Assessment of Opportunities for Global Harmonization of Minimum Energy Performance Standards And Test Standards for Lighting Products

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BY

Collaborative Labeling and Appliance Standards Program (CLASP)

in Partnership with en.lighten

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Acronyms

ALC	Asia Lighting Compact
APEC	Asia-Pacific Economic Cooperation
ANSI	American National Standard Institute
AS/NZS	Australian and New Zealand national standard
ASSIST	Alliance for Solid-State Illumination Systems and Technologies
CCT	Correlated Color Temperature
CAGR	Compound Annual Growth Rate
CFL	Self-ballasted Compact Fluorescent Lamp
CFLi	International CFL Harmonization Initiative
CORM	Council for Optical Radiation Measurements
CQS	Color Quality Scale
CALiPER	DOE Commercially Available LED Product Evaluation and Reporting Program
CLASP	Collaborative Labeling and Appliance Standards Program
ES	ENERGY STAR
ELI	Efficient Lighting Initiative
EST	Energy Saving Trust
ESIS	Energy Standards Information System(APEC)
EU	European Commission
FTC	Federal Trade Commission
GB standard	China National Standard
HID	High Intensity Discharge Lamp
IEA	International Energy Agency
IEC	International Electrotechnical Commission
LED	Light Emitting Diode
IL	Incandescent Lamp
ISO	International Organization of Standardization
LRC	Lighting Research Center
MEPS	Minimum Energy Performance Standard
NA	Not Applicable
NGO	Non-governmental organization
ROI	Return on Investment
S&L	Standards and Labeling
SDCM	Standard Deviation of Color Matching
SEAD	Super-Efficient Equipment and Appliance Deployment Initiative
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
US	United States

Executive Summary

Lighting is responsible for 19% of the world's electricity consumption and constitutes 7% of global carbon dioxide (CO_2) emissions (IEA 2006) equal to the combined total emissions of Germany and Japan. Governments have a pivotal role to play in accelerating the adoption of energy-efficient lighting in their countries. This role could consist of one or more actions around regulatory measures, labeling, and market-pull incentives as well as efforts around communication and harmonization with other countries. For example, a government may choose to establish energy regulations that prohibit the sale of inefficient lighting technologies, favoring adoption of high efficiency, good quality and cost effective alternatives. Or, a government could also engage in labeling activities that help ensure that the energy costs and lighting efficacy are visible to the market at both the product and the system level.

In 2009, the United Nations Environment Programme (UNEP) initiated the Global Market Transformation for Efficient Lighting Project, known as the en.lighten initiative – Efficient Lighting for Emerging and Developing Countries. One of the key goals of the en.lighten project is to try and facilitate the harmonization of lighting standards at a global level. In order to do this effectively, it is imperative to have a detailed understanding of the best regulatory practices in the lighting sector and a robust assessment of the current state-of-the-art in energy-efficient lighting technologies, both on- and off-grid.

The objective of this report is to assess the test procedures and minimum energy performance standards (MEPS) for compact fluorescent lamps (CFLs) and light emitting diode (LED) lamps across multiple regions including: Africa, Asia-Pacific, China, Europe, India, Latin America, the Middle East and North America. Based on the test procedures and MEPS reviewed, this report:

- Identifies similarities and gaps between the various regions and economies;
- Describes some key market trends in energy-efficient lighting;
- Examines the potential opportunities, benefits and barriers to the alignment of multiple regions/economies to a single, global test procedure and MEPS;
- Provides recommendations on steps that could further progress toward alignment to a single, global test procedure and common specifications for MEPS where possible; and
- Identifies potential steps toward market transformation initiatives that encourage rapid market uptake of new energy-efficient lighting technologies.

METHODOLOGY

CLASP conducted an exhaustive literature review and desk-study of international and national CFL and LED test procedures, MEPS and related documentation including labeling and performance and quality requirements in Africa, Asia-Pacific, China, Europe, India, Latin America, the Middle East and North America. These data were then synthesized to produce a comparative analysis of CFL and LED performance levels and quality criteria across the selected countries and regional economies. This report reflects the findings of CLASP's analysis of this literature and our salient findings and recommendations to UNEP's en.lighten program.

KEY FINDINGS

Although many lighting products are more energy-efficient than incandescent lamps, CFLs and LEDs are two outstanding products with key roles to play in the global efforts to phase out incandescent lamps. CFLs are a widely used, reliable, and internationally traded efficient lighting source that has been commercially available for decades. LEDs are an emerging technology, in a rapid technological improvement phase, and are regarded by many experts as the "next generation" efficient light source.

CFL quality is a major issue of concern in many countries. This is due to: (1) fierce market competition, which results in some manufacturers prioritizing cost reductions over quality; (2) a lack of CFL regulatory performance requirements in many countries; (3) the absence of a harmonized global system for testing and rating CFL quality; (4) a lack of market monitoring, verification and enforcement (MV&E) of CFL regulatory and quality standards; and (5) a general lack of consumer awareness about CFL quality.

Although there are many national MEPS and performance requirements for CFLs worldwide, there are differences between them due to uncoordinated efforts in the standards making processes. The proliferation of, and variation between, CFL regulations and performance requirements (e.g., operating life, lamp run-up time, power factor, lumen maintenance) has created a regulatory patchwork that is undesirable, ineffectual and costly. This situation prevents consumers from distinguishing good-quality from poor-quality CFLs, increasing the risk that they may gravitate toward lower-priced products, exacerbating the proliferation of lower-quality products.

For CFL testing standards, several countries reference a handful of international test standards, including IEC 60969-2001, IEC 61000-3-2, and CIE 13.3. Although not every major economy references these international standards, there exists the potential that countries could harmonize around a set of common global test procedures, including tests to measure electrical and photometric performance, electromagnetic interference and colorimetry.

With regard to LEDs, the main issue of concern is the difficulty in determining a product's reliability and quality. This issue is due to: (1) the relative immaturity of LED performance test procedures supporting the market; (2) a lack of harmonized international MEPS and quality standards to control the quality of LEDs traded internationally, which may contribute to market spoiling (i.e., poor consumer experience with LED products); and (3) a lack of labeling and endorsement schemes to help governments and consumers identify and consume quality LED products.

LED standards development is at a stage similar to where CFLs were twenty years ago. Most LED lighting products are manufactured in a few countries for global distribution, and a few leading countries have already published product performance and test standards. However, the available LED standards have limited coverage of LED products, and significant variations exist between the product scope and test methods of the different standards. **It would be advantageous for countries to coordinate their LED performance standard and test methods in order to avoid repeating the same mistakes made with CFLs.**

CONCLUSIONS AND RECOMMENDATIONS

CLASP has clustered our recommended actions designed to encourage harmonization of standards and labeling of CFLs and LED lamps into the following areas: (1) communication, (2) test methods, (3) labeling, and (4) MEPS. Each area has several potential recommended actions which would help achieve the overall objective of harmonization for CFLs and LED lamps.

Summary of Recommendations and Conclusions

Area	Objective	Actions
I. Communication	Encourage, facilitate and expand the communication and sharing of information between regulators, test experts, consumers and other stakeholders.	*I.A Improve transparency of regulatory processes and communication between regulators* *I.B Raise awareness among consumers about high-quality, energy-efficient CFLs and LED lamps*
II. Test Methods	Align methods of measurement and metrics of performance for CFLs and LED lamps.	*II.A Support the development of international harmonized test methods, coordinated around review cycles* *II.B Develop a framework to promote the global recognition of test data around the use of consistent test methods and certified laboratories*
III. Product Labeling	Develop consistent, uniform labeling schemes that recognizably communicate energy-efficiency	*III.A Establish a framework for setting labels or establishing a quality mark* *III.B Develop a global voluntary "reach" efficiency standards and labeling system*
IV. Minimum Energy Performance Standards	Align current energy performance requirements and potentially establish forward-looking, ambitious regulatory requirements	*IV.A Develop an international framework for harmonizing MEPS for CFLs and LED lamps*

Each of these potential actions is discussed in more detail below, in some instances with explicit recommendations on first steps that could be taken.

I. Communication

Objective: Encourage, facilitate and expand the communication and sharing of information between regulators, test experts, consumers and other stakeholders.

I.A. Improve transparency of regulatory processes and communication between regulators

Even when a policymaker knows that both they and another country are simultaneously regulating a product, it can be difficult to find relevant technical and policy information that could valuably transfer from one policy environment to the other. One of the reasons these difficulties may arise, or be more problematic to address, is because not all aspects of the regulatory process are in the public domain. Openness and transparency of the standard-making process can enhance communication among standard-making authorities. This in turn can increase the potential for international harmonization of standards.

Establishing an international mechanism to facilitate better communication between the national regulators will enable multi-lateral technical level information sharing and collaboration on testing, technology, market and other issues associated with the development of efficiency standards. Currently, there are a few international initiatives such as the United States / European Commission (US/EC) cooperation, the International Energy Agency's (IEA) 4E Solid-State Lighting (SSL) Annex, and the Super-Efficient Equipment and Appliance Deployment (SEAD) program that promote standards harmonization. A combined, coordinated effort by these organizations could help advance both the technology roadmap and standards harmonization. They can also work together to arrive at the recommended performance and quality categories, as well as recommended product categories, test methodologies, data sharing plans, etc. suitable for and acceptable to agencies and stakeholders globally.

<u>Action</u>: UNEP's en.lighten initiative could collaborate with SEAD to develop a comprehensive global information sharing resource for the standards development of lighting products, starting with LED lamps. Each country may need to establish lead technical-team points of contact, and organize information sharing discussion between their respective teams of experts working on active areas of collaboration at least once per quarter during periods of regulatory development and analysis.

I.B. Raise awareness among consumers about high-quality, energy-efficient CFLs and LED lamps

The increased adoption of high-quality, energy-saving CFLs and LEDs provides an opportunity for mitigating global climate change, while also enhancing international collaboration on common clean energy challenges. A move toward this as well as increasing regulatory transparency and sharing of analysis fits well with the current state of awareness and support for global harmonization efforts.

<u>Action</u>: UNEP's en.lighten initiative could work to improve communication about CFL and LED quality to consumers. UNEP could work to take a coordinating role engaging governments, manufacturers of CFLs and LEDs (and their associations), NGOs and social-impact groups to increase end-user awareness of the importance of promoting high-quality CFL and LED products. This communications strategy could include a global promotional network, a large scale marketing program to raise awareness, and other outreach efforts.

II. Test Methods

Objective: Align methods of measurement and metrics of performance for CFLs and LED lamps.

II.A. Support the development of international harmonized test methods, coordinated around review cycles

For CFLs which are a mature product with approximately 30 years in the market, countries should be encouraged to work toward aligning their respective test methods in future scheduled revisions.

For instance, all countries could consider harmonizing around a consistent set of IEC and CIE test methods as the basis for common test procedures on quality and energy performance of CFLs.

Action: UNEP en.lighten could commission a comprehensive technical study comparing all aspects of the IEC, CIE and ANSI/IESNA test methods for CFLs, with recommendations on how these test methods could be combined into one consistent test method.

For LEDs, due to the recent emergence of the LED general illumination industry, there are only a handful of testing standards with the IEC and ANSI/IESNA as the leading reference standards. For LEDs, the aim should be to secure the adoption of harmonized test requirements and efficiency metrics as there are currently very few adopted around the world at this time. Therefore, it's an excellent opportunity for countries to work collaboratively on the development and adoption of new, harmonized test procedures for LED lamps.

Action: UNEP en.lighten could partner with proactive global and regional stakeholders working on LED standards, such as IEA's 4E SSL Annex, to extend country participation, provide technical and administrative resources, and ultimately assist in helping to ensure the process moves quickly toward the drafting of one test method that can be adopted by the appropriate international bodies.

As with CFLs, international organizations such as the IEC are where these global test procedures should be maintained. The idea behind these proposed actions is to organize a process or a forum which can help to generate material for the IEC technical committees to review and adopt. These supportive activities should reduce the burdens on the technical experts who volunteer their time at the IEC, and enable them to accelerate adoption of a harmonized global test method.

II.B. Develop a framework to promote the global recognition of test data around the use of consistent test methods and certified laboratories

Countries can enhance international cooperation on quality testing of CFLs and LED lamps through efforts to extend the global recognition of test data. Countries could be supported to conduct random testing of samples from the market, and publishing those test results for sharing across the globe. In addition, countries and national and international test agencies should consider initiating cross-country round-robin testing to compare a laboratory's capacity to test lighting products, including CFLs and LED lamps. These round-robin tests improve the general testing capability, and ensure a level play field for manufacturers producing high quality lighting products.

Each country could establish lead technical teams with designated points of contact and organize information sharing discussions between the teams to actively work on areas of collaboration. Such technical level collaboration will reveal harmonization opportunities and increase the likelihood of maximizing cost-effective reductions in energy use and emissions for participating countries.

Action: UNEP en.lighten could establish this framework to facilitate global cooperation on test methods for CFLs and LED lamps. Key tenets of this framework would include: (1) random sampling, testing and publication of test results; (2) a round-robin testing to compare test quality and reliability across multiple jurisdictions; and (3) identify points of contact within each participating country who can organize information sharing and collaboration within their country.

III. Product Labeling

Objective: Develop consistent, uniform labeling schemes that recognizably communicate energy-efficiency.

III.A. Establish a framework for setting labels or establishing a quality mark

While it may be difficult to arrive at a customer-facing categorical label about energy-efficiency that is accepted in all countries around the world, there is the potential to establish a business-to-business label similar to the one for external power supplies which is marked on virtually all products sold globally. This type of approach could be very effective in certifying and communicating energy performance on both CFLs and LED lamps. The quality mark for LEDs could be designed to include unassigned label categories, as LEDs are projected to improve their energy-performance significantly over the next decade.

Action: UNEP en.lighten could be partner with existing regional initiatives such as the Asia Lighting Council (ALC) CFL Quality Charter and EC's Joint Research Centre (JRC) European LED Quality Charter to establish a framework around the establishment of a regional quality mark or label that would be applicable to CFLs and one for LED lamps. These initiatives should be designed to have the potential to be applied globally.

Due to the special characteristics of LED lighting, the development of LED standards needs to pay careful attention to evaluating the system, not simply the LED itself. It's the whole replacement lamp –LEDs, driver, lens, heat sink and housing – the overall system that should be assessed and marked in the performance label.

Countries could benefit by working together to find common ground on minimum quality ratings, and develop common performance quality standards. There is a need for agreement on CFL and LED performance and quality levels that are recognized across nations, focusing on a common set of criteria covering all aspects of CFL and LED performance, not just a few attributes.

Action: UNEP en.lighten could bring nations together around this issue of quality CFLs and LED lamps, and support the work to identify the minimum performance specification that will ensure all sub-standard lamps are identified, so they can be blocked from importation or manufacture.

III.B. Develop a global voluntary "reach" efficiency standards and labeling system

In order to ensure that CFLs and LED lamps are pushed to the highest achievable efficiency levels, UNEP en.lighten may consider supporting the development of a global voluntary "reach" efficiency standard that recognizes the top 10% of products in the global market. UNEP could work to help develop a market-based Top Runners Program for highly efficient products and manufacturers to stimulate the enthusiasm of industry and promote market transformation to high quality CFLs and LED lamps.

Action: UNEP en.lighten could establish a global "reach" efficiency standard for CFLs and LED lamps that is ambitious in terms of efficacy and quality standards, pushing manufacturers to compete for recognition in a program focused on identifying premium products.

IV. Minimum Energy Performance Standards

Objective: Align current energy performance requirements and potentially establish forward-looking, ambitious regulatory requirements.

IV.A. Develop an international framework for harmonizing MEPS for CFLs and LED lamps

Countries need to work together to identify opportunities to harmonize MEPS when such harmonization is feasible, legally permissible, and consistent with other program objectives.

In dealing with the inaccuracy of LED performance claims in the market, government regulators can establish a LED certification scheme to certify LED products with high quality standards, and promote high quality LED products in the market by conducting outreach to help inform manufacturers and retailers about best performing products.

Harmonization of MEPS for CFLs is not easy thing to do, due to the existence of a large number of MEPS across the globe, and it requires time-consuming process to reach political consensus. Compared to CFL, LED is at a right stage of standard development with better conditions for international harmonization of MEPS, as no LED MEPS have been established yet.

Action: UNEP en.lighten could create an international framework that would prioritize harmonization of MEPS for CFLs and LED lamps, recognizing the critical juncture for both of these products in the market as the global incandescent phase-out commences.

This support needs to involve updating energy efficiency standards in countries with existing standards, in order to reflect changes in industry and consumer expectation, and with enhanced communication with international best practices, to pursue a greater degree of harmonization of standards. Efforts need to be made to harmonize country-specific MEPS to ones that can help improve the quality of CFLs and LED lamps, save energy, and achieve the maximum degree of alignment with international best practices. Activities undertaken in this framework could include support and training for countries with poor technical knowledge and that are unable to identify and evaluate efficient lighting options to develop MEPS standards, certain capacity training and technical support.

1.Introduction

Lighting is responsible for 19% of the world's electricity consumption and constitutes 7% of global CO_2 emissions—a quantity equal to the combined total emissions of Germany and Japan ((IEA 2006)). And lighting consumption is significant across the various market segments - in the EU for example, lighting accounts for about 10.5% of a home's electricity use (EC JRC 2011). In China, lighting accounts for about 12% of the country's electricity consumption (UNDP 2008). New technology and incremental improvements on existing lighting products have yielded a range of new energy-efficient lighting solutions, including compact fluorescent lamps (CFLs), light emitting diodes (LEDs), halogen, and fluorescent lamps—delivering an equivalent amount of light while using less energy. These lighting solutions are widely available in the market, and present an opportunity for consumers, businesses, governments and all other segments of economies to save money while enjoying equal or better levels of lighting service.

Governments have a pivotal role to play in accelerating the adoption of energy-efficient lighting in their countries. This role could consist of one or more of actions around regulatory measures, labeling, and market-pull incentives as well as efforts around communication and harmonization with other countries. For example, a government may choose to establish energy regulations that prohibit the sale of inefficient lighting technologies, favoring adoption of high efficiency, good quality and cost effective alternatives. Or, a government could also engage in labeling activities that help ensure that the energy costs and lighting efficacy are visible to the market at both the product and the system level.

Over the last decade, the world has witnessed a rapid increase in national efforts to lift the threshold of energy-efficiency standards and eliminate inefficient products from the market. Many countries have also expanded and increased the stringency of endorsement and comparative labeling programs, thereby recognizing and improving the visibility of high efficiency products. Taken together, these government-led efforts encourage manufacturers to bring more efficient products to the market. Australia, China, the European Union (EU), Japan and the United States (US) are leaders among the global efforts toward development of standards and labeling (S&L) initiatives in the lighting sector, and have benefitted from achieving significant energy savings.

Outside of individual countries' efforts, a number of multilateral and bilateral initiatives are actively working to transform the global lighting market, including: the Asia Lighting Compact (ALC) under USAID ECO-Asia Clean Development and Climate Program; and European LED Quality Charter developed by the EC JRC; the International Finance Corporation's Efficient Lighting Initiative (ELI); lites.asia; the IEA 4E SSL Annex; and the Super-Efficient Equipment and Appliance Deployment Initiative (SEAD). These initiatives promote and coordinate global efforts to accelerate market adoption of energy-efficient lighting. Each of these initiatives may have a different focus, but they generally advocate for the global commercialization and market adoption of efficient lighting technologies by working cooperatively with government agencies, international organizations, manufacturers, testing laboratories, lighting associations, retailers and other stakeholders. These efforts accelerate the widespread adoption of energy-efficient lighting products and thereby reduce greenhouse gas emissions.

Overall, the global trend has been toward the development of unique, national approaches to regulatory standards and labeling. This leaves industry with an array of compliance requirements for different countries / territories. The aforementioned multilateral and bilateral initiatives are working to try and reverse this trend, encouraging regional harmonization of lighting requirements in the EU, US and other countries and regions in Asia and South America.

