Overview of the On-Grid and Off-Grid Lighting Markets in East and Southern Africa

Final Report

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Authors

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Project Context

This market assessment is part of a regional study considering the potential for establishing national and regional market transformation policies and programmes to promote energy-efficient lighting in Eastern and Southern Africa. This work is being led by the United Nations Industrial Development Organisation (UNIDO), in cooperation with institutions of the East African Community (EAC), the Southern African Development Community (SADC) and its four key partner organisations: (1) SACREEE, the SADC Centre for Renewable Energy and Energy Efficiency (www.sacreee.org), (2) EACREEE, the East African Centre of Excellence for Renewable Energy and Energy Efficiency (www.eacreee.org), (3) SADCSTAN, the SADC Organisation for Standardisation and (4) EASC, the East African Standards Committee.

This report is part of the inception and preparatory phase of a larger project called "Energy Efficient Lighting and Appliances in EAC and SADC" (EELA). The project is funded by the Swedish International Development Cooperation Agency (Sida) with in-kind contributions from UNIDO, SACREEE and EACREEE. The EELA project seeks to promote a market transformation for energy efficient lighting and appliances in the EAC and SADC regions. More specifically, the project aims to create market and institutional conditions to enable a transformation of the sector to stimulate increased diffusion of efficient lighting products and appliances across all sectors. The EELA project will bring regional support to private sector-led activities that will lead to increased use of energy efficient high quality lighting and appliances through regional regulatory and trade harmonization interventions; while also considering inclusiveness of all project activities to assure socially sustainable project outcomes. Ultimately, the EELA project will increase access to modern energy services across various sectors and promote private sector involvement.

The inception and preparatory phase of EELA (EELA-PREP) ran from 1 October 2018 to 11 February 2019, developing baseline studies, the theory of change for the project, stakeholder consultations, implementation arrangements and partnerships. The lighting market research was summarised in this report and presented at a validation workshop in Tanzania on 11-13 February 2019. The main technical partners during the EELA-PREP were CLASP (www.clasp.ngo), the Swedish Energy Agency (http://www.energimyndigheten.se/en/) and the Swedish Standard Institute (https://www.sis.se/en/).

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Acronyms and Abbreviations

ADER	Agency for Rural Electrification Development (Madagascar)
BGFA	Beyond the Grid Fund for Africa
BNM	Bureau des Normes de Madagascar
BWP	Botswana Pula
CAGR	Combined Annual Growth Rate
CCT	Correlated Colour Temperature
CEO	Chief Executive Officer
CFL	Compact Fluorescent Lamp
CFLni	Compact Fluorescent Lamp not integrally ballasted
CIE	Commission Internationale de l'Eclairage
CO2	Carbon Dioxide
CRI	Colour Rendering Index
CTCN	Climate Technology Centre and Network
DGE	Direction Générale de l'Energie (Madagascar)
DoE	Department of Energy (South Africa)
DSM	Demand Side Management
EAC	East African Community
EACREEE	East African Centre of Excellence for Renewable Energy and Efficiency
ECB	Electricity Control Board (Namibia)
EEAU	Energy Efficiency Association of Uganda
EEI	Energy Efficiency Index
EELA	Energy Efficient Lighting and Appliances
EESL	Energy Efficiency Services Limited (India)
ERA	Electricity Regulatory Authority (Uganda)
ERB	Energy Regulation Board (Zambia)
ESCO	Energy Service Company

GDP	Gross Domestic Product
GLS	General Lighting Service
GOGLA	Global Off-Grid Lighting Association
GWh	Gigawatt Hours
HID	High Intensity Discharge
HVAC	Heating, Ventilation and Air Conditioning
IAP	Innovations Against Poverty
IC	Interlaboratory Comparison
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineering (USA)
IES	Illuminating Engineering Society (North America)
ISO	International Standards Organisation
JIRAMA	Jiro sy Rano Malagasy (Madagascar)
kWh	kilowatt-hours
LED	Light Emitting Diode
LFL	Linear Fluorescent Lamp
LPG	Liquefied Petroleum Gas
MBI	Market Based Initiative
MEH	Ministry of Energy and Hydrocarbons (Madagascar)
MEMD	Ministry of Energy and Mineral Development (Uganda)
MEPD	Ministry of Energy and Power Development (Zimbabwe)
MEPS	Minimum Energy Performance Standard
MEWD	Ministry of Energy and Water Development (Zambia)
MGA	Malagasy Ariary
MME	Ministry of Mines and Energy (Namibia)
MUR	Mauritian Rupee
MVE	Monitoring, Verification and Enforcement
MW	Megawatt
MZM	Mozambique Metical
NAD	Namibian Dollar
NDC	Namibian Development Corporation
NEI	Namibia Energy Institute
NERSA	National Energy Regulator of South Africa
NIST	National Institute of Standards and Technology (USA)
NRCS	National Regulator for Compulsory Specifications (South Africa)
NSC	Namibian Standards Council
NSI	Namibian Standards Institution
ORE	Office de Regulation de l'Electricité (Madagascar)
PF	Power Factor
PPP	Public-Private Partnerships
PT	Proficiency Test
REA	Rural Electrification Agency (Uganda also Zimbabwe)
REA	Rural Electrification Authority (Zambia)
REF	Rural Electrification Fund (Zimbabwe)
REMP	Rural Electrification Master Plan (Zambia)
RoHS	Regulation of Hazardous Substances (Europe)
S&L	Standards and Labelling
SABS	South African Bureau of Standards
SACREEE	Southern African Development Community (SADC) Centre for Renewable Energy and Energy Efficiency
SADC	Southern African Development Community
SANEDI	South African National Energy Development Institute
SAZ	Standards Association of Zimbabwe
SCR	Seychelles Rupee
SEC	Seychelles Energy Commission

SIAZ	Solar Industry Association of Zambia
SIDA	Swedish International Development Cooperation Agency
SRF	Solar Revolving Fund
SSL	Solid State Lighting
SSNBS	South Sudan National Bureau of Standards
SSP	South Sudanese Pound
SZL	Swazi Iilangeni
THD	Total Harmonic Distortion
U4E	United for Efficiency (UNEP/UNE)
UAE	United Arab Emirates
UEDCL	Uganda Electricity Distribution Company Limited
UEGCL	Uganda Electricity Generation Company Limited
UETCL	Uganda Electricity Transmission Company Limited
UGX	Ugandan Shilling
UNBS	Uganda National Bureau of Standards
UNCDF	United Nations Capital Development Fund
UNEP	United Nations Environment Programme (also UNE – United Nations Environment)
UNIDO	United Nations Industrial Development Organization
US	United States
USD	United States Dollar ($)
USEA	Uganda Solar Energy Association
VAT	Value Added Tax
WWF	World Wildlife Fund
ZABS	Zambian Bureau of Standards
ZAR	South African Rand
ZEMA	Zambia Environmental Management Agency
ZERA	Zimbabwe Electricity Regulatory Authority
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambian Electricity Supply Company
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZMW	Zambian Kwacha
ZPC	Zimbabwe Power Company

1 Executive Summary

1.1 Policy and Standards Context

Across the region of Eastern and Southern Africa there are 450 million people living of which approximately two-thirds are off-grid and one-third is on-grid.[1] While the off-grid population sizes vary from country to country it represents the majority of the market and any policy measures and programmes suggested for the region will need to take into account both on-grid and off-grid products.

The policy context of the region is receptive to demand-side management interventions and other sustainable energy solutions. Looking across the region, all six of the focal countries had energy policies in place and several were also developing or had recently adopted energy policies that emphasised renewable energy and energy-efficiency. The country governments looked at the provision of energy services to rural off-grid areas, and discussed the importance of delivering those services to those people. Government programmes, both for electrification/grid-extension and off-grid provision of mini-grids, solar home systems and pico-solar products, are driving markets, creating opportunities for small businesses and delivering sustainable energy services across the region.

Lighting energy-efficiency measures have also been adopted by several countries. Some governments in the region have adopted policies to phase out incandescent lighting and halogen lighting through a technology ban, only allowing compact fluorescent lamps and light emitting diode (LED) lamps to be sold. But the quality of both products is very poor (in particular concerning the product lifetime, which can be as little as a few weeks), so consumers are complaining. However, challenges remain because countries lack test capacity or are only focused on certain performance characteristics. Furthermore, if the government applies pre-market enforcement at the borders, that can take a long time; meanwhile products (including incandescent lamps) are brought into the market, as the enforcement of these regulations is a challenge due to ‘capacity constraints’ both in terms of people and test equipment.

Some governments waive import duties on energy-efficient light sources to encourage importation of more energy-efficient lighting and luminaires, but paradoxically this carries the risk of adversely affecting the development or sustainability of domestic luminaire assembly because they would have to pay normal import duties on imported parts. That said, some countries provide incentives including tax holidays to help local manufacturing and assembly to allow locally manufactured products to be more competitive.

There is growing market interest in LED products, but they are new to the market and thus some governments lack safety standards for these lamps and luminaires. Safety standards must be identified and recommended for the lighting markets in the context of this project, to ensure governments are aware of them and can put them in place if they choose to protect their markets. In some countries who do not yet have safety standards for these products, some suppliers voluntary comply with the standards of a nearby markets and use that compliance as a differentiator in the market. An example of this would be the use of the South African Bureau of Standards (SABS) in another SADC country.

1.2 Economic Context

The trend within the economies of the region is generally positive, with economic reforms, investment and development progressing on an on-going basis. Overall, the economies of the region have experienced a combined annual growth rate of 7.5% between 2000 and 2015. While there have been some periods of low or negative growth, and some specific issues relating to individual countries, the region as a whole is growing. Figure 6 presents the GDP of all 21 countries is presented in billions of current US dollars

[1] The total population of the region is approximately 446.3 million people, of which 36% are connected to the grid (162.3 million) and 64% are not connected to the grid (284.0 million). Sources for these estimates are the IEA, 2017 for electrification and the World Bank, 2018 for population.

(World Bank, 2018). The data show that the cumulative GDP for EAC and SADC was US$234.9 billion in 2000 and grew to US$803.4 billion in 2017 – with about US$100 billion in growth between 2016 to 2017.

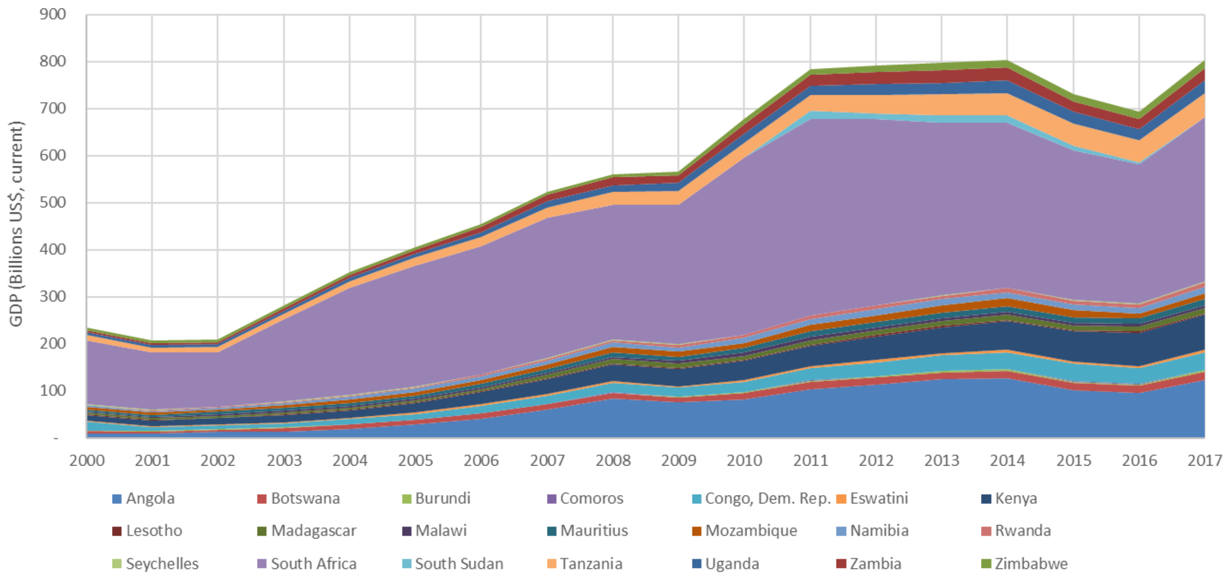


Figure 1. GDP of the 21 Countries from 2000 to 2017 (billions US$, current)

This rate of GDP growth is indicative of healthy economic activity; however it can also be difficult for governments to sustain. If, for example, the countries are experiencing power shortages, then they are not as attractive to investors because projects must also carry the cost of back-up generation. In countries which are experiencing a short-fall in supply, demand side management energy-efficiency measures can offer a fast-track solution to supply constraints, by reducing peak demand and thus improving overall reliability overall. For example, in Namibia, the national electric utility implemented a programme to promote efficient lighting by giving away several hundred thousand lamps. Their teams visited people's homes and replaced the lamps in the high use sockets, six lamps per home, and over the course of the project are expected to achieve 10MW of peak power savings.

Financing mechanisms to support and promote investment in sustainable energy are used in the region to introduce new technologies and to encourage further penetration. Some financing programmes have been initiated to help support investment into energy-efficiency and renewable-energy projects.

1.3 Market and Technology Context

All of the major light source technologies are used in the region – including tungsten filament (both incandescent and halogen), fluorescent (both full-size linear fluorescent and compact fluorescent), high-intensity discharge lamps (all types) and light emitting diode lamps and luminaires. For the most part however, virtually all the lighting products on the market are imports. There was an incandescent factory in Madagascar and a CFL manufacturing facility in Lesotho, but they were both closed a few years ago rather than converting to LED lamp production. There is some local assembly of luminaires (i.e., "fixtures"), which source parts from overseas and do final assembly in-country.

LED lighting technology is widely available across the region, in both the on-grid and off-grid (and rural) areas. LED lamps have experienced a very rapid reduction in cost, driven in part by global trends in LED products as well as local promotional programmes such as (e.g., NamPower's 1 million LED lamp trade-in scheme in Namibia and ZESCO's 3 million LED lamp installation programme in Zambia). Most of the new lighting systems being installed today in newly constructed buildings and refurbished office spaces are installing new LED lighting systems. The above notwithstanding, some countries are still giving away compact fluorescent lamps, e.g., South Africa still has several million CFLs they will be distributing in the coming year. The problem with CFLs is the fact that there is no separate recovery of compact fluorescent lamps, thus the mercury contained in those lamps is likely to end up in municipal land-fills with the concomitant contamination of soil and water.

Governments have put policies and programmes in place to try and support the promotion of more energy-efficient lighting in the region. The table below summarises the current policies in the six focus countries as well as those who responded to the written interview guides.

Table 1. Policies Supporting a Transition to Energy-Efficient Lighting

Country	Policies
Kenya	• MEPS on compact fluorescent lamps, fluorescent lamps and lamp ballasts • Energy labelling (comparative) on non-directional lamps
Madagascar	• Renewable energy products are VAT-free • Draft of regulation banning incandescent lighting expected June 2019. • Draft of national energy-efficiency policy
Namibia	• Draft of national energy-efficiency policy
Seychelles	• VAT Act of 2010 allows energy efficient products can be VAT exempted. • A labelling program is at the initial stages, all products are imported. • An energy efficiency policy is being proposed to support the initiatives.
South Africa	• Adopted a compulsory specification banning incandescent lighting in 2014, took effect in 2015 • Energy labelling (comparative) for non-directional household lamps
Uganda	• MEPS for CFLs: FDUS 902:2011 - Self-ballasted lamps for General Lighting Services (GLS) — Performance requirements • MEPS for LFLs: FDUS 903-1:2011, Double-capped fluorescent lamps-performance specifications — Part 1: Minimum Energy Performance Standard (MEPS) • MEPS for Ballasts: US 904-1:2011, Performance of electrical lighting equipment-ballasts for fluorescent lamps — Part 1: Energy labelling and Minimum Energy Performance Standards requirements • Energy Efficiency and Conservation Bill has been drafted to enforce the efficient use of energy, including MEPS for lighting
Zambia	• Adopted a law banning incandescent lighting, Statutory Instrument No. 74 of 2016
Zimbabwe	• Banned inefficient lighting products and required labelling of lighting products, Statutory Instrument 21 of 2016 and SI 2008 of 2018.

Several experts interviewed highlighted the fact that the quality of products being sold is a major concern – including for example shorter than expected lifetimes. If problems like these are not addressed, there is a risk of market spoilage, whereby a technology is associated with poor quality due to the many low quality models sold into a given market. It should also be noted that some products are being made available on the market advertising that they incorporate power surge protection, however there is no IEC test standard to verify this declaration.

In response to questions about who chooses the lighting technology used in the home, respondents indicated that in general women choose the luminaire (fixture) for the home, but the light source inside is not seen to be as critical as long as it fits / works, it tends to simply be the person who is going out and/or who has the money.

1.4 Recommended Intervention Actions

Based on the findings of the market assessment in this region, the following intervention actions are recommended for consideration by the governments and regional experts. Interventions 1 through 3 are considered foundational, that all countries should undertake if they have not already, thereby ensuring a consistent, level playing field across the region. Interventions 4 through 7 are designed to be no-regrets market-pull initiatives, which will incentivise or facilitate a transition to more energy-efficient products. These market-pull interventions are not mandatory, but they open markets, lower cost barriers and generally raise awareness in the supply chain of more efficient technologies and products. Interventions 8 and 9 are market push approaches, which apply regulatory pressure and requirements to national markets. Intervention 8 would ideally be a harmonised regulatory measure, and it is recommended that governments start with a domestic lighting regulation (Bångens, 2016) to gain experience with the process and the timing of each stage.

Table 2. Recommended Interventions to Support Market Transformation

#	Intervention	Description
1	Build Laboratory Capacity	Regional action. Facilitate the expansion and strengthening of the test laboratory capacity throughout the region. Consider conducting an Interlaboratory Comparison of lighting laboratories to help promote accreditation and ensure labs are calibrated to the same international standards (for both on-grid and off-grid lighting products). Consult with Dr. Franz Hengstberger from the National Metrology Institute of Ethiopia, a former president of the CIE and regional lighting metrology expert, for advice on efforts to build laboratory capacity in the region. Consider a bulk-purchase of the LightSpion test instruments and training work to build government capacity for testing and enforcing regulations. These recommendations are especially important for countries who have (or seek to develop) local manufacturing and/or product assembly.
2	Legislative Framework	National action. Ensure the government has created the legislative framework that grants authority to a Ministry for establishing mandatory standards and labelling (S&L) on consumer products and commercial equipment. S&L are the cornerstone of national programmes to transform markets towards more energy-efficient products.
3	Participate in Regional Energy-Efficiency Centres	National level action for regional benefit. Engagement with the regional energy-efficiency centres, SACREEE / EACREEE and participating in the dialogue and planning to establish programmes designed to support market transformation, including harmonised performance standards, bulk procurements, product specifications, policy recommendations and much more.
4	Green Procurement Specification	Regional action (potentially led by EACREEE and SACREEE). Develop a specification for the public sector to lead by example – Ministries, Parliament, Municipalities and other public entities would purchase from the green procurement specification which sets regional product purchasing criteria for a range of products – from street lights to office refrigerators; consider offering tax incentives to encourage the private sector to utilise the same list when making procurements for their facilities. One model for this bulk procurement that could be organised and implemented regionally is the successful joint venture in India called Energy Efficiency Services Limited (EESL).

#	Intervention	Description
5	Develop ESCOs and Funding Scheme	National / Regional action. Energy Service Companies (ESCOs) are an excellent way to unleash the power of the private sector to deliver energy savings in a given market. EACREEE and SACREEE could work together with national governments to develop a training programmes, case studies, spreadsheet tools, reference documents and resources that would stimulate entrepreneurs in the region to create ESCOs. If needed, a low interest fund which they can use, governments will enable them to more easily sign-up new clients and implement change, upgrading lighting, HVAC, appliances, equipment, building envelope and other solutions. ESCOs can specialise in commercial buildings, industries (e.g., mining, processes), or other market niche. By establishing a fund (e.g., with a local financial institution), this intervention would encourage more ESCOs to be formed and for those that already exist, it would enable them to expand their portfolio of business.
6	Electric Utility Engagement	National action. Electric utilities offer another avenue for market intervention because of their pivotal role between the end-user and their energy-supply. It is suggested that governments consider employing market-based instruments (MBIs) such as white-certificates which would obligate utilities to save energy but not prescribe the methodology they must follow. This could result, for example, in a change in the utility regulatory language requiring it to engage in end-user DSM initiatives. Those initiatives could trigger a range of different energy-efficiency initiatives. DSM programmes can then be launched that would promote efficient products and provide energy savings.
7	Stimulating Development of Energy-Efficiency Businesses	National / Regional action. Working with the regional energy efficiency centres and national ministries of trade and industry, help to develop a pipeline of green-tech projects and businesses that can stimulate and facilitate the development of environmentally sustainable businesses across the region. These businesses would seek to establish themselves, build local expertise, employment and create value-added products in the region. Examples of projects could include: LED luminaire manufacturing, micro-solar home systems, ceiling fans, and much more. If green finance is needed, establish a loan facility, potentially modelled after the Beyond the Grid Fund for Africa (BGFA), that provides grants to existing or start-up green-technology companies who are seeking to establish domestic production of products that are more efficient than the standard products on the market.
8	Quality and Performance Regulations	Regional action, adopted nationally. Minimum energy performance standards (MEPS) are the most sustainable option for achieving high levels of energy efficiency and for phasing out less efficient technologies. MEPS apply to both energy and performance-related characteristics, and should be developed in consultation with stakeholders' input and economic analysis, taking into account regional harmonisation. MEPS programmes need to be monitored, evaluated, updated, reviewed and revised. Lighting – both on-grid and off-grid lighting is an excellent starting point as it would enable processes to be trialled and understood, and once established, other products can be regulated through the same process. CLASP suggests a possible set of products for consideration and encourages the formation of an inclusive process where stakeholders can have a say: tertiary sector lighting, air-conditioning, domestic refrigeration, electric motors and televisions. Discussion on all of these products can be found in Chapter 6.

#	Intervention	Description
9	Market Surveillance	Regional and National Action. To ensure the MEPS are successful, governments need to a functional system of monitoring, verification and enforcement capable of ensuring full compliance of products with any regulatory measures. This Team within the government would be dedicated to Market Surveillance and would work in partnership with domestic industry as well as the customs office to monitor, inspect, test and ultimately accept or reject products from the market based on their compliance with the national regulations.

