality tiers of the Asia Lighting Compact:[6] Tier I, which is equivalent to China's minimum performance standards and represents "good" quality; Tier 2, which is harmonized with the standard of the Efficient Lighting Initiative (ELI) and represents "better" quality; and Tier 3, which is equivalent to the quality standard for European lamps, the United Kingdom's Energy Saving Trust and represents "the best" quality. **Figure 1** shows that only two of three lamps tested (66%) can meet the Tier 1 standard, and just 58% of lamps meet the Tier 2 standard.

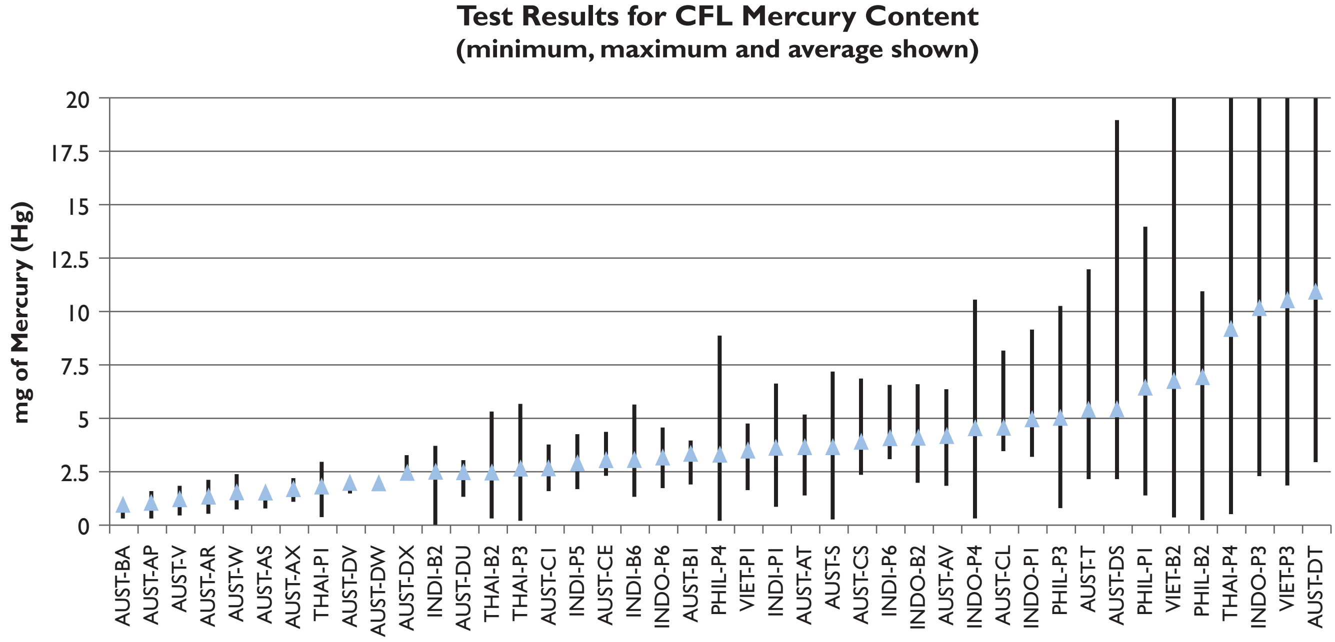
A subset of the lamp models was tested for their mercury content, and the results from a total of 43 randomly selected models from the six countries are presented below in **Figure 2.** The results showed that at least 25% of the lamps have average mercury content of more than 5 mg, and lamps with higher average mercury content are present in all markets.[7] Furthermore, when the mercury content of lamps is considered against the lamp costs, some of the lower-priced lamps also have much higher mercury content relative to lamps with higher costs or from more well-known manufacturers.

Figure 1. Overall CFL Performance Versus Established Quality Standards.



6. The Asia Lighting Compact (ALC) is a non-profit public-private partnership that works to improve the quality of lighting products and encourage the adoption of energy-efficient lighting in Asia. The ALC was formed in October 2009 with members including national lighting associations in Asia, international lighting manufacturers, and government agencies.
7. 5 mg is the maximum level being set for the US and European markets by various organizations.

Figure 2. **CFL Mercury Content Test Results**



CONCLUSIONS AND RECOMMENDATIONS

The following are some of the main conclusions that can be drawn from the results of this benchmark testing effort:

- At least one-third of the sample failed to meet what may be considered as minimum performance standards (or the criteria for what may be considered a "quality" lamp) for the region.[8]
- The overall failure rate is likely to be significantly higher than presented here due to limitations in laboratory testing, and that only a subset of all required metrics defining a quality CFL was evaluated.
- At least 90% of tested products do not meet the requirements for ALC Tier 3, or European equivalent standards.
- Name-brand models generally performed better than low-priced models in most cases against most metrics. Exceptions to this rule were noted.

With the formation of the Asia Lighting Compact (ALC) and the release of the ALC's CFL Quality Guidelines, which present a comprehensive set of CFL quality criteria developed based upon internationally accepted standards, there is now a set of quality standards that could be recognized and applied across the region.

The ALC along with other actors in Asia can and need to work together, in order to scale up the discussions of CFL promotion to the international level and to forge an agreement on common solutions, before a combination of policy missteps and consumer backlash limit the potential expansion of the regional and global CFL market. In addition, regional measures specific to CFL testing and market monitoring are presented below.

8. Note: "Failure" as used in this context, indicates that the average of results from the tested samples of a particular CFL model does not meet a defined performance level (i.e., for efficacy, power factor or CRI), rather than a physical or mechanical failure that renders the lamp inoperative. This applies to all parameters evaluated except for the survivability test results, which indicate actual lamp failures.

- A regional agreement on a common test procedure, a data-sharing plan, and ways to mutually recognize test results across nations is urgently needed among standards and enforcement agencies.

- There is a pressing need for a uniform, recurring, regional, process to test and assure the quality of CFLs sold in the region. Such regular efforts can serve to inform policy makers on the state of the market, and also to insure the integrity of programs to promote CFLs.

- Government agencies, the private sector (including manufacturers and retailers of CFLs), and non-governmental organizations (NGOs) in the region should take concrete actions to increase user awareness of high-quality CFL products and ways to identify them, and support independent actions such as the ALC to ensure quality products are available for all of Asia.

- A number of countries in the region need technical assistance in setting up the infrastructure (testing facility, development of standards, training of laboratory personnel, etc.) to certify the performance of CFLs to a common, regional level, as well as in recycling CFLs and dealing with end-of-life issues, including mercury content and safe lamp disposal.[9]

- More testing is recommended to corroborate these initial findings. This would be particularly useful in CFL models intended for the very large and quickly growing Chinese market. Regulators and program managers would be well-served by an on-going, regular, regional testing regime.

- As about half of the lamp models tested have at least one or more samples with more than 5 mg of mercury. The issue of mercury content and dosing control in lamps as well as test methodologies, merit a second, focused round of testing efforts that can cover more of the regional markets, and may also help to inform mercury recycling and educational programs.

- The value of a robust, harmonized set of quality standards for the region cannot be understated. With such a mechanism, well-performing products could be identified independently, allowing purchasers to select products based on value (price) while being assured of at least a minimum level of performance.

9. One example of this technical assistance is the need for facilities to conduct CRI testing of lamps in India.

OVERVIEW: THE CFL MARKET IN ASIA

BACKGROUND

National and local efforts to promote energy efficiency have been gathering strength world-wide, spurred by heightened concerns over issues of energy security, environmental degradation, and climate change. Many of these efficiency efforts include programs targeting lighting, as it accounts for about one-fifth of global electricity consumption.[10] To date, more than forty countries, including many Asian countries, have announced plans to phase out the use of incandescent lamps, with the compact fluorescent lamp (CFL) being promoted as a direct, readily available, and cost effective alternative.[11]

The increasing focus on CFLs has significantly accelerated the global demand for these lamps. The most dramatic increase happened within the past decade: annual global CFL production is estimated to have reached one billion units per year just over five years ago, and now exceeds three billion units annually. If current growth trends continue, global CFL production could exceed four billion units annually by 2010. This is expected to accelerate, as the phaseout of incandescent lamps could boost demand of CFLs to as many as 10 billion units per year.

During the early stages of CFL production, manufacturing was dominated by a few well-known international brands and production was based in Europe, the US, Japan, and China. Presently, the production of CFLs is being carried out mostly by a large group of less well-known manufacturers throughout Asia. China currently leads the world in the number of CFL manufacturers and CFL production (**Figure 3**): there are at least 200 CFL manufacturers and 400 suppliers of specialized CFL materials and components; more than 90 percent of the CFLs sold worldwide are manufactured in China.[12]

CFL ADOPTION IN ASIA AND THE ISSUE OF QUALITY

As a whole, countries in Asia face a number of serious challenges when it comes to adoption of CFLs. Purchase cost can be a formidable barrier. Although it represents one of the quickest and easiest means of delivering energy conservation, a CFL can present an economic challenge to the average Asian consumer. Compared to an incandescent lamp, a CFL typically carries a 10 to 15 times price premium, putting it in line with some families' daily income, and placing it out of reach for many parts of Asia.

Suspect product quality is another challenge to CFL adoption, especially given its price premium. Since CFLs are being promoted as a direct replacement for incandescent lamps, CFLs that do not outperform incandescent lamps can result in serious consumer dissatisfaction with the product category as a whole.

Unfortunately, for Asia, there is no widely used regional or international standard for CFL quality and performance, nor are there widely and publically available lamp test data. While there have been a number of product testing efforts in place or on-going, the lack of regionally accepted standards and data exchange mechanisms have made it difficult for countries to recognize and share test results.[13] Therefore, CFLs typically have been assessed in relation to national standards and guidelines or to manufacturers' advertised claims. Generally speaking, a poor-quality CFL is a lamp that burns out faster, or gives off less light, than advertised, or than prescribed by national standards and guidelines.[14]

10. *From Idea to Action: Clean Energy Solution for Asia to Address Climate Change*. USAID Asia May 2007.

11. *Phasing in Quality: Harmonization of CFLs to Help Asia Address Climate Change*. USAID Asia, March 2009.

12. Chen Yanshen, *China Response to Phase-out of Inefficient Lighting*. Presented at the Phase-Out 2008 – Working Towards Global Phase-out of Inefficient Lighting workshop. Sofitel Hyland Hotel, Shanghai, China, May 2008.

13. For example, China has a comprehensive CFL quality monitoring and supervision system for domestic CFLs. Philippines Department of Energy and Thailand's Electricity Generating Authority also have testing programs.

14. However, this approach does not allow a direct comparison of product quality across the region.

Figure 3. **Estimated Chinese CFL Production 1996–2007**

Source: Chen, Yansheng. China Association of Lighting Industry, 2008.

The terms "low-quality," "lower-quality," "sub-standard," "poor," or "shoddy" are now being used by experts, program managers, and regulators to describe the poor-performing CFLs that are being produced in large quantities and sold in many markets in the region. Generally speaking, for CFLs, quality refers to their ability to perform as expected, particularly as related to longevity, color, and light output. It should be noted that a significant presence of poor-quality CFLs in the market can lead to a condition known as "market spoilage," and can result in limiting CFL penetration rates as consumers consider the products a poor value proposition.

CFL quality issues have become pronounced in Asian markets as a result its significant growth and consumer sensitivity to purchase costs. This cost-sensitivity has led to the availability of CFLs that are generally cheaper than those in North American or European markets, but these lower costs have often been achieved at the expense of product quality.

Beyond this, CFLs that fail significantly before their rated lives pose risks for policy makers as they weigh cost-to-impact decisions aimed at achieving reductions in energy usage and/or greenhouse gas production.

In 2007, ECO-Asia published a report analyzing CFL markets and programs in China, India, and the four largest ASEAN countries – Indonesia, the Philippines, Thailand, and Vietnam.[15] The report assessed the quality of CFLs available in regional markets and found that as many as half of the CFLs produced and sold in Asia were shoddy or sub-standard (e.g., burning out faster or producing less light than advertised or required by national regulations). The report proposed an immediate and intensive coordination of existing regional CFL initiatives in order to support development of a broad-based quality assurance process in Asia.

A number of regional efforts have been undertaken in an effort to improve CFL quality in Asian markets, including the development of national performance standards for CFLs. Many of these standards require CFLs to achieve certain minimum performance benchmarks (including efficacy, life, start-up time, run-up time, and mercury content) in order to be certified as compliant. There are also testing requirements associated with a number of national standards.[16]

While these standards have addressed many of their

15. *Confidence in Quality: Harmonization of CFLs to Help Asia Address Climate Change.* USAID Asia. October 2007.

16. For example, in India, lamps must meet the Bureau of Indian Standards (BIS)'s requirements to bear the BIS logo and be allowed on the market.

Box 1. Defining CFL Quality

CFLs are complex electrical devices, and have grown more so with the incorporation of electronic ballasts, along with the market drive to reduce the size of the CFL while maximizing the number of locations and fixtures in which it can be suitably installed. As a consequence, manufacturers must balance a number of physical and production factors in order to deliver a CFL that will simultaneously meet consumer expectations in terms of product functions and price, while satisfying regulators and utilities on energy performance. In this balancing act, a small adjustment of one performance factor has the potential to affect other factors in significant ways.

In defining what constitutes a "quality" CFL, it is important to consider and even group its various characteristics in order to identify the ones that are necessary for broad acceptance, first and foremost by consumers, but also by regulators, program managers, utilities, energy advocates, and program administrators. In addition, each of these characteristics needs to be considered in the context of a mass-produced, international product that has to be efficient, affordable, long lasting, and approximate the incandescent lamp in fit, function, and light quality.

Many organizations have developed standards and criteria for CFLs based on their area or areas of responsibilities, ranging from safety to energy efficiency, and their results reflect these multiple views of CFL performance that can take the CFL quite far in one direction, often at a cost to its other attributes. For example, a super high-efficacy lamp may be more expensive to produce, or may not be able to maintain its lumen output over its life, depending on how the manufacturer chooses to address the issue. Similarly, a long-life (10,000+ hrs) lamp needs a more reliable starting mechanism than a normal life lamp (6,000-8,000 hrs), and may require a longer starting time.

Addressing this product quality issue on a piecemeal, country-by-country basis is not practical – a regional approach is needed. In June 2008, a coalition of national lighting associations and the world's largest lighting companies signed an agreement to push for the elimination of substandard CFLs in the Asia market. Under this agreement, known as the "Manila Compact", lighting suppliers committed to develop common performance levels to rate the quality of CFLs sold in Asia, introduce a product marking system, and establish an on-line regional database that identifies those CFLs that meet quality standards. In order to implement this certification and marking system, the signatories grouped together to formally establish the Asia Lighting Compact in October 2009.

objectives with regards to CFL quality issues, they have paradoxically introduced a new barrier to the market: market confusion arising from the lack of standardization or harmonization between these standards. This lack of harmonization creates concerns for both consumers of CFLs, who must decide if a CFL is "high-quality" if it passes some standards but fails some others, and for manufacturers of CFLs who must develop, test, and label products to multiple standards.

PURPOSE AND SCOPE OF THIS REPORT

In order to assess and address these CFL product quality and standards harmonization issues, USAID's ECO-Asia Clean Development and Climate Program partnered with the Australian Department of Environment, Water, Heritage, and the Arts (DEWHA) in 2008 under the aegis of the Asia-Pacific Partnership on Clean Development and Climate (APP) to initiate a substantial regional CFL quality and performance benchmark testing program. The primary objectives of this CFL testing program were:

Table 1: Key Metrics and Compliance Standards Evaluated

Key Metrics Tested and Compared to Standards	Compliance Standards Used for Comparisons
Efficacy	ALC – Tier 1
Survival Rate	ALC – Tier 2 (ELI)
Lumen Maintenance	ALC – Tier 3 (UKEST 6.1)
Power factor	ALC – Tier 2
Color Rendering Index (CRI)	ALC – Tier 2

- To assess the overall quality of CFLs currently being sold in various Asian and Australian markets.
- To assess the opportunities for harmonization of CFL standards based on test results.
- To gain insight into the possibility of implementing a regional product testing program and its complexity.
- To gather a first-order examination of lamp mercury content.

This report presents the major findings of this laboratory CFL benchmark testing program. While the complete raw testing data is provided for all tested variables, the analysis in this report focuses on how the follow testing results for five key metrics compare to the associated requirements for three compliance standards (summarized in **Table 1**). Asian Lighting Compact (ALC) Tiers 1, 2 and 3 were used as the primary compliance standards for comparison of the tested lamp results.[17] The ALC Tiers were chosen, first and foremost, because the only way the tested lamps can be directly and fairly compared, is against one set of standards. As noted above, there is no commonly recognized regional or international standard for CFL quality and performance in Asia at the time of testing.[18] Most countries reference IEC standards – specifically IEC 60969, but this can only be used as a testing standard for CFLs, not as performance or quality standard.[19]

The second reason that the ALC Tiers were chosen was that in the absence of such agreement a set of developed metrics to characterize CFL quality is needed as a basis in analyzing these CFL test results. The metrics incorporated by the ALC Tiers include: lighting characteristics (color rendering and color correlated temperature), and other performance parameters (start-up time, lifetime, and lumen maintenance). Finally, it should be noted that ALC Tier 2 has been aligned with the Efficient Lighting Initiative's Voluntary Technical Specification for CFLs (ELI), and ALC Tier 3 has been aligned with the UK Energy Saving Trust Lamp Specifications for CFLs (EST).[20] Thus pass/fail reporting in this report for ALC Tier 2 and ALC Tier 3 can be applied to ELI and UK EST 6.1 respectively.

17. Included as Appendix A.

18. ELI (the Efficient Lighting Initiative) standards are referenced in certain procurement efforts, but not recognized by national governments other than Australia.

19. IEC 60969 Ed. 1.3 b:2009. Self-ballasted lamps for general lighting services - Performance requirements.

20. ELI Quality Certification Institute, "ELI Voluntary Technical Specification for Self-Ballasted Compact Fluorescent Lamps 2006-03-01," and the UK Energy Saving Trust, "Energy Saving Trust: Lamp Specification, Version 6.1 – 2009."