In 2009, the United Nations Environment Programme (UNEP) commenced its Global Market Transformation for Efficient Lighting Project, known as the en.lighten initiative – Efficient Lighting for Emerging and Developing Countries. En.lighten aims to become an umbrella initiative for the promotion of efficient lighting in the target countries and thereby reduce greenhouse gas (GHG) emissions from lighting.

One of the key goals of the en.lighten project is to facilitate the harmonization of lighting standards at a global level, starting with CFLs and LED lamps. In order to do this effectively, UNEP needs a detailed overview of best regulatory practices for these products and an awareness of the current state-of-the-art for these light sources.

OBJECTIVE OF THIS REVIEW

This report compiles test procedures and minimum energy performance standards (MEPS) for CFLs and LEDs in Africa, Asia-Pacific, China, Europe, India, Latin America, the Middle East and North America. Based on the data collected, the report presents an assessment of the test procedures and MEPS globally, and identifies key gaps and similarities between them.

This report also examines the opportunities for the alignment of various economies to one global test procedure and corresponding MEPS for CFLs and LEDs. It provides recommendations on possible steps for policymakers and the en.lighten project to undertake that will encourage and accelerate the global uptake of energy-efficient lighting technologies.

2. The Global Efficient Lighting Market

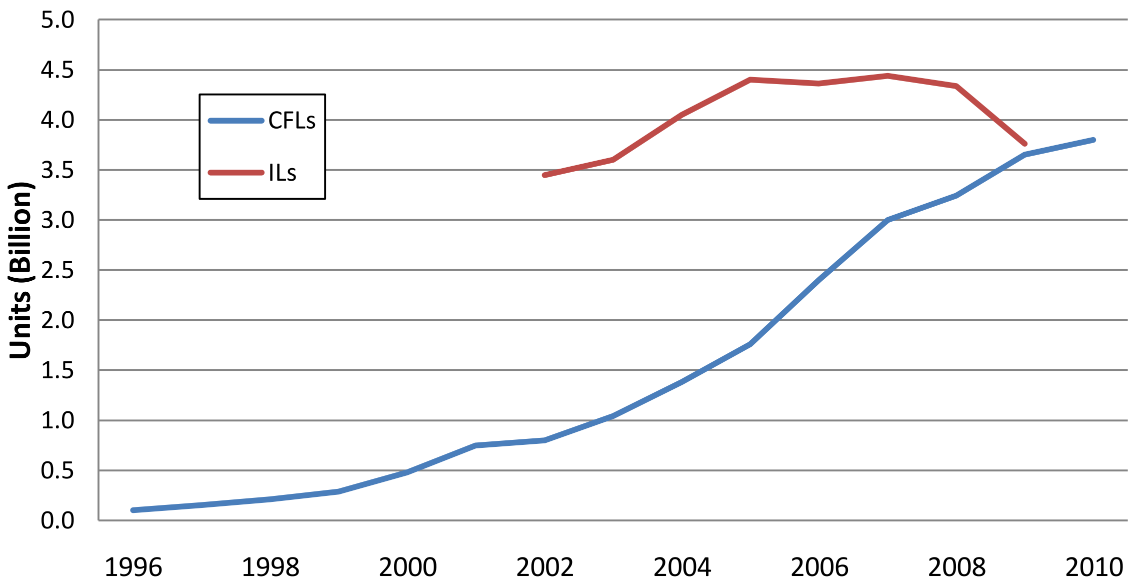
2.1 Compact Fluorescent Lamps (CFLs)

National and local efforts to promote energy-efficiency have been gathering strength worldwide in the past decade, spurred by heightened concerns over issues of energy security, environmental degradation and climate change. Many of these efforts include programs targeting lighting. To date, more than 40 countries around the world have announced plans to phase out the use of incandescent lamps, with CFLs being promoted as a direct, readily-available, and cost effective alternative.

Integrally-ballasted CFLs can be installed in a standard (mains voltage) light socket, and operate in a similar way to a miniature fluorescent lighting system. The CFL consists of a lamp and ballast, permanently connected, and an end-cap for installing the CFL into a light socket. The lamp is a narrow glass tube lined with a phosphor that produces light when electricity is passed through the tube. The ballast starts and maintains the flow of electricity through the tube, and is designed to operate on standard mains voltage (e.g. 120V, 240V), thus CFLs are commonly used as direct replacements for incandescent lamps.

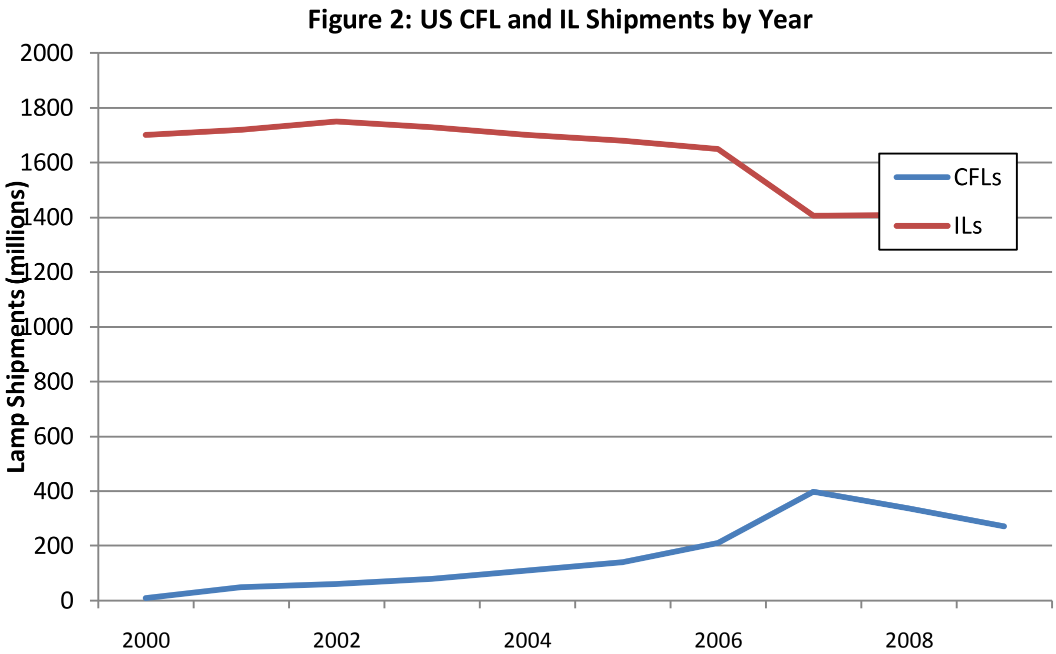
The international market for CFLs has expanded rapidly in recent years. Global production of CFLs in 2009 was estimated to be about 4.75 billion units, and incandescent lamps (ILs) were about 11.2 billion units(CALI 2010). China is the leading manufacturing economy, producing about 80% of the world's CFLs, and about one-third of the worlds' total ILs (CALI 2010). Figure 1 illustrates the steady growth of CFL production in China particularly over the last 10 years. This growth stands in stark contrast with IL production that went into decline starting in 2007.

Figure 1: CFL and IL Production in China



Sources: CALI 2010

The figure below estimates national shipments of compact fluorescent and incandescent lamps in the US (ENERGY STARENERGY STAR 2010). Although the US adopted regulations in 2007 that will phase-out ILs, these regulatory standards haven't yet taken effect and will only start being phased-in on January 1, 2012. Thus, it is expected that starting in 2012, a more pronounced trend in shipments will be observed, with CFL shipments increasing and IL shipments decreasing.



Source: ENERGY STAR CFL Market Profile, Data trends and market insights, September 2010.

Figure 2 and the recent ENERGY STAR CFL Market Profile study indicate that, even in the US, CFLs still have the potential to deliver considerable energy savings in residential lighting. As most US household light sockets still hold incandescent lamps, more than two-thirds of the savings potential from CFLs remains unrealized. Even in states in the US that have long-running and well-funded CFL programs, CFLs only occupy about one in five sockets. In other states, the household average can be as low as one CFL for every twenty sockets (ENERGY STAR 2010). While recent CFL shipments in the US have grown substantially over sales in 2000, shipments of ILs were still five times greater than CFLs in 2009.

CFLs are a long-lasting, energy efficient, and reliable light source that is more cost-effective than ILs. Nevertheless, for the US and many other countries, the potential for CFLs to replace ILs remains high. CFLs are characterized as one of the best available alternatives to replace ILs, and the increasing focus on CFLs has significantly accelerated their global demand. The most dramatic growth in demand occurred in the last decade, and experts are forecasting that CFLs could more than double their 2009 production estimate reaching as many as 10 billion units per year (USAID ECO-Asia 2010) as more countries phase out incandescent lamps.

2.2 Light Emitting Diode (LEDs)

A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current is passed through it. Although the light output from a single LED is less than an incandescent lamp, retrofittable LED-based lamps have been developed recently which incorporate multiple LEDs into one packaged product. Like CFLs, these LED lamps require a ballast (called a “driver”) to convert and regulate mains voltage into an electrical supply that will operate the LEDs.

LED-based lighting products have recently emerged into lighting markets around the world as a credible, energy-efficient, long-lasting, and low-maintenance alternative for commercial and industrial applications. Good quality LED-based lighting products for residential applications have also followed, although many products are not yet considered cost-effective by consumers.

General illumination with LEDs relies primarily on high-brightness (HB) LEDs, which are also used in back-lighting of liquid-crystal display (LCD) monitors and televisions. According to Strategies Unlimited, a market research company based in California that tracks the LED market, the worldwide HB LED market jumped from US$5.6 billion in 2009 to US$10.8 billion in 2010, a growth rate of 93% (LED Magazine 2011). This significant growth was driven primarily by demand for backlights for LCD TVs and monitors, as well as portable device display applications. Strategies Unlimited projects that the total market for HB LEDs will reach US$18.9 billion in 2015, representing a compound annual growth rate (CAGR) of 11.8%. This growth will increase innovation and competition in the market, and will help to continue the downward price trend for LEDs, ultimately making them more affordable for consumers.

In Asia, the market for LEDs is rapidly expanding. For example, China's total LED industry (i.e., HB LEDs and other LED products) revenue was US$6.5 billion in 2008. The industry then experienced an annual increase of over 80% to US$12 billion in 2009 (NLTC 2011). The total LED industry investment in China surpassed US$4.55 billion in 2010, and according to China's national economic plan, LED lighting will account for 30% of the general lighting market in 2015 (NLTC 2011). Experts estimate that the lighting semiconductor industry output in 2015 will exceed US$72 billion, and earn export revenues of US$30 billion (NLTC 2011).

LEDs are generally regarded as the next-generation light source that will replace incandescent lamps and eventually CFLs. In addition to being an energy-efficient light source, LEDs have a number of advantages over CFLs including the absence of mercury; longer lifetimes; and a more durable package (i.e., the CFL's glass tube can be easily broken). The main barrier to LEDs entering the mainstream lighting market is their high production cost which translates into a high sales price. However, LEDs are projected to become much more affordable, driven by efficacy gains and other technological improvements, as well as manufacturing innovations leveraged through massive expansion of the production base to supply the TV and display markets. Due to their value proposition – both in terms of energy and maintenance savings – LEDs are already cost-effective in many commercial and industrial applications.

2.3 Other Lighting Products

There are many other light sources that are more energy-efficient than incandescent lamps. These include linear fluorescent, halogen and high intensity discharge (HID) lamps.

Linear florescent lamps are most often used for commercial purposes such as office, retail and industrial illumination. With the notable exception of some countries including India, the use of linear fluorescent lamps in residential applications is limited. Also, these lamps require a ballast to operate and are not designed to be used as a direct replacement for an incandescent lamp in a standard line voltage socket.

Halogen lamps are similar to incandescent lamps in that they produce light by heating a tungsten metal filament until it becomes so hot that it emits light. Halogen lamps are different from incandescent lamps in that they burn this filament in a small, high-pressure atmosphere containing halogen gases that collect and re-deposit evaporated molecules of tungsten back onto the filament. Halogen lamps can be found both in a directional lamp type format (i.e., reflector lamps) as well as a non-directional format (i.e., replacement for the common pear-shaped general lighting service incandescent lamp). Halogen lamps are about 20-30% more efficient than incandescent lamps, but they are also more expensive and do not achieve the significant efficacy improvements associated with CFLs and LEDs.

HID lamps are similar to fluorescent lamps in that they require a ballast to operate, emit light from a sustained electrical arc, and are energy-efficient. HID lamps include mercury vapor lamps, high pressure sodium lamps and metal halide lamps. Mercury vapor is the least efficient of these three, and is gradually losing market share to metal halide, which offers a much more efficient and better quality white-light. High pressure sodium HID lamps can commonly be found in street-lighting applications, where their yellow-orange light emission is considered satisfactory. Metal halide lamps are an area where industry is continuing to invest and improve the technology, particularly with the development of highly energy-efficient ceramic metal halide which incorporates a ceramic arc-tube in the lamp. HID lamps tend to be used in high-flux applications such as stadium lighting, street and area flood lighting.

Although the three light sources above offer higher efficiency than incandescent lamps, they are generally not designed to be used in residential applications and therefore were not selected as technologies to replace incandescent lamps in this study. On the other hand, CFLs are a reliable, internationally traded efficient light source, and LEDs are an emerging high-efficiency technology. Both CFLs and LEDs can be used as direct energy-efficient replacements for incandescent lamps, and therefore CLASP focuses this analysis of global standards and labeling programs on these two technologies.

3. CFL Standards and Labels Worldwide

Compact fluorescent lamps (CFLs) are an efficient lighting alternative to traditional incandescent light bulbs and have been actively promoted through different policies and initiatives. As CFL technology has matured, CFL efficiency levels have been regulated through mandatory MEPS, mandatory energy information labels and/or endorsement labels across the globe.

3.1 Overview of Global MEPS, Labeling Performance and Test Standards for CFLs

At the time of this report printing, 19 economies have announced mandatory MEPS, 22 economies have voluntary endorsement labels, and 15 economies have issued mandatory energy labels. The details of these programs and schemes are presented in the following Tables 1-3.

Table 1: Minimum Energy Performance Standard (MEPS) - Mandatory for CFLs

Economy	Title
Australia	AS/NZS 4847.2-2010: Self-ballasted lamps for general lighting services - MEPS requirements (07-04-2008)
Brazil	Portaria Inmetro 289/2006 - CFLs (2006)
Chile	MEPS for Residential Lighting (CFLs)
Chinese Taipei	CFL Standard
Colombia	Programme for the Rational and Efficient Use of Energy and Other Non-Conventional Energy Forms(1988)
Ecuador	Draft Technical Regulation RTE INEN 036: Energy Efficiency, Compact Fluorescent Lamps, Energy Performance Ranges and Labeling
EU Member Countries	Draft Commission Regulation implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for non-directional household lamps - CFLs (2005)
Ghana	Ghana Electrical Appliance Labeling and Standards Programme (GEALSP) - Standard for CFLs (30-06-2005)
India	MEPS for CFLs
Mexico	NOM-017-ENER/SCFI-2008: Energy efficiency of compact fluorescent lamps. Limits and test methods (2008)
New Zealand	MEPS for compact fluorescent lamps
Nicaragua	Nicaraguan Mandatory Technical Standard (NTON) No. 10 008-08: Energy Efficiency, Self-Ballasted Compact Fluorescent Lamps, Energy Efficiency Requirements (2008)
Pakistan	Compact Fluorescent Lamps - Pakistan
People's Republic of China	GB 19044-2003:Limited values of energy efficiency and rating criteria of self-ballasted fluorescent lamps for general lighting service (01-09-2003)
Philippines	PNS IEC 969:2006 - Self Ballasted Lamps for General Lighting Service - Performance Requirements (2002)
Republic of Korea	MEPS for Compact Fluorescent Lamps - Korea (01-07-1999)
Thailand	TIS 2310-2549 (2006): Self-Ballasted Lamps for General Lighting Services: Energy Efficiency Requirements (2006)
United States	MEPS for Medium Base Compact Fluorescent Lamps (CFLs) (2006)
Vietnam	MEPS for Compact Fluorescent Lamps - Vietnam

Source: APEC ESIS 2011

Note: The year in parentheses after each program name is its effective date.

Table 2: Global Voluntary Labels for CFLs

Economy	Title
Argentina	Efficient Lighting Initiative (ELI) Program - Argentina
Canada	ENERGY STAR - Compact Fluorescent Light Bulbs (Canada)
Colombia	Programa Colombiano de Normalización, Certificación y Etiquetado de Equipos de Uso Final de Energía (CONOCE) – CFLs
Czech Republic	Efficient Lighting Initiative (ELI) Program - Czech Republic
Hungary	Efficient Lighting Initiative (ELI) Program - Hungary
India	Voluntary Label for CFLs

Economy	Title
Indonesia	Energy Efficiency Labeling for CFLs - Indonesia
Latvia	Efficient Lighting Initiative (ELI) Program - Latvia
Mexico	Sello FIDE - Compact Fluorescent Lamps (1995)
New Zealand	Compact Fluorescent Lamps - New Zealand (2009)
People's Republic of China	CQC Mark Certification - Fluorescent Lamps for General Lighting Service (Self-Ballasted) (2009)
Peru	Efficient Lighting Initiative (ELI) Program - Peru
Philippines	Efficient Lighting Initiative (ELI) Program - Philippines
Poland	Poland Efficient Lighting Project (PELP)
Republic of Korea	High-efficiency Appliance Certification Program - CFLs (1996)
Singapore	Green Labeling Scheme - CFLs -Singapore (07-04-1993)
South Africa	Efficient Lighting Initiative (ELI) Program - South Africa
Sri Lanka	Labels for Compact Fluorescent Lamps - Sri Lanka
Thailand	Green Label Scheme - CFLs
United Kingdom	Energy Saving Trust Recommended - Compact Fluorescent Lightbulbs (CFLs) (2006)
United States	ENERGY STAR - Compact Fluorescent Lamps (2009)
Vietnam	Label for Compact Fluorescent Lamps

Source: Source: APEC ESIS 2011

Note: The year in parentheses after each program name is its effective date.

Table 3: Mandatory Labels for CFLs

Economy	Title
Argentina	Programa de Calidad de Artefactos Electricos para el Hogar (PROCAEH) - CFLs
Brazil	Stamp Procel de Economia de Energia (Energy Efficiency Stamp) - Compact Fluorescent Lamps (1993)
Brazil	INMETRO Brazilian Labeling Program for Compact Fluorescent Lamps
Canada	Lamp Package Labeling - CFLs (01-06-2009)
Chile	Mandatory Label for Compact Fluorescent Lamps (Chile) (30-06-2007)
Ecuador	Labeling Program for Compact Fluorescent Lamps
EU Member Countries	Commission Directive 98/11/EC - CFLs (2000)
Ghana	Ghana Electrical Appliance Labeling and Standards Programme (GEALSP) - Label for CFLs (30-06-2005)
Hong Kong, China	The Hong Kong Mandatory Energy Efficiency Labeling Scheme (MEELS) for CFLs (09-11-2009)
Nicaragua	Nicaraguan Mandatory Technical Standard (NTON) No. 10 009-08: Energy Efficiency, Self-ballasted Compact Fluorescent Lamps, Rating and Labeling
People's Republic of China	China Energy Label - Self-ballasted Fluorescent Lamps (01-06-2008)

Economy	Title
Philippines	PNS 2050-2: 2006 - Lamps and related equipment - Energy Efficiency and Labeling requirements - Part 2: Self ballasted lamps for general lighting services (01-09-2003)
Republic of Korea	Energy Efficiency Rating Labeling Program for Compact Fluorescent Lamps (01-07-1999)
Thailand	The Energy Efficiency No.5 label - CFLs (08-1994)
United States	EnergyGuide - Medium Base Compact Fluorescent Lamps (CFLs) (2007)

Source: Source: APEC ESIS 2011
Note: The year in parentheses after each program name is its effective date.