Looking across the region, there are advantages if countries choose to develop harmonised policies and actions. Harmonising policy measures would mean adopting the same requirements, test standards and/or other requirement as another country (or countries) in a region. Through harmonisation, consumers benefit from lower prices and better product choice because the supplier's administrative trade barriers are reduced, and testing and compliance certification reporting costs are lower. The compliance costs are spread across a larger number of products, enabling consumers in those markets to enjoy better prices and choice of goods associated with the other (generally larger) economies with which they are harmonised.

Harmonisation of test standards enables multiple national markets to be accessible for the cost of only one test. Testing standards underpin all lamp MEPS and energy labelling programmes because they are the means by which a product's performance is measured and compared. Harmonisation of test procedures facilitates: trade; comparison of performance levels; technology transfer; and encourages replication of best practices. The most widely used test methods today for measuring the performance of lamps are those of the International Electrotechnical Commission (IEC) and the Commission Internationale de l'Eclairage (CIE). To ensure that they have an opportunity to participate in the development of these test methods, countries are encouraged to join the IEC.

2 Introduction

The objective of this initial market assessment was to gather sufficient information on the lighting markets of Southern and East Africa to enable policy-making decisions to be made about the phasing out of inefficient lighting and promoting the adoption of more energy-efficient alternatives. Through the implementation and enforcement of new, harmonised energy-efficiency regulations for lighting, the region will enjoy not only improvements in energy security and economic development, but also simultaneously reduce energy bills for households and businesses and improve lighting quality.

The sections in this chapter provide an introduction to the project, including a discussion on the scope of the market assessment from both a country and a technology basis, the methodology followed by the research team, the data sources accessed, and the analysis and suggested market strategy. While undertaking this work, CLASP worked very closely with all the EELA partners, but particularly with representatives from SACREEE and EACREEE, who participated in all the interviews and contributed to the research findings and recommendations.

2.1 Scope of the Market Assessment

From a country perspective, the scope of this assignment encompasses a total of 21 countries across East and Southern Africa. These countries are Angola, Botswana, Burundi, Comoros, Democratic Republic of Congo, Eswatini, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Seychelles, South Africa, South Sudan, United Republic of Tanzania (Tanzania), Uganda, Zambia and Zimbabwe.

Of these six countries are considered part of the East African Community (EAC): Burundi, Kenya, Rwanda, South Sudan, United Republic of Tanzania, Uganda. And sixteen countries are considered part of the Southern African Development Community (SADC): Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, United Republic of Tanzania, Zambia and Zimbabwe. Please note that the United Republic of Tanzania is classified as part of both East Africa and Southern Africa, thus it appears twice in the regional list.

The market study was based on desk research as well as on questionnaires which were sent to the country focal points of the 21 Member States of EAC and SADC. For a more in-depth analysis, detailed assessments and interviews were carried out in six countries – of which five are from SADC (i.e., Madagascar, Namibia, South Africa, Zambia and Zimbabwe) and one is from EAC (i.e., Uganda).

The selection of the countries aims to provide a robust and representative cross-section of the Southern and East African regions. Considering, for example, the distribution of GDP, population and GDP per capita, they offer analytical points across the range of countries considered in this analysis. In the figures below, the red dots represent the six focus countries and the blue dots represent the other 15 countries which are not considered (World Bank, 2018).

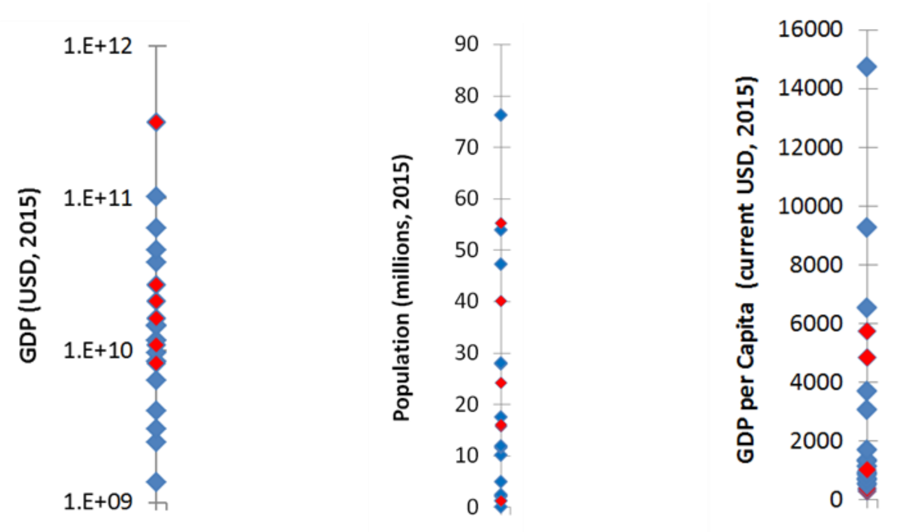


Figure 2. GDP, population and GDP per capita with focus countries marked red

Furthermore, these focus six countries also provide good geographic representation, with one island-nation two costal countries and three which are land-locked. They are distributed predominantly towards the southern tip of the region, however this aspect was not seen as skewing or detrimental to the representativeness of the analysis. The following map depicts the countries which are part of the study, with the six focus countries shaded in red.

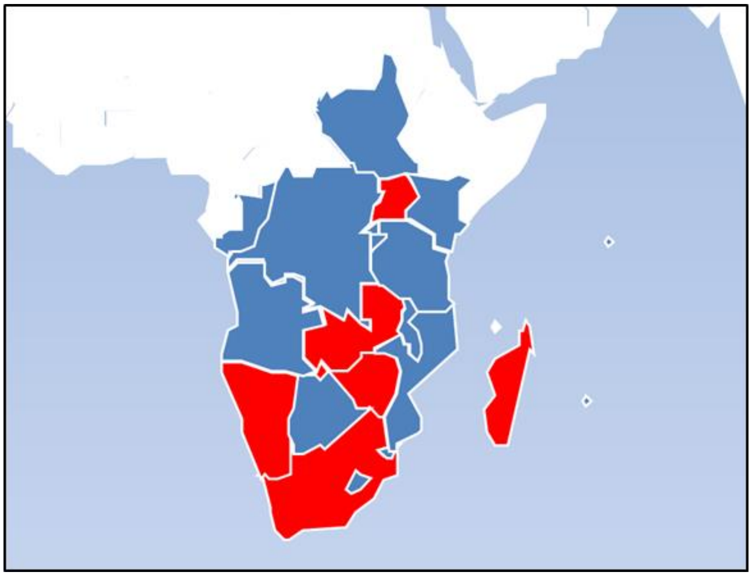


Figure 3. Twenty countries in the study with the focus countries shaded red

From an electrification point of view, these countries are also representative spanning a range of electrification rates, from 19% in Uganda to 86% in South Africa. The total population of these six countries represents 35% of the total population in the focus region (446.3 million), with slightly more of the population living off-grid: 73 million people on-grid and 81 million people off-grid. The data for these six countries is shown in the table below.

Table 3. Electrification rates of urban and rural people in the six focus countries

Country	2016 % electrified	2016 % urban electrified	2016 % rural electrified	Total Population	Population On-Grid	Population Off-Grid
Madagascar	23%	52%	7%	24,234,088	5,573,840	18,660,248
Namibia	56%	78%	34%	2,425,561	1,358,314	1,067,247
South Africa	86%	87%	83%	55,291,225	47,550,454	7,740,772
Uganda	19%	23%	19%	40,144,870	7,627,525	32,517,345
Zambia	34%	67%	7%	16,100,587	5,474,200	10,626,387
Zimbabwe	34%	81%	11%	15,777,451	5,364,333	10,413,118
				153,973,782	72,948,666	81,025,116

From a lighting technology perspective, the scope of coverage has included both on-grid and off-grid lighting technologies commonly found in markets around the world. These include light sources that are used in domestic, commercial, industrial and outdoor applications. The images below name and depict the light sources studied in this assessment.

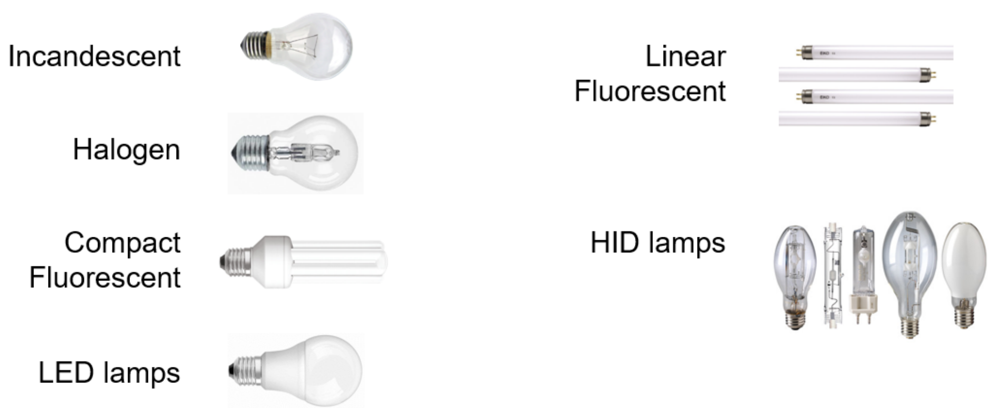


Figure 4. On-Grid Lighting Technologies Studied in the Scope of this Market Assessment

In the off-grid sector, a range of different light sources were also considered, in addition to mini-solar home systems, which are often used now for lighting as well as other end-use applications in the home such as mobile phone charging, entertainment, refrigeration and more (depending on the size of the system and the battery storage capacity).

Figure 5. Off-Grid Lighting Technologies Studied in the Scope of this Market Assessment

Market information was gathered on the typical technologies used for domestic and off-grid retail lighting (e.g., pop-up markets) and is presented in the relevant sections of this report.

2.2 Methodology Followed and Data Sources Accessed

CLASP implemented a methodology designed to yield the best information in the time available for the research. There were three phases to the work conducted by CLASP, which were conducted in this order:

1) Literature Review
2) Interviews with Experts
3) Analysis and Report

2.2.1 Literature review

CLASP conducted a review of all the available literature on lighting and energy use in the region. This included researching data and through the following sources of information:

- The recent SIDA study looking at the lighting markets in three key countries – Mozambique, Uganda, Zimbabwe;
- U4E country lighting assessments and energy and CO2 savings estimates – all twenty countries in EAC and SADC;
- The CTCN study by DNV GL – covering Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe
- Studies conducted in the EAC and SADC regions by overseas aid agencies, researchers, multilateral development banks (African Development Bank, World Bank/IFC, Development Bank of Southern Africa, etc.) and other sources;
- National and regional electric utility studies on demand side management (DSM);
- National and regional lighting manufacturer associations and standardization bodies;
- Conference proceedings and presentations, journal papers and other associated literature; and
- The United Nations Comtrade database, focusing on lighting-related trade with China and India.

2.2.2 Interviews with Experts

The literature review provided the foundation for country-specific interview guides that were prepared for all twenty-one countries and sent by SACREEE and EACREEE to the energy-efficiency focal points in each of the twenty-one countries. In their cover note issued, they informed the recipients about the project, the purpose of the questionnaire and asked that they please complete it. The survey instrument covered both on-grid and off-grid lighting, and took into consideration the following key aspects of the market: the lighting supply chain, estimates of the technologies involved and the quantity of energy savings, key players operating in the market, technologies found in the market, whether those technologies are changing, what prices people typically pay, what market barriers to energy-efficiency are experienced, lighting policies and programs in place or in development, average household electricity price, and information on power quality or supply.

In addition to issuing the questionnaire, in the six focal countries CLASP worked through its project partners to conduct interviews with national experts. Interviews were conducted with two to three key stakeholders in each country (e.g., government representative, private sector / lighting importers, and the national electric utilities). The interviews were initiated by the SACREEE or EACREEE representative, and then run by CLASP staff, covering the on-grid sector and then the off-grid. CLASP gathered this information to compliment the literature review, characterising the supply-chain in each country and the key stakeholders involved. These interviews with experts from the six focus countries provided an opportunity to discuss the preliminary data compilation, update and revise any outdated values found, and fill-in any gaps in the key areas of interest in that country's lighting market.

Table 4 identifies the experts who provided a completed questionnaire and/or who were interviewed for the market assessment. All 21 countries were sent a questionnaire and some of the countries who responded are not part of the six we focused on, therefore they were not interviewed as follow-up. Their contributions are included in the Annex for information, and relevant points made are reflected in the chapters of this report.

Table 4. Experts Contributing to this Report – Survey Instrument and Interviews

Country	Name	Title	Survey	Interview
Botswana	James Molenga	Department of Energy, Botswana	Yes	n/a
Eswatini	Mzwandile Thwala	Senior Energy Officer, Ministry of Natural Resources and Energy, Eswatini Government	Yes	n/a
Malawi	Stephen A.J. Chalimba	Malawi Bureau of Standards	Yes	n/a
Mauritius	Hemant Multra	Senior Engineer, Ministry of Energy and Public Utilities, Mauritius	Yes	n/a
Madagascar	Tsiky Robison Barnia Flowernysd Raherinantenaina	Head of Service, Renewable Energy Development, Ministry of Energy and Hydrocarbons, Government of Madagascar	Yes	Yes
Mozambique	Miserio Banze	National Directorate of Energy, Ministry of Mineral Resources and Energy	Yes	No
Namibia	Paulus Mulunga	CEO, Light Systems Namibia	Yes	Yes
Namibia	Helvi Ileka and Fenni Shidhika	Namibia Energy Institute	No	Yes
Seychelles	Cynthia Alexander	Seychelles Energy Commission, Seychelles	Yes	n/a
South Africa	Serame Moeketsi	Department of Energy, South African Government	No	Yes

Country	Name	Title	Survey	Interview
South Africa	Barry Bredenkamp	General Manager, South African National Energy Development Institute	No	Yes
South Sudan	Tom Remis	Ministry of Energy and Dams, South Sudan Government	Yes	n/a
Uganda	Winnie Onziru	Senior Officer, Uganda National Bureau of Standards	No	Yes
Uganda	Usamah Kaggwa and Augustine Tsongo	Ministry of Energy and Mineral Development (MEMD), Government of Uganda	Yes	No
Zambia	Mafayo Ziba	Senior Energy Officer, Ministry of Energy	No	Yes
Zambia	Shupe Mambalakata	Zambian Electricity Supply Company (ZESCO)	Yes	Yes
Zimbabwe	Benson Zeyi	Senior Research Scientist, the Scientific and Industrial Research and Development Centre	Yes	Yes
Zimbabwe	Simbarashe Muhle	Ministry of Energy, Government of Zimbabwe	Yes	No

The following are the questions that were in the interview guide distributed to all 21 countries for their optional completion and/or in the six focal countries, an interview.

Part I. On-Grid Lighting

I.1 Lighting Supply Chain

I.1.A) Are there any lamp or luminaire manufacturers in your country? If so, what are their names and what products do they produce?
I.1.B) Who are the lamp importers operating in your country? What are their names and what products do they import?
I.1.C) Taking a national perspective, please estimate the respective market shares of the top companies.
I.1.D) Is there a lighting manufacturer's association, whether national or regional?
I.1.E) Please consider the Supply Chain diagram below and comment – key players, main routes to market, market share.

I.2 Lighting Technologies and Volumes

I.2.A) Which light sources are offered in your national market?
I.2.B) Please discuss which sectors purchase these lamp types (i.e., domestic, commercial, industrial, municipal/outdoor).
I.2.C) Please provide stock estimate of the following types of lamps for your country, giving the year and source of data. [data for each country was provided from the UNE/U4E market model]
I.2.D) How would you describe the rate of penetration of LED sources in the market, both as lamps and luminaires? New installations, refurbishments and retrofits.

I.3 Efficient Lighting Policies and Programmes

I.3.A) Are there any national policies in place that promote efficient lighting? (e.g., regulatory policy, import tax relief / duty, subsidy/financing, labelling, or other information programme). If so, can you provide details and/or a link?
I.3.B) Are there any regional, municipal, utility or other entity offering programmes to promote efficient lighting? If so, can you provide details and/or a link?
I.3.C) Which body is responsible for lighting product testing standards in your country?

I.4 Customer Related Issues

I.4.A) What are the typical prices paid for the popular / common lamp types?
I.4.B) What is the average residential electricity tariff? Does that vary between rural and urban?
I.4.C) What are the barriers to more energy-efficient lighting? Is it: availability, awareness, accessibility, affordability, acceptance?
I.4.D) What are the notable trends in the markets?
I.4.E) Are there any other points you'd like to make or raise about your national on-grid lighting market?

Part II. Off-Grid Lighting

II.1 Off-Grid Lighting Supply Chain

II.1.A) Are there any off-grid lighting product manufacturers in your country? If so, what are their names and what products do they produce?
II.1.B) Who are the importers of off-grid lighting products? What are their names and what products do they import?
II.1.C) From a national perspective, please estimate the respective market shares of the top companies.
II. 1.D) Is there a local Association representing manufacturers and importers of off-grid lighting products? If so, what's their name?
II.1.E) Please consider the Off-Grid Lighting Supply Chain diagram below and comment – key players, main routes to market, market share.

I.2 Lighting Technologies and Volumes

II.2.A) Which off-grid light sources are used in your country?
II.2.B) Please discuss which sectors purchase these lamp types (i.e., domestic, commercial, industrial, municipal/outdoor).
II.2.C) Please provide estimate of the off-grid lighting stock estimate for your country, giving the year (latest) and source of data. Millions of lamps in the installed base.
Installed Stock Estimates (millions), 2015 UNEP Off-Grid Model
Average Household Monthly Consumption

II.3 Efficient Lighting Policies and Programmes

II.3.A) Are there any national policies in place that promote off-grid lighting products and/or phase-out fuel-based light sources? (e.g., regulatory policy, import tax relief / duty, subsidy/financing, labelling, or other information programme). If so, can you provide details and/or a link?
II.3.B) Are there any regional, municipal, utility or other entity offering programmes to promote solar lighting? If so, can you provide details and/or a link?
II.3.C) What body is responsible for testing standards for lighting products?

II.4 Customer Related Issues

II.4.A) Please provide price estimates for the following in your country (Latest data). [data for each country was provided from the UNEP/U4E market model]
II.4.B) What are the typical prices paid for the popular / common off-grid lighting products types? (in your local currency)
II.4.C) Does the customer purchase on a cash-basis or through credit system?

II.4.D) Are the off-grid lighting products sold with warranty or without warranty? Where applicable, please indicate product name?
II.4.E) How does the customer redeem warranty if applicable?
II.4.F) Are there any notable trends in the off-grid lighting markets?
II.4.G) Are there any other points you'd like to make or raise about your national off-grid lighting market

2.2.3 Analysis and Report

The data and inputs from all the interviews, surveys and literature review were then compiled for publication in this report. For the fifteen countries in SADC and EAC which are not the focus countries, CLASP prepared a high-level summary, relying on readily available data and known policy-measures, and scaling results from neighbouring countries of similar socio-economic status and demographics. In this way, CLASP provides an aggregate regional energy savings estimate from lighting policy measures with scaled-up savings for the region. CLASP also prepared estimates of the savings potential for each of the fifteen countries, relying on scaled savings estimates from the U4E lighting market model, updated to reflect any new information gathered through the literature review and regional interviews.

Part of the analysis conducted for this project was to update the U4E lighting market model stock estimate with input from the countries and new United Nations Comtrade data which is published online every few years (UN, 2018). UN Comtrade is a database of official international trade statistics and analytical tables that are completed by each of the individual countries and compiled by the UN. These estimates were prepared for all 21 countries in order that a complete regional assessment as well as individual national estimates can be presented for policy-makers. CLASP notes too that the UN Environment's U4E programme is in the process of updating its 2015 stock estimates, confidentially obtaining new private sector data from their partners and preparing new energy savings estimates. CLASP will communicate our findings to the new U4E modelling expert (David Wellington, UK) to ensure that they are able to benefit from the estimates prepared under this Market Assessment.

For the six focus countries, the Intervention Strategy contains a high-level economic analysis of the phasing-out of incandescent lighting by providing a cost calculation looking at the essential economic indicators for policy-makers, including: pay-back periods associated with technology-policy options; life-cycle cost per lamp or typical household; net national benefits – energy, CO_2, financial savings; and project benefits for realistic first effective year of the policy measure taking effect. The calculation relies on national pricing, electricity and typical operating hours in the home. The spreadsheet underpinning these calculations in the Intervention Strategy is provided separately to UNIDO as a deliverable under this contract so that government policy-makers and their expert analysts in these six countries can conduct their own sensitivity analyses on the findings.

Finally, this report was prepared for presentation at the Validation Workshop from the preparatory phase of EELA which is scheduled to be convened in Tanzania on 11-13 February 2019. This report provides an overall view of the lighting market in SADC and EAC, including information on shipments, stakeholders, costs, market and technology trends, policy measures, savings potential, DSM schemes currently in place in EAC and SADC, market barriers, and opportunities in the on-grid and off-grid lighting markets. This final report includes more detail on the six focal countries, including a national summary profile included in the body of this report as well as six appendices which present the summary findings from the interviews and literature review.

2.3 Market Intervention Strategy

Building on the foundation of the EAC and SADC Market Assessment – including the regional expert interviews, literature review, and data analysis, CLASP developed and presents some suggested interventions which may be considered under the EELA project for the implementation phase of the work. Some of these interventions relate to high-impact, cost-effective lighting policy measures – for example, setting quality and performance standards for on-grid and off-grid lighting products:

- On-grid lighting - the focus of this strategy would be to consider phasing-out incandescent and halogen light sources, as well as possibly removing mercury-containing compact fluorescent lamps from the market through a harmonised policy-measure adopted across the region; and

- Off-grid lighting - the focus of the strategy is to evaluate various performance specifications, such as IEC TS 62257-9-5:2018 ("*Recommendations for renewable energy and hybrid systems for rural electrification - Part 9-5: Integrated systems - Laboratory evaluation of stand-alone renewable energy products for rural electrification*")[2] and also the Lighting Global quality assurance specification. The overarching goal would be to discuss with governments the possibility of developing an mandatory quality and performance specification for off-grid lighting.

Other interventions are looking at other sectors and programmes, such as product testing and finance. Overall, the region offers tremendous potential and has been demonstrating very rapid growth and upliftment in recent years. Introducing policies and programmes now will enable future investment and development to take place on a more sustainable and cost-effective way, improving the overall quality of life for the people living throughout the region.

