



Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING

UN Environment - Global Environment Facility | United for Efficiency (U4E)



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FOREWORD

Electricity for lighting accounts for approximately 15 per cent of global power consumption and 5 per cent of greenhouse gas (GHG) emissions. High-efficiency lighting technologies offer up to an 85 per cent improvement in energy efficiency compared with conventional lighting technologies, while providing an equal or better quality of light.

Because of this potential, the United Nations Secretary-General's Sustainable Energy for All (SEforALL) initiative identifies energy-efficient lighting as a "High Impact Opportunity". It can reduce countries' GHG emissions, generate significant economic benefits, enhance energy security, and improve people's wellbeing.

To leverage this opportunity a lighting initiative, en.lighten, was established in 2010. en.lighten aimed to accelerate a global market transformation to energy-efficient lighting technologies, as well as to develop strategies to transition to energy-efficient lamps. It was a public-private partnership (PPP) between the UN Environment, OSRAM and Philips Lighting, supported by the Global Environment Facility (GEF). As part of the partnership, the National

Lighting Test Centre of China established the Global Efficient Lighting Centre (GELC), and the Australian Government supported developing countries in Southeast Asia and the Pacific.

Building on the success of the en.lighten initiative, UN Environment and the GEF launched a new United for Efficiency (U4E) initiative in 2015. The initiative supports countries in their transition to the use of energy-efficient lighting, appliances and equipment. en.lighten now represents the lighting chapter under U4E. It focuses on developing countries and emerging economies, which are seeing the largest growth in energy-consuming products. U4E works under the umbrella of the SEforALL initiative, as the leading "Energy Efficiency Accelerator"

for Lighting and Appliances and Equipment.

This report is published as part of U4E and focuses on lighting. The report guides policymakers on how to promote energy-efficient lighting in their respective national markets. It is based on the integrated policy approach, which has been used around the world to bring about sustainable and cost-effective market transformation.

This report was developed in a holistic process with participation from over 20 organisations. This included international organisations, environmental groups, international lighting manufacturers, government officials, and academic institutions. Our experience is that the sort of credible guidance



resulting from a balanced expert group is very effective in reducing uncertainty, and measurably helps countries adopt energy policies that make economic sense and help reduce carbon emissions.

The earlier work of en.lighten complements this report. This includes reports such as *Achieving the Global Transition to Energy Efficient Lighting Toolkit*, *Developing Minimum Energy Performance Standards for Lighting Products: Guidance Note for Policymakers*, and a series of six reports aimed to improve the monitoring, verification, and enforcement (MVE) of lighting products that can lead to other energy efficiency measures including legislation and administrative processes. This new report also provides an update

in policy recommendations to adjust for the market shift to light emitting diodes (LEDs), which offer significantly greater electricity and financial saving.

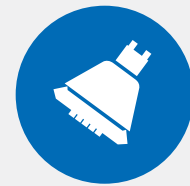
The report is part of a series of U4E reports on five product groups. The other reports in the series cover room air conditioners, residential refrigerators, electric motors, and distribution transformers. An additional overarching report, "Policy Fundamentals Guide," provides crosscutting, general guidance critical to the establishment of a successful energy efficiency programme.

It is our hope that decision-makers will use the information in this report to select the right policies for the coming decades.

This report was developed in a holistic process with participation from over 20 organisations.



THIS REPORT FOCUSES ON ENERGY-EFFICIENT LIGHTING



OTHER GUIDES IN THIS SERIES INCLUDE:



AND AN OVERARCHING FUNDAMENTAL GUIDE:



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EXECUTIVE SUMMARY

Lighting is widely used in everyday life. It is a significant factor contributing to our quality of life and productivity of our workforces. Artificial illumination extends the productive day, enabling people to work in homes, offices, buildings and factories.

Lighting equipment, however, consumes resources. It does so in the manufacturing phase and, more importantly, when installed and operating (i.e. producing light). As our economies grow and populations expand, the global demand for lighting will increase.

Policy measures that transform markets toward higher energy efficiency are needed. Lighting is one of the most cost-effective products for setting such measures. This is partly because in some markets the incumbent

products include technology such as incandescent lamps, which are based on a 125 year-old technology and are replaceable with widely available products that can cut power use by 80 - 90 per cent. Globally, according to a UN Environment lighting market model including over 150 country lighting assessments, there are still seven billion incandescent lamps in use in 2016.

Lighting technology spans great ranges of performance. There are inefficient products burning

Energy-efficient lighting is usually the lowest life-cycle cost option.

fuel or heat metal (i.e. tungsten filament lamps) and highly efficient designs producing light from gas discharge lamps or semiconductor junctions. Governments can establish cost-effective policy measures that remove the least efficient products from the market and accelerate the adoption of the highest efficiency models.

There are multiple advantages of energy-efficient lighting for governments. Energy-efficient lighting is usually the lowest life-cycle cost option. It can be used to stimulate efficiency in the market across other products and to promote accelerated adoption of more efficient technology. It reduces peak loading, lowers customer bills and reduces mercury and the volume of material being sent to the landfill.

Payback time of energy-efficient lighting varies depending on equipment and energy costs. It ranges from less than one year (for direct retrofit of a light source) to two to three years for a complete lighting system overhaul. The latter requires higher investments but will render higher annual savings in return.

We currently consume 2,900 TWh of electricity per year for lighting. This is equivalent to five times the total national consumption of Germany. Over the next two

decades lighting services are projected to rise by approximately 50 per cent relative to current levels of demand.

By 2030, these policy measures would reduce electricity demand for lighting to 2,160 TWh per year, saving up to 640 TWh of electricity, according to the UN Environment model. This slight savings in step with such a large increase in lighting service is due to a widespread shift from conventional lighting technologies like incandescent, halogen and fluorescent lamps to lighting products based on light-emitting diodes (LEDs).

This period of technology transition from old to new products is an opportunity to governments. They can introduce cost-effective policy measures across all lighting applications yielding substantial savings and accelerating the adoption of LED-based lighting. By 2030, governments could save up to 640 TWh of electricity, according to the UN Environment model. This is up to 23 per cent of the projected (no new policy) demand. In terms of CO₂ emissions, governments could avoid upwards of 390 million metric tonnes annually. Taken on a cumulative basis, between 2015 and 2030 the CO₂ savings would be up to 3.3 gigatonnes of avoided CO₂.

The guidance provided in this document is meant to be flexible, rather than prescriptive. It can be applied to a diverse range of lighting applications, including indoor lighting in public, commercial and residential buildings and outdoor lighting as in the case of urban and rural street lights and parking lots. The scope of this document encompasses all light sources, including incandescent, halogen, compact fluorescent, linear fluorescent, high-intensity discharge, and solid-state lighting.

UN Environment encourages countries to follow a five-stage integrated policy approach for transforming their respective markets towards higher energy efficiency:

- **Standards and Regulations (MEPS¹)** – cover a collection of related requirements defining which products can be sold and those that should be blocked from the market. Standards and regulations form the foundation from which to ensure the success of any efficient lighting transition strategy.
- **Supporting Policies** – are necessary to ensure the smooth implementation of standards and regulations, and to achieve a broad public acceptance. Supporting

policies include labelling schemes and other market-based instruments, often initiated and promoted by regulatory incentives, and information and communication campaigns that inform end users in order to change or modify their behaviour.

- **Finance and Financial Delivery Mechanisms** – addressing high first-cost challenges with efficient light sources, looking at economic instruments and fiscal instruments and incentives, such as rational electricity prices and tax breaks. Also consider financing incentive mechanisms that help address the initial incremental costs such as through dedicated funds, electric utility on-bill financing, and pay-as-you-save schemes based on shared savings transactions through Energy Service Companies.
- **Monitoring, Verification and Enforcement (MVE)** – successful market transition depends on effective monitoring (i.e. verify product efficiency), verification (i.e. verify declarations of conformance); and enforcement (i.e. actions taken against noncompliant suppliers) of the regulations

(MEPS). Enhancing the capacity of various countries and the sharing of information and skills between countries and across regions provides an effective means through which to promote best practice, quickly and thoroughly.

- **Environmentally Sound Management of Lighting Products** – mercury and other hazardous substance content standards should be established in line with global best practice in order to minimize any environmental or health impact. Special attention should be given to the development of a legal framework for environmentally sound, end-of-life activities.

In order to support governments in promoting energy efficiency and removing obsolete and energy intensive lighting technologies from their markets, United for Efficiency has developed a step-by-step guide called “Fundamental Policy Guide: Accelerating the Global Adoption of Energy Efficient Products”. This guide offers an overview of the key elements required to transform a national appliance market towards more energy-efficient products through the application of the U4E Integrated Policy Approach.

The Fundamental Policy Guide is cross-cutting for all United for Efficiency priority products including lighting, residential refrigerators, air conditioners, distribution transformers and electric motors.

For more information on the approach see Chapter 8 for a brief overview or the U4E Fundamental Policy Guide for complete description.

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ACRONYMS AND ABBREVIATIONS

CCT.....	Correlated Colour Temperature	Mt.....	megatonnes (10 ⁶ tonnes)
CDM.....	Clean Development Mechanism	MVE.....	Monitoring, verification and enforcement
CFL.....	Compact fluorescent lamps	MW.....	megawatt
CIE.....	Commission Internationale de l'Eclairage	NAMA.....	Nationally Appropriate Mitigation Actions
CO ₂	Carbon dioxide	NGO.....	Non-governmental organisation
CRI.....	Colour rendering index	O&M.....	Operation and Maintenance
DIN.....	Deutsches Institut für Normung (German industrial standard)	OECD.....	Organisation for Economic Co-operation and Development
DSM.....	Demand Side Management	PAS.....	Publically Available Specifications
EESL.....	Energy Efficiency Services Limited	PFI.....	Private Finance Initiative
EPR.....	Extended producer responsibility	PPP.....	Public Private Partnership
ESCO.....	Energy service company	R&D.....	Research and Development
FAQ.....	Frequently Asked Questions	QR.....	Quick Response (QR code)
GEF.....	Global Environment Facility	SEAD.....	Super-efficient Equipment and Appliance Deployment
GOGLA.....	Global Off-Grid Lighting Association	SEforALL.....	Sustainable Energy for All initiative
HID.....	High Intensity Discharge	TWh.....	Terawatt-hour
IEC.....	International Electrotechnical Commission	U4E.....	United for Efficiency
INDC.....	Intended Nationally Determined Contributions	UN.....	United Nations
K.....	Kelvin (unit for CCT)	UNDP.....	United Nations Development Programme
kW.....	kilowatt	\$.....	United States Dollars
LED.....	Light Emitting Diode	UV.....	Ultraviolet
LFL.....	Linear fluorescent lamp		
lm.....	lumen		
MEPS.....	Minimum Energy Performance Standards		



1. INTRODUCTION

Lighting is a significant factor contributing to our quality of life and productivity of our workforces. Artificial illumination extends the productive day and enables people to work in enclosed dwellings, offices, buildings and factories where there is no natural light. Additionally, as our economies grow and populations expand, the global demand for lighting increases.

Policy makers in countries around the world are tackling this topic. They are looking at ways to help transform their markets to find cost-effective energy savings (through higher efficacies³) while improving lighting service on a least life-cycle cost basis.

This guide is designed to support that policy-making process. It was designed in a holistic process with participation of 20 organisations, including international organisations, environmental groups, international manufacturers, government officials, and academic institutions.

The guidance provided in this document is meant to be flexible, rather than prescriptive. It can be applied to a diverse range of lighting applications, including indoor lighting in public, commercial and residential buildings and outdoor lighting as in the case of urban and rural street lights and parking lots. The scope of this document encompasses all light sources including incandescent, halogen, compact fluorescent, linear fluorescent, high-intensity discharge and solid-state lighting.

Products and technologies from all sectors and all stationary end-use general illumination applications are covered in this report. All lighting technologies are considered within the scope of coverage, although some of these technologies could be phased out of the market if they fail to meet the energy-efficiency or quality criteria of an economy's regulation. The guidance can be applied to a diverse range of lighting applications, including indoor lighting in public, commercial and residential buildings and outdoor lighting as in the case of urban and rural street lights, and parking lots.

Countries have specific local contexts that should be kept in mind. Each country is encouraged to analyse its own market, consider the guidance in this document, and then make policy decisions on based on its specific priorities and circumstances.

1.1 WHY LEAPFROG TO ENERGY-EFFICIENT LIGHTING?

Many countries and economies promote energy-efficient lighting solutions in their national markets. They do this through a combination of regulatory measures, supporting policies, and financing mechanisms. Many countries, including Argentina, Brazil, Ecuador, Ghana, Jordan, the Russian Federation, Senegal, South Africa, and Tunisia, are working to take such action in their respective lighting markets.

48 developing and emerging countries have completed, with the support of U4E, national or regional efficient lighting strategies. These countries have policies in place to phase-out inefficient incandescent lamps by the end of 2016.

Policy measures that will transform markets toward higher energy efficiency are needed. Lighting is one of the most cost-effective products for setting such measures. This is partly because in some markets the incumbent products include technology such as incandescent lamps, which are based on a 125 year-old technology and are replaceable with widely available products that can cut power use by 80 - 90 per cent. Globally, according to a UN Environment lighting market model including over 150 country lighting assessments, there are still seven billion incandescent lamps in service today.

However, half of the countries in the world have not yet initiated a phase-out of inefficient lighting.⁴ These are mostly developing countries and emerging economies. The lack of technical capacities, know-how and financial means are some of the factors limiting their ability to take action.

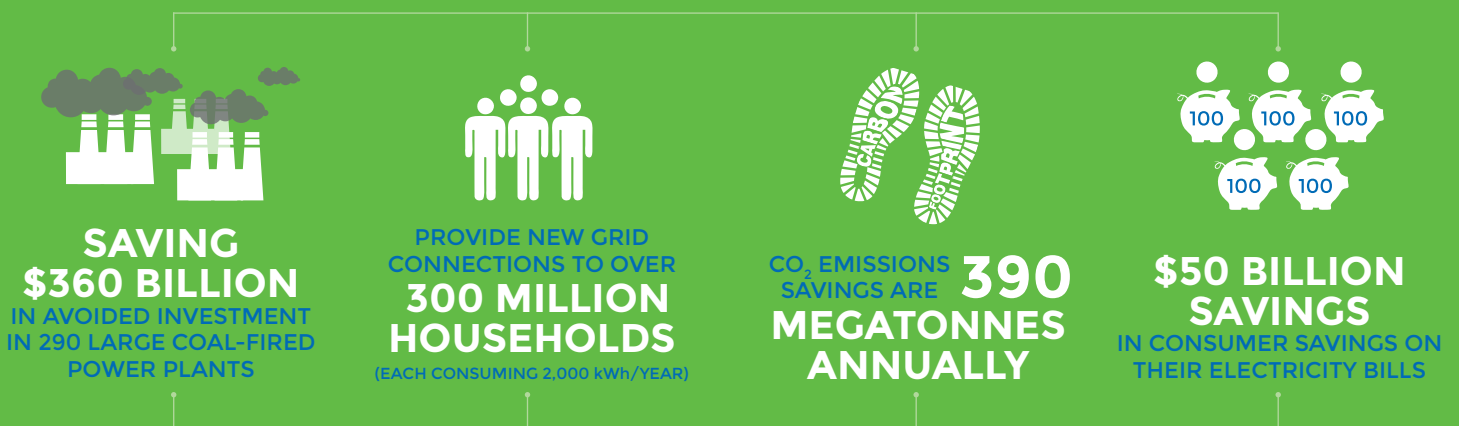
Advanced Efficient Lighting: a contribution to the goals of SEforALL

The SEforALL initiative⁵ was launched in 2012 to mobilize action from all sectors of society to achieve three interlinked objectives by 2030:

- Ensure universal access to modern energy services;
- Double the global rate of improvement in energy efficiency;
- Double the share of renewable energy in the global energy mix.

A transition to energy-efficient lighting would reduce the global electricity demand for lighting by 30 - 40 per cent in 2030. Given this tangible reduction potential and its economic, environmental, and social benefits, U4E identified advanced lighting as a market accelerator to help realise the energy-efficiency goal.

THE ANNUAL GLOBAL ELECTRICITY SAVINGS FOR LIGHTING WILL REACH 640 TWh IN 2030



THESE SAVINGS ARE EQUIVALENT TO THE CURRENT CONSUMPTION OF CANADA



The accelerator depicts a scenario where countries follow the integrated policy approach (see Section 2.3). They realise the benefits of energy-efficient lighting through efficient-lighting policies would take effect in 2020. In 2030, the annual global electricity savings for lighting reaches 640 TWh per year. This reduction in power equates to \$360 billion in avoided investment in 290 large coal-fired power plants.⁶ The savings would be enough electricity to provide new grid-connections to over 300 million households⁷, each consuming 2,000 kWh/year. The CO₂ emission savings from this global transition to efficient lighting would be 390 megatonnes per year in 2030.⁸ In addition the electricity savings result in over \$50 billion in consumer savings on their electricity bills.

The expected cumulative savings are significant. The cumulative savings of the energy-efficient lighting policy scenarios relative to the business as usual case between now and 2030 are 5,400 TWh of global electricity. The cumulative avoided emissions from this transition to efficient lighting globally are 3.3 gigatonnes of avoided CO₂. This is equivalent to over three times the current GHG emissions of

Germany. Within the non-OECD group, Asia stands out as the region with the highest gains in electricity savings and avoided CO₂ emissions.

Many other global programmes and activities help find mechanisms to cost-effectively mitigate climate change. This includes country commitments through Intended Nationally Determined Contributions (INDCs), the UN Framework Convention on Climate Change's Conference of the Parties XXI (COP21) emission reduction targets, the SEforALL Lighting Accelerator, the Clean Energy Ministerial Global Lighting Challenge's 10 billion lamps announcement, GEF projects implemented by the World Bank and others, the Super-efficient Equipment and Appliance Deployment (SEAD) Global Efficiency Award Medal for Lighting.

The work promoting efficient lighting in each country should touch upon and draw from these programmes and initiatives. Most importantly, it should establish a more sustainable, energy-efficient and better quality national lighting market for that specific country.



THE CUMULATIVE SAVINGS

of the energy-efficient lighting policy scenarios relative to the business as usual case between

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Within the non-OECD group, Asia stands out as the region with the



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CO₂ EMISSIONS.**

This is equivalent to over

**THREE TIMES
THE CURRENT GHG
EMISSIONS OF GERMANY.**



1.2 THE INTEGRATED POLICY APPROACH

When designing a market-transformation programme, policy makers know that barriers to the adoption of energy-efficient lighting and controls need to be taken into

account at the design phase to ensure they do not prevent the success of the initiative. Some of these barriers are presented in Table 1.

BARRIER	DESCRIPTION	EXAMPLES
FINANCIAL	Magnitude of the first cost relative to other technologies	<ul style="list-style-type: none"> Higher relative cost of LED lighting products, posing an initial investment hurdle, despite favourable payback periods Lack of sustainable financing schemes Lack of incentives to local manufacturers to promote sales of efficient-lighting products
MARKET	Market structures and constraints that prevent efficient-lighting investments and energy-saving benefits	<ul style="list-style-type: none"> Limited availability of low-cost, high-quality products High import costs or tariffs Lack of support to establish energy service companies (ESCOs) Split incentive–landlord/tenant discrepancy Negative impact on local manufacturers and related industries
INFORMATION AND AWARENESS	Lack of information provided on efficient technologies and their energy-savings benefits	<ul style="list-style-type: none"> Lack of lighting-related knowledge and skills among policymakers, lighting system designers, suppliers, operations and maintenance (O&M) facility managers Poor promotion of efficient-lighting products Business as usual approach/risk aversion Low level of public awareness of the technologies and their benefits Metrics (e.g. correlated colour temperature, colour rendering index, lumens) that are new to consumers and are difficult to understand
REGULATORY AND INSTITUTIONAL	Structural characteristics of the political and legal system that make it difficult to promote efficient lighting	<ul style="list-style-type: none"> Lack of policies and practical experience to transition local lamp manufacturers Lack of policies encouraging energy-efficient lighting, including regulatory, monitoring/verification, enforcement Lack of warranties to ensure product quality
TECHNICAL	Lack of resources and infrastructure for promoting efficient lighting	<ul style="list-style-type: none"> Poor quality mains power supply affects the longevity and performance of all lamp types Lack of adequate or accredited testing facilities Limited resources to monitor, verify and enforce regulations Accessibility of poor quality lighting through unorganised units disrupts consumer choices
ENVIRONMENTAL AND HEALTH RISK PERCEPTION	Concerns over health or safety relating to lighting technologies	<ul style="list-style-type: none"> Lack of collection and recycling schemes for recovery and treatment at end of life Addressing light safety issues such as blue light and flicker, etc. Public information campaigns about the effects of efficient-lighting technologies on health

Table 1.
Barriers to the adoption of energy-efficient lighting and controls

Many countries undertake massive programmes to procure and distribute millions of energy-efficient lamps. This is in particular the case of public and residential buildings as well as municipal street lighting (see Chapter 5 for more details). In 1990s and 2000s, most of these programs focused on replacing inefficient incandescent lamps with compact fluorescent lamps (CFLs) to mitigate electricity shortages and enhance energy security and reliability.

New programmes may also include LED lamps. This technology is becoming more efficient, cost-effective and affordable. Without supporting policies and mandatory regulations to permanently remove inefficient incandescent lamps from the marketplace, users may revert to the still available and lower price, inefficient incandescent lamps. The presence of poor quality lamps in the market may even result in consumers abandoning efficient lamps after a first try.

Short-term bulk procurement and deployment programs supported by governments are important. They trigger market transformation and increase awareness and demand for energy-efficient light. These market-transformation strategies should be complimented by long-term actions to ensure a complete and permanent phase-out of inefficient lamps. Such strategies should include an environmentally sound management system

to reduce the use of hazardous materials in manufacturing, and to provide effective systems to collect and recycle lamps.

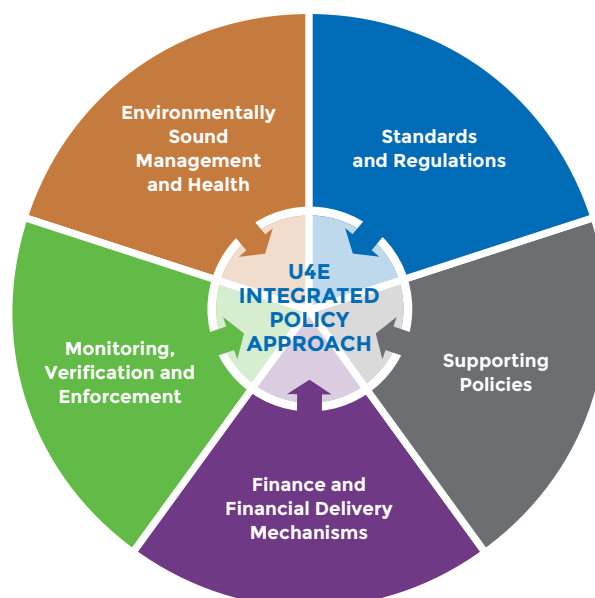
UN Environment recommends an integrated policy approach to address these issues. Such an approach (See Figure 1) has five elements and guarantees a sustainable transition to efficient lighting. It incorporates the needs and priorities of public and private sectors and civil society.

Standards and Regulations

Standards and regulations are a combination of measurement methods and policy measures. They define minimum performance levels that must be met in order for a given product to be sold in an economy. Regulations, which are sometimes referred to as MEPS, represent the cornerstone of the integrated policy approach and are the basis on which policy makers build a successful efficient-lighting-transition strategy.

UN Environment encourages countries to consider mandatory performance requirements when looking at regulation for lighting products. Governments should look at limits for energy efficiency, sustainability and safety. Regulating these aspects protects consumers by ensuring that quality lighting products are admitted to the market in a controllable manner through effective policies and their enforcement.

Figure 1.
Integrated
policy
approach
for a rapid
transition
to efficient
lighting



Countries and regions should define the parameters, stringency and implementation periods. Regulations should always be cost effective, and the degree of stringency applied to the market may have an impact on product cost.

Regulations may also refer to product labelling requirements. Governments can demonstrate commitment by making it a procurement policy that only products that meet or exceed the requirements are purchased by government ministries, departments and agencies.

Supporting Policies

Supporting policies reinforce the smooth implementation of regulations (MEPS) and standards. A combination of complementary policies and measures should be implemented, including market-based instruments containing elements of voluntary or mandatory action (e.g. labelling, smart-phone apps, Quick Response Codes), and information and communication campaigns informing end users in order to change or modify their behaviour.

Financing and Financial Delivery Mechanisms

Financing and financial-delivery mechanisms must be addressed to help ease the transition to more efficient technologies. High first-cost challenges of efficient light sources represents a barrier, and economic and fiscal instruments and incentives may be considered, including rational electricity prices and tax breaks. Financing incentive mechanisms that help address the initial incremental costs such as through dedicated funds, electric utility on-bill financing, and pay-as-you-save schemes based on shared savings transactions through ESCOs, should be considered.