3.2 Comparison of CFL Performance Standards

Currently, over 19 economies have developed performance standards (including MEPS and other requirements) for CFLs (APEC ESIS 2011). Of these, CLASP chose a representative sample of countries and international organizations to ensure that the comparisons made would cut across the global economy and capture trends currently being observed in the markets. The selected countries compared in this section of the report include developed and emerging economies, and encompass all the major global economies – specifically, Australia/New Zealand, Brazil, China, the EU, India, Japan, the UK, and the US. CLASP also included CFL requirements published by the International Electrotechnical Commission (IEC, which is the world's leading organization on international standards for electric-related technology), the International Finance Corporation's (IFC) Efficient Lighting Initiative (ELI) Voluntary Technical Specification for Self-Ballasted CFLs issued in March 2011, and the Asia Lighting Compact's (ALC) quality guidelines for CFL product marking.

This study considers performance standards, rather than MEPS only, because CFL quality is critical to consumer acceptance and market penetration. Color, lumen maintenance, and lifetime are all very important parameters for CFLs. That said, Brazil's MEPS and Procel labeling programs and Japan's Top-Runner program focus on efficacy, thus they only appear in the comparative tables on efficacy.

Scope of CFL MEPS and Performance Standards and Labeling Scheme
The scope of a standard defines the products covered under its domain, and enables other parties to determine the comparability of applicable standards. Only CFLs of the same type can be compared in terms of their technical parameters. This section presents the scopes of coverage for the CFL programs compared in this study.

Among the standards/programs compared below, Australia/New Zealand, Brazil, China, the EU and the US (not ENERGY STAR) are all MEPS, which means they include mandatory performance requirements for CFLs within their scope of coverage. The other programs are voluntary, however, they are quite influential and have significant impacts on the energy-efficient lighting market.

Table 4: Scope of CFL MEPS and Performance Standards and Labeling Scheme

Standard	Scope

Standard	Scope
Australia / New Zealand, AS/NZS 4847	4847.1 Applies to CFLs with integrated means for controlling starting and stable operation that are intended for domestic and similar general lighting service. This standard applies to self-ballasted lamps of all voltages and wattages irrespective of the type of lamp cap.
ALC CFL Quality Guidelines Version 1.1	Applies to bare CFLs with integral electronic ballasts (CFLi) only.
Brazil MEPS and Procel Program	Applies to bare, covered and reflector type self-ballasted or and externally ballasted CFLs and circular fluorescents, with electronic or magnetic ballasts.
China GB/T 17263-2002	Self-ballasted CFLs used for domestic and similar general lighting purposes, with Edison cap type or Bayonet cap type, rated voltage of 220V, frequency of 50Hz, and power no greater than 60W. MEPS requirements (GB 19044-2003) do not apply to products with covers.
ELI voluntary standard, March 2011	Applies exclusively to self-ballasted compact fluorescent lamps (CFLs)—with or without a cover, and without any reflector element. These lamps have an integrated means for controlling starting and stable operation and are intended for general lighting purposes. They have screw or bayonet caps, a rated power up to 60W and a rated voltage of 100V to 250V.
EU, EC No 244/2009	Applies to products essentially for the full or partial illumination of a household room, by replacing or complementing natural lighting with artificial light, in order to enhance visibility within that space. (Also applies to LEDs.)
IEC 60969-2001 Edition 1.2	This standard specifies the performance requirements together with the test methods and conditions required to show compliance of tubular fluorescent and other gas-discharge lamps with integrated means for controlling starting and stable operation (self-ballasted lamps) intended for domestic and similar general lighting purposes having: 1) a rated wattage up to 60 W; 2) a rated voltage of 100 V to 250 V; and 3) Edison screw or bayonet caps.
IEC 60969 Ed.2 Draft	This standard applies to self-ballasted lamps of voltages >50V and all wattages with lamp caps complying with IEC 60061.1 and integrated means for controlling starting and stable operation intended for general lighting purposes.
Indian Standard (IS) 15111 (Part 2) 2002	Applies to tubular and other gas discharge bare lamps with integrated means for controlling starting and stable operation (self-ballasted lamps), intended for domestic and similar general lighting purposes having: a rated wattage up to and including 26W; a rated voltage up to and including 250V;Edison screw E14 and E27 or bayonet caps B15d and B22d.
Japan Top-Runner	Applies to CFLs, including covered/ reflector type, dimmable type, special color type, non-integrated type.

Standard	Scope
UK EST Lamp Spec, V7.0-2010	The document contains the requirements for performance, and quality for CFLs which are directly replaceable in filament sockets or holders. These CFLs are divided into seven classes, which mainly include: (1) bare CFLs with wattage no higher than 35W; (2) covered CFLs with wattage no higher than 25W; (3) reflector lamps with integral control gear intended to replace specific incandescent filament reflector lamps and reflector lamps for general illumination; and (4) dimmable lamps.
US ENERGY STAR (ES) V4.2	This specification applies to (1) Medium (Edison) or candelabra screw base CFLs with integral electronic ballasts; (2) Circline lamps with a maximum diameter of nine inches, and square lamps with a maximum side length of eight inches and with medium screw with electronic ballasts that are tested and packaged with the lamp; (3) Medium (Edison) or candelabra screw base fluorescent lamps with integral electronic ballasts, which have a translucent cover over the bare fluorescent tube. The cover may be globe, bullet, pear, torpedo, candle, or any other shape; and (4) Medium (Edison) screw base CFLs with integral electronic ballasts, which have a reflector that may be open or enclosed. The lamp shall be primarily intended to replace wide beam incandescent reflector lamps.

Looking across the scopes of coverage, the differences between the various national and international standards become evident. Although all the regulations are applying to the same product in their respective markets, the scopes of coverage address socket types, lamp shapes, voltage ranges (or rated for point values), wattage ranges, with or without a second cover, and dimming function. All of these scopes include, at least in part, self-ballasted CFLs – while not every standard is applicable to separately ballasted CFLs. Some of the standards are focused on lots of detail in the scope (e.g., UK EST), while others are more generic, yet expansive in their coverage (e.g., US ES).

For this report, some of the most commonly used types of CFLs – bare lamp, integrally electronically ballasted, non-dimmable, CCT below 3000K, medium screw base (E26 and E27), and wattage below 30W–have been selected and their requirements from different standards are discussed below.

Comparison of Luminous Efficacy (including requirements of MEPS)
A comparison of the luminous efficacy of all types of CFLs is complicated because different standards use different methods to classify and regulate the lamps. Some standards break down the regulations by power (e.g., 5W, 15W, 26W, etc.), others do it by correlated color temperature (e.g., 2700K, 4000K, 6500K, etc.), and others differentiate on the basis of product type (e.g., bare, covered, reflector, etc.). Some examples of the efficacy specifications are presented in the following pages for the reader to better understand the requirements in the national/program standards.

Australia/New Zealand's AS/NZS 4847: This is a mandatory MEPS which provides a maximum power consumption for a regulated lamp based on its luminous flux (i.e., light output). The equation states that the maximum power shall be no greater than $(1 / ((0.24/\sqrt{F})+0.0103))$ where F is the initial luminous flux measured in lumens.

Table 5: Brazil's MEPS and Procel Program

Lamp Power (Watts)	Brazil's MEPS Luminous Efficacy (lm/W)	Brazil's Procel Program Luminous Efficacy (lm/W)
<= 8	43	48
8 < lamp power <= 15	50	55
15 < lamp power <= 25	55	60
> 25	57	62

China's GB/T17263-2002: The standard contains (a) mandatory MEPS, (b) voluntary levels of Evaluating Value of Energy Conservation (EE for short), and (c) Top level (highest efficacy in the market). As shown in the table, this standard classifies CFLs by rated wattage and CCT.

Table 6: China's MEPS

Rated Wattage (W)	Initial Luminous Efficacy (lm/W)					
	Efficacy Tiers (6500K, 5000K)			Efficacy Tiers (4000K, 3500K, 3000K, 2700K)		
	Top	EE	MEPS	Top	EE	MEPS
5-8	54	46	36	58	50	40
9-14	62	54	44	66	58	48
15-24	69	61	51	73	65	55
25-60	75	67	57	78	70	60

ELI Voluntary Standard, March 2011: this is a voluntary standard, and the value of the initial luminous efficacy of the lamps shall not be less than the value indicated in the table below:

Table 7: ELI Voluntary Standard

Input Power of Lamp (Watts)	Initial Luminous Efficacy (lm/W)					
	Correlated Color Temperature (CCT)					
	6500K	5000K	4000K	3500K	3000K	2700K
≥ 5 to < 9	46		50			
≥ 9 to < 15	52		55			
≥ 15 to < 25	57		60			
≥ 25 to ≤ 60	62		65			

EU,EC No 244/2009: MEPS, maximum power shall be no greater than $(1 / ((0.24/\sqrt{F})+0.0103))$ (Same as AS/NZS)

IEC 60969: 2001: No efficacy requirements for CFLs. However, the new **IEC 60969 Ed.2 (Draft for Comment 2010-10-29)** has CFL efficacy requirements that are the same as EU EC No. 244/2009 and AS/NZS4847.1.

India IS 15111, Part 2: This is a voluntary standard and also works for Bureau of Indian Standards (BIS) certification, which is generally a voluntary certification scheme. It breaks down the regulated

CFLs by rated lamp wattage and CCT. Within that matrix, the lamps have different efficacy requirements.

Table 8: India IS 15111 Part 2

Lamp Wattage (W)	Luminous Efficacy (lm/W)		
	For 2700K	For 4000K	For 6500K
<=7	45	44	42
8-10	50	49	47
11-15	55	54	51
16-23	60	59	56
24-26	60	59	56

Japan's Top-Runner: This is a voluntary program that classifies products by rated power and CCT. The bin values differ from both China's GB 19044-2003 and India's IS 15111. CCTs in the Top-Runner program are defined as simulated color rather than actual CCT value.

Table 9: Japan's Top-Runner Standard

Rated power (Watts)	Rated color (CCT)	Standard Efficacy
<=10	Usual electric bulb color	60.6
	Daylight white	58.1
	Daylight	55.0
10<=lamp power<=15	Usual electric bulb color	67.5
	Daylight white	65.0
	Daylight	60.8
15<lamp power<=25	Usual electric bulb color	72.4
	Daylight white	69.5
	Daylight	65.2

UK EST program: This is a voluntary labeling program in the UK which works to inform consumers about better quality (EST "Recommended") CFLs. The EST specification was adopted by Australia as a requirement for entering the Australian market.

Table 10: UK EST Program

Watts	Minimum efficacy Stick	Minimum efficacy Spiral	Watts	Minimum efficacy Stick	Minimum efficacy Spiral	Watts	Minimum efficacy Stick	Minimum efficacy Spiral
5	49.0	58.3	16	56.8	60.0	27	62.6	62.9
6	49.8	58.4	17	57.5	60.2	28	63.0	63.2
7	50.6	58.6	18	58.0	60.5	29	63.4	63.6
8	51.3	58.7	19	58.6	60.7	30	63.7	63.9
9	52.1	58.8	20	59.2	60.9	31	64.1	64.3
10	52.8	59.0	21	59.7	61.2	32	64.4	64.6
11	53.5	59.1	22	60.2	61.5	33	64.7	65.0
12	54.2	59.3	23	60.7	61.7	34	65.1	65.4
13	54.9	59.5	24	61.2	62.0	35	65.3	65.7
14	55.6	59.6	25	61.7	62.3			
15	56.2	59.8	26	62.1	62.6			

The United States: The US has both a voluntary program (ENERGY STAR) and a mandatory MEPS regulation, 10 CFR 430.32(u). The efficacy requirements of these two programs are presented in the table below.

Table 11: US ENERGY STAR and MEPS

Lamp Power (Watts)	US ENERGY STAR Luminous Efficacy (lm/W)	US MEPS 10 CFR 430.32(u) Luminous Efficacy (lm/W)
<10	50	45
10<= lamp power <15	55	
>=15	65	60

The following table provides a comparison across the various CFL efficacy regulations for a discrete range of wattages, spanning 10W to 23W. In order to make the comparison between the efficacy requirements easier to visualize, the cells are shaded from yellow (least efficient) to green (most efficient) for each of the wattages. The columns that contain mandatory minimum efficacy columns are identified with the acronym “MEPS” in the heading. The other columns which do not contain “MEPS” are voluntary programs. This presentation of the efficacy requirements shows that the MEPS columns are lower than the voluntary program levels.

Asia Lighting Compact (ALC) CFL Quality Guidelines: The ALC aims to stimulate the uptake of high quality CFLs in Asia by promoting a set of common quality criteria and setting performance levels for qualified CFLs, and promote the adoption of the guidelines by stakeholders.

Table 12: ALC CFL Quality Charter Guidelines

Criteria	Asia CFL Quality Charter Guidelines Criteria Requirements					
	Tier 1		Tier 2 (ELI - Equivalent)		Tier 3 (EST 6.1 - 2009)	
Efficacy (lm/W)					EST 6.1-2009 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

Table 13: Comparison of Luminous Efficacy

Power	AS/NZS, EU & IEC MEPS	Brazil MEPS	Brazil Procel	China GB MEPS	China GB-2 EE Tier	China GB-1 Top Tier	India IS 15111 Part 2	IFC ELI	Japan Top-Runner	UK EST-spiral	UK EST-stick	US Energy Star	US MEPS
10w	46.7	50	55	48	58	66	50	55	60.6	59.0	52.8	55	45
11w	48.3	50	55	48	58	66	55	55	67.5	59.1	53.5	55	45
12w	49.7	50	55	48	58	66	55	55	67.5	59.3	54.2	55	45
13w	51.0	50	55	48	58	66	55	55	67.5	59.5	54.9	55	45
14w	52.1	50	55	48	58	66	55	55	67.5	59.6	55.6	55	45
15w	53.2	50	55	55	65	73	55	60	67.5	59.8	56.2	65	60
16w	54.2	55	60	55	65	73	60	60	72.4	60.0	56.8	65	60
17w	55.1	55	60	55	65	73	60	60	72.4	60.2	57.5	65	60
18w	56.0	55	60	55	65	73	60	60	72.4	60.5	58.0	65	60
19w	56.8	55	60	55	65	73	60	60	72.4	60.7	58.6	65	60
20w	57.6	55	60	55	65	73	60	60	72.4	60.9	59.2	65	60
21w	58.3	55	60	55	65	73	60	60	72.4	61.2	59.7	65	60
22w	58.9	55	60	55	65	73	60	60	72.4	61.5	60.2	65	60
23w	59.6	55	60	55	65	73	60	60	72.4	61.7	60.7	65	60

Table 13 shows that for MEPS, the China GB and EU/new IEC/AS/NZS are similar, particularly at the lower wattages. The EU/new IEC/ AS/NZS uses an equation that follows a curve while the Chinese regulation is based on clusters of wattages being subject to the same efficacy requirement. The table below presents the top and the bottom efficacy MEPS requirement at each of the selected wattages, identifying the country / economy from which it is derived. Brazil, Australia/New Zealand, EU and IEC's MEPS requirements are among the most stringent in the world, while that of the US is weak at the lower wattages and the MEPS in Brazil and China are more lenient at the higher wattages.

Table 14: Comparison of MEPS Luminous Efficacy

CFL Power (Watts)	Minimum Values		Maximum Values	
	Efficacy (lm/W)	Country or Entity	Efficacy (lm/W)	Country or Entity
10w	45	US	50	Brazil
11w	45	US	50	Brazil
12w	45	US	50	Brazil
13w	45	US	51.0	AS/NZS, EU, IEC
14w	45	US	52.1	AS/NZS, EU, IEC
15w	50	Brazil	60	US
16w	54.2	AS/NZS, EU & IEC	60	US
17w	55	Brazil/China	60	US
18w	55	Brazil/China	60	US
19w	55	Brazil/China	60	US
20w	55	Brazil/China	60	US
21w	55	Brazil/China	60	US
22w	55	Brazil/China	60	US
23w	55	Brazil/China	60	US

Making a similar comparison among the voluntary programs, the table below presents the minimum and maximum luminous efficacy values for those programs reviewed in this study. The UK's Energy Savings Trust value for stick CFLs tends to have the lowest efficacy requirements of any endorsement label. At the high end of the efficacy, the Chinese GB-Top level and the Japanese Top Runner program are close, with the Chinese GB-Top levels just edging out the Top Runner program for a few wattage ratings.

Table 15: Comparison of Voluntary Program Luminous Efficacy

CFL Power (Watts)	Minimum Values		Maximum Values	
	Efficacy (lm/W)	Country or Entity	Efficacy (lm/W)	Country or Entity
10w	50	India	66	China GB-Top
11w	53.5	UK EST-stick	67.5	Japan TR
12w	54.2	UK EST-stick	67.5	Japan TR
13w	54.9	UK EST-stick	67.5	Japan TR
14w	55	Brazil Procel / ES / ELI / India	67.5	Japan TR
15w	55	Brazil Procel / India	73	China GB-Top
16w	56.8	UK EST-stick	73	China GB-Top

CFL Power (Watts)	Minimum Values		Maximum Values	
	Efficacy (lm/W)	Country or Entity	Efficacy (lm/W)	Country or Entity
17w	57.5	UK EST-stick	73	China GB-Top
18w	58.0	UK EST-stick	73	China GB- Top
19w	58.6	UK EST-stick	73	China GB- Top
20w	59.2	UK EST-stick	73	China GB- Top
21w	59.7	UK EST-stick	73	China GB- Top
22w	60	Brazil Procel / ELI / India	73	China GB- Top
23w	60	Brazil Procel / ELI / India	73	China GB- Top

3.3 Comparison of Technical Performance Criteria

Color Rendering Index (CRI)
The color rendering index (CRI) is a measurement of the ability of any light source to render colors accurately relative to a reference light source of the same correlated color temperature. The CRI is a measurement of the spectral characteristics of the light emitted by a lamp, and generally, the higher the value of CRI, the better the ability of the light source to render the real color of the illuminated object.

Generally, most standards including China GB, US ENERGY STAR, Australia AS/NZS, ALC (Tier 1,2,3) and the EU Directive require a minimum sample average CRI of at least 80. The China GB standard has a more detailed classification on the product type by CCT, and permits a tolerance of -3, while the US ENERGY STAR and new IEC standard also offer some tolerance. Some of the other standards such as the EU regulation, the UK EST, and Australia AS/NZS simply require a CRI of 80 without making allowances for sample tolerance.

Table 16: Comparison of Color Rendering Index (CRI)

Standard	Color Rendering Index Requirement
ALC 2009 (Tier 1,2,3)	>=80
Australia / New Zealand, AS/NZS 4847	Minimum 80
China GB/T 17263.2002	80 for CFLs of RR(6500K) and RZ(5000K) 82 for CFLs of RL(4000K) and RB(3500K) 84 for CFLs of RN(3000K) and RD(2700K)
ELI voluntary standard, March 2011	At least 80, measured in accordance with CIE 13.3.
EU, EC No 244/2009	>=80
IEC 60969-2001 Edition 1.2	IEC 60081
IEC 60969 Ed.2 Draft	Average measured value shall be >=97% (minimum 80) of rated value
Indian Standard (IS) 15111 (Part 2) 2002	N/A
UK EST Lamp Spec, V7.0-2010	>80
US ENERGY STAR (ES) V4.2	80 on average, no more than 3 samples less than 77

Correlated Color Temperature (CCT) and Standard Deviation of Color Matching (SDCM)
The color of the lamp is sometimes called the “color appearance,” and it a characteristic of the light emitted by a lamp. Normally the CCTs of CFLs range from 2700 Kelvin (K) to 6500K, ranging from a warm, yellowish white light (i.e., incandescent color at 2700K) to a cool, bluish white light (i.e., daylight color at 6500K).ENERGY STAR requires products to fall in one of the six CCT values (i.e.,

2700K, 3000K, 3500K, 4000K, 5000K and 6500K) in the program specification standard. All the other standards, however only recommend these six CCT values as preferred targets.

For SDCM, all standards except ENERGY STAR have the same requirements, which are based on IEC 60081 – that 5 is the maximum value allowed for the distance between the actual point to the target point, while ENERGY STAR extends 5 to 7.The number (e.g. 5 and/or 7) means the steps of deviation from the target value. However, please note that, the color coordinates used by US ENERGY STAR (referencing the American National Standards Institute, ANSI) and IEC are not necessarily the same. For example, in ANSI, 2700K is x=0.459 and y=0.412 while in IEC 60081, 2700K is x=0.463 and y=0.420. Thus the requirements based on two slightly different color coordinates.