[2] Copy of the IEC standard can be obtained from: https://webstore.iec.ch/publication/59747
https://www.lightingglobal.org/quality-assurance-program/our-standards/

3 Programmes, Economy and Policy

3.1 Lighting Initiatives and Programmes

When considering working on energy-efficient lighting and appliances in Eastern and Southern Africa, it is important to ensure any work undertaken is coordinated with existing programmes and initiatives that are underway. In this region, there are active initiatives which are working to promote renewable energy and energy-efficiency in both the on-grid and the off-grid markets. This initiative has the potential to look across these two traditionally separate markets and establish cooperative arrangements through the regional energy-efficiency centres, EACREEE and SACREEE. By helping to coordinate the work undertaken by the EELA initiative with that of the existing organisations and governments, any redundancy will be eliminated, scarce resources will be optimally utilised, and the overall impact of the work – both of EELA and the other activities will be improved.

The following list represents some of the larger and most relevant initiatives that are underway in the region. There may be others that were not identified through our research, therefore this list should be taken as indicative but not necessarily complete. Brief descriptions of each of the initiatives can be found in the table, and if they have not already, it is suggested that EACREEE and SACREEE contact these entities to inform them about EELA and to engage in a dialogue to help ensure coordination and cooperation.

Table 5. Key On-Grid and Off-Grid Programmes and Initiatives on Lighting and Appliances

Name	On / Off-Grid	Brief Description
African Union Commission	Both	The African Union is a continental union consisting of 55 member states located on the continent of Africa, with exception of various territories of European possessions located in Africa. The bloc was founded on 26 May 2001 in Addis Ababa, Ethiopia and launched on 9 July 2002 in South Africa. Among many activities, the Union is working to provide guidance to governments on setting minimum energy performance standards (MEPS) for products.
African Energy Commission (AFREC)	Both	The African Energy Commission (Afrec) is a continental African organisation under the African Union which has the responsibility to ensure, co-ordinate and harmonise the protection, preservation, development and the national exploitation, marketing and integration of the energy resources of the African continent.
Clean Energy Ministerial	Both	A partnership of the world's key economies working together to advance the deployment of clean energy. Together, they account for approximately 90% of the world's clean energy investments and 75% of global emissions. Hold annual meetings with high-level Ministerial representatives, with year-round technical work through action-driven, transformative clean energy initiatives and campaigns, led by governments and supported through strong partnerships with the private sector, international organizations, and other stakeholders. To find out more, visit: www.cleanenergyministerial.org

Name	On / Off-Grid	Brief Description
Efficiency for Access Coalition	Off-Grid	Efficiency for Access was launched in 2015 and now includes twelve organisations which are coordinating their work promoting energy efficiency and clean energy access. Coalition programmes aim to scale up markets and reduce prices for super-efficient, off- and weak-grid appropriate products, support technological innovation, and improve sector coordination.
Global Off-Grid Lighting Association	Off-Grid	GOGLA is the global association for the off-grid solar energy industry. Established in 2012, GOGLA now represents over 140 members as a neutral, independent, not-for-profit industry association. Our services assist the industry to build sustainable markets and profitable businesses delivering quality, affordable off-grid electricity products and services to as many customers as possible across the developing world.
Lighting Africa	Off-Grid	A joint IFC-World Bank Lighting Africa programme that has set itself the ambitious and important target of enabling more than 250 million people across sub-Saharan Africa currently living without electricity to gain access to clean, affordable, quality-verified off-grid lighting and energy products by 2030. Lighting Africa's aim is to achieve this by catalysing the market through a number of different activities across the supply chain. Lighting Africa is part of the World Bank Group's contribution to Sustainable Energy for All (SE4All).
Lighting Global	Off-Grid	Lighting Global is the World Bank Group's platform to support sustainable growth of the international off-grid solar market as a means of rapidly increasing energy access to the 1 billion people without grid electricity. The Lighting Global program supports market development by working with private companies to lower first-mover risk and mobilize private sector investment through market intelligence, quality assurance, business support services and consumer education.
Low Energy Inclusive Appliances (LEIA) programme	Off-Grid	The Low-Energy Inclusive Appliances (LEIA) Programme is a research and innovation programme that seeks to double the efficiency and half the cost of a range of electrical appliances suited for off- and weak-grid household, small business, and industrial consumers. Supported by UK Aid, LEIA was designed with extensive industry consultation regarding the specific challenges and opportunities of the off-grid appliance market. The programme delivers a range of activities to stimulate the sector, including the Global LEAP Awards. The focus of LEIA includes technologies such as off-grid refrigeration, solar water pumps, fans and televisions.

Name	On / Off-Grid	Brief Description
Sustainable Energy for All (SEforALL)	Both	Launched in 2011, Sustainable Energy for All (SEforALL) is an International Organization working with leaders in government, the private sector and civil society to drive further, faster action toward achievement of Sustainable Development Goal 7 (SDG 7), which calls for universal access to sustainable energy by 2030, and the Paris Climate Agreement, which calls for reducing greenhouse gas emissions to limit climate warming to below 2 degrees Celsius. SDG 7.1 concerns access to electricity and clean cooking; SDG 7.2 concerns targets on renewables and SDG 7.3 concerns energy efficiency. The next Sustainable Energy for All Forum will be hosted by Rwanda and take place in Kigali 26 – 28 May 2020.
United for Efficiency (U4E)	On-Grid	The United Nations Environment Programme manages U4E, a global initiative to support developing countries and emerging economies in the transition to energy-efficient appliances and equipment. U4E brings together stakeholders active in the area of product efficiency. U4E informs policy makers of the potential environmental, financial and economic savings of a transition to high-efficiency products. The programme identifies and promotes global best practices in transforming markets. It also offers assistance to governments to develop and implement national and regional strategies.

3.2 Regional Economic Overview

The economies of Southern and Eastern Africa are expanding. While there have been some periods of low or negative growth, and some specific issues relating to individual countries, the region as a whole is growing. The combined annual growth rate of the GDP of all 21 countries grew by 7.5% per annum. Figure 6 presents the GDP of all 21 countries is presented in billions of current US$, spanning the time period from 2000 to 2017 (World Bank, 2018). The data show that the cumulative GDP for EAC and SADC was US$234.9 billion in 2000 and grew to US$803.4 billion in 2017 – a CAGR of 7.5% across the region, with around US$100 billion in growth between 2016 to 2017.

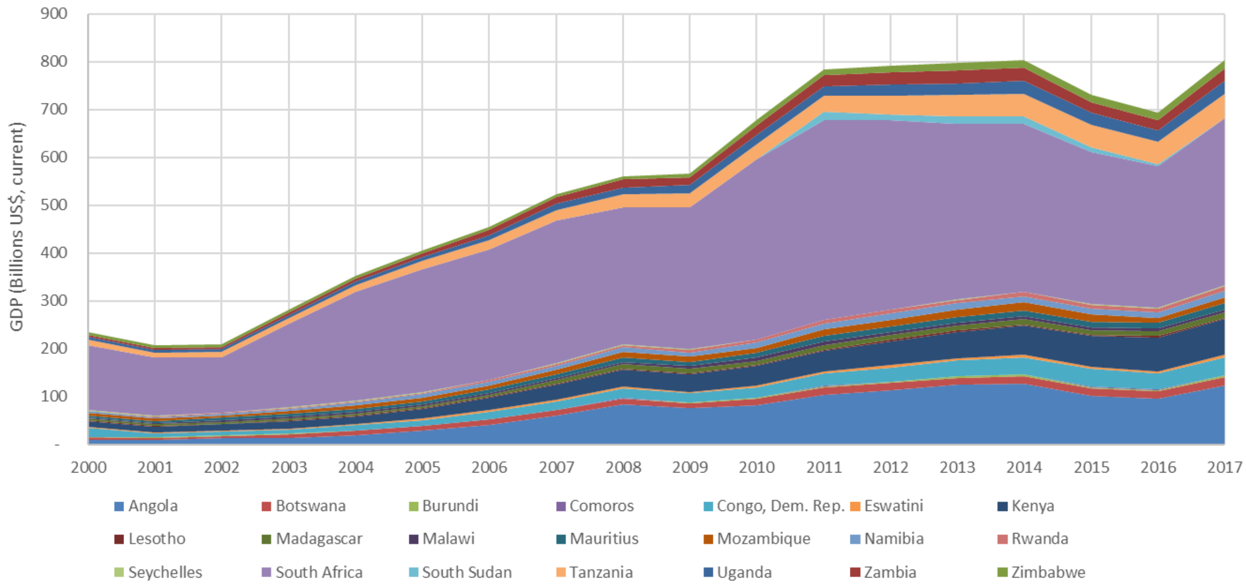


Figure 6. GDP of the 21 Countries from 2000 to 2017 (billions US$, current)

Figure 7 presents the annual growth rate of GDP for each of the 21 countries in Southern and Eastern Africa (World Bank, 2018). This graph is difficult to interpret due to the number of countries presented and the volatility in this year-on-year plot, however it does confirm that in general terms the growth rate that averages around the 7.5% that was calculated overall. When comparing the CAGR and the individual lines in this figure, the overall size of the market has a very significant effect on the overall weighting that is ultimately calculated. Also, it is worth noting that some countries experienced high volatility in GDP annual growth rate over the time period, from very high levels to some very low ones as well.

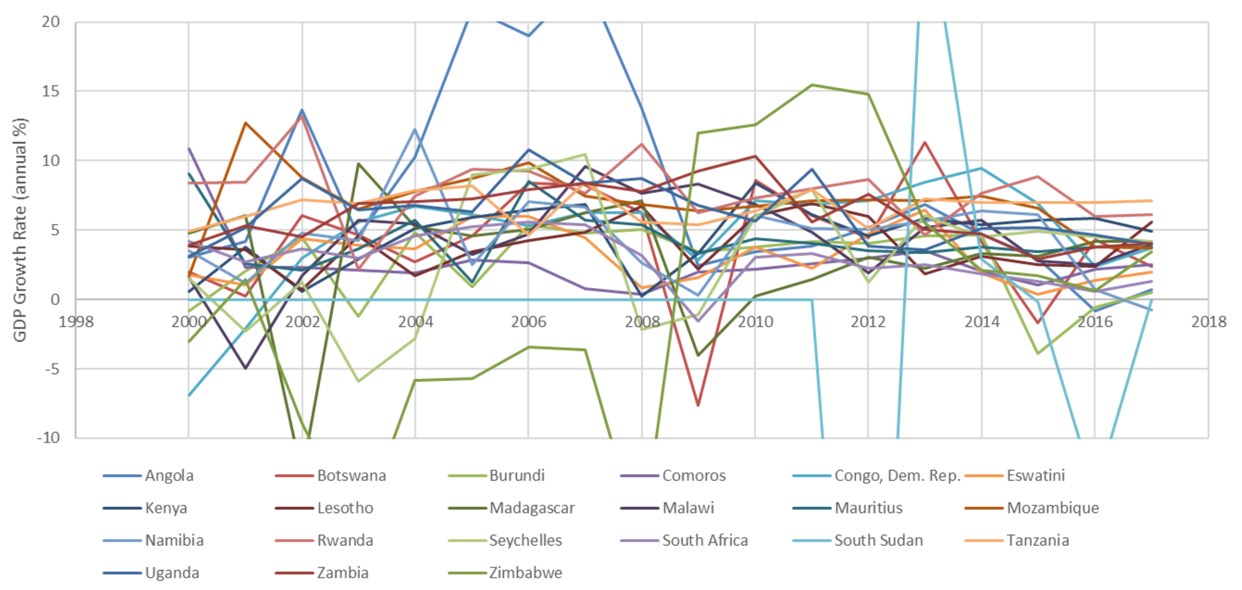


Figure 7. GDP Growth Rate of the 21 Countries from 2000 to 2017 (annual percentages)

Figure 8 presents the regional population over the same time period, spanning from 2000 to 2017. These data show that in 2000 the population was 296.4 million people and by 2017 had reached 471.5 million, equating to a CAGR of 2.8%. If this population growth rate is maintained, these 21 countries will reach half a billion people in early 2020 – just one year from now.

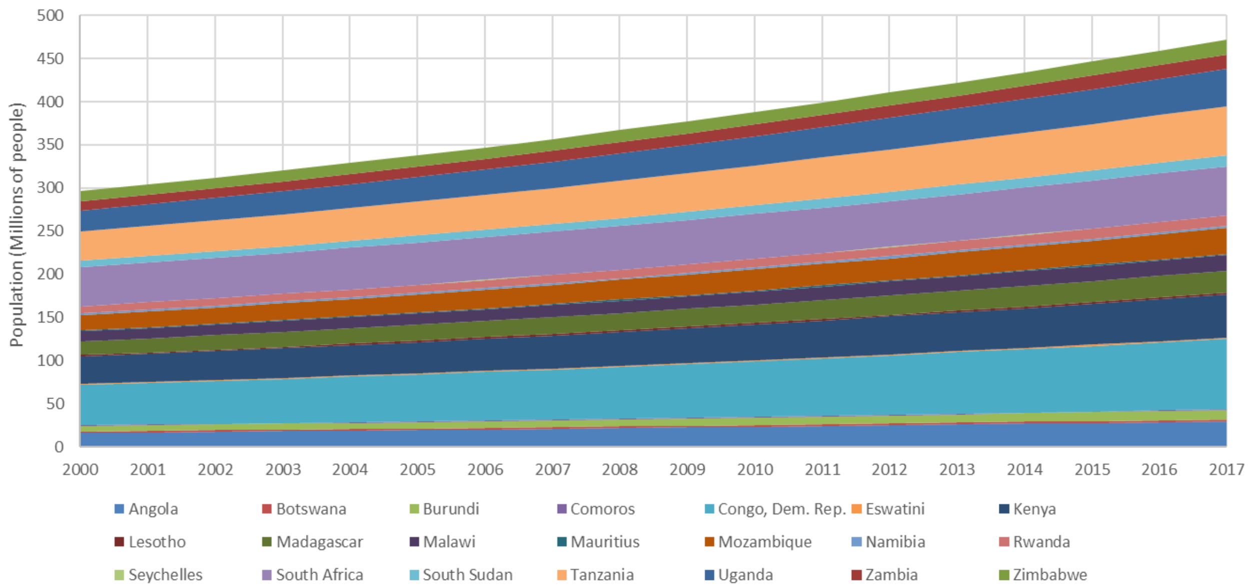


Figure 8. Total Population of the 21 Countries from 2000 to 2017 (millions of people)

And while that population is expanding, the region is experiencing a trend towards urbanisation, as shown in Figure 9 (World Bank, 2018). This graph depicts the percentage of urban population in each of the countries over the same time period. If the lines were flat, then the proportion of urban population relative to the total population would be constant, each growing at the same pace. However, due to the fact that 19 of the 21 countries are sloping upward over the time period, this is an indication that the urban populations are increasing faster than the rural ones. In 2000, the urban population across these 21 countries totalled 93.9 million people and in 2017, it had grown to 180.5 million people. This equates to a CAGR of 4.0%, which is higher than the total population growth across the region of 2.8%. And while that trend is high, it should be noted that in 2017 approximately 38% of the regional population reside in urban areas while the majority – 62% - are living in rural areas.

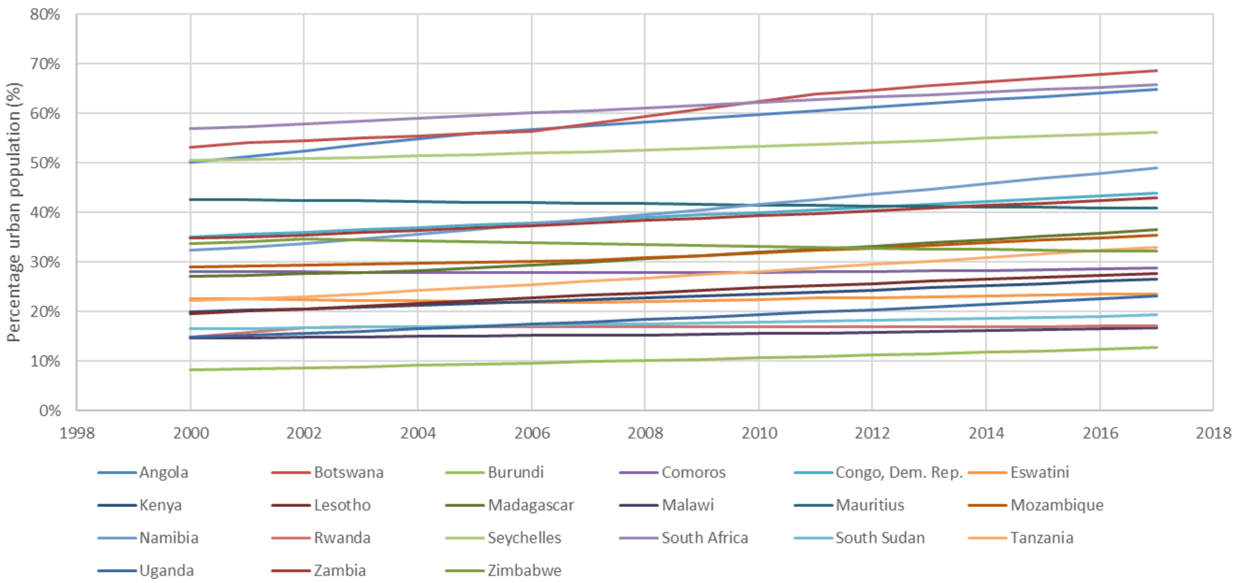


Figure 9. Percentage of Population Residing in Urban Areas for the 21 Countries, 2000 to 2017 (%)

Furthermore, some countries experienced higher rates of urbanisation than others. The countries with the highest change in percentage of urban population over this time period were Namibia (17%), Angola (15%), Botswana (15%) and Tanzania (11%). The Democratic Republic of Congo and South Africa, the two most populous countries in the region both experienced a net increase of 9% more urban population in 2017 compared to 2000. The countries experiencing negative growth (i.e., a smaller urban percentage in 2017 compared to 2000) were Mauritius (-2%) and Zimbabwe (-2%).

Figure 10 shows the CO_2 emissions for the region, spanning a slightly shorter time period – from 2000 to 2014 (years that data are available) (World Bank, 2018). The cumulative emissions were 436 million metric tonnes of CO_2 in 2000 and had risen to 612 million metric tonnes by 2014, representing a CAGR of 2.4%. This rate of growth in CO_2 emissions is notably slower than the economic growth of the region (reported above at a CAGR of 7.5%), thus the CO_2 per unit GDP was decreasing over this time period. Figure 10 illustrates that South Africa represents approximately 80% of the total emissions across all 21 countries, in part due to their large industrial sector and high proportion[3] of electricity generated from coal, the most carbon-intensive of the fuels used to generate electricity.

[3] The Guardian newspaper reports that more than 85% of South Africa's electricity is provided from coal (Guardian, 2014).

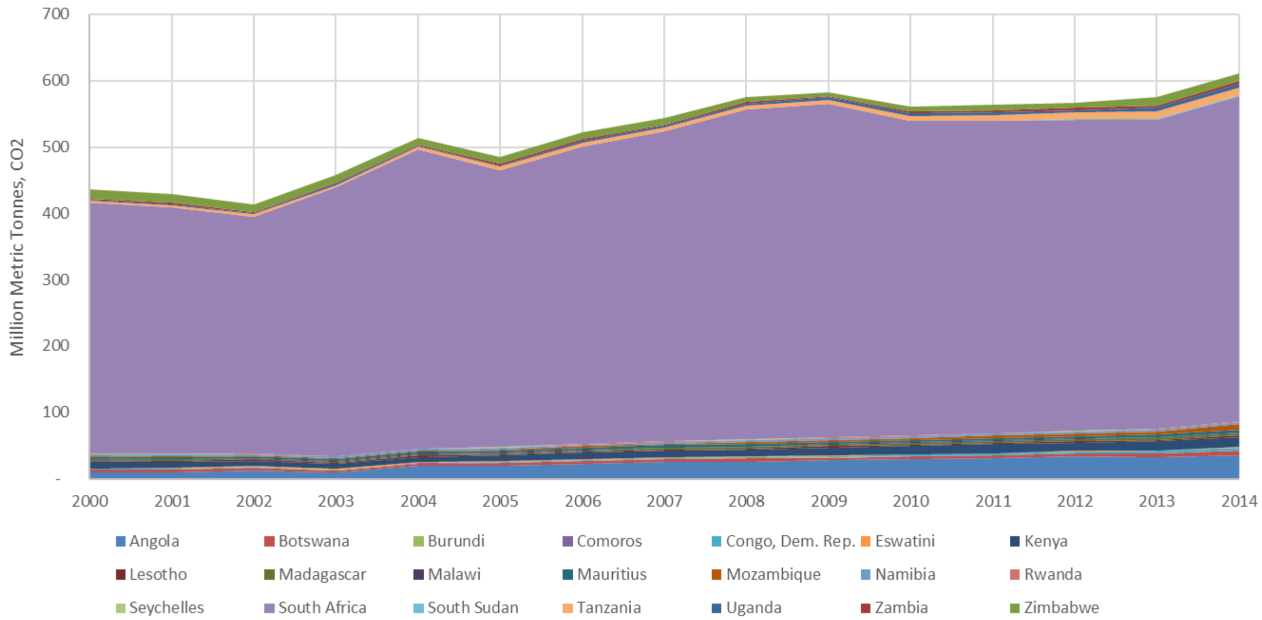


Figure 10. Total CO_2 emissions for the 21 Countries from 2000 to 2014 (millions of metric tonnes)

The next two figures present the carbon intensity of the countries in the region. Figure 11 presents the CO_2 emissions per unit GDP and Figure 12 shows the CO_2 emissions per capita for each of the countries in 2014. On a per unit GDP basis, South Africa has the highest emissions, at 1.4 kg CO_2/US dollar of GDP. Most of the countries in the region are less CO_2 intensive, being around 0.2-0.4 kg CO_2/US dollar of GDP.