Monitoring, Verification and Enforcement (MVE)

The success of efficient-lighting policies depends on a well-functioning system of monitoring, control, and testing. This

ensures enforcement and compliance with regulations (MEPS) and standards. Unless effective and timely market-surveillance systems are in place, substandard products risk entering markets in increasing numbers and reducing energy and financial savings.

Poor quality products also create disappointment for consumers. They may avoid these products in the future. Substandard products also create an uneven playing field, penalising producers who comply with the mandated standards.

Governments need to integrate MVE activities into their national lighting market-transformation programmes. To enhance market-enforcement capacities, the sharing of information and skills between countries and across regions offers an effective way through which to promote best practice. International and regional cooperation for enforcement through the sharing of laboratory and test capacities, programmes and test data, is highly recommended.

Environmentally Sound Management and Health

Mercury and other hazardous substances should be managed in line with global best practice. This minimises any environmental or health impact. If one doesn't already exist, special attention should be given to the development of a legal framework for environmentally sound, end-of-life activities, including waste recovery and design for disassembly or reuse (also known as circular economy). Policy and rigorous legislation should be instituted before the establishment of formal collection channels and recycling facilities. Government and industry should raise awareness among consumers to stimulate collection and avoid landfill.

These recommendations reflect global initiatives addressing hazardous waste such as the "Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal," and the recently agreed "Minamata Convention on Mercury."^{11,12}

1.3 REPORT OVERVIEW

This report offers an overview of the most important elements needed for transforming a national lighting market toward more energy-efficient lighting. It is based on the application of the integrated policy approach. The following are brief descriptions of each of the chapters in this report:

Chapter 2

Lighting Markets and Technology—gives an overview of lighting technology, touching on lamps and controls; provides a description of some of the recent changes that are now driving changes in the market. It provides an overview of the market (end-use sectors) and trends in lighting technology. Finally, this chapter offers an overview of the five-part integrated policy approach for transforming lighting markets.

Chapter 3

Standards and Regulation—provides an overview of the test methods and metrics used to measure the performance and quality of lighting equipment and are used in product regulations. It also provides a summary of energy-efficiency requirements, functionality-related requirements and product information obligations.

Chapter 4

Supporting Policies—offers a synopsis of the two main areas of supporting policies, product labelling and communication and education. The labelling summary explores the different types of labels, including comparative and endorsement labels. The communications and education section focuses on the critical aspect of empowering stakeholders with information, enabling them to understand how they can benefit from least life-cycle cost.

Chapter 5

Financing and Financial Delivery Mechanisms—addresses the critical issue of overcoming first-cost barriers to market adoption, including topics such as financing

sources, approaches and stakeholders. Areas covered include energy service companies, lender finance, bulk procurement schemes, electric utility programmes and multilateral development institutions.

Chapter 6

Market Monitoring, Verification and Enforcement (MVE)—discusses the importance of MVE from both a manufacturer's and consumer's perspective. Discusses the critical role of government in establishing and maintaining a robust market surveillance programme.

Chapter 7

Environmental Sustainability and Health—provides a summary of the importance and benefits of recycling of used lamps and luminaires and possible financing mechanisms.

Chapter 8

Conclusions and Recommendations—offers an overview of the main value and benefits associated with efficient lighting. Touches on the critical aspects of standards and regulations (MEPS), supporting policies, finance, MVE and environmental sustainability, offering a sustainable approach overall.

Chapter 9

Implementation—provides a summary of the process governments may choose to follow to implement a policy-driven market transformation in their respective national markets.

Chapter 10

Resources—presents an overview of reports and resources and energy-efficient lighting programmes and initiatives from around the world, including a high-level summary, web links and additional information.

Finally, a glossary (Annex A) of commonly used terms in this report is presented.

2. LIGHTING TECHNOLOGIES AND MARKETS

WHAT?	An overview of lighting technology—lamps and controls; a description of recent changes and forecast for LED; an overview of the market (end-use sectors and applications) and the barriers faced; and an overview of the five-part integrated policy approach.
WHY?	Provides the background context on technology and markets affecting all the subsequent discussion and decisions that need to be made.
NEXT?	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • When should my country shift its markets to energy-efficient lighting products and controls? • LED technology is transforming the entire lighting market, across end-use sectors and applications—how can I position my country to benefit from this change? • What are the market barriers to more efficient lighting in my country, and how can I overcome these? • Who are the stakeholders in our national supply chain, including non-governmental organisations (NGOs) community and so on who would be interested in a national initiative?

2.1 LIGHTING TECHNOLOGIES

This section provides a high-level overview of lighting technologies.

The objective is to help ensure a good understanding of the technologies being considered within the scope of any lighting regulations. The lighting technologies

are classified into incandescent lighting, fluorescent lighting, high-intensity discharge lighting and LED lighting. In addition, this section provides a summary of common lighting controls systems.

2.1.1 INCANDESCENT LIGHTING

Originally developed in the late 1800s, incandescent lamps produce light by passing electrical current through a tungsten metal wire suspended in an inert atmosphere inside a glass bulb. The electric current causes the filament to heat up so much that it glows and produces visible light and a lot of heat.

Halogen lamps are an improvement over incandescent (offering better efficacy, and

a slightly longer bulb life). These lamps contain a small quantity of halogen (iodine or bromine) inside a filament capsule that re-deposits evaporated tungsten back onto the filament, preventing the blackening of the filament capsule and increasing the lamp lifetime. Table 2 provides a summary of the key features of these lamps.



Table 2.
Incandescent
and halogen
lighting typical
performance
specification

CHARACTERISTIC	INCANDESCENT TYPICAL QUANTITY	HALOGEN TYPICAL QUANTITY
LUMINOUS EFFICACY RANGE	8-17 lm/W	11-21 lm/W
LAMP LIFETIME	1,000-1,500 hr	2,000-3,000 hr
COLOUR RENDERING INDEX (RA)	100	100
CORRELATED COLOUR TEMPERATURE	2,600-2,800 K	2,800-3,200 K
DIMMABLE?	Yes	Yes

↑ ADVANTAGES OF INCANDESCENT AND HALOGEN

- Low purchase price;
- Highest colour rendering;
- No control gear needed;
- Easily dimmed;
- Universal operating position.

↓ DISADVANTAGES OF INCANDESCENT AND HALOGEN

- Low efficacy (lots of wasted electricity);
- Short lifetime, typically
1,000 hours incandescent
3,000 hours halogen;
- High operating costs (i.e. electricity use);
- High operating temperature.

2.1.2 FLUORESCENT LIGHTING

CFLs are direct retrofits for incandescent lamps, which incorporate an electronic ballast and phosphor-lined glass tube. An electrical arc is struck at the tube's electrodes, causing the mercury atoms to emit ultraviolet (UV) light, exciting the phosphor coating and emitting visible light. CFLs were developed in the 1970s, and are essentially a miniaturised version of a linear fluorescent lamp (LFL). Compared to incandescent lamps, CFLs use approximately 75 per cent less electricity while producing the same amount of light and last about ten times longer.

Linear fluorescent lamps operate in the same manner as described for CFLs. Table 3 provides more details. They do not incorporate a ballast, and thus require a dedicated fixture incorporating a ballast to operate. Linear fluorescent lamps are typically classified by their tubular diameter (most common are: T12 = 38mm, T8 = 25mm, T5 = 16mm) and by their length and wattage.



Table 3.
Fluorescent lighting typical performance specification

CHARACTERISTIC	CFL TYPICAL QUANTITY	LFL TYPICAL QUANTITY
LUMINOUS EFFICACY RANGE	50 - 70 lm/W	80 - 110 lm/W
LAMP LIFETIME	6,000 - 15,000 hr	15,000 - 30,000 hr
COLOUR RENDERING INDEX (RA)	70 - 85	60 - 95
CORRELATED COLOUR TEMPERATURE	2,500 - 6,500 K	2,700 - 6,500 K
DIMMABLE?	If dimmable ballast	If dimmable ballast

↑ ADVANTAGES OF FLUORESCENT

- Low running costs;
- High efficacy;
- Long operating life;
- Very good to excellent colour rendering.

↓ DISADVANTAGES OF FLUORESCENT

- Control gear (ballast) required for operation;
- Frequent switching can shorten life;
- Dimming requires special ballast;
- Contains mercury.

2.1.3 HIGH INTENSITY DISCHARGE LIGHTING

High intensity discharge (HID) lighting produces light from an electrical arc contained within a capsule of gas which is sealed inside a bulb. HID lights require a ballast to start and operate, which regulates the voltage supplied to the capsule of gas. Light is produced by the electrical arc passing through a metal vapour; however, HID bulbs only produce 5 per cent of their light when first started, and require several minutes to achieve full brightness. If an HID lamp is switched off, it must cool before a new arc can be re-struck in the capsule and light produced.

HID lighting has several variants, but the main ones are mercury vapour (white light, least efficacious), high pressure sodium (orange light, very efficacious), and metal

halide (white light, range of efficacies).

Table 4 provides more details. HID lighting is commonly found in outdoor lighting applications such as street lighting, area flood lighting and sports stadium lighting. HID lighting is also found indoors in places such as large retail outlets, warehouses and manufacturing facilities.



Table 4.
High intensity discharge lighting typical performance specification

CHARACTERISTIC	MERCURY VAPOUR TYPICAL QUANTITY	HIGH PRESSURE SODIUM QUANTITY	METAL HALIDE TYPICAL QUANTITY
LUMINOUS EFFICACY RANGE (INITIAL)	45 - 55 lm/W	105-125 lm/W	80-100 lm/W
LAMP LIFETIME	20,000 hr	20,000 - 24,000 hr	10,000 - 20,000 hr
COLOUR RENDERING INDEX (RA)	15 - 50	25	65-85
CORRELATED COLOUR TEMPERATURE	3,900 - 5,700 K	2,000 - 2,100 K	4,000 - 5,000 K
DIMMABLE?	If dimmable ballast	If dimmable ballast	If dimmable ballast

↑ ADVANTAGES OF HID LIGHTING

- Low running costs;
- High efficacy for high pressure sodium and metal halide lamps;
- Long operating life - typically 20,000 hours;
- High flux in a small package;
- Range of colour rendering, with metal halide able to achieve excellent colour.

↓ DISADVANTAGES OF HID LIGHTING

- Control gear (ballast) required for operation;
- Re-strike after operation can take time;
- Can be several minutes to reach full brightness;
- Frequent switching can shorten life;
- Dimming requires special ballast;
- Contains mercury.

2.1.4 LED LIGHTING

LED lamps and luminaires are rapidly expanding into general illumination applications all over the world. As LED technology improves in performance and becomes less expensive, this market expansion will accelerate, replacing traditional light sources with more efficient and better performing LED technology.

LEDs offer unique characteristics that make them a compelling source of light. They are compact, have long life, resist breakage and vibration, offer their best performance in cold operating environments, are instant-on and some models are dimmable. Depending

on the drive circuit and LED array in a particular light source, LEDs can also be adjusted to provide different coloured light or colour temperatures of white.

Unlike incandescent and fluorescent lamps, LEDs are not inherently white light sources. Instead, LEDs emit nearly monochromatic light, making them highly efficient for coloured light applications such as traffic signal and exit signs. To be used as a general light source, white light is needed, by combining different LEDs or using a phosphor. Figure 2 shows the different ways that white light can be achieved with LEDs.

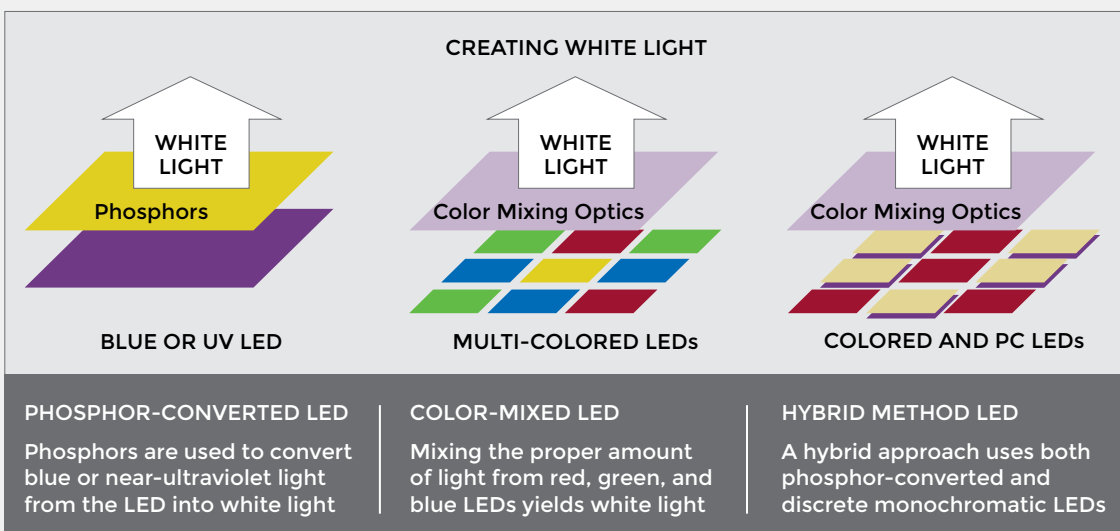


Figure 2.
Producing white light with LEDs

Source:
www.energy.gov/eere/ssl/led-basics

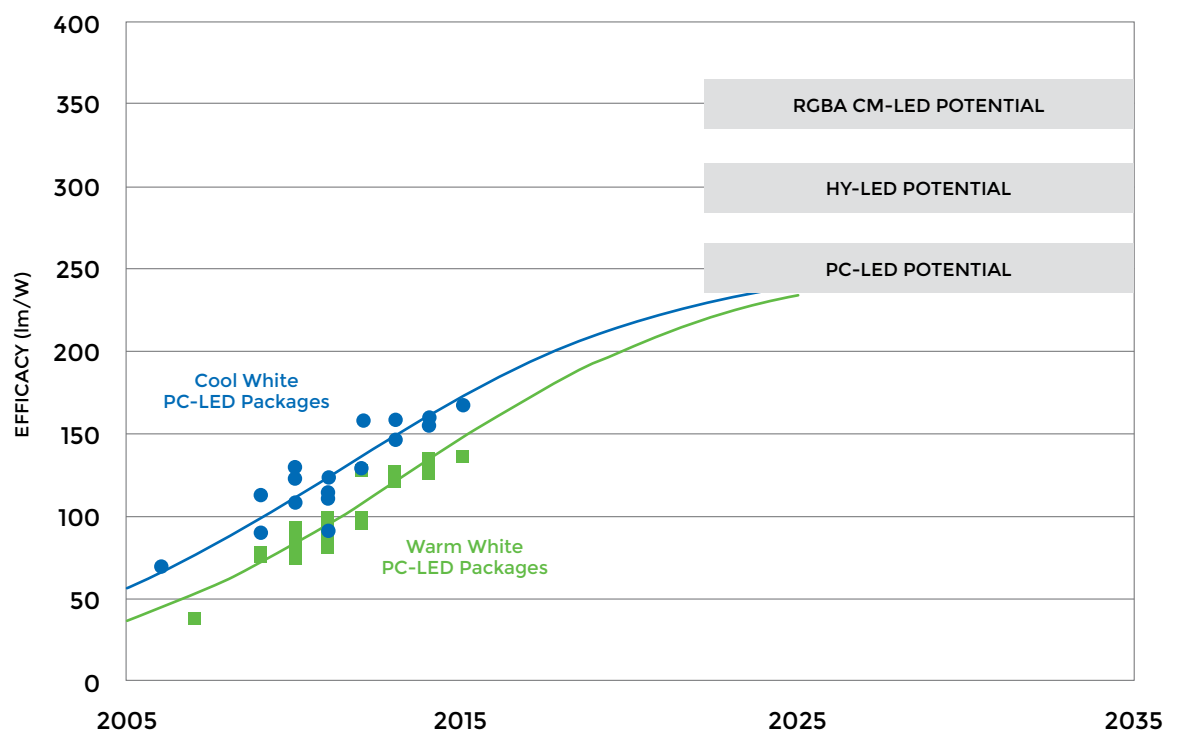
LEDs are highly energy efficient when measuring light output for watts of electricity input. In the market today, the most efficacious LED lamps operate at around 130 lumens per watt. Table 5 provides more details. This is more than double the energy performance of a CFL and over 10 times more efficient than an incandescent lamp.

As the technology continues to evolve in the coming years, efficacy will improve and costs decline. LEDs offer the potential to produce high-quality white light with unprecedented energy efficiency. For countries choosing to phase-out incandescent lamps and jump straight to LED, the electricity savings for consumers will be more than 85 per cent, without compromising light quality and while enjoying much longer service life.

Figure 3 shows the projected performance improvement expected for LED products. Focus is on products already considered efficient, but still expecting a doubling in performance by 2025. The figure shows the historic and projected performance improvement for LED packages under specific operating conditions.¹³ LED packages are the LED light sources used in lamps and luminaires that are already very efficient. Their performance varies significantly with the operating temperature of the LED and the electrical current density. As of today, LEDs are operating with efficacies of 220 lumens per watt, under favourable conditions. The grey-shaded bars show the potential for further improvement with phosphor-converted blue or violet LEDs (PC-LED), hybrid mixtures containing additional red emitters (HY-LED) and with four or more primary emitters covering the whole spectrum (RGBA CM-LED).

Figure 3.
Efficacies of commercial LED packages measured at 25°C and 35 A/cm² current density

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy Division



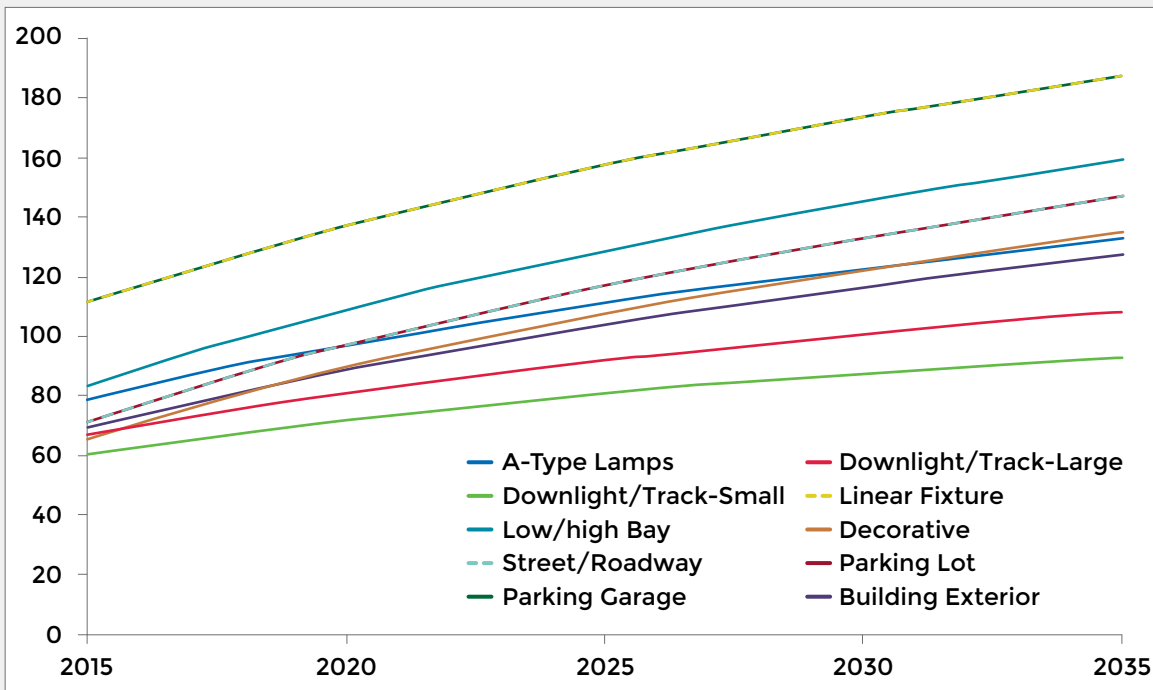


Figure 4.
Market average LED lamp and luminaire efficacy projections

The projected values for Linear Fixture and Parking Garage are the same, as are those for Street/Roadway and Parking Lot; therefore these two sets of lines are superimposed on each other.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy Division

Substantial losses occur when these packages are used in lamps or luminaires. Increasing the current density through each LED reduces the number of LEDs needed by increasing the light output of each LED and thus lowering the cost. However, it also reduces the efficacy of the LEDs. The lamp or luminaire also incurs electrical losses in the drivers and control systems, and optical (light output) losses. Taken together, the efficacy of LED products is usually less than those shown in Figure 3 by 30 per cent or more.

Figure 4 shows the projected market average efficacies of various types of commercial LED lamps and luminaires, as used by the US Department of Energy in

their recent report calculating the energy savings potential of solid-state lighting.¹⁴

The trend for increasing efficacy also means users tend to get more and better quality light at a lower running cost. That is, the higher energy efficiency of the LED sources translates into lower energy bills and greater reductions in CO₂ emissions. Figure 5 shows average global retail price of a LED and CFL replacement lamp for a 60W incandescent. LED costs fall rapidly, then slow in 2017, reaching near parity with CFLs in 2020. Actual LED pricing in a given country may vary from these levels. They depend on, for example, volume of imports and consumer demand.

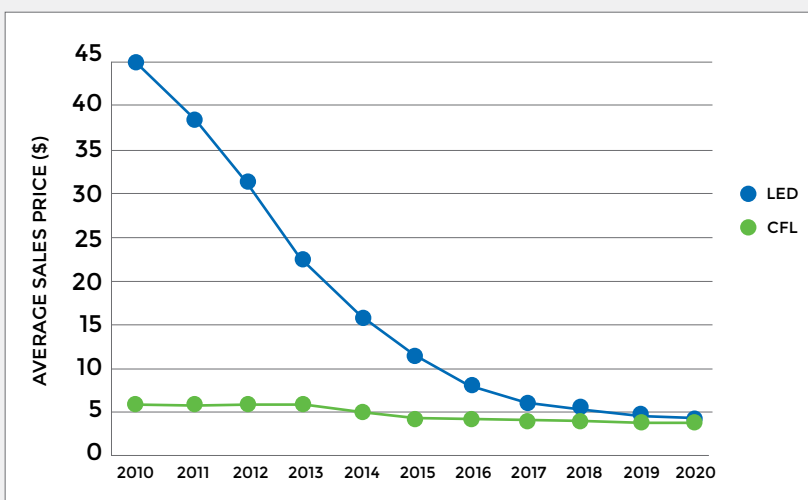


Figure 5.
LED vs. CFL Retail Price for a 60W replacement lamp¹⁵

Source: Memoori Business Intelligence, 2013; Chapter 5.2.2.

Figure 6 depicts some examples of the thousands LED products available on the market today. From left to right, a frosted nondirectional household lamp, a clear nondirectional LED filament lamp, a directional (or “spot”) light, LED tubular lamps to replace fluorescent tubes, and a surface-mounted dedicated LED luminaire. There are also LED street lights, flood lights, high-bay replacements, many other luminaires and technologies offered in the dynamic LED lighting market.



Figure 6. Images of some examples of LED lamps and an LED luminaire

Table 5. Light emitting diode (LED) lighting typical performance specification

CHARACTERISTIC	LED LAMP TYPICAL QUANTITY	LED LUMINAIRE TYPICAL QUANTITY
LUMINOUS EFFICACY RANGE (INITIAL)	60 - 130 lm/W	80 - 150 lm/W
LAMP LIFETIME	15,000 - 30,000 hr	20,000 - 60,000 hr
COLOUR RENDERING INDEX (RA)	70 - 95	80 - 95
CORRELATED COLOUR TEMPERATURE	2,700 - 6,500 K	2,700 - 6,500 K
DIMMABLE?	If dimmable driver	If dimmable driver

↑ ADVANTAGES OF LED LIGHTING

- Highest efficacy light sources available;
- Lowest running costs;
- Very long operating life - typically more than 20,000 hours;
- High flux in a small package, good for optical control;
- Can offer excellent colour rendering;
- Instant on, instant re-strike, dimmable;
- Contains no mercury.

↓ DISADVANTAGES OF LED LIGHTING

- Control gear (driver) required for operation;
- Higher relative first costs (but competition is driving prices down);
- Needs good thermal design because waste heat is conducted, not projected.

2.1.5 LIGHTING CONTROLS

Energy consumption for lighting can also be saved with a lighting controls system. They vary from the most basic and familiar switch on the wall to a sophisticated computer control system that manages a whole building. Industry-driven research has led to advances in occupancy and daylight sensing, making them even more effective and affordable.

A combination of a lighting controls system and energy-efficient lamps and luminaires produces the best possible outcome in terms of lighting performance in a building. Lighting controls systems can save a further 20 - 40 per cent of energy consumption for lighting. They constantly monitor use and ambient light levels, and only run lighting when it is needed.

Some of the strategies in use today for lighting controls systems include:

- **Time clocks and photocells (light sensors)**—offering simple, reliable and cost-effective ways of adding the most basic of controls to a lighting system;
- **Occupancy sensors as well as sound and heat-sensing technology**—are used to detect the presence of people and turn the lights off when an illuminated space is unoccupied. These systems incorporate intelligence into the designs to avoid false or too frequent turning off

for the light fixtures.