Box 2. The ALC Quality System

The Asia Lighting Compact (ALC) is an independent, non-profit organization dedicated to reducing greenhouse gas emissions by improving the quality of lighting products and encouraging the adoption of energy-efficient lighting in Asia. Formed through a public-private initiative, the ALC works to reduce barriers to trade and mitigate climate change by harmonizing quality and energy-efficiency standards for lighting across the region.

The ALC does not recreate lighting standards. Instead, the ALC is based on the international testing standards developed by the International Electrotechnical Commission (IEC). Based on the IEC test procedures for CFL performance, the ALC has developed a three-tier quality system that is designed to work cooperatively with other lighting quality standard initiatives.

Tier 3. The "Best" tier is currently based on the UK Energy Savings Trust 6.1 standard and will migrate to Europe's EUP CFL standard once this standard is finalized.

Tier 2. The "Better" tier is based on and harmonized with the Efficient Lighting Initiative (ELI) standard for CFLs.

Tier 1. The "Good" tier represents an initial realistic entry-level performance standard for countries in the Asia region that provides quality, efficiency and performance.

The three levels are necessary for the region because not all Asian consumers can afford the very highest quality CFLs, but they should be protected against poor-quality products. This ALC system is voluntary, transparent, publicly reviewed, consistent with the standards of International Electrotechnical Commission (IEC), and is based on the IEC's safety and performance test standards.

Suppliers can qualify the quality of their CFLs with the ALC using an online registration system. Registered CFLs will carry the markings of their qualifying levels, and will be listed in the ALC Quality Registry.

THE PERFORMANCE TEST PROCESS

This section describes the details of the benchmark test process that was implemented to address the quality and harmonization issues discussed above. This includes a discussion of how the CFL test sample was selected and procured, where and how the tests were conducted, and what parameters were measured. The results of these tests, including which sample lamp parameters conformed to which standards, will be presented in the "Test Results" section that follows.

CFL SAMPLE

Sample design and acquisition are perhaps the most influential determinants to the eventual testing results. As such, a very detailed selection and procurement process was developed with the goal of acquiring samples that were reflective of the overall CFL market in each of the following countries:

- Australia
- India
- Indonesia
- Philippines
- Thailand
- Vietnam

The test plan had originally included China, but due to complications in acquiring a representative sample, China had to be dropped from the study.[21]

ECO-Asia worked with DEWHA to design a collection methodology that took into account the available CFL brands and pricing in each of the market. Then, ECO-Asia worked with partners and offices in each of the target countries to procure the samples.

Australian lamps were purchased by DEWHA staff, and lamps in India, Indonesia, Philippines, Thailand and Vietnam were purchased by ECO-Asia staff. These samples were purchased through ordinary retail outlets in a standardized selection process to acquire a representative mix of CFL models.

While procurement plans varied slightly between countries, the sample generally conformed to the following:

Number of Models: 16 unique lamp models were sampled in each country, with the exception of Australia, where a much larger sample of 77 models was acquired. These 77 models represent a significant portion of the Australian lamp market.

Types of Manufacturers: The models were chosen to include a broad range of manufacturers/distributors. For each of the six countries, models were assigned one of three "manufacturer type" identifiers so that sub-group analysis could be performed later. These three manufacturer groups types were:

- **High:** Major international brands
- **Mid:** Known local or regional brands
- **Low:** Unknown or low-cost brands

Types of Models: The selected models were all bare screw-based CFLs. A number of covered and reflector lamps from Australia were also purchased and tested, but the results were not reported here, as those categories represent a much smaller percentage in the rest of Asia.

21. Note that the procurement effort was designed to obtain samples representative of products available on the market in each country. Market share information was not available in sufficient detail for weighting of the test results.

Lamp Wattages: The primary target for procurement was the CFL equivalent of the most popular incandescent lamp – the 60-Watt lamp. However, a range of wattages was selected in order to better understand the efficacy distribution of the lamps available.

Quantities of CFLs per model: Generally 10–12 samples of each CFL model were acquired. In some cases up to 24 samples were acquired for the purposes of sending 10–12 samples to each of the two performance testing laboratories for cross-laboratory comparisons. For a randomly selected subset of models, 6 to 18 additional samples were procured for the purpose of mercury content testing at three testing laboratories, which requires a minimum of 5 working samples for each of the test laboratory.[22]

Purchase Location: Samples of each tested model were purchased in a minimum of three separate geographic locations to ensure that samples would be randomly chosen.

Location of Manufacture: The majority of lamps were made in China. Where there were local manufacturers, teams made every effort to include a mix of local and imported products.[23]

The following information was recorded for all selected samples:

- Purchase Region
- Brand
- Model Name
- Category (high/medium/low)
- Rated Power (W)
- Rated Color Temp
- Rated Life (hours)
- Tube or Envelope Shape
- No. in Each Package Purchased
- Package Price (Retail, converted into US$ at the exchange rates at the time of purchase).
- Price per Lamp (Retail, US$)

Table 2 summarizes the breakdown of the number of models and quantity of CFLs used for testing. Overall, the results from 137 tested models are reported here.[24] It should be noted that the lamps purchased in Australia CFL dominate the sample and, as such, the test results for the aggregate sample should not be expected to provide information on the region as a whole without reweighting the sample.

TESTING PROCESS

Four laboratories were selected to test the CFL samples. The laboratories were:

- The National Lighting Test Center (NLTC) in Beijing, China, which conducted testing on the majority of the sample lamps from Australia and ASEAN countries for performance, and also a subset of the sample models for mercury content.

- Electrical Research and Development Association (ERDA) in Baroda, Gujarat, India, which tested the lamp samples from India and ASEAN countries for performance parameters only.

- Spectro Laboratories, in New Delhi, India, which tested a subset of the Australian, Indian, and ASEAN lamp samples for mercury content.

- Advanced Analytical Australia, North Ryde NSW, Australia, which also tested a subset of the lamp samples from Australia, India, and ASEAN countries for mercury content.

22. To account for breakage and other handling issues that may occur when lamps are transported to various international laboratories for testing, procurement teams were asked to obtain at least 12 samples of each model from at least 3 separate geographical locations for performance testing (ensuring a minimum sample set of 10), and 6 samples from at least 3 separate geographical locations for mercury content testing (ensuring a minimum sample set of 5). Thus for a model that is being tested for both performance and mercury content at all 4 labs, a maximum of 42 samples were procured. Overall, about 2,600 lamps were procured in six countries over a four-week period.

23. Except in the case of India, where all the lamps tested were of Indian manufacture.

24. The actual number of unique models tested is likely slightly less than 137 as similar international brand models were purchased in various countries. These models are being treated separately in this report even though they may be identical. Conversely, many more samples per model were required for this process since testing took place in four laboratories in three countries.

Table 2: Breakdown of CFL Sample for Laboratory Testing

Country of Purchase	# of Models Tested
Australia	77
India	16
Indonesia	10
Philippines	12
Thailand	12
Vietnam	10
TOTAL	**137**

All CFLs were subjected to the following measurements or evaluations[25]:

After 100 hours of operation (Sample size = 10 lamps):

- lamp power (Watts)
- luminous flux (lumens)
- power factor
- total harmonic distortion (THD)
- Color Rendering Index (CRI)
- X and Y coordinates
- Correlated color temperature (CCT)
- SCDM
- start-up time

After 2,000 hours of operation (Sample size = remaining operational lamps):

- lamp power (Watts)
- luminous flux (lumens)

A subset of the CFLs were subjected to the following measurements or evaluations:

After verification of operation (Sample size = 5 lamps):

- mercury content

The test method used to measure performance was the most recent version of IEC draft test method for integrated CFLs (to replace IEC 60969), titled *IEC 60969 Committee Draft V04-21-6-07,* with amendments as discussed at the IEC PRESCO meeting in November 2007 (as outlined in document *34A/1253/CC - Template for Comments and Secretariat Observations Dated 14/11/07 regarding 34A/1235A/CD - IEC 60969 Ed.2).* This test method is available from IEC (www.iec.ch).

For CFL samples that failed prior to reaching 2,000 hours, their time of failure was recorded. For the tests listed above, only lamp power, luminous flux, power factor, CRI, and time of failure (when appropriate) were utilized for the analysis discussed in this report.

The test method used to measure mercury content of the lamps was the most recent version of the AS/NZS 4782.3-2006 (int) *Part 3: Double-capped fluorescent lamps - Performance specifications, Part 3: Procedure for quantitative analysis of mercury present in fluorescent lamps. This test method is available from Standards Australia* (www.standards.com.au). This is a destructive test method, and lamps were confirmed to be operational before the test was conducted.

25. The Indian laboratory did not have the capability to measure some color-related metrics, thus CRI and SCDM were not recorded for the 687 CFLs measured in this lab.

TEST RESULTS—PERFORMANCE

This section presents the performance results of laboratory testing of 137 bare CFLs models from six countries. Presented results focus on the following five key metrics:

1. Efficacy
2. Survival Rate
3. Lumen Maintenance
4. Power factor
5. Color Rendering Index (CRI)

Following the discussion of the numerical results of these five key metrics, we detail how these results compare to ALC Tiers 1, 2 and 3. Because the number of CFLs and CFL models from Australia are significantly larger than the samples from the other countries, a presentation of the aggregate test results would be disproportionately influenced by the Australian lamp results. For this reason, we have chosen to disaggregate the Australian data from the remaining data so that the reader can view the results independent of this weighting effect, or in the aggregate with this weighting effect highlighted.

As discussed earlier, during sample selection, the selected models were categorized by manufacturer type during procurement. For several of the metrics, we have shown results disaggregated by manufacturer type based on the high, mid and low definitions outlined.

EFFICACY

The ability to efficiently convert power to light – efficacy – is the CFL's single most important attribute, and is one of the few parameters covered by every CFL standard. **Figure 4** shows the efficacy (lumens/Watt) vs. measured power (W) from the tested lamp samples after the 100-hour burn-in period.[25] **Figure 5** presents the same efficacy data plotted as a histogram that indicates the number of models that fall into various efficacy bins.

As expected, the overall dataset shows efficacy trending upward slightly for higher-powered CFLs. More strikingly, wide variations in efficacy can be seen between models of similar input power. Several very poor performing low-wattage CFLs are seen in the sample, with efficacies below 40 lumens/Watt.

Figure 6 presents the same results as Figure 2 but identifies the models by manufacturer type. Generally speaking, "high" or international brands yielded the highest efficacies, while "low" manufacturers yielded the lowest efficacies. Several highly efficacious "low" models can be seen, however. **Figure 7** shows the lamps' efficacies versus their purchase price.

The efficacy requirements for ALC Tiers 1, 2 and 3 vary depending on the rated wattage and color temperature of the CFL. These requirements are included in the appendix of this report. For the 137 models tested, measured efficacy (presented above), along with rated wattage and color temperature, were compared to ALC Tier 1, 2, and 3 to determine pass or fail rates for each model. **Table 3** and **Figure 8** present the results of this analysis.

SURVIVAL RATE

Lamp survival records were maintained during testing and survival rates were calculated after 2,000 hours of operation.[26] The survival rates were defined as the fraction of the models' functioning samples at 100 hours that were still functional at 2,000 hours. The survival rate can be a predictor of whether or not lamps will last for the duration of their claimed life.

Figure 9 shows the sample survival rates for each of the 137 models tested. The Australian models are models 1-78 (left of black bar) and the non-Australian models are number 79-137 (right of bar).

25. A "burn-in" period is specified by test methodologies as the typical time needed for lamps to reach their stable operational state needed for accurate testing.

26. Due to timing and resource constraints, it was not possible to test all lamp models for the full 6,000 hours.

Figure 4. **Average Efficacy (lumens/Watt) of Test Models vs. Measured Power Taken After a 100-hour Burn-in Period.**

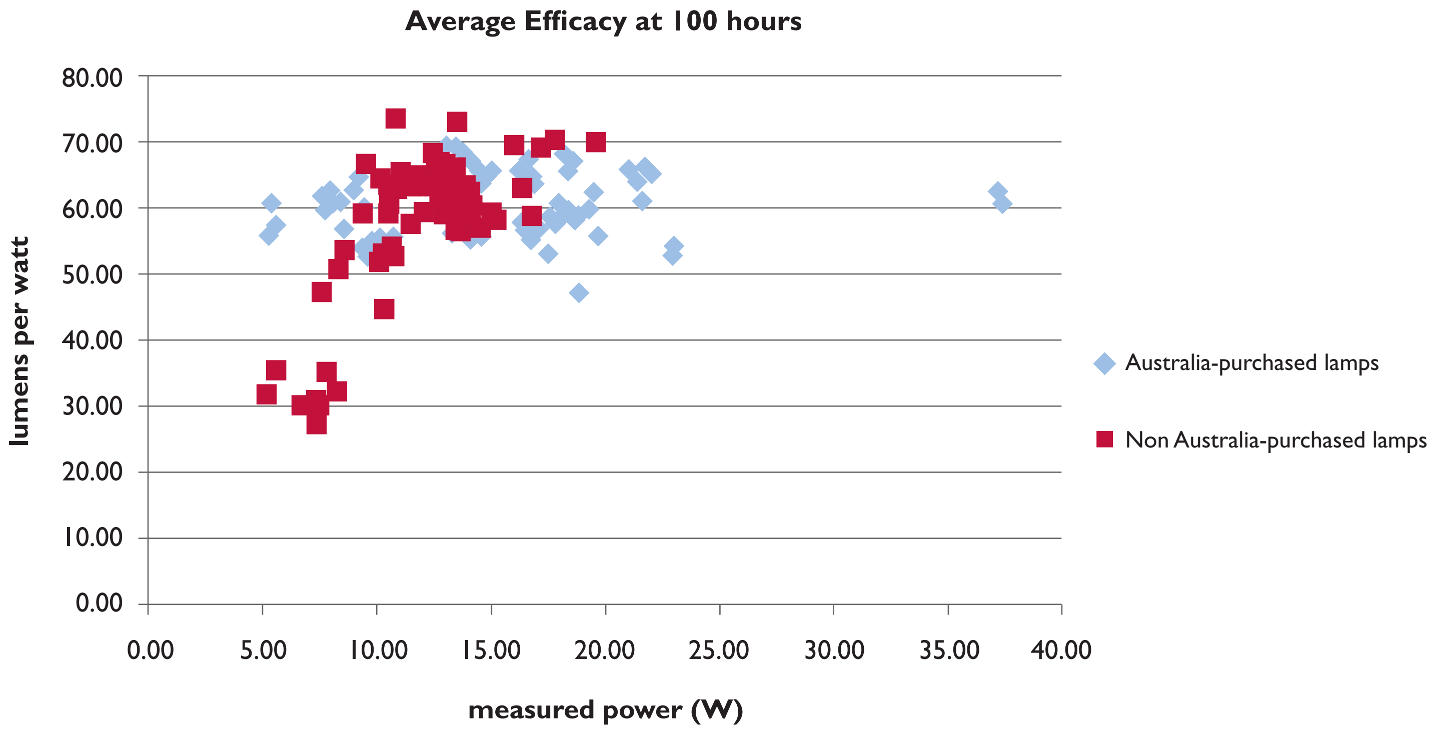


Figure 5. **Average Efficacy (lumens/Watt) of Test Models by Efficacy Bins**

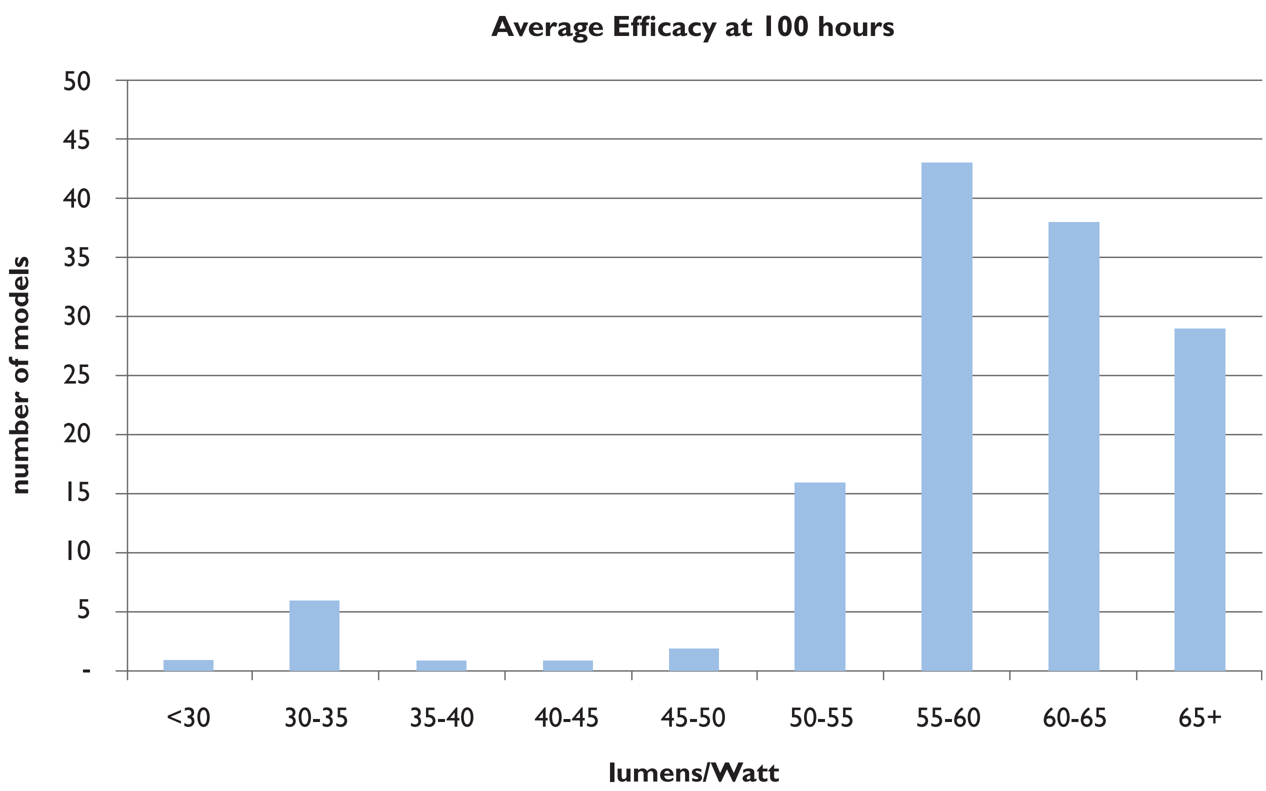


Figure 6. Average Efficacy (lumens/Watt) by Brand Type[27]