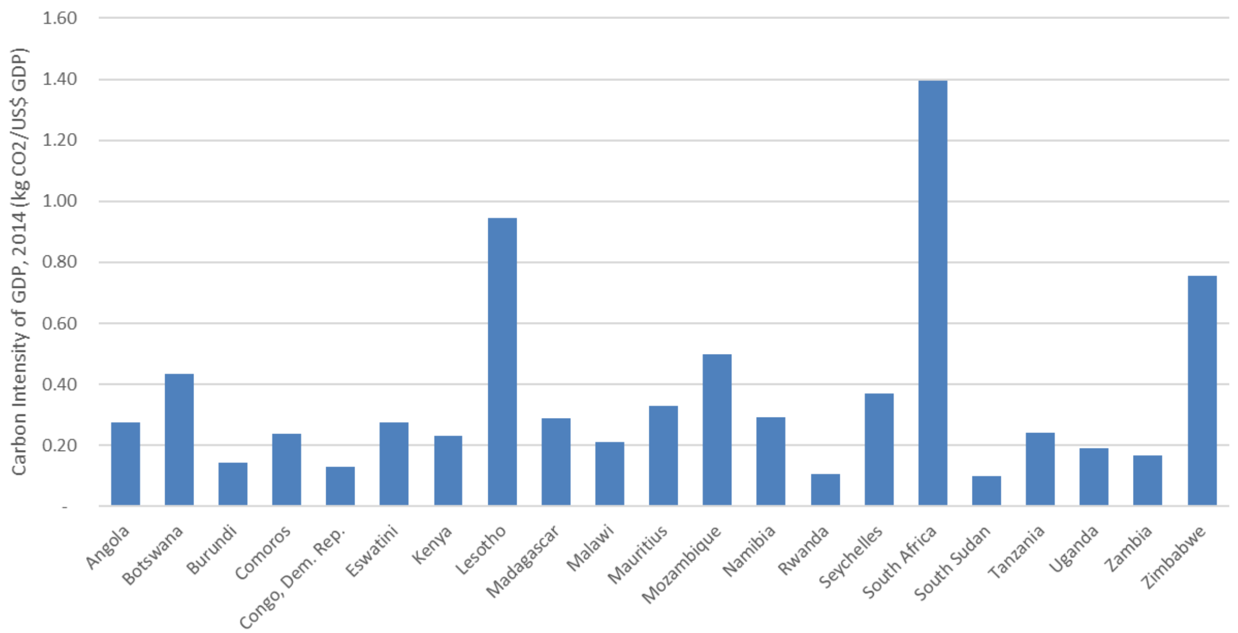


Figure 11. CO_2 emissions per unit GDP for the 21 Countries (kg CO_2 / USD, 2014)

From a per capita perspective, Figure 12 shows that South Africa has the highest emissions per person in the region with approximately 9 metric tonnes per person per year, followed by Seychelles at 5.5 metric tonnes and then Botswana and Mauritius at approximately 3.3 metric tonnes. On a per capita basis, 13 of the 21 countries emit less than 1 metric tonne per person, and some countries with emissions as low as 0.04 metric tonnes per person per year.

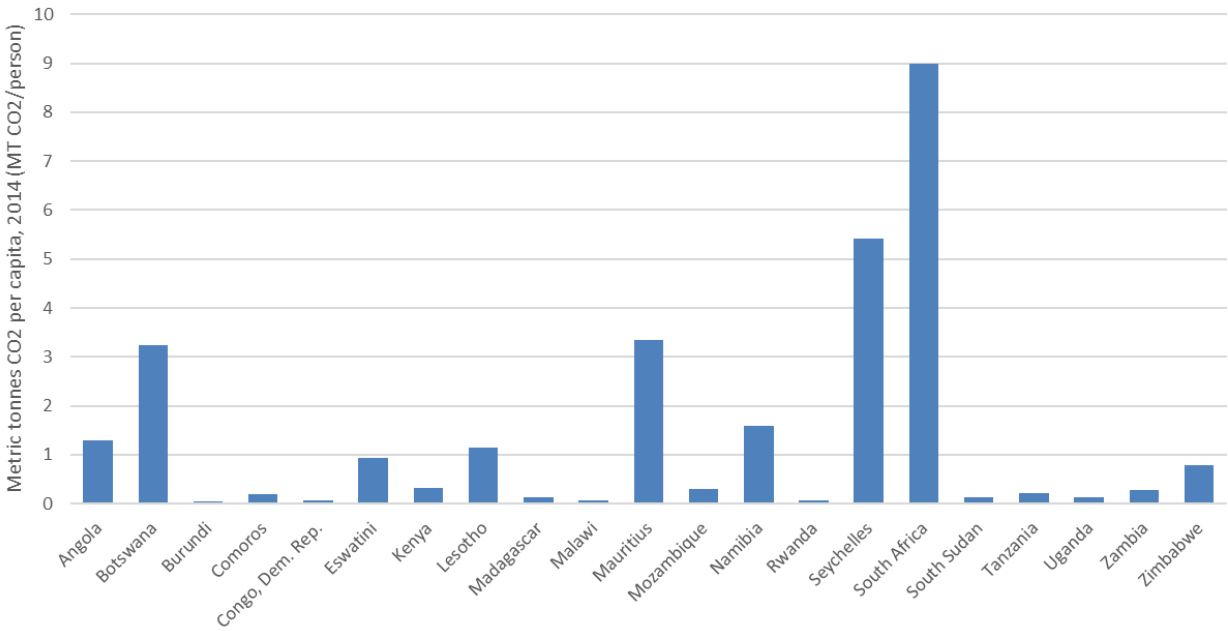


Figure 12. CO_2 emissions per capita for the 21 Countries (metric tonnes / person, 2014)

3.3 Governmental Institutions

In this section, we identify the key governmental institutions focusing on the energy sector in each of the six focal countries.

3.3.1 Madagascar

Table 6 presents the key energy-related government agencies in Madagascar who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 6. Key Energy-Related Government Agencies in Madagascar

Government Agencies	Description
Ministry of Energy and Hydrocarbons (Ministère de l'Energie et des Hydrocarbures – MEH)	The Ministry of Energy and Hydrocarbons (MEH) has the mandate to set national energy policy, provide strategic coordination in the energy sector, and oversee the national water and electricity company (JIRAMA's). The MEH grants licenses and permits for the exploration, generation, transmission and distribution of energy. MEH manages the Directorate General for Energy (Direction Générale de l'Energie – DGE) which looks at electricity infrastructure, renewable energy and energy-efficiency.
Rural Electrification Agency (Agence de Développement de l'Electrification Rurale – ADER)	The Agency for Rural Electrification Development, ADER, was established in 2002 for rural electrification and delivers it through grid-extension and off-grid mini-grid systems. ADER is a public institution which has technical supervision from the Minister of Energy and budgetary supervision from the Minister of Budget. ADER's mission is to implement the policy of the electricity sector in rural areas. This is done through grid-extension and off-grid mini-grid systems.

Government Agencies	Description
	ADER promotes electricity services in rural areas, and supervises / finances rural electrification. ADER also manages the National Electricity Fund.
Board of Electricity Regulation (Office de Regulation de l'Electricité, ORE)	The Board of Electricity Regulation (Office de Regulation de l'Electricité) is an independent entity which manages the electricity sector. ORE was established in 2002 and is composed of two bodies: the Council of Electricity (Conseil de l'Electricité), which is the decision-making body, and the Executive Secretariat (Secrétariat Exécutif), which is the administrative and technical body. ORE sets and monitors the electricity prices, to ensure the continuity of service and compliance with the standards of service quality. ORE is also in charge of competition in the sector.
Malagasy Water and Electricity Company (Jiro sy Rano Malagasy – JIRAMA)	JIRAMA is Madagascar's vertically integrated state-owned water and electricity company. It was created in 1975 and is responsible for the majority of the generation, transmission, and distribution of electricity as well as for water services in urban areas. Since 1999 and the liberalization of the electricity sector, JIRAMA is no longer the exclusive generator of electricity in Madagascar, but it does retain control over transport and distribution and is expected to remain the relay of the Malagasy state in the establishment of the country's electricity infrastructure. The company is under the joint supervision of the Ministries in charge of Water, Finance and Budget, and MEH.
Madagascar's Standards Office (Bureau des Normes de Madagascar – BNM)	The BNM is in charge of standards and conformity assessment in Madagascar. Besides drafting and publishing national standards, BNM manages national trademarks and standards. BNM's mission also includes representing Madagascar at regional and international standards organizations such as the ISO (International Organization for Standardization).

3.3.2 Namibia

Table 7 presents the key energy-related government agencies in Namibia who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 7. Key Energy-Related Government Agencies in Namibia

Government Agencies	Description
Ministry of Mines and Energy (MME)	The Ministry of Mines and Energy (MME) is the State's lead agency for setting national energy policy and for coordinating investment in resources exploration and development. It provides data on minerals and energy resources, and management of an equitable and secure titles systems for the mining, petroleum and geothermal industries. MME is responsible for regulating these extractive industries and dangerous goods in the country, including the collection of royalties, and ensuring that safety; health and environmental standards are consistent with the relevant State and Commonwealth legislation, regulations and policies.
Electricity Control Board (ECB)	The Electricity Control Board (ECB) is the national electricity regulator with a statutory responsibility to advise MME on electricity-related issues and serves a critical function developing regulations and legislation including codes, standards and guidelines under the Act. The regulator requires that the national utility conduct demand side management programme.

Government Agencies	Description
Namibia Energy Institute (NEI)	The Namibian Energy Institute was created in 2012 and consists of four centres covering all energy sectors: (1) energy-efficiency and renewables; (2) nuclear power; (3) oil and gas; and (4) electricity supply. The energy-efficiency and renewables centre has several on-going projects, including an energy-efficiency buildings project, training energy auditors and conducting energy-efficiency surveys. In the off-grid space, NEI has initiatives on (a) electrifying municipal buildings with solar systems; (b) a solar revolving fund; and (c) energy shops in the rural areas to demonstrate renewables and energy-efficient products. The NEI's energy-efficiency and renewable energy centre works to create a culture of energy consciousness, to improve framework conditions for renewable energy and energy efficiency, and to create dialogue platforms for the advancement of renewables and energy efficiency.
Namibian Standards Institution (NSI)	The Namibian Standards Institution (NSI) was established by the Standards Act 18, of 2005. The NSI is governed by the Namibian Standards Council (NSC), and is mandated to carry out the following functions including: to manage and coordinate the National Quality Policy; to develop, adopt and publish Namibian standards (NAMS) in compliance to World Trade Organisation requirements; to provide training, to provide measurement traceability to international standards, to provide reliable testing services, particularly on food items.
NamPower	NamPower is the national (government owned) electric utility company who are responsible for generation, transmission, system operation, trading and distribution. NamPower conducts national demand side management schemes, including a one-million LED lamp trade-in scheme which is being completed over the next year. https://www.nampower.com.na/ledmicrosite/

3.3.3 South Africa

Table 8 presents the key energy-related government agencies in South Africa who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 8. Key Energy-Related Government Agencies in South Africa

Government Agencies	Description
Department of Energy (DoE)	The South African Department of Energy (DoE) is responsible for national energy planning, policy formulation and implementation, relevant sub-sectors include electricity generation, transmission/distribution, energy efficiency and electrification. The DoE is responsible for drafting and implementing the Integrated Resource Plan (IRP) which determines required generation capacity and distinguishes between capacity to be implemented by Eskom and the independent power producers. The DOE manages the public procurement programme for IPP projects based on coal, gas and renewable energy generation.
National Energy Regulator of South Africa (NERSA)	The electricity, gas and petroleum industries are regulated by the National Energy Regulator of South Africa (NERSA), an independent regulator established under the 2004 National Energy Regulatory Act. NRESA issues, among other things, generation licenses and enforces their compliance, regulates electricity tariff increases, develops regulatory rules for relevant industries and sets the standards.

Government Agencies	Description
South African National Energy Development Institute (SANEDI)	The South African National Energy Development Institute (SANEDI) was established in 2011 under the National Energy Act, 2008 (Act No. 34 of 2008). The Act provides for SANEDI to direct, monitor and conduct energy research and development, promote energy research and technology innovation as well as undertake measures to promote energy efficiency throughout the economy. SANEDI's portfolio of initiatives are closely attuned to technology advancements, declining technology costs and continued innovation in the energy sector. As a whole, these can enable South Africa to take full advantage of their energy resources and the associated infrastructure development as a vehicle for economic growth, industrialisation, employment creation and sustainable development.
National Regulator for Compulsory Specifications (NRCS)	The National Regulator for Compulsory Specifications (NRCS) was established on 1 September 2008, in accordance with the provisions of the National Regulator for Compulsory Specifications Act, (Act no.5 of 2008) (NRCS Act). It emerged as an independent organisation from the original Regulatory Division of the South African Bureau of Standards and falls within the area of responsibility of the Department of Trade and Industry. NRCS's mandate includes promoting public health and safety, environmental protection and ensuring fair trade. This mandate is achieved through the development and administration of technical regulations and compulsory specifications as well as through market surveillance to ensure compliance with the requirements of the compulsory specifications and technical regulations.
Eskom	Eskom is the national electric utility responsible for generation, transmission and distribution of electricity to industrial, mining, commercial, agricultural and residential customers and redistributors. Eskom is a single buyer of electricity produced by numerous IPPs and it oversees all grid operations, including the connection of new customers and provision of continuous service.

3.3.4 Uganda

Table 9 presents the key energy-related government agencies in Uganda who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 9. Key Energy-Related Government Agencies in Uganda

Government Agencies	Description
Ministry of Energy and Mineral Development (MEMD)	The MEMD's works to "establish, promote, strategically manage and safeguard the rational and sustainable exploitation and utilisation of energy and mineral resources for social and economic development." The Ministry provides policy guidance, to create an enabling environment to attract investment, to collect, analyse and interpret data in order to establish the energy and mineral resource potential of Uganda; and to monitor the activities of private companies working in the sectors of energy and mining.

Government Agencies	Description
Electricity Regulatory Authority (ERA)	The ERA is a statutory body established in 2000 in accordance with the Electricity Act of 1999. The ERA's purpose is to regulate the generation, transmission, distribution and sales (including export and import) of electricity in Uganda. It guides the liberalisation of the electricity industry, and manages licensing, rates, safety and other matters concerning the industry. It ensures that electricity companies meet the conditions of their licences, and protect the interests of consumers – both on pricing and quality of supply.
Rural Electrification Agency (REA)	Established in 2001, the REA is a semi-autonomous agency in the MEMD, with a mission to implement the rural electrification strategy under a public-private partnership. The REA serves as the secretariat of the Rural Electrification Board, which carries out the Minister's rural electrification responsibilities, as defined in the Electricity Act of 1999. The REA is working towards achieving a rural electrification rate of at least 22% by 2022. (The IEA estimates that the electrification rate in Uganda was 19% in 2016)
Uganda Electricity Generation Company Limited (UEGCL)	The Uganda Electricity Generation Company (UEGC) was established in 2001 and is owned by the government of Uganda. It is responsible for the generation of electric power, and the sale of power in Uganda or as exports to neighbouring countries. UEGC is also responsible for building, operating and maintaining electricity generation plants; monitoring the operation of and maintaining its assets; and providing technical support as and when required. UEGL owns the 180 MW Nalubaale hydropower plant and the 200 MW Kiira hydropower plant which have been operated and maintained by Eskom Uganda Limited since 2003 pursuant to a 20-year contract.
Uganda Electricity Distribution Company Limited (UEDCL)	UEDCL was also created in 2001 as part of the liberalisation of the power sector. Its role is electricity distribution and it owns the electricity distribution network. In 2004, as UEDCL granted a concession to Umeme for the management of the electricity network, its responsibilities evolved to incorporate the administration of the lease and assignment agreement and the supervision of the completion of rural electrification projects.
Uganda Electricity Transmission Company Limited (UETCL)	UETCL is owned by the Ministry of Finance, Planning and Economic Development. It is the only operator of the electricity transmission system in Uganda, and as such has the role of national system operator and is responsible for the operation of the high voltage transmission system. UETCL is responsible for bulk power purchases and sales, imports and exports of energy. It sells on power to the distribution network companies.
Uganda National Bureau of Standards – UNBS	The Uganda National Bureau of Standards (UNBS) is a statutory body under the Ministry of Trade, Industry and Co-operatives. It was established by the UNBS Act Cap 327 and became operational in 1989. The Bureau of Standards is governed by the National Standards Council and headed by an Executive Director. UNBS writes and promotes standards concerning public health and safety and protection of the environment against dangerous and sub-standard products. It ensures fairness in trade and enhances the competitiveness of Ugandan industry in regional and international markets.
Umeme	In 2004, the Uganda Electricity Distribution Company Limited (UEDCL) 33 kV distribution assets were transferred under a 20-year contract to a consortium consisting of Globeleq and Eskom (the South African national utility). This company is responsible for operating, maintaining, upgrading and expanding the distribution network. It also sells electricity to customers.

3.3.5 Zambia

Table 10 presents the key energy-related government agencies in Zambia who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 10. Key Energy-Related Government Agencies in Zambia

Government Agencies	Description
Ministry of Energy and Water Development (MEWD)	The Department of Energy is part of the Ministry of Energy and Water Development. The Ministry has overall national responsibility for the development and management of energy and water resources in the country. MEWD leads the development of national energy policy, coordinates and works with energy-sector stakeholders, creates the national energy strategy and new energy programmes, and monitors and evaluates current policies.
Energy Regulation Board (ERB)	The ERB was established in 1996 under the Energy Regulation Act and is responsible for energy-related regulatory work in Zambia. This includes the licensing of Independent Power Producers (IPPs), setting petrol prices and electricity tariffs, developing technical standards, resolving complaints and conflict between stakeholders, and promoting new grid connections. In January 2017, the ERB began regulating the solar sector by enforcing regulations on import of solar components. (RECP, 2018d)
Rural Electrification Authority (REA)	Established in 2003, the REA oversees all the government's work with respect to rural electrification. This includes management of the rural electrification fund, management of rural electrification project tenders and the development of proposals to the government on everything to do with rural electrification. The REA also implements the Rural Electrification Master Plan (REMP), promoting the use of sustainable energy sources in the rural areas.
Zambia Electricity Supply Corporation (ZESCO)	ZESCO operates the electricity grid in Zambia and is responsible for most of the power generation. It is wholly government owned (via the Industrial Development Corporation). ZESCO functions as a monopoly in the country, where it has to support heavily subsidized electricity tariffs. These power subsidies limit the available revenue for national grid maintenance and investment.
Zambia Environmental Management Agency (ZEMA)	The Zambia Environmental Management Agency is the entity responsible for the formulation and implementation of environmental policies in the country. ZEMA addresses issues relating to the environment, ensuring that environmental concerns are incorporated into the overall national planning. The Agency also reviews environmental impact assessments (EIA) for projects and the strategic environmental assessment (SEA) reports.
Zambia Bureau of Standards (ZABS)	ZABS is the national body responsible for standards in Zambia. ZABS addresses all aspects of standardization, including formulation, quality control, quality assurance, import and export quality inspections, certification, and removal of technical barriers to trade.

3.3.6 Zimbabwe

Table 11 presents the key energy-related government agencies in Zimbabwe who may wish to play a part in any future policy or programme activity promoting energy-efficient lighting in the market.

Table 11. Key Energy-Related Government Agencies in Zimbabwe

Government Agencies	Description
Ministry of Energy and Power Development (MEPD)	The Ministry has overall responsibility for all energy issues nation-wide. It is responsible for policy formulation, market monitoring and regulation of the energy sector. The Ministry also encompasses research, development and promotion of new and renewable sources of energy. The Ministry oversees ZESA Holdings and its subsidiaries.
Zimbabwe Electricity Regulatory Authority (ZERA)	ZERA is a statutory body that was established under the Energy Regulatory Act of 2011, the Electricity Act of 2002 and the Petroleum Act of 2006. ZERA works to regulate the energy sector, creating an enabling environment for competition and promoting an efficient electricity supply industry. The Energy Regulatory Act also gives ZERA responsibility for licensing all players in generation, transmission and distribution; and the authority to set electricity tariffs.
Rural Electrification Agency (REA) and Rural Electrification Fund (REF)	Zimbabwe's government established the REF and the REA to promote development in the rural communities. The Agency works to promote rapid and equitable electrification of rural areas, with over 5,000 rural institutions, farms, villages, boreholes, dam points and irrigation schemes. (RECP, 2018e). The National Energy Policy of 2012 emphasized the importance of coordination across the electrification programme, setting targets and the appropriate mix of on- and off-grid technologies for the rural areas.
Zimbabwe Electricity Supply Authority (ZESA)	The electricity sector in Zimbabwe is controlled by the government-owned Zimbabwe Electricity Supply Authority Holdings (ZESA Holdings). This entity oversees the generation, importation and distribution of electricity across Zimbabwe through its two subsidiaries: (1) the Zimbabwe Power Company (ZPC) and (2) the Zimbabwe Electricity Transmission and Distribution Company (ZETDC). The 2012 National Energy Policy passed in Zimbabwe called for the unbundling and privatisation of this vertically-integrated electricity system. Initial steps were taken towards this objective, however private sector participation in the electricity sector has yet to be actualised. (RECP, 2018e)
Zimbabwe Power Company (ZPC)	Founded in 1999, the Zimbabwe Power Company (ZPC) acts as an investment vehicle for generating electricity. The ZPC works construct, own, operate and maintain the electrical power generation plants in Zimbabwe. They currently manage four coal-fired power stations: Hwange, Bulawayo, Munyati and Harare thermal stations, and a hydro power station Kariba. ZPC has a total installed capacity of 1,960 MWe.
Zimbabwe Electricity Transmission and Distribution Company (ZETDC)	A subsidiary of ZESA Holdings, the Zimbabwe Electricity Transmission and Distribution Company (ZETDC) manages the transmission of electricity from the power stations through to the distribution to the end-users. ZETDC consists of two main divisions: (1) the Zimbabwe Electricity Transmission Company which balances supply and demand and the transmission of electricity from domestic facilities and trading with the Southern African Power Pool; and (2) the Zimbabwe Electricity Distribution Company which is responsible for the distribution of electricity to the end users. The ZEDC is also responsible for asset management in the distribution network and planning network expansion.
Standards Association of Zimbabwe (SAZ)	The Standards Association of Zimbabwe (SAZ) is the organisation responsible for the development and implementation of standards in Zimbabwe, covering technology, industries and businesses. SAZ is also involved in laboratory development in the country.