Occupancy sensors can gather data to optimise building utilisation;



Example of a motion sensor

- **Dimming technologies**—including manual dimming switches and more sophisticated technology that automatically reduces light output according to the availability of daylight or other ambient light. Dimming of some lamps and luminaires (e.g. CFLs, LEDs) can be accomplished, provided the ballast enables dimming;
- **Day lighting sensors**—adjust luminaire light output levels in areas near windows in response to natural outdoor light entering the building. Day lighting controls are available in continuous dimming and stepped reduction of lighting levels;
- The most sophisticated lighting controls systems are characterised by automated lighting management systems, offering centralized computer control of lighting systems;
- Personalized lighting setting, e.g. via mobile apps, to enhance comfort and user experience.

↑ ADVANTAGES OF LIGHTING CONTROLS

- Improves the overall performance of an energy-efficient lighting system, achieving even greater energy savings;
- Lowers running costs;
- Provides automated performance of systems, does not require constant human interaction (i.e. “set it and forget it”);
- Can gather useful data on performance, usage and even predictive.

↓ DISADVANTAGES OF LIGHTING CONTROLS

- Higher first cost in purchase of additional equipment for an installation;
- Higher installation and commissioning costs, due to time to set the controls system correctly;
- To manage the system effectively, may require expert consultants or training of staff;
- Unless owner-occupied, there could be limited incentive for controls.

2.1.6 OFF-GRID LIGHTING

More than 1.6 billion people live without electricity. They must rely on fuel-based light sources. For these people, the promise of energy-efficient, sustainable and safe light sources is packaged in a product or system that utilises a renewable energy source (usually solar energy), a battery storage system and an energy-efficient LED light source. These products are already cost-effective, and they provide additional health and safety, education and employment benefits with their increased market penetration.

Energy-efficient, off-grid lighting solutions offer the most promising and scalable means to eliminate adverse health outcomes associated with fuel-based lighting. They also lower the costs and reduce GHG emissions. Off-grid lighting technologies will benefit women and children and yield significant health benefits. Examples include improved illumination in healthcare facilities and safe and efficient lighting systems distributed and promoted where housing is dense and poorly defended from fire and where fuel adulteration is common.¹⁶

The potential for new employment opportunities around the introduction of solar lanterns is significant. In the Economic Community Of West African States (ECOWAS), UN Environment estimates that the increased market penetration of solar lanterns could create approximately 30 times more jobs—and often higher-quality jobs—than fuel-based lighting does. This positive effect on the result reflects the common finding that renewable and energy efficiency sources create many times more jobs than do non-renewable sources.¹⁷

To help ensure the supply of high-quality products to the market, the International Finance Corporation, a division of the World Bank, launched “Lighting Global” programme. One of its core elements is a



Quality Assurance programme¹⁸, which is designed around five guiding principles, driven by the market:

- **Affordability:** Seek an appropriate balance between quality and affordability;
- **Diversity and Innovation:** Allow for product diversity in technology, utility, and price; encourage innovation by using nonprescriptive, performance-based metrics and goals;
- **Rigor:** Develop rigorous testing standards that can be carried out using reasonably low-cost instruments; provide technically valid test results that can be accepted globally;
- **Stability:** Maintain stable and transparent quality assurance policies so stakeholders know what to expect;
- **Insight:** Effectively communicate key product quality and performance information so buyers can make informed purchasing decisions.

The Quality Assurance framework and test methods were adopted by the International Electrotechnical Commission (IEC) IEC/TS 62257-9-5, Edition 2.0. This technical specification provides a common framework that can be used to enable widespread adoption of a harmonized quality assurance approach. The testing conducted under this framework assesses both the components (e.g. photometrics, battery and charge control, solar module) as well as the system tests (e.g. full-battery run time, solar-charge run time, physical ingress and water protection).

OFF-GRID
LIGHTING
TECHNOLOGIES
WILL BENEFIT
WOMEN AND
CHILDREN
AND YIELD
SIGNIFICANT
HEALTH BENEFITS.

...THE
INCREASED
MARKET
PENETRATION OF
SOLAR LANTERNS
COULD CREATE
APPROXIMATELY
30 TIMES
MORE JOBS
—AND OFTEN
HIGHER-QUALITY
JOBS—THAN
FUEL-BASED
LIGHTING DOES.

2.2 MARKET DEVELOPMENTS

The lighting industry is transforming. This is partly due to a disruptive technology, LED, which is entering all end-use applications in the lighting market. In the past, the lighting industry had two general distinct product segments: manufacturers of lamps (i.e. light bulbs) and manufacturers of luminaires (i.e. fixtures). The manufacturers of lamps (or commonly called “light bulbs”) were a small number of large, global suppliers whose majority of business was based around the sale of replacement lamps. Manufacturers of luminaires, where there are a large number of companies, tended to be more application- and regionally-focused, specialising in the production of comparatively small batches of a large variety of luminaires.

Today the boundaries between the lamp and luminaire businesses have blurred. This is because of the increasing number of LED solutions. LED light sources bring the potential for ultra-long service life, which will gradually eliminate the replacement lamp business.

LEDs’ market share is increasing. According to LED inside, a market-research agency, LEDs achieved a 31 per cent share of the \$82.1 billion global lighting market

in 2015, and point to the fact that there will be “significant growth” over the next decade. The fast pace of LED technology combined with the fierce competition means that product engineers must work extremely hard to keep pace with the rate of innovation and ensure their companies remain competitive, offering consumers high-quality, affordable LED products with a good return on investment.

The lighting industry is no longer a local business. Products are manufactured and sold globally, and thus product quality issues such as lifetime, colour quality and efficacy cut across the economies where they are sold.

LED lighting and new controls systems are starting to enter all end-use applications. In the medium to long-term, LEDs are expected by many to be the primary light source in all applications. Table 6 depicts the six sectors found in the global lighting market, with a brief description of each and some discussion on the conventional found today and the future light sources expected in the next 5 to 10 years (i.e. a reasonable policy-planning scenario).

LED light sources bring the potential for ultra-long service life, which will gradually eliminate the replacement lamp business.

Table 6.
Overview
of end-use
sectors and
typical current
and future
light sources

SECTOR	DESCRIPTION	CURRENT SYSTEM	FUTURE SYSTEM
RESIDENTIAL	General lighting for the home, including kitchens, hallways, dining rooms and bathrooms; tend to have lower operating hours (1 - 5 hours/day)	Incandescent, halogen, CFLs, LFLs	LED and controls
COMMERCIAL RETAIL	Illumination of products, general lighting; tend to have high annual operating hours (10 hours/day)	LFLs, CFLs, LED, high-intensity discharge (HID)	LED and controls
OFFICE	General lighting for working office environments; tend to have higher annual operating hours (10 hours/day); also cooler colour temperatures, with more blue content	LFLs, CFLs, LED	LED and controls
INDUSTRY	Illumination of production lines and processes, architectural lighting, safety lighting; tend to have high annual operation hours (12 - 24 hours/day)	HID, LFLs, LED	LED (with some metal halide) and controls
OUTDOOR	Street lighting, walkway lighting, public spaces and parks, large area flood lighting (12 hours/day)	HID, LFLs, CFLs, LED	LED (with some metal halide) and controls
OFF-GRID	General lighting for the home, but not grid-connected; emphasis on task lighting (e.g. reading) (1 - 3 hours/day); some small commercial applications (3 - 5 hours/day)	Kerosene, candles, battery torches	LED

The introduction of LED to the global lighting market has been disruptive. It has led to significant changes within the lighting businesses. In 2015, IHS market research reported that manufacturers are placing much more emphasis on vertical integration, extending their scope of products chip-on-board modules and light engines all the way

to finished lamps and luminaires. Extending their coverage of the supply chain makes them more competitive and nimble in this dynamic market. Both Philips and OSRAM, top global players in the LED business, have taken the steps to separate their lighting businesses from their core business to enable faster responses-to-market.



3. STANDARDS AND REGULATIONS

WHAT?	<p>An overview of the test methods and metrics used to measure lighting equipment performance and quality; a summary of regulatory measures (also called MEPS), which include energy requirements and sometimes performance requirements like lifetime, light quality, power quality and so on.</p>
WHY?	<p>Provides information on regulations (also called MEPS), the first part of UN Environment's integrated policy approach, which is the cornerstone of market transformation.</p>
NEXT?	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • What is the status of test standards in my country? Are we affiliated with the International Electrotechnical Commission? • Do we have accredited testing facilities for lighting equipment or can we partner? • Which would be better for our country—technology neutral or technology-specific requirements? • What level of ambition would be appropriate; should we have a second, higher set of tiers in the future so industry gets a clear signal on where the market is heading? • In addition to energy efficiency, what other lighting product phenomena and quality criteria should be included in a regulation and which should be included in a supporting policy measure (e.g. labelling and information at the point of sale?)

When selecting the performance aspects such as energy efficiency, light quality, lifetime and other critical parameters, policy makers must identify the test standard by which a performance parameter should be quantified and assessed. Test standards are developed and published by organisations such as the International Electrotechnical Commission (IEC)⁹ or the International Commission on Illumination (CIE). The standards published by these organisations establish a consistent set of procedures for the measurement and assessment of these performance metrics.

This chapter focuses on regulations on energy efficiency, functionality and product-information obligations for energy-efficient lighting. It is primarily aimed at authorities that lack a regulatory

framework, or those that have a regulatory framework but lack regulations for energy-efficient lighting. It aims to offer practical guidance on the processes to follow when establishing regulations on energy-efficient lighting in developing and newly industrialising countries.

Although they are also critical to the operation of any market, Safety, Electro-Magnetic Compatibility (EMC) and Environmental regulations are not considered within the scope of this report. UN Environment recommends that governments contact the International Electrotechnical Commission (IEC) for information on the Safety, Electro-Magnetic Compatibility (EMC) and Environmental standards in place for all lighting products placed on their national markets.

3.1 METRICS AND TESTING STANDARDS

Policymakers may consider several phenomena when regulating the energy efficiency, functionality and product-information obligations of lighting products. The list of metrics below is defined and explained in Annex B to this report. This list provides a sample of some commonly used key phenomena, but there could be more, depending on the technologies being studied and issues that are identified as important to a given market. Please note that not all of these phenomena are relevant to all lamp technologies, and these simplified definitions are intended to describe the phenomena, but they themselves are not definitions such as those provided by the international standards bodies.

- **Energy Efficiency**–
Luminous efficacy;

- **Light quality metrics**–
Luminous flux; Lamp lumen maintenance factor; Endurance (supply switching test); Luminous intensity; (Spatial) distribution of luminous intensity; Colour rendering index (CRI); Correlated colour temperature (CCT);
- **Operation**–
Starting time; Run-up time; Lamp life;
- **Electrical parameters**–
Power factor; Fundamental power factor; Non-fundamental power factor; Total harmonic distortion (THD); Harmonic Component; Dimmer compatibility;
- **Health and safety issue parameters**–
Safety requirements and marks; Photobiological hazard class (UV and blue light); Mercury content; Flicker; Stroboscopic effect.

3.2 REGULATORY REQUIREMENTS

Standards establish the measurement methods and sometimes the limiting values for considered phenomena. Regulations set the requirements that must be met by those products. In the case where a particular standard doesn't include limits for the standardized phenomena, the regulation itself might set the limit or might require information on it.

Governments began adopting energy-efficiency regulations on lighting products nearly two decades ago. They worked to transform their markets to benefit from higher efficiency light sources. The hyperlinks below enable readers to view the current lighting regulations of Australia, Europe and the US. These are three examples of lighting regulations around the world. There are dozens more that could be listed.

- **Australian Government:**
Lighting Regulations;
- **European Commission:**
Lighting Regulations;
- **US Department of Energy:**
Lighting Regulations.

This report uses the term "Regulations" to refer to the mandatory performance requirements of lighting products. The acronym "MEPS" has been used for decades to refer to mandatory performance requirements of regulated products. MEPS had originally focused on energy consumption; however, over time and with the expansion of regulatory programmes to address quality and performance issues, MEPS came to be associated with phenomena beyond energy efficiency.

Regulations offer a highly cost-effective policy option for removing inefficient lighting technologies from a market and, when applied in conjunction with supporting policies, they encourage manufacturers to improve product efficiency. However, establishing the right level of regulation is critically important, and governments typically conduct detailed cost-benefit analyses to ensure that the adopted regulatory measures provide a positive economic benefit.

Advantages:

- Provides a high degree of certainty for delivering energy savings;
- Minimises impact on governmental fiscal influence, such as subsidies;
- Encourages manufacturers to invest in research and development (R&D) and create new, more efficient lamps;
- Can be adjusted periodically as lamps improve or new lamps become available;
- Can be designed to maximise consumer benefits with very low per unit transaction costs.

Constraints:

- Energy-efficient lamps may not be widely available or may be limited in the market;
- Energy-efficient lamps may not meet equivalent quality levels to what they are replacing;
- The initial cost of energy-efficient lamps may be greater;
- Local production of lamps may be affected, so sufficient time must be scheduled.

CASE STUDY: Ecodesign Requirements for Nondirectional Household Lamps, Europe

In Europe, regulation EC No.244/2009 on nondirectional household lamps was issued on 18 March 2009. Through six stages, this regulation works to prohibit the placing on the market of the least energy-efficient lamps for household use. Table 7 provides more details. Lamps placed on the market must comply with luminous efficacy requirements and some minimum performance requirements. The European regulation follows a step-by-step approach that phases out inefficient incandescent lamps in a series of stages (between 2009 and 2018). It divides the non-directional lamp market into “clear” and “nonclear” lamps, and sets a requirement equivalent to typical CFL for the latter. For clear lamps, it sets the requirement at a mains-voltage halogen until stage 6 when it increases the ambition to low-voltage halogen. A graph of these equations appears in Figure 7.

Table 7.
European
regulation
for omni-
directional
lamps, EC
No.244/2009

APPLICATION DATE	Maximum rated power (P _{max}) for a given rated luminous flux (φ) (W)	
	CLEAR LAMPS	NONCLEAR LAMPS
Stages 1 to 5	$0.8 * (0.88\sqrt{\phi} + 0.049\phi)$	$0.24\sqrt{\phi} + 0.0103\phi$
Stage 6	$0.6 * (0.88\sqrt{\phi} + 0.049\phi)$	$0.24\sqrt{\phi} + 0.0103\phi$

3.3 PROCESS TO FOLLOW TO ESTABLISH REGULATORY REQUIREMENTS

The following is a summary of the steps described in a UN Environment publication that was prepared to help policy makers prepare MEPS for lighting products.²⁰

Initiation Steps

- 1. Establish a legal framework:**
Review existing legislation and establish framework legislation to develop a legal basis for, and political commitment to, mandatory efficiency standards and energy labels.
- 2. Appoint an administrative agency:**
Assess existing institutional capacity for developing, implementing and maintaining a standards and labelling programme. Develop an overall standards and labelling plan and assign one government agency with primary responsibility for driving each element of the programme.
- 3. Assemble a stakeholder group:**
Identify the key relevant people in the economy who would be interested and invite them to participate in the process.

Product Steps

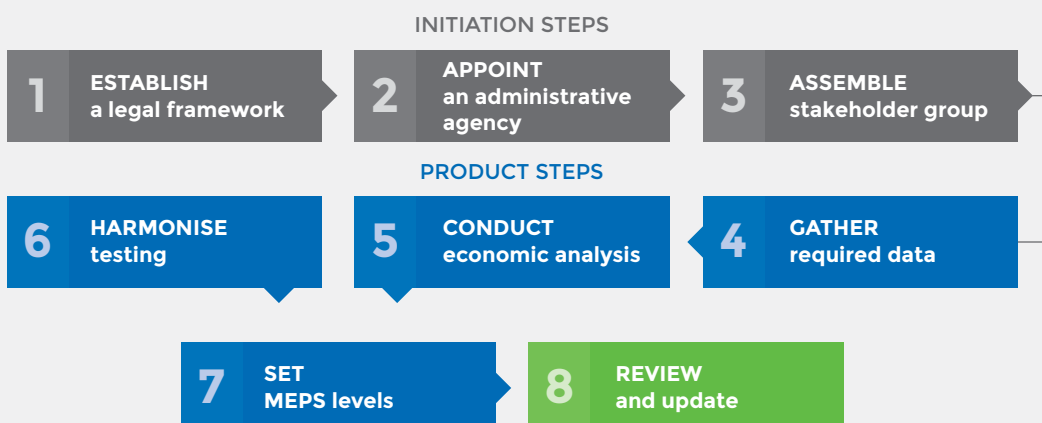
- 1. Gather required data:**
Establish minimum data needs and develop a plan for collecting the data necessary to conduct analysis to support the programme. This includes information on the market, technology, engineering and usage of the product.

- 2. Conduct an economic analysis:**
Use cost effectiveness analysis to determine the appropriate level of ambition for the regulatory measure(s).
- 3. Harmonise testing:**
To the greatest extent possible, harmonise energy performance test procedures with international protocols (such as International Electrotechnical Commission test standards) to facilitate testing and reduce barriers to trade.
- 4. Set MEPS levels:**
Determine the technically feasible, economically optimal regulatory level; invite stakeholder comment and refine MEPS if necessary; secure political endorsement; publish regulatory notice; and specify a future date when MEPS will take effect.
- 5. Review and update:**
Plan to periodically review and update the MEPS every few years to ensure they remain appropriate and relevant.

Please review the UN Environment report (“Developing Minimum Energy Performance Standards for Lighting Products, Guidance Note for Policymakers”) for further information on these steps and the importance of following a regulatory development process so that all stakeholders are consulted, feel they were part of the process and support the policy outcome when it becomes effective.



Please review the UN Environment report **DEVELOPING MINIMUM ENERGY PERFORMANCE STANDARDS FOR LIGHTING PRODUCTS** for more information.



The components required to be in place for a lighting regulatory programme, spanning any number of lighting products, are presented in Table 8.

Table 8.
Components
Required to
be in Place
for a Lighting
Regulatory
Programme

COMPONENT	DESCRIPTION
SCOPE OF COVERAGE	The policy framework must clearly lay out the products covered within the scope of the regulation. This would also need to include, for example, products that may be “phased out” by the regulation if they do not meet the Performance Requirements.
TEST STANDARDS	This is the identification of the test methods for all the different parameters that are identified under the regulation. The test standards are typically issued by standardisation bodies like the IEC, CIE and ISO. The policy needs to state the method by which the covered products will have their performance characteristics assessed.
PERFORMANCE REQUIREMENTS	The regulation needs to specify the minimum performance levels that will be required. Manufacturers then develop products meeting or exceeding these requirements. Note that the performance requirements could be one level at one point in time, or could be multiple levels, phased in over a longer period of time. The multiple levels approach offers more planning horizon to manufacturers, but a greater degree of regulatory uncertainty when setting the standards as to what level of ambition might be appropriate five to six years into the future.
CERTIFICATION AND COMPLIANCE	The regulation must inform manufacturers of the procedure they will follow when certifying products as compliant; this could include filing paperwork, entering information into a product registry database, and keeping paperwork in house for a period of time. The manufacturers and importers need clear instruction as to what is expected of them when they wish to demonstrate they comply.
MARKET SURVEILLANCE	The regulation should inform suppliers as to the test method that governments will use to conduct market surveillance. This could include, for example, the sample size tested, the escalation if a sample size is found to be in violation, and the tolerances and statistics involved. Due to the fact that this could end up in a legal proceeding, it is important to set out the procedure clearly and fairly.
REVIEW AND REVISE	Finally, it is important that regulatory measures be reviewed and updated from time to time, as lighting technology is continually improving—and this is particularly true for light emitting diode sources. For example, a country may choose to require a review of the regulation that would publish findings within one year of the final stage of a lighting regulation taking effect.

3.4 HARMONISATION OF REGULATIONS AND STANDARDS

Countries should consider which existing Regulations and Standards they should harmonise with. If Regulations and Standards are to be adopted in a country or regional market (e.g. ECOWAS), stakeholders should consider whether to harmonise with existing lamp Regulations and Standards in their region or with the lamp Regulations and Standards of a large market with which they have trade relationships.

Countries' decisions impact supply chains and costs. If one country in a trading region chooses to adopt Regulations and Standards that are not compatible with its neighbouring markets, this decision could be disruptive to the supply chain and may increase the cost of energy-efficient lamps for all parties. This could occur due to the added costs to manufacturers of needing to perform different or additional lamp tests, creating unique labels and catalogue numbers for each market, and tracking, keeping inventory and shipping country-specific lamp products.

Harmonisation of Regulations and Standards offers many benefits. They allow countries, private sector and consumers to avoid the costs of duplicating testing and noncomparable performance information and requirements. Stakeholders thus benefit

from the removal of this administrative trade barrier and are able to leverage the better prices and choice of goods associated with the larger economies to which they are harmonised. If countries have different requirements, it is difficult and time consuming for a manufacturer to carry out the necessary tests for each specific country. Harmonisation enables multiple national markets to be accessible for the cost of only one test. The harmonisation of standards can easily be achieved by implementing the Standards of the International Electrotechnical Commission (IEC) and/or the International Commission on Illumination (CIE).

Figure 7 offers a comparison of the minimum efficacy requirements currently in place for the US and Europe for nondirectional household lamps. Due to the fact that these two markets operate on different voltages (120V and 230V respectively), which affects the efficacy of the lamps, the requirements for the US had to be adjusted to 230V requirement equivalencies. They show reasonably good alignment around the halogen lamps, that is, the red line for European clear lamps stages 1-5 and the low efficacy requirements of the US "saw-tooth" curve coincide.

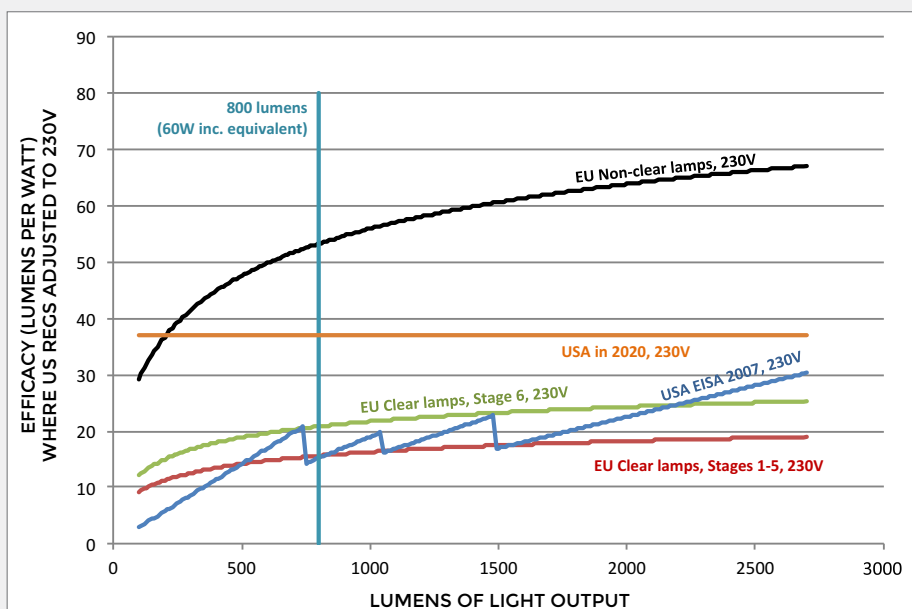


Figure 7.
Comparison of energy efficiency requirements in place in 2016 in Europe and the US, 230V plot

For reference: the US 2020 standard will be 45 lumens per watt at US voltage (110-130V). The graph reflects the conversion to high voltage (230V).

Working within a region and with different organisations (e.g. government, private sector, civil society) can result in more effective outcomes. Such cooperation results in positive results through sharing resources for energy-efficient lighting policies and programmes. Many such programmes are initiated each year at local, national and regional levels, which can inadvertently duplicate effort, create conflict, or cause confusion. A regional cooperation initiative helps to coordinate such programmes. Conflict can be avoided and results can be achieved in a cost-effective manner. It enables lower product cost as manufacturers can leverage their production volume across multiple markets.

For a regional cooperation initiative to be successful consensus among the stakeholders is important. The following are suggestions for how to promote regional cooperation.

- Conduct roundtables and other consensus-building activities to reach agreement about particular issues, policies, guidelines, standards, and related subjects;
- Identify liaisons in each country to be point of contact and lead on local activities;
- Establish bilateral activities with another country in the region;
- Conduct in-person and online events to share experiences and information;
- Develop infrastructure for communication between stakeholders.

For promoting energy-efficient lighting, regional cooperation can include:

- Developing a regional efficient lighting roadmap to identify areas of cooperation and ways to share resources and build regional markets for efficient lighting;
- Establishing or harmonizing lighting specifications and standards that include energy performance and quality criteria;
- Coordinating around MVE activities, e.g. verification of labels, mutual recognition of test results, or sampling and checking regulations (MEPS) and standards compliance;
- Expanding lamp test facilities to reduce costs and build a network of professionals, with some countries potentially specialising in certain aspects of testing;
- Establishing regional resources for environmentally sound management, including collection and recycling schemes and information programmes²¹;
- Pooling resources and making use of the available structures and capacities within regions to improve the effectiveness, mutual reinforcement, and synergy between the various country programmes, making them more cost effective and impactful.