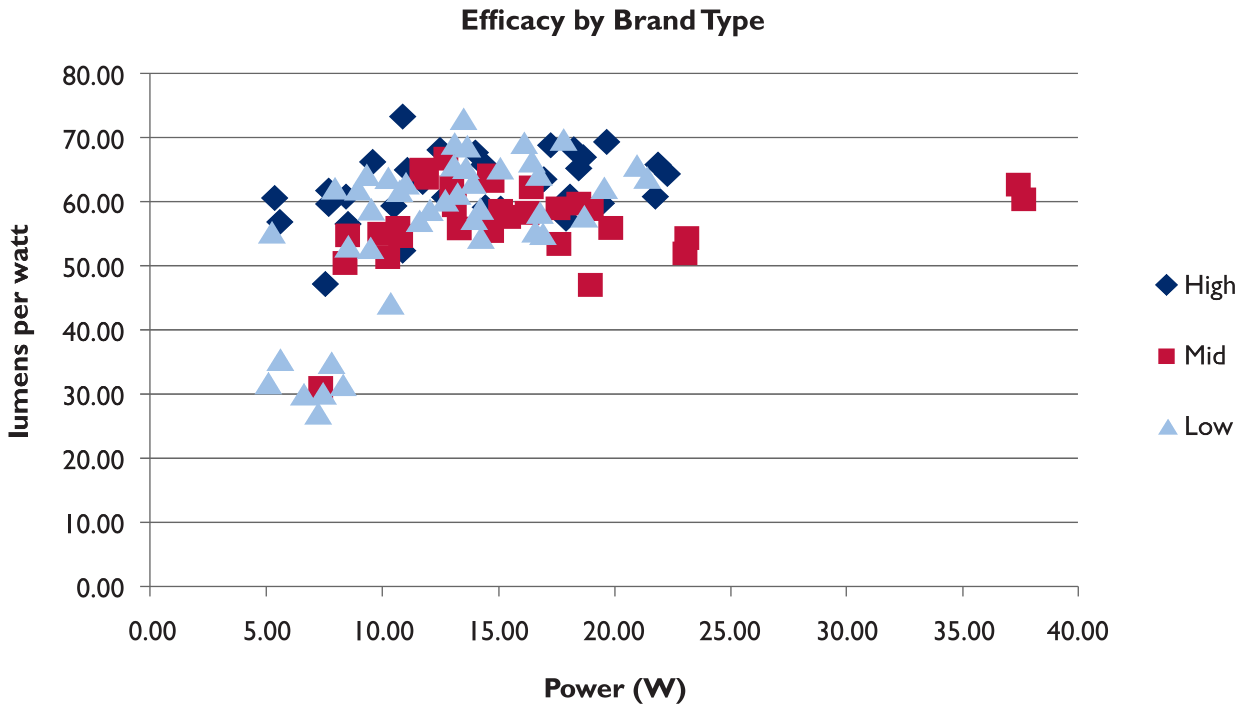
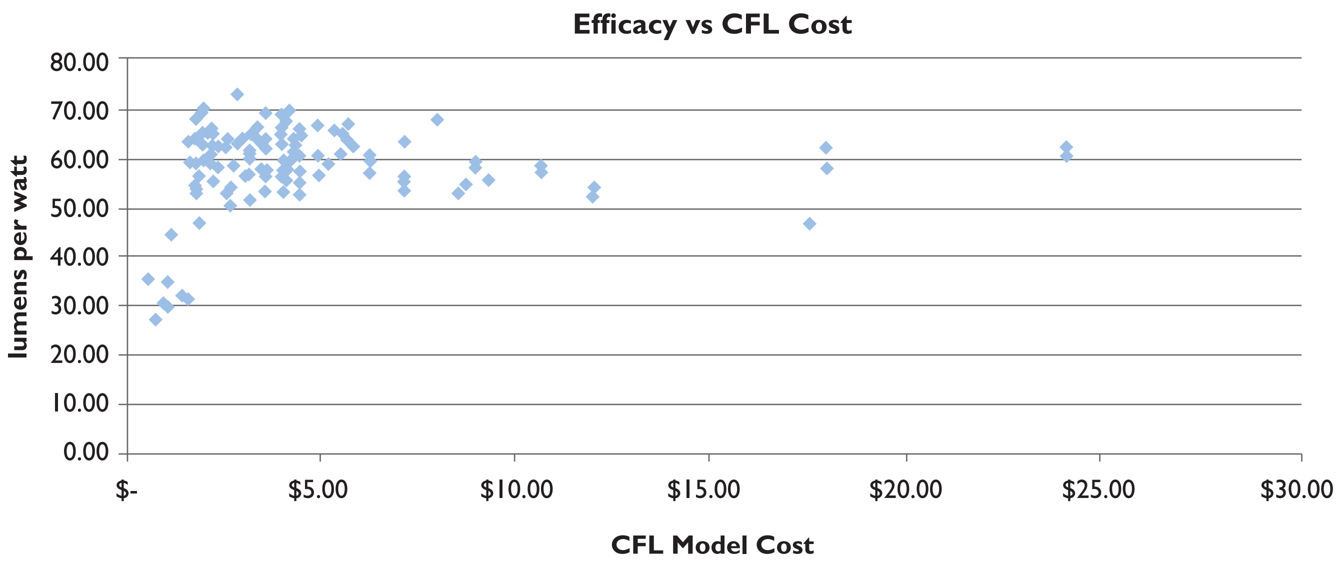


Figure 7. Lamp Efficacies and Costs



27. For each of the six countries, models were assigned one of three "manufacturer" or 'brand" type identifiers so that sub-group analysis could be performed. These three types were:
- High: Major international brands
- Mid: Known local or regional brands
- Low: Unknown or low-cost brands

Table 3: **Efficacy Test Pass Rates for All 137 Models vs. ALC Tiers 1, 2, and 3**

	Tier 1	Tier 2	Tier 3
Aus	96.1%	72.7%	90.9%
Non-Aus	86.7%	83.3%	85.0%
All Models	92.0%	77.4%	88.3%

Figure 8. **Pass/Fail Rates for All 137 Models Tested vs. ALC Tier 1, 2, and 3 Efficacy Test**

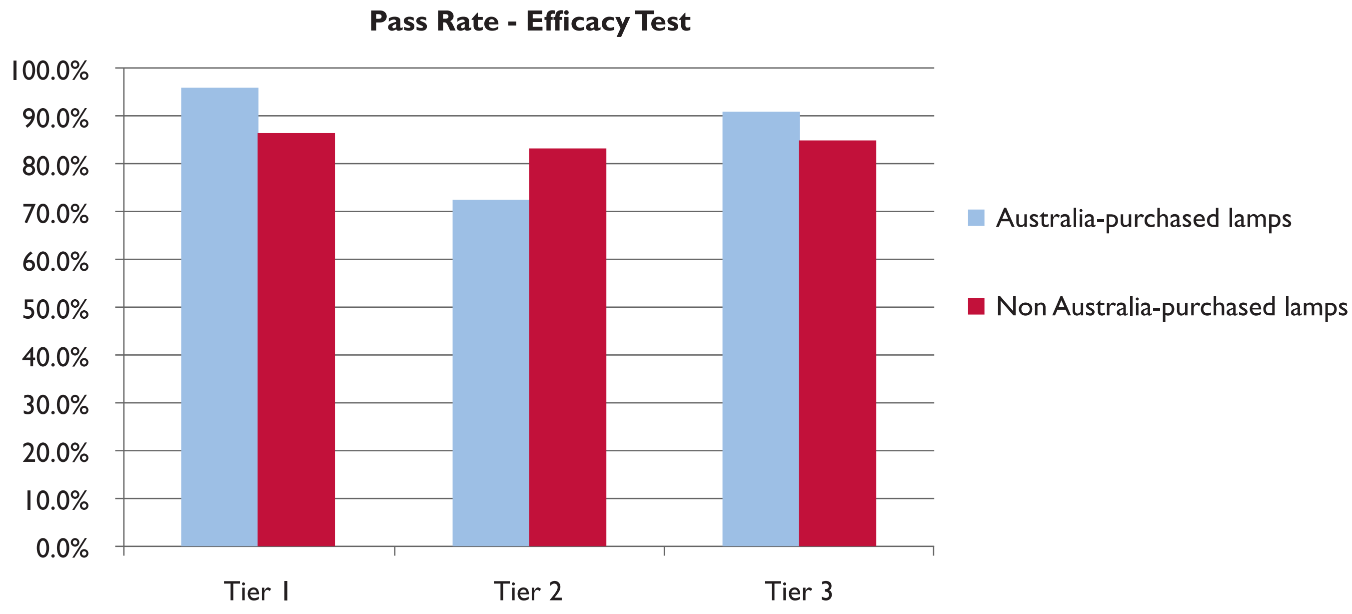


Figure 9. **Individual Survival Rates for Each of the 137 Models Tested**

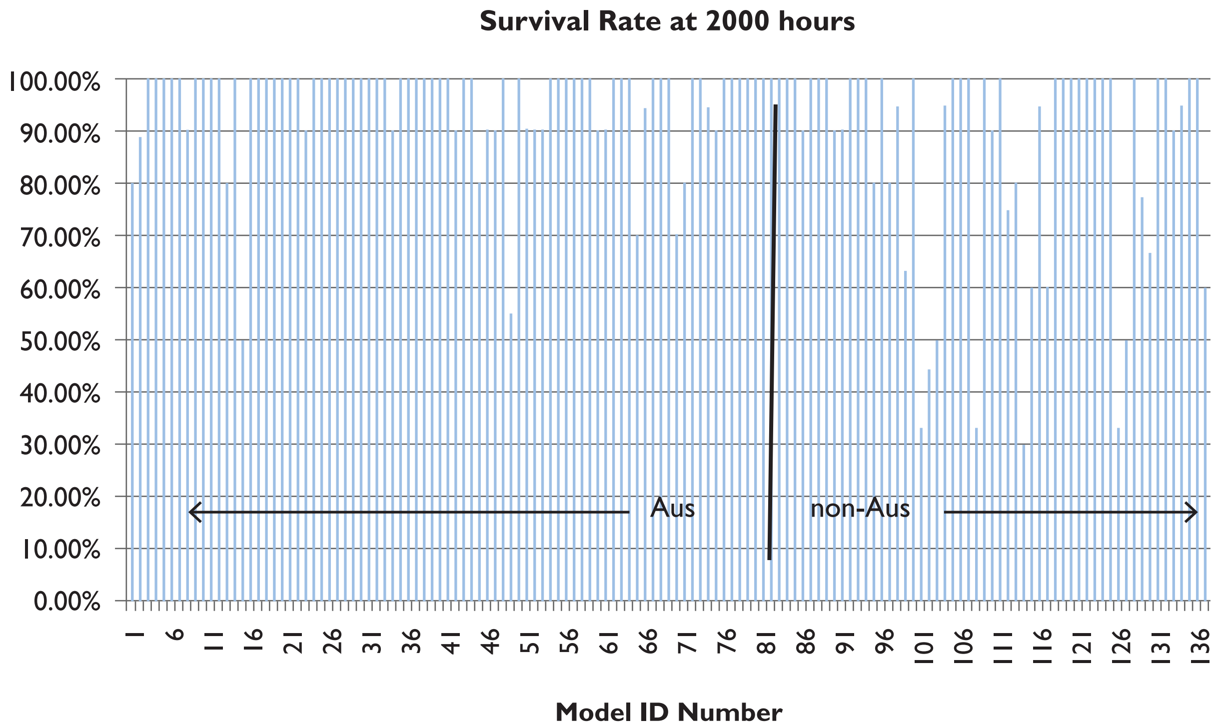


Figure 10. **Survival Rates for 137 Tested Models by Survival Rate Bins**

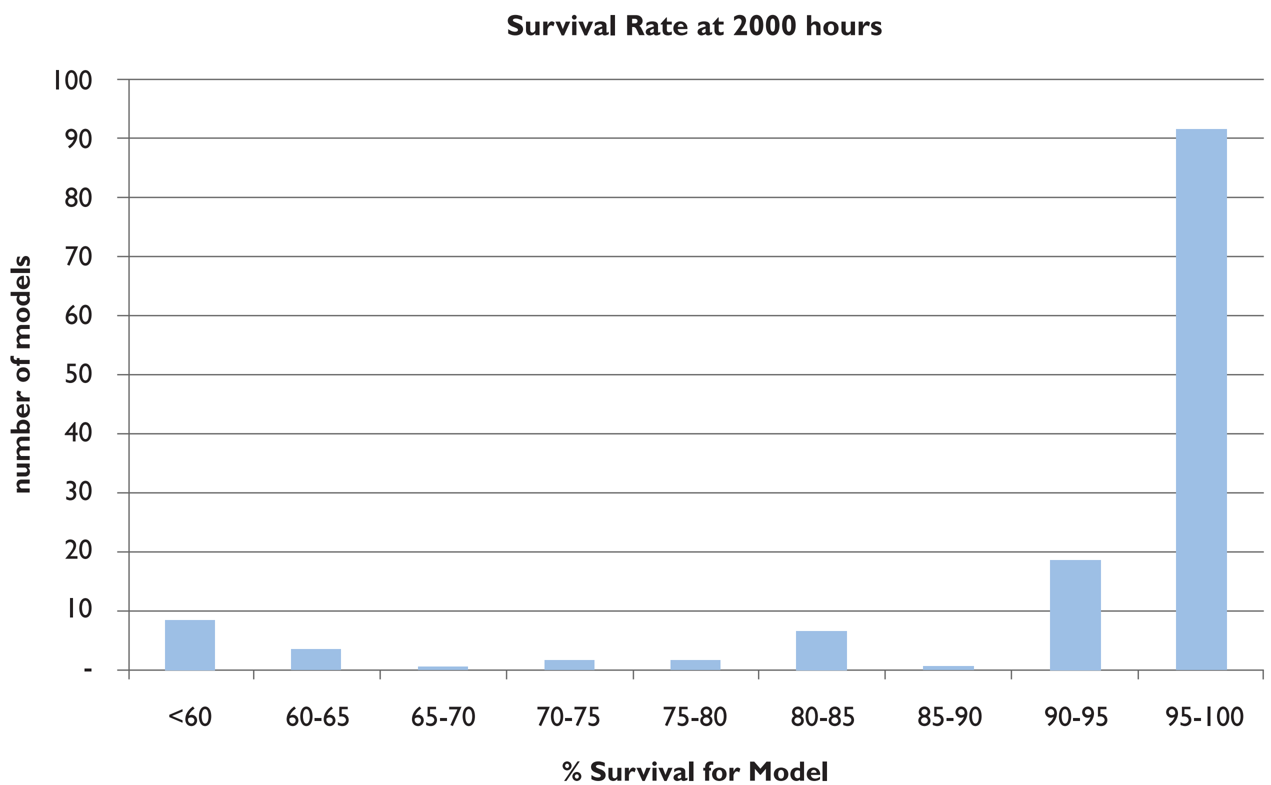


Figure 11. **Survival Rates and Brand Type** [28]

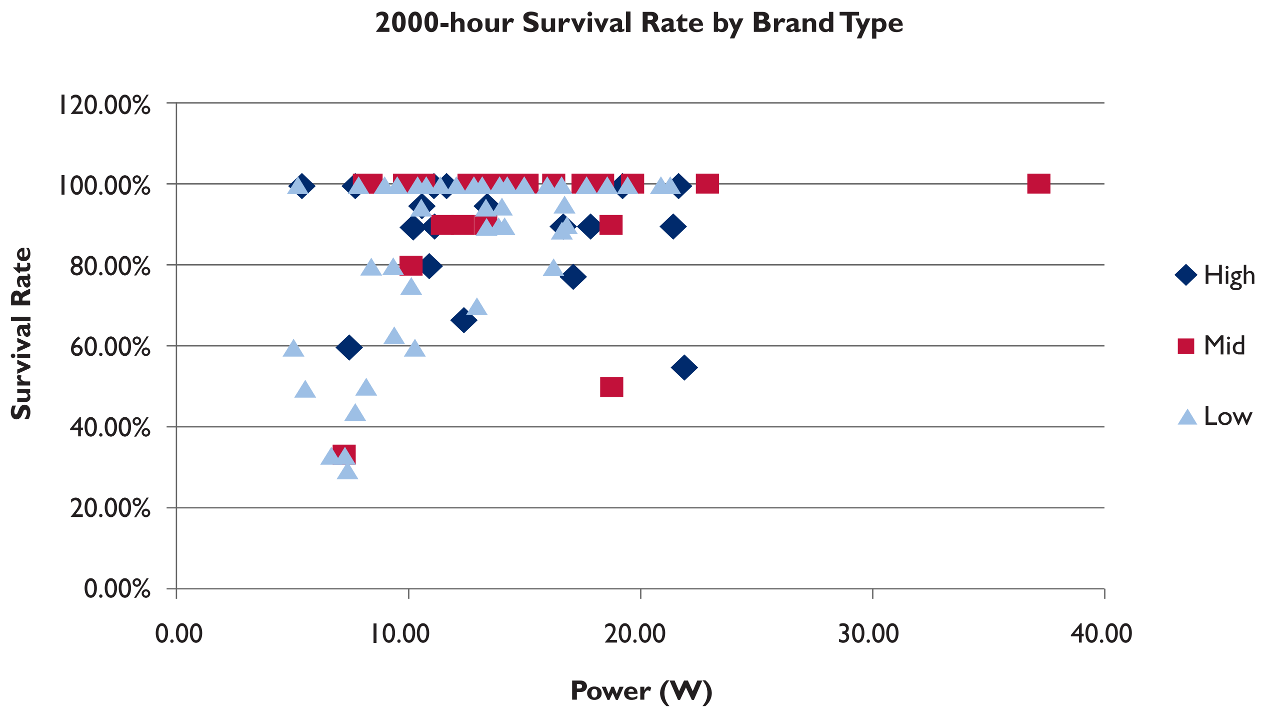


Figure 10 shows the same dataset in the form of a histogram. As Figures 9 and 10 show, while the majority of models experienced little to no failures, several models experienced significant failures. In fact, 11 models (8% of those tested) produced just over 50% of the failures during testing. Eighty-eight models (64%) experienced no sample failures during the 2,000-hour test period. Overall, the 31% of the Australian lamps model experienced sample failures, and 42% the non-Australian lamp models experienced sample failures.