3.4 Policy context

3.4.1 Energy Policies in Madagascar

Electricity Law – Loi n° 2017-020 portant Code de l'électricité à Madagascar (replaces Loi 98 – 032 sur l'Electricité)
The new Electricity Law adopted on 10 April 2018 that supersedes Law No. 98-03 of 20 January 1999 focuses on the use of renewable energy sources in order to secure the supply of electricity and a drastic increase in the rate of access to electricity at the national level. This rate is now 15% and the State aims to raise it to 70% by 2030 through the application of the electricity code and the adoption of related measures. The development of the revised electricity law started in 2015 with the support of GIZ. Compared to the 1999 law, the 2018 law further facilitates the electrification of the country and the development of renewable energy though a better integration of renewable sources and advantages for customs and taxes. The new law also creates a lighter process for small-scale electricity producers and self-production. It also clarifies roles and responsibilities in the electricity sector.

The Law 2002 – 001 creating the National Electricity Fund (NEF)
The costs or rural electrification are high and the NEF was set up tofinance rural electrification initiatives using grants provided to operators holding the requisite authorization or concession. The income is provided by a consumer tax of 1.25% on electricity bills for consumption above 20 kWh/month. The NEF is managed by ADER, the Rural Electrification Agency (Agence de Développement de l'Electrification Rurale)

The Law 2015 – 039 reforming Public-Private Partnerships
This law is meant to facilitate Private Public Partnerships (PPPs), in particular for the construction and rehabilitation of key infrastructure.

2015 – 2030 New Energy Policy (Nouvelle Politique de l'Energie)
As a part of the National Development Plan 2015 – 2019, the Government has created a New Energy Policy for 2015 – 2030. The New Energy Policy outlines a series of objectives, including: the provision of access to modern energy for 70% of households (equivalent of 7,900 GWh). This is projected to happen via 70% grid extension, 20% mini off-grid, 5% SHS (Solar Home System) and 5% solar lamps. 85% of the country's energy mix is planned to come from renewables by 2030 (75% hydro, 5% wind, 5% solar). The NEP also sets targets for energy efficiency measures, especially for businesses and industries.

Fiscal incentives for Renewable Energy Investment
The Tax Code of 2015 includes a number of fiscal incentives for investments in the production and distribution of renewable energy, investments in renewable energy can benefit from a reduction in corporate income tax can be exempted from VAT; and can be depreciated at an accelerated rate of 30% of the net value. Similar measures for energy efficiency products are under consideration.

3.4.2 Energy Policies in Namibia

National Energy Policy of 2017 – The National Energy Policy of Namibia was based on the country's White Paper on Energy Policy of 1998 which functioned as the country's first energy policy. The White Paper provided guidance in the energy sector for nearly 20 years, but the market changed and new guidance was needed so the government initiated a revision to the measure several years ago. The 2017 Energy Policy created a future-oriented energy policy for Namibia, expressing the government's intent to develop in a way that aligns with Vision 2030. The National Energy Policy aims to "ensure the development of Namibia's natural capital and its sustainable use for the benefit of the country's social, economic and environmental wellbeing". The National Energy Policy vision is a future in which secure, affordable, accessible and sustainable modern energy is available for the country's development, to the benefit of all Namibians. The mission is to initiate the timely development, provision and efficient use of all relevant energy resources necessary for the sustainable development of the country, and enhance access to and the productive use of energy, to the benefit of the present and future generations of Namibians. The main goals are to ensure the security of all relevant energy supplies to the country; to create cost-effective, affordable, reliable and equitable access to energy for all Namibians; to promote the efficient use of all forms of energy; and to incentivise the discovery, development and productive use of the country's diverse energy resources.

3.4.3 Energy Policies in South Africa

White Paper on Energy Policy (1998) – the White Paper sets out objectives for South Africa's energy sector: (1) Increase access to affordable energy services; (2) Improve energy governance; (3) Secure supply through diversity; (4) Stimulate economic development, and (5) Manage energy-related environmental and health Impacts. The White Paper calls for achieving a more sustainable energy mix by capturing more of the country's renewable energy potential and identifies the challenges in energy supply and demand.

National Energy Act 34/2008 – this law considers security of supply, optimisation and utilisation of energy production and integrated planning of energy resources. The Act promotes the implementation of energy efficiency measures and creates a National Energy Development Institute as an public institution to conduct research on energy-related topics.

Amendment of the Compulsory Specification for Incandescent Lamps (VC 8043) – this regulation published in the South African Government Gazette on 7 February 2014 sets efficacy requirements on incandescent lamps such that they must incorporate halogen technology. This regulation took effect on 7 February 2015 and phased out incandescent lamps, under the authority of the National Regulator for Compulsory Specifications Act (Act 5 of 2008).

Integrated National Electrification Programme (INEP, updated in 2016) – started in 2001 and updated in 2016, this programme compliments the 1998 Energy White Paper with a goal of delivering universal energy access to rural households. It provides policy guidance for agencies involved in the implementation of energy planning in South Africa, including Eskom, municipalities and non-grid service providers. The free basic electricity tariff was introduced by this Programme in 2004.

3.4.4 Energy Policies in Uganda

Electricity Act of 1999 - The Electricity Act of 1999 established the institutions and their sources of funding for the electricity sector. The Act sets out the assignment of licenses, the rural electrification objectives and the rights and duties of regulated customers are regulated. The key features of the Act include: (1) liberalization of the electricity industry; (2) disband of the vertically integrated Uganda Electricity Board into three companies – generation, transmission and distribution; (3) establish the Electricity Regulatory Authority; (4) establish the Rural Electrification Fund; (5) establish the Electricity Dispute Tribunal to resolve conflicts referred to it.

Energy Policy 2002 - The Energy Policy of 2002 seeks to meet the energy needs of the population of Uganda for social and economic development in an environmentally sustainable way. The Policy calls for an increase in the access to modern and reliable energy services, including: (1) establish the availability, potential and demand of various energy resources in the country; (2) increase access to modern affordable and reliable energy services as a contribution to poverty eradication; (3) improve energy governance and administration; (4) manage energy-related environmental impacts and (5) increase the role of private sector in the power sector operations and future development.

3.4.5 Energy Policies in Zambia

Energy Regulation Act 1995 (amended 2003) – this Act created the Electricity Regulatory Board (ERB) and defined the responsibilities and powers in the sector. The ERB works to set fuel prices, electricity tariffs (which are subsidised), and oversees the implementation of the Zambia Grid Code, working cooperatively with the Zambia Bureau of Standards for energy supply standards.

Rural Electrification Act 2003 – this Act created the Rural Electrification Authority and established the Rural Electrification Fund. The REA works to implement the Rural Electrification Master Plan (REMP) by establishing and monitoring the work of rural electrification businesses. The Rural Electrification Fund is financed by the Zambian Parliament, along with electricity levies, loans and grants.

Zambian Grid Code of 2006 – the Code was approved by the ERB in 2007 and published in the Zambian Gazette in August 2013. The objective of the Code is to open access to the transmission system, and to enhance more efficient and rapid electrification inline with the country's goals.

Republic of Zambia Vision 2030 – Zambia published its Vision 2030 document in 2006 outlining its goal to become 'a prosperous middle-income nation by 2030'. Contained in this document are goals and objectives designed to establish clean, reliable and affordable energy, and with the lowest total economic, financial, social and environmental cost by 2030.

National Energy Policy (Revised 2008) – this was the main Policy driving the energy sector over the last decade. It worked to open up all market segments to private operators and established two new key institutions for regulating the energy markets and managing investment in the sector.

3.4.6 Energy Policies in Zimbabwe

Rural Electrification Fund Act, 2002 - this Act established the Rural Electrification Fund Board which holds and allocates funding from the Renewable Energy Fund (REF) for projects. The Act also set out the plan for expanding the national grid to rural government buildings and businesses.

Environmental Management Act, 2002 – this Act calls for the sustainable management and protection of Zimbabwe's natural resources, in line with global commitments made by the government.

Energy Regulatory Act, 2011 – this Act established ZERA, the entity responsible for regulating the energy sector and is responsible for creating the legal framework for competition within the sector. ZERA has responsibility for licensing all players in generation, transmission and distribution; and the authority to set electricity tariffs.

National Energy Policy, 2012 – this Policy established a framework for measures to support the development of the energy sector. The objectives of the policy are to accelerate economic growth, promote small and medium-sized enterprises, encourage rural investment, and promote environmentally friendly energy and efficient utilisation of energy resources in Zimbabwe. The policy calls for the unbundling and privatisation of ZESA, promotes the use of renewables and calls for the installation of an additional 1,250 MW of hydro capacity by 2020. The policy calls for the installation of solar water heaters on all new homes, incentives for retrofitting solar water heaters and the use of feed-in tariffs to promote on-grid and off-grid solar applications.

Electricity (Inefficient Lighting Products Ban and Labelling) Regulations, 2017 – this Policy measure sets out minimum energy performance standards for lighting products, maximum mercury content of fluorescent lamps, defines exempted lamp types and identifies specific lighting test standards. Lighting products are required to be labelled with (a) input power in Watts, (b) lumens output, (c) life in hours, (d) voltage rating, (e) energy efficiency labelling (A to G rating). Minimum performance specifications covering efficacy, lumen maintenance and lifetime are then set for linear fluorescent tubes, compact fluorescent lamps, and self-ballasted LED lamps (both directional and non-directional). Section (4)(1)(f) reads that no person shall import, manufacture, distribute or sell an incandescent or filament light bulb.

3.5 Population Distribution – Regionally and Nationally

Overall, approximately two-thirds of the population of nearly 450 million people are living off-grid and one third are connected.[4]

Table 12. Electrification rates and population on/off-grid across the region

Country	2010 % electrified	2016 % electrified	2016 % urban electrified	2016 % rural electrified	Population On-Grid	Population Off-Grid
Angola	40%	35%	69%	6%	9,750,757	18,108,548
Botswana	45%	55%	69%	32%	1,215,058	994,139
Burundi	5%	10%	35%	7%	1,019,927	9,179,343
Comoros	40%	71%	89%	62%	551,971	225,453
Dem. Rep. Congo	15%	15%	35%	0%	11,429,493	64,767,126
Eswatini	35%	84%	90%	71%	1,107,969	211,042
Kenya	18%	65%	78%	60%	30,703,568	16,532,691
Lesotho	17%	34%	63%	24%	739,379	1,435,266
Madagascar	17%	23%	52%	7%	5,573,840	18,660,248
Malawi	9%	11%	49%	3%	1,933,097	15,640,510
Mauritius	99%	100%	100%	100%	1,262,613	0
Mozambique	15%	29%	57%	15%	8,123,100	19,887,591
Namibia	44%	56%	78%	34%	1,358,314	1,067,247
Rwanda	10%	30%	72%	12%	3,488,866	8,140,687
Seychelles	58%	99%	99%	99%	92,485	934
South Africa	83%	86%	87%	83%	47,550,454	7,740,772
South Sudan	0%	1%	4%	0%	118,821	11,763,315
Tanzania	15%	33%	65%	17%	17,780,386	36,099,571
Uganda	9%	19%	23%	19%	7,627,525	32,517,345
Zambia	19%	34%	67%	7%	5,474,200	10,626,387
Zimbabwe	37%	34%	81%	11%	5,364,333	10,413,118
Totals:			70%	43%	162,266,149	284,011,331

Sources: Electrification rates are from IEA, 2017a. Population data is World Bank, 2018.

[4] The total population of the region is approximately 446.3 million people, of which 36% are connected to the grid (162.3 million) and 64% are not connected to the grid (284.0 million). Sources for these estimates are the IEA, 2017 for electrification and the World Bank, 2018 for population.

3.6 Harmonised Trading Code System

The harmonised standard coding system for tracking trading and applicable tariffs around the world is used to classify to track lamps and luminaires (i.e., ‘fixtures’ or ‘fittings’) sold around the world. In general, for household and general lighting equipment including light fittings or illumination devices such as table, wall or ceiling fittings, the section heading code 9405 is applicable. For lamps and lighting equipment for use in self-powered portable lights, heading 8513 applies. Replacement bulbs, lamps and parts have specific headings depending on the technology, however they are primarily found under heading code 8539. Under this heading the more detailed information, the better such as the type of lamp (halogen, tungsten, fluorescent) and the rated voltage.

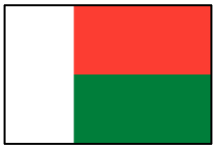
Table 13. Harmonised Codes for Lighting-Related Products

Item	Heading code
Electric ceiling or wall-lighting fittings, chandeliers, excluding those of a kind used for lighting public open spaces or thoroughfares	9405 10
Electric table, desk, bedside or floor-standing lamps	9405 20
Searchlights and spotlights	9405 40 10
LED strip comprising of Light Emitting Diodes, transistors, resistors and protection diodes, (EC Reg 708/2013)	940540
Portable electric lamps designed to function by their own source of energy, for example, battery power torch	8513 10 00 00
Electric filament or discharge lamps, including sealed beam lamp units and ultra-violet or infra-red lamps, arc lamps; light-emitting diode (LED) lamps	8539
Seal beam lamp units	8539 10 00 90
Mains voltage halogen bulbs greater than 100 volts	8539 21 92 90
Low voltage halogen bulbs less than 100 volts	8539 21 98 90
Standard tungsten lamps greater than 100 volts	8539 22 90 90
Tungsten reflector lamps greater than 100 volts	8539 22 10 90
Fluorescent tube - double ended cap type	8539 3110 90
Energy-saving lamps	8539 31 90 90
Mercury vapour lamps	8539 32 20 00
Sodium vapour lamps	8539 32 20 00
Metal halide lamps	8539 32 90 90
Light-emitting diode (LED) lamps and bulbs	8539 50 00 00

Source: Partial list of lighting products, based on BEIS, 2018.

4 Lighting Market Overview

4.1 Country Profile Summary: Madagascar



Capital: Antananarivo
Language: Malagasy French
Median age: 19.5 years (2016 estimate)
National currency: Malagasy Ariary (MGA)

Table 14. At-a-glance Information on Madagascar

Indicator	2015
Population total[1]	24,234,088
Population growth (annual %)[1]	2.68%
Urban Population, % of Total[2]	22%
Rural Population, % of Total[2]	78%
GDP (Current US$)[1]	11,499,803,807
GDP Growth (Annual %)[1]	4.17%
GDP per capita (current US$)[1]	US$450
GDP Annual Growth Rate Forecast to 2019[2]	8.38%
Inflation, consumer prices (annual %)[1]	8.28%
Electrification Rate[3]	23%
Human Development Indicator (rank of 188)[2]	154
TI Corruption Index, 2016 (rank of 100)[2]	28

Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017.

Map source: Nations Online Project, 2018.

4.1.1 On-Grid Lighting Market in Madagascar

There are no lamp or luminaire manufacturers in Madagascar. There had been one that made incandescent lamps until a few years ago, but that company has closed. There are many lamp importers who are operating in Madagascar, most of them import electrical products more broadly and are not exclusively importing lighting products. Lighting products originate from either China or India and some of the largest importers are: Maison Moulou, Master Trade and SANIFER. There is no trade association for lighting suppliers, although there is a consumer association.

The flow diagram below depicts the Supply Chain for lighting products in Madagascar. There is no domestic production (it is a 100% import market).

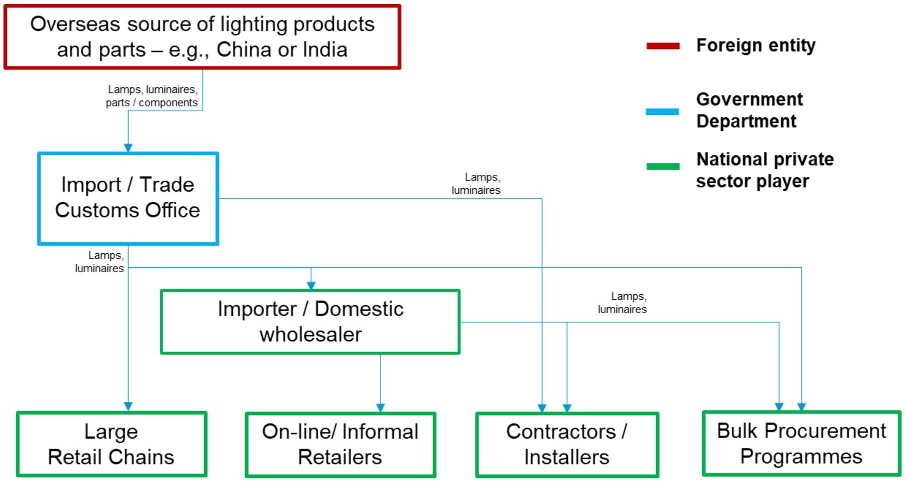


Figure 13. Flow diagram depicting the lighting supply chain in Madagascar

In terms of lighting technologies and volumes, Madagascar's lighting market includes all the technologies identified – incandescent, halogen, compact fluorescent lamps, linear fluorescent, high-intensity discharge (HID) lamps, and light emitting diode lamps and luminaires. For general household lighting, there are low consumption alternatives, but people continue to use incandescent lamps, which are now about 50% of the market.

The tables below provide the estimated annual sales and installed stock of the major lamp types for Madagascar, based on the United Nation's Comtrade database, spanning from 2010 through 2017 and adjusted to account for any irregularities and gaps. These data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017. Compact fluorescent lamps have remained a popular light source throughout this period.

Table 15. Estimated Total Annual Sales of Lamps for All End-Use Sectors in Madagascar

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	588,476	730,225	730,225	871,974	1,157,751	1,157,751	1,443,529	1,231,312
Halogen	140,615	333,765	283,603	233,441	445,573	514,388	850,527	1,144,131
CFL	113,932	129,451	363,073	596,695	334,332	245,413	266,770	228,262
Linear Fluores.	139,250	158,217	443,755	729,293	408,628	299,949	326,052	278,986
HID Lamps	279,980	55,450	41,110	26,770	32,520	34,650	34,650	34,650
LED Lamp	-	-	-	34,042	77,506	115,053	204,866	260,370
LED Tube	-	-	-	14,586	16,345	17,997	26,084	27,899
LED Outdoor	-	-	-	535	1,301	2,079	2,772	3,465

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in Madagascar. The table below presents this estimate, broken down by end-use sector.

Table 16. Estimated Installed Stock of Lamps by Sector in Madagascar (millions of units)

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	0.550	0.056	0.011	0.616
Halogen	0.444	0.057	0.011	0.512
Compact Fluorescent	0.878	0.310	0.034	1.222
Linear Fluorescent	0.327	1.557	0.097	1.981
High Intensity Discharge	0.007	0.029	0.109	0.146
LED Omni-directional	0.165	0.052	0.009	0.226
LED Tube	0.007	0.039	0.002	0.049
LED Outdoor	0.000	0.001	0.003	0.004
Total	**2.378**	**2.100**	**0.278**	**4.757**

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in Madagascar can be calculated. For the above stock of lamps, this equates to 0.295 TWh/yr of electricity consumption, or about 13.6% of the national consumption of 2.170 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

LEDs are on the market in Madagascar and are already used by those who are convinced of its efficiency. LED lamps and luminaires are already used for most of the new building construction projects, however at the household level people are reluctant because of the high upfront cost and they question the value for money.

Madagascar has a national law that is currently being finalised that will ban the use of incandescent lamps. It's expected that this law will be published in June 2019. In addition, the IEC standards relating to energy-efficient lamps have been adopted by Madagascar, including the safety and performance specifications. In 2015, the Energy Ministry recently released a new energy policy which has a target of 100% electrification by 2030.

In addition to these policies, there are also programmes which have sought to promote more energy-efficient lighting. In 2014 the government launched a 3 year incandescent lamp exchange programme, whereby people could bring their incandescent lamps and get 2 low consumption lamp in exchange. Through this programme, one million incandescent lamps were taken out of the installed base. The World Wildlife Fund (WWF) has supported television advertisements, brochures and other information to raise awareness about energy-efficiency. More information about the WWF Madagascar programme can be found by clicking here and clicking here. Discussion underway with the Ministry of Finance to offer incentives to buy energy-efficient lamps, and they are working on a communications campaign to raise awareness and encourage people to switch to energy-efficient lighting.

The BNM (Bureau des Normes de Madagascar) is the agency responsible for standards in the country and only recently has the BNM moved to adopt the IEC standards relating to energy-efficient lighting (up until now, there has not been a specific law/decree concerning these lighting products).

4.1.2 On-Grid Lighting Economic Analysis for Madagascar

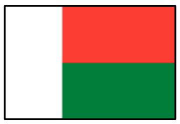
The typical prices paid for popular / common lamps in Madagascar depend on the quality of the product. An incandescent lamp is about US$0.30 for a Chinese or Indian brand. While some LED lamps can be purchased at US$1.00 per lamp, some of the better quality ones are approximately US$5.00 at this time. CFLs are less than US$3.00. The best place to view lamp prices is on the Sanifer website:
https://www.sanifer.mg/64-ampoule-et-led-tananarive-madagascar

Electricity tariffs can be found on this website which has residential tariffs varying between about US$0.15 and 0.25 depending on the geographical area and demographical situation. For this economic calculation, we will use the average of about US$0.20 per kilowatt hour. Given these data, a socket-level economic analysis can be conducted to ascertain the value of moving toward energy-efficient lighting. The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate.

Table 17. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in Madagascar

Madagascar

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.