Table 17: Comparison of Correlated Color Temperature (CCT) and Standard Deviation of Color Matching (SDCM)

Standard	CCT and SDCM
ALC 2009	Tier1: Within 7 color steps (SDCM) per the IEC standard Tier1: Within 5 color steps (SDCM) per the IEC standard Tier 3: IEC 60081 Graph D-16 for CCT of 2700K
Australia / New Zealand, AS/NZS 4847	All CCTs are to be approved following IEC 60081 Graph D-16 SDCM: maximum 5 from the target point
China GB/T 17263.2002	Recommend six reference CCTs, others are acceptable on demand. SDCM: maximum 5 from the target point
ELI voluntary standard, March 2011	Must comply with IEC 60969 and the color tolerance shall be within 5SDCM from the target values.
EU, EC No 244/2009	All CCTs *except* for lamps having the following chromaticity coordinates x and y: — x < 0,200 or x > 0,600 — y < – 2,3172 x2 + 2,3653 x – 0,2800 or y > – 2,3172 x2 + 2,3653 x – 0,1000; No requirements on SDCM
IEC 60969-2001 Edition 1.2	Comply with the declaration of manufacturer, vendor or the marking on the lamp. SDCM: maximum 5 from the target point
IEC 60969 Ed.2 Draft	Recommend six reference CCTs. SDCM: maximum 5 from the target point
Indian Standard (IS) 15111 (Part 2) 2002	The standard covers six standardized rated values (CCT) and tolerance areas (SDCM) for fluorescent lamps. (referred to CIE publication 15.2, 1931). For non-standardized products,, rated values shall be assigned by the manufacturer or the vendor. SDCM: maximum 5 from the target point
UK EST Lamp Spec, V7.0-2010	In alignment with EU EC No 244/2009, directive 2005/32/EC SDCM: maximum 5 from the target point
US ENERGY STAR (ES) V4.2	Has to be one out of the six designated CCT values only. SDCM: fall in 7-step ANSI Mac Adam ellipse from the target point

Lumen Maintenance

Lumen maintenance is a measure of the rate at which a lamp's lumen output deteriorates over its operating life. Mathematically, lumen maintenance is expressed as a percentage of the luminous flux of a lamp at a given time in its life divided by the lamp's initial luminous flux. The lumen maintenance test is part of the lamp life test, which tests the length in hours of the total operational time of a lamp. If the lamp fails the lumen maintenance test, then there is no need to go on to further life testing.

China GB and the EU directive require a lumen maintenance test after 2000h of operation. The new IEC requires at least 70% lumen maintenance at 40% of the rated life (e.g.,2400h if rated life is 6000h), while ENERGY STAR requires two tests, one after 1000h and one at 40% of rated life. The Australian / New Zealand regulation has stringent requirements at 2000h and 5000h requiring 88% and 80% of the initial lumen output to be maintained. The UK's EST has the most complicated classifications and test time points.

Table 18:Comparison of Lumen Maintenance

Standard	Lumen Maintenance
ALC 2009	Tier 1: 80% of measured 100-hour lumen level after 2,000 hrs Tier 2: 80% of measured 100-hour lumen level after 2,000 hrs Tier 3: 88.1% @ 2,000 hrs 78.1% @ 6,000 hrs 75.1% @ 10,000 hrs
Australia / New Zealand, AS/NZS 4847	On average: 1. At 2 000 h: >= 88 % 2. At 5 000 h: >= 80 % All lamps shall fall within 2 standard deviations of the average.
China GB/T 17263.2002	No less than 80% @ 2000h
ELI voluntary standard, March 2011	The luminous flux of the lamp must be 80% of initial levels at 40% of model's rated lifetime.
EU, EC No 244/2009	At 2 000 h: >= 85 % (>= 80 % if lamps are with second envelope)
IEC 60969-2001 Edition 1.2	No less than manufacturer's declaration
IEC 60969 Ed.2 Draft	Shall meet both of the following requirements: 1. Average measured values shall be >=90% of rated values; 2. Average measured values (@ 40% of lamp life) shall be >=70%
Indian Standard (IS) 15111 (Part 2) 2002	At 2 000 h: >= 85 %

<table>
<tr><th>Standard</th><th>Lumen Maintenance</th></tr>
<tr><td>UK EST Lamp Spec, V7.0-2010</td><td>Class 1: All types without a secondary covering or bulb. All wattages up to and including 25W; Class 2: Types with a secondary covering or bulb of 11W and above up to and including 25W; Class 3: Types with a secondary covering or bulb of less than 11W rating.
<table>
<tr><th>Lamp Life
Hx1000</th><th>Class1
% LM</th><th>Class2
% LM</th><th>Class3
% LM</th></tr>
<tr><td>0.0</td><td>100.0</td><td>100.0</td><td>100.0</td></tr>
<tr><td>1.0</td><td>95.0</td><td>91.8</td><td>89.6</td></tr>
<tr><td>2.0</td><td>89.9</td><td>85.4</td><td>82.7</td></tr>
<tr><td>3.0</td><td>86.0</td><td>81.0</td><td>78.9</td></tr>
<tr><td>4.0</td><td>83.3</td><td>78.4</td><td>76.4</td></tr>
<tr><td>5.0</td><td>81.4</td><td>76.7</td><td>74.4</td></tr>
<tr><td>6.0</td><td>79.7</td><td>75.0</td><td>73.1</td></tr>
<tr><td>7.0</td><td>78.6</td><td>73.7</td><td>71.8</td></tr>
<tr><td>8.0</td><td>77.7</td><td>72.5</td><td>70.6</td></tr>
<tr><td>9.0</td><td>77.0</td><td>71.6</td><td>69.6</td></tr>
<tr><td>10.0</td><td>76.6</td><td>71.0</td><td>68.9</td></tr>
<tr><td>11.0</td><td>76.2</td><td>70.3</td><td>68.2</td></tr>
<tr><td>12.0</td><td>76.0</td><td>69.9</td><td>67.6</td></tr>
<tr><td>13.0</td><td>75.9</td><td>69.6</td><td>67.1</td></tr>
<tr><td>14.0</td><td>75.8</td><td>69.2</td><td>66.7</td></tr>
<tr><td>15.0</td><td>75.7</td><td>68.9</td><td>66.4</td></tr>
</table></td></tr>
<tr><td>US ENERGY STAR (ES) V4.2</td><td>90% @1000h and no more than 3 samples less than 85%;
80% @ 40% of rated lifetime and no more than 3 samples less than 75%;</td></tr>
</table>

Lamp Power

Lamp power is the active input power drawn by a lamp under test. Only five of the standards being compared, namely China GB, India IS, IEC, new IEC, and IFC ELI - have requirements for lamp power. The new IEC standard employs the strictest requirement–"average measured value shall be between 90% and 110% of rated value".

Table 19: Comparison of Lamp

Standard	Lamp Power Requirements
ALC 2009	N/A
Australia / New Zealand, AS/NZS 4847	N/A
China GB/T 17263.2002	Actual power shall be within from 85% to 115% of rated power
ELI voluntary standard, March 2011	Lamp wattage shall be classified based on the rated wattage, but the test wattage shall be within ± 15% of rated wattage.
EU, EC No 244/2009	N/A
IEC 60969-2001 Edition 1.2	Shall not exceed 115% of rated value

Standard	Lamp Power Requirements
IEC 60969 Ed.2 Draft	Average measured value shall be between 90% and 110% of rated value
Indian Standard (IS) 15111 (Part 2) 2002	Shall not exceed 115% of rated value
UK EST Lamp Spec, V7.0-2010	N/A
US ENERGY STAR (ES) V4.2	N/A

Power Factor

Power Factor is defined as the ratio of the real power flowing to the load divided by the apparent power in the circuit. Power factors range from 0 to 1, and a value closer to 1 means that the device utilizes grid power more efficiently. A low power factor means that there will be higher harmonic currents and higher power losses in the electric utility's distribution network and power generation infrastructure.

Most of the standards and programs analyzed in this study have specified the requirements for CFL power factors except for China and India. China's GB has no requirement on the actual value of power factor, but it states that the power factor cannot be smaller than rated value by more than 0.05. India IS requires that the actual power factor value comply with manufacturer's declaration. Other standards have identical or similar levels of requirements, which are normally 0.5 and 0.55 for regular CFLs (e.g. wattage lower than 25W).In the fifth regulatory stage, which starts from 1 September 2013 (EC No. 244/2009), the EU MEPS program will adopt a slightly more stringent minimum power factor requirement of 0.55 for lamps below 25W of rated power. The EU requires higher power factors (i.e., >=0.90) for CFLs with power rated greater than 25W.

Table 20: Comparison of Power Factors for CFLs

Standard	Power Factor Requirements
ALC 2009	Tier 1,2: >=0.5 Tier 3: 0.55 for "normal" , 0.9 for "high"
Australia / New Zealand, AS/NZS 4847	Minimum 0.55; Minimum 0.9 for high PF; Average >=value specified.
China GB/T 17263.2002	Actual value should not be smaller than rated value by over 0.05
ELI voluntary standard, March 2011	Power factor shall be >= 0.5 at maximum power.
EU, EC No 244/2009	Minimum 0.5 if Power <25W; Minimum 0.9 if Power >=25W At Stage 5, Minimum 0.55 for lamps with power <25W; Minimum 0.90 if Power >=25W
IEC 60969-2001 Edition 1.2	N/A
IEC 60969 Ed.2 Draft	Average measured value shall be >=90% of rated value; Minimum 0.50; and 0.90 if high power factor claimed. (measured on average)
Indian Standard (IS) 15111 (Part 2) 2002	Shall comply with the value declared by the manufacturer. (The value of Power Factor is under consideration)

Standard	Power Factor Requirements
UK EST Lamp Spec, V7.0-2010	Minimum 0.55 if Power <25W; Minimum 0.9 if Power >=25W or claimed as High Power Factor.
US ENERGY STAR (ES) V4.2	Greater than 0.5 on average

Starting Time

This parameter measures how fast a CFL starts to light after being switched on. It is important to limit the starting time because most users are accustomed to the near-instantaneous response from incandescent lamps. Furthermore, end-users do not want to wait 4 or 5 seconds after flipping a switch for the lamp to start, particularly where only a few seconds of light is needed.

Different standards have slightly different definitions of this parameter. The new IEC and AS/NZS standards have the same definition, which is "the period from the start of the test to when the lumen output reaches the first peak point after which the lamp shall start fully and remain alight." The term "the first peak point" accurately identifies the time point at which to stop measuring. Alternatively, the US ENERGY STAR and EU standards define starting time as "the time needed after switching on for the lamp to start fully and remain alight." The China GB standard has the most lax requirement for starting time, which is four seconds. Most of the other standards require two seconds or less.

Table 21: Comparison of Lamp Starting Time

Standard	Lamp Starting Time
ALC 2009	Tier 1,2: 1.5 seconds maximum Tier 3: 2.0 seconds maximum
Australia / New Zealand, AS/NZS 4847	80% of lamp samples shall start within 2 seconds
China GB/T 17263.2002	No longer than 4 seconds for electronic ballast CFL
ELI voluntary standard, March 2011	Must continuously illuminate within 1.5 seconds
EU, EC No 244/2009	Maximum 2 seconds
IEC 60969-2001 Edition 1.2	Comply with manufacturer's declaration
IEC 60969 Ed.2 Draft	80% of lamp samples shall start within 1.5 seconds, with average measured value <=110% of rated value
Indian Standard (IS) 15111 (Part 2) 2002	No longer than 4 seconds
UK EST Lamp Spec, V7.0-2010	Refer to column of "2 sec" in the requirements for "Run-up Time" below.
US ENERGY STAR (ES) V4.2	No longer than 1second

Run-up Time

Similar to starting time, run-up time is another visible performance factor of a lamp. This parameter measures the time needed for the lamp to attain a certain portion of its stable light output after being switched on. The current version of the IEC standard, China GB, India IS, ELI and ENERGY STAR each defines the "certain portion" of light output as 80%, while new IEC standard, AS/NZS, and the EU define it as 60%. Furthermore, there is variation between the run-up time itself. China's GB standard recommends 3 minutes (informative); India's IS standard takes 2 minutes as the requirement, and AS/NZS requires 1 minute; and the new IEC calls for 1.5 minutes. The EU and ENERGY STAR consider the form of mercury inside the lamp tubes and have two requirements respectively for amalgam type and non-amalgam type of lamps. For non-amalgam, they both require 1 minute. For amalgam, the EU opted for 2 minutes, while ENERGY STAR requires 3 minutes.

The UK's EST has a unique approach, in that it classifies the CFLs by wattage and whether the bulb is bare or covered. Also, its requirements of lamp run-up time are based around a defined portion of the luminous flux at a prescribed time.

Table 22: Comparison of Lamp Run-Up Time

Standard	Lamp Run-Up Time
ALC 2009	Tier 1, 2: Up to 3 minutes to reach 80% of light output(should be aligned with changes in IEC standard) Tier 3: >=60% of light output after 1 minute
Australia / New Zealand, AS/NZS 4847	<=60 sec to reach 60% of initial luminous flux.
China GB/T 17263.2002	No longer than 3 min (informative)
ELI voluntary standard, March 2011	Up to 3 minutes to reach 80% of light output
EU, EC No 244/2009	Known as "lamp warm-up to 60% luminous flux":<60 sec; or<120 sec for lamps containing mercury in amalgam form
IEC 60969-2001 Edition 1.2	Comply with manufacturer's declaration
IEC 60969 Ed.2 Draft	Average measured value to 60% of stable luminous flux shall be <= 110% of rated value; Maximum 90 sec.
Indian Standard (IS) 15111 (Part 2) 2002	Within 120 seconds.

<table>
<tr><th>Standard</th><th>Lamp Run-Up Time</th></tr>
<tr><td>UK EST Lamp Spec, V7.0-2010</td><td>Class 1: ALL types without a secondary covering or bulb. All wattages up to and including 25W; Class 2: Types with a secondary covering or bulb of 11W and above up to and including 25W; Class 3: Types with a secondary covering or bulb of less than 11W rating; Class7: Lamps with no secondary bulb with wattages >=25 and <= 35. These lamp types must comply with relevant requirements of Classes 1 or 7 as appropriate:
<table>
<tr><th>Primary Class</th><th>Product</th><th>2 sec</th><th>60 sec</th></tr>
<tr><td></td><td>Stick</td><td></td><td></td></tr>
<tr><td>1</td><td>W<11</td><td>30</td><td>75</td></tr>
<tr><td>1</td><td>11<=W<25</td><td>35</td><td>80</td></tr>
<tr><td>7</td><td>25<=W<=35</td><td>35</td><td>80</td></tr>
<tr><td></td><td>Spiral</td><td></td><td></td></tr>
<tr><td>1</td><td>W<11</td><td>30</td><td>75</td></tr>
<tr><td>1</td><td>11<=W<15</td><td>30</td><td>75</td></tr>
<tr><td>1</td><td>15<=W<25</td><td>30</td><td>80</td></tr>
<tr><td>7</td><td>25<=W<=35</td><td>35</td><td>80</td></tr>
<tr><td></td><td>Covered</td><td></td><td></td></tr>
<tr><td>3</td><td><11</td><td>6</td><td>70</td></tr>
<tr><td>2</td><td>11<=W<15</td><td>10</td><td>70</td></tr>
<tr><td>2</td><td>15<=W<=25</td><td>10</td><td>65</td></tr>
</table>
</td></tr>
<tr><td>US ENERGY STAR (ES) V4.2</td><td>1 min for non-amalgam; 3 min for amalgam type, covered and outdoor reflectors</td></tr>
</table>

Rated Lifetime

The rated lifetime of a CFL is a very important design feature, and represents one of the strongest advantages over incandescent lamps. Consumers may not be experts in evaluating all the parameters related to CFL performance, but it is clear to them how long a CFL lasts. Most of the standards reviewed set 6000 hours as the minimum lifetime requirement, whereas an incandescent lamp is typically rated at 750 or 1000 hours. Under the assumption that CFLs are used five hours per day, 6000hours means they can last for nearly three and a half years.

Rated lifetime is defined by all standards as the time at which 50% of sample lamps reach the end of their operating life. Although 6000 hours is commonly the minimum requirement, US ENERGY STAR program upgraded its requirement to 8000 hours in late 2009, and the EST also requires 8000 hours as its minimum requirement for bare lamps. Regardless, EST has a relatively detailed classification on the types of products. EU requires a higher survival rate of 70% at 6000 hours in Stage 5 referred in the Directive.

Table 23: Comparison of Rated Lifetime

Standard	Average Operating Life
ALC 2009	Tier 1: 6000h Tier 2: 8000h Tier 3: 10000h
Australia / New Zealand, AS/NZS 4847	Life of the median lamp (or 11th of sample size of 20) shall be greater than 6000h
China GB/T 17263.2002	No less than 6000h
ELI voluntary standard, March 2011	Must be at least 8,000 hours and lifetime should be clearly indicated in hours on product packaging.
EU, EC No 244/2009	Lamp survival factor at 6000h>=0.5 (life of the median lamp (e.g. 6th of sample size of 11) shall be greater than 6000h); In Stage 5, it required that survival rate is 70% at 6000 hours
IEC 60969-2001 Edition 1.2	No less than manufacturer's declaration
IEC 60969 Ed.2 Draft	The median lamp (or 6th of sample size of 11) shall be greater than rated value, which is 6000h at minimum.
Indian Standard (IS) 15111 (Part 2) 2002	No less than 6000h
UK EST Lamp Spec, V7.0-2010	1. Bare CFLs must be >=10000h for T3 or higher tubes; or >=8000 for T2 or lower tubes; 2. Covered and Reflector CFLs must be>=6000h.
US ENERGY STAR (ES) V4.2	Comply with manufacturer's declaration, but no less than 6000h.

Rapid Cycle Stress Test/Switching Test

Every time a CFL is switched on, some components of the lamp experience an electric pulse which is necessary to start the lamp. This test is a measurement of the lamp's ability to withstand frequent switching and not exhibit a significant reduction in operating life. Not every standard under review includes this requirement, for example China's GB, India's standard and old version of IEC 60969 don't have requirements for this parameter. The other standards tend to require the minimum number of on/off switching cycles to be half of the CFL's rated lifetime in hours. So in other words, if a lamp is rated for 6000 hours, then it should be subject to 3000 on/off switching cycles for this rapid cycle stress test.

Table 24: Comparison of Lamp Rapid Cycle Stress Test/Switching Test

Standard	Rapid Cycle Stress Test /Switching Test
ALC 2009	Tier 1, 2: At least 3,000 cycles based on cycle of 270 seconds off and 30 seconds on Tier 3: N/A
Australia / New Zealand, AS/NZS 4847	>=80% shall operate for number of cycles specified, with a minimum of 3000
China GB/T 17263.2002	N/A
ELI voluntary standard, March 2011	50% of lamp life as switching (i.e., 4000 switches for 8000 hour lamp life claimed). Lamp will be cycled once for every two hours of rated lamp life.

Standard	Rapid Cycle Stress Test /Switching Test
EU, EC No 244/2009	>=half the lamp lifetime expressed in hours; >= 10 000 if lamp starting time > 0.3 s
IEC 60969-2001 Edition 1.2	N/A
IEC 60969 Ed.2 Draft	>=80% of samples shall survive a number of cycles equal to half of the rated lifetime in hours
Indian Standard (IS) 15111 (Part 2) 2002	N/A
UK EST Lamp Spec, V7.0-2010	Same as EC No 244/2009
US ENERGY STAR (ES) V4.2	At least 5 out of 6 samples must survive. Lamp will be cycled once for every two hours of rated lamp life.

Mercury Content

CFLs contain a small amount of mercury, which is used to produce light. The mercury is contained inside the glass tube, and when subjected to an arc, emits an ultraviolet light, which is then converted by the phosphor coating into visible light. Mercury is, however, a hazardous substance and as more CFLs enter end-users' homes, concern about mercury contamination of land-fills (and eventually ground water) increases. Although not every standard reviewed establishes limits on mercury, some of the more recent ones, such as ENERGY STAR V4.2, the new IEC standard, the EU regulation, and AS/NZS 4847 have included maximum mercury amounts in their respective specifications.