Figure 11 presents the same survival rate data as a function of brand type and power. As might be expected, low-priced brands were responsible for most of the odels with poor survival rates, but some mid and high manufacturers also produced models that had survival rates of 60% or lower.

Figure12 presents the lamp survival rates as a function of their purchase price.

Figure 13 presents survival rates compared with ALC requirements.

ALC Tiers 1 and 2 require a survival rate of 90% or higher after 1,000 hours, while Tier 3 requires a survival rate of 90% or higher after 30% of rated life. For Tiers 1 and 2, survival rates at 1,000 hours were calculated and compared to the 90% survival test. In order to compare test results to Tier 3 requirements, survival rates at 3,000 hours or longer (as Tier 3 requires a rated life of at least 10,000 hours) would need to be known.

Testing was only conducted until 2,000 hours, however, so for the Tier 3 survival test, a 2,000-hour survival rather than 3,000 hours was used. Therefore, if a model has a 90% or greater survival rate at 2,000 hours, it was considered to have passed the Tier 3 survival test.

The effect of this approximation is that more of the tested models will be given a "pass" rating for Tier 3 survival than they likely would have had testing continued to 3,000 hours or beyond (as we are effectively assuming zero failures will occur in the hours between the 2,000-3,000 hour time period).

28. See footnote 27.

Figure 12. Lamp Survival Rates and Purchase Price

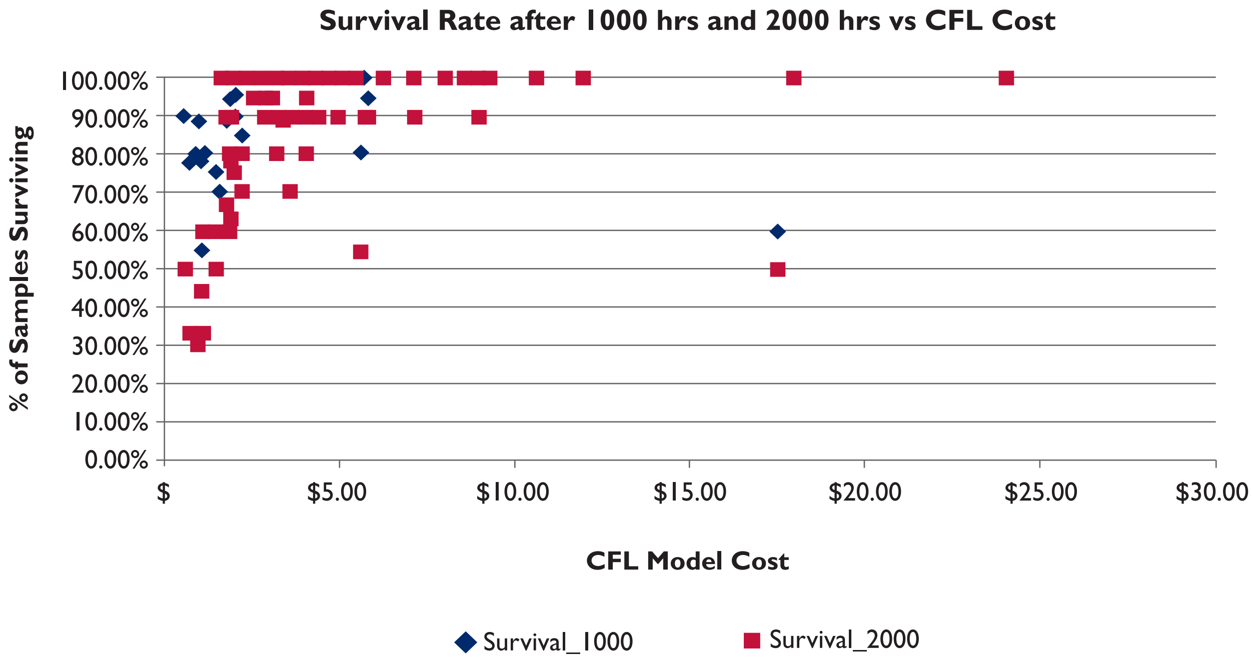


Figure 13. Survival Test Pass Rates vs. ALC Tier 1, 2, and 3

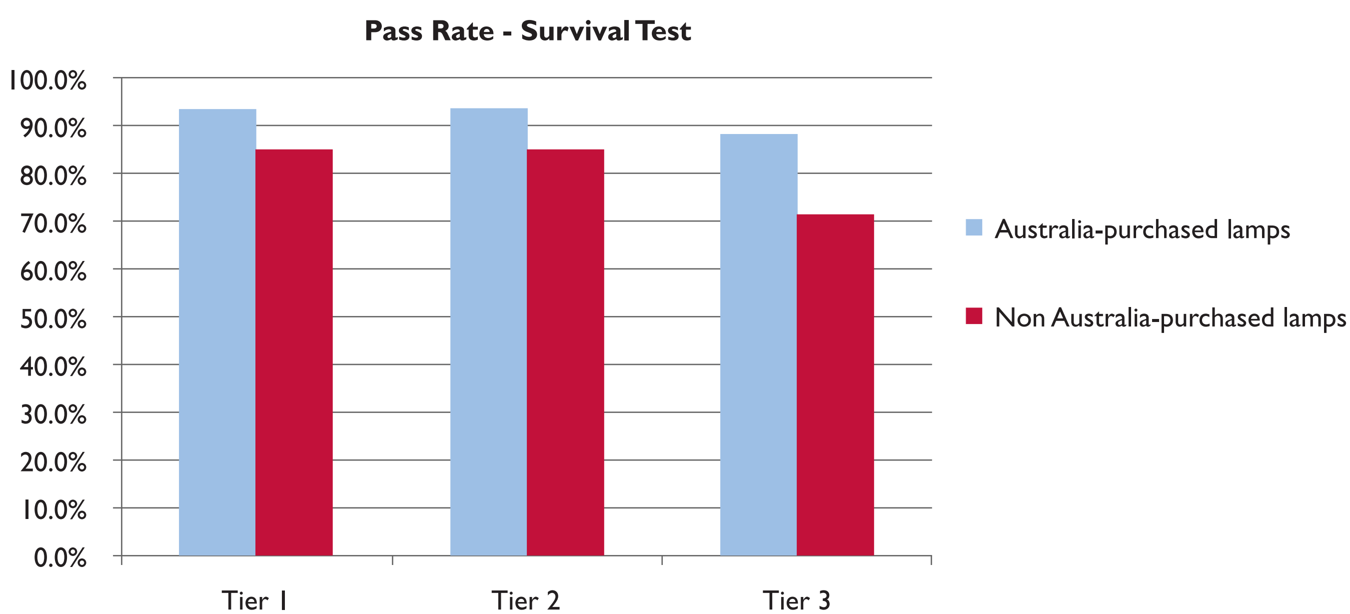
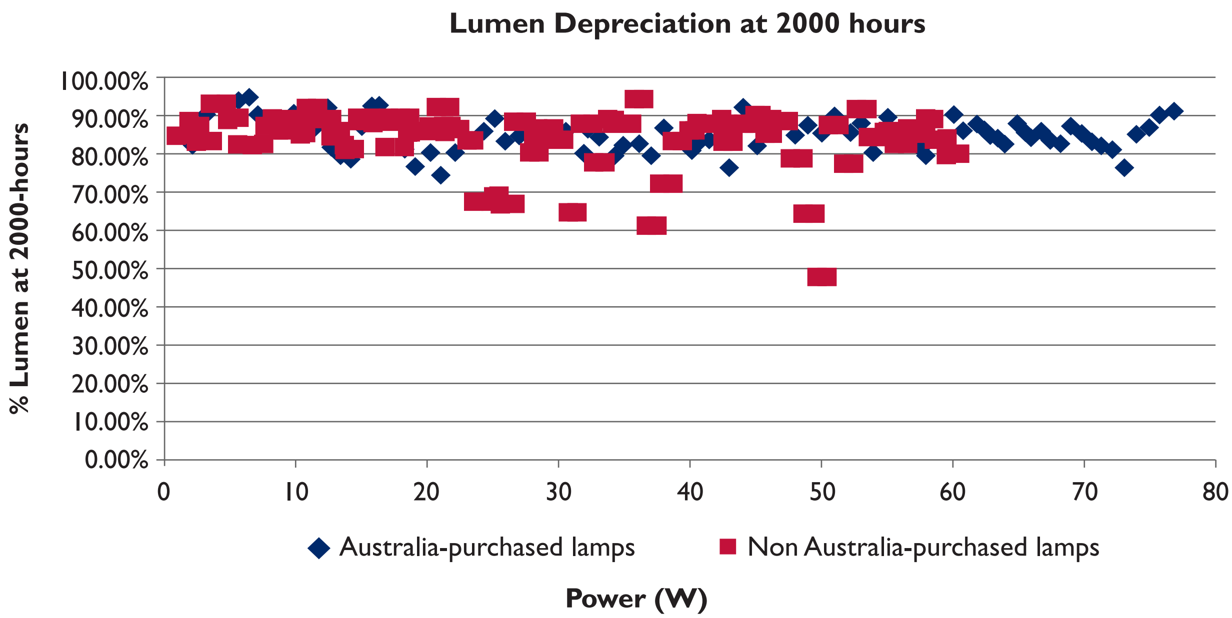


Table 4: Survival Test Pass Rate for All 137 Models vs. ALC Tier 1, 2, and 3

	Tier 1	Tier 2	Tier 3
Aus	93.5%	93.5%	88.3%
Non-Aus	85.0%	85.0%	71.7%
All Models	89.8%	89.8%	81.0%

Figure 14. Lumen Depreciation of Models after 2,000 Hours of Operation



LUMEN MAINTENANCE

Another important performance metric that was evaluated was lumen maintenance (or lumen depreciation) – whether or not lamps can maintain a certain level of light output over their operational lifetime. Lumen maintenance at 2,000 hours was calculated by comparing a model's average 100-hour lumen output (initial lumen measurements) from the initial sample set, to that model's average 2,000-hour lumen output from the remaining samples.

Figure 14 shows the lumen maintenance values for all 137 models tested. **Figure 15** shows the same dataset as a histogram. 125 of the 137 models experienced a lumen depreciation of at least 10% (i.e., lumen maintenance dropping below 90%). 23 models, or about one-sixth of the tested models, had lumen depreciation of more than 20%.[29] Nine models experienced a lumen depreciation of at least 25% (lumen maintenance below 75%). **Figure 16** presents lumen maintenance as a function of power and brand type. Once again, the "low" brands predictably make up the bulk of the poorest performing models when looking at lumen maintenance. In fact, Figure 14 shows striking similarities to the efficacy versus brand type comparison shown in Figure 4.

29. 20% is the maximum allowed by ALC Tiers 1 & 2.

ALC Tiers 1 and 2 require that lumen maintenance remain at 80% or above after 2,000 hours while Tier 3 requires lumen maintenance of 88.1% or above after 2,000 hours.

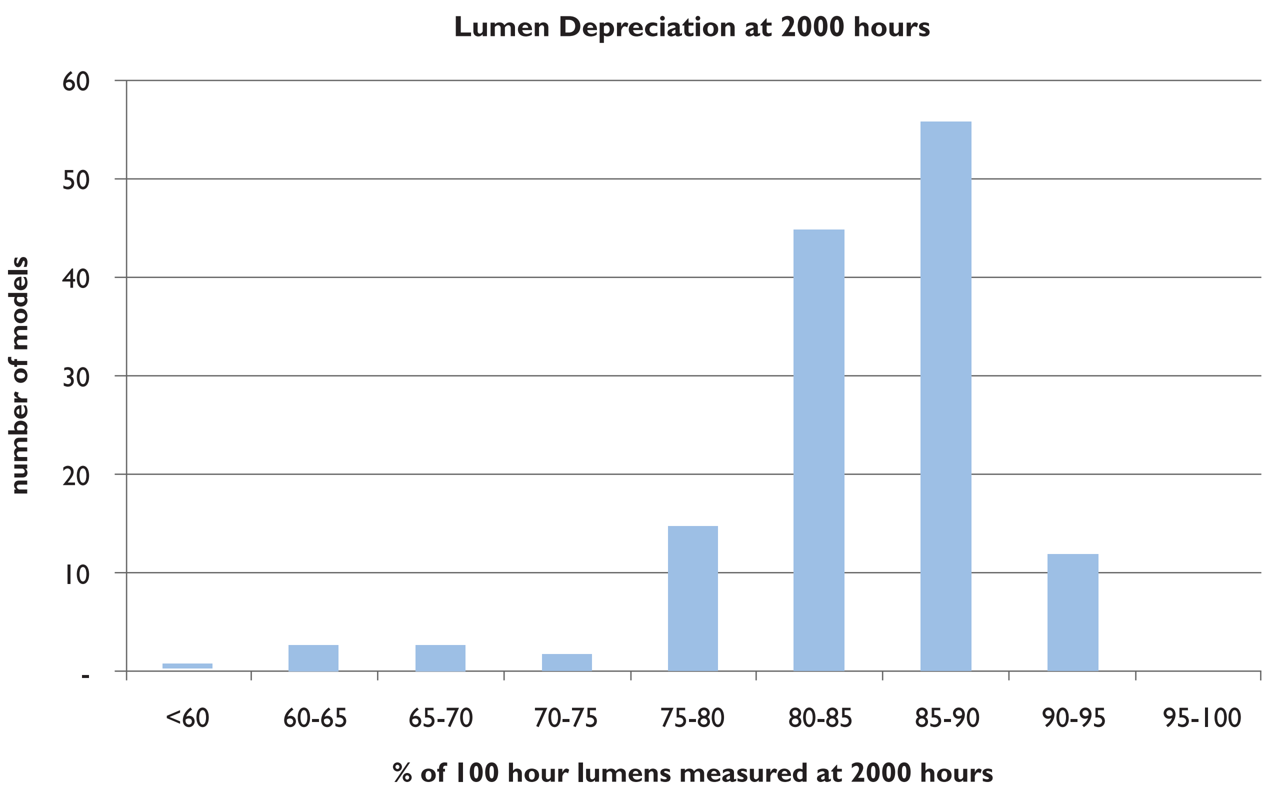
Tier 3 also specifies lumen maintenance requirements at 6,000 hours (78.1%) and at 10,000 hours (75.1%). Because testing did not continue long enough to apply the 6,000-hour and 10,000-hour tests, models were considered to have passed the Tier 3 lumen maintenance test if they simply passed Tier 3's 2,000-hour requirement.

Table 5 and **Figure 17** present the lumen maintenance test pass rates for the 137 tested models vs. ALC Tiers 1, 2, and 3. Only 30 of the 137 models passed the Tier 3 lumen maintenance test.[30]

Table 5: Lumen Maintenance Test Pass Rate for ALC Tiers 1, 2 and 3

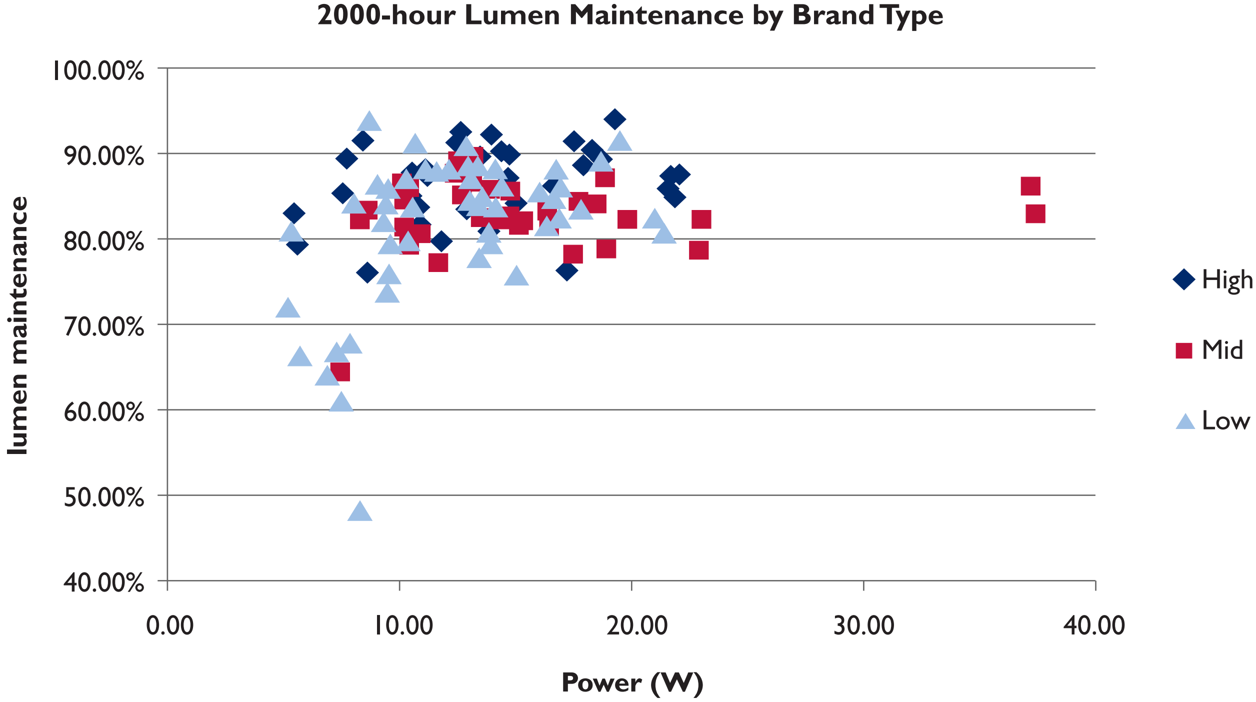
	Tier 1	Tier 2	Tier 3
Aus	85.7%	85.7%	22.1%
Non-Aus	78.3%	78.3%	21.7%
All Models	82.5%	82.5%	21.9%

Figure15. Lumen Depreciation Bins of Models After 2,000 Hours of Operation



30. It should be noted that none of the tested models claimed to be EST certified, therefore the test results should be viewed as an indicator of current market performance only.