Country:	**Madagascar**	MGA
Currency conversion to US$:	0.00028	Malagasy Aryary/US$
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.20	US$/kWh
Electricity price:	714	MGA/kWh
Annual change in price of Electricity	7.4%	percent
Electricity CO2 intensity:	0.564	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	**Incandescent**	**Halogen**	**CFL**	**LED**	
Lamp wattage:	60	52	15	7	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	0.50	1.50	2.75	5.00	US$/lamp
Price for one lamp (MGA):	1,786	5,357	9,821	17,857	MGA/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	11	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	77	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	88%	percent
Electricity cost for operating the lamps each year:	17.52	15.23	4.38	2.10	US$/year
Financial savings of electricity costs per year vs. incandescent:		2.29	13.14	15.42	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	183.38	164.05	50.99	26.38	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	19.33	132.38	157.00	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	11%	72%	86%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	6.9	8.1	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.44	0.17	0.29	years
Simple Payback period in months, compared with incandescent:	---	5.3	2.1	3.5	months
Payback period is (X) percent better than halogen payback period:	---	---	61%	33%	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	181%	659%	388%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	494.1	429.6	123.5	59.3	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	64.4	370.5	434.8	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	575%	percent

Given the data provided for Madagascar, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 3.5 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$157.00 – far exceeding the incremental first cost of US$4.50. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in Madagascar. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

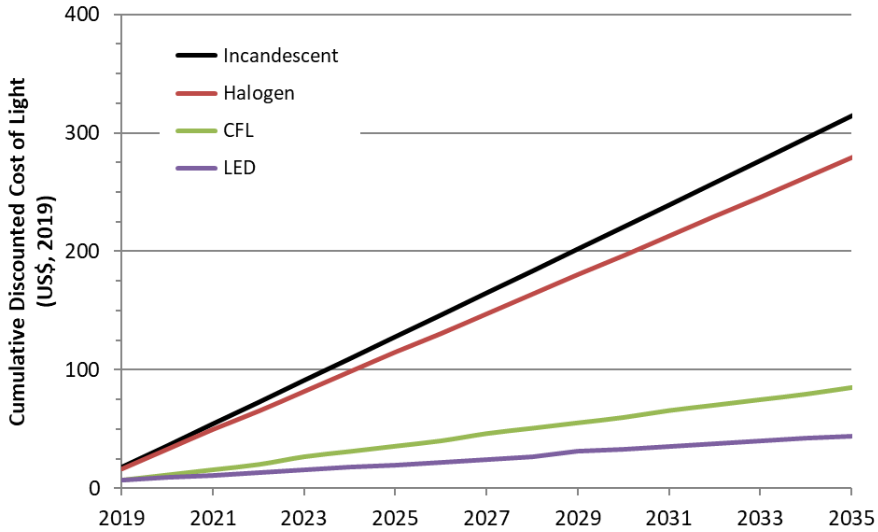


Figure 14. Cumulative Discounted Cost of Light Graph for a Lamp in a Madagascar Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

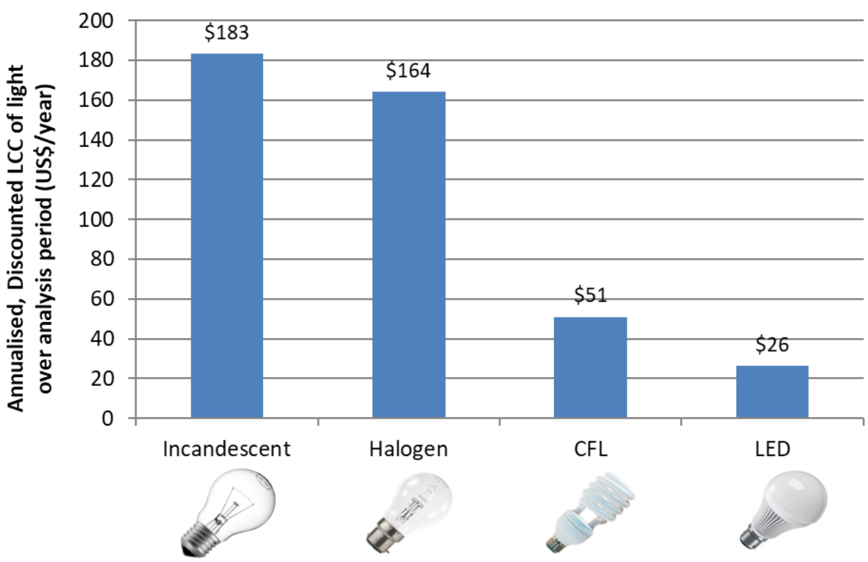


Figure 15. Annualised Discounted LCC for a Lamp over 10-years in a Madagascar Household

While the above economics are compelling, there are still some market barriers in Madagascar which need to be overcome for energy-efficient lighting. The main barriers are awareness and affordability. First, people need to be aware of the low consumption light source and the benefits that it can offer them, and secondly they need to be able to afford the up-front cost which is several times more than an incandescent lamp. The trend in the market is towards low-consumption lamps, but these barriers will affect the rate at how quickly the market adopts them.

4.1.3 Off-Grid Lighting Market in Madagascar

All of the off-grid lighting technologies commonly found in the market are used in Madagascar – candles, kerosene (simple and hurricane lamp), torches and solar LED lanterns and solar home systems. In terms of where these technologies can be found, the kerosene and candles are specifically for domestic use and small retailers, they are not used for larger or more formal retail establishments. For practical reasons, people tend to use candle and kerosene lamps indoors and then torches when they need to walk somewhere at night.

In Madagascar there are a lot of candle manufacturers, both on an industrial scale but also hand-made by small enterprises. There are no local manufacturers of solar LED lanterns, however there is assembly of the components of solar kits. The companies that are participating in this market are Baobab+ and other members of the Global Off-Grid Lighting Association (GOGLA), and they are local branches of foreign manufacturers.

The off-grid lighting supply chain diagram below indicating key players, main routes to market and so-on is representative of Madagascar, bearing in mind that all lighting products are included in the flow.

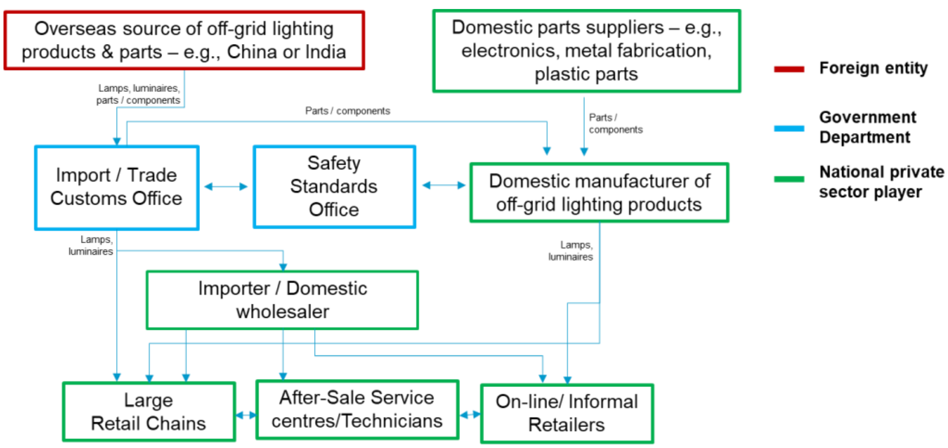


Figure 16. Flow diagram depicting the off-grid lighting supply chain in Madagascar

The following table provides an estimate of the off-grid lighting stock estimate for Madagascar, based on analysis that was prepared by the United Nations Environment Programme (UNEP) en.lighten initiative, and published in 2015. This table provides an estimate of the millions of lamps in the installed base of households and small businesses across Madagascar. Overall, it is estimated that there are approximately 8.4 million light sources for off-grid households and 0.9 million light sources for off-grid small businesses.

Table 18. Installed Stock Estimate of Off-Grid Lighting in Madagascar

Light source	Households	Businesses
Kerosene lamp (glass cover)	1.2186 (14.4%)	0.3922 (42.0%)
Kerosene lamp (simple wick)	6.0061 (71.1%)	0.3588 (38.4%)
Torch (flashlight)	0.8705 (10.3%)	0.1252 (13.4%)
Candles (light points)	0.3482 (4.1%)	0.0584 (6.3%)
Total:	8.4434 million	0.9346 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in Madagascar, spending around US$5.16 per month on fuel-based lighting.

Table 19. Average Household Monthly Costs, Off-Grid Lighting in Madagascar

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	6 litres	0.73 USD / litre	4.38 USD
Candles	2.8 candles	0.10 USD / candle	0.28 USD
Batteries	1 battery	0.50 USD / battery	0.50 USD
		Total:	**5.16 USD**

To promote more sustainable energy technologies, the Madagascar government has a policy that renewable energy sources do not pay value added tax (VAT). In addition to this, there are some programmes that have been recently launched that are promoting solar lighting, including:

- Baobab + is a social enterprise that works in the fields of access to energy and digital. We market innovative products with financing solutions in Senegal, Mali, Madagascar and Ivory Coast. In parallel with the distribution of solar kits through the agencies of the Baobab network, they offer a Pay-As-You-Go offer to make their products accessible to all. https://www.baobabplus.com

- HERi places kiosks in rural villages and offers both a solar lantern rental scheme as well as a pay-as-you-go system. For less than 200 ariary per day (around four Euro cents), customers can rent a solar lantern that is charged in the kiosks during the day and delivered to their home before nightfall. As a result, people without access to reliable energy can benefit from clean, reliable and affordable lights – all by making daily micro-payments, just like they were already doing to buy candles or kerosene. https://heri.mg/

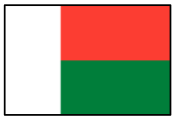
4.1.4 Off-Grid Lighting Economic Analysis for Madagascar

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for Madagascar), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting and deliver far more light (higher lumens).

Table 20. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in Madagascar

Madagascar

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.



Country:	**Madagascar**	MGA
Currency conversion to US$:	0.00028	Malagasy Aryary/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	0.73	US$/litre
Average kerosene price:	2607	MGA/litre
Annual change in price:	7.4%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	**Candle**	**Kero Lamp Sm**	**Kero Lamp Lg**	**Solar Small**	**Solar Large**	**Solar Home Sys.**	
Price for one light source (USD):	0.10	1.50	6.00	20.00	40.00	90.00	US$/product
Price for one light source (MGA):	357	5,357	21,429	71,429	142,857	321,429	MGA/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	1.50	6.00	20.00	40.00	90.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	36.50	20.25	31.97	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	208.34	130.29	204.54	52.73	72.65	90.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	155.61	135.69	118.34	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	75%	65%	57%	percent
LCC savings compared with kerosene lamp large:	---	---	---	151.82	131.89	114.54	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	27%	37%	45%	percent
Discounted, annualised LCC of light over 6 years of use:	34.72	21.72	34.09	8.79	12.11	15.00	US$/year
As above, but normalised for 1 megalumen-hour of light:	1,894	992	778	60	28	10	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.55	1.09	2.46	years
Simple Payback period in months, compared with candles:	---	---	---	6.5	13.1	29.6	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.44	1.06	2.63	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	5.3	12.8	31.5	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	164%	84%	43%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for Madagascar, the calculation shows that the payback period of moving from candles to a solar system has a payback of 0.55 to 2.46 years, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 0.44 and 2.63 years – still less than 3 years even for the most expensive solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in Madagascar is compelling – hence the success of the Bayobab+ and HERi business models.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in Madagascar. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the third year compared with the fuel-based light sources.

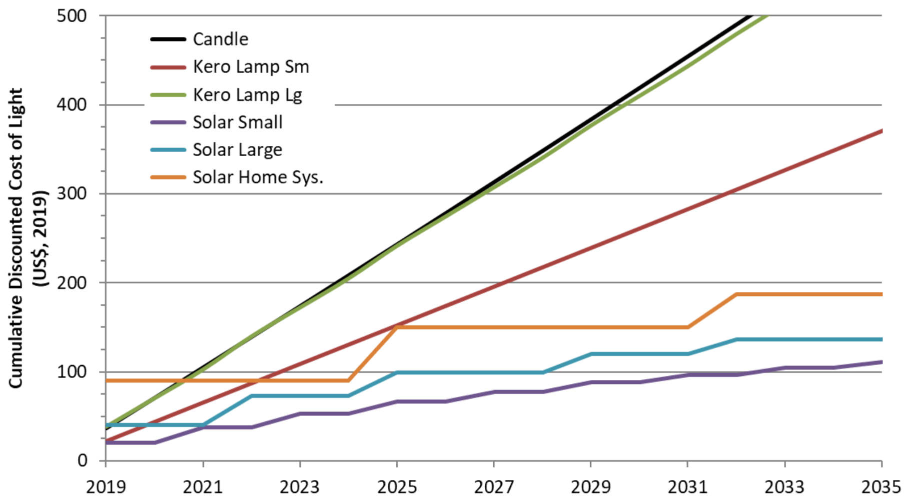


Figure 17. Cumulative Discounted Cost of Off-Grid Lighting for a Madagascar Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-4 times cheaper to own and operate compared to the kerosene and candle-based sources.

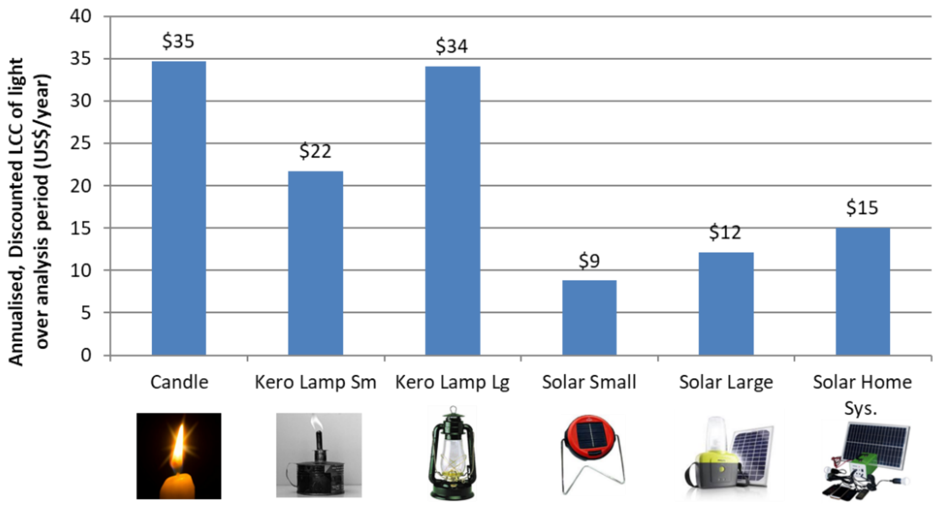


Figure 18. Annualised, Discounted LCC of Off-Grid Lighting for a Madagascar Household

Off-grid solar lighting systems tend to be sold with warranty, however in most cases it is actually after sales service and repair, rather than replacement. Companies like Baobab+ stay in villages for a while, as sales increase and decrease. As long as they are around, they provide aftersales service to their customers – their technicians help people fix the products, fixing it for free if no expensive spare parts are needed. If they have to order a replacement part for the repair, then the customer would have to pay. There is a notable trend in the off-grid lighting market towards solar lighting, moving away from kerosene and candle-based lighting.

4.2 Country Profile Summary: Namibia

Capital: Windhoek
Language: English, Hereo, Kwangali
Median age: 21 years
National currency: Namibian dollar (South African Rand)

Table 21. At-a-glance Information on Namibia

Indicator	2015
Population total[1]	2,425,561
Population growth (annual %)[1]	2.28%
Urban Population, % of Total[2]	49%
Rural Population, % of Total[2]	51%
GDP (Current US$)[1]	11,769,045,772
GDP Growth (Annual %)[1]	6.11%
GDP per capita (current US$)[1]	US$4852
GDP Annual Growth Rate Forecast to 2019[2]	3.30%
Inflation, consumer prices (annual %)[1]	3.41%
Electrification Rate[3]	56%
Human Development Indicator (rank of 188)[2]	129
TI Corruption Index, 2016 (rank of 180)[2]	53

Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017.

Map source: Nations Online Project, 2018.

4.2.1 On-Grid Lighting Market in Namibia

The lighting supply chain in Namibia is characterized by a purely import business. There are no lamp or luminaire manufacturers in Namibia. There are several importers identified:

- Main electrical companies – Beka Lighting; Pupkewitz MegaTech; Voltex; Global Electric;
- Electrical Wholesalers: Electrotech, Ellies, CTS – these also sell electrical parts.
- Construction companies – cash build, build-it
- Supermarkets – Pick n Pay, Game, ShopRite; Now; Spar, Checkers
- Small companies – Target Rating – they import directly lights and LEDs from China; Windhoek Electrical Warehouse
- A lot of Chinese companies – sell tiles and LEDs and solar lighting, batteries plus many other things.
- LED Lighting

Most of these distributors supply different types of lamps, but the focus is now shifting to LED lamps, including both LED filament and normal LED lamps. The lighting importers also import fluorescent lamps – both compact fluorescent lamps and linear fluorescent tubes.

At the national level, the leading suppliers are: Game, Pupkewitz, MegaTech, Beka Lighting and Voltex. There is currently no lighting manufacturers association in Namibia.

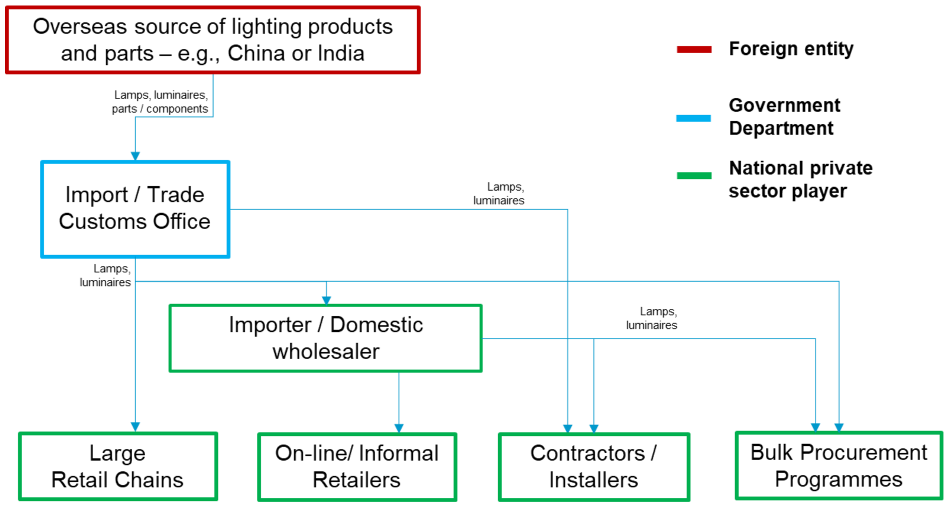


Figure 19. Illustration of the Lighting Supply Chain in Namibia

The market carries all lamp types that were presented in the questionnaire – incandescent, halogen, compact fluorescent, light emitting diode, linear fluorescent, high-intensity discharge lamps. These lamps are sold in all the sectors – domestic, commercial and industrial.

In terms of safety standards, there are no standards which are adhered to at the moment in Namibia. Companies can import products like street lights from China, for example, and there are no questions about the standard or compliance. Essentially, there aren't any safety standards in place, and if there were, there is limited capacity for oversight by the government. In the absence of Namibian standards, the market has started using the South African Bureau of Standards (SABS) requirements for customers who want some quality and safety assurances.

According to the experts interviewed, when it comes to household level decisions about lighting, in general it is the women who choose the fixture / fitting – to match the design and look they want to achieve in their home. The lighting technology that is used inside is not so critical, as long as it fits and works – the technology choice can be made by either the husband or the wife, depending on who is going to the store for the family.

The tables below provide the estimated annual sales and installed stock of the major lamp types for Namibia, based on the United Nation's Comtrade database, spanning from 2010 through 2017 and adjusted to account for any irregularities and gaps. These data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017. Compact fluorescent lamps have remained a popular light source throughout this period.

Table 22. Estimated Total Annual Sales of Lamps for All End-Use Sectors in Namibia

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	1,216,658	699,871	183,083	540,182	545,546	545,546	550,910	550,910
Halogen	233,451	341,290	131,118	169,599	413,545	601,505	868,330	1,083,958
CFL	793,265	793,265	284,220	343,764	641,736	1,672,245	1,232,415	2,207,061
Linear Fluores.	969,546	969,546	347,380	420,156	784,344	2,043,855	1,506,285	2,697,519
HID Lamps	48,430	33,890	77,209	37,020	102,190	75,800	76,940	76,940
LED Lamp	-	-	-	21,071	64,033	169,158	212,132	384,193
LED Tube	-	-	-	8,403	31,374	122,631	120,503	269,752
LED Outdoor	-	-	-	740	4,088	4,548	6,155	7,694

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in Namibia. The table below presents this estimate, broken down by end-use sector.

Table 23. Estimated Installed Stock of Lamps by Sector in Namibia (millions of units)

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	0.268	0.027	0.005	0.301
Halogen	0.457	0.060	0.012	0.529
Compact Fluorescent	2.201	0.894	0.099	3.194
Linear Fluorescent	0.830	3.697	0.231	4.758
High Intensity Discharge	0.012	0.048	0.179	0.239
LED Omni-directional	0.159	0.084	0.011	0.254
LED Tube	0.024	0.130	0.008	0.162
LED Outdoor	0.000	0.002	0.007	0.009
Total	3.952	4.941	0.554	9.447

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in Namibia can be calculated. For the above stock of lamps, this equates to 0.615 TWh/yr of electricity consumption, or about 16.2% of the national consumption of 3.800 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

LED lamps are expanding their market share in Namibia. The national electric utility, Nampower is currently running a 1 million Light Emitting Diode (1mLED) Campaign has given great impetus the penetration of LEDs as a method of reducing expenses on Electricity by Residents and Businesses. As a result, retailers are stocking LED's. Solar Companies are also playing a role in this shift as they mostly use LED Lamps for their installations and advice their clients to have LED lamps instead of the previously popular incandescent lamps. However, it is still possible to purchase incandescent lamps in Namibia, as their first cost is very low and there are some users who are unwilling to change.

There is no policy in Namibia to promote EE lighting at this time, although SADC has issued a regional directive to ban incandescent lamps. Currently, the Ministry of Mines and Energy is looking to prepare a National Energy Efficiency Policy by 2020. Namibia is also interested in looking at energy labelling, to help communicate information about energy and running costs to consumers.

There is no organization responsible for lighting product testing in Namibia at the moment. The most likely organization to take over this responsibility in the short term would be the Namibia Standards Institute (NSI) in collaboration with the Namibia Energy Institute (NEI). Both are government institutions. NSI focuses on all the standards on all the products being imported and manufactured in the country. NEI focuses on all aspects relating to energy and developing an energy policy for the country. Within NSI, Technical

Committee 4 (TC4) is responsible for Energy Efficiency. Both NSI and NEI will be important to engage to ensure the right quality, performance and safety standards are adopted, and that they are enforced.

4.2.2 On-Grid Lighting Economic Analysis for Namibia

The prices of lighting technologies paid by people vary by technology and by region. In the rural areas, things are a little bit more expensive because retailers have to factor in transport due to long distances for a large country like Namibia. The prices given in Table 24 represent national averages.

Table 24. Estimated Average National Prices of Common Lamps in Namibia (Dec 2018)

Lamp Type	Namibian $	US $
Incandescent	N$15.00	$1.08
Compact Fluorescent	N$27.00	$1.94
LED Lamps	N$89.00	$6.41
LED Filament Lamps	N$73.00	$5.26

The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate. Electricity costs, on average, around N$2.10/kWh – about US$0.15/kWh.[5]

[5] The Namibian Electricity Control Board website provides good pricing information for electricity: https://www.ecb.org.na/index.php/electricity/economic-regulation/tariffs

Table 25. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in Namibia

Namibia

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.