Regional coordination and planning is crucial for the success of projects of a larger scale. Such complex projects typically have cross-border and trade implications or are important for more than one government to address. Organisations aiming to stimulate cross-national cooperation can be a valuable platform to develop harmonized policies on energy-efficient lighting (e.g. ECOWAS in West Africa, or Latin American Energy Organization, OLADE, in Latin America).



4. SUPPORTING POLICIES



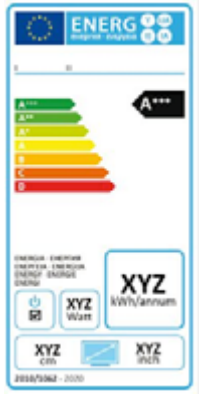
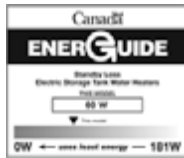
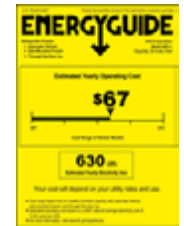


WHAT?	An overview of product labelling as well as communication and outreach activities. Product labelling explores the different label types, including endorsement and comparative. The communication discussion focuses on stakeholder empowerment through raising awareness and disseminating information.
WHY?	Provides information on supporting policies, the second part of UN Environment's integrated policy approach, and which is critical for securing public support and accelerating the transformation of energy-efficient lighting markets.
KEY QUESTIONS	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • What appliance labelling schemes exist or have been tried in my country in the past? • Which type of label will be the most effective way to communicate appropriate choices to consumers? • Can we adopt existing labelling scheme with proven validity and effectiveness? • How to secure correctness of the claims on the label or compliance to the criteria for affixing the label? • Has our country convened an energy efficiency communications campaign in the past? If so, what worked and what didn't work? Are there lessons to be learned from other communications campaigns that could help? • Who would lead a national campaign in our country promoting energy-efficient lighting? What partners would be needed? What impact could the campaign have?

4.1 LABELLING

Product labelling is one of the most direct and effective means of delivering information about energy efficiency to consumers. When implemented well, it is also one of the most cost-effective energy-efficient policy measures.

There are, generally, three major groups of labels—endorsement, comparative and informative. Comparative labels have two major subgroups—continuous comparative and categorical comparative. Table 9 provides the categories and brief description of these four types of labels.

Table 9.
General types
of product
labels used
around the
world

TYPE	ENDORSEMENT LABELS	COMPARATIVE - CATEGORIES	COMPARATIVE - CONTINUOUS	INFORMATIONAL
INFO	For products that meet or exceed a specified set of criteria; recognises premium models in the market; can be top efficiency—most efficient	Facilitate comparison between products on energy or other performance aspect in a discrete set of categories	Similar to comparative—categorical, but replaces the A to G or Star rating with a continuous sliding scale	Provides data on product performance or attributes (e.g. capacity, sound) but doesn't attempt to scale or rank.
SELECTION	Voluntary	Mandatory	Mandatory	Mandatory or Voluntary
EXAMPLES	US Energy Star Germany Blue Angel; SEAD Global Efficiency Medal	European A to G Thailand five star India star rating	Canadian Energuide US EnerGuide	US DOE's Lighting Facts QR codes
PICTURES	 		 	 

Labels can be either mandatory or voluntary. They should always be designed for the needs, benefit and convenience of consumers. As such, it is wise to conduct consumer research and convene focus groups when designing labels. It can be beneficial to adopt an existing labelling scheme with proven effectiveness. This would avoid a proliferation of different labels that could distract or confuse customers, reduce compliance costs, and lower manufacturer and importer costs by avoiding the need to have unique labels.

Product labels should be simple and easy to understand. They may be accompanied by supplemental information such as a brochure or a user's manual. The information

typically conveyed on a lighting label would most often include the light output, the wattage, the CCT and the CRI. Other information that may also appear on the label includes the lamp base type (e.g. E27, B22), operating voltage, incandescent lamp wattage equivalency, whether the lamp is dimmable, its annual running cost and if it contains mercury.

The success of any labelling scheme depends on its credibility. Whether the public trusts the information on the packaging is crucial. Less reputable companies may be tempted to abuse the label by claiming compliance while being unable or unwilling to invest in the necessary quality measures.

4.1.1 MANDATORY LABELLING

Mandatory labelling schemes are government regulations requiring the placement of labels on products, such as consumer appliances. These labels provide end users with information about the product's energy performance. This empowers end users to make informed choices and choose products with high levels of efficiency and quality.

Labelling programmes can be combined with other policy instruments. These include regulations (MEPS) and standards, financial incentives or voluntary agreements enhancing their effectiveness. Successful

programmes employ a combination of legal, financial, and social considerations, depending on the structure, economics, and culture of the society to which they apply. While labelling programmes are very helpful, labelling programmes alone cannot phase out inefficient lighting (hence the need for the integrated policy approach).

To develop and implement a labelling programme to its fullest potential, government officials and stakeholders must combine various features to develop or adopt a programme that is most suitable to their country's specific needs.

This empowers end users to make informed choices and choose products with high levels of efficiency and quality.

Advantages:

- Provides consumers with relevant information on energy-efficient, high-quality products;
- Can serve as a basis for other instruments such as financial schemes, rebates and subsidies;
- Widespread recognition of a label provides a strong market incentive for energy efficiency;
- Programmes accelerate the pace of market evolution and adoption of new technologies.

Constraints:

- Significant investment in time and effort to build awareness with end users and retailers;
- Mandatory programmes are more rigid than voluntary programmes and if they are poorly designed, they can create additional market barriers;
- Requirement of transparent monitoring to ensure fair participation and effective enforcement;
- Quantification of impact may be difficult since the impact of a programme depends on consumer awareness and market adoption.

CASE STUDY: Mandatory Star Rating, Fluorescent Tubes, Bureau of Energy Efficiency, India

India's energy labelling programme offers significant benefits to consumers, enabling them to reduce their energy bills by providing critical information on energy use at the time of purchase. The Bureau of Energy Efficiency (BEE), Government of India, is working to promote the efficient use of energy and its conservation across India. The number of stars can vary from 1 to 5, with more stars indicating higher energy efficiency and more savings for consumers. The illustration below is the BEE Star Rating Plan for Fluorescent Lamps.

For more information [click here](#).



BEE STAR RATING PLAN					
STAR RATING	★	★★	★★★	★★★★	★★★★★
Lumens per Watt at 0100 hrs of use	<61	>=61 & <67	>=67 & <86	>=86 & <92	>=92
Lumens per Watt at 2000 hrs of use	<52	>=52 & <57	>=57 & <77	>=77 & <83	>=83
Lumens per Watt at 3500 hrs of use	<49	>=49 & <54	>=54 & <73	>=73 & <78	>=78

4.1.2 VOLUNTARY LABELLING

Voluntary labelling programmes engage product suppliers who label their energy-efficient lighting products to inform end users about product performance. Greater awareness of energy performance enables end users to make informed purchasing decisions and contribute to developing a stronger market for energy-efficient products.

Voluntary labelling is effective if combined with integrated awareness campaigns. Such campaigns demonstrate the benefits of energy-efficient lighting products to purchasers and manufacturers. Voluntary labels are implemented in countries as diverse as Brazil, India, Thailand and the US. Only highly efficient lamps are likely to be labelled because manufacturers and retailers have no incentive to label low-efficiency lamps. Voluntary labelling programmes can serve as an interim step toward mandatory programmes, particularly if a country is new to labelling or has limited resources.

Advantages:

- Provides consumers with relevant information on energy-efficient, high-quality products;

- Can serve as a basis for other instruments such as financial schemes, rebates and subsidies;
- Acts as a cost-effective means to encourage energy savings;
- Results in energy savings that are relatively simple to quantify and can be easily verified;
- Requires less legislation and analysis compared with mandatory programmes because they are nonbinding and nonregulatory.

Constraints:

- Requires a considerable investment in time and effort to build awareness with end users and retailers;
- Requires a large investment to persuade manufacturers to participate, as non-participation can erode confidence in the programme;
- Have a market sampling scheme to verify labelled products and ensure that labelled products perform as claimed.

CASE STUDY: Energy Star, Department of Energy and Environmental Protection Agency, US

ENERGY STAR is a US Environmental Protection Agency (EPA) voluntary program helping businesses and individuals save money and protect the planet's climate by promoting highly energy-efficient products. ENERGY STAR was established in 1992, under the authority of the Clean Air Act Section 103(g), which directed the EPA "to develop, evaluate, and demonstrate nonregulatory strategies and technologies for reducing air pollution." The Energy Policy Act of 2005 amended the statute directing the Department of Energy and the EPA to manage a voluntary program to identify and promote energy-efficient products and buildings in order to reduce energy consumption, improve energy security, and reduce pollution through voluntary labelling. Now in its 23rd year, the ENERGY STAR programme has boosted the adoption of energy-efficient products, practices, and services through valuable partnerships, objective measurement tools, and consumer education.

For more information [click here](#).



Voluntary labels can also be associated with competitions for “best in market.” In this type of scheme, a programme specification is established, and suppliers enter the competition to ideally earn the accolade from participation and potentially winning the competition. The Group of Eight (G8)’s

Clean Energy Ministerial established the Super-Efficient Equipment and Appliance Deployment (SEAD) Global Efficiency Medal in 2012 and has been conducting global competitions on lighting products as well as televisions and electric motors.²²

4.2 COMMUNICATION AND EDUCATION

Awareness-raising campaigns support National Efficient Lighting Strategies. They also promote energy-efficient lighting technologies through good governmental policies and programmes. Changes in end-user behavior can also contribute to energy savings, by making end users more “energy-aware” through communication and education programmes. Changes in energy conservation, lifestyle, awareness, low-cost actions and small investments contribute to the overall energy savings.

Public awareness and education campaigns help energy-efficient lighting programmes gain momentum in the market. They reinforce the long-term effects of other related energy efficiency measures. In addition to providing end users with knowledge about efficient lighting technologies and their environmental and financial benefits, they can help to promote general acceptance and create a positive public environment for energy efficiency.

Communication campaigns should accentuate the positive. They should focus on the range of benefits and outcomes that

end users will enjoy as a result of seeking out and selecting efficient lighting products. If end users can feel good about the outcome, they are more motivated to take an interest in seeking out information and to understand why it is meaningful to their purchasing decision. Dry, factual messages will have less impact than positive, beneficial statements.

Programme implementers should avoid developing complicated or technical text, graphs or charts. Messages should be factual enough to be compelling but also user friendly and simple to be memorable. Some successful campaigns on efficient lighting have focused on the following:

- Monetary savings;
- National pride;
- Energy efficiency and energy savings;
- Convenience (long life);
- A simple and hassle-free switch;
- Environmental responsibility;
- Political and economic advantages;
- Energy security and reliability.

CASE STUDY: A Communications Campaign About Efficient Lighting, Zambia

ZESCO, the utility company serves Zambia, launched a “Switch and Save” campaign urging customers to lower their usage by turning off lights and appliances whenever they are unneeded. The company encourages its clients to save power to ensure they can have enough power for everyone.

For more information [click here](#).

4.2.1 DESIGNING A COMMUNICATIONS CAMPAIGN

The success of a communications campaign depends on its design. Objectives should be established in line with policy goals. The objectives should be specific, measurable, attainable, relevant and time bound (SMART). They determine the choice of communication tools and messages as well as evaluation parameters.

Communication design varies depending on the target audiences. For governments, the approach should persuade officials to formulate policy that promotes and maintains efficient lighting best practices. For business, practical tools such as online information and printed materials, new media, targeted training programmes, events and trade shows and design competitions. For the public, tools should be designed to shape thoughts, change an attitude, or induce action.

The communication messages should be simple and relevant to the audience. Messages should make the desired behavior attractive and easy and demonstrate benefits to end users. Usually, monetary savings are a strong motivator in all communications campaigns about efficiency, but in some developing countries, messages that tap into a sense of national pride may resonate as strongly.

Communication plans should be flexible. They should allow for adjustments based on monitoring results and any circumstantial changes. Project management skills are needed to successfully manage the launch and ongoing operation of the campaign. Diagnostic skills are used to recognize whether the campaign fulfills its expectations. If the campaign falls short of its goals, then its problems must be addressed.

CASE STUDY: I LED the Way–UJALA India Communications Campaign, India

In India, a communications campaign is being run to help underpin the national work of the Energy Efficiency Services Limited (EESL) promoting LED lighting. The programme uses on-line resources, advertising and other means of outreach to engage the public to participate in this national programme to promote LED lighting. The programme promotes national pride, with the slogan “Join a Movement to Make India Brighter and Smarter!”. The programme focuses on affordability and lowering people’s electricity bills, encouraging them to take advantage of the UJALA (Unnat Jyoti by Affordable LEDs for All) scheme by EESL, which offers LED lighting at lower prices thanks to the programmes robust and large bulk-procurement scheme. The campaign also encourages programme participants to promote the scheme, instructing them to tell others you switched to a smarter lighting solution and say I led the way!

For more information:

[UJALA India LED program Dashboard](#)

[Consumer Awareness of LEDs in India and Pledging](#)

POWER THE MOVEMENT TOGETHER
#ILEDTHEWAY



4.2.2 IDENTIFYING AND ENGAGING STAKEHOLDERS

Identifying the target audience for a campaign is critical. This helps in tailoring the messaging. Figure 8 depicts the four

major target audiences and some examples of the stakeholders within those groups.

Figure 8.
Major target audiences for communications campaign on energy-efficient lighting

- Governments
- Electric utilities
- Standards organisations
- Customs authorities
- Testing labs
- Trade unions



- Manufacturers
- Industry associations
- Wholesalers and retailers
- Specifiers
- Building owners and managers

- Media
- Research and training institutes

- Customers
- Civil society
- Consumer and community associations
- Environmental organisations

CASE STUDY: Regional Efficient Lighting Strategy, Central America

Central American countries are developing a regional communications programme to support the replacement of incandescent lights in low-income sectors through transition to efficient lighting. The programme will focus on low-income sectors. It will use print, broadcast, and billboard posters to inform the public about energy-efficient lighting. The broad regional communications strategy is combined with guidelines aligned with each country's particular characteristics.



For more information [click here](#).

Table 10 provides information on the communication interests of these target audiences. It includes their primary interests and their areas of involvement with respect to energy efficiency for appliances.

TARGET AUDIENCE	PRIMARY INTERESTS	AREAS OF INVOLVEMENT
INSTITUTIONS/GOVT. <ul style="list-style-type: none"> • Government • Electric Utilities • Standards bodies • Customs authorities • Testing labs • Trade unions 	<ul style="list-style-type: none"> • Reducing electricity use and GHG emissions through efficient appliances • Ensuring efficiency standards and product quality in market • Developing new products and effective distribution 	<ul style="list-style-type: none"> • Support regulatory and legislative initiatives and policy implementation through available funding opportunities • Provide experienced support in identifying success factors for promoting efficient appliances and market transformation • Evaluate and monitor processes against established targets
BUSINESS <ul style="list-style-type: none"> • Manufacturers • Lighting industry associations • Wholesalers and retailers • Specifiers • Building owners and managers 	<ul style="list-style-type: none"> • Promoting innovative, energy-efficient new technologies • Business prospects • Corporate responsibility • Reducing electrical consumption 	<ul style="list-style-type: none"> • Facilitate direct and indirect end-user communication • Key actors in promoting sustainable policies and transforming markets to efficient appliances • Provide best practice solutions at local, regional or international level • Provide guidance on technical feasibility and realistic time schedules
END USERS <ul style="list-style-type: none"> • Customers • Civil society • Consumer and community associations • Environmental organisations 	<ul style="list-style-type: none"> • Acquire information to make informed decisions about the savings associated with a switch to efficient lighting • Promote energy-efficient products 	<ul style="list-style-type: none"> • Acceptance and utilisation of energy-efficient appliances based on first-hand experience and affordability • Provide information about buying habits • Increase the consumption of energy-efficient lighting, and sustain the change in consumption patterns
MEDIA AND OTHERS <ul style="list-style-type: none"> • Media • Research and training institutes 	<ul style="list-style-type: none"> • Increase awareness and develop knowledge about energy-efficient lighting among professionals and consumers 	<ul style="list-style-type: none"> • Disseminate information on energy-efficient lighting to consumers • Identify best practices and policies • Assist governments in implementing sustainable appliance policies • Publish formal and informal education and training materials

Table 10.
Communication campaign stakeholders and areas of interest/ involvement



5. FINANCE AND FINANCIAL DELIVERY MECHANISMS

WHAT?	<p>This chapter addresses topics relating to financing of energy-efficient lighting, including both sources of financing and implementation vehicles and mechanisms. Some of the topics covered in this chapter include overcoming first-cost barriers to market adoption, traditional and innovative financing mechanisms, energy service companies, bulk public procurement schemes and electric utility demand-side management and on-bill financing programmes.</p>
WHY?	<p>Affordability of efficient lighting can be a market barrier, especially for low income residential consumers and municipalities. This chapter addresses how public finance, multilateral development finance, and climate finance, in coordination with the private sector, can help address this barrier through macro and micro financial schemes, innovative market delivery and repayment mechanisms, and other approaches to leverage private sector investments in these sectors.</p>
KEY QUESTIONS	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • Which economic policies or financial incentive programmes could be effective in facilitating market transformation in our country? • Which stakeholders should we engage to learn about financing opportunities, and work with to encourage the creation of new market-delivery mechanisms? • What new market-delivery mechanisms such as energy service companies, leasing schemes or other approach could be effective in our country? • Are there bi-lateral or multi-lateral sources of technical assistance, grants or finance that would stimulate and accelerate the efficient lighting market?

Enabling a market transition to energy-efficient lighting often requires policy interventions and financial incentives. To be successful in achieving market transformation, countries need to follow an approach that helps in overcoming market and other barriers, increases local investor confidence, and mobilises private sector investments and participation. Governments can achieve this objective by raising awareness and promoting an enabling environment which addresses the risks and barriers of lighting market stakeholders (such as consumers, manufacturers, utilities, ESCOs), and facilitates the scaling up energy-efficient lighting and other technologies.

Initial higher cost of energy-efficient lighting could make them unaffordable for some consumer categories in developing countries. This happens even when policies and regulations are in place. Overcoming first-cost barriers to market adoption requires the involvement of policy makers and institutions. Identifying and securing financial resources to support a market shift to efficient lighting can be difficult for some countries and sectors, such as low-income residential consumers and municipalities.

Public finance can be used in a manner that maximises the leverage of private sector

capital. Advanced planning and blending of financing sources with appropriate mechanisms is essential to managing the financial ecosystem, including risk- and cost-sharing arrangements to address risks. In this context, multilateral finance can further complement public finance sources in helping scaling up investments and expanding the impact in the area of energy-efficient lighting. Such funding can be applied to develop and strengthen the Regulations and Standards and their enforcement, as well as supporting policies like promotional schemes and rebates and other financial incentive mechanisms.²³

This chapter is divided into two parts. The first part is a high-level summary of the sources of funding that countries can access to supplement their own domestic public and private sector funds. More detail on these sources can be found in the U4E Fundamentals Guide, which sits as a companion guide to this report and provides information on topics that cut across all the products covered under U4E, including funding. The second part of this chapter concentrates on the implementation practices and delivery mechanisms that are driven by financial incentives to help facilitate successful market transition to energy-efficient lighting.

5.1 SOURCES OF FINANCE

Several sources of finance exist to help support energy-efficiency programmes, particularly for resource constrained countries. This section identifies some of the sources. Readers are directed to the U4E Fundamentals Guide, which provides an overview along with case studies and hyperlinks to various sources of finance for energy-efficiency projects and programmes in general.

- **Domestic sources of finance**—the most direct way for governments to pay for energy-efficient lighting programmes is to allocate public funds from the

domestic budget. Many lighting phase-out programmes are financed either fully or partially through public funds, for example, Argentina, Brazil, Cuba, Lebanon and South Africa. Another option is to involve electric utilities through the traditional Utility Demand Side Management (DSM) approach. The financial, technical, procurement capability and customer relationships makes utilities good implementers to channel large scale financial incentive-based programs to deploy energy-efficient lighting;

- **Private sector finance**—commercial financial institutions are starting to understand the compelling aspects of energy-efficiency and are developing suitable financing mechanisms. The economics and financing of efficient lighting is attractive and offers lighting equipment vendors, suppliers and ESCOs an incentive to invest in energy efficiency that is recovered through energy savings. Examples of private sector finance include bank loans, leasing, third-party financing, performance contracting through ESCOs, including ethical or green investment funds;
- **Non-domestic sources of finance**—some developing countries who do not have adequate public finance and resources to finance a technology phase out or large scale deployment programme, may seek nondomestic sources of finance—including from the World Bank, the Asian Development Bank, and the European Bank for Reconstruction and Development. Nondomestic sources of finance can provide concessional funding to governments (including soft loans, and guarantees) to help trigger market transformation through large-scale deployment programs, along with initiating phase-out programmes, raising investor confidence and attracting private investors;
- **Climate financing**—financing mechanisms designed to reduce CO₂ emissions often provide grants and low-cost loans, which can be blended with other sources of finance to help scale up the implementation of energy efficiency programmes, including for energy-efficient lighting. Examples of climate financing include the GEF, Green Climate Fund, Clean Development Mechanism (CDM), Nationally Appropriate Mitigation Actions (NAMAs), and Climate Investment Funds. These financing mechanisms require robust measurement and verification of CO₂ emissions reduction in addition to that of energy savings.

5.2 FINANCE AND FINANCIAL DELIVERY MECHANISMS

Numerous financing mechanisms utilise the finance sources to deliver energy-efficient lighting deployment initiatives. These mechanisms typically have to overcome perceived risks of different stakeholders, thereby facilitating transactions that will lead to investments in LED lighting programmes. Some examples of delivery mechanisms are:

- Utility Demand Side Management (On-bill financing, Rebates, pay-as-you-save);
- Energy Savings Performance Contracting through ESCOs (Shared Savings, Guaranteed Savings and Annuity Based);
- Bulk Public Procurement through Public Super ESCOs or Utilities;
- Public-Private Partnership Financing and Delivery Model;
- New Business Models, including Public Lighting Lease to Own Model.

5.2.1 UTILITY DEMAND SIDE MANAGEMENT

On-bill financing (OBF) refers to a loan made to a utility customer, such as a homeowner or a commercial building owner, to enable the customer to purchase and switch to energy-efficient lighting. These schemes provide qualified utility customers with finance for energy-efficient appliance rebates and incentive programmes and schemes.

The loans issued are interest-free or very favourable terms. They are intended to cover costs incurred in connection with a qualified retrofit project. The consumer enjoys energy savings accrued on the electricity bills. The beneficiary consumer pays off the loan through a payment in the monthly electricity bills over a certain agreed period of time.

The utility (or programme administrator) distributes the energy-efficient lamps. It does this through its own offices and distribution centres or through the local retailers. The incentive sometimes does not require an actual payment. It is provided virtually upon showing the valid and eligible

electricity bill or through a coupon that can be cashed in with the participating retailers. Loan repayment by consumer is made through regular monthly payments on the utility bill until it is fully repaid.

An OBF programme may be limited to particular types of customers. These can be commercial building owners, commercial tenants, or residential homeowners. In most on-bill financing programmes, the loan funds are provided directly by the utility (or programme administrator), and the repayment risk is held by the same entity until the loan is paid off.²⁴

The advantage for the participating consumer is getting a high-quality, energy-efficient lamp. Often the lamp comes with a replaceable warranty, as it is procured in bulk by the utility (or programme administrator). The utility incurs the procurement costs along with program delivery costs, which includes consumer awareness and information programs associated with such deployment schemes.

5.2.2 ENERGY SAVINGS PERFORMANCE CONTRACTING THROUGH ESCOs

An ESCO is a commercial business that provides a broad range of turn-key energy solutions. These include energy audits, system designs and implementation of energy efficiency projects. ESCOs often act as project developers for a comprehensive range of energy efficiency measures and assume the technical and commercial risk.

ESCOs and other energy efficiency companies differ in that ESCOs use energy savings performance-based contracting and guarantees the savings. It takes the technical risks. Their compensation is directly linked to the measured and verified actual energy savings obtained by the end-user client.

In case of shared savings model, ESCOs borrow from banks or invest their own funds. They take both credit and technical risks. In case of guaranteed savings ESCO approach, the end user invests and the ESCO provides just the performance guarantee and thus takes technical risks only.

In most countries, part of the technology offering promoted by ESCOs, such as vendor ESCOs, is for high-efficiency LED public street lighting and controls. These technologies also prompt the development of new financing and operating business models, to exploit their high energy efficiency and extended operating lifetimes.