Figure16. Lumen Maintenance by Brand Type



POWER FACTOR

Power factor was measured for all models tested. **Figure 18** presents the average power factor results for each model after 100 hours of testing[31] **Figure 19** shows the same data as a histogram. 135 of the models look to have "normal" or "low" power factors while only two models can be considered "high power factor" CFLs.

ALC Tiers 1 and 2 require power factors of 0.5 or greater, while Tier 3 requires 0.55 or greater. **Table 6** and **Figure 20** present the power factor test pass rates of the tested models.

COLOR RENDERING INDEX (CRI)

Color Rendering Index (CRI) was recorded for 91 of the 137 models tested – CRI is a quantitative measure of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source, and can be an approximation of perceived light quality. Light sources with a high CRI are desirable in color-critical applications such as photography and cinematography. The Indian test laboratory (ERDA) did not have the capabilities to measure CRI, so these results are not available for the 46 models that were tested exclusively in India.[32] The models that did not receive CRI testing were disproportionately non-Australian models as more of these models were tested in India.

Figure 21 shows the CRI results for the 91 models tested, while **Figure 22** presents the same dataset as a histogram. The results range from 73 to 86 with the majority of models having a CRI of 81 or higher. A CRI of 80 is generally considered very good, and is the minimum level required by the ALC Tiers.

Figure 23 shows CRI test results vs. manufacturer type. The performance distinction between high, mid and low manufacturer type is less distinct for CRI than that which was shown for efficacy, lumen depreciation, and survival. It is difficult to read too much into this result, however, as the sample of lamps tested for CRI was limited, particularly for non-Australian lamps.

31. It should also be noted that none of the lamps tested claimed to have high power factor (HPF), so the results here should be viewed as an indication of the overall power factor of lamps available on the market.

32. In fact, the Indian National Physical Laboratory (NPL) confirms that CRI is not typically measured in India, and is not a requirement of the Bureau of Indian Standard's CFL standards.

Figure17. **Lumen Maintenance Test Pass Rate for ALC Tiers 1, 2 and 3**

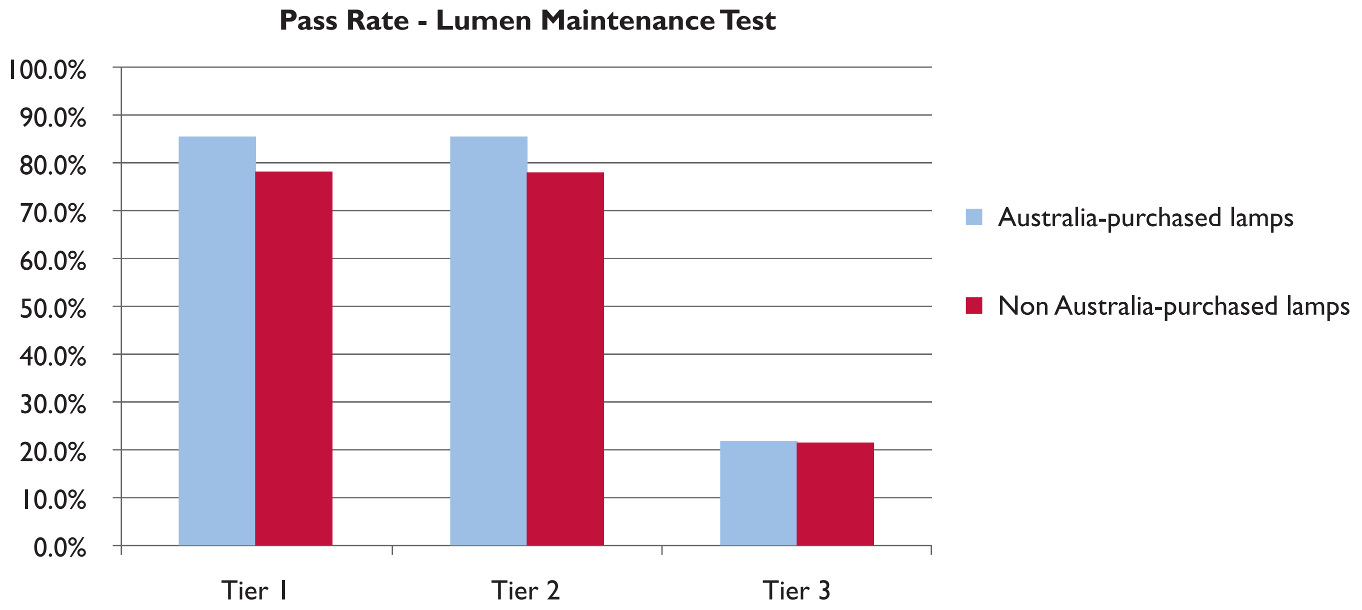


Figure18. **Average Power Factor Results for All 137 Models Tested**

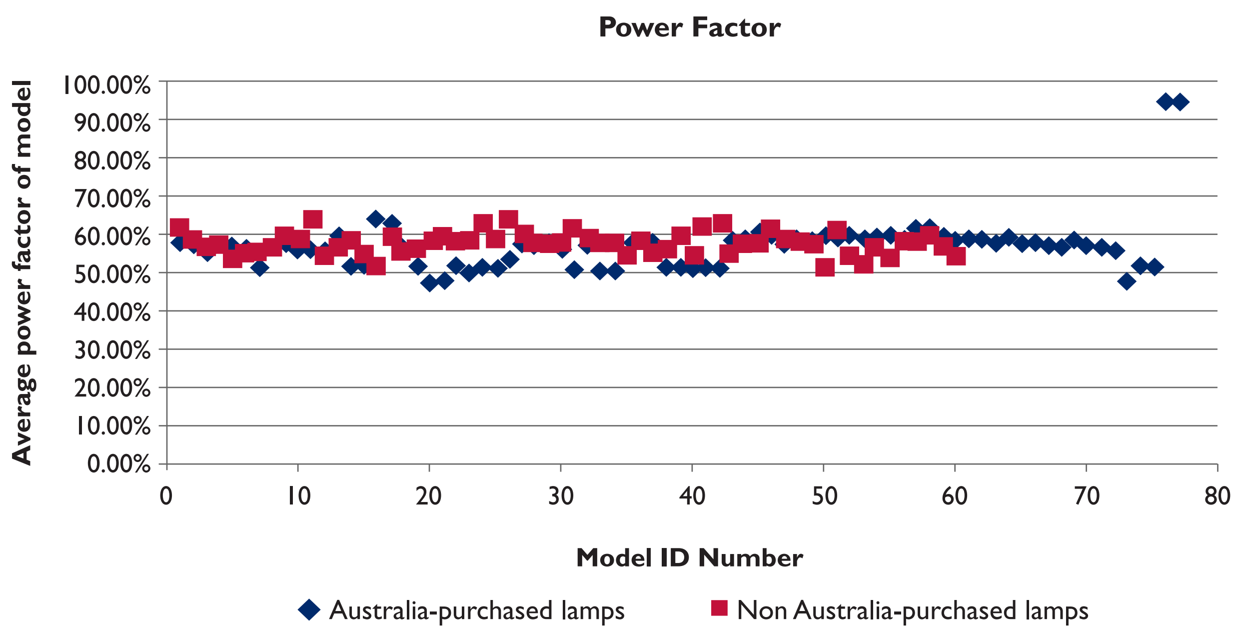


Table 6: **Power Factor Test Pass Rate for ALC Tiers 1, 2 and 3**

	Tier 1	Tier 2	Tier 3
Australia-purchased lamps	94.8%	94.8%	70.1%
Non Australia-purchased lamps	100.0%	100.0%	78.3%
All Models	97.1%	97.1%	73.7%

Figure19. **Power Factor of Models Separated in Bins**

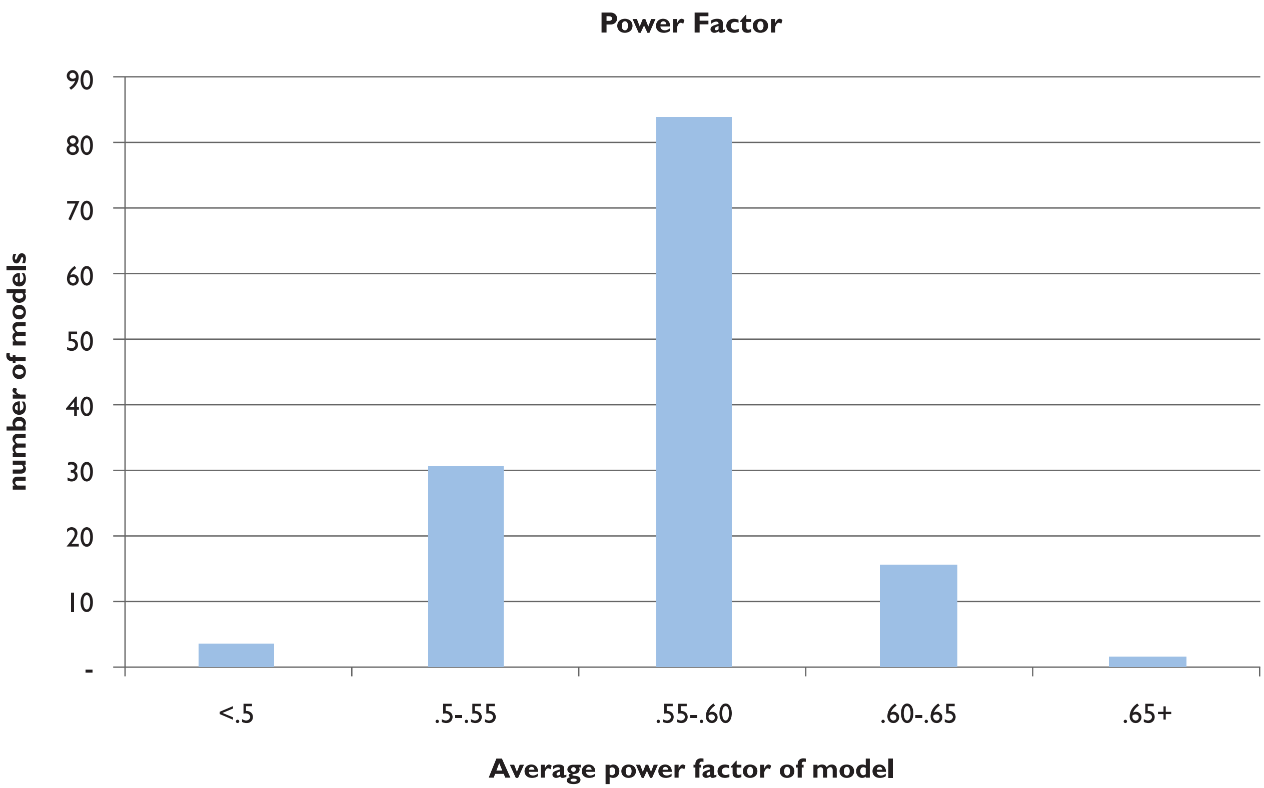


Figure 20. Power Factor Test Pass Rate for ALC Tiers 1, 2 and 3

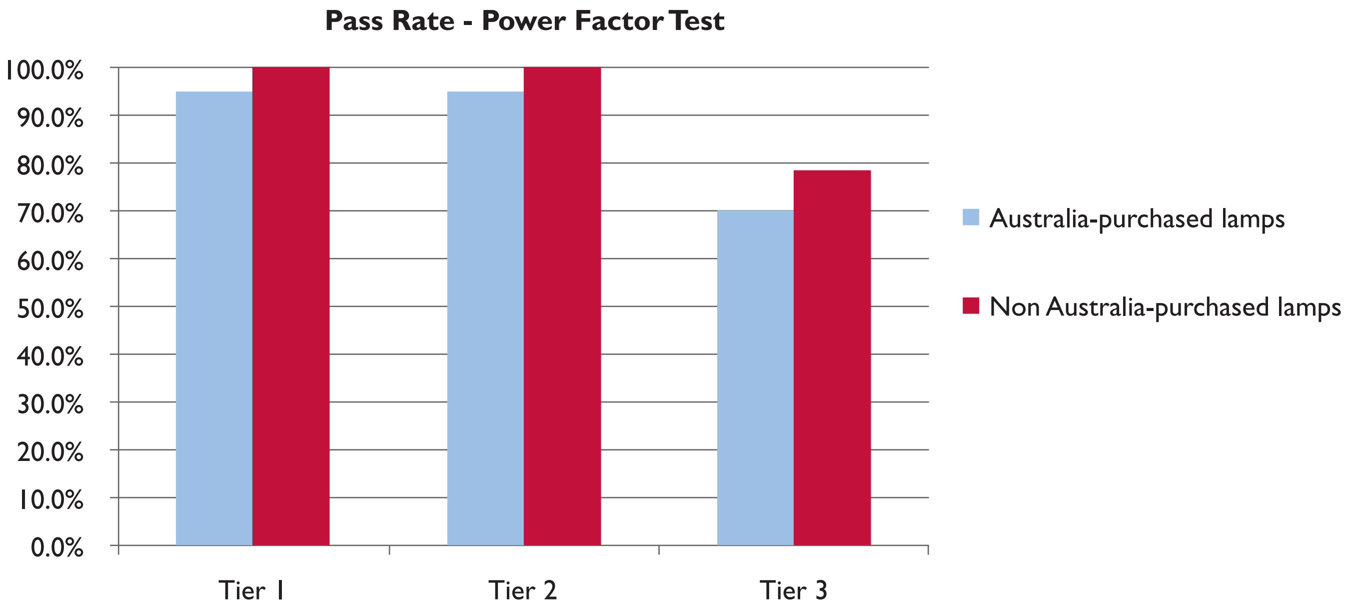


Figure 21. Color Rendering Index (CRI) for 91 Tested Models (46 Models Were not Tested)

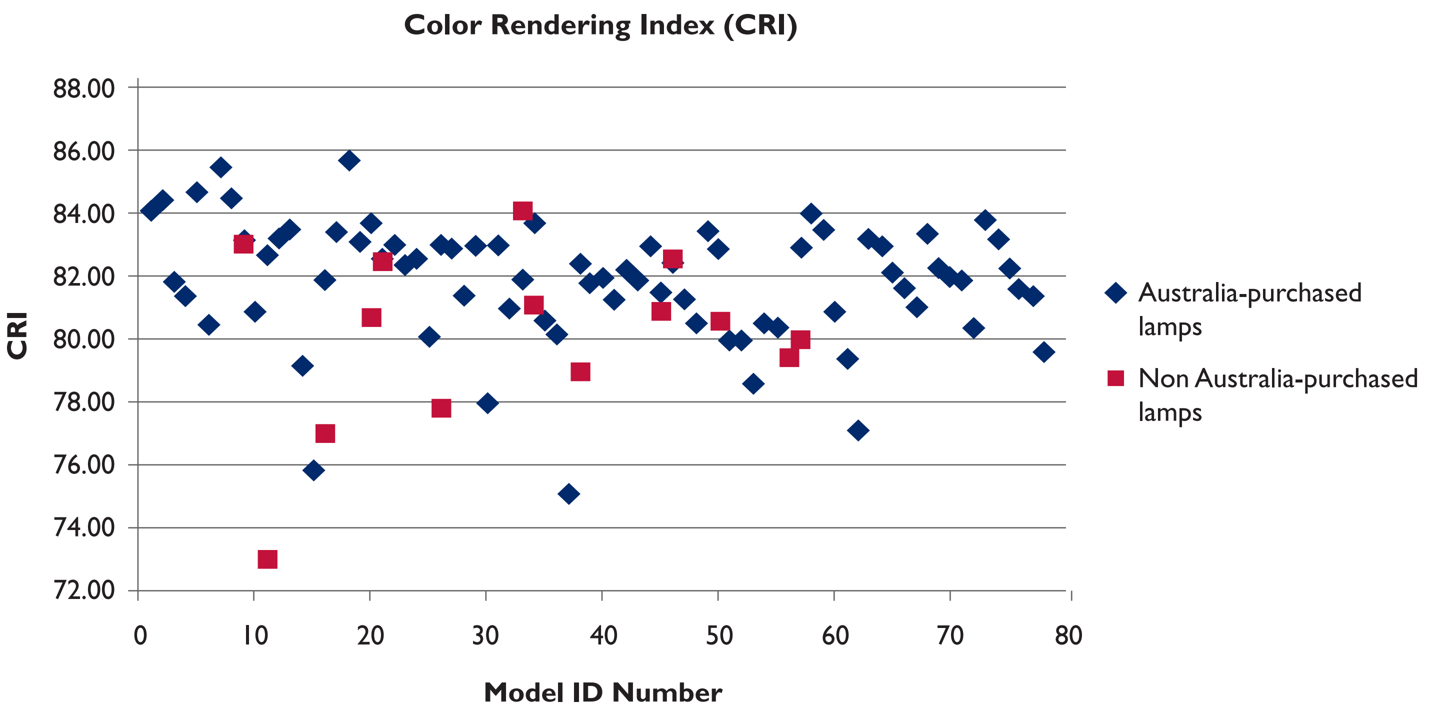
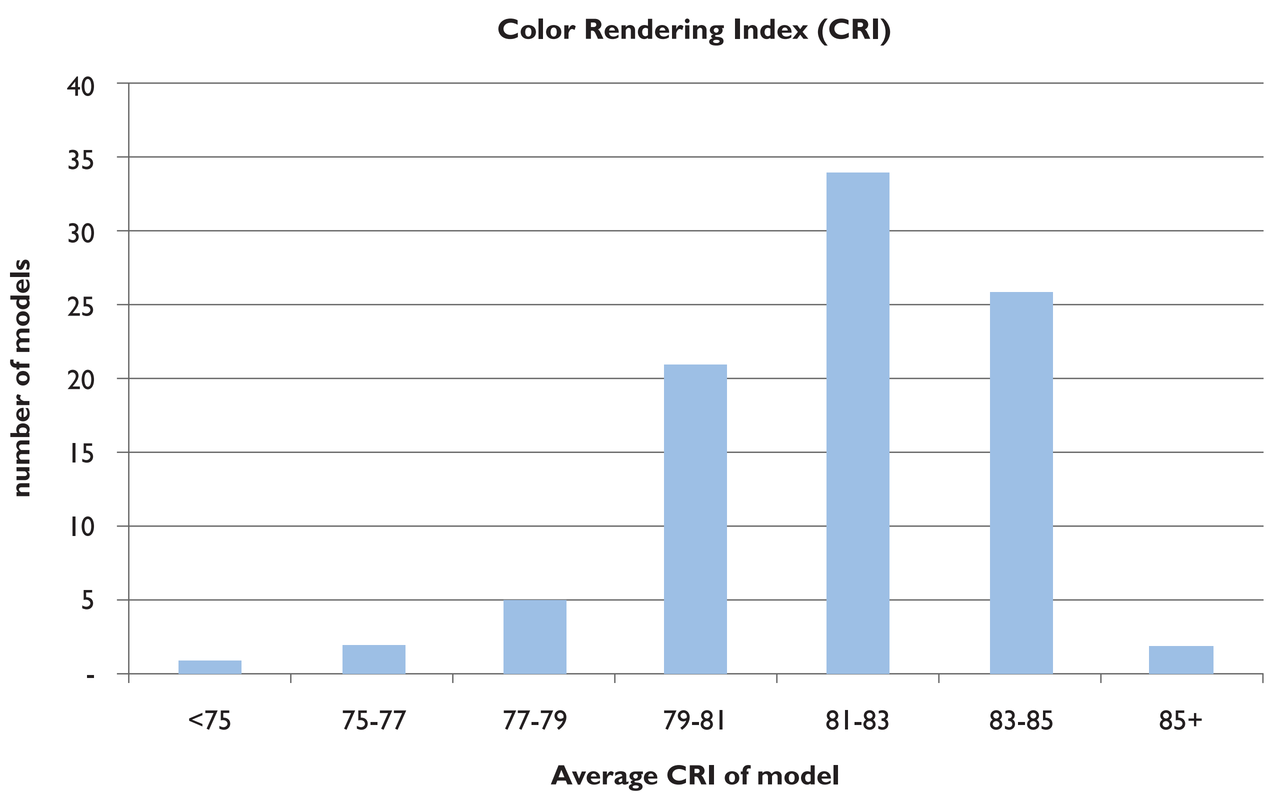