Country:	**Namibia**	NAD
Currency conversion to US$:	0.072	Namibian Dollar
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.15	US$/kWh
Electricity price:	2.08	NAD/kWh
Annual change in price of Electricity	3.4%	percent
Electricity CO2 intensity:	0.051	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	**Incandescent**	**Halogen**	**CFL**	**LED**	
Lamp wattage:	60	52	15	7	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	1.08	1.50	1.94	6.00	US$/lamp
Price for one lamp (NAD):	15	21	27	83	NAD/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	10	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	77	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	88%	percent
Electricity cost for operating the lamps each year:	13.14	11.43	3.29	1.53	US$/year
Financial savings of electricity costs per year vs. incandescent:		1.71	9.86	11.61	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	124.47	107.58	32.86	19.21	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	16.89	91.61	105.26	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	14%	74%	85%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	5.4	6.2	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.25	0.09	0.42	years
Simple Payback period in months, compared with incandescent:	---	2.9	1.0	5.1	months
Payback period is (X) percent better than halogen payback period:	---	---	64%	not defined	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	382%	1322%	274%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	44.7	38.8	11.2	5.2	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	5.8	33.5	39.5	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	577%	percent

Given the data provided for Namibia, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 5.1 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$105.26 – far exceeding the incremental first cost of US$5. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in Namibia. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

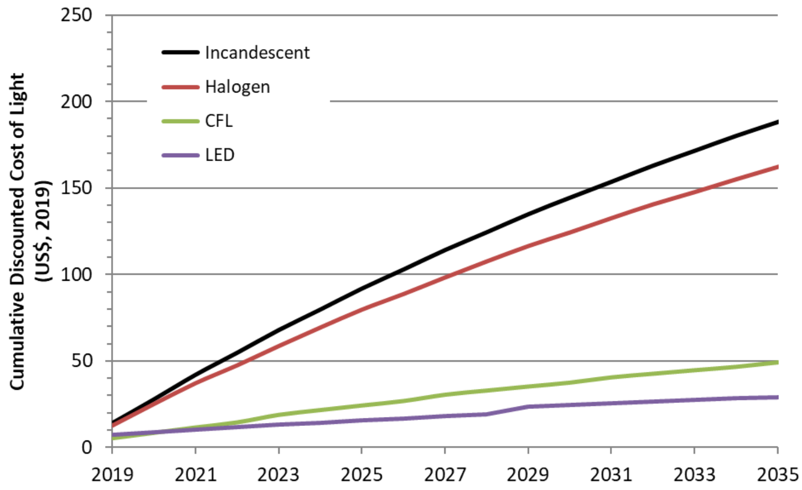


Figure 20. Cumulative Discounted Cost of Light Graph for a Lamp in a Namibian Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

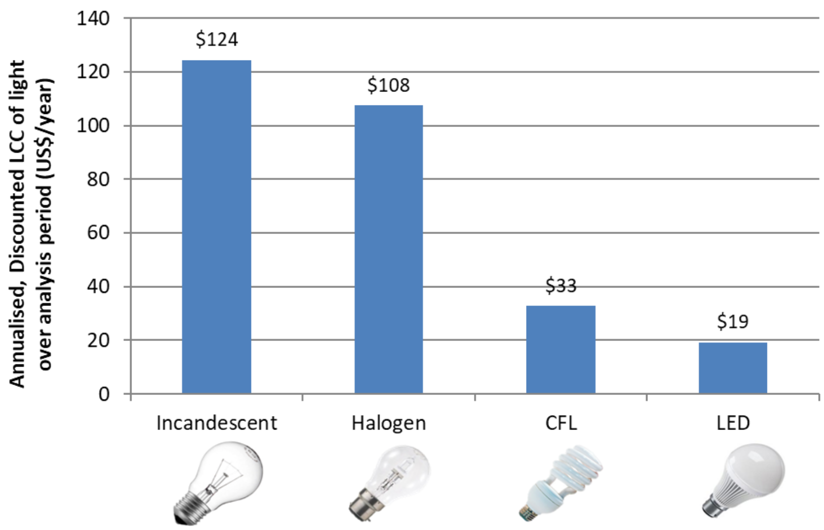


Figure 21. Annualised Discounted LCC for a Lamp over 10-years in a Namibian Household

In Namibia, affordability is a major barrier to energy-efficient lighting – when they look at the cost of the bulb and it's a little bit higher, they may not know about the cost and payback period, and they just choose the cheaper bulb. After affordability, the next most important barriers are availability and customer awareness - sometimes people in the rural areas understand the differences between the light bulbs and what it means. Acceptance is not a barrier - efficient lighting is the way to go, and so it just becomes a question of whether they can afford to go that route.

4.2.3 Off-Grid Lighting Market in Namibia

All of the off-grid lighting technologies commonly found in the market are used in Namibia – candles, kerosene (simple and hurricane lamp), torches and solar LED lanterns and solar home systems. The technologies used by the typical household in Namibia will depend on the income level of that home. The poorest families will still use candles and kerosene, with a torch if they need to walk at night. Some households might have a solar lantern or solar kit, and finally for those who can afford it, they'll have a solar home system which could even run some energy-efficient appliances.

There are no off-grid lighting product manufacturers in Namibia, off-grid lighting is purely an import market at this time. Most of the off-grid market is served by renewable energy companies who procure from the suppliers identified in the on-grid market - Luminaires Direct, Electro Dynamics, Beka Lighting, Windhoek Electrical Warehouse, Megatech and retails stores (e.g., Pick 'n Pay, OK, Shoprite, GAME, Woermann Brock, etc).

There is no national association for solar off-grid lighting suppliers, although there is an association for renewable energy where aspects of efficient off-grid lighting are part of that bigger body. This renewable energy body will focus on standards for on-grid and off-grid – and within the off-grid standards, would look at efficient lighting. This renewable energy association is a very small group, having very few members.

The off-grid lighting supply chain diagram below indicating key players, main routes to market and so-on is representative of Namibia, bearing in mind that there is no domestic manufacturing or assembly of off-grid lighting products at this time.

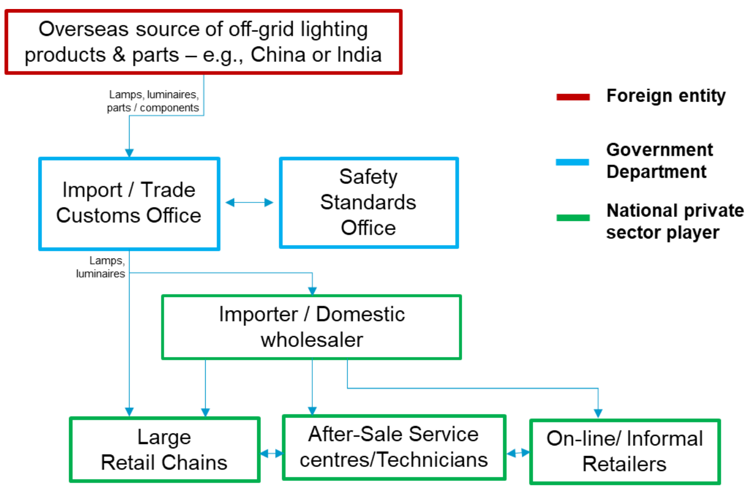


Figure 22. Flow diagram depicting the off-grid lighting supply chain in Namibia

When looking at off-grid, the focus is mostly residential. For businesses, they try to do one of two things – either move their businesses to grid connected areas or invest in off-grid technology (which is not very common). So the supply chain shown above is mostly for the residential household. Namibia is a very large country with a relatively small population, so people are sparsely located. This is a simplified value chain, but in fact it could be simplified even further – companies can get bulbs directly from a foreign supplier.

The following table provides an estimate of the off-grid lighting stock estimate for Namibia, based on analysis that was prepared by the United Nations Environment Programme (UNEP) en.lighten initiative, and published in 2015. This table provides an estimate of the millions of lamps in the installed base of households and small businesses across Namibia. Overall, it is estimated that there are approximately 0.9 million light sources for off-grid households and 61 thousand light sources for off-grid small businesses.

Table 26. Installed Stock Estimate of Off-Grid Lighting in Namibia

Light source	Households	Businesses
Kerosene lamp (glass cover)	0.0546 (6.3%)	0.0087 (14.3%)
Kerosene lamp (simple wick)	0.0728 (8.3%)	0.0087 (14.3%)
Torch (flashlight)	0.0273 (3.1%)	0.0130 (21.4%)
Candles (light points)	0.7194 (82.3%)	0.0303 (50.0%)
Total:	0.8742 million	0.0606 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in Namibia, spending around US$7.25 per month on fuel-based lighting.

Table 27. Average Household Monthly Costs, Off-Grid Lighting in Namibia

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	1.1 litres	1.12 USD / litre	1.23 USD
Candles	58.6 candles	0.10 USD / candle	5.86 USD
Batteries	0.3 batteries	0.55 USD / battery	0.16 USD
		Total:	**7.25 USD**

The only national policy that promotes off-grid lighting products is from 2007, its called the "Off-Grid Energisation Master Plan for Namibia". It is available by clicking on this link. Although this policy is more than ten years old it is a very important one because it set up several of the institutions in Namibia today working to promote solar in the off-grid space, as part of the national electrification strategy. For example, the Revolving Solar Fund was created from this policy document.

The customer purchases solar lighting systems either through a cash payment or through two alternative schemes:

- Cash purchase – in this scenario, the customer purchases a solar lighting system with cash. There are energy shops near where they live and they can just go in and buy the system they want with cash. Given that most of the amps retailing at 300 or 400, they tend to pay cash;
- PAYGO purchase – in this approach, the customer pays through a local mobile network operator and they own the system once they have finished paying. This is being done by the commercial players who use the mobile network as a payment platform – the pay-as-you-go (PAYGO) system – they can switch on/off if the customer hasn't paid and they can either pay per week or per month until they finish paying and own the product.
- Solar Revolving Fund – Namibia also offers customers access to the Solar Revolving Fund (SRF). The SRF is outsourced by the Namibia Development Corporation (NDC), to NamPower, the national electric utility. The SRF is a credit facility established by MME to stimulate demand for the utilization of renewable energy technologies in the rural areas, especially for communities living in off-grid areas, but also to urban clients.

In general, about half the households purchase with cash and half using the SRF. The SRF provides loans up to N$35000 for a solar home system, and the interest on the loan is 5% and the loan term is 5 years (60 months). The fund is open to all nationals, as long as you show the ability to pay back the loan (i.e., it is not a grant) – and the Ministry of Mines and Energy maintains a list of pre-qualified installers that carry out the installations for the clients. There are approximately fifteen installers in Namibia. The SRF was capitalised initially and facilitates approximately 70 million per annum of investment in the off-grid, of which SRF is part of the total budget.

4.2.4 Off-Grid Lighting Economic Analysis for Namibia

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for Namibia), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting and deliver far more light (higher lumens).

Table 28. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in Namibia

Namibia

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.

Country:	**Namibia**	NAD
Currency conversion to US$:	0.072	Namibian Dollar/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	1.00	US$/litre
Average kerosene price:	14	MGA/litre
Annual change in price:	3.4%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	**Candle**	**Kero Lamp Sm**	**Kero Lamp Lg**	**Solar Small**	**Solar Large**	**Solar Home Sys.**	
Price for one light source (USD):	0.10	2.00	8.50	25.00	40.00	100.00	US$/product
Price for one light source (NAD):	1	28	118	347	556	1,389	NAD/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	2.00	8.50	25.00	40.00	100.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	36.50	27.74	43.80	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	195.99	163.29	257.16	65.91	72.65	100.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	130.08	123.34	95.99	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	66%	63%	49%	percent
LCC savings compared with kerosene lamp large:	---	---	---	191.25	184.50	157.16	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	2%	6%	20%	percent
Discounted, annualised LCC of light over 6 years of use:	32.67	27.21	42.86	10.98	12.11	16.67	US$/year
As above, but normalised for 1 megalumen-hour of light:	1,781	1,243	979	75	28	11	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.68	1.09	2.74	years
Simple Payback period in months, compared with candles:	---	---	---	8.2	13.1	32.8	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.38	0.72	2.09	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	4.5	8.6	25.1	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	119%	79%	34%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for Namibia, the calculation shows that the payback period of moving from candles to a solar system has a payback of 0.68 to 2.74 years, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 0.38 and 2.09 years – basically 2 years for the most expensive option, the solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in Namibia is compelling – hence the success of the SRF business model.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in Namibia. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the third year compared with the fuel-based light sources.

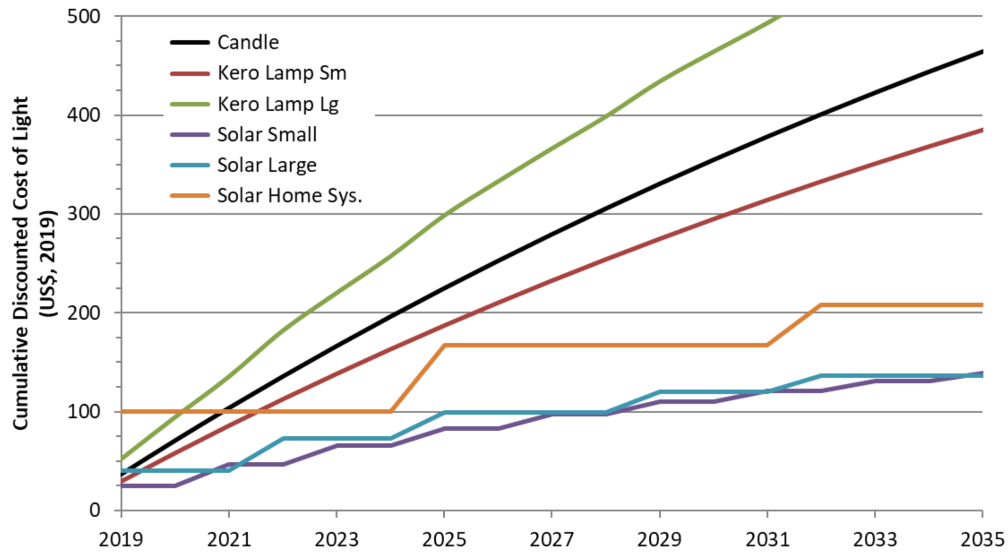


Figure 23. Cumulative Discounted Cost of Off-Grid Lighting for a Namibia Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-4 times cheaper to own and operate compared to the kerosene and candle-based sources.

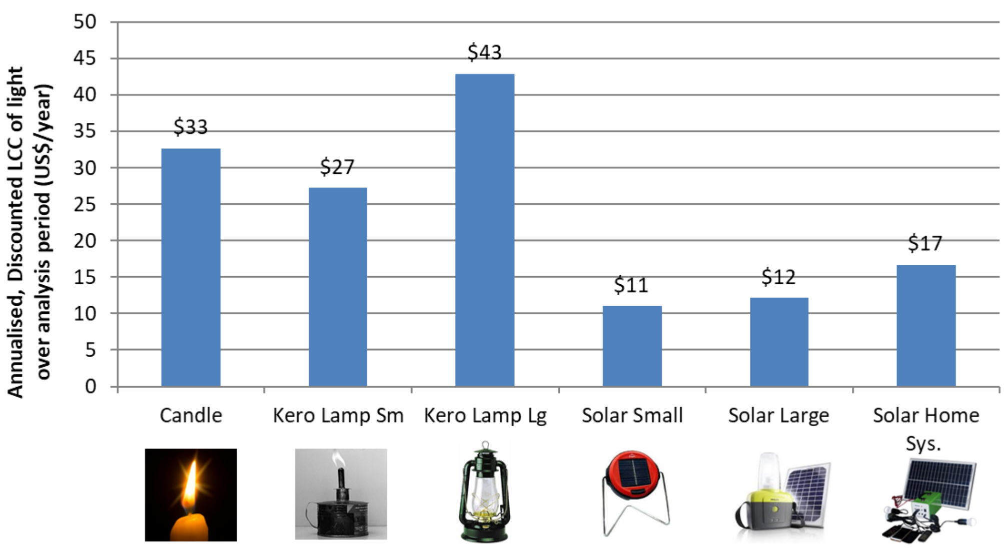


Figure 24. Annualised, Discounted LCC of Off-Grid Lighting for a Namibian Household

Affordability is the top criterion for customers today. They may choose to go with a Chinese product and get no warranty, but for a client who can afford it, they do look at the warranty.

There is a lot of activity taking place in Namibia in the off-grid sector. There are many small, registered companies who are trying to be innovative by going out, raise awareness in the community and through that process, they sell the products. Many schools and many public institutions are switching to use solar technology – they are using mini-grids, and a number of schools are now supplied through mini-grids. Furthermore, there is trend towards the people wanting Internet access – and you'll find that suppliers are being innovative and offer to set-up internet so they can collect their payments for the smaller systems with very low overhead costs.

4.3 Country Profile Summary: South Africa

Capital: Pretoria (Executive), Cape Town (Legislative), Bloemfontein (Judicial)
Language: 11 Official Languages, but English is commonly used in Government
Median age: 26.5 years (2015 estimate)
National currency: South African Rand (ZAR)

Table 29. At-a-glance Information on South Africa

Indicator	2015
Population total[1]	55,291,225
Population growth (annual %)[1]	1.37%
Urban Population, % of Total[2]	64%
Rural Population, % of Total[2]	36%
GDP (Current US$)[1]	317,741,039,198
GDP Growth (Annual %)[1]	1.28%
GDP per capita (current US$)[1]	US$5747
GDP Annual Growth Rate Forecast to 2019[2]	2.28%
Inflation, consumer prices (annual %)[1]	4.59%
Electrification Rate[3]	86%
Human Development Indicator (rank of 188)[2]	113
TI Corruption Index, 2016 (rank of 167)[2]	61

Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017.

Map source: Nations Online Project, 2018.

South Africa is the largest economy in the region, representing 43% of the total GDP of all twenty-one countries across SADC and EAC. South Africa has the fourth highest GDP per capita, and the second largest population with 55 million people. Many of the lamps and luminaires sold in the region are either made in South Africa or come through its ports. For this reason, South Africa is in a pivotal position to drive market transformation in the region and potentially also play a strong role in regional market surveillance.

4.3.1 On-Grid Lighting Market in South Africa

Luminaire manufacturing is a robust industry in South Africa, with approximately five to six companies making products for the local and export markets. There are a few companies that claim to be 'manufacturers' of LEDs, but they are actually doing advanced assembly, such as making LED light modules. The products are made for both the residential and professional markets, and to some extent are more of the up-market / decorative type fittings. And despite the local manufacturing, the South African luminaires market is approximately 70 percent imports and 30 percent local. There is no lamp manufacturing in South Africa anymore, thus lamps are a 100 percent import market. There had been a CFL manufacturing plant in Lesotho which was created as part of the World Bank / International Finance Corporation's Efficient Lighting Initiative (ELI), but the Philips Lighting joint venture did not sustain on-going investment and eventually stopped producing CFLs and was closed.

The lamp importers operating in South Africa are as follows:
All the major global brands are offered for sale in South Africa, including for example Philips Lighting, Osram/LEDvance and General Electric. Radiant Lighting, EuroLux and Ellies are also major players in the market, with sales domestically and regional exports. Radiant Lighting and Eurolux lead the strong wholesale market in South Africa. These companies import large volumes of branded LEDs sourced directly from China. Many building designers and architects buy these two brands, they are the two dominant players in South Africa with a combined market share of 80% though EuroLux is a little bigger than Radiant.

The prices of LED lamps have come down substantially in part due to poor quality products being imported, e.g., lasting only 1000 hours or less. The pricing observed in South Africa is pretty standard across the market, however you might see slightly higher prices in rural areas because of volumes & transport costs. Domestic LED lamps cost are now normally around R30-50. Some of the retailers in South Africa who carry the LED lamps include: Builders Warehouse, Game, Makro, PickNPay, Shoprite/Checkers and Spar.

South Africa has a lighting manufacturers association – the Illuminating Engineering Society of Southern Africa (IESSA). They have a working group for LED which focuses on the developing market for LED, standardisation of tests for LED and so-on. This association is both a standards organisation and a manufacturer's association.

The flow diagram below depicts the Supply Chain for lighting products in South Africa. Lighting products are both imported and manufactured domestically, so retailers can source from either channel. The domestic manufacturers constitute about 30% of the volume in the market.

There is no domestic production (it is a 100% import market), and apparently the Office of Standards is not yet involved in controlling the lamps, so retailers are able to purchase lamps directly from overseas.

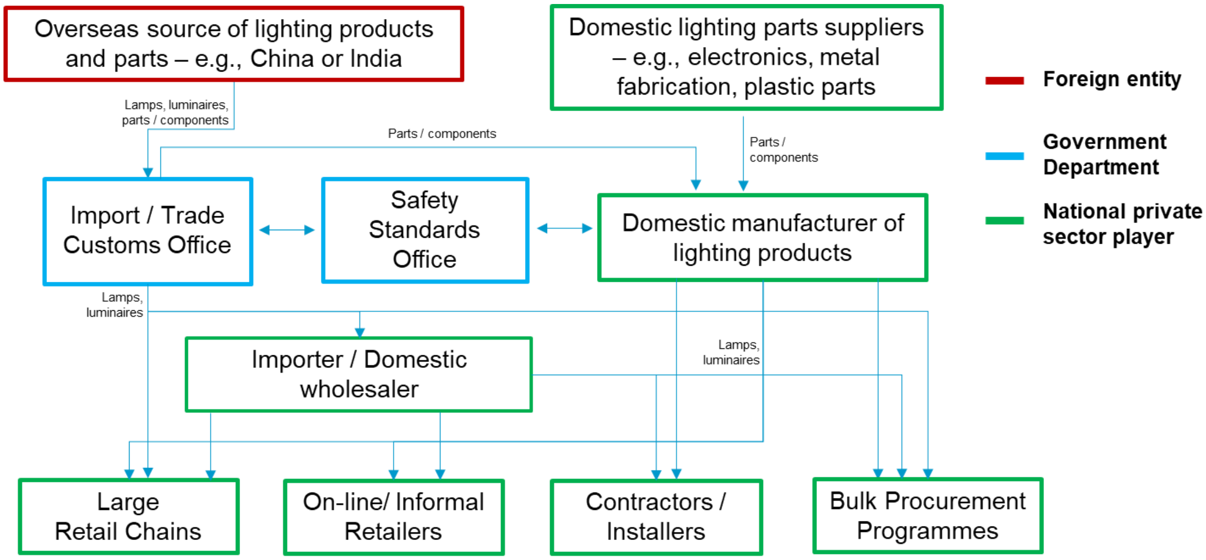


Figure 25. Flow diagram depicting the lighting supply chain in South Africa

The market carries all lamp types that were presented in the questionnaire – incandescent, halogen, compact fluorescent, light emitting diode, linear fluorescent, high-intensity discharge lamps. These lamps are sold in all the sectors – domestic, commercial and industrial. In the commercial sector, the market is transforming itself into LED without any outside influence. LED lamps are chosen most often....right across the spectrum, even in the off-grid market with the solar home systems. It is very rarely to find other technologies specified or newly installed. South Africans like to adopt best practice, especially from European markets.