For example, where the traditional regular replacement of bulbs will be replaced by new “lighting as a service” business models (see section 5.2.6). In these scenarios, the financial risk and management of the

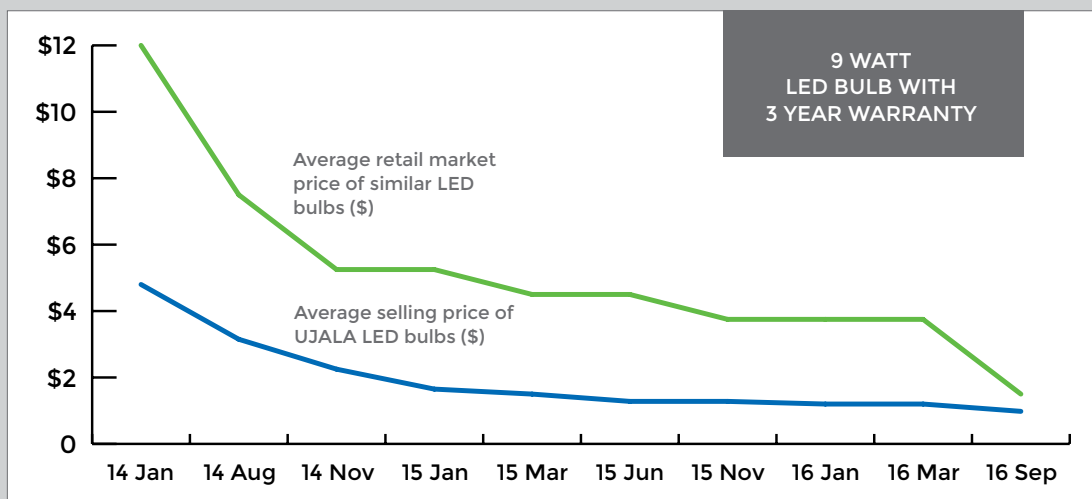
lighting system is transferred to a service provider, who may be in the best position to manage the risk and develop new client services in the future.

CASE STUDY: Energy-Efficiency Services Limited (EESL), India

In India, the Ministry of Power set up Energy Efficiency Services Limited (EESL), a joint venture of four power PSUs—NTPC, Rural Electrification Corporation, Power Finance Corporation and Powergrid Corporation of India to facilitate implementation of energy-efficiency projects. EESL works across multiple disciplines to promote energy efficiency. EESL is the first company in South Asia exclusively focused on energy-efficiency implementation and is responsible for facilitating bulk procurement of both LED household lamps and LED streetlights lowering the cost of the product, making it affordable for consumers with a view to replace 770 million LEDs in households and 35 million LED street lights by 2019. By August 2016, 155 million household LED lamps and 1.2 million LED streetlights had been deployed. With the use of bulk procurement, EESL’s 9 Watt household LED lamp (branded under UJALA) has decreased its selling price from \$4.80 at the start of 2014 to around \$1.00 by the end of 2016. Similar LED lamps in normal retail markets in India also decreased to approximately \$1.50 over the same time period. EESL works with utilities through on-bill financing (OBF) and classic pay-as-you-save mechanisms with residential consumers and with manufacturers and vendors through annuity-based financing for municipal street lighting. The low selling price may not be achieved in other countries due to the large economy of scale that India is able to achieve with its bulk procurement.

For more information:
[click here](#) | [click here](#)

Source: Personal communication, N. Moran, Energy Efficiency Services Limited (EESL), India; UN Environment, 2016.



EESL Energy Efficiency Services Limited
A Public Sector Enterprise

5.2.3 BULK PROCUREMENT

Bulk procurement refers to the purchase of a large volume of products by an organisation that then distributes those products directly to consumers. By doing this the organisations pass along the savings from the large purchase contact and supply-chain bypass.

Bulk procurement projects are not intended to be sustained, long-term efforts. They are primarily individual projects intended to stimulate the market and rapidly accelerate the adoption of a given technology. The organisations implementing bulk procurement projects include electric utilities, government procurement entities at federal, state, provincial or municipality levels, public Super ESCOs, and other implementing organisations using public funds or funds borrowed from domestic banks or multilateral banks.

Bulk procurement is generally conducted using a competitive bidding process. The purchasing entity defines the technical and performance specifications of the products being promoted, to ensure that the programme will meet its energy-efficiency goals. Bulk procurement programmes enable the purchasing entity to move up the supply chain, which lowers the cost but maintains the quality and performance of equipment like LED lamps. This in turn raises the awareness and comfort level of consumers about energy-efficient products. Typically, this results in a significantly lower final retail price to the consumer, for a product incorporating the features the government may want to promote, including highly efficient CFL and LED lighting.

CASE STUDY: Philips Lighting—25 Parking Garages in Washington, D.C., US

Philips Lighting announced a contract with Washington Metropolitan Area Transit Authority (WMATA) to install LED lights at 25 parking garages at Washington Metro stations in 2013. The fixtures, or luminaires, have a wireless control system with sensors for daylight and motion to optimize energy efficiency, while delivering enough light to meet WMATA's safety requirements. Replacing 13,000 fixtures is projected to reduce electricity use by 68 per cent, the equivalent of the electricity used by more than 1,400 homes.

5.2.4 PPP FINANCING AND DELIVERY MODEL

PPPs emerged in the 1990s as a mechanism enabling governments to fund and operate services through contracts with private companies. They come in a wide variety of structures and formats. Finance can be sourced from either the public sources or the private sector or both, depending on the design of the partnership contract.

The private sector brings its implementation expertise to a project usually considered within the public domain and assumes much of the financial or performance risk. For example, with LED products, failures remain

entirely the responsibility of the private company. The PPPs offer a mechanism under which they can take on large-scale projects with private sector financing and management expertise, while retaining management control and key decision powers.

According to the European Investment Bank, PPP transactions in the European Union (EU) stood at EUR 15.8 billion (\$ 21.2 billion) in 2010. About 1,400 deals have been implemented over the past two decades.

CASE STUDY: PPP Delivery Model; Birmingham, United Kingdom (UK)

A LED public lighting programme in Birmingham was part of a larger PPP encompassing bridges and roads. The private sector financed and implemented the project, then assumed ownership and maintenance of the infrastructure under a 25-year PPP contract, within the UK's Private Finance Initiative (PFI) framework. The success of the PFI-PPP project depended on the legal, institutional, financial, and technical support from the private sector. The framework provided contracting guidelines among the different stakeholders, an environment familiar enough for private investors to provide financing and technical assistance to parties to the PPP.

5.2.5 NEW BUSINESS MODELS

Leasing agreements establish a contract where a consumer rents an asset from the equipment supplier or vendor instead of purchasing it. This is in many ways a specialized form of ESCO financing. It is generally applied to LED public lighting projects.

The finance for the leasing contract may be done by the equipment supplier or vendor itself or supported by a loan derived from a financial institution. The equipment supplier or leasing company provides the installation and commissioning costs associated with the lighting system. National tax laws can impact lease operations.

There are a few different financing structures that can be applied. These include an "operating lease" where by the vendor offers the lessee a fixed short-term lease, and transfers only the right to use the lighting equipment for a fixed monthly rent, after which it remains the property of the owner. Another financing structure is "hire purchase agreements," which allows for a gradual payment for the lighting system over a defined operating period, and at the end of the contract the assets, fully paid off, automatically become the property of the lessee or customer.



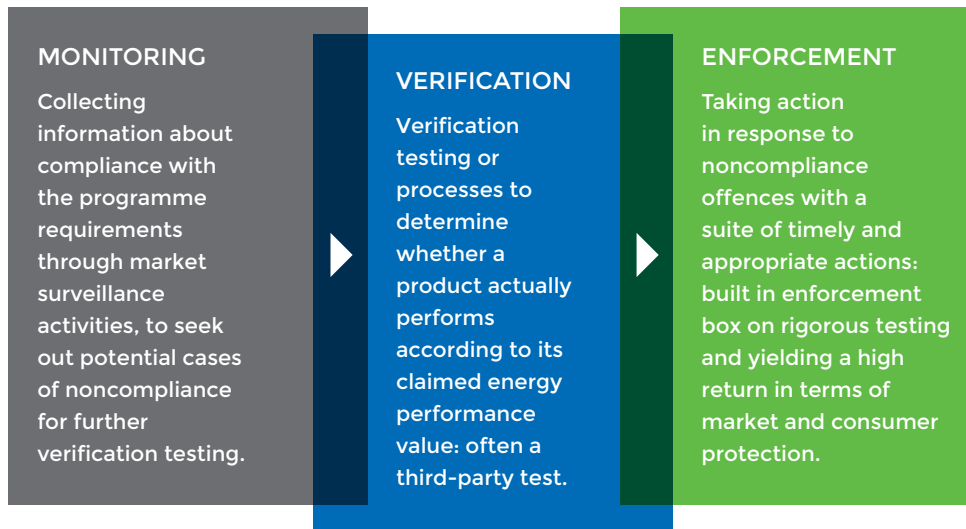
6. MARKET MONITORING, VERIFICATION AND ENFORCEMENT

WHAT?	Clarifies the critical importance of MVE to ensuring a level playing field, so businesses comply and consumers benefit. Highlights the central role of government in establishing and maintaining a robust market surveillance programme.
WHY?	Just as police enforce the law and prevent crime, national governments must work to monitor, verify and enforce regulations and standards to ensure the policies and programmes that were created to transform their respective markets are followed. In addition, the absence of MVE may tempt less reputable manufacturers to make false performance claims, thereby causing consumer disappointment and eroding the credibility of the programme. Robust MVE schemes are absolutely fundamental to achieving successful policy-driven market transformation outcomes.
KEY QUESTIONS	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • How can market surveillance improve the effectiveness and impact of the regulations? • Do we have the legal framework around which to structure a complete MVE scheme? • Which government ministries oversee product safety standards and requirements? Could their function be expanded to include additional regulations and standards enforcement? • What are the costs and benefits of running a market-surveillance programme? • Can we simplify the implementation, by adopting existing international Regulations, Standards and MVE schemes such as the International Electrotechnical Commission for Electrical Equipment's (IECEE) CB-scheme?"

Market MVE is an indispensable component of the integrated policy approach. It revolves around monitoring markets, verifying

compliance and enforcing the regulation on companies that fail to meet them. Figure 9 highlights the fundamental aspects of MVE.

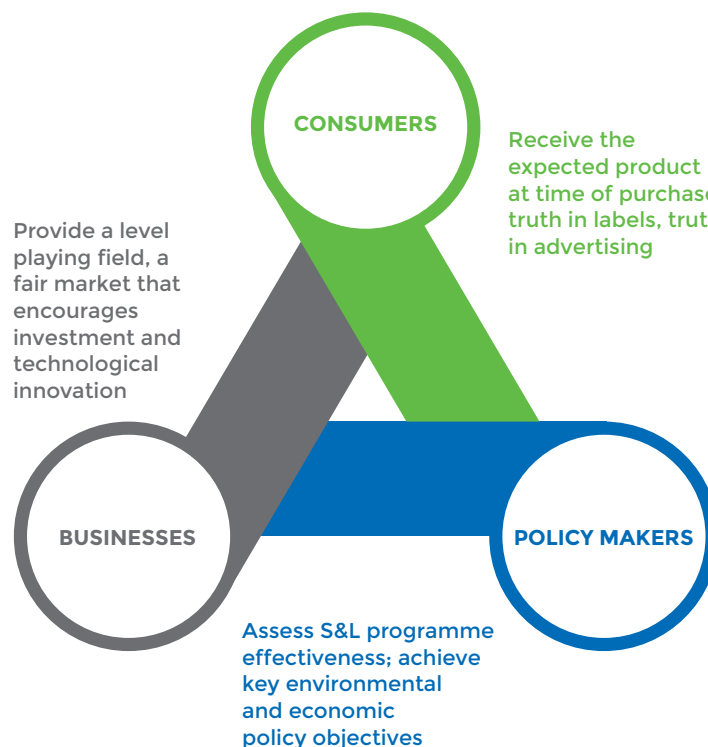
Figure 9.
Fundamental aspects of the Market MVE process



Effective MVE schemes ensure a level playing field. Manufacturers comply with standards and labelling programmes, enabling consumers and companies alike to benefit. Considering the three main stakeholders involved, industry, consumers and governments, MVE offers benefits to all, as depicted in Figure 10.

The goal of MVE is to ensure the integrity of market-transformation programmes. It does this by minimising the negative costs associated with the sale of noncompliant products after the effective date of a regulation.

Figure 10.
MVE benefits to stakeholders



6.1 LEGAL AND ADMINISTRATIVE FRAMEWORK

A strong foundation within the national legal framework is crucial for a MVE scheme. This foundation should encompass legal authority, enforcement powers and penalties. The legal framework for an energy efficiency enforcement regime will depend on the national governance structure, on existing legislation, and on the infrastructure and design of the MVE process.

Legal frameworks must clearly delineate responsibilities between the different government agencies implementing MVE nationally. Including the agency responsible

for coordinating the MVE scheme, and other agencies such as customs, standards and metrology that will have central roles. The framework could bestow the authority for an agency to issue fines and block the sale of noncompliant products from entering the market.

The operational framework within which the enforcement authority operates should be transparent. This improves compliance rates through clear communication and understanding of the MVE scheme.



Please review the UN Environment report **ENFORCING EFFICIENT LIGHTING REGULATIONS** for more information.

CASE STUDY: Building on Existing Product Safety Legislation, Cambodia

Cambodia currently has no legal framework in place for authorising the enforcement of noncompliance for energy efficiency. However, a regulatory framework exists for the Safety Label for Electrical and Electronic Household Products. This piece of legislation covers provisions for:

- Commercial fraud repression
- Actions against products or services which are likely to induce grave or imminent dangers
- Inspection procedures for quality and safety of products, goods and services
- Offences

Although these provisions focus on product safety, they can be modified and adapted to address energy-efficiency violations. The same agencies responsible for enforcement of product safety, the Ministry of Industry and Handicraft and the Ministry of Mines and Energy, can adapt their experience to enforce energy efficiency legislation.

6.2 FINANCING MVE SCHEMES

The costs of a national MVE scheme vary. They depend on the scope of the programme as well as local or regional factors, such as labour and services costs. When planning how to allocate funding for an MVE scheme, the managing agency typically takes into account the relative scale of the harm caused (including cost of wasted energy, loss of consumer confidence, the frequency of noncompliance).

More resources are allocated toward addressing cases of noncompliance. They have the greatest impact and occur frequently. Budget allocation should be an evidence-driven, risk-based process that is transparent and defensible.

The areas of an MVE scheme which incur costs are listed below:

- **Establishment costs**—setting up a main office and possibly field offices with new equipment;
- **Staff costs**—hiring and training of the staff, covering the key areas of administration, investigation and management, and in specialist areas such as customs officials and test labs;
- **Communications**—informing the market about the regulations, the MVE scheme and enforcement proceedings, as deterrence is highly cost effective;
- **Legal and enforcement action**—the MVE agency needs to have (and be seen to have) sufficient funding to use its full range of legal powers.

The success of an MVE scheme depends on identifying a secure and sustainable source of funding that will be maintained for a given market. Governments must assess what is equitable and feasible and construct a solution that will fit within their framework. Robust MVE schemes require good market awareness, sampling and testing.

The most common source of funding is the government's own general operating budget. This does not need to be the only source of funding. Cost recovery from suppliers can also be another source of

funding, with many programmes around the world introducing cost recovery elements to their schemes. Cost recovery can be partial or complete and can be achieved through, for example, registration fees, verification testing fees and enforcement fines.

Many programmes collect funds from suppliers during registration. This may take the form of an annual payment, a one-off payment for a specified period, or a higher initial fee followed by a smaller annual payment. Registration fees are generally levied on product models rather than brands or suppliers, as this best reflects the costs involved. In India, for example, the total fees a supplier must pay to the Bureau of Energy Efficiency increases with the number of models registered and the number of individual lamps of each model sold in India.

An increasing number of programmes require that products have third-party certification. This comes from an independent body as a condition of entry to the programme. While this is not cost recovery per se, it can reduce the costs of the programme. This is because the system administrator is in effect delegating some of the responsibility for ensuring products meet the necessary requirements to third parties that are paid by the product suppliers.

CASE STUDY: Climate Technology Centre and Network Support for Accreditation of Lighting Laboratory, Jordan

In early 2016, the Climate Technology Centre and Network (CTCN) extended support to assist the Jordanian Standards and Metrology Organisation (JSMO) with the process for earning accreditation for testing of energy-efficient lighting. The lighting laboratory needs international accreditation to ensure the test results are reliable and will be accepted by other governments and the market. The expected support from this on-going project is to assist with a proficiency test for the laboratory, train the staff on applying test methods, lighting standards and regulations, and to offer expert advice on all important elements to earn accreditation.

For more information [click here](#).

Support for MVE schemes can also be derived from stakeholders in the market. Collaboration and cooperation with industry or civil society may provide additional resources. Including through joint testing programmes, by providing expertise, supporting data collection and sharing, or even providing testing facilities. Prior to

engaging in this form of collaboration, the goals of cooperating need to be established. Some contributions may not be admissible as a foundation for legal action. There may be a conflict of interest in using industry funding to legally prove noncompliance of competitors in the market.

6.3 EFFICIENT LIGHTING MARKET BASELINES AND ASSESSMENTS

A market baseline provides a snapshot of the products available in a market at a given point in time. It provides a sound technical foundation for the development of new, or revised, policies for efficient lighting. Market baselines enable policymakers to gain a thorough understanding of product availability, performance, pricing and other important factors influencing policy development.

Market baselines are refreshed over time. Because of this, they enable policymakers to identify and understand market trends and responses to government policies

and programmes. This supports the development of more effective regulations and supporting policies in the future.

UN Environment has published a guidance note²⁵ on the development and maintenance of market baselines and market monitoring activities. The note is aimed at policymakers who wish to establish or update policies to facilitate the transition to efficient lighting. It provides a practical resource for those developing a market baseline for the first time, or those who are looking to update existing baselines for market monitoring purposes.



Please review the UN Environment report **EFFICIENT LIGHTING MARKET BASELINES AND ASSESSMENT** for more information.

6.4 PRODUCT REGISTRY SYSTEMS

Product registration systems offer an initial compliance gateway. Suppliers register compliant products with the regulatory authority. The registration process requires manufacturers to submit test results on the products, and certify that the product performance meets the regulations, standards, and any labelling requirements, before the product can be placed on the market.

The data recorded in these include typically brand, model, lamp type, rated power, light output, efficacy, CRI, and CCT. Energy-performance data, technical product

specifications, sales figures and product prices can be included in these systems.

Governments set up product registration systems via legislative and regulatory authority. Mandatory registration systems are in place for products with energy labelling in Australia, Canada, China, New Zealand, Singapore and the US, among others.

Registration systems are designed to meet the needs of many different stakeholder groups, as shown in Table 11.

Table 11.
Product Registry
System Users
and their
Potential Needs

STAKEHOLDER	POTENTIAL USER NEEDS
POLICYMAKERS AND GOVERNMENT	Provides a record of baseline data to support policy making; expands the evidence database for market surveillance; serves as a storehouse of ancillary information and data about products on the market
MANUFACTURERS AND SUPPLIERS	Facilitates declaration of conformity with regulatory or voluntary requirements; provides information about innovation in product design (fostering competition and innovation); strengthens brand credibility; helps to ensure a level playing field
CONSUMERS	A database of product-specific information in the public domain; opportunity for advanced features through apps or other tools, doing product searches; enhances transparency of communication about product performance
DISTRIBUTORS	Retailers can verify that products being supplied are registered and compliant with local laws
OTHER PLAYERS	Registry information can be used to determine product performance for market pull programmes that incorporate financial incentives, subsidies and prizes

For more information on product registry databases, see the recent *UN Environment publication on Developing Lighting Product Registration Systems*.²⁶ The following are examples of mandatory product registry databases in Australia and the US:

- [Australia–Equipment Energy Efficiency Appliance and Equipment Database;](#)
- [The US Department of Energy’s Compliance Certification Database;](#)
- [U4E prototype registration database.](#)

6.5 TEST LABORATORIES

Measurement of the performance of a product, as part of a coordinated MVE strategy, provides the foundation for the effective implementation of energy-efficient lighting policies and regulations. Product testing constitutes the cornerstone of any product compliance certification report, whether for a voluntary or mandatory programme.

There are two principle pieces of photometric measurement equipment. These are the integrating sphere and the goniophotometer, both of which require

on-going calibration maintenance to ensure accuracy and reliability of measurements.

UN Environment recently published a report titled “Good Practices for Photometric Laboratories,” which guides practitioners who wish to establish a photometric laboratory or improve the conformance of an existing laboratory. The topics covered include (a) traceability and accreditation; (b) calibration; (c) uncertainties; (d) testing processes; and (e) records and storage.²⁷ Table 12 depicts the essential elements for the reliable operation of a testing laboratory.

ELEMENT	ESSENTIAL ELEMENTS
TRACEABILITY AND ACCREDITATION	<ul style="list-style-type: none"> • Linking measuring equipment to SI unit • Accreditation for specific test procedures • Proficiency testing
CALIBRATION	<ul style="list-style-type: none"> • Externally calibrated reference lamps and meters • Internal equipment calibration • Monitoring laboratory conditions
UNCERTAINTIES	<ul style="list-style-type: none"> • Confidence intervals • Determining the uncertainty
TESTING	<ul style="list-style-type: none"> • General considerations • Integrating sphere considerations • Goniophotometer considerations
HOUSEKEEPING	<ul style="list-style-type: none"> • Record keeping system • Lamp identification • Storage conditions • Length of time • Lamp disposal

Having a national laboratory can be a prestigious asset to manage. However, laboratories are expensive facilities to establish, commission, earn accredited and maintain. There needs to be a certain minimum level of business in a given market in order to sustain the laboratory and to ensure it has adequate revenue with which

to operate and maintain its calibration and accreditation.

Countries with smaller economies may consider outsourcing laboratory test needs to neighbouring countries.²⁸ Then later, after their economy has grown, they can justify direct investment in a domestic testing facility.



Please review the UN Environment report **GOOD PRACTICES FOR PHOTOMETRIC LABORATORIES** for more information.

Table 12.
Essential elements for the reliable operation of a test laboratory

CASE STUDY: GELC, Beijing

In September 2011, the GELC - UN Environment Collaborating Centre for Energy Efficient Lighting was launched at the UN Environment headquarters in Nairobi. The GELC is located in Beijing, and is a specialised and accredited facility that provides lighting testing, training, advice, quality control and capacity building support to the developing and emerging countries. It has been established to promote the rapid development of the energy-efficient lighting technologies around the world. Countries who have joined U4E Global Partnership Program are the first to benefit from the new Centre. Staffed by experienced lighting experts, the Collaborating Centre will support developing and emerging countries with: (1) Assistance in the establishment or strengthening of national and/or regional lighting laboratories; (2) Technical support to establish or enhance the quality control capabilities for lighting products; (3) Specialised support to develop quality control tests; and (4) Technical support to improve production of energy-efficient lighting products.



For more information [click here](#).

6.6 PROACTIVE COMMUNICATIONS

Communication is a critical element of any successful MVE scheme. For manufacturers, it helps to ensure they are aware of their legal obligations, and what happens if they were found to be noncompliant. For consumers, it lets them know that their government is working hard for them, ensuring that the national market for a given product offers a fair and level playing field. Communications can also be a powerful tool in gaining the respect of the regulated businesses and improving compliance rates; for example, taking quick action to minimise market damage and making it visible, as a deterrent to others.

It is necessary for governments to develop a communications plan. This plan should be fine tuned and appropriate for the domestic market. It should take into account all the main stakeholders involved in the supply chain and the importance of communicating key messages to them about the requirements themselves, the

risk of detection and sanctions, and any corrective action taken. Governments may choose to list the number and frequency of surveys and tests, identify plans for future compliance work and publish information about their work. Some governments may also consider identifying products and brands that are noncompliant (also called the “name and shame” approach).

Governments can offer a number of tools, training and guidance to improve compliance rates. They can offer training courses to explain regulatory requirements or maintain a regulatory hotline or email service to answer questions that the suppliers may have. They can publish a frequently asked questions (FAQ) website, and provide guidance on compliance reporting and documentation requirements. All of these approaches help to minimise the costs of demonstrating compliance and will thereby help to ensure higher compliance rates and more successful outcomes.

CASE STUDY: Communications Outreach to Inform Suppliers, Sweden

The Swedish Energy Agency has recognised that one of the best ways to strengthen their MVE programme is through proactive communication with manufacturers and importers in Sweden. The Agency organises information sessions and webinars, prepares leaflets and postal campaigns, advertises in trade magazines, provides software tools, and operates a hotline to ensure complete and transparent information about any new regulations. By conducting proactive communications, Sweden helps to ensure all the stakeholders are informed about the requirements and the programme they operate around MVE, thus serving as a deterrent to any companies who may be considering not being compliant.

For more information [click here](#).