The strictest standard reviewed is from the EU, which requires all CFLs to contain no more than 4mg of mercury. The new IEC, IFC ELI and AS/NZS use 5mg as the maximum value. ENERGY STAR also has a maximum of 5mg for CFLs with wattages below 25W, but also allows for 6mg of mercury in CFLs with wattages between 25W and 40W.

Although having the lowest requirement, technical information published by the EU states that CFLs can be efficient and good quality while using only 1.23mg of mercury. This means there is great potential to reduce CFL mercury content from the current levels.

Table 25: Comparison of Mercury Content

Standard	Mercury Content
ALC 2009	Tier 1,2,3: =<5mg
Australia / New Zealand, AS/NZS 4847	Maximum 5mg.
China GB/T 17263.2002	N/A
ELI voluntary standard, March 2011	Mercury content should be less than 5mg
EU, EC No 244/2009	Maximum 4mg
IEC 60969-2001 Edition 1.2	N/A
IEC 60969 Ed.2 Draft	All samples shall measure <5mg
Indian Standard (IS)	N/A

Standard	Mercury Content
15111 (Part 2) 2002	
UK EST Lamp Spec, V7.0-2010	N/A
US ENERGY STAR (ES) V4.2	Maximum 5mg for lamps below 25W; 6mg for 25W to 40W

3.4 Comparison of Test Standards

Globally, there are more than 30 CFL test standards, however among these there are only a few standards that are commonly referenced. The table below shows the reference test standards for the performance standards compared above.

Table 26: Comparison of 6 CFL Testing Standards

Performance/MEPS Standards compared above	Reference standards for test procedures			
	Electrical and photometric tests	EMC/ EMI/Harmonics	Colorimetry	Mercury Content
Australia / New Zealand, AS/NZS 4847	IEC 60969-2001	IEC 61547	CIE 13.3, 15, 63, 84, 121	IEC 62321, AS/NZS 4847.3-2006
China GB/T 17263.2002	IEC 60969-2001	IEC 61000-3-2	CIE 13.3, 15, 18.2, 63, 84, 97,	GB/T 23113-2008
ELI voluntary standard, March 2011	IEC 60969 2001	IEC 61000-3-2 and IEC 61547.	CIE 13.3	IEC62321
EU, EC No 244/2009	IEC 60969-2001	EN 61000-3-2	CIE 13.3, 15, 18.2, 63, 84, 97,	EU, 2002/747/EC
IEC 60969-2001 Edition 1.2	IEC 60081-1984	/	/	/
IEC 60969 Ed.2 Draft	IEC 60081	IEC 61000-3-2	CIE 13.3, 15, 63, 84, 121	IEC 62554 (under preparation)
Indian Standard (IS) 15111 (Part 2) 2002	IS 15111 (Part 2) 2002 (referred to IEC 60969-2001)	IS 15111 (Part 2) 2002 (referred to IEC 60969-2001)	CIE 15	/
UK EST Lamp Spec, V7.0-2010	IEC 60969-2001, EU regulation No 244/2009	/	/	/
US ENERGY STAR (ES) V4.2	ANSI C78.5, IESNA LM 9, LM45, LM65, LM66	FCC 47 CFR Part 2 and Part 18	CIE 13.3	/

With the notable exception of the US ENERGY STAR program, which references American National Standards Institute (ANSI) and Illuminating Engineering Society of North America (IESNA) test methods, all the other standards reviewed cite IEC's test method as the basis of their testing regime. While these individual standards may have slightly modified or varied test methods, the underlying test principle is the same, which means all tests are based on the same basic theory (e.g. similar test circuit, similar test equipment, etc.).For this reason, a select subset of the standards is compared below, rather than all of them, in order to elucidate the differences and identify opportunities for a harmonized test method.

For mercury content test, Australia AS/NZS, China GB, and EU have developed their own standards, and the IEC is developing a new/updated testing standard. This is a relatively new area, and it may require more dialogue and focused effort in order to work on harmonization.

Ambient Condition

The Ambient Condition requirement describes the surroundings of the test laboratory where measurements take place. The performance of CFLs is quite sensitive to the environment, and that is why we need to set a standard Ambient Condition under which the measurements are taken. The variables that can be taken into consideration include temperature, air flow, humidity, etc.

Table 27: Comparison of Ambient Conditions for CFL Testing

Standard	Ambient Condition
Australia / New Zealand AS/NZS 4847	For initial measurements: Draught-free; Temperature of (25 ±1) °C; Relative humidity of 65% maximum; Air movement shall be in accordance with CIE 121; For aging, life test and switch withstand test: Temperature in the range of 15°C to 40 °C; Some draught is allowed but vibration and shock should be minimized.
China GB/T 17263.2002	Same as IEC 60969-2001
IEC 60969-2001 Edition 1.2	For initial measurements: Draught-proof; Temperature of (25 ± 1) °C; Relative humidity of 65% maximum; For life test: Temperature: 15°C to 40°C;Excessive draught and extreme vibration and shocks shall be avoided;
IEC 60969 Ed.2 Draft	Same as AS/NZS 4847.1
US ENERGY STAR (ES) V4.2	**For photometric and electrical tests:** This temperature shall be maintained at 25°C ± 1°C (77°F ± 2°F). Air flow shall not exceed 4 m/min.(13.1 ft./min.) **For life test** Ambient temperature must be controlled within the limits set by the lamp manufacturer and ballast manufacturer. These are usually between 15°C (60°F)and 35°C (95°F).Airflow shall be minimized for proper lamp starting and operation.

Test Voltage and Frequency

Because test results of parameters, such as light output and power, can change significantly when test voltage changes, it is fluctuation is strictly regulated in the test standard. As shown in the table below, all standards have requirements for testing voltage and tolerance, which haven't changed significantly in the more recent standards. That said, the draft new IEC standard adds one additional requirement for testing frequency tolerance, which is 0.1%. Due to practical experience, regulating frequency is much easier than voltage.

Table 28: Comparison of Test Voltage and Frequency for CFL Testing

Standard	Test Voltage and Frequency
Australia / New Zealand AS/NZS 4847	Test frequency: at rated frequency, with tolerance of 0.1% Test voltage and tolerance: at rated voltage; mean value if the rated voltage is a range; at the higher voltage or the mean value of the higher range for tests if rated voltage is a dual (e.g. rated voltage is 110V and 230-240V); for starting time test: 92% of rated lamp voltage, or 92% of the minimum value if rated voltage is a range; Tolerance:0.5% for stabilization;0.1% for measurements;2% for life testing.
China GB/T 17263.2002	Same as IEC 60969-2001
IEC 60969-2001 Edition 1.2	Test frequency: at rated frequency; Test voltage and tolerance: at rated value; or mean value if the rated voltage is range;Tolerance:0.5% for stabilization;0.2% for measurements;2% for life testing;
IEC 60969 Ed.2 Draft	Same as AS/NZS 4847.1
US ENERGY STAR (ES) V4.2	**For photometric and electrical tests:** The rms voltage of the ac power source shall be regulated to within ± 0.1 percent. **For life test:** Input voltage shall conform to the rated input voltage (rms) and frequency of the ballast. If the ballast input voltage is a range, the center value shall be used. The input voltage must be monitored and regulated to within ± 2 percent of the rated rms value.

Sample Size

For sample size, China GB has a sample size of 12, while IEC 60969-2001 is 20. US ENERGY STAR requires 10 CFLs for general electrical, photometry, and colorimetry tests, six unique CFLs for switching withstand test, and one for electromagnetic interference (EMI) measurements. Some relatively newly drafted standards, like AS/NZS and new IEC have specific requirements on sample size for individual test item, but old standards, e.g. IEC 60969-2001 and GB stated only a general number for sample size.

Table 29: Comparison of Sample Size for CFL Testing

Standard	Sample Size
Australia / New Zealand AS/NZS 4847	10 samples for tests of: Starting time, Run-up time, Lumen maintenance, Premature lamp failure, Lifetime, True power factor, Color (xy, CCT), CRI, Switching withstand, Low temperature starting, Lamp wattage, Initial luminous flux, Initial efficacy; 3 samples for tests of: Mercury content; 1 sample for tests of: Light distribution, EMC requirements, Harmonics, Immunity; NOTE: some of the tests can share the same samples.
China GB/T 17263.2002	10 for lumen maintenance and life tests; 12 for all the other tests
IEC 60969-2001 Edition 1.2	20 samples

Standard	Sample Size
IEC 60969 Ed.2 Draft	11 samples for tests of: Premature lamp failure, Lifetime; 10 samples for tests of: Switching withstand, Lamp wattage, Initial luminous flux, Initial efficacy; 6 samples for tests of: Starting time, Run-up time, Lumen maintenance, Power factor, Color (xy, CCT), CRI, Low temperature starting; 5 samples for tests of: Mercury content; 1 sample for tests of: Light distribution, EMC requirements, UV content; NOTE: some of the test can share the same samples.
US ENERGY STAR (ES) V4.2	10 samples for tests of: Efficacy, Starting time, Run-up time, CCT, CRI, Lumen maintenance, Power factor, Life; 6 samples for tests of: Switching withstand test; 5 samples for tests of: Transient protection; 1 sample for tests of: EMI;

Base Position

For base position, IEC (both the 2001 and the draft new version), China GB, and Australia AS/NZS all require the CFL to be "base-up", meaning the glass tube is pointing downward and the heat emanated during operation rises up into the ballast. US ENERGY STAR's sample of 10 lamps requires that 5 of them are tested base-up and 5 are tested base-down.

Table 30: Comparison of Base Position for CFL Testing

Standard	Base Position
Australia / New Zealand AS/NZS 4847	Base position/direction: Unless otherwise specified for a specific purpose by the supplier, lamps shall be operated in a vertical base-up position for all tests including lumen maintenance tests.
China GB/T 17263.2002	Same as IEC 60969-2001
IEC 60969-2001 Edition 1.2	Base position: Vertical base-up position for all tests including life tests.
IEC 60969 Ed.2 Draft	Same as AS/NZS 4847.1
US ENERGY STAR (ES) V4.2	For general electrical and photometric tests, 5 base-up, 5 base-down, unless otherwise specified. For switching test, follow manufacturer's statement;

Test Preparation of the CFL

For this part of the test, all standards share the same requirement as in the table below.

Table 31: Comparison of Test Preparation of the CFL for Testing

Standard	Test Preparation of the CFL
Australia / New Zealand AS/NZS 4847	Aging (including life test) and cycles: 100 hours before all test, unless otherwise specified.
China GB/T 17263.2002	
IEC 60969-2001 Edition 1.2	
IEC 60969 Ed.2 Draft	
US ENERGY STAR (ES) V4.2	

Starting and Run-up Time

The differences among test standards of starting time mainly lie on two aspects: 1. Test before ageing or after ageing; 2. Test voltage. Newly established standards, such as AS/NZS and New IEC use aged samples for tests, while old standards, such as GB and IEC 60969-2001 requires tests carried out before ageing. Some of the standards (e.g. AS/NZS, old and new IEC) use 92% of the rated voltage for starting time test, while some (e.g. GB) uses 90%. For both starting time and run-up time tests, it is obvious that new standards have given a more detailed description on test procedures and more factors have been taken into consideration.

Table 32: Comparison of Starting and Run-up Time for CFL Testing

Standard	Starting Time and Run-up Time Test
Australia / New Zealand AS/NZS 4847	Starting Time test: The starting time test shall be conducted on lamps aged for 100 hours. Prior to the test the lamps shall be stored for at least 24 hours in planned test position at 25 ±1°C .The test voltage shall be equal to 92% of rated lamp voltage. Where the lamp is rated for a range of voltages, the test voltage shall be 92% of the minimum value of that range. Run-up Time test: The run-up time test shall be conducted on lamps aged for 100 hours. Prior to the test the lamps shall be stored for at least 24 hours in planned test position at 25 ±1°C ambient temperature
China GB/T 17263.2002	Starting Time Test before aging; Test voltage: 90% of rated value, or the minimum value if rated voltage is a range; Run-up time test voltage is as rated value or the mean value if rated voltage is a range.
IEC 60969-2001 Edition 1.2	Test before aging; Test voltage: 92% of rated value, or the minimum value if rated voltage is a range; Run-up time test voltage is as rated value or the mean value if rated voltage is a range.

Standard	Starting Time and Run-up Time Test
IEC 60969 Ed.2 Draft	Starting Time test: Lamp shall be stored in complete darkness for 24 hours prior to the test. Test in dark room. The starting time test shall be conducted on lamps aged for 100 hours. Prior to the test the lamps shall be stored for at least 22h at 20 to 27 ℃ ambient temperature, and additional storing shall be at least 2 hours in planned test position at 25±1°C ambient temperature. The test voltage shall be 92 % of rated voltage. Where the lamp is rated for a range of voltages, the test voltage shall be 92 % of the minimum value of that range. Run-up Time test: Lamp shall be stored in complete darkness prior to the test for 24 hours. Test in dark room. The run-up time test shall be conducted on lamps aged for 100 hours. Prior to the test the lamps shall be stored for at least 22 hours at 20 to 27℃ambient temperature, and additional storage shall be at least 2hours in planned test position at 25±1°C ambient temperature.
US ENERGY STAR (ES) V4.2	Lamps shall be off and shall be stored at the specified ambient test temperature for at least 12 hours prior to the test.

Lamp Lifetime

The difference of test methods of lifetime lies on ON and OFF time of each cycle.

Table 33: Comparison of Lamp Lifetime Test for CFLs

Standard	Lamp Lifetime Test
Australia / New Zealand AS/NZS 4847	Lamp ageing (incl. life testing) shall take place in the ageing room. Lamps shall be cycled repeatedly, such that they are on for 2 h 45 min and off for 15 min.
China GB/T 17263.2002	Same as IEC 60969-2001
IEC 60969-2001 Edition 1.2	8 times of SWITCH OFF in every 24 hours. 10 to 15 minutes for OFF period; and at least 10 minutes for ON.
IEC 60969 Ed.2 Draft	Same as AS/NZS 4847.1
US ENERGY STAR (ES) V4.2	180 minutes on, 20 minutes off

Switching Test

This is another parameter that didn't taken into consideration in relatively old standards (e.g. GB and old IEC). However, for those which have test methods, there exists difference in defining time for each cycle.

Table 34: Comparison of Switching Test for CFL Testing

Standard	Switching Test
Australia / New Zealand AS/NZS 4847	Samples shall be aged for 100 hours; 0.5 minutes on, 4.5 minutes off
China GB/T 17263.2002	N/A
IEC 60969-2001 Edition 1.2	N/A

IEC 60969 Ed.2 Draft	Samples shall be aged for at least 2 hours; 0.5 minutes on, 4.5 minutes off
US ENERGY STAR (ES) V4.2	5 minutes on, 5 minutes off

EMI / EMC / Harmonics

Except for the US ENERGY STAR standard, which references the US law of the Federal Communication Commission (FCC) 47 CFR as the test method of electromagnetic interference (EMI) of CFLs, all the other standards reviewed make reference to the international testing standard, IEC61000-3-2.

Table 35: Comparison of EMI / EMC / Harmonics for CFL Testing

Standard	EMI / EMC / Harmonics
Australia / New Zealand AS/NZS 4847	IEC 61000-3-2
China GB/T 17263.2002	IEC 61000-3-2
IEC 60969-2001 Edition 1.2	IEC 61000-3-2
IEC 60969 Ed.2 Draft	IEC 61000-3-2
US ENERGY STAR (ES) V4.2	FCC 47 CFR including Part 2 and Part 18 for consumer RF lighting equipment limits

3.5 Summarizing Common CFL Issues

The increasing worldwide attention on the CFL as a key energy-saving product has resulted in some significant changes to CFL manufacturing and marketing. In response to this new energy-saving product status, CFL production has increased, CFL manufacturing has concentrated in regions with low labor and material costs (primarily China), and there has been a proliferation of standards and other programmatic CFL requirements and specifications.

The major problem for CFLs in many countries is poor quality product. CFLs that fail to out-perform incandescent lamps can result in serious consumer dissatisfaction with CFL technology as a whole. Disillusioned consumers can significantly undermine efforts to transform markets from low efficient (e.g., incandescent or fuel-based lighting) to highly efficient light sources, such as CFLs. According to a 2008 USAID-funded quality assessment of CFLs sold into the Asian and Australian markets (USAID ECO-Asia 2008), the lamps being sold are sub-standard. More than 2,600 CFL were purchased, representing 160 models, from retail stores in Australia, India, Indonesia, the Philippines, Thailand, and Vietnam. These samples were tested and the results compared to the three quality tiers of the Asia Lighting Compact:

- Tier 1, equivalent to China’s minimum performance standards and represents “good” quality;
- Tier 2, equivalent to the standard of the Efficient Lighting Initiative (ELI) and represents “better” quality; and
- Tier 3, equivalent to the quality standard for European lamps developed by the United Kingdom’s Energy Saving Trust and represents “the best” quality.

The study found that only 66% of the sample of 2,600 CFLs met Tier 1, which is the entry level. It concluded that CFL quality needs to be improved to ensure consumer acceptance of CFLs as energy-efficient replacements for incandescent lamps.

An earlier study by the USAID ECO-Asia Program in 2007 estimated that close to half of the CFLs produced in Asia in 2006 – between 1 and 1.3 billion units – were of low quality. If the issue of quality is not addressed in the near term, programs and consumers that rely on CFLs to reduce energy use (and associated greenhouse gas emissions) will not achieve the desired results.

There are several reasons for the sustained presence of low quality CFLs in the global market:

(1) Fierce market competition, which results in some manufacturers prioritizing cost reductions over CFL quality;
(2) A lack of CFL regulatory performance requirements in many countries;
(3) The absence of a harmonized global system for testing and rating CFL quality;
(4) A lack of market monitoring, verification and enforcement (MV&E) of CFL regulatory and quality standards; and
(5) A general lack of consumer awareness about CFL quality.

Each of these five issues is discussed in further detail below.

1. Some manufacturers prioritize reducing cost reductions over CFL quality

In general, suppliers have the capability to produce high-quality CFLs, however due to market competition and limited consumer awareness of CFL quality, price became the determinant factor driving sales. In addition, in the wider global market, countries either have no CFL quality standards or they have standards which are unique to their market. The lower the price, the more attractive CFLs become to importers, especially in developing countries. In these markets, manufacturers lack incentive to produce quality CFLs even when they have the expertise and the capacity to do so. Quality CFLs are more expensive to produce because they incorporate better designs and higher-quality components. Without market support, manufacturers who supply higher-quality CFLs often lose sales.

2. The lack of CFL regulatory performance requirements in many countries

At present, 19 economies in the world have published their mandatory CFL MEPS, 22 economies have voluntary CFL energy labels, and 15 economies have issued mandatory energy labels for CFLs. However, the rest of the world still does not have CFL quality standards, which perpetuates the supply of low- quality of CFLs, which are neither monitored nor controlled.

3. The absence of a harmonized global system for testing and rating CFL quality

Worldwide, there are currently 48 different national standards and labeling systems for CFLs either in place or in draft. This patchwork of different CFL standards and testing requirements burdens manufacturers and regulators alike. Compliance with the various programs and testing schemes increases manufacturing overhead costs and off-set some of the cost efficiency gains from volume production. The cost of complying with testing and certification requirements (usually a small percentage of production costs) can rise as high as 4 to 5 percent (USAID ECO-Asia 2009). For the regulators, the differences in the patchwork of test standards reduces their ability to leverage and share test data from other jurisdictions, and thereby eliminates a potential cost saving measure for an enforcement agency.

Currently, there is no harmonized international test procedure or recognized set of quality criteria for CFLs. Production of CFLs is becoming increasingly concentrated in fewer countries for global distribution, and they are subject to location-specific requirements. Although more than 80 percent of CFLs are produced in China, each country surveyed maintains different test procedures, specification levels, and MEPS, if any at all. Countries that have adopted test procedures based on the IEC standards are perceived as taking the first step toward harmonization of the test method. The IEC test standard for CFL performance (IEC 60969) defines how to measure performance but does not establish performance targets. In the absence of a common definition of product quality and an accepted means to measure and share the results, it is very difficult for consumers to distinguish between quality products.