Table 7: CRI Test Pass Rate for ALC Tiers 1, 2 and 3

	Tier 1	Tier 2	Tier 3
Australia-purchased lamps	87.0%	87.0%	87.0%
Non Australia-purchased lamps	53.3%	53.3%	53.3%
All Models	81.5%	81.5%	81.5%

Figure 22. CRI Test results Separated Into Bins



ALC Tiers 1, 2, and 3 require CRI values of 80 or higher. **Table 7** and **Figure 24** present the CRI test pass rates for just the 91 models for which CRI was measured. A large discrepancy is seen between CRI pass rates from the Australian models and those from non-Australian models. It is unknown if this is a real effect that would have been documented had CRI testing of all non-Australian models been performed, or if this is a statistical anomaly due to the relatively small sample of non-Australian models tested for CRI (only 15 of the 46 non-Australian models were tested).

ALL METRICS

It is possible to produce an estimated pass rate for all 137 models tested by sorting them into models that passed all five tests above from those which failed one or more of the tests. There are limitations to this estimate, however, based on deviations between the ALC requirements and the tests performed. The primary limitations to be noted include:

1. Pass rates only based on 5 requirements:
Only the five tests discussed here are used to generate

this pass rate. ALC's CFL Quality Guidelines has many other requirements (such as maximum run-up time, maximum mercury content, switching cycle test survival, safety and labeling requirements, etc.). Thus, it is possible that a CFL model could pass the 5 tests discussed here, but still not conform to the ALC Guidelines because of other requirements.

2. Limitations related to CRI testing: While all 137 models were tested against four of the metrics, only 91 were tested against CRI. For the 91 models that were tested to all five metrics, they were required to pass all five requirements for the various tiers to be considered to have passed all metrics. But for the 46 models that were not tested for CRI, we were forced to assume a 100% pass rate for the CRI test when calculating their "passes all metrics" test. Of the 46 models that were given this "free pass" on CRI, 31 had passed all the other Tier 1 tests, 30 passed Tier 2 tests and 3 passed Tier 3 tests. Thus for Tiers 1 and 2, approximately two thirds of the models that did not get tested for CRI would have had their "all metrics" pass/fail test riding on the result of the CRI test. The effect of the missing CRI test on Tier 3 is limited, however, as most models had already failed at least one other of the test criteria.

3. Tier 3 Survival Rate: The survival rate test was applied at 2,000 hours rather than 3,000+ hours.

4. Tier 3 Lumen Depreciation Rate: The lumen depreciation test specified at 2,000 hours was applied, but test required at 6,000 hours and 10,000 hours were not.

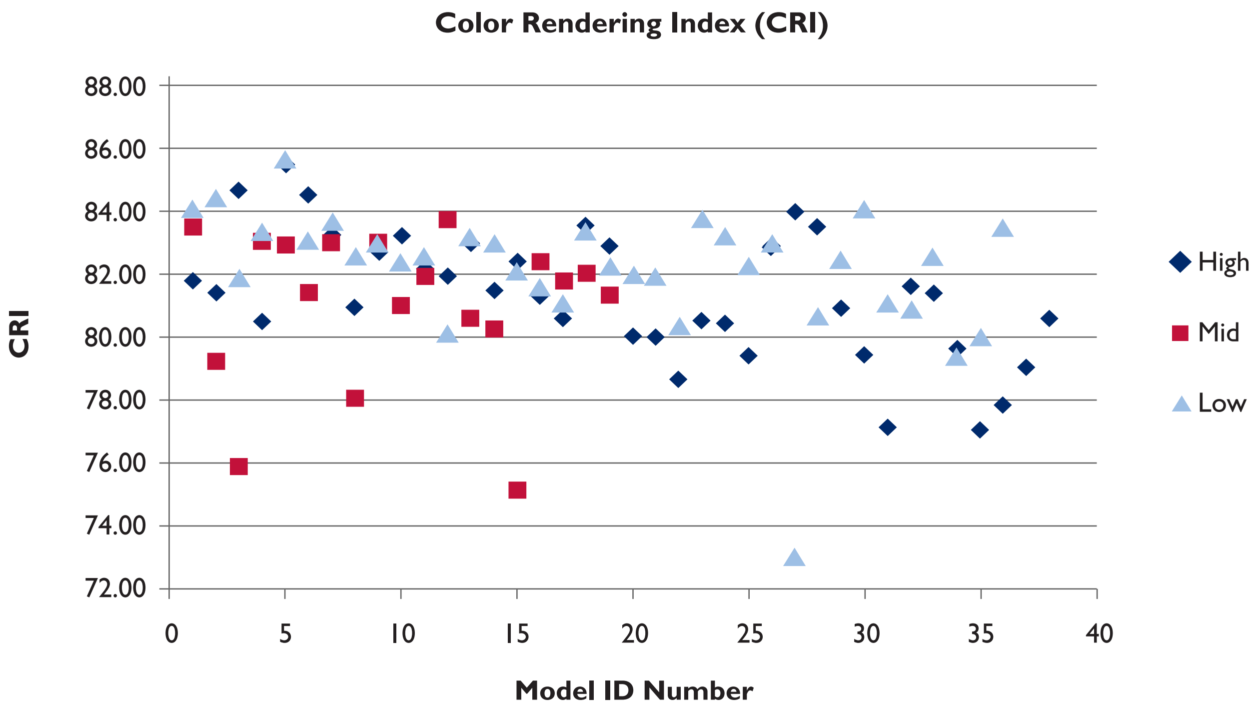
All of the limitations listed above could result in an overestimation of the pass rates for the 137 models tested. For that reason, the pass rates listed below should be considered as a "ceiling" rather than a definitive estimate on compliance rates.

Table 8 and **Figure 25** present the pass rates against all tested metrics, subject to the limitations listed above.

Table 8: Pass Rate for all Tested Metrics[33]

	Tier 1	Tier 2	Tier 3
Australia-purchased lamps	67.5%	53.2%	16.9%
Non Australia-purchased lamps	65.0%	63.3%	10.0%
All Models	66.4%	57.7%	13.9%

Figure 23. CRI Test Results by Brand Type[34]



33. It is important to note that none of the lamps tested claimed to be EST certified, so that the passing rate for Tier 3 should only be viewed as the current state of the lamps available on the market only.

34. See footnote 27.

Figure 24. **CRI test pass rate for ALC Tiers 1, 2 and 3**

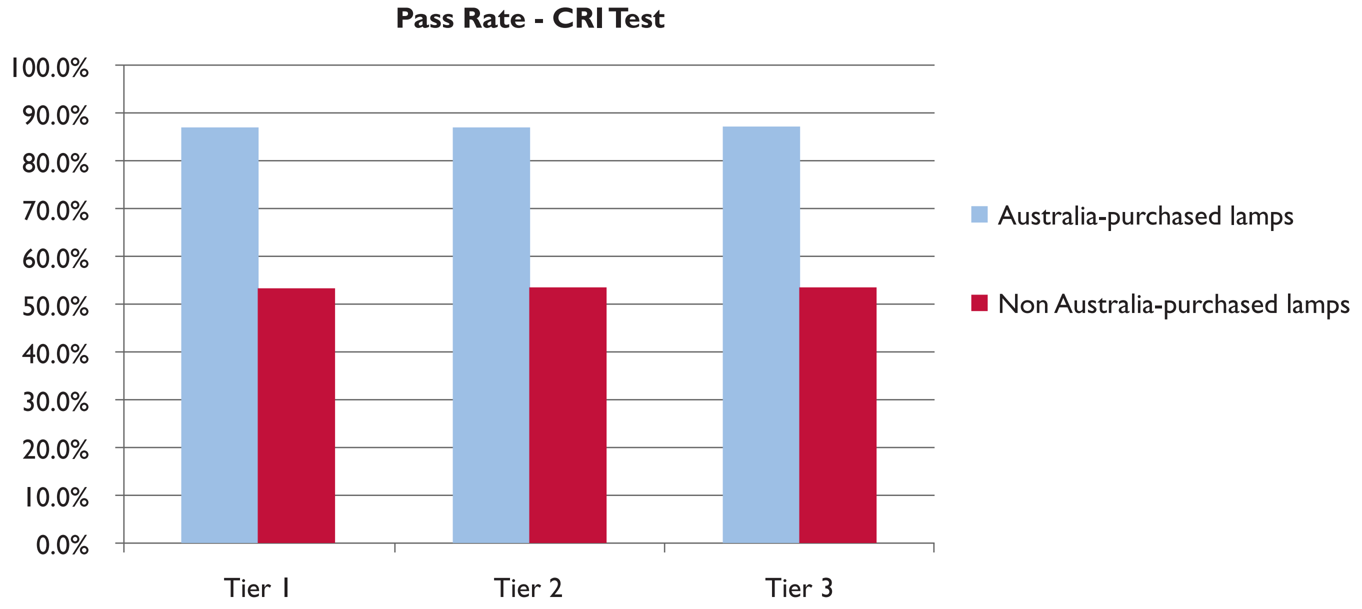
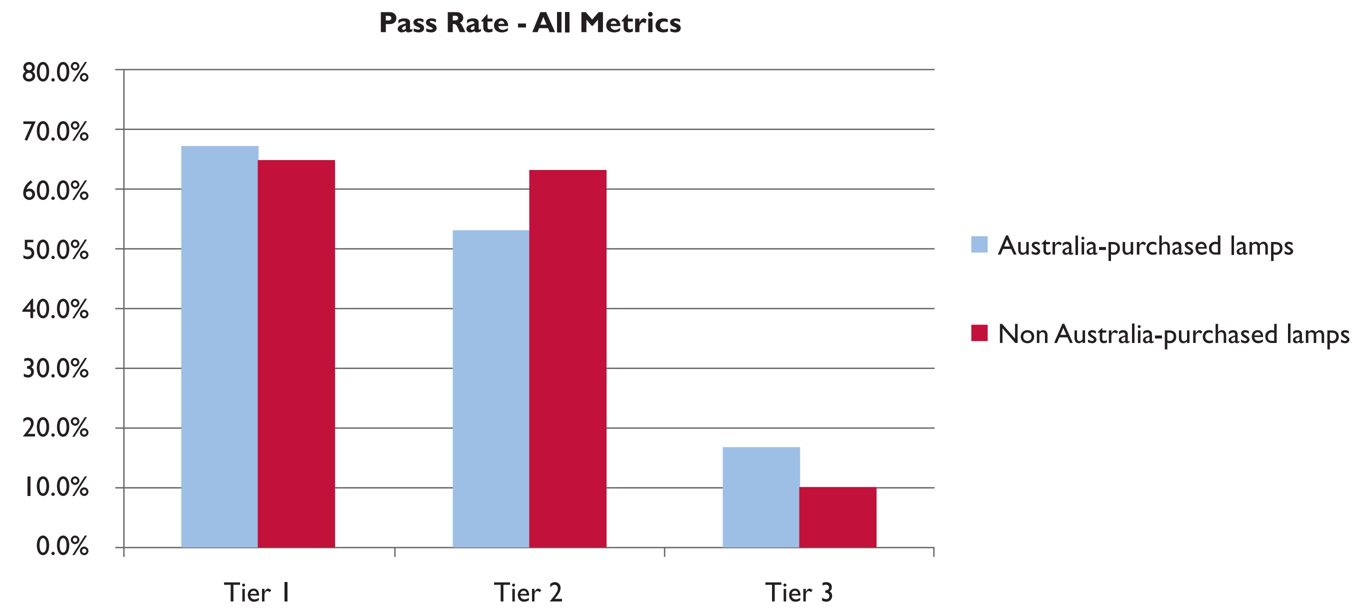


Figure 25. **Pass Rate for All Tested Methods**



TEST RESULTS—LAMP MERCURY CONTENT

A subset of the lamp models was tested for their mercury content. A total of 43 randomly selected models from all three selection categories (high/medium/low) from the six countries were tested using one of the available methods for testing mercury content of fluorescent lamps—*AS/NZS 4782.3-2006 (int) Part 3: Double-capped fluorescent lamps—Performance specifications, Part 3: Procedure for quantitative analysis of mercury present in fluorescent lamps.* The results are presented below.

As can be seen from the test results presented in **Figure 26**, although the average range of the tested models centers around 6.5 mg to 7.5 mg depending on the purchase location (ALC Tiers require lamps to have less than 5 mg of mercury), the range of the lamp mercury content can be quite broad (note that the chart is capped at 20mg). It can be seen that lamps with higher average mercury content are present in all markets: the right half or the high mercury content side of the chart contains lamps from all 6 countries tested.

Further, as can be seen in **Figure 27**, when the mercury content lamps are considered against the lamp costs, some of the lower priced lamps also have much higher mercury content relative to lamps with higher costs or from more well-known manufacturers. This could be due to the fact that more well-known and international manufacturers have invested in more advanced manufacturing equipment that can better control mercury dosing, and/or use amalgam mercury rather than liquid mercury in their lamps.

It should be noted that the results presented here should be treated as a preliminary investigative results only, and not a definitive characterization of mercury content in CFL in Asia. This is due to:

1. Sample Size: A limited sample size: not all lamps models were tested for mercury content

2. Test Method: The test methodology was chosen for its simpler process and repeatability over its ability to produce exact results.[35]

3. Commonly Accepted Methodology: There were on-going discussions taking place by IEC to select a commonly accepted method during the testing process.

35. In fact, the abilities of mercury test methodologies to yield exact results are still under discussion as of late 2009.