The tables below provide the estimated annual sales and installed stock of the major lamp types for South Africa, based on estimates indexed from the United Nation's Comtrade database, spanning from 2010 through 2017. The data were calibrated with estimates of the national sales from the national impacts analysis on the lighting regulation. Overall, these data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017. Compact fluorescent lamps have remained a popular light source throughout this period and are currently being promoted by Eskom, the national utility.

Table 30. Estimated Total Annual Sales of Lamps for All End-Use Sectors in South Africa

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	8,547,383	7,798,913	7,050,444	5,873,364	4,696,283	2,975,007	2,741,233	2,428,721
Halogen	109,632,474	119,957,899	68,283,640	76,014,087	82,425,058	79,845,826	78,231,737	74,232,885
CFL	32,331,798	36,722,342	28,196,253	33,401,639	34,795,643	35,308,134	38,310,260	39,915,808
Linear Fluor.	39,516,642	44,882,863	34,462,087	40,824,226	42,528,008	43,154,386	46,823,652	48,785,988
HID Lamps	1,796,211	2,040,130	1,566,459	1,855,647	1,933,091	1,961,563	2,128,348	2,217,545
LED Lamp	-	-	-	2,305,782	4,876,679	7,087,738	9,542,658	11,657,741
LED Tube	-	-	-	816,485	1,701,120	2,589,263	3,745,892	4,878,599
LED Outdoor	-	-	-	37,113	77,324	117,694	170,268	221,754

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in South Africa. The table below presents this estimate, broken down by end-use sector.

Table 31. Estimated Installed Stock of Lamps by Sector in South Africa (millions of units)

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	2.8	0.2	0.0	3.1
Halogen	88.1	7.0	1.4	96.5
Compact Fluorescent	100.4	31.4	3.5	135.3
Linear Fluorescent	36.8	162.0	10.1	209.0
High Intensity Discharge	0.3	1.3	4.8	6.4
LED Omni-directional	9.6	4.0	0.6	14.2
LED Tube	0.8	4.1	0.3	5.1
LED Outdoor	0.0	0.0	0.2	0.2
Total	238.8	210.1	20.9	469.8

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in South Africa can be calculated. For the above stock of lamps, this equates to 25.1 TWh/yr of electricity consumption, or about 11.0% of the national consumption of 228.2 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

Across South Africa, new installations of lighting systems are close to 100% LED. Amongst the retrofits and office / commercial space refurbishments the proportion of LED based lighting systems is also very, very high. In fact, according to one expert, it is getting difficult to find non-LED systems to purchase. For street lights, there is a grant scheme funded by the Department of Energy which supports participating municipalities. All classes of roads have LED specifications for them.

The Department of Energy runs a scheme called the Energy Efficiency Demand Side Management (EEDSM) programme. The EEDSM programme supports municipalities in their efforts to reduce electricity consumption by optimising their use of energy. Selected municipalities receive grants for the planning and implementation of energy efficient technologies ranging from traffic and street lighting to energy efficiency in buildings and water service infrastructure. The estimated electricity saving potential for traffic lights is up to 80%; for street lighting between 40-70%; for office building 20-30%; and 15-25% for pumps that are used for water provision and treatment.

South Africa has a national MEPS programme that sets minimum performance requirements for several products. MEPS regulations have been put in place to protect consumers from purchasing appliances that use a wasteful amount of electricity and it is illegal to sell appliances on the South African market that do not meet or exceed the MEPS that are defined in the regulations. For example, all air conditioners sold in South Africa must have a rating of Class B or better. The covered products are air conditioners, audio-visual equipment, dishwashers, electric ovens, freezers, refrigerators, fridge-freezers, storage water heaters, tumble dryers, washer-dryers and washing machines. Lighting is not in this list yet because the country is actively working on setting MEPS for lighting products through a cooperation between the South African government and UNDP.

From a policy point of view, the South African government adopted a law that banned incandescent lamps in favour of more efficient light sources – including CFL and LED - in 2014. Titled the "Amendment of the Compulsory Specification for Incandescent Lamps (VC 8043)" – this regulation published in the South African Government Gazette on 7 February 2014 sets efficacy requirements on incandescent lamps such that they must incorporate halogen technology. This regulation took effect on 7 February 2015 and phased out incandescent lamps, under the authority of the National Regulator for Compulsory Specifications Act (Act 5 of 2008).

In addition to this regulatory policy, the South African Bureau of Standards (SABS) has adopted IEC performance standards for many products, including lighting products. SABS standards for lighting cover a range of topics from quality management systems to test methods for specific materials or parts. In total, SABS has 71 National Standards that have been adopted, some of which relate to performance requirements. However these performance requirements do not include efficacy (i.e., efficiency) requirements:

- SANS 475 - Luminaires for interior lighting, streetlighting and floodlighting - Performance requirements
- SANS 60064 - Tungsten filament lamps for domestic and similar general lighting purposes - Performance requirements
- SANS 60969 - Self-ballasted lamps for general lighting services - Performance requirements
- SANS 62612 - Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements

The following are three examples of programmes that have been run by the national electric utility to promote energy-efficient lighting:

- Eskom's large scale exchange of CFLs in the residential sector – Eskom conducted large-scale mass rollouts replacing incandescent lamps with CFLs. Up through 2010/11, they had installed over 47 million CFLs, resulting in demand side management savings of 1,958 MW of capacity and creating over 30,000 temporary jobs nationally. Click here for more information.
- Eskom's national programme of effective management of energy demand (IDM) – it consists of several incentive-based mechanisms, aimed at achieving DSM savings in the Residential, Commercial and Industrial sectors – including lighting in all sectors. The motivation for this programme was to reduce load shedding, reduce peak power costs, improve economic growth, add to the growing demand reduction nationally (4000MW by 2016), and to mitigate Eskom's impact. Click here for more information.
- Eskom has a initiative titled "Electricity smart lighting: Reducing energy costs in the hospitality sector" which focuses on interventions to save money in lighting used in the hospitality sector. Click here for more information.

Overall, there is a lot of emphasis on LED in the South African market. This situation contrasts with what experts faced in South Africa when trying to make the transition from incandescent to CFL. In those schemes, project implementation partners had spent a long-time interviewing and persuading the others to join in with the national conversion.

4.3.2 On-Grid Lighting Economic Analysis for South Africa

The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate. Electricity costs, on average, around R$1.20/kWh (US$0.09/kWh).

Table 32. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in South Africa

South Africa

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.

Country:	**South Africa**	ZAR
Currency conversion to US$:	0.073	South African Rand
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.09	US$/kWh
Electricity price:	1.23	ZAR/kWh
Annual change in price of Electricity	4.6%	percent
Electricity CO2 intensity:	0.901	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	**Incandescent**	**Halogen**	**CFL**	**LED**	
Lamp wattage:	60	52	15	8	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	0.50	1.50	2.00	4.00	US$/lamp
Price for one lamp (ZAR):	7	21	27	55	ZAR/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	12	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	76	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	87%	percent
Electricity cost for operating the lamps each year:	7.88	6.86	1.97	1.05	US$/year
Financial savings of electricity costs per year vs. incandescent:		1.03	5.91	6.83	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	76.51	71.12	22.52	13.51	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	5.39	53.99	63.00	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	7%	71%	82%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	10.0	11.7	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.97	0.25	0.51	years
Simple Payback period in months, compared with incandescent:	---	11.7	3.0	6.1	months
Payback period is (X) percent better than halogen payback period:	---	---	74%	47%	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	60%	454%	226%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	789.3	686.3	197.3	105.2	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	102.9	592.0	684.0	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	564%	percent

Given the data provided for South Africa, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 6.1 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$63 – far exceeding the incremental first cost of US$3.50. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in South Africa. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

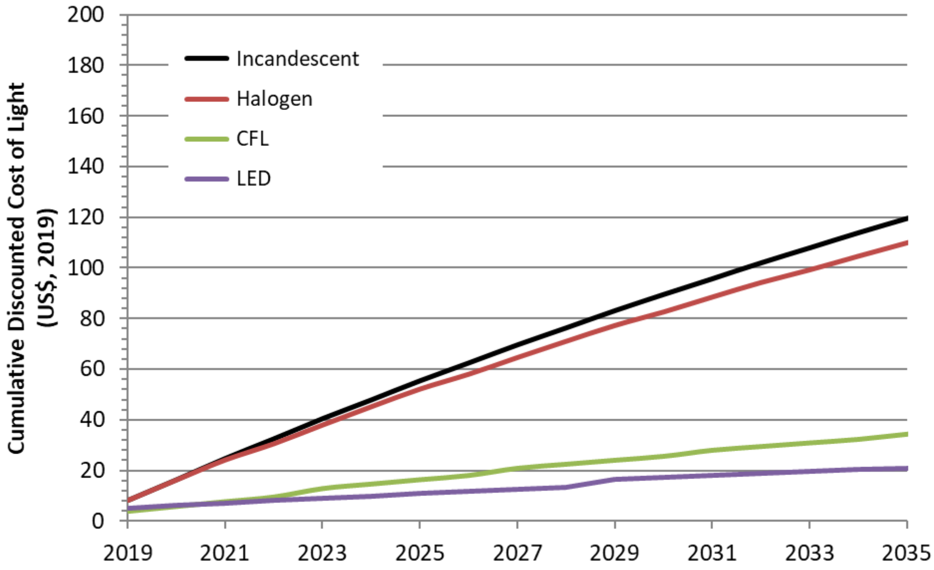


Figure 26. Cumulative Discounted Cost of Light Graph for a Lamp in a South African Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

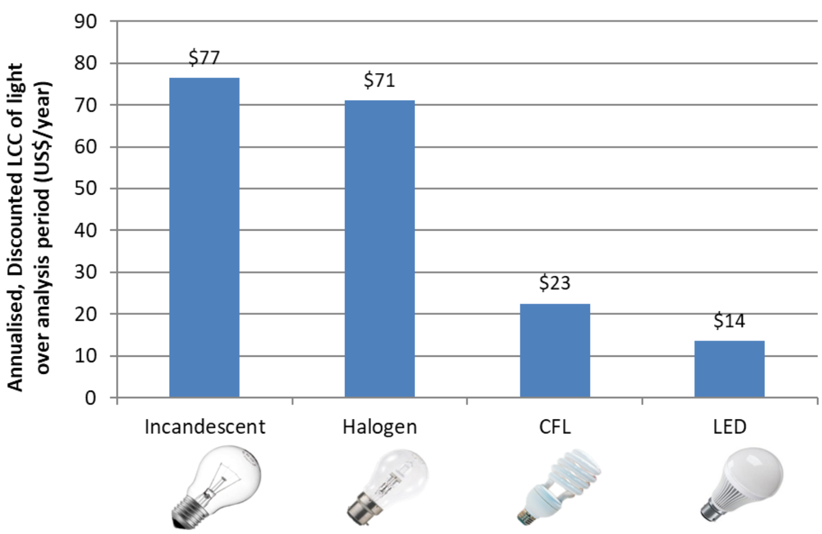


Figure 27. Annualised Discounted LCC for a Lamp over 10-years in a South African Household

In South Africa, consumers have expressed concern about the lifetime of LED lamps. After persuading consumers to shift to LED, they are not satisfied if the lamp fails in a short space of time – especially when its far, far less than the rated lifetime on the package. This perception of inferior quality gives people a certain hesitancy and they're not confident about the quality of the LED lamps they're purchasing.

In terms of affordability, LED lighting pricing has become quite competitive – in the last year to 18 months that has improved. This is important because everyone looks at the price. In terms of accessibility, there is no problem – the lamps are widely available from the corner shop to the major retailer, you can find LEDs everywhere. In some of the rural areas it's likely there would be less access to the broad LED market found in urban areas.

Eskom, the national electric utility has announced that load shedding will take place over the next 3-5 years. Residential households have standby generators and will therefore not be switching to off-grid because of load shedding, and the country has seen very high sales volume of petrol standby generators. Energy-efficient lighting is one of the best ways to address this issue, reducing energy consumption by 80-90 percent while still providing the same service.

4.3.3 Off-Grid Lighting Market in South Africa

In South Africa there are two general off-grid lighting markets: (1) the leisure/outdoor camping and recreational markets which services the medium to high income households and (2) the concession markets which focuses on providing off-grid solutions to remote and rural areas. In terms of market size, the camping market is around 10-15% of sales and the rural households market is around 85-90%. In terms of technology, both of these markets have now shifted from CFL to 12V LED.

The South African Department of Energy is running a rural electrification programme which works to provide about 20,000 connections per year. The standard system is a 95W solar panel with a 95 ampere-hour battery. The system includes 8 lights – six inside the house and two outside, and the wattages are 3W for the inside and 24W for the outside. The system can also power a television and a radio. They have installed over 180,000 solar home systems like this across the country, but the rate of applications is starting to slow as the national grid is continually expanding and reaching areas that might otherwise have sought a solar home system.

There are manufacturers of solar home systems in South Africa. There are many of them, and they produce specialised systems with lamps that are designed to the meet the needs of their customers. They buy the components in and make harnesses. Some of the lights that are used in these systems are supplied by MaxLite and Specialised Solar Systems, both of whom manufacture in South Africa.

The off-grid lighting supply chain diagram below indicating key players, main routes to market and so-on is representative of South Africa which has domestic manufacturing of off-grid lighting products.

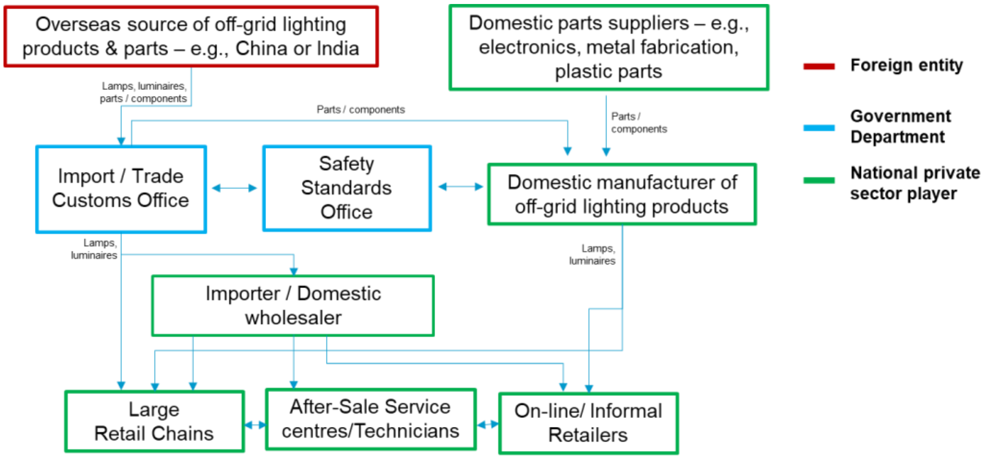


Figure 28. Flow diagram depicting the off-grid lighting supply chain in South Africa

In terms of after sales support, it is easier to get support from local manufacturers, so that is a reason to choose a South African supplier rather than one from overseas. There are also challenges faced by the Department with the implementation of the programme in terms of guaranteeing quality – meaning for example that the specification that was in the tender is supplied by the organisation.

The following table provides an estimate of the off-grid lighting stock estimate for South Africa, based on analysis that was based on the United Nations Environment Programme (UNEP) en.lighten initiative estimates published in 2015. The table was adjusted for the rapid electrification rate in the country, taking into account the fact that there are approximately 7.7 million people living without electricity and that they would typically have 2-4 persons per household and 2-4 light sources per dwelling. Thus, overall, it is estimated that there are approximately 7.2 million light sources for off-grid households, half of which are kerosene. For the businesses, the estimate was maintained at the same UNEP estimate from 2015 of 1.3 million light sources for off-grid small businesses.

Table 33. Installed Stock Estimate of Off-Grid Lighting in South Africa

Light source	Households	Businesses
Kerosene lamp (glass cover)	3.6 (49%)	0.9 (69%)
Kerosene lamp (simple wick)	1.6 (22%)	0.07 (6%)
Torch (flashlight)	1.4 (19%)	0.14 (11%)
Candles (light points)	0.7 (10%)	0.2 (14%)
Total:	7.2 million	1.27 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in South Africa, spending around US$7.01 per month on fuel-based lighting.

Table 34. Average Household Monthly Costs, Off-Grid Lighting in South Africa

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	8.6 litres	0.70 USD / litre	6.02 USD
Candles	3.9 candles	0.10 USD / candle	0.39 USD
Batteries	1.1 batteries	0.55 USD / battery	0.60 USD
		Total:	**7.01 USD**

The South African Department of Energy has a "Non-Grid Electrification Policy Guideline" which sets out the national policy around electrification. The guidelines promote energy-efficient lighting in the specification. For more information click on this link.

4.3.4 Off-Grid Lighting Economic Analysis for South Africa

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for South Africa), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting and deliver far more light (higher lumens).

Table 35. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in South Africa

South Africa

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.

Country:	**South Africa**	ZAR
Currency conversion to US$:	0.073	South African Rand/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	0.70	US$/litre
Average kerosene price:	10	ZAR/litre
Annual change in price:	4.6%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	**Candle**	**Kero Lamp Sm**	**Kero Lamp Lg**	**Solar Small**	**Solar Large**	**Solar Home Sys.**	
Price for one light source (USD):	0.10	1.90	5.80	18.00	35.00	90.00	US$/product
Price for one light source (ZAR):	1.4	26	79	247	479	1,233	ZAR/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	1.90	5.80	18.00	35.00	90.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	36.50	19.42	30.66	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	199.55	119.83	184.44	47.45	63.57	90.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	152.09	135.98	109.55	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	76%	68%	55%	percent
LCC savings compared with kerosene lamp large:	---	---	---	136.99	120.87	94.44	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	31%	39%	53%	percent
Discounted, annualised LCC of light over 6 years of use:	33.26	19.97	30.74	7.91	10.60	15.00	US$/year
As above, but normalised for 1 megalumen-hour of light:	1,814	912	702	54	24	10	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.49	0.96	2.46	years
Simple Payback period in months, compared with candles:	---	---	---	5.9	11.5	29.6	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.40	0.95	2.75	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	4.8	11.4	33.0	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	182%	95%	40%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for South Africa, the calculation shows that the payback period of moving from candles to a solar system has a payback of 0.49 to 2.46 years, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 0.40 and 2.75 years – basically 2 years for the most expensive option, the solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in South Africa is compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in South Africa. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the third year compared with the fuel-based light sources.

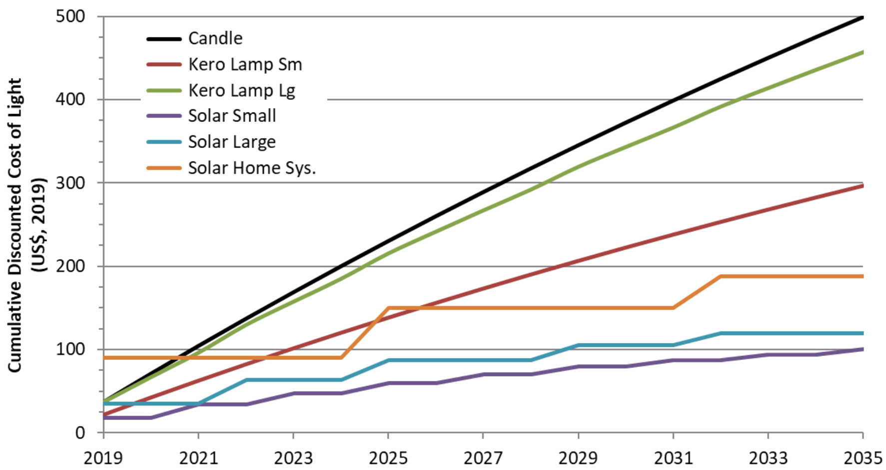


Figure 29. Cumulative Discounted Cost of Off-Grid Lighting for a South African Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-4 times cheaper to own and operate compared to the kerosene and candle-based sources.

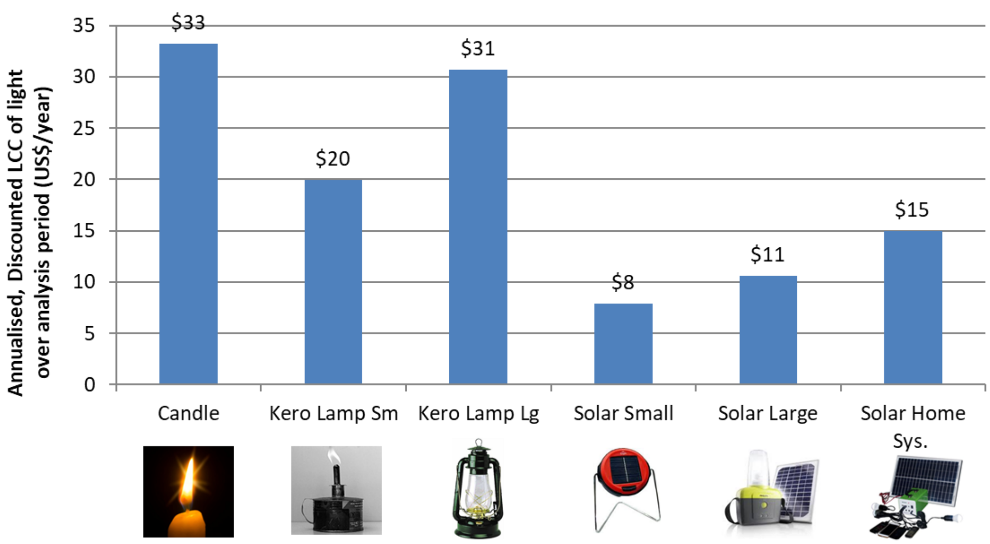