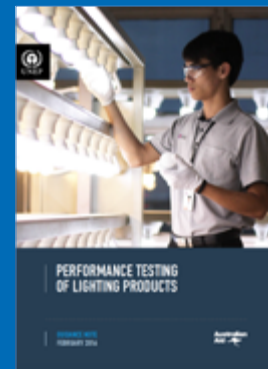


Please review the UN Environment report **PRODUCT SELECTION AND PROCUREMENT FOR LAMP PERFORMANCE TESTING** for more information.

6.7 MARKET MONITORING

A critical function of a government market-surveillance authority is to regularly monitor the market. By doing this they ensure that the products being supplied to the market are compliant. UN Environment recently published a report tailored for policymakers and enforcement agencies who wish to understand the performance of products in their market. The report discusses methodologies for cost-effective identification and selection of lamps for establishing a market baseline prior to regulation, as well as for identifying lamp models when conducting lamp testing for compliance in an already regulated market. It covers topics such as (a) defining the product scope; (b) selecting the procurement methodology; (c) transparency and traceability of procurement; and (d) packaging and transportation practices.²⁹

UN Environment has also studied the approach that laboratory personnel may follow when conducting testing. In another report, UN Environment provides recommendations for processes to follow for testing products, interpreting testing results, and using them to inform policy making. This testing report covers topics such as (a) identifying testing objectives; (b) determining where to test products; (c) adopting appropriate test standards; (d) selecting parameters to be tested; and (e) conducting testing and applying test results. The recommendations in this report focus on the identification of which type of products should be monitored, determining how performance testing data is used, determining where the testing will be conducted (e.g. national, regional, third-party), and ensuring that test results are accurate and correctly interpreted.³⁰



Please review the UN Environment report **PERFORMANCE TESTING OF LIGHTING PRODUCTS** for more information.

6.8 REGULATORY ENFORCEMENT

In cases of noncompliance, the enforcement authorities should carefully consider the degree of noncompliance. By doing this they can respond with a proportionate enforcement action. The available enforcement actions should be flexible, enabling the enforcement authority to assess the non-compliance situation and initiate a proportionate action. The penalties and powers of the enforcement authority should be set out in law. The toolkit of powers and actions should be further outlined in administrative procedures or operational guidelines.

Many enforcement authorities develop an “Enforcement Pyramid” to inform and manage their enforcement response strategies. The bottom of the pyramid typically features more informal actions, while the top of the pyramid should reflect the most severe enforcement response to noncompliance (see Figure 11).

The pyramid can be populated to be most effective for the national enforcement strategy, in accordance with the legal requirements and resources available to the enforcement authority, and the characteristics of the programme and its participants and stakeholders.

For more information on effective enforcement schemes, please see a recent UN Environment report³¹ that serves as a practical resource to policy-makers on the steps to follow when implementing a national enforcement programme. This report covers (a) legal and administrative foundation for enforcement; (b) enforcement budget and activity planning; (c) identifying types of non-compliance; and (d) communicating to stakeholders.

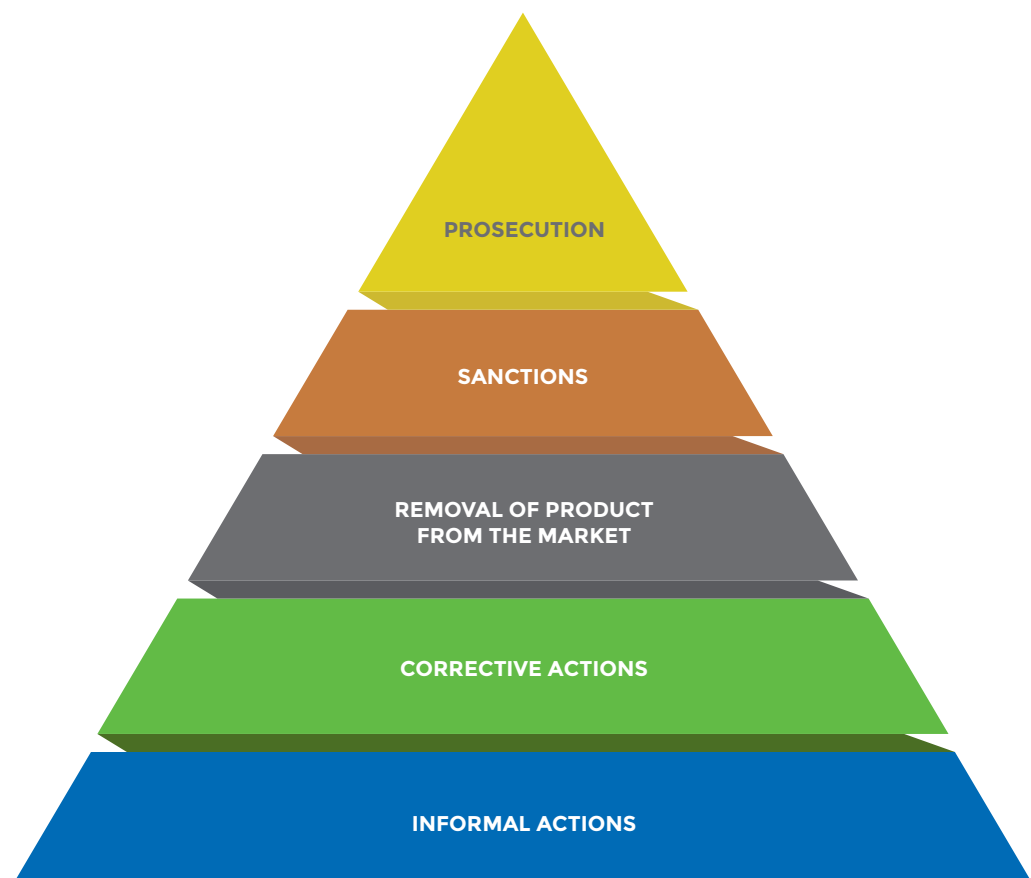


Figure 11.
Pyramid of
escalating
enforcement

Please review the UN Environment report **ENFORCING EFFICIENT LIGHTING REGULATIONS** for more information.

CASE STUDY: Enforcement Practices, UK

The United Kingdom's enforcement authority, Regulatory Delivery, relies on national legislation to inform enforcement procedures. Their processes must adhere to a range of "Better Regulation" principles. These principles form the foundation of the Regulators' Code, which helps to deliver better regulation—essentially reducing regulatory burdens and supporting compliant business growth. The enforcement authority is committed to seeking an appropriate balance between noncompliance deterrents and ensuring the costs of complying are not too burdensome on programme participants. The principles help them to meet their commitment, by ensuring that all enforcement regulation be transparent, accountable, proportionate, consistent and targeted (to those cases where enforcement action is needed).

For more information [click here](#).



7. ENVIRONMENTAL SUSTAINABILITY AND HEALTH

WHAT?	Provides a summary of the importance and benefits of recycling of used lamps and luminaires, the use of hazardous materials in lighting, and possible financing mechanisms for recycling programmes.
WHY?	The energy-efficient lighting and controls promoted through this initiative do contain materials that can be recycled, recovered or reused, as well as some materials that could be hazardous if simply dumped in a landfill. By establishing a national collection and recycling scheme, a “circular economy” objective can be achieved, avoiding hazardous waste contamination of landfills.
NEXT?	<p>Some key questions to keep in mind:</p> <ul style="list-style-type: none"> • What are the hazardous materials used in lighting products? • What waste collection and recycling schemes are already being conducted in our country? • Who are the critical players who would need to be informed and/or participate in planning a lamp or lighting equipment recycling scheme? • What are the financial requirements of such a programme and how can we find the resources to cover them (which approach will work best in our country)?

Environmentally sound management incorporates the concept of a product's full lifecycle. It begins from raw materials used in manufacturing through to end-of-life recovery and recycling. This approach gives regulators a suitable framework to analyse and manage the performance of goods and services in terms of their impact on the environment.

When life-cycle management principles are applied to lighting products and equipment, the assessment concentrates on the following three stages:

- **Production:** focuses on the raw materials and production techniques involved in manufacturing the product, including hazardous substances. The production phase is a natural point of intervention for hazardous substance regulators in the product lifecycle, for example, the level of mercury in CFLs;
- **Usage:** focuses on the environmental impact of lamps during the use phase (i.e. from power plant related emissions) but can also include health and safety aspects of lighting such as the steps to take in case of a lamp breakage;
- **End-of-Life:** focuses on the end-of-life management of lighting products, highlighting current regulatory frameworks, examples of best practices in establishing, managing and financing end-of-life collection; recycling and environmentally sound management; and disposal.

Life-cycle assessments conducted on lighting products³² have concluded that the "usage" stage is the most important from an environmental impact point of view. Researchers have also pointed out that as the energy efficiency of lighting products improves, the usage stage still dominates, but other aspects of the lifecycle including production and end of life become more important.

Optimisation across these stages requires minimising the environmental impacts during each stage. The phase out of inefficient lighting is an effective intervention from a "use" point of view, as it can offer a significant reduction in energy consumption and prevention of climate change through avoided CO₂ emissions and mercury pollution from certain fossil fuel power stations. In all aspects of a lamp's lifecycle, reducing energy consumption is by far the most significant and positive change to be made. Because some of the efficient alternatives, such as CFLs, contain mercury, a more integrated policy approach is required. The approach should follow the principles of pollution prevention and environmentally sound management.

This approach includes maximising energy efficiency and lamp life and minimizing toxicity at the design and manufacturing stages, while ensuring the sustainable management of spent lamps. This is consistent with global international policies that reduce and safely manage hazardous waste, such as the "Basel Convention on the Control of Transboundary Movement of Hazardous Wastes" and the "Minimata Convention on Mercury." Several national and regional collection systems have been mandated by law in the last few years to facilitate recycling of materials as well as safe disposal of hazardous substances.³³

The implementation of environmentally sound management requires that the following elements are taken into account: (1) policy and legal framework; (2) collection schemes and related awareness raising activities; (3) transportation, storage and recycling programmes; and (4) financial mechanisms to cover the running costs.

7.1 POLICY AND LEGAL FRAMEWORK

In order to have a national programme that is required and enforceable, governments must have a legal framework for electronic waste and hazardous waste management, as well as maximum mercury levels. This encourages the development of initiatives in the country or region for relevant international conventions.

Policy makers should consider regulations that limit the content of mercury and other hazardous substances in lamps. Limits should be set in line with the international best practice standards, aiming for progressively lower levels of mercury in CFLs. Limits should be reviewed regularly and adjusted to account for technical progress.

7.2 COLLECTION SCHEMES

Improper handling, collection, storage, transportation or disposal of hazardous materials and waste can lead to releases of pollution that can persist in the atmosphere, soil and water. Waste consisting of elemental mercury or waste containing or contaminated with mercury should be treated to recover the mercury or to immobilise it in an environmentally sound manner. Collection and recycling programmes for lamps and luminaires are important because they:

- Promote the recovery of other materials found in end-of-life mercury-added lamps such as glass, ferrous and nonferrous metals and phosphors containing mercury. Some of these materials may be sold to lamp and glass businesses. Reuse of waste glass may offer secondary commercial opportunities in developing countries that decide to implement collection and recycling systems. Mixed glass is used, either directly or after appropriate pre-treatment, for glass products with lower purity requirements, or as an aggregate material in industrial processes;

- May be able to offer waste back to industry for reuse. Efficient CFLs use rare earth oxides in their phosphors. Collection and recycling programmes may be able to offer waste back to industry for reuse. For example, European collection and recycling organisations have been approached by “upcyclers” to supply them with CFL waste;
- Allow for the proper collection of spent LED lamps that contain electronic waste and other components that need to be disposed of in an environmentally sound manner. Having a separate LED waste stream that contains no mercury residues and enhances recovery rate is a possibility.

Raising awareness among consumers about high-quality, low mercury lighting products guides their purchasing decisions. Ensuring good quality lamps in the market and verifying their compliance with maximum mercury limits will minimize health and safety risks. When introducing new lighting-related laws, regulators should ensure adequate compliance with existing health and safety laws.



CASE STUDY: Selecting a Suitable CFL Recovery Solution for the Western Cape, South Africa

The South African e-waste Association conducted a special study to select a suitable CFL recovery solution for the Western Cape among low, medium and high income groups. It discovered that for all income categories groups specially demarcated and suitably safe bins at central locations is an acceptable recovery option for spent CFLs. For most, points of sale or retailers would constitute a central location, but in the low income areas “central” refers to “within walking distance.” Mobile units would, therefore, represent a potentially plausible solution in lower income areas. Similar studies may be necessary to conduct in countries where waste separation and recycling are unfamiliar and not generally practiced concepts.

For more information [click here](#).

7.3 RECYCLING PROGRAMMES

Approaches for the environmentally sound management of spent lamps should be coupled with technologies that capture and securely contain mercury vapour and residues. Further processing to recover mercury and recycle other lamp components is not only manageable but affordable under the appropriate system. Regulators can explore and adopt approaches that encourage the collection and recycling of mercury-added lamps. These approaches should be adapted to national conditions. If effectively designed and managed, they can also create jobs in collection and recycling.

Mercury emissions from spent lamps can be virtually eliminated. This can be achieved by following the Basel Convention Technical Guidelines for the Environmentally Sound Management of Wastes Consisting of Elemental Mercury and Wastes Containing or Contaminated with Mercury. Extended producer responsibility systems where all stakeholders share in the responsibility have proven to be most cost-effective. These systems can be funded in various ways, depending on country conditions and resources.

CASE STUDY: CFL Recycling Scheme, Sri Lanka

Pitipana, a small town 35 km from Sri Lanka’s capital Colombo, is home to South Asia’s first CFL recycling plant, Asia Recycling. The plant is owned by Orange Electric, which has a local market share of 48 percent in CFLs. Operational since 2011, the state-of-the-art plant has the capacity to recycle up to 30 million CFLs annually—nearly three times more than the annual usage in Sri Lanka. The facility has been set up in partnership with Nordic Recycling AB of Sweden. The plant collects CFL waste from institutions such as banks, schools and universities, factories, hospitals and government agencies. Households are encouraged to dispose their CFL waste at designated collection centres such as supermarkets and distribution points. The company also entices consumers with monetary incentive.

For more information [click here](#).

7.4 FINANCING ENVIRONMENTALLY SUSTAINABLE MANAGEMENT

Decision makers address policy questions related to designing collection schemes. These schemes address when, to what extent, and in what manner consumers pay. Regulators should look at the market and decide which stakeholders will support the programme.

Many regulatory initiatives exist to stipulate the collection and recycling of mercury-added lamps and lamps in line with extended producer responsibility norms. They require producers to set up the system that will facilitate the collection and recycling of lighting products.

In a nonregulated system, the costs for collection and recycling are not assigned. To ensure that spent lamps are sustainably collected and recycled, regulations should account for economies of scale, minimizing the costs to the end user. Information to purchasers and transparency of system finance costs on collection and recycling is also essential for the effective development of these systems. Consumers who are aware that a product needs to be recycled will tend to change their behaviour resulting in increased rates of collection.

Principal financing mechanisms include:

- **Full cost internalization**—reflecting individual producer responsibility, this mechanism establishes a direct incentive for competition and design improvement. Costs are passed to the end user, but a company that can reduce its internal costs through process redesign can gain a market advantage;
- **Advance disposal fee systems**—industry manages fees in a so-called “eco-fee.” In this system, a small portion of the purchase price of a product supports an end-of-life management system;
- **Deposit-refund systems**—some countries choose the traditional deposit-refund system, where consumers pay a deposit at the time of purchase. They receive the same amount as a refund when they return the used product to the collection system;
- **Last-owner-pays**—this collective scheme establishes and sets flat fees to be charged to the last owner, the consumer. This last owner is the pays and returns the used lamp at the same time; however, this scheme is avoidable by simply throwing the lamps directly into the municipal waste system;
- **Regional systems**—the establishment of regional systems can be the optimal solution in cases where national-approaches are not financially viable to support recycling of lamps in one single country.

To ensure that spent lamps are sustainably collected and recycled, regulations should account for economies of scale, minimizing the costs to the end user.

7.5 HEALTH

Potential health risks associated with LEDs and products incorporating general illumination LEDs are presented in this section. Many of these risks are not unique to LEDs. They are factors that should be taken into consideration when assessing other lighting products:

- **Photobiological risks**—the interactions of light with the skin and the eye;
- **Glare and flicker**—undesired effects of light on the vision system;
- **Nonvisual effects of light**—for example, disrupting circadian rhythms.

A photobiological safety assessment takes into consideration the risks of blue light hazards. Risk groups are defined in IEC 62471, with additional information given in IEC TR 62471-2 and IEC TR 62778. There is a potential risk of retinal damage when the blue light radiance is too high (it can cause irreparable damage to eyesight at high doses), thus establishing safe thresholds is very important for consumer safety. A photobiological safety assessment can be conducted on LED products using the joint CIE S009 / IEC 62471 standard. Following the guidelines of IEC TR 62778, manufacturers report the risk group of their product according to three classifications, RG0, RG1 and RG2. For SSL products aimed at consumer applications (e.g. retrofit LED lamps), the risk groups could be RG0 or RG1 at 200 mm (the shortest viewing distance encountered at home). Further study is needed to assess impacts on groups of people characterised by an accrued sensitivity to visible light, such as people having pre-existing eye or skin conditions.

When high flux LED components are visible, glare can become a health issue. Glare does not constitute a risk in itself but it is a source of discomfort and temporary visual disability that could be indirectly responsible for accidents and injuries. The maximum luminance of the LED products should be specified so the luminance ratio between the light source and the background can be computed and adapted to each lighting installation.

Flicker is the rapid on-off modulation of light output from a source. Flicker can induce a range of symptoms in the general public, ranging from headaches and dizziness to impaired visual performance and even seizures in patients who suffer from photosensitive epilepsy. Establishing maximum flicker levels would help to protect these sensitive subsets of the population.

Nonvisual effects of light sources should be considered when designing a lighting system. Light can be used to delay or advance the natural circadian clock, with beneficial and undesirable effects that need to be taken into account. This is an issue for all artificial lights, not just LED lighting. The non-visual effects of light depend on the illuminance level, the exposure duration, the timing of the exposure and the light spectrum. Keeping the retinal irradiance as low as possible is a general rule that can be given to minimize the non-visual effects of light. In comparison with the other light technologies, LED technology is not expected to have more direct negative impacts on human health with respect to nonvisual effects.



8. PROGRAMME PREPARATION, DESIGN AND IMPLEMENTATION

In order to support governments in promoting energy efficiency and removing obsolete and energy intensive lighting technologies from their markets, United for Efficiency has developed a step-by-step guide called “Fundamental Policy Guide: Accelerating the Global Adoption of Energy Efficient Products”. This guide offers an overview of the key elements required to transform a national appliance market towards more energy-efficient products through the application of the U4E Integrated policy approach.

The Fundamental Policy Guide is cross-cutting for all United for Efficiency priority products including lighting, residential refrigerators, air conditioners, distribution transformers and electric motors. The approach can also be expanded to other energy consuming products.

By following the approach outlined in the Fundamental Policy Guide, national governments and regional institutions can develop a clear vision and policy goals;

identify specific objectives; and determine the required processes (such as identifying resource requirements and responsibilities and tracking performance to ensure transparency). By establishing a systematic plan, regions and countries ensure that the approach adopted is coherent, and will save time, effort and resources.

While each section of the Fundamental Policy Guide is outlined in detail in the guide, the actual components in the strategy may vary according to each country’s situation and needs. Therefore the guidance should be adapted to meet the local context and needs.

The process should be led by governments or regional institutions with methodological support, guidance and technical advice from United for Efficiency (and/or other) experts. It should involve all relevant stakeholders to jointly determine priorities and the most appropriate pathways to achieve them.

The following is a brief overview of the Fundamental Policy Guide:



Please review the UN Environment report **DEVELOPING A NATIONAL OR REGIONAL EFFICIENT LIGHTING STRATEGY** for more information.

Chapter 1

Introduction – provides an overview of the benefits of energy-efficient products and the U4E Integrated policy approach.

Chapter 2**How to Prepare for Programme**

Implementation – introduces the organising bodies and overarching legislative and legal frameworks that need to be in place to operate an effective programme. It provides guidance on the resources required for implementing a programme and strategies for securing those resources. It also provides information on collecting data and prioritising products for inclusion in a programme.

Chapter 3**How to Design and Implement Market**

Transformation Programmes – provides the basic steps to follow when designing and implementing market transformation policies—including market assessment, barrier analysis, regulations, standards, labels, awareness campaigns, and awards and recognition programmes. It provides case studies of effective implementation in countries across the world and recommendations for developing regional initiatives.

Chapter 4**How to Make Efficient Products Affordable**

– addresses the critical issue of overcoming first-cost barriers to market adoption, including topics such as financing sources, approaches and stakeholders. Topics covered include energy service companies, financing programmes, bulk procurement schemes, and electric utility programmes. This section also describes how countries with subsidised electricity tariffs can use innovative schemes to drive efficiency.

Chapter 5**How to Establish and Improve Compliance**

Programmes – discusses the importance of monitoring, verification, and enforcement (MVE) schemes from both a manufacturer's and a consumer's perspective. It also discusses the critical role of government in establishing and maintaining a robust market surveillance programme.

Chapter 6**Environmentally Sound Management**

– provides a summary of the importance of safe and sustainable recycling and disposal programmes. It also touches on the development of health and safety standards for products, particularly those with toxic or harmful components.

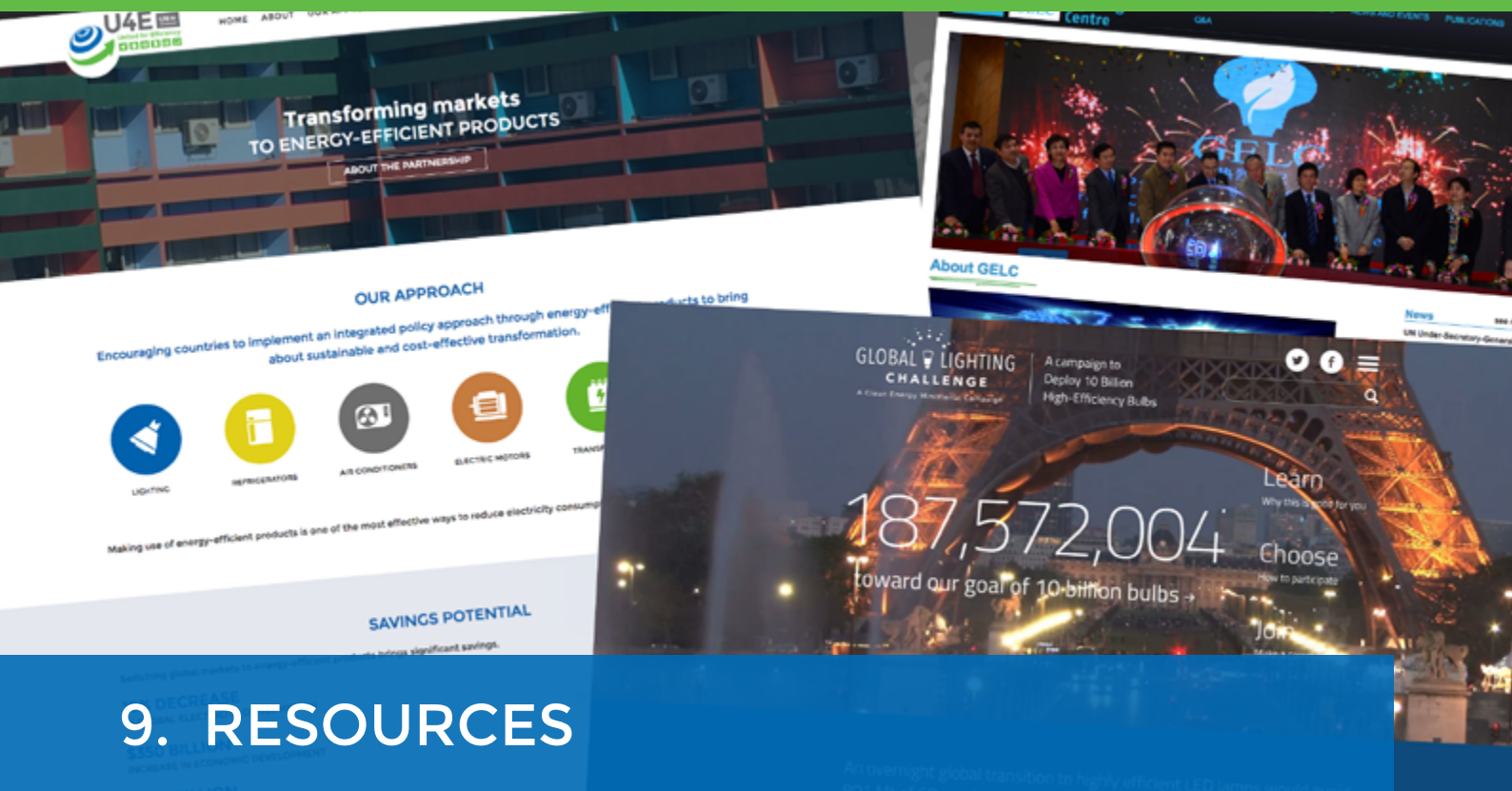
Chapter 7**How to Measure Success and Improve**

Programmes – describes the key components of an evaluation framework to measure the results from market transformation programmes and then use those results to improve programmes.