Figure 26. **Mercury Content of Selected CFL Models (note: Chart Capped at 20 mg)**

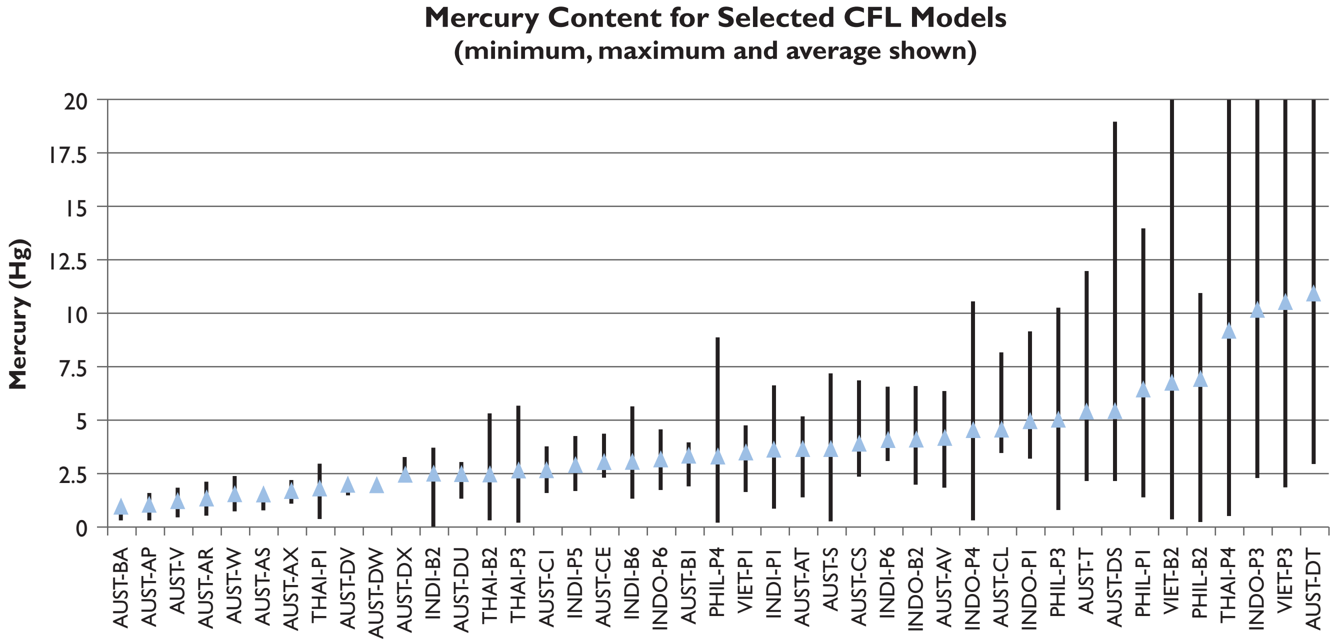
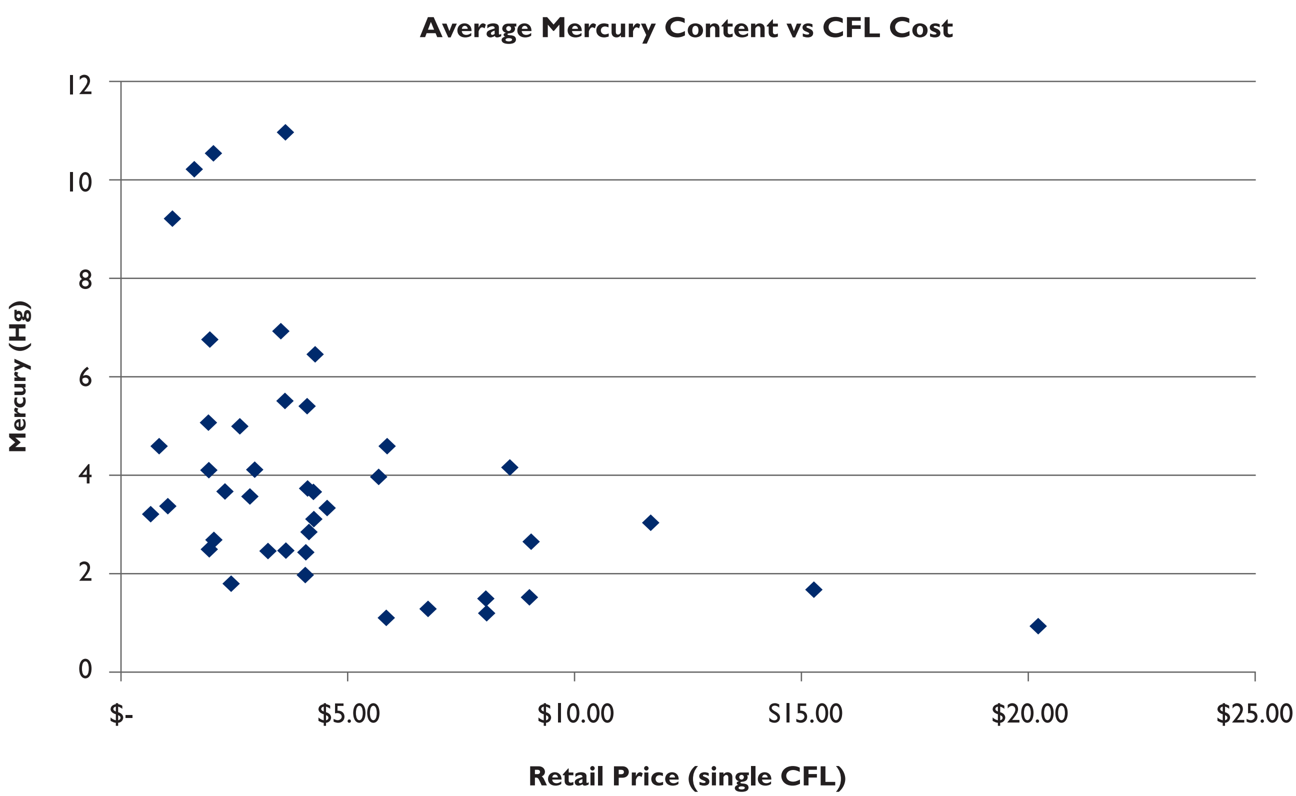


Figure 27. **Mercury Content of Versus Lamp Cost**



CONCLUSIONS AND RECOMMENDATIONS

Anecdotal evidence has long suggested that there are significant quality issues with CFLs in Asian markets. Prior reports have estimated that as much as half of the CFLs in some Asian markets are shoddy.[36] The results presented in this report, although representing only a snapshot of these dynamic markets, are the first hard data to back up this anecdotal evidence and estimates from earlier reports.

The following are some of the main conclusions that can be drawn from the results of this testing effort:

- Laboratory evaluation of a representative sample of CFLs from five Asian countries and Australia found that at least one-third of the sample failed to meet what may be considered as minimum performance standards (or the criteria for what may be considered a "quality" lamp) for the region.

- The overall failure[37] rate as well as the failure rate for each of the tiered comparison, are likely to be significantly higher. This is due to: a) limitations in the laboratory testing, and b) the fact that it was possible to evaluate only a subset of all required metrics for each Tier.

- At least 90% of tested products do not meet the requirements of the tier comparisons, or European equivalent standards, suggesting that CFLs produced for and marketed to Asian and Australian markets are manufactured to lower standards that those of Western markets.[38]

- The generalization of "you get what you pay for" was largely accurate based on the test results, with name-brand models performing better than low-priced models in most cases against most metrics.

It should be noted that ECO-Asia has released two earlier reports covering the Asia CFL market with a number of policy recommendations for the region. Those policy recommendations remain valid in the context of improving overall product quality, international and regional cooperation, as well as greenhouse gas emissions reduction. It is also important to reiterate the two reports' assertion that sub-standard CFLs are a significant policy problem that requires immediate, coordinated regional actions.[39]

With the formation of the Asia Lighting Compact and the release of the ALC's CFL Quality Guidelines, which present a comprehensive set of CFL quality standards developed and based upon internationally accepted standards by regional stakeholders, there is now a set of quality standards that could be recognized and applied across the region. The ALC along with other actors in Asia can and need to work together in order to scale up the discussions of CFL promotion to the international level, and to forge an agreement on common solutions, before a combination of policy missteps and consumer backlash limit the potential expansion of the regional and global CFL market.

36. *Confidence in Quality: Harmonization of CFLs to Help Asia Address Climate Change.* USAID Asia. October 2007.

37. "Failure" as used in this context, indicates that the average of results from the tested samples of a particular CFL model does not meet a defined performance level (i.e., for efficacy, power factor or CRI), rather than a physical or mechanical failure that renders the lamp inoperative. This applies to all parameters evaluated except for the survivability test results, which indicate actual lamp failures.

38. Note that none of the lamps tested claimed certification for European standards.

39. From *Phasing in Quality:* "High-level policymakers must recognize that while CFLs represent a viable and cost effective tool for climate change mitigation, the prevalence of low-quality (i.e. sub-standard, or shoddy) CFLs in the market represents a significant barrier to the full realization of this strategy for the whole region."

The findings of this study suggest that a number of regional measures specific to CFL testing and market monitoring, as outlined below, need to be broadly considered.

- A regional agreement on a common test procedure, a data-sharing plan, and ways to mutually recognize test results across nations is needed among standards and enforcement agencies. There is a pressing need for a uniform, recurring, regional, if not international, process to test and assure the quality of CFLs sold in the region. Such regular efforts can serve both to inform policymakers on the state of the market, and also to insure the integrity of labeling programs.

- Government agencies, the private sector (including manufacturers and retailers of CFLs), and non-governmental organizations (NGOs) in the region should take concrete actions to increase user awareness of high-quality CFL products and ways to identify them, as well as support independent actions such as the ALC to ensure that quality products are available for all Asia.

- A number of countries in the region need technical assistance in setting up the infrastructure (testing facility, development of standards, training of laboratory personnel, etc.) to certify the performance of CFLs, as well as in recycling CFLs and dealing with end-of-life issues, including mercury content and safe lamp disposal.

- More testing is recommended to corroborate these initial findings. This would be particularly useful for CFL models intended for the very large and quickly growing Chinese market.

- The issue of mercury content and dosing control in the production of CFLs merit a second, focused round of testing efforts that can cover more of the regional markets, and may also help to inform mercury recycling and educational programs.

- The value of a robust, harmonized set of quality standards cannot be understated. With such a mechanism, well-performing products could be identified independently, allowing purchasers to select products based on value (price) while being assured of at least a minimum level of performance

Although CFLs have been shown to be one of the most significant and cost-effective measures that can be deployed to achieve reduction of greenhouse gas emissions, this calculation can be dramatically altered by poor-quality products. A regional, coordinated testing and data-sharing program among standards and enforcement agencies can form a significant barrier to prevent lower-quality products entering the Asian market.

APPENDIX

Asia Lighting Council Compact Fluorescent Lamp Quality Guidelines for Bare Lamps Version 1.1 May 2009

1.0 GENERAL INFORMATION

1.1 Purpose

The Asia Lighting Council (ALC) seeks to promote quality compact fluorescent lamps (CFLs or CFLIs) in order to increase the protection of consumers from exposure to sub-standard products, to increase protection of manufacturers from unfair competition, to deliver the improvements in energy performance planned by mandatory or voluntary schemes, and to reduce emissions of greenhouse gases through reduction in electricity consumption.

The ALC aims to stimulate the uptake of high quality CFLs by promoting a set of common quality criteria and setting performance levels for qualified CFLs for sale in the Asia region, and promote the adoption of these guidelines by stakeholders. Full details of the overall Asia Lighting Council's founding principles – the Manila Compact – can be found at www.cleanenergyasia.net.

This document defines the technical requirements that are required for a CFL in order to qualify for the ALC Product Marking. Protocols on the Ongoing Monitoring of products, Application Procedures and processes are available separately. Failure of any product to meet any or all of the requirements set out in this protocol will result in that product not being qualified to bear the ALC product mark. The use of ALC's product mark without qualifications may result in ALC actions against the product manufacturer.

1.2 Scope

Version 1.0 of these guidelines below, covers the requirements for bare CFLs with integral electronic ballasts (CFLi) only. CFLs which have translucent or reflector envelopes over the bare fluorescent tube are not covered. A product must meet all of the guidelines' quality performance criteria for its product tier in order to qualify.

1.3 Reference Standards

ALC qualified CFLs shall comply with the relevant clauses of the following standards:

- AS/NZS 4782.3-2006 (int) Part 3: Double-capped fluorescent lamps - Performance specifications, Part 3: Procedure for quantitative analysis of mercury present in fluorescent lamps. (Notes: 1. This standard shall be superseded by the IEC reference standard once the IEC standard is available; 2. JEL 303-2004, referenced below, can be used as an alternative method for determining mercury content of lamps).

- CISPR 15 Ed 7.1 (2007), Amendment 2 (2008) - Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment.

- Energy Saving Trust: Lamp Specification, Version 6.1 – 2009.

- IEC 60968 Ed. 1.2 b:1999. Self-ballasted lamps for general lighting services - Safety requirements.

- IEC 60969 Ed. 1.3 b:2009. Self-ballasted lamps for general lighting services - Performance requirements.

- IEC 61000-3-2 Ed. 3.0 (2005), Amendment 1 (2008) - Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).

- IEC 61547 Ed. 1.0 b:1995. Equipment for general lighting purposes - EMC immunity requirements.

- JEL 303-2004, Standard of Japan Electric Lamp Manufacturers Association. Practical quantitative analysis procedure for mercury containing in fluorescent lamps.

(Notes: 1. This standard shall be superseded by the IEC reference standard once the IEC standard is available; 2. AS/NZS 4782.3-2006 (int.) Part 3, referenced above, can be used as an alternative method for determining mercury content of lamps).

2.0 TECHNICAL REQUIREMENTS

2.1 Testing Requirements

The performance of CFLs to be qualified under the ALC process should be tested using the standards referenced in Section 1.3.

The safety of CFLs to be qualified under the ALC process should be tested using the standards referenced in Section 1.3.

The EMC of CFLs to be qualified under the ALC process should be tested using the standards referenced in Section 1.3, as applicable.

2.2 Quality Performance Criteria

Table 2.3.1. Criteria with levels that vary with tier

Criteria	Asia Lighting Council Guidelines Criteria Requirements					
	Tier 1		Tier 2 (ELI- Equivalent*)		Tier 3 (EST 6.1 - 2009**)	
Efficacy (lumens per Watt)					Attachment A, Figure 1 for Class 1 lamps	
Wattage bins/CCT	≤ 4500K	> 4500K	≤ 4500K	> 4500K	≤ 4500K	> 4500K
< 5W	40	36	45	42	4W = 32	4W = 26
5W to < 9W	44	40	50	46	8W = 43	8W = 39
9W to < 16W	48	44	55	52	15W = 53	15W = 48
16W to < 25W	55	51	60	57	24W = 60	24W = 54
≥ 25W	60	57	65	62	35W = 65	35W = 59
Lifetime	6,000 hours		8,000 hours		10,000 hours	
Lumen maintenance	80% of measured 100-hour lumen level after 2,000 hrs		80% of measured 100-hour lumen level after 2,000 hrs		88.1% @ 2,000 hrs 78.1% @ 6,000 hrs 75.1% @ 10,000 hrs	
Colour (x,y)	Within 7 color steps (SDCM) per the IEC standard		Within 5 color steps (SDCM) per the IEC standard		IEC 60081 Graph D-16 for CCT of 2700K	

* ELI Voluntary Technical Specification for Self-Ballasted Compact Fluorescent Lamps 2006-03-01.
** Energy Saving Trust Lamp Specification 6.1 – 20

Table 2.3.2. With minimum threshold levels

Criteria	Asia Lighting Council Guidelines Criteria Requirements		
	Tier 1	Tier 2	Tier 3 (EST 6.1 - 2009**)
Start-up time	1.5 seconds maximum		2.0 seconds maximum
Premature failure	Not more than 10% failure within 1,000 hours		Maximum 10% failure at 30% of rated life
Run-up time	Up to 3 minutes to reach 80% of light output (should be aligned with changes in IEC standard)		≥ 60% of light output after 1 minute
Color rendering index (CRI)	≥ 80		≥ 80
Power factor	≥ 0.5		0.55 for "normal" 0.9 for "high"
Mercury content	≤ 5 mg		≤ 5 mg
Switch withstand test	At least 3,000 cycles based on cycle of 270 seconds off and 30 seconds on*		NA
Safety	Products should meet safety regulations per IEC 60968		Comply with EN 60968, 61547 for transient protection
EMC and harmonics	Products should meet safety regulations per CISPR 15, IEC 61547, IEC 61000-3-2		1. EN 61000-3-2 for supply current harmonics 2. EMC EN 55015 3. EMC EN 62547

* ELI Voluntary Technical Specification for Self-Ballasted Compact Fluorescent Lamps 2006-03-01.
** Energy Saving Trust Lamp Specification 6.1 – 20

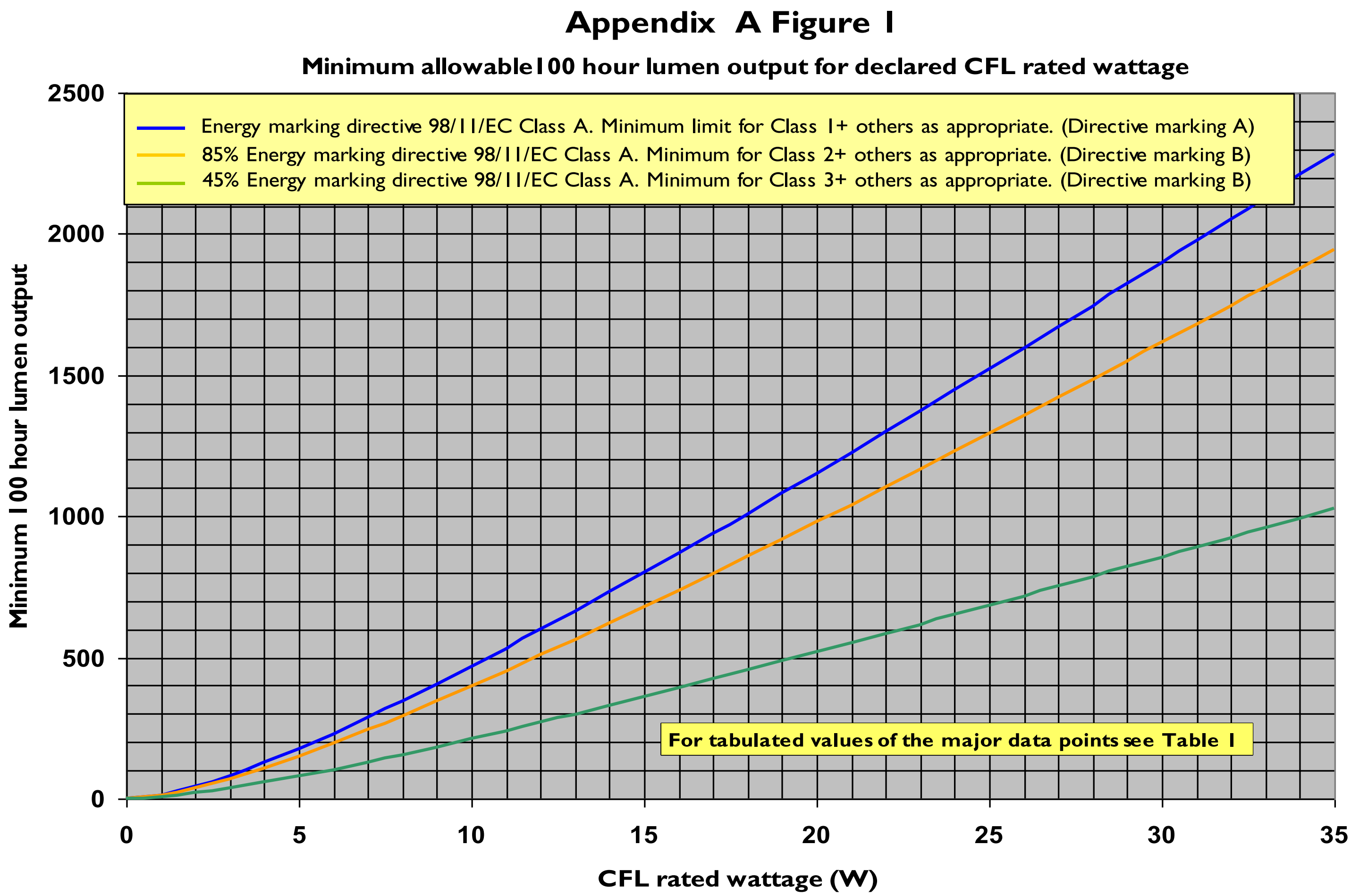
Table 2.3.3. **Passing Conditions**

Category	Requirements for Each Tier	Passing Performance	Sample Size	Additional Conditions/ Clarification
Initial Efficacy	Tiers 1 and 2: As defined by colour temperature and wattage in section 2.3.1. Tier 3: Per Section 3.4.1 of EST 6.1 - 2009	Tiers 1 and 2: 1. Average of calculated values for all lamps equal to, or higher than, tier requirement and 2. Average value equal to, or higher than manufacturer declared value if shown and 3. Initial luminous flux of all samples must be ≥ 90% of the rated value. Tier 3: Must be above values given by upper curve given in Appendix A, Figure 1.	Tiers 1 and 2: Minimum 10 lamps (Minimum 9 lamps if one sample fails prematurely before 100 hour testing complete) Tier 3: 20 Lamps, unless otherwise indicated by IEC standard.	Tiers 1 and 2: 1. Luminous flux divided by wattage, both measured at 100 hrs. 2. Average of all samples or of remaining lamps in case of early burn out. 3. A 3% tolerance is allowed (pending decision by IEC). Tier 3: Maximum 10% reduction in initial lumen values for CCT > 5000K.
Lifetime	Tier 1: 6,000 hours Tier 2: 8,000 hours Tier 3: 10,000 hours. Per Section 3.4.2 of EST 6.1 - 2009		Tiers 1 and 2: Minimum 10 lamps. Tier: 3 20 Lamps, unless otherwise indicated by IEC standards.	Tiers 1 and 2: Rated value self-declared Tier 3: Declared median lamp life should not be less than 10,000 hours
Lumen Maintenance	Tiers 1 and 2: 80% of initial (100-hour) average lumen output Tier 3: Per Section 3.4.3 of EST 6.1 – 2009	Tiers 1 and 2: 1. Average measured lumen output measurement to be greater than 80% measurement and 2. No more than 3 individual samples can have a lumen output measurement less than 80%. Tier 3: Must be above values given by the specified curve in Appendix A Figure 2.	Tiers 1 and 2: All remaining samples from Initial Efficacy Test (Minimum 6 samples must remain operational for valid result) Tier 3: 20 Lamps, unless otherwise indicated by IEC standard.	Tiers 1 and 2: Measurement at 2,000 hours
Lamp Wattage Rating	Tiers 1 and 2: Average wattage ≤115% of rated value.	Tiers 1 and 2: Average of calculated values for all lamps	Tiers 1 and 2: Minimum 10 lamps (Minimum 9 lamps if one sample fails prematurely before 100 hour testing complete)	Tiers 1 and 2: 1. Rated value self-declared 2. No lower wattage limit