4. The lack of market monitoring, verification and enforcement of CFL regulatory and quality standards

Often, countries like China and India establish mandatory MEPS for CFLs, but these laws are then not followed-up as there is little enforcement, and unscrupulous manufacturers soon learn that the regulations can be ignored. Lack of funding, lack of expertise and competing priorities often result in weak enforcement bodies that do not have sufficient capacity to monitor the quality of CFLs and other regulated products sold in their jurisdiction.

5. The general lack of consumer awareness about CFL quality

Part of the reason consumers choose CFLs by price is the lack of awareness about product quality. Consumers' experience with lighting products is based primarily on the incandescent lamp, which is a simple appliance having little variation between types and manufacturers. This experience is applied to CFLs, with apparently little appreciation that a CFL is a much more complex lamp, comprised of a set of tubes and electronic components. Consumers are often unaware that a manufacturer could choose to use low quality materials to produce CFLs, enabling a lower price but at the same time compromising the lamp's quality (i.e., short lifetime and low reliability). The consumer may not have information about the quality of CFLs they purchase, so apart from brand, so price becomes the determining factor used to choose a CFL. However, if the CFL burns out after 300 hours of service instead of 6000 hours, consumer confidence in CFLs can be undermined and dissatisfied consumers may slow the rate of market acceptance and adoption.

Lessons learned from past international CFL harmonization initiatives

The past few years have seen a number of international initiatives for harmonization of CFL standards, including for example Asia Lighting Compact (ALC)[1] and International CFL Harmonization Initiative (CFLi). Most of these efforts found that the need for harmonization is universal. Generally, they concluded that obtaining high-level support for harmonization from regulators in different countries was not difficult, but agreeing to specific details of harmonization is often a challenge.

[1]http://www.asialighting.org/index.php?menu=p1

Certainly this is mainly due to the complex nature of appliance standards. Different regulators from different countries or organizations often have varying opinions on standards. The different opinions are often caused by the diverse development paths of national standards, challenges in aligning standards development schedules, and differences in expert knowledge and opinion.

4. Overview of LED Standards Worldwide

4.1 Overview of LED standards

Unlike traditional light sources, LEDs are not normally used individually for general lighting. Instead, multiple individual LEDs are bundled together into LED modules, lamps and luminaires which then have sufficient light output that they can be used in general lighting applications. LED lighting products are commonly classified in five categories which are described below: (1) LED chip/individual, (2) LED package, (3) LED module, (4) LED lamp, and (5) LED luminaire.

LED chip / die: A p-n junction semiconductor device that emits incoherent optical radiation when an electric current passes through it. The optical radiation can be in the ultraviolet, visible, or infrared wavelengths, depending on the chemistry of the p-n junction.

LED package: An assembly of one or more LED chips / dies that includes wire bond or other type of electrical connections, packaged with thermal, mechanical, and electrical connections and possibly with an optical lens. A power source / LED driver and standardized lamp bases are not incorporated into the LED package.

LED module / LED array: An assembly of packaged LEDs (components) on a printed circuit board or substrate, possibly with optical elements and additional thermal, mechanical, and electrical interfaces that are intended to connect to the load side of LED driver. A power source and standardized lamp bases are not incorporated into the LED module.

LED lamp: An integrated lamp assembly consisting of packaged LEDs (components) or LED modules, an LED driver, a standard lamp base and other optical, thermal and mechanical and electrical parts as necessary. The LED lamp is able to be connected directly to mains voltage (e.g., 120VAC or 240VAC) through a standard lamp-holder / socket (e.g., E26/E27, B22d). Similar to an integrally ballasted CFL, the LED lamp can be used as a direct replacement for a general service incandescent lamp.

LED luminaire: A complete light fixture consisting of an LED-based light source and a matched LED driver, assembled in a fixture that distributes the light, positions and protects the light emitting elements, and connects the unit to mains voltage (e.g., 120VAC or 240VAC). The LED based light emitting elements may take the form of packaged LEDs (components), LED modules, or LED lamps. The LED luminaire is intended to be directly hard-wired to mains voltage.

Due to the importance and popularity of LED lighting, many countries and entities are prioritizing LED products over other lighting products for standard making. The LED products covered and to be covered in the standards include all types of mentioned above. China has established standards for LED modules, self-ballasted LED lamps, LED street lighting products, etc. CIE has developed test method for measuring individual LED photometric and electrical parameters and defining influential factors (e.g. heat). The US has a series of standards covering from LED lamp to LED luminaire and from photometric and electrical to colormetric. IEC has published a Public Available Standard (PAS) of self-ballasted LED lamps and is working on some more performance and test standards to cover more LED lighting products. Some organizations have also developed voluntary specifications, aiming to increase the market share of LED products through technical support to the manufacturers, raising consumer awareness and confidence in LED products, etc. Such activities include EC JRC LED Quality Charter, ELI, and UK EST. They have come up with specifications for certification/labeling programs for some kind of LED products, including self-ballasted lamps. Moreover, some other regions/organizations, such as India and EU, are pacing in making standards for LED lighting products, which could be expected to publish in the near future.

The table below presents a summary of existing LED related standards and voluntary labeling programs in some of the main economies.

Table 36: LED Related Standards, Voluntary Labeling Programs, and International Standards:

Program	Performance Standard	Test Method Standard
China GB/T	GB/T 24908-2010: performance requirements for self-ballasted LED lamps for general lighting; GB/T 24823-2009: performance requirements for LED modules for general lighting;	GB/T 24908-2010: performance requirements for self-ballasted LED lamps for general lighting; GB/T 24824-2009: measurement methods of LED modules for general lighting
ELI	ELI Voluntary Technical Specification for Self-Ballasted LED Lamps for General Lighting Services	ELI Voluntary Technical Specification for Self-Ballasted LED Lamps for General Lighting Services
EU	EU 244/2009; EC JRC LED Quality Charter	EU 98/11/EC; EU 244/2009; New eco-design regulation for directional lamps coming in 2011;
IEC	IEC/PAS 62612: Performance requirements for self-ballasted LED lamps for general lighting;	IEC/PAS 62612: Performance requirements for self-ballasted LED lamps for general lighting;
UK Energy Savings Trust	EST LED Lamps and Modules V2.0	N/A
US ENERGY STAR	ES Program Requirements for Integral LED Lamps V1.3	LM 79-08: electrical and photometric measurement of SSL products LM 80-08: measurement of lumen maintenance of LED light sources;

4.2 Comparison of LED Technical Performance Criteria

LED standards are adopting a rigorous and high-quality approach to lighting. LEDs are commonly recognized as the next generation of lighting products, offering advantages like high efficacy, environment friendliness, and flexibility for application.

LED lamps are most often used for domestic lighting in the form of either integrated LED lamps (i.e., similar to CFLs) or dedicated LED luminaires (i.e., hard-wired to mains power). For the purposes of this study, our scope and focus is on the integrated LED lamps which can be installed as a direct replacement for an incandescent lamp in a standard screw or bayonet socket. There are a limited number of LED standards available at this time, however we have selected the five standards from the table above -China GB/T 24908-2010, IEC/PAS 62612, IFC Efficient Lighting Initiative, UK Energy Savings Trust LED Lamps and Modules v2.0 and US ENERGY STAR Integral LED Lamps v1.3– and compare the requirements of these standards in the tables that follow.

Scope of Coverage of LEDs
LED lighting products are manufactured and sold in many different configurations, including component parts, integrated lamps, portable lamps and even dedicated luminaires with replaceable and non-replaceable light sources. When comparing the product scope of different standards, this report focuses on self-ballasted LED lamps with conventional lamp caps (e.g., E26/E27, B22), which are designed for domestic and similar general lighting purposes, with power up to 60W, and voltage up to 250V AC. The following table presents the language from each of the five standards reviewed, all of which include these lamps.

Table 37: Comparison of Scope of LED Performance Standards and Voluntary Certifications

Standard	Scope of LED Coverage
China GB/T 24908-2010	Apply to self-ballasted LED lamps used for domestic and similar general lighting purpose, having: (1) a rated wattage up to 60 W; (2) a rated voltage of up to 250 V AC or DC; and (3) lamp cap according to relevant GB standards.
ELI LED Specification	This specification applies exclusively to non-directional Self-Ballasted LED Lamps. These lamps have an integrated means for stable operation and are intended for general lighting purposes. They have screw or bayonet caps, a rated power up to 60W and a rated voltage of up to 250V AC or DC.
EC JRC LED Quality Charter	The scope of the present version LED Quality Charter is limited to LED lamps intended primarily for use in the residential sector. At this stage the European Quality Charter for LED does not include LED modules, luminaires and lamps specific for use in the commercial sectors.
IEC/PAS 62612	Apply to lamps having: (1) a rated wattage up to 60 W; (2) a rated voltage of up to 250 V AC or DC; and (3) a lamp cap according to IEC 62560.1. And does not cover lamps that intentionally produce tinted or colored light or OLEDs.

Standard	Scope of LED Coverage
UK EST LED Lamps and Modules v2.0	Lamp voltage rating marking shall be 230/240V, 240V or a range including 230Vand 240V. Lamp supply frequency rating shall be 50Hz or a range including 50Hz. **GROUP 1 Integral driver products -** Mains voltage LED lamps, using typical type of lamps bases, which provide an 'energy efficient' alternative to standard incandescent or halogen lamps. **Class 1 Mains voltage GU10 -** Directional LED lamps designed to replace existing mains voltage GU10 reflector lamps. **Class 2 Mains voltage type A -** Non-directional LED lamps designed to replace any existing Mains Voltage (240V) type lamps. **Class 3 Mains voltage type B -** Directional LED lamps designed to replace any existing Mains Voltage (240V) nonspecific "reflector" type lamp. **Class 4 Mains voltage reflectors -** Directional LED Lamps intended to replace existing mains voltage reflector lamps. **GROUP 2 Non-integral driver products, Modules and Lamps -** LED lamps/modules that provide an 'energy efficient' alternative to standard incandescent or halogen lamps **Class 21 Low voltage LED reflector lamp modules-** LED reflector modules designed to physically replace existing Low Voltage (12V)MR16 halogen lamps in standard luminaires. As this is a replacement system, lamp module voltage is not limited to 12V. **Class 22 Low voltage LED reflector lamps-** Lamps intended to replace existing low voltage MR16 reflector lamps with typicallyGU5.3 bases but requiring specific 12V power supplies specified by the manufacturer.
US ES LED Specification v1.3	Applies to integral LED lamps, including lamps of non-standard form, and those intended to replace standard general service incandescent lamps, decorative (candelabra style) lamps, and reflector lamps.

Lamp Wattage and Initial Luminous Flux

For lamp wattage requirements, China's GB/T 24908-2010 and the IFC Efficient Lighting Initiative specification both require the power be between 85% and 115% of the rated wattage. The IEC/PAS 62612has a similar requirement, but it is one-sided, stating that the LED product shall not exceed the rated wattage by more than 15%. In other words, the IEC standard is not concerned with lamps that consume less power than they are rated. The UK EST has a wattage requirement, but it relates to the power consumption of the lamp being replaced by the LED lamp. The EST requirements state that LED products shall have power consumption no greater than 25% of the lamp it is designed to replace. This means that in order to get the same amount of light output, LED products have to be at least 4 times as efficient as traditional light sources.

The luminous flux requirements in these standards relate to light output performance. China's GB/T 24908-2010 and IEC/PAS 62612 both have the requirement that the measured light output shall not be less than 90% of the rated luminous flux (i.e., light output). The US ENERGY STAR specification for "omnidirectional" lamps (i.e., emitting light in all directions, simulating to the light distribution pattern of an incandescent GLS lamp) provides the minimum levels of light output relative to the nominal wattage of the lamps being replaced. In other words, if an LED lamp is designed to replace a 100 watt incandescent lamp, its luminous flux would have to be at least 1,600 lumens. The following table presents the language from each of the five programs.

Table 38: Comparison of LED Lamp Wattage and Luminous Flux Requirements

<table>
<tr><th>Standard</th><th>Lamp Wattage Requirements</th><th>Luminous Flux Requirements</th></tr>
<tr><td>China GB/T 24908-2010</td><td>Shall be between 85% to 115% of the rated wattage, or within 0.5W.</td><td>Measured value shall be greater than 90% of the rated value.</td></tr>
<tr><td>ELI LED Specification</td><td>Test wattage shall be within ± 15% of rated wattage.</td><td>The initial luminous flux measured after the ageing time shall be not less than90% of the rated luminous flux.</td></tr>
<tr><td>EC JRC LED Quality Charter</td><td>N/A</td><td>N/A</td></tr>
<tr><td>IEC/PAS 62612</td><td>Shall not exceed the rated wattage by more than 15 %.</td><td>Shall not be less than 90 % of the rated.</td></tr>
<tr><td>UK EST LED Lamps and Modules v2.0</td><td>LED products shall have a rated wattage no greater than 25% of any lamp it is claimed to replace.</td><td>N/A</td></tr>
<tr><td>US ES LED Specification v1.3</td><td>N/A</td><td>For non-standard type: 200 lumen;
For omnidirectional replacement lamps: Lamp shall have minimum light output at least corresponding to the target wattage of the lamp to be replaced as shown below. Target wattages between the given levels may be interpolated.
<table>
<tr><th>nominal wattage of lamp replaced</th><th>minimum initial light output</th></tr>
<tr><td>25 W</td><td>200 lumens</td></tr>
<tr><td>35 W</td><td>325 lumens</td></tr>
<tr><td>40 W</td><td>450 lumens</td></tr>
<tr><td>60 W</td><td>800 lumens</td></tr>
<tr><td>75 W</td><td>1,100 lumens</td></tr>
<tr><td>100 W</td><td>1,600 lumens</td></tr>
<tr><td>125 W</td><td>2,000 lumens</td></tr>
<tr><td>150 W</td><td>2,600 lumens</td></tr>
</table></td></tr>
</table>

Correlated Color Temperature (CCT)

The CCT is measured in degrees Kelvin (K) and refers to the appearance of light output of the lamp from a theoretical black body heated to high temperatures. The performance standards compared all define six popular CCT ratings – 2700K, 3000K, 3500K, 4000K, 5000K and 6500K. The only difference is the US ENERGY STAR rating, which defines these six plus two additional ones at 4500K and 5700K. Other than these two additional CCT ratings in ENERGY STAR, the CCT ratings for China's GB/T, ELI, EC JRC LED Quality Charter, the UK EST, the US ENERGY STAR and the International Electrotechnical Commission (IEC) are the same. The table below presents the CCT requirements in the five standards.

Table 39: Comparison of Correlated Color Temperature for LED Lamps

Standard	CCT Requirements
China GB/T 24908-2010	Nominal CCT / Color coordinates x, Y / Target CCT 6500K 0.313 0.337 6430K 5000K 0.346 0.359 5000K 4000K 0.380 0.380 4040K 3500K 0.409 0.394 3450K 3000K 0.440 0.403 2940K 2700K 0.463 0.420 2720K
ELI LED Specification	Must comply with IEC/PAS62612 and the color tolerance shall be within 7 SDCM from the target values.
EC JRC LED Quality Charter	CCT shall be in the interval 2600 - 3500 K. The rated color shall preferably be one of the three values: F2700 (2720K, X=0.463, Y=0.420) F3000 (2940K, X=0.440, Y=0.403) F3500 (3450K, X=0.409, Y=0.394)
IEC/PAS 62612	The rated CCT shall preferably be one of the following six values: 2 700 K, 3 000 K, 3 500 K, 4 000 K, 5 000 K or 6 500 K **Color Indication CCT x y** F 6500 6400 0,313 0,337 F 5000 5000 0,346 0,359 F 4000 4040 0,380 0,380 F 3500 3450 0,409 0,394 F 3000 2940 0,440 0,403 F 2700 2720 0,463 0,420
UK EST LED Lamps and Modules v2.0	**Color Indication CCT x y** F 6500 6400 0,313 0,337 F 5000 5000 0,346 0,359 F 4000 4040 0,380 0,380 F 3500 3450 0,409 0,394 F 3000 2940 0,440 0,403 F 2700 2720 0,463 0,420
US ES LED Specification v1.3	**Lamps must have one of the following CCTs below:** **CCT x y** 6500K 0.3123 0.3282 5700K 0.3287 0.3417 5000K 0.3447 0.3553 4500K 0.3611 0.3658 4000K 0.3818 0.3797 3500K 0.4073 0.3917 3000K 0.4338 0.4030 2700K 0.4578 0.4101

Color Maintenance

This requirement is based around the concern that poor quality LEDs may experience a noticeable color shift during their operating lifetime. The ELI, the IEC and US ENERGY STAR all have specifications on this parameter which establish a maximum shift. ELI and the US ENERGY STAR have virtually identical requirements, providing a maximum shift in chromaticity over the lumen maintenance test period of 6000 hours. Both standards require that there be no more than a 0.007 shift on the CIE1976 (u', v') diagram. The IEC's requirement is slightly different, stating that the measured CCT values at the initial and 25% of rated life time point (max 6000 hours) shall not move beyond the nominal CCT tolerance category associated with the LED. Three of the standards being compared, the Chinese GB/T24908-2010, EC JRC Charter and the UK EST performance specification do not have a color maintenance requirement.

Table 40: Comparison of Color Maintenance Requirements for LED Lamps

Standard	Color Maintenance Requirements
China GB/T 24908-2010	N/A
ELI LED Specification	The change of chromaticity over the lumen maintenance test period (6000 hours)shall be within 0.007 on the CIE1976(u',v') diagram.
EC JRC LED Quality Charter	N/A
IEC/PAS 62612	Both CCT values (initial and at 25 % of rated lamp life, max 6000h) shall not move beyond the CCT tolerance category described below: Tolerance (categories) on nominal CCT values (Ellipse type) (CCT category) 1-step ellipse Cat 1 2-step ellipse Cat 2 3-step ellipse Cat 3 4-step ellipse Cat 4 5-step ellipse Cat 5 6 step ellipse Cat 6 7 step ellipse Cat 7 >7 step ellipse Cat 8
UK EST LED Lamps and Modules v2.0	N/A
US ES LED Specification v1.3	The change of chromaticity over the minimum lumen maintenance test period (6000 hours) shall be within 0.007 on the CIE 1976 (u',v') diagram.

Color Rendering Index (CRI)

The CRI is a measure of a light source's ability to accurately reproduce colors when compared with a reference lamp. Although CRI is measured differently in the Americas (by reflectivity) versus Europe (by spectral composition), it is still a measurement that is accepted and used to describe the performance of light sources worldwide. Each of the five standards compared has a minimum CRI requirement.

Four of the standards – China GB/T 24908-2010; EC JRC LED Quality Charter, ELI, UK EST v.2.0 and US ES v.1.3 – each have a requirement of minimum 80 CRI. In addition to this minimum CRI value, the US ENERGY STAR rating also requires that the R9 value be greater than zero.[2] The IEC standard has a slightly different requirement, looking at changes in the CRI over the operating life of the lamp. The IEC requires that two tests for CRI be conducted – one initial measurement and one at 25% of rated lamp life (maximum 6000 hours of operation), and that the two values shall not decrease by more than 5 points from the rated value.

In general, LED standards have much higher attention to colorimetry than CFL products and color parameters remain a major issue for LED in the future standard development.

Table 41: Comparison of Color Rendering Index Requirements for LED Lamps

Standard	Color Rendering Index Requirements
China GB/T 24908-2010	Greater than80.
ELI LED Specification	Color Rendering Index (CRI) should be at least 80.
EC JRC LED Quality Charter	CRI > 80
IEC/PAS 62612	Two measurements for CRI: Initial and at 25% of rated lamp life (maximum 6000 h). Neither of the two values shall decrease by more than 5 points from the rated CRI value.
UK EST LED Lamps and Modules v2.0	Greater than 80.
US ES LED Specification v1.3	Minimum CRI (Ra) of 80. In addition, the R9 value must be greater than 0.