Chapter 8

Resources – presents reports and resources from energy-efficient appliance, equipment, and lighting programmes and experts around the world.

The Fundamental Policy Guide is cross-cutting for all United for Efficiency priority products including lighting, residential refrigerators, air conditioners, distribution transformers and electric motors.



9. RESOURCES

To support countries and regions in the development of efficient lighting activities and strategies, the U4E offers a wide array of practical tools including:

Publications

- **Achieving the Transition to Energy Efficient Lighting Toolkit**—delivers best practice guidance for policy development and provides technical and practical tools for those directly involved in national phase-out activities. This toolkit is available online in five languages: Arabic, English, French, Russian and Spanish.
- **Guidebook for the Development of a Nationally Appropriate Mitigation Action Strategy on Efficient Lighting**—this guidebook provides step-by-step direction on how to transform a National Efficient Lighting Strategy into a proposal for a Nationally Appropriate Mitigation Action.
- **Developing Minimum Energy Performance Standards for Lighting Products: Guidance Note for Policymakers**—this guidance note focuses on the development and implementation of mandatory regulations (MEPS) for energy-efficient lighting. It aims to be a practical resource for governments on the processes to follow when establishing mandatory requirements in a national market.
- **Developing a National or Regional Efficient Lighting Strategy**—available in English and in Spanish. As discussed in Chapter 9 of this report, this guide offers national governments and regional institutions guidance on how to develop and implement a policy-driven efficient-lighting strategy.
- **Developing Lighting Product Registration Systems: Guidance note**—provides practical guidance and examples to energy-efficiency programme administrators on how to develop, operate and maintain a registration system for lighting products.
- **Efficient Lighting Market Baselines and Assessment: Guidance note**—provides practical guidance to policymakers and energy-efficiency programme administrators on how to determine national baselines, use this data for market monitoring purposes, and how to monitor the market to continuously update the baselines.
- **Enforcing Efficient Lighting Regulations: Guidance note**—presents best practices for enforcing energy efficiency regulations for lighting products. It can be used as a practical resource by policymakers and enforcement bodies when developing or

revising their enforcement regime.

- **Good Practices for Photometric Laboratories: Guidance note**—provides guidance on the operation of photometric laboratories to ensure that testing results are fully supported by evidence of the legitimacy of the measurement values obtained and to give confidence in the accuracy of these results and conformance with test procedures/conditions.
- **Performance Testing of Lighting Products: Guidance Note**—outlines the process for carrying out energy efficiency performance testing for lamps and how to interpret and use the data. It is a practical resource for energy efficiency policymakers and programme administrators.
- **Product Selection and Procurement for Lamp Performance Testing: Guidance note**—provides guidance on the steps required when selecting and procuring residential lamps to undergo performance testing, including defining the product scope, selection methodology, and the procurement and tracking protocol.

Online Tools

- **U4E Country Assessments**—used to analyse the potential benefits gained through the global adoption of efficient lighting, appliances and equipment. The reports provide estimates of potential energy savings, CO₂ reductions

and financial gains. In addition, off-grid lighting reports model a transition from fuel-based lighting to one based on solar-powered light emitting diodes. For all assessments regional results can either be compiled from the assessments of the constituent countries, or, in cases where U4E does not offer an assessment for each country, U4E can work with the region to develop estimates based on best available data.

- **Efficient Lighting Savings Forecasting Model**—this open-source tool is meant to help users model the potential savings that a region or country could realise by a rapid transition to energy-efficient lighting. The spreadsheet forecasts the electrical energy and carbon-dioxide emission savings potential of efficient-lighting regulations relative to a business-as-usual scenario.
- **U4E Prototype Lighting Product Registration System**—this resource provides practical guidance for policymakers on how to design, establish, commission and maintain a robust and reliable registration system for lighting products. It primarily targets countries wishing to establish a product registration system either because they lack a system in any form, they are considering upgrading from a paper-based system to an online registration system, or wish to upgrade an existing online registration system to include more features. A product registration system is an initial compliance gateway wherein

manufacturers and importers register eligible products with the regulatory authority prior to market entry.

- **World Bank e-learning in Energy Efficiency**—the e-learning programme has been developed under the City Energy Efficiency Transformation Initiative (CEETI) managed by the Energy Sector Management Assistance Program (ESMAP) and has benefitted from a collaboration between ESMAP, the World Bank Climate Change Group and the Online Learning Centre. The programme provides a series of learning courses to support city leaders enhance the energy efficiency and sustainability of cities around the world.
- **World Bank: India : Energy-Efficient Street Lighting-Implementation and Financing Solutions**—the objective of this manual is to support the preparation and implementation of street lighting projects in India, using performance contracting and other public private partnership-based delivery approaches. This manual draws upon global best practices, including practices that have been tried and presented within India and South Asia and draws from their failures and successes to document the major lessons learned. The manual provides a brief overall background of energy efficiency in India, the kind of barriers faced in the implementation of energy efficiency projects, and the

kind of prevalent policy environment for EE in the country.

- **World Bank’s “CFL Toolkit” (originally developed with ESMAP support in 2010)**—the objective of this toolkit is to help policy makers develop good-practice operational models and templates or toolkits to help scale up the replication of large-scale, energy-efficient lighting programmes. The overall goal is to review and synthesize the critical operational (design, financing and implementation) elements, including those related to carbon finance and GEF synergies from the experience of the Bank and other organisations, together in a user-friendly web-based format. The project is addressing CFL based programs primarily for the residential and small commercial markets.
- **World Bank: Energy Efficient Household Lighting—The CFL Experience (2013)**—this CFL Experience toolkit guides users through the process of creating a CFL programme. It is designed with two main functions. First, to walk users through the phases of a CFL program, these phases are represented in the CFL Toolkit wheel. Second, to act as a knowledge centre where users can find case studies, technical specifications, templates and links to use in the customisation of their own energy efficient lighting programs.

Expertise and Collaborating Centres

- **U4E Centre of Excellence**—comprised of a large network of manufacturers, international organisation, environmental groups, government officials and academic institutions. U4E offers recommendations, technical guidance and expertise to accelerate the shift to energy efficient lighting, appliances and equipment.
- **UN Environment Collaborating Centre for Energy Efficient Lighting, China**—the Global Efficient Lighting Centre (GELC) offers a wide range of technical services to developing countries including laboratory and establishing systems for lamp quality control.
- **AMBILAMP Academy, Spain**—the AMBILAMP International Academy for the Recycling of Light has been created to provide expertise for establishing environmentally sound management systems for spent lamps in developing and emerging countries.

Other Relevant Resources

- **American Council for an Energy-Efficient Economy (ACEEE)**—ACEEE is a nonprofit, 501(c)(3) organisation, acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviours. Focusing on the US, ACEEE seeks to harness the full potential of energy efficiency to achieve greater economic prosperity, energy security, and environmental protection. ACEEE carries out its mission

by: (1) conducting in-depth technical and policy analyses; (2) advising policymakers and program managers; (3) working collaboratively with businesses, government officials, public interest groups, and other organisations; (4) convening conferences and workshops, primarily for energy efficiency professionals; (5) assisting and encouraging traditional and new media to cover energy efficiency policy and technology issues; and (6) educating consumers and businesses through our reports, books, conference proceedings, press activities, and websites. ACEEE was founded in 1980 by leading researchers in the energy field. Since then it has grown to a staff of about 50. ACEEE focuses on energy policy (federal, state, and local), research (including programs on buildings and equipment, utilities, industry, agriculture, transportation, behaviour, economic analysis, and international initiatives).

- **CLASP**—CLASP improves the environmental and energy performance of the appliances and related systems, lessening their impacts on people and the world around us. CLASP develops and shares practical and transformative policy and market solutions in collaboration with global experts and local stakeholders. It is a nonprofit international organisation promoting for energy efficiency standards and labels (S&L) for appliances, lighting, and equipment. Since 1999, CLASP has worked in over

50 countries on six continents pursuing every aspect of appliance energy efficiency, from helping structure new policies to evaluating existing programs.

- **The Climate Group**—The Climate Group is an award-winning, international non-profit with offices in Greater China, North America, India and Europe. Our goal is to help leaders transition to a prosperous low-carbon economy, driven by the rapid scaleup of clean and renewable energy. We work in partnership with the world's most influential business, state, regional, finance and civil society leaders. For over a decade we have worked to demonstrate the economic and business case for the low-carbon economy and create the political conditions necessary for a strong global framework that addresses climate risks and maximizes climate opportunities. The global climate deal that has been struck at the Paris COP represents a new beginning: the chance to accelerate our low carbon future. They work with governments, businesses and investors to implement the Paris Agreement, holding them to account where appropriate through reporting mechanisms, and ensuring to bend the emissions curve downward to secure a thriving, clean economy for all.
- **European Council for an Energy Efficient Economy (ECEEE)**—the ECEEE is a membership-based nonprofit

association. As Europe's largest and oldest NGO dedicated to energy efficiency, they generate and provide evidence-based knowledge and analysis of policies, and they facilitate co-operation and networking. ECEEE members are found among private and public organisations, as well as among all those professionals from all sectors who share ECEEE's goals. ECEEE offers governments, industry, research institutes and citizen organisations a unique resource of evidence-based knowledge and reliable information. ECEEE promotes the understanding and application of energy efficiency in society and assists its target groups—from policy makers to programme designers to practitioners—with making energy efficiency happen. ECEEE is registered as a Swedish organisation and has its secretariat in Stockholm. ECEEE participates actively in the European policy-making process, the organisation participates in a number of EU policy making and advisory fora, and frequently comments on European energy policy through position papers and responses to public consultations. ECEEE has also held expert workshops and briefings for policy makers. It has co-operated with the European Commission, the Parliament and the EU presidency, to hold expert seminars. These institutions appreciate the competence and integrity offered by ECEEE's network of members.

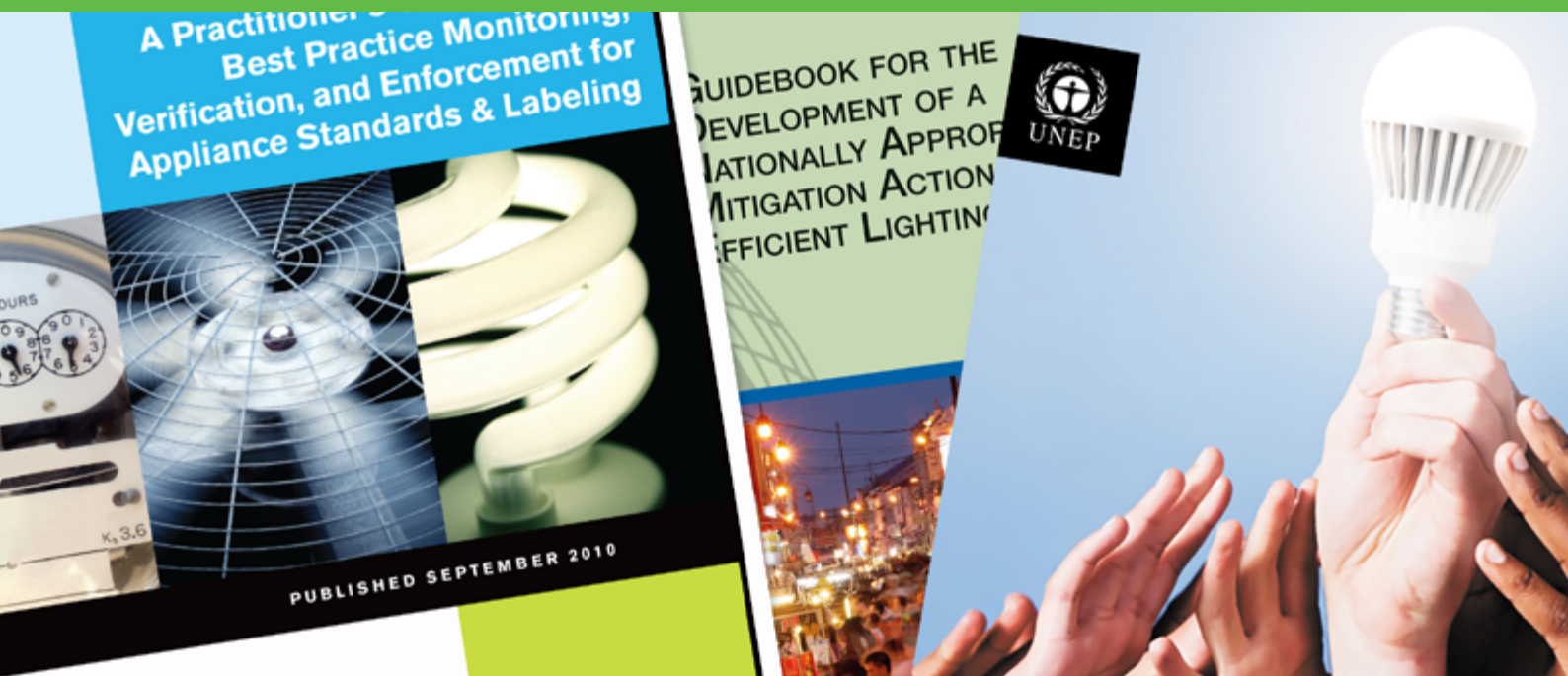
- **Global Lighting Association**—the GLA unites on a global level the leading national and regional industry associations for lighting technology. GLA functions as a forum for exchange and formulation of technical and policy information and is a recognized authority on issues of concern to the global lighting industry. The Global Lighting Association is the voice of the lighting industry on a global basis. The primary mission of the GLA is to share information, within the limits of national and EU competition law, on political, scientific, business, social and environmental issues of relevance to the lighting industry and to develop, implement and publish the position of the global lighting industry to relevant stakeholders in the international sphere.
- **The Global Lighting Challenge**—a Clean Energy Ministerial campaign in the form of an “everybody wins” race to reach the cumulative global sales of 10 billion high-efficiency, high-quality, and affordable advanced lighting products, such as LED lamps, as quickly as possible. By recognizing actions and commitments from businesses, governments and other stakeholders, the Global Lighting Challenge showcases the leaders driving the global transition to efficient lighting. The Challenge has received commitments from over 40 stakeholders including national and subnational governments, lighting manufacturers and

retailers, as well as industry associations and trade groups.

- **International Energy Agency (IEA)**—the IEA is an autonomous organisation that works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA's four main areas of focus are: energy security, economic development, environmental awareness, and engagement worldwide. Founded in response to the 1973/4 oil crisis, the IEA's initial role was to help countries co-ordinate a collective response to major disruptions in oil supply through the release of emergency oil stocks. The IEA has a staff of 260 enthusiastic professionals (energy analysts, modellers, data managers/statisticians, technicians, secretaries and support staff) working together on global energy challenges.
- **IEA 4E SSL Annex**—the SSL Annex was established in 2009 under the framework of the International Energy Agency's Efficient Electrical End-Use Equipment (4E) Implementing Agreement to provide advice to its ten member countries seeking to implement quality assurance programs for SSL lighting. This international collaboration brings together the governments of Australia, China, Denmark, France, Japan, The Netherlands, Republic of Korea, Sweden, UK and US. China works as an expert member of the 4E SSL Annex.
- **International Solid State Lighting Alliance (ISA)**—the ISA is an international not-for-profit NGO, aiming to foster an “eco-system” to promote the sustainable development and innovation/application of SSL worldwide. ISA members consist of major players in the global SSL community, including national or regional SSL associations, leading industry, academic and application entities, which represent 70 per cent of the output of global SSL industry. The ISA Technical Committee on Standardization (TCS) has been established to influence and accelerate the development of regional/global SSL standardization, making recommendations and cooperating with other worldwide standardization organisations. The ISA Board of Advisors consists of three Nobel Prize laureates in Physics and a number of renowned global experts/academics. ISA publishes its annual global SSL report as well as other professional publications, holds five global events every year and makes three annual awards for outstanding contributions.
- **Lites.Asia**—Lites.Asia was established following a meeting in October 2009, when representatives from Australia, China, India, Indonesia, Philippines, Sri Lanka, Thailand, the US and Vietnam met to discuss the potential benefits of regional co-operation on the development of lighting standards. Lites.Asia was founded around a ten-point plan to improve knowledge of standards in force and under development across the region; to increase participation of regional economies in the IEC standards development process to ensure resulting test methods and performance standards are appropriate to the region; and to accelerate the development of national and regional capacity for compliance in standards and labelling processes. Lites.Asia has grown since its inception, to over 700 participants from 30 countries, with delegates actively participating in IEC meetings, sharing knowledge on local standards and labelling electronically and in regional meetings, plus a number of other cooperative actions.
- **Lighting Global**—Lighting Global is the World Bank Group's platform supporting sustainable growth of the international off-grid lighting market as a means of increasing energy access to people not connected to grid electricity. Through Lighting Global, IFC and the World Bank work with the Global Off-Grid Lighting Association (GOGLA), manufacturers, distributors, and other development partners to develop the off-grid lighting market. The Lighting Global program provides market insights, steers development of quality assurance frameworks for modern, off-grid lighting

devices and systems, and promotes sustainability, in partnership with industry.

- **LUMINA project**—An initiative of Lawrence Berkeley National Laboratory, the Lumina project provides analysis and information on off-grid lighting solutions for the developing world. Activities combine laboratory and field-based investigations to help ensure the uptake of products and policies that maximize consumer acceptance and market impact.
- **Super-Efficient Equipment and Appliance Deployment (SEAD) Initiative**—An initiative of the Clean Energy Ministerial, SEAD seeks to engage governments and the private sector to transform the global market for energy efficient equipment and appliances. SEAD initiated an international collaboration of technical and policy experts in solid state lighting, which worked to promote alignment and improvements in the scope and stringency of international standards and labelling programmes. The collaboration participants included Australia, Canada, France, Korea, Mexico, the UK, and the US. Current SEAD member governments include Australia, Brazil, Canada, the European Commission, Germany, India, Indonesia, Korea, Mexico, Russia, Saudi Arabia, South Africa, Sweden, the United Arab Emirates, the UK, and the US, and China maintains an observer status.
- **Zhaga Consortium**—A cooperation between companies from the international lighting industry. They are working to standardise the electrical, thermal and mechanical connections between LED modules and drivers, and other LED lighting components. This work enables interchangeability of LED modules made by different manufacturers into a given fixture. Zhaga has members from over 200 companies internationally.



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ANNEX A. GLOSSARY

Average Life: the average of the individual lives of the lamps subjected to a life test, the lamps being operated under specified conditions and the end of life judged according to specified criteria. (IEC)

Bulb: transparent or translucent gas-tight envelope enclosing the luminous element(s) (IEC)

Conformité Européenne Marking (CE Marking): states that a product is assessed before being placed on the market and meets EU safety, health and environmental protection requirements. Used in European Economic Area ("EEA", consisting of the 28 EU Member States, and the EFTA countries Iceland, Liechtenstein and Norway). Per DECISION No 768/2008/ EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 July 2008 on a common framework for the marketing of products, and repealing Council Decision 93/465/EEC.

Colour Rendering: effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant. (IEC)

Colour Rendering Index (CRI): measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation. (IEC)

Compliance: conforming to a rule, such as a law, policy, specification or standard. Also, fulfilment by countries/businesses/individuals of emission reduction and reporting commitments under the UNFCCC and the Kyoto Protocol. (UNFCCC)

Correlated Colour Temperature (CCT): the temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions. Unit: K (IEC)

Dimmer: a device in the electric circuit for varying the luminous flux from lamps in a lighting installation. (IEC)

Directional Lamp: a lamp having at least 80 per cent light output within a solid angle of π sr (corresponding to a cone with angle of 120°). (EC)

Efficacy: see luminous efficacy

End of Life: when a lamp's usefulness has ended.

Full Procedure Verification Test: a test where all procedures for measurements and records stipulated in the entry conditions for an accreditation scheme have been followed.

Greenhouse Gases (GHGs): The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent but very powerful GHGs are: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). (UNFCCC)

Illuminance (At a Point of a Surface): quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element. (IEC)

Illumination: application of light to a scene, objects or their surroundings so that they may be seen. (IEC)

Incandescent (Electric) Lamp: lamp in which light is produced by means of an element heated to incandescence by the passage of an electric current (IEC)

Interim Life Test: test conducted at a specified point during the rated lifetime of a lamp.

Lamp: source made in order to produce an optical radiation, usually visible. Note: This term is also sometimes used for certain types of luminaires. (IEC)

Lamp Cap (Lamp Base-US): that part of a lamp which provides connection to the electrical supply by means of a lampholder or lamp connector and, in most cases, also serves to retain the lamp in the lampholder. Note 1: The term base is also used in both the UK and the US to denote an integral part of a lamp envelope which has been so shaped that it fulfils the function of a cap. It may engage either a holder or a connector, depending on other design features of the lamp- and holder system. Note 2: The cap of a lamp and its corresponding holder are generally identified by one or more letters followed by a number which indicates approximately the principal dimension (generally the diameter) of the cap in millimetres. (IEC)

Life (of a Lamp): the total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria. Note: Lamp life is usually expressed in hours. (IEC)

Life Test: test in which lamps are operated under specified conditions for a specified time or to the end of life and during which photometric and electrical measurements may be made at specified intervals. (IEC)

Light Emitting Diode (LED): solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current. (IEC)

Lumen (lm): SI unit of luminous flux: Luminous flux emitted in unit solid angle (steradian) by a uniform point source having a luminous intensity of 1 candela. (IEC)

Lumen Depreciation: luminous flux lost at any selected, elapsed operating time, expressed as a percentage of the initial output. Converse of lumen maintenance.

Lumen Maintenance (Luminous Flux Maintenance Factor): ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions. Note: This ratio is generally expressed in per cent. (IEC)

Luminaire: apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply. (IEC)

Luminous Efficacy: quotient of the luminous flux emitted by the power consumed by the source. unit: lm / W; symbol: η_v or Φ_v (IEC)

Luminous Flux: quantity derived from radiant flux Φ_e by evaluating the radiation according to its action upon the CIE standard photometric observer. Unit: lm (IEC)

Luminous Intensity (of a Source, in a Given Direction): quotient of the luminous flux $d\Phi_v$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction, by the element of solid angle

$$I_v = \frac{d\Phi_v}{d\Omega}$$

unit: cd = lm · sr⁻¹. (IEC)

Maximum Mercury Content: maximum amount of mercury added to gas discharge lamps to enable their operation.

Mercury (Hg): a metallic element, the only one that is liquid at room temperature.

Metal Filament Lamp: incandescent lamp whose luminous element is a filament of metal (IEC)

Minimum Energy Performance Standard (MEPS), also Called a Regulations: a mandatory minimum performance level that applies to all lamp products sold in a market, whether imported or manufactured domestically. Note 1. The lamp MEPS can be technology-neutral, or, it can apply to specific technologies. Most often the lamp MEPS includes a requirement relating to luminous output per unit input power demand, but it can also

include other requirements such as lamp lifetime, colour rendering index, and other characteristics. MEPS are minimum requirements, not lamp product design standards, so manufacturers and importers are encouraged to innovate and offer lamps that exceed the MEPS requirements, as a way of differentiating their lamps and adding value for the user.

Omnidirectional Lamp: emits light in all (or near to all) directions.

Peak Energy Demand: period in which electrical power is expected to be provided for a sustained period at a significantly higher than average supply level.

Photometry: measurement of quantities referring to radiation as evaluated according to a given spectral luminous efficiency function, e.g. $V(\lambda)$ or $V'(\lambda)$. (IEC)

Power Factor: under periodic conditions, ratio of the absolute value of the active power P to the apparent power S:

$$\lambda = \frac{|P|}{S}$$

Note: Under sinusoidal conditions, the power factor is the absolute value of the active factor. (IEC)

Power Quality: characteristics of the electric current, voltage and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters. Note: These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power system. (IEC)

Product Life; Lifetime: see rated lifetime radiometry: measurement of the quantities associated with radiant energy. (IEC)

Rated Lifetime: measure of the declared lifetime of a lamp, in operating hours. Generally, the time after which 50 per cent of a specified large number of lamp units cease to operate.

Rated Luminous Flux (of a Type of Lamp): the value of the initial luminous flux of a given type of lamp declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions. Unit: lm. Note 1: The initial luminous flux is the luminous flux of a lamp after a short ageing period, as specified in the relevant lamp standard. Note 2: The rated luminous flux is sometimes marked on the lamp. (IEC)

Rated Power (of a Type of Lamp): the value of the power of a given type of lamp declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions. Unit: W. Note: The rated power is usually marked on the lamp. (IEC)

Rated Voltage or Rated Voltage Range: nominal voltage/range of voltage at which a piece of electrical equipment is designed to operate.

Rating (of a Lamp): the set of rated values and operating conditions of a lamp which serve to characterize and designate it. (IEC)

Rebound Effect: behavioural responses to the introduction of new, more efficient, technologies whereby consumers use the product in question more

frequently or for longer because of its increased efficiency. This results in a reduction in the beneficial effects of the new technology.