Category	Requirements for Each Tier	Passing Performance	Sample Size	Additional Conditions/ Clarification
Lamp Operating Voltage	Tiers 1 and 2: All lamps must start at minimum declared voltage.	Tiers 1 and 2: All lamps must start at minimum declared voltage	Tiers 1 and 2: Minimum 10 lamps (Minimum 9 lamps if one sample fails prematurely before 100 hour testing complete)	Tiers 1 and 2: Rated voltage self-declared
Lamp Lumen Rating	Tiers 1 and 2: Initial luminous flux of all samples must be ≥ 90% Tier 3: Per Section 3.1.5 of EST 6.1 - 2009	Tiers 1 and 2: 1. Initial luminous flux of all samples must be ≥ 90% of the rated value or 2. Implied lumen output, based on rated efficacy and rated wattage Tier 3: Must not be below values given by the specified curve in Appendix B Figure 1.	Tiers 1 and 2: Minimum 10 lamps (Minimum 9 lamps if one sample fails prematurely before 100 hour testing complete) Tier 3: 20 Lamps, unless otherwise indicated by IEC standard.	Tiers 1 and 2: Rated values self-declared
Start-up Time	Tiers 1 and 2: 1.5 seconds maximum Tier 3: Per Appendix D of EST 6.1 – 2009 (2 seconds)	Tiers 1 and 2: At least 5 lamps shall start within 1.5 s Tier 3: The average lumen output shall be >=20% of the average final stabilised light output after 2 seconds.	Tiers 1 and 2: Minimum 6 lamps Tier 3: 20 Lamps	
Premature Failure	Tiers 1 and 2: Not more than 10% within 1,000 hrs Tier 3: Per Section 2.4.1 of EST 6.1 - 2009		Tiers 1 and 2: Minimum 10 lamps Tier 3: 20 Lamps unless otherwise indicated by IEC standard	
Run-up Time	Tiers 1 and 2: Up to 3 minutes to reach 80% of 100 hrs luminous flux Tier 3: Per Appendix D of EST 6.1 - 2009	Tiers 1 & 2: All samples must reach 80% value within 3 minutes Tier 3: At 60 seconds, the average lumen output shall be >= 60% of the average final stabilised light output	Tiers 1 and 2: Minimum 6 lamps Tier 3: 20 Lamps.	
CRI	Tiers 1 and 2: 80 minimum Tier 3: Per Section 3.1.8 of EST 6.1 - 2009	Tiers 1 and 2: 1. Average of all samples ≥ 80 and 2. No more than 2 individual samples can have a CRI value of < 77 Tier 3: Average of all samples shall not be <80	Tiers 1 and 2: Minimum 6 lamps Tier 3: 20 Lamps	

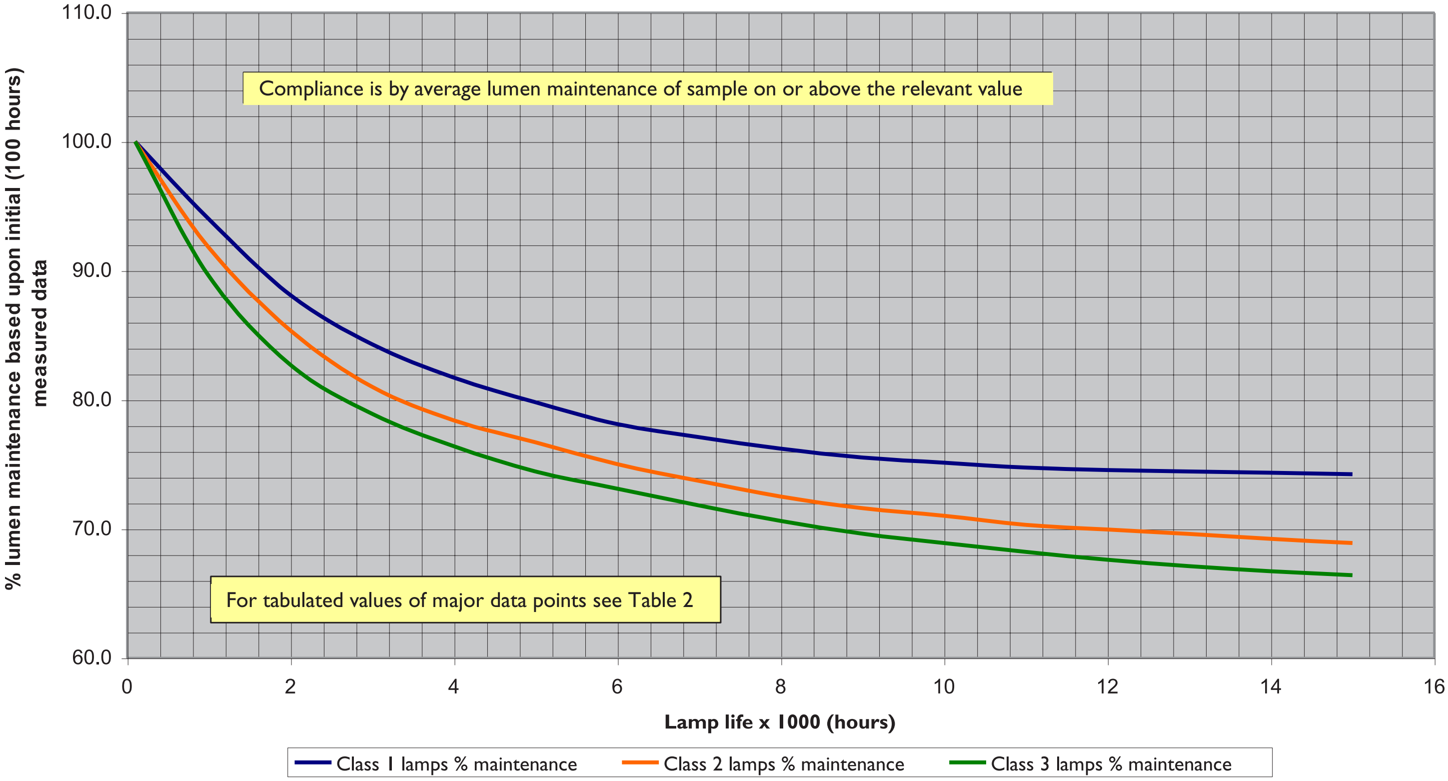
Category	Requirements for Each Tier	Passing Performance	Sample Size	Additional Conditions/ Clarification
Power Factor	Tiers 1 and 2: No less than 0.5 Tier 3: Per Section 3.1.9 of EST 6.1 - 2009	Tiers 1 and 2: Average of all samples must be 0.5 or greater. Tier 3: Power factor shall not be < 0.55	Tiers 1 and 2: Minimum 6 lamps Tier 3: 20 Lamps	
Mercury	Tiers 1 and 2: Maximum of 5 mg Tier 3: Per Appendix K of EST 6.1 - 2009	Tiers 1 and 2: 1. Average of all samples ≤ 5mg and 2. No more than 2 samples can exceed 5.5mg Tier 3: Submission requirements for WEEE	Tiers 1 and 2: Minimum 5 lamps (unique samples required)	
Rapid Cycle/Switch Withstand	Tiers 1 and 2: Minimum 3,000 cycles Tier 3: NA	Tiers 1 and 2: No more than 2 failures allowed	Tiers 1 and 2: Minimum 10 lamps (unique samples required)	
SDCM	Tier 1: Within 7 SCDM of declared value Tier 2: Within 5 SCDM or declared value Tier 3: Per Section 4.1.3 of EST 6.1 - 2009	Tiers 1 and 2: All samples to comply Tier 3: Comply with the requirements of the relevant section/graph of IEC 60081	Tiers 1 and 2: Minimum 6 lamps Tier 3: 20 Lamps	Tiers 1 and 2: Rated value self-declared
EMC	Tiers 1 and 2: Compliance with: CISPR15, IEC 61547, IEC 61000-3-2 Tier 3: Per Section 3.2.5 of EST 6.1 - 2009	Tiers 1 and 2: Comply with the relevant clauses. Tier 3: Comply with relevant clauses of EN 55015 and EN 61547	Minimum1 Lamp	Tiers 1 and 2: When interpreting the results of harmonics using IEC 61000-3-2, the laboratories should carefully read the instructions and be aware that the harmonics targets are different for low-wattage lamps (< or = 25 W) vs. high-wattage (> 25 W) lamps.
Safety	Tiers 1 and 2: Compliance with: IEC 60968 Tier 3: Per Section 3.1.1 of EST 6.1 - 2009	Tiers 1 and 2: Comply with the relevant clauses. Tier 3: Comply with the relevant clauses of IEC 60969	Tiers 1 and 2: All Lamps	Tiers 1 and 2: Compliance to be verified by certified laboratory

ATTACHMENT A: ENERGY SAVING TRUST LAMP SPECIFICATION VERSION 6.1 2009 – REFERENCED FIGURES AND TABLES



Appendix A Figure 2

Minimum limit for lumen maintenance of primary Classes 1,2 and 3 lamps, and any other CFL Class as detailed in the specification, at any time through life



Appendix B Figure 1

Standard EN 60064 tungsten filament lamp rating equivalence claim requirements

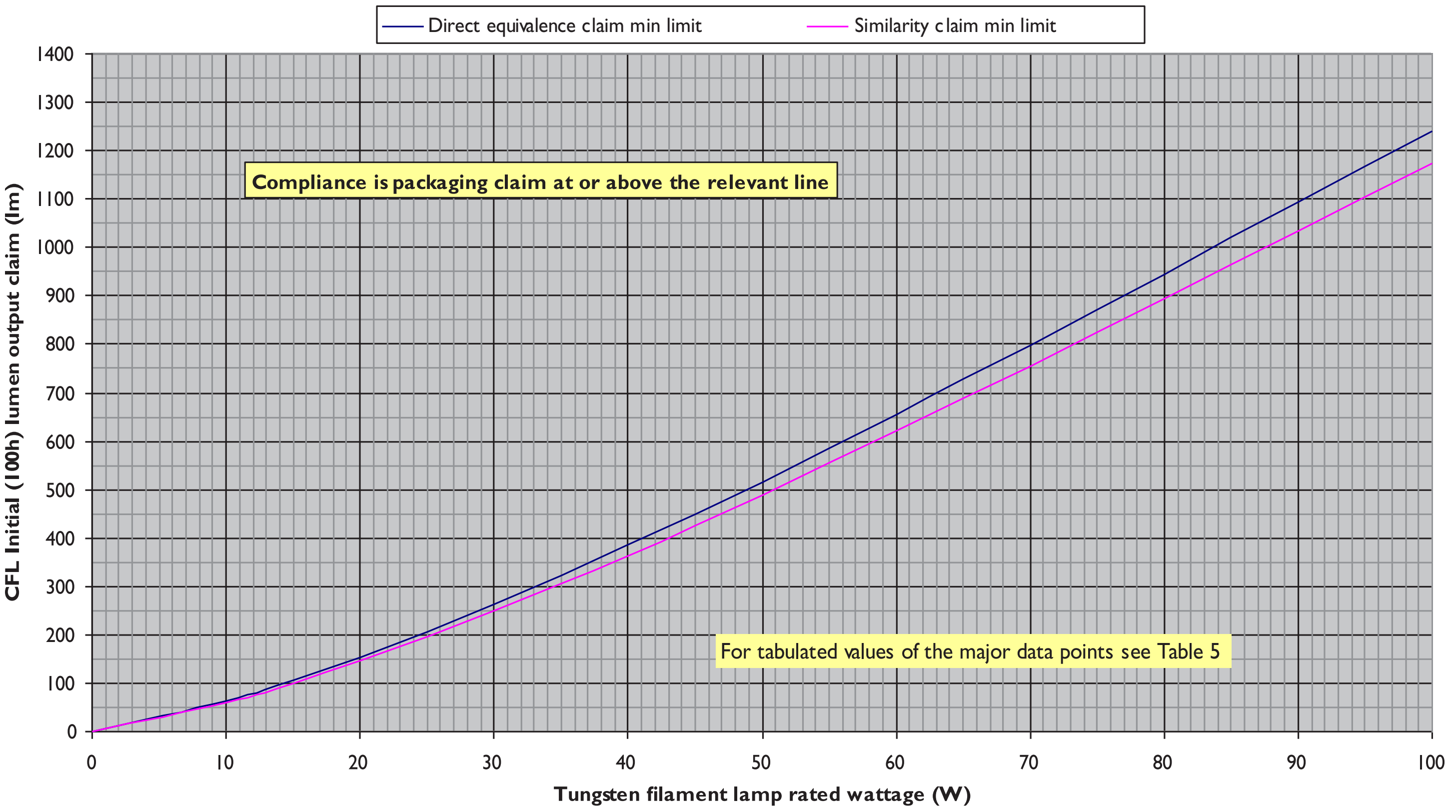


Table 1. **Table of values used in Appendix A Figure 1**

	Lumens		
Lamp Wattage (W)	Minimum for A rated lamps class 1+ other relevant classes	Minimum for B rated lamps class 2+ other relevant classes	Minimum for B rated lamps class 3+ other relevant classes
0	0	0	0
1	13	11	6
2	42	36	19
3	81	69	37
4	126	107	57
5	176	150	79
6	230	195	103
7	286	243	129
8	344	292	155
9	405	344	182
10	467	397	210
11	531	451	239
12	596	507	268
13	663	563	298
14	730	620	328
15	798	678	359
16	867	737	390
17	937	797	422
18	1008	857	454
19	1079	917	486
20	1151	979	518
21	1224	1040	551
22	1297	1102	584
23	1370	1165	617
24	1445	1228	650
25	1519	1291	684
26	1594	1355	717
27	1669	1419	751
28	1745	1483	785
29	1821	1548	820
30	1898	1613	854
31	1975	1678	889
32	2052	1744	923
33	2129	1809	958
34	2207	1876	993
35	2285	1942	1028

Table 2. **Table of values used in Appendix A Figure 2**

	% Maintenance		
Lamp Life Hx1000	Class 1 lamps	Class 2 lamps	Class 3 lamps
0	100.0	100.0	100.0
1	94.0	91.8	89.6
2	88.1	85.4	82.7
3	84.3	81.0	78.9
4	81.7	78.4	76.4
5	79.8	76.7	74.4
6	78.1	75.0	73.1
7	77.1	73.7	71.8
8	76.2	72.5	70.6
9	75.5	71.6	69.6
10	75.1	71.0	68.9
11	74.7	70.3	68.2
12	74.5	69.9	67.6
13	74.4	69.6	67.1
14	74.3	69.2	66.7
15	74.2	68.9	66.4

Derived from Energy Marking Directive 98/11/EC

Table 3. Table of values used in Appendix B Figure 1

GLS Rated Wattage	Direct equivalence claim min limit	Similarity claim min limit
(watts)	(lumens)	(lumens)
0	0	0
10	65	61
15	107	101
20	154	146
25	206	195
30	262	248
35	322	304
40	384	363
45	449	425
50	516	489
55	585	554
60	656	620
65	727	688
70	799	756
75	872	825
80	946	895
85	1019	965
90	1093	1034
95	1167	1104
100	1241	1174

Tabulated values derived from available EN60064 minimum lumen requirements

Table 4. Table of values used in Appendix B Figure 2

"Soft" Coated GLS tungsten filament lamp wattage	Direct equivalence claim min limit	Similarity claim min limit
(watts)	(lumens)	(lumens)
5	25	24
10	57	54
15	95	90
20	138	131
25	187	176
30	239	226
35	295	279
40	354	335
45	415	393
50	479	453
55	544	515
60	610	577
65	677	641
70	745	704
75	812	765
80	879	831
85	945	894
90	1010	955
95	1073	1016
100	1135	1074

Tabulated values derived from manufacturers average performance claims

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