Lumen Maintenance

Lumen maintenance is a measure of the rate at which a lamp's lumen output deteriorates over its operating life. Mathematically, lumen maintenance is expressed as a percentage of the luminous flux of a lamp at a given time in its life divided by the lamp's initial luminous flux. The lumen maintenance test is a very important part of evaluating an LED lamp's life performance, as the lifetime testing would be very hard or impossible due to the fact that good quality LED products could last up to 50,000 hours, which represents more than 5.5 years of continuous operation. The table below provides the requirements for lumen maintenance.

The IEC standard doesn't have mandatory requirements for lumen maintenance, but instead creates five categories that describe the different lumen maintenance values. The UK EST requires

[2]The requirement that color rendering be reported for deep red (the R9 metric) in addition to the eight colors comprising the traditional CRI (Ra) was adopted because of the exaggerated effect of R9 in the color space. Simply having a requirement of a value greater than 0 is sufficient to prevent poor rendering of deep red. For example, a tri-phosphor T8 lamp with CRI (Ra) of 85 has an R9 score of 2. (DOE, 2009)

that maintenance for lives greater than 15,000 hours shall be derived from the measurements taken up to and including the 15,000 hour values. China's GB/T 24908-2010 establishes three test time points, at 3000h, 6000h and 70% of rated life, and establishes requirements of lumen maintenance relative to the initial lumen output. The US ES also has a requirement around lumen maintenance, stating that lamps must emit at least 70% of their initial lumen output after 25,000 hours of service (approximately 3 years of continual operation). The EC JRC Charter sets two time points for lumen maintenance, which are 1000h and 15,000h, with requirements of lumen maintenance value and failure rate respectively.

Table 42: Comparison of Lumen Maintenance Requirements for LED Lamps

Standard	Lumen Maintenance Requirements
China GB/T 24908-2010	>=92% at 3000h; >=88% at 6000h; >=70% at 70% of rated lifetime.
ELI LED Specification	(Taking initial value as 100%), the luminous flux of the lamp must be (no less than) 96% at 3000h, and (no less than) 91.8% at 6000h.
EC JRC LED Quality Charter	L70F50 ≥15,000 hours: Maximum 50% lamps having lumen maintenance below 70% after 15,000 hours; L85F05 ≥ 1000 hours Maximum 5% lamps having lumen maintenance below 85% after 1000 hours.
IEC/PAS 62612	Luminous flux decrease at 25% of rated lifetime (max 6000h) as % of 0 h value, and category. 10 % Cat A 20 % Cat B 30 % Cat C 40 % Cat D 50 % Cat E
UK EST LED Lamps and Modules v2.0	Maintenance for lives greater than 15,000 hours shall be derived from the measurements taken up to and including the 15,000 hour values.
US ES LED Specification v1.3	>= 70% lumen maintenance (L70)at 25,000 hours of operation

Power Factor

Power Factor is defined as the ratio of the real power flowing to the load divided by the apparent power in the circuit. Power factors range from 0 to 1, and a value closer to 1 means that the device utilizes grid power more efficiently. A low power factor means that there will be higher harmonic currents and higher power losses in the electric utility's distribution network and power generation infrastructure.

The US ENERGY STAR program has a requirement of a minimum 0.7 for lamps with power consumption greater than 5 watts. The UK EST requires a minimum 0.7 for mains voltage type LED lamps (Classes 1, 2, 3 and 4), and 0.9 for low voltage types (Classes 21 and 22). China's GB/T 24908-2010 requires that the power factor for LED lamps to be the same as for CFL. This requirement states that the measured power factor shall be not be less than 0.05 of the nominal rated power factor. EC JRC Charter and ELI has a requirement that power factor shall be greater than or equal to

0.5 at the maximum rated power of the LED lamp. The IEC has no requirement on power factor. Thus, of the five standards reviewed, the UK EST standard places the most stringent requirements on power factor.

Table 43: Comparison of Power Factor Requirements for LED Lamps

Standard	Power Factor Requirements
China GB/T 24908-2010	Actual value should not be smaller than rated value by over 0.05
ELI LED Specification	Power factor shall be ≥ 0.5 at maximum power.
EC JRC LED Quality Charter	The power factor shall at least be 0.5 for lamps of wattage 2-25W.
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules v2.0	The power factor required shall be: • Class 1, 2, 3 and 4 lamps shall be 0.7. • Class 21 and 22 system shall be 0.9, (High power factor type).
US ES LED Specification v1.3	For lamp power <=5W and for low voltage lamps, no minimum power factor is required; For lamp power >5W, power factor must be >= 0.70

Efficacy

Efficacy is a measure of the light output (i.e., lumens) per unit of energy input (i.e., watts). The term 'efficacy' is used when referring to light sources because it is not a unit-less dimension like efficiency, instead it represents a measure of the lumens per watt of the light source. The US ENERGY STAR, the ELI specification, EU Charter and China's GB/T 24908-2010 all have efficacy requirements. The ELI and China classify the LED lamp products into different types by wattage and CCT rating, establishing a separate efficacy requirement for each classification. The US ENERGY STAR program followed its requirements for CFLs, by simply classifying products by wattage, irrespective of the CCT. The EC JRC LED Charter divides products by CRI value and for higher CRI products (e.g. CRI>90), the stringency of efficacy requirement is lower, which seems to sacrifice efficacy for better CRI. The EC JRC LED Charter also lists target value from 2011 through 2015. The UK EST's LED lamps specification states that LED Lamps should have a rated wattage no greater than 25% of the wattage they are replacing. This is not a discrete lumen per watt efficacy requirement, however it does provide an indicative requirement of the expected wattage consumption per equivalent lamp light output. The IEC standard does not contain efficacy requirements.

For the three standards that do contain efficacy requirements, the stringency levels are reasonably similar. They all range between 40 and 60 lumens per watt. GB/T MEPS requirement is lower than the US ES, but the Tier 1 (Top Level) requirement is higher, while the Tier 2 (EE Level) is about the same as the US ENERGY STAR.

Table 44: Comparison of Efficacy Requirements for LED Lamps

Standard	Efficacy Requirements						
China GB/T 24908-2010	Rated Power (Watts)	Efficacy (lm/W) for CCT 4000K, 5000K, 6500K			Efficacy (lm/W) for CCT 2700K, 3000K, 3500K		
		Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3
	1-5 W	60	50	40	55	45	35
	6-10W	65	55	45	60	50	40
	11-25W	65	55	45	60	50	40
	>25W	60	50	40	55	45	35

Standard	Input Power (Watts)	Efficacy (lm/W)	
ELI LED Specification		CCT: 5000K, 6500K	CCT: 2700K, 3000K, 3500K, 4000K
	1-5 W	50	45
	6-10W	55	50
	11-25W	55	50
	25-60W	50	45

Standard		CRI	Min efficacy	2011	2012	2013	2014	2015
EC JRC LED Quality Charter	NDLS	>80	lm/W	61	65	70	75	80
		>90		52	55	60	65	70
	DLS	>80		50	55	60	65	70
		>90		40	45	50	55	60
	NDLS = Non Directional Lighting Sources DLS = Directional Lighting Sources In the future, 2012 to 2015 targets might be revised according to the development in LED efficacy. Any revision will be discussed and approved at least 6 month before the entry into force							

Standard	Efficacy Requirements
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules v2.0	LED products shall have a rated wattage no greater than 25% of any lamp it is claimed to replace.
US ES LED Specification v1.3	For non-standard LED lamps and replacement LED lamps, luminous efficacy: LED lamp power — Minimum Efficacy < 10W — 50lm/W >=10W — 55lm/W

The table below draws a comparison between the efficacy requirements of CFLs and LEDs for some common wattages and lamps with a CCT no greater than 3500K. The efficacy requirements in both the Chinese and American programs are lower for LEDs than for CFLs. In other words, the standards are more stringent on CFLs, holding them to a higher efficacy requirement than LEDs.

Table 45: Comparison of Efficacy Requirements for CFLs and LED Lamps

Rated Power of Lamp	China's GB/T LED (lm/W)	China's GB/T CFL (lm/W)	US ENERGY STARLED (lm/W)	US ENERGY STARCFL (lm/W)
5 W	35	40	50	50
8 W	40	40	50	50
10 W	40	48	55	55
15 W	40	55	55	65
20 W	40	55	55	65
25 W	40	60	55	65
28 W	35	60	55	65

Average Lamp Life:
Compared to other lamps, LED lighting products can have a very long lifetime and to properly validate (i.e., test) the performance of an LED lamp over these timelines would exceed the lifecycle of the product, due to the rapid changes in LED and driver technology. Three of the standards reviewed have lamp lifetime requirements, with China's GB/T 24908-2010 and the UK EST both having requirements for lifetime of at least 25,000 hours and 15,000 respectively. The UK EST standard defines lamp lifetime as that of the lamp/module L70, F50 point(average lumen maintenance 70% and/or 50% lamp failure), while other standards don't have specific description. The IEC and US ENERGY STAR specifications control life performance by setting requirements for lumen maintenance and do not have specific requirements for lifetime.

Table 46: Comparison of LED Lamp Lifetime Requirements

Standard	Lamp Life Requirements
China GB/T 24908-2010	Average lifetime shall be no less than 25000h.
ELI LED Specification	Must have a minimum rated lifetime of 25,000 hours when 50% of the sample group fails.
EC JRC LED Quality Charter	N/A
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules v2.0	The manufacturers declared life shall be that of the lamp/module L70, F50 point (average lumen maintenance 70% and/or 50% failure to light). This shall not be less than 15,000 hours.
US ES LED Specification v1.3	N/A

Switching Withstand Test

The switching withstand test is designed to ensure that the lamp under test will not fail prematurely or have problems starting or reduced light output as a result of frequent switching. The IEC standard incorporates this parameter as part of Endurance for Built-in Electronic Ballast. The differences between the Chinese, ELI and US ENERGY STAR standards are primarily around the "on and off" time and the number of cycles. Some tests may be needed to provide practical evidence for a persuasive harmonized requirement.

Table 47: Comparison of Switching Withstand Test Requirements for LED Lamps

Standard	Switching Withstand Test Requirements
China GB/T 24908-2010	Cycle for 15,000 times and every time 0.5 minutes on, 0.5 minutes off. LED lamp shall remain alight for at least 15minutes after cycling completion.
ELI LED Specification	At least 12,500 cycles (50% of lamp life)
EC JRC LED Quality Charter	N/A
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules v2.0	N/A
US ES LED Specification v1.3	Lamp cycled once for every two hours of required minimum L70 life.

EMI / EMC / Harmonics

Except for the US ENERGY STAR standard, which references the US Federal Communication Commission's (FCC) 47 CFR as the test method for measuring LED lamps, all of the other standards reviewed make reference to the international testing standard, IEC61000-3-2, except EC JRC LED Quality Charter which does not have requirements on this parameter,. The ELI LED specification also cites IEC 61457, CISPR 15 and local regulations as factors that must be taken into consideration.

Table 48: Comparison of EMC / EMI / Harmonics Requirements for LED Lamps

Standard	EMC/EMI/Harmonics Requirements
China GB/T 24908-2010	IEC 61000-3-2
ELI LED Specification	IEC 61000-3-2, IEC 61547, CISPR 15, local regulations
EC JRC LED Quality Charter	N/A
IEC/PAS 62612	IEC 61000-3-2

Standard	EMC/EMI/Harmonics Requirements
UK EST LED Lamps and Modules v2.0	IEC 61000-3-2
US ES LED Specification v1.3	FCC 47 CFR

4.3 Comparison of LED Test Standards

Unlike CFLs, the test standards for LED are still undergoing fundamental change and improvement as they develop into robust, repeatable test methods that are accurate and predictable of LED performance. LED lighting is an emerging technology, and is projected to eventually become the main-stream light source over the next decade, however even now, there are not many test methods, and issues relating to testing of LEDs are still being debated.

For the purposes of this review, the referenced test method standards associated with the performance standards discussed in the previous section are listed in the table below.

Table 49: Test Standards Referenced for LED Lamps

Performance Standards compared	Reference standards for test procedures			
	Electrical and photometric test	EMC/ EMI/ Harmonics	Colorimetry	Definition and terminology
China GB/T 24908-2010	GB/T 24824 (NEQ to CIE 127)	IEC 61000-3-2	CIE 15	GB/T 24826 (neq to IEC 62504)
ELI LED Specification	IEC/PAS 62612	IEC CISPR 15 IEC 61000-3-2 IEC 61547	CIE 13.3	N/A
EC JRC LED Quality Charter	IEC/PAS 62612 Ed1; IESNA LM79 IESNA LM80	N/A	CIE 13.3	N/A
IEC/PAS 62612	IEC 60081 IEC 60598-1 CIE 84: 1989	IEC 61000-3-2	CIE 1931	IEC 62504
UK EST LED Lamps and Modules v2.0	IESNA LM79 IESNA LM80	FCC 47 CFR	ANSI C78.377 CIE 13.3 IESNA LM16	ANSI/IESNA BP-16-05
US ES LED Specification v1.3	IEC/PAS 62612	61000-3-2	ANSI C78.377 (referred to CIE 13.3, CIE 15, IESNA LM79)	IEC 62504 (Draft)

As shown in the table, most of the photometric and colorimetric tests are ultimately refer to CIE standards. For electrical, EMC/EMI/Harmonics and definitions, there are still two lineups, which are IEC and ANSI/IESNA/FCC. Based on this situation, three out of four standards under comparison of performance parameters are selected for test method comparison. They are: IEC/PAS 62612,UK EST LED Lamps and Modules V2.0 and ES Integral LED Lamps V1.3.

Ambient conditions for LED measurement

Ambient conditions have effect on LED performance, like what they do to CFLs. Similar to CFLs, LEDs radiate heat when operating. Differently, LEDs produce more heat and more easily affected. This is a fair reason for standards to consider more details on it. As shown in the table below, US standards (e.g. LM 79) have relatively much detailed description and regulation on ambient conditions, while IEC and UK EST lack of specific requirements for ambient conditions.

Table 50: Comparison of Ambient Condition for LED Measurement

Standard	Ambient conditions for LED measurement
ES LED Spec V1.3	**(From LM 79, to which ES LED Spec referred)** **Air Temperature** The ambient temperature in which measurements are being taken shall be maintained at 25°C ± 1°C. If measurements are performed at other than this recommended temperature, this is a non-standard condition and shall be noted in the test report. **Thermal Conditions for Mounting SSL Products** The SSL product shall be mounted to the measuring instrument so that heat conduction through supporting objects causes negligible cooling effects. **Air Movement** Air flow around the SSL product being tested should be such that normal convective air flow induced by device under test is not affected.
IEC/PAS 62612	For measurements, Draught-free, Lamps shall be operated in free air; Ambient temperature of (25 ±1) °C; Relative humidity of 65 % maximum;
UK EST LED Lamps and Modules V2.0	All life tests for Classes 2 and 3 shall be carried out in free air.

Test voltage and frequency

This part of requirement mainly adopted from CFLs. Comparing with IEC, more specific description could be useful for ES and UK EST.

Table 51: Comparison of Test voltage and frequency

Standard	Test voltage and frequency
ES LED Spec V1.3	**(From LM 79, to which ES LED Spec referred)** Frequency of 60 Hz or 50Hz, and RMS summation of the harmonic components does not exceed 3 percent of the fundamental during operation of the test item. The voltage shall be regulated to within±0.2 percent under load.
IEC/PAS 62612	Test voltage stable within ±0.5 %, during stabilization periods; ±0.2 % for measurements; 2 % for ageing and luminous flux maintenance testing; Power supply's THD shall not exceed 3 %; All tests shall be carried out at rated frequency;
UK EST LED Lamps and Modules V2.0	All life testing will be carried out at 240 volts.

Base position

The principle of giving light is different between CFLs and LEDs. There is no mercury or cathode in LED lighting, however, base position can influence the performance due to radiated heat while operating. The method of setting up samples for measurement is exactly the same as CFLs.

Table 52: Comparison of Base position

Standard	Base position
ES LED Spec V1.3	In general, unless otherwise specified: 5 base up 5 base down;
IEC/PAS 62612	Vertical base-up for all tests.
UK EST LED Lamps and Modules V2.0	Cap up

Sample size

Method of sampling is inherited from their CFL specification respectively. For new tests, such as luminous intensity distribution, ES believes 1 sample would be representative.

Table 53: Comparison of sample size

Standard	Sample size
ES LED Spec V1.3	1 for operating frequency; 1 for EMI; 1 for luminous intensity distribution; 5 for transient protection; 10 for other tests, e.g. efficacy, lumen output, CCT, CRI, lumen maintenance, switching withstand test, power factor, color maintenance.
IEC/PAS 62612	Minimum 20 samples
UK EST LED Lamps and Modules V2.0	10 lamps

Preparation before initial test

All standards under comparison share the same method of preparation before initial test. As mentioned above, LEDs work differently from CFLs, thus there is no need for a 100-hour ageing before initial tests.

Table 54: Comparison of Preparation before initial test

Standard	Preparation before initial test
ES LED Spec V1.3	**(From LM 79, to which ES LED Spec referred)** Shall be tested with no seasoning.
IEC/PAS 62612	No ageing needed prior to testing
UK EST LED Lamps and Modules V2.0	No ageing needed

Life test

Lifetime test is different from CFLs. LEDs don't die suddenly, but decrease in lumen output gradually during usage. Different standards may set different levels to define lamp failure. For example, IEC uses 70% of initial lumen output (expressed as L70) as the bottom line for professional applications, and 50% for domestic use. There is also a failure rate value involving the definition of average lifetime. The standards under comparison all use 50% (expressed as F50).

Table 55: Comparison of Life test

Standard	Life test
ES LED Spec V1.3	N/A
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules V2.0	Life time definition: L70: Life to 70% Lumen maintenance for test batch. F50: Max 50% failure within a test group against lumen maintenance requirement.

Luminous flux

Although LED chips are considered as directional light sources, but self-ballasted LED lamps could be assembled to omnidirectional like bare CFLs. However, IEC is considering a more specialized test method of luminous flux for LED lamps.

Table 56: Comparison of Luminous flux

Standard	Luminous flux
ES LED Spec V1.3	**(From LM 79, to which ES LED Spec referred)** Two testing systems introduced: (for details please refer to LM 79) 1. Integrating sphere 2. Gonio photometer
IEC/PAS 62612	Currently referring to CIE 84, but considering optimization for LED lamps
UK EST LED Lamps and Modules V2.0	1. Each sample is positioned centrally ("cap-up") in a 1.0m diameter Integrating Sphere Photometer; 2. Absorption correction; 3. Lamp stabilization; Note: If the lamp has integrated electronics, the lamp would be allowed to stabilize for a minimum period of 1hr outside of the sphere on a "stabilizing rack" and using a black interconnecting lead and a switch "changeover" box (this switch simultaneously disconnects power to the lamp from the stabilizing rack, and connects power to the lamp from the interconnecting lead), allowing the lamp to be transferred to the sphere without loss of power.

Switching withstand test

Like CFLs, self-ballasted LEDs incorporate electronic components and LED chips experience electric current impacts each time turned on and off. However, the ON and OFF time is different from CFLs in ES.

Table 57: Comparison of Switching withstand test

Standard	Switching withstand test
ES LED Spec V1.3	2 minutes on, 2 minutes off.
IEC/PAS 62612	N/A NOTE: the purpose of Endurance test for built-in electronic ballast is similar to Switching withstand test
UK EST LED Lamps and Modules V2.0	N/A

Luminous intensity distribution

This test ensures the uniformity of light given by light sources, which are self-ballasted LEDs in the context. Non-reflector type CFLs do not take this test as physically and technically they are symmetric. However, a self-ballasted LED is a united light source of several (e.g. 6 to 20) individual LED chips. In this case, tests shall be taken to make sure the quality of assembly of LED chips is good enough to produce uniform light.

Table 58: Comparison of Luminous intensity distribution

Standard	Luminous intensity distribution
ES LED Spec V1.3	See LM 79
IEC/PAS 62612	N/A
UK EST LED Lamps and Modules V2.0	N/A

EMI/EMC/Harmonics

The EMI/EMC/Harmonics for LED lamps are the same as their CFL counterparts.