Registration Verification: process of confirming that registered products meet the requirements of a programme's entry conditions

Regulations: see minimum energy performance standard.

Relamping: replacement of the removable lamp in a luminaire. May describe replacement of inefficient lamps with more efficient lamps.

Self-ballasted Lamp: a discharge lamp with the ballast integrated into the unit.

Self-certification: practice of submitting information about one's product in a formal statement rather than being obliged to ask a third party to do so.

SI Unit: any of the units adopted for international use under the *Système International d'Unités*.

Special Purpose Lamp: designed for specific applications and not suitable for general illumination.

Spectral Power Distribution: power per unit area per unit wavelength of an illumination (radiant exitance), or more generally, the per-wavelength contribution to any radiometric quantity (radiant energy, radiant flux, radiant intensity, radiance, irradiance, radiant exitance, or radiosity)

Start-up Time: amount of time it takes for a lamp to reach stabilized light output after being switched on.

Tungsten Filament Lamp: incandescent lamp whose luminous element is a filament of tungsten (IEC)

Tungsten Halogen Lamp: gas-filled lamp containing halogens or halogen compounds, the filament being of tungsten (IEC)

ANNEX B. KEY PHENOMENA CONSIDERED IN LIGHTING POLICY MEASURES

Lighting products can be defined by a large number of phenomena that are relevant to end users. When it comes to stimulating the adoption of energy efficient lighting, policy makers should take into consideration critical aspects such as energy efficiency, safety and sustainability. Other phenomena selected and included in policy measures and programmes should be appropriate to the goals and objectives of the government, taking into account effective implementation and enforcement. Complementary policy measures, such as compulsory product performance information at point-of-sale, should be considered for some phenomena.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
ENERGY EFFICIENCY			
LUMINOUS EFFICACY	CIE eILV 17-729 luminous efficacy (of a source) [η_v ; η] : quotient of the luminous flux emitted by the power consumed by the source; Unit: lm/W	The ratio of the total amount of visible light of a lamp (luminous flux) to the electrical power consumed in producing it.	The higher the efficacy value, the more energy efficient the lighting product. This criterion provides information on how well the light source produces visible light—an important indicator for saving energy and money.
LIGHT QUALITY METRICS			
LUMINOUS FLUX	CIE eILV 17-738 luminous flux [Φ_v ; Φ] ; quantity derived from the radiant flux, Φ_e , by evaluating the radiation according to its action upon the CIE standard photometric observer; Unit: lm	Quantifies the total amount of visible light of a lamp.	Luminous flux must be measured in order to determine the efficacy of the product. Luminous flux is also important in evaluating the accuracy of manufacturer/retailer lamp equivalency claims, which assist consumers in making the transition to efficient lighting. The importance of this aspect will diminish over time as products cease to be sold according to claimed equivalencies and consumers begin to select lamps on the basis of light output (lumens) rather than wattage. The accuracy of luminous flux claims is also important because lamp luminous flux (along with lighting design) determines overall illumination levels, which can be important for meeting illumination standards for safety and work conditions.
LAMP LUMEN MAINTENANCE FACTOR	CIE eILV 17-738 luminous flux [Φ_v ; Φ] ; quantity derived from the radiant flux, Φ_e , by evaluating the radiation according to its action upon the CIE standard photometric observer; Unit: lm	Quantifies the total amount of visible light of a lamp.	Luminous flux must be measured in order to determine the efficacy of the product. Luminous flux is also important in evaluating the accuracy of manufacturer/retailer lamp equivalency claims, which assist consumers in making the transition to efficient lighting. The importance of this aspect will diminish over time as products cease to be sold according to claimed equivalencies and consumers begin to select lamps on the basis of light output (lumens) rather than wattage. The accuracy of luminous flux claims is also important because lamp luminous flux (along with lighting design) determines overall illumination levels, which can be important for meeting illumination standards for safety and work conditions.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
LIGHT QUALITY METRICS			
ENDURANCE (SUPPLY SWITCHING TEST)	IEC 62612 Section 11.3.3: At test voltage, the lamp shall be switched on and off for 30 s each. The cycling shall be repeated for a number equal to half the rated life in hours (Example: 10,000 cycles if rated life is 20,000 h.)	The rapid switching on and off of a solid state lighting product to simulate how a product will be used over its lifetime. The test is carried out to stress a solid state lighting product over a short period of time to determine the failure rates of a product.	Can help verify that a lighting product will not fail when used in a typical consumer application (e.g. on for relatively short durations).
LUMINOUS INTENSITY	CIE eILV 17-739 luminous intensity (of a source, in a given direction) $[I_v; I]$; quotient (I_v) of the luminous flux, $d\Phi_v$, leaving the source and propagated in the element of solid angle, $d\Omega$, containing the given direction, by the element of solid angle; Unit: $\text{cd} = \text{lm}\cdot\text{sr}^{-1}$	Quantifies the amount of visible light emitted from a light source in a particular direction from a two dimensional angle.	This is an important criterion to evaluate the performance of directional lamps/products, particularly in terms of the centre beam luminous intensity.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
LIGHT QUALITY METRICS			
(SPATIAL) DISTRIBUTION OF LUMINOUS INTENSITY	CIE eILV 17-1204 (spatial) distribution of luminous intensity (of a source); presentation, by means of curves or tables, of the values of the luminous intensity of the source as a function of direction in space.	The spatial distribution pattern of the measured luminous intensity of a lighting product.	It is of high importance to measure this because many “omnidirectional” products currently being sold, such as LED lamps, only poorly approximate the light distribution of the products they claim to replace.
COLOUR RENDERING INDEX (CRI)	CIE eILV 17-222 colour rendering index [R] ; measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation	A measure of the ability of a light source to reveal the colours of various objects faithfully when compared to a radiant blackbody light source of the same correlated colour temperature) such as an incandescent lamp or sunlight. The highest CRI attainable is 100, with the scale dropping to negative values for some light sources.	Colour rendering is important for consumer satisfaction with a lighting product. Colour is important for specialised tasks where colour is important (such as, food preparation, applying makeup, and painting). Incandescent lighting (including halogen lamps) has a CRI of, or very close to, 100. Note: Other metrics for colour rendering are currently under consideration by the international standards bodies.
CORRELATED COLOUR TEMPERATURE (CCT)	CIE eILV 17-258 correlated colour temperature [T _{cp}]; temperature of the Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a diagram where the (CIE 1931 standard observer based) u', $\frac{2}{3}v'$ coordinates of the Planckian locus and the test stimulus are depicted; Unit: K	A measure of the colour “shade” of white light emitted by a lamp, relating to the colour of light emitted by an ideal blackbody radiator when heated to a particular temperature, measured in Kelvin. Spectrally, “warm” shades contain more yellowish/red light content and are at lower Kelvin (2,700 -3,500 K), while “cool” shades contain more blue (5,000+ K) to create their overall white “colour” appearance.	Important for consumer information—allowing the selection of the appropriate product depending on light colour preference and matching of light colour across different manufacturer lighting products. The accuracy of the colour temperature claim is therefore important and some mandatory regulations may specify a maximum tolerance for colour temperature.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
OPERATION			
STARTING TIME	IEC 60969: Time needed, after the supply voltage is switched on, for the lamp to start fully and remain alight. Note: There is a time delay in the starting device between the time when power is applied to this device and the time when power is applied to the lamp electrodes. The starting time is measured from the latter moment.	The time it takes for a lamp to start when switched on.	Short start times are important for consumer acceptance. Short start times are necessary for emergency situations and general safety. They are preferable in tasks where the light will only be on briefly (i.e. pantries, toilets and for outdoor security).
RUN-UP TIME	IEC 60969 : The time needed for the lamp after start-up to emit a defined proportion of its stabilised luminous flux. Note: For CFLs the IEC defined proportion is 60 per cent; for amalgam lamps it is 80 per cent.	The time it takes for a lamp to reach maximum brightness when switched on.	Important for the same reasons as start time. Market testing has found a wide variation in run-up times for CFLs and some regulations may specify a maximum acceptable start- or run-up time.
LAMP LIFE	CIE eILV 17-656 life (of a lamp); total time for which a lamp has been operated before it becomes useless or is considered to be so according to specified criteria	The total time (in hours) for which a lamp operates before it becomes useless. Typically, this involves failure to start or to operate continuously or to generate a sufficient amount of light. Note: For a lamp model (i.e. not a single lamp), the rated (declared) product life is typically, the time after which 50 per cent of a specified number of lamp units, of that model, become useless.	Important for consumer information—providing information on how long it will typically take a lighting product to fail. Longer life times can help the consumer to save money.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
ELECTRICAL PARAMETERS			
POWER FACTOR	IEC 60969: Ratio of the measured active input power to the product of the supply voltage (rms) and the supply current (rms).	<p>The ratio of the power that a lamp consumes to the volt-ampere product of the supplied power.</p> <p>This (total) power factor is more recently being discussed in terms of its primary metrics—fundamental power factor (also called displacement power factor) and nonfundamental power factor (also called distortion power factor).</p> <p>These primary metrics are more sophisticated than the composite metric power factor.</p>	<p>This is of importance to electricity distributors and generators in some countries as it may mean they must generate more than the minimum amperes necessary to supply the real power, which increases generation and transmission infrastructure capacity requirement and costs and increases power line losses. The level of importance in part depends upon the nature (transmission distance and existing capacity) of the generation network.</p> <p>Additionally, the distortion of the mains current can affect the quality of the electrical utility's grid. This is particularly important where power line control signals are used.</p>
FUNDAMENTAL POWER FACTOR	IEC 61000-1-7: Clause 6.5.2. ³⁵	<p>The fundamental power factor is sometimes called displacement factor or displacement power factor.</p> <p>It quantifies the displacement (phase-shift) between the fundamental current and voltage waveforms by calculating the cosine of the phase-shift angle.</p> <p>Fundamental power factor is a more detailed measure to quantify the displacement of the current and its effect on the power supply network.</p>	Same as power factor.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
ELECTRICAL PARAMETERS			
NON-FUNDAMENTAL POWER FACTOR	IEC 61000-1-7: Clause 6.5.3	<p>The nonfundamental power factor is sometimes called distortion factor or distortion power factor.</p> <p>It quantifies the distortion of the current.</p> <p>Furthermore, the nonfundamental power factor is proportional to the Total Harmonic Distortion (THD) of the mains current and consequently to the individual harmonic components.</p> <p>The individual harmonic components are the preferred measures to quantify the distortion of the mains current and its effect on the power supply network.</p>	Same as power factor.
TOTAL HARMONIC DISTORTION (THD)	<p>IEV 551-20-13: Ratio of the r.m.s. value of the harmonic content to the r.m.s. value of the fundamental component or the reference fundamental component of an alternating quantity.</p> <p>Note: The harmonic content is the sum of the harmonic components of a periodic quantity [IEV 551-20-12]</p>	<p>THD is proportional to the nonfundamental power factor (see IEC 61000-1-7 clause 6.5.3).</p> <p>Furthermore, the THD is proportional to the individual harmonic components.</p> <p>The individual harmonic components are a more detailed measure to quantify the distortion of the mains current and its effect on the power supply network.</p>	Same relevance as nonfundamental power factor.

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
ELECTRICAL PARAMETERS			
HARMONIC COMPONENT	IEV 551-20-07: sinusoidal component of a periodic quantity having a harmonic frequency.	The individual harmonic components are the more detailed measures to quantify the distortion of the mains current and its effect on the power supply network.	Same as nonfundamental power factor. The international limits for the harmonic components are given in IEC 61000-3-2:2014. ³⁶
DIMMER COMPATIBILITY	None	An evaluation of whether a retro-fitted ballast-driven lamp (fluorescent) or circuit-driven lamp (LED) will operate sufficiently well with existing installed dimmers used for incandescent light sources.	<p>Dimmer compatibility is of high importance for the consumer as many solid state lighting products are often not completely compatible with commonly available dimmers (resulting in noticeable flicker, slow oscillation in light output or failure to operate).</p> <p>The wide variety of dimmers and controls installed in housing stock in some markets makes it difficult for a manufacturer to claim 100 per cent compatibility.</p> <p>Some regulations or labelling programmes may require product marking regarding dimmer compatibility.</p>

PHENOMENA	OFFICIAL DEFINITION (INTERNATIONAL STANDARD)	SIMPLIFIED DEFINITION	RELEVANCE
HEALTH AND SAFETY ISSUE PARAMETERS			
SAFETY REQUIREMENTS AND MARKS	None	An indication that a product meets electrical safety and marking requirements in an economy.	All products must meet all safety regulations of the country or region in which it is sold and used, while marking requirements give consumers assurance that the product meets these regulations.
PHOTOBIOLOGICAL HAZARD CLASS (UV AND BLUE LIGHT)	IEC 62471 : Ultraviolet (UV) and blue light hazard (BLH) risk group classes as defined in CIE S009/IEC 62471 specify the limits of optical radiation emitted by a lighting product in range of 100-400 nm and 400-500 nm spectrums, respectively.	A definition of a classification system for the possible health risks related to short-wavelength light emitted by the lamp.	Photobiological hazard classification is important for consumer safety. UV and blue light can cause irreparable damage to eyesight. Some human health conditions also result in high sensitivity from skin exposure to these wavelengths. Some regulations may require that products be evaluated to determine their appropriate photobiological hazard class and/or specify UV emission levels.
MERCURY CONTENT	None	The small amount of mercury that is integral to the operation of discharge lamps such as compact and linear fluorescent lamps.	As mercury is a hazardous substance, requirements exist (For example, IEC 60969) which requires that lamps do not contain more than a designated amount. This will minimise exposure to mercury in the event that a lamp tube is broken
FLICKER	IEV 845-02-49: Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.	A relatively low frequency (below approximately 100 Hz) variation in brightness and/or colour of a lighting product that is directly perceived as unacceptable by an average observer.	Minimal flicker is important for consumer satisfaction and resultant acceptance of different technology lamp products. Certain human health conditions are characterized by severe reactions to light sources that flicker at certain frequencies, with effects ranging from headaches to extreme seizures.
STROBOSCOPIC EFFECT	For both “stroboscopic effect” and the ‘stroboscopic visibility measure’ (SVM), no official definitions exist. The following definition is currently proposed in CIE: Change in motion perception induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for a static observer in a non-static environment.	A “stroboscopic effect” is an effect that is visible for an average observer when relatively high frequency variation in brightness and/or colour of a lighting product is illuminating a moving or rotating object. The effect occurs when the rate of rotation or movement is close to the frequency of the light ripple. It may appear that a rotating object is standstill or a “wagon-wheel effect” can be perceived.	For installations where lighting is placed near or illuminating working machinery or equipment, such as a manufacturing line, this effect could cause a hazard if it were to make a moving machinery or a production line appear to be still or slowly moving. Also in sport stadiums or sports courts “stroboscopic effect” may lead to unwanted effect.

FOOTNOTES

- ¹ MEPS is an abbreviation for “Minimum Energy Performance Standard”; however, in lighting the regulations often apply to more than energy consumption. They may also relate to other performance aspects such as lifetime, light quality and product durability.
- ² UN Environment has developed a step-by-step guide called “Developing a National or Regional Efficient Lighting Strategy,” which is available in both English and in Spanish.
- ³ Efficacy, or luminous efficacy, is a measure of the efficiency at which a lighting technology is able to convert electricity into visible light. It is the quotient of the luminous flux (i.e. lumens) divided by the power consumption (i.e. watts). The higher the ratio lumen per watt, the more efficient the light source at producing light from a given amount of power.
- ⁴ en.lighten (2015). Global Policy Map. This percentage includes two groups of countries: (a) countries that have not initiated a phase out of incandescent light bulbs, 26 per cent, and (b) countries that have not reported any information to UN Environment, 22 per cent.
- ⁵ www.sustainableenergyforall.org
- ⁶ Assuming 2,500 \$/kW and a 500MW power plant operating at 0.50 availability, yields 2.19 TWh/yr
- ⁷ Assumes 2,000 kWh/yr/newly electrified household
- ⁸ Assuming an average global emissions factor of 0.512 Mt CO₂ per TWh of electricity production
- ⁹ International Energy Agency(2014) Key World Energy Statistics. Total electricity consumption was 4694 TWh (2012) in China
- ¹⁰ Ibid. In 2012, the US emissions were 5,074 Mt CO₂.
- ¹¹ Basel Convention: Protocol on Liability and Compensation for Damage Resulting from Transboundary Movement of Hazardous Wastes and their Disposal, UN Environment, 1989.
- ¹² In February 2009, the UN Environment Governing Council adopted Decision 25/5 on the development of a global legally binding instrument on mercury. This process was completed in January 2013. Details on the Minamata Convention can be found at: www.UNEnvironment.org/hazardous-substances/MinamataConvention/tabid/106191/Default.aspx
- ¹³ Solid State Lighting R&D Plan, US Department of Energy (June 2016); energy.gov/eere/ssl/downloads/solid-state-lighting-2016-rd-plan-binding-instrument-on-mercury. This process was completed in January 2013.
- ¹⁴ Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, US Department of Energy (September 2016) energy.gov/eere/ssl/ssl-forecast-report
- ¹⁵ Memoori research, 2014. www.allledlighting.com/author.asp?section_id=3271
- ¹⁶ “Light for Life: Identifying and Reducing the Health and Safety Impacts of Fuel-Based Lighting”, by Evan Mills, LBNL. UN Environment en.lighten initiative, 2014. <http://evanmills.lbl.gov/pubs/pdf/light-for-life-2014.pdf>
- ¹⁷ “Light and Livelihood: A Bright Outlook for Employment in the Transition from Fuel-Based Lighting to Electrical Alternatives”, by Evan Mills, LBNL. UN Environment en.lighten initiative, 2014. www.enlighten-initiative.org/portals/0/documents/Resources/publications/Light%20and%20Livelihood%20-%20A%20Bright%20Outlook%20for%20Employment.pdf
- ¹⁸ For information on Lighting Global’s Quality Assurance programme, see: www.lightingglobal.org/lighting-global-quality-assurance-roadmap/
- ¹⁹ IEC International Standards are consensus-based and represent the work of key stakeholders from every nation participating in their work. The IEC involves developing and newly industrializing countries through its Affiliate Country Program which offers IEC participation without the financial burden of actual membership, making full use of IEC resources. Harmonising around IEC standards helps promote trade in these new markets, as participants adopt its conformity assessment systems IECEE CB-scheme. This helps governments by offering assurance that products offered will operate safely and efficiently.
- ²⁰ “Developing Minimum Energy Performance Standards for Lighting Products, Guidance Note for Policymakers” published by UN Environment en.lighten, June 2015 PDF copy: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Developing_MEPS_for_Lighting_Products_web_14-07-15.pdf

- ²¹ The Basel Convention and many national laws establish strict guidelines for the movement of hazardous wastes to other countries, but exceptions can be made if certain conditions are met by the proposed programme. A country or group of countries planning to collaborate in the establishment of a regional recycling programme should consult with the Basel Convention Secretariat and its Regional Centres to obtain information and guidance.
- ²² For more information, please see: superefficient.org/Global-Efficiency-Medal.aspx
- ²³ Financing large-scale elements such as end-of-life recovery and recycling of used lamps could also be sourced internally, through extended producer responsibility (EPR) approaches or other means.
- ²⁴ Source: www.nrdc.org/sites/default/files/on-bill-financing-IB.pdf
- ²⁵ Efficient Lighting Market Baselines and Assessment, Guidance Note, UN Environment, February 2016. PDF: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Efficient_lighting_market_baselines_and_assessment_February%202016.pdf
- ²⁶ Developing Lighting Product Registration Systems, Guidance Note, UN Environment, February 2016. PDF: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Developing_lighting_product%20registration_systems_February%202016.pdf
- ²⁷ Good Practices for Photometric Laboratories, Guidance Note, UN Environment, February 2016. PDF: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Good_practices_for_photometric_laboratories_February%202016.pdf
- ²⁸ The use of existing lab capacities that are recognised according to the IECEE scheme ensures a defined level of quality and accuracy and allows for international acceptance of test results. IECEE, the IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components, is a multilateral certification system based on IEC International Standards. Its members use the principle of mutual recognition (reciprocal acceptance) of test results to obtain certification or approval at national levels around the world. For more information: www.iecee.org/index.htm
- ²⁹ Product Selection and Procurement for Lamp Performance Testing, Guidance Note, UN Environment, February 2016. PDF: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Product_Selection_and_Procurement_February_2016.pdf
- ³⁰ Performance Testing of Lighting Products, Guidance Note, UN Environment, February 2016. PDF: www.enlighten-initiative.org/portals/0/documents/Resources/publications/Performance_testing_of_lighting_products_February%202016.pdf
- ³¹ Enforcing Efficient Lighting Regulations, Guidance Note, UN Environment, February 2016. PDF: http://www.enlighten-initiative.org/portals/0/documents/Resources/publications/Enforcing_Efficient_Lighting_Regulations_February_2016.pdf
- ³² As an example, the US Department of Energy published "Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part 2: LED Manufacturing and Performance" in June 2012. apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_led_lca-pt2.pdf
- ³³ For more details please refer to Section 5, Safeguarding the Environment and Health, of the UN Environment -GEF [en.lighten initiative](http://en.lighteninitiative.org) toolkit, Achieving the Transition to Energy Efficient Lighting.

PHOTO CREDITS

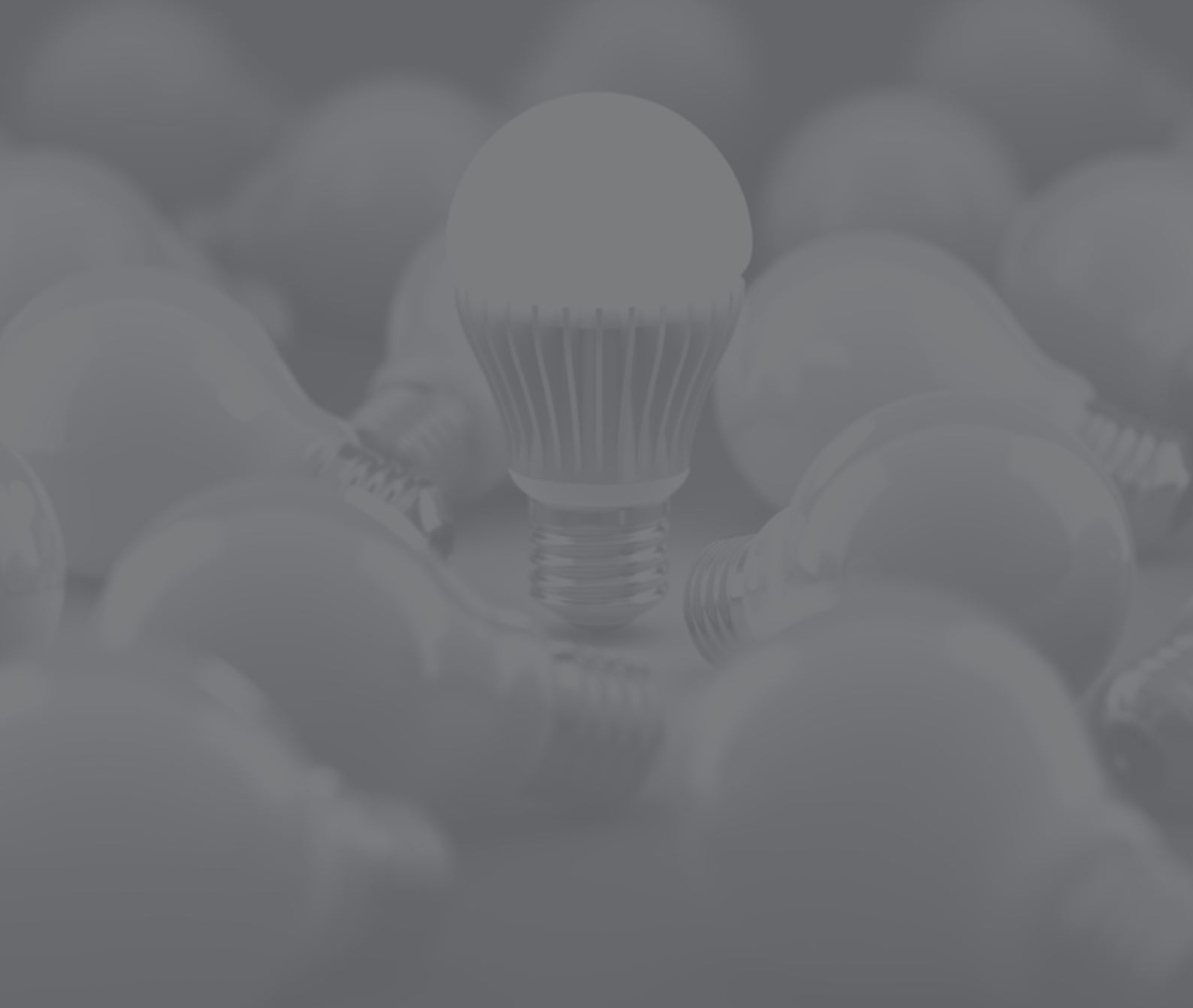
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