Table 59: Comparison of EMI/EMC/Harmonics

Standard	EMI/EMC/Harmonics
ES LED Spec V1.3	FCC 47 CFR
IEC/PAS 62612	IEC 61000-3-2
UK EST LED Lamps and Modules V2.0	61000-3-2

From the tables presented above on LED test methods, it's clear that for some parameters related to LED lamps, there are no existing test methods in some standards yet. For example, the IEC test method does not include Luminous Intensity Distribution, and EST does not have Switching Withstand test.

For general test conditions, it is obvious that the three standards under comparison have inherited a lot from CFL test standards, such as IEC still requiring a sample size of a minimum of 20 lamps and in vertical base up position for test, and ES still requiring 10 samples for electrical and photometric tests and five base up and five base down.

Tests methods for electrical and photometric parameters stay mainly the same as for CFLs, such as requirements for power supply, equipment selection and test circuit. However, comparing with other types of light sources, individual LEDs are quite small and directional, so test method for some parameters need to be modified from CFLs and incandescent. Currently IEC is using CIE 84 for luminous flux measurement, but considering a proper update suitable for LEDs. On the other hand, ANSI and IESNA have developed a series of test methods for LED lamps (and LED modules, etc.), which could be used for other countries and organizations, who are putting efforts into LED standards development.

In general, LEDs are lacking of mature test standards globally. Although efforts are being made to this area, some attention shall be paid to improving and promoting the existing standards rather than establishing new ones in order to raise the work efficiency and pave for harmonization.

5.Conclusions and Recommendations

Although many lighting products are more energy-efficient than incandescent lamps, CFLs and LEDs are two outstanding products with key roles to play in the global efforts to phase out incandescent lamps. CFLs are a widely used, reliable, and internationally traded efficient lighting source that has been commercially available for decades. LEDs are an emerging technology, in a rapid technological improvement phase, and are regarded by many experts as the "next generation" efficient light source.

CFL quality is a major issue of concern in many countries. This is due to: (1) fierce market competition, which results in some manufacturers prioritizing cost reductions over quality; (2) the absence of a harmonized global system for testing and rating CFL quality; (3) a lack of market monitoring, verification and enforcement of CFL regulatory and quality standards; and (4) a general lack of consumer awareness about CFL quality.

Although there are many national MEPS and test standards for CFLs worldwide, there are differences between them due to uncoordinated efforts in the standards making processes. The proliferation of and variation between CFL regulations and testing requirements around the globe has created a regulatory patchwork that is undesirable, ineffectual and costly.

Regardless some recent efforts made regionally by some initiatives such as Asia Lighting Compact (ALC), there is no globally adopted and harmonized test procedure or recognized set of quality criteria for CFLs. Without a common definition of product quality or a consistent and accepted global test procedure, consumers cannot distinguish good-quality from poor-quality CFLs. In this situation, consumers either rely on brand-name recognition or gravitate toward lower-priced products, exacerbating the proliferation of lower-quality products.

With regard to LEDs, the main issue of concern is the difficulty in determining a product's reliability and quality. This issue is mainly due to: (1) the relative immaturity of LED performance and test procedures supporting the market, which allows a wide degree of variance in reliability and quality of LED products in the market; (2) a lack of harmonized international MEPS, quality standards and test procedures to control the quality of LEDs traded internationally, leading to poor consumer experience in the LED market and discouraging manufacturers from producing high quality LED products; and (3) a lack of labeling and endorsement schemes to help governments and consumers identify and consume quality LED products.

LED standards development is at a stage similar to where CFLs were twenty years ago. Most LED lighting products are manufactured in a few countries for global distribution, and a few leading countries have already published product performance and test standards. However, the available LED standards have limited coverage of LED products, and significant variations exist between the product scope and test methods of the different standards. It would be advantageous for countries to coordinate their LED performance standard and test methods in order to avoid the same missteps of CFLs.

There are many areas where action could be taken that would support and facilitate global harmonization around test methods, standards and labels for both CFLs and LED lamps. If these initiatives were undertaken and adopted by regulators and market transformation actors working in all the major and emerging economies, the impact would be considerable. Overall, the alignment of lighting products standards could bring the following benefits:

- Provide a coordinated platform and criteria to address the quality issue of lighting products, eliminating low quality products and accelerate the phase-out inefficient lamps;
- Enable the realization of substantial additional energy savings through adoption of stringent performance requirements and broader product scopes than are currently in place;
- Lower compliance costs for manufacturers through the use of uniform test methods and other regulatory and informational mechanisms;
- Improve the potential for local and cross border enforcement actions, increasing global trade / market competition, and potentially lowering costs to consumers; and
- Improve the credibility and clarity of product information to consumers.

In this study, CLASP compared the performance standards, test methods and referenced standards associated with integrally ballasted CFLs and LED lamps. Through this study and comparison at a detailed level, it emerged that there is good potential for harmonization around both products – even though for general illumination, CFLs have approximately 30 years of market presence whereas LEDs only have five years. CLASP found that for CFLs, many of the standards and MEPS reviewed had similar requirements and referenced the same (or with slight deviations from) established international test methods. It would be feasible therefore to assemble the regulatory teams and initiate a dialogue that concentrates on these differences and seeks to address those which have a material impact.

For LED lamps, the test methods and labeling schemes are still emerging and are subject to being actively refined as the technology evolves and new and better testing methods are developed. In many ways, the LED lamps presents a 'green-field' potential to coordinate international test methods, standards and labeling and avoid the situation observed today in CFLs of a costly patchwork of regulations and requirements.

CLASP has clustered its recommended actions around encouraging harmonization of CFLs and LED lamps around four areas: (1) Communication, (2) Test Methods, (3) Labeling, and (4) Minimum Energy Performance Standards. Each of these areas has several potential recommended actions which would help achieve the overall objective of harmonization for CFLs and LED lamps.

Table 60: Summary of Recommendations and Conclusions

Area	Objective	Actions
I. Communication	Encourage, facilitate and expand the communication and sharing of information between regulators, test experts, consumers and other stakeholders.	*I.A Improve transparency of regulatory processes and communication between regulators* *I.B Raise awareness among consumers about high-quality, energy-efficient CFLs and LED lamps*
II. Test Methods	Align methods of measurement and metrics of performance for CFLs and LED lamps.	*II.A Support the development of international harmonized test methods, coordinated around review cycles* *II.B Develop a framework to promote the global recognition of test data around the use of consistent test methods and certified laboratories*
III. Product Labeling	Develop consistent, uniform labeling schemes that recognizably communicate energy-efficiency	*III.A Establish a framework for setting labels or establishing a quality mark* *III.B Develop a global voluntary "reach" efficiency standards and labeling system*
IV. Minimum Energy Performance Standards	Align current energy performance requirements and potentially establish forward-looking, ambitious regulatory requirements	*IV.A Develop an international framework for harmonizing MEPS for CFLs and LED lamps*

Each of these potential actions is discussed in more detail below, in some instances with explicit recommendations on first steps that could be taken.

I. Communication

Objective: Encourage, facilitate and expand the communication and sharing of information between regulators, test experts, consumers and other stakeholders.

I.A Improve transparency of regulatory processes and communication between regulators

Even when a policymaker knows that both they and another country are simultaneously regulating a product, it can be difficult to locate relevant technical and policy information that could valuably transfer from one policy environment to the other. One of the reasons these difficulties may arise, or be more problematic to address, is because not all aspects of the regulatory process are in the public domain.

Openness and transparency of the standard-making process can enhance communication among standard-making authorities. This in turn can increase the potential for international harmonization of standards. Government standard-making organizations need to share regulatory information with stakeholders such as industry and appliance consumers to increase openness in the rulemaking process. This can enable all stakeholders to provide informal contribution to the standard making process.

Establishing an international mechanism to facilitate better communication between the national regulators will enable multi-lateral technical level information sharing and collaboration on testing, technology, market and other issues associated with the development of efficiency standards. Such an international mechanism can provide a platform to:

- Periodically share information on regulatory schedules and plans so that overlapping schedules can be identified and, when feasible, schedules can be coordinated to foster increased collaboration.
- Share product certification and testing data when feasible and of interest to all participating programs, and explore options for other forms for cooperation related to enforcement of minimum energy efficiency requirements.
- Periodically compare MEPS requirements and test procedures to identify regulatory gaps and underutilized energy savings potential.

Currently there are a few international initiatives such as US/EC cooperation, 4E SSL Annex research, and the SEAD program that promote standards harmonization. A combined, coordinated effort by these organizations could help advance both the technology roadmap and standards harmonization. They can also work together to arrive at the recommended performance and quality categories, as well as recommended product categories, test methodologies, data sharing plans, etc. suitable for and acceptable to agencies and stakeholders globally.

SEAD is developing online technical and programmatic resources for the appliance/equipment efficiency activities for all SEAD member countries. These resources may include a database of product standards coverage, comparisons of minimum efficiency requirements, schedules for new or updated requirements and test procedures, and product performance data as part of a platform for increasing openness and transparency of the regulatory process. However, much of these data will be available only to SEAD member countries.

Action: UNEP's en.lighten initiative could collaborate with SEAD to develop a comprehensive global information sharing resource for the standards development of lighting products, starting with CFLs and LED lamps. Each country may need to establish lead technical-team points of contact, and organize information sharing discussion between their respective teams of experts working on active areas of collaboration at least once per quarter during periods of regulatory development and analysis.

I.B Raise awareness among consumers about high-quality, energy-efficient CFLs and LED lamps

The increased adoption of high-quality, energy-saving CFLs and LEDs provides an opportunity for mitigating global climate change, while also enhancing international collaboration on common clean energy challenges. A move toward this as well as increasing regulatory transparency and sharing of analysis fits well with the current state of awareness and support for global harmonization efforts.

Action: UNEP's en.lighten initiative could work to improve communication about CFL and LED quality to consumers. UNEP could work to take a coordinating role engaging governments, manufacturers of CFLs and LEDs (and their associations), NGOs and social-impact groups to increase end-user awareness of the importance of promoting high-quality CFL and LED products. This communications strategy could include a global promotional network, a large scale marketing program to raise awareness, and other outreach efforts.

II. Test Methods

Objective: Align methods of measurement and metrics of performance for CFLs and LED lamps.

II.A Support the development of international harmonized test methods, coordinated around review cycles

At the core of any international effort to promote high-quality, energy-efficient products are test procedures to measure performance and provide metrics that are useful in a voluntary and regulatory context. Under the established international protocols for test procedure standards development, participants need to promote technical collaborations and identify opportunities to harmonize test methods where possible. When full harmonization is not feasible, the technical teams should develop and adapt test methods that produce consistent metrics that enable performance comparison between jurisdictions.

The anticipated process to achieve harmonization of global test procedures is for CFLs and LED lamps are slightly different. For CFLs which are a mature product with approximately 30 years in the market, countries should be encouraged to work toward aligning their respective test methods in future scheduled revisions. For instance, all countries could consider harmonizing around a consistent set of IEC and CIE test methods as the basis for common test procedures on quality and energy performance of CFLs. Nearly all Asian governments and EU countries that have CFL programs in place use the IEC test procedures as their international reference standard, however the large US market references different (domestic) test methods.

Action: UNEP en.lighten could commission a comprehensive technical study comparing all aspects of the IEC, CIE and ANSI/IESNA test methods for CFLs, with recommendations on how these test methods could be combined into one consistent test method.

For LEDs, due to the recent emergence of the LED general illumination industry, there are only a handful of testing standards with the IEC and ANSI/IESNA as the leading reference standards. For LEDs, the aim should be to secure the adoption of harmonized test requirements and efficiency metrics as there are currently very few adopted around the world at this time. Therefore, it's an excellent opportunity for countries to work collaboratively on the development and adoption of new, harmonized test procedures for LED lamps.

The IEA initiated a program, Efficient Electrical End-Use Equipment (4E) which has an annex focusing on solid-state lighting (SSL), which includes LEDs. One of the three objectives of the 4E annex on SSL is to harmonize SSL performance testing, which includes working to assess a range of existing SSL test procedures and build a system of testing that is manageable, robust and acceptable to a broad range of stakeholders.

Action: UNEP en.lighten could partner with proactive global and regional stakeholders working on LED standards, such as IEA's 4E SSL Annex, to extend country participation, provide technical and administrative resources, and ultimately assist in helping to ensure the process moves quickly toward the drafting of one test method that can be adopted by the appropriate international bodies.

As with CFLs, international organizations such as the IEC are where these global test procedures should be maintained. The idea behind these proposed actions is to organize a process or a forum which can help to generate material for the IEC technical committees to review and adopt. These supportive activities should reduce the burdens on the technical experts who volunteer their time at the IEC, and enable them to accelerate adoption of a harmonized global test method.

II.B Develop a framework to promote the global recognition of test data around the use of consistent test methods and certified laboratories

Countries can enhance international cooperation on quality testing of CFLs and LED lamps through efforts to extend the global recognition of test data. Countries could be supported to conduct random testing of samples from the market, and publishing those test results for sharing across the globe. This approach would lower overhead costs associated with market monitoring and compliance verification, and help to ensure that manufacturers servicing multiple markets provide accurate and truthful reporting on their products.

In addition, countries and national and international test agencies should consider initiating cross-country round-robin testing to compare a laboratory's capacity to test lighting products, including CFLs and LED lamps. These round-robin tests improve the general testing capability, and ensure a level play field for manufacturers producing high quality lighting products.

Each country could establish lead technical teams with designated points of contact and organize information sharing discussions between the teams to actively work on areas of collaboration. Such technical level collaboration will reveal harmonization opportunities and increase the likelihood of maximizing cost-effective reductions in energy use and emissions for participating countries.

Action: UNEP en.lighten could establish this framework to facilitate global cooperation on test methods for CFLs and LED lamps. Key tenets of this framework would include (1) random sampling, testing and publication of test results; (2) a round-robin testing to compare test quality and reliability across multiple jurisdictions; and (3) identify points of contact within each participating country who can organize information sharing and collaboration within their country.

III. Product Labeling

Objective: Develop consistent, uniform labeling schemes that recognizably communicate energy-efficiency

III.A Establish a framework for setting labels or establishing a quality mark

Labeling products to inform businesses and/or consumers about the energy performance of a product has been used by many countries for decades. These labels, including the US Energy Guide and ENERGY STAR, the European A to G and the Asian scale of stars all communicate information about the energy use of the product and work to promote market adoption of more energy-efficient products. On the other hand, the variety of labels, categories, test methods and other differences creates problems and incurs costs for manufacturers participating in these schemes.

While it may be difficult to arrive at a customer-facing categorical label about energy-efficiency that is accepted in all countries around the world, there is the potential to establish a business-to-business label similar to the one for external power supplies which is marked on virtually all products sold globally. The label is the "External Power Supply International Efficiency Marking Protocol", and it provides a medium for power supply manufacturers to designate the efficiency of their product so their customers and government regulators alike can easily determine whether the unit is efficient. This label consists of a Roman numeral (I – VII) printed on the power supply nameplate. The scale is designed with I being the least efficient and VII being the most efficient. To date, levels I – V have been set and levels VI and beyond have been reserved for future use as more efficient power supply technology is developed. Energy performance of the power supply is measured under the internationally supported test method.

This type of approach could be very effective in certifying and communicating energy performance on both CFLs and LED lamps. The quality mark for LEDs could designed to include unassigned label categories as LEDs are projected to improve their energy-performance significantly over the next decade.

Currently, there are two regional initiatives promoting a set of common quality criteria and performance levels for qualified CFLs and LEDs. One is the Asia Lighting Compact CFL Quality Guidelines which set 3 tiers for a CFL to quality for the ALC product marking. The second is the European LED Quality Charter initiated by the European Commission Joint Research Centre, this Charter offers a high quality voluntary standard for European utilities, industries to manufacture, market and sell high quality LED lamps in EU.

<u>Action</u>: UNEP en.lighten could be partner with existing regional initiatives such as ALC and European Commission Joint Research Centre to establish a framework around the establishment of a regional quality mark or label that would be applicable to CFLs and one for LED lamps. These initiatives should be designed to have the potential to be applied globally.

The importance of a quality mark for LED lamps cannot be overstated. Presently, many consumers are subject to exaggerated and unverified claims of performance and quality. As the LED products fail to achieve the professed level of performance, a 'market spoiling' effect occurs with consumers rejecting this emerging technology. Therefore, it becomes increasingly critical that agencies work toward the development of a product quality mark or label to help consumers select quality products.

Due to the special characteristics of LED lighting, the development of LED standards needs to pay more careful to evaluating the system, not simply the LED itself. It's the whole replacement lamp – LEDs, driver, lens, heat sink and housing – the overall system that should be assessed and marked in the performance label.

Countries could benefit by working together to find common ground on minimum quality ratings, and develop common performance quality standards. These quality standards could be used to keep low-quality CFLs and LED lamps out of the market, not acting as a barrier to good-quality products. There is a need for agreement on CFL and LED performance and quality levels that are recognized across nations, focusing on a common set of criteria covering all aspects of CFL and LED performance, not just a few attributes.

Action: UNEP en.lighten could bring nations together around this issue of quality CFLs and LED lamps, and support the work to identify the minimum performance specification that will ensure all sub-standard lamps are identified, so they can be blocked from importation or manufacture.

III.B Develop a global voluntary "reach" efficiency standards and labeling system

In addition to harmonization of performance, MEPS standards and test methods, countries may work together on the performance requirements associated with the best-performing products, clearly differentiating these products for consumers. This type of effort can stimulate technical innovation and competition amongst manufacturers.

In order to ensure that CFLs and LED lamps are pushed to the highest achievable efficiency levels, UNEP en.lighten may consider supporting the development of a global voluntary "reach" efficiency standard that recognizes the top 10% of products in the global market. The concept of a top-runners programme is already well established in Asia, through Japan's program and the new Chinese standards which include the top-runner products. UNEP could work to help develop a market-based Top Runners Program for highly efficient products and manufacturers to stimulate the enthusiasm of industry and promote market transformation to high quality CFLs and LED lamps.

Action: UNEP en.lighten could establish a global "reach" efficiency standard for CFLs and LED lamps that is ambitious in terms of efficacy and quality standards, pushing manufacturers to compete for recognition in a program focused on identifying premium products.

IV. Minimum Energy Performance Standards

Objective: Align current energy performance requirements and potentially establish forward-looking, ambitious regulatory requirements

IV.A Develop an international framework for harmonizing MEPS for CFLs and LED lamps

Research shows that over the long-term it is important to have mandatory testing and labeling of all products in the market and to develop minimum energy performance standards. Countries need to work together to identify opportunities to harmonize MEPS when such harmonization is feasible, legally permissible, and consistent with other program objectives, such as the achievement of the maximum reduction in energy use and emissions that is economically justified in each country.

In dealing with the inaccuracy of LED performance claims in the market, which misleads the consumers in the selection of high quality LED lighting product, government regulators can establish a LED certification scheme to certify LED products with high quality standards, and promote high quality LED products in the market by conducting outreach to help inform manufacturers and retailers about best performing products.

Harmonization of MEPS for CFLs is not easy thing to do, due to the existence of a large number of MEPS across the globe, and it requires time-consuming process to reach political consensus. Compared to CFL, LED is at a right stage of standard development with better conditions for international harmonization of MEPS, as no LED MEPS have been established yet.

Action: UNEP en.lighten could create an international framework that would prioritize harmonization of MEPS for CFLs and LED lamps, recognizing the critical juncture for both of these products in the market as the global incandescent phase-out commences.

This support needs to involve updating energy efficiency standards in countries with existing standards, in order to reflect changes in industry and consumer expectation, and with enhanced communication with international best practices, to pursue a greater degree of harmonization of standards. Efforts need to be made to harmonize country-specific MEPS to ones that can help improve the quality of CFLs and LED lamps, save energy, and achieve the maximum degree of alignment with international best practices. Activities undertaken in this framework could include support and training for countries with poor technical knowledge and that are unable to identify and evaluate efficient lighting options to develop MEPS standards, certain capacitytraining and technical support.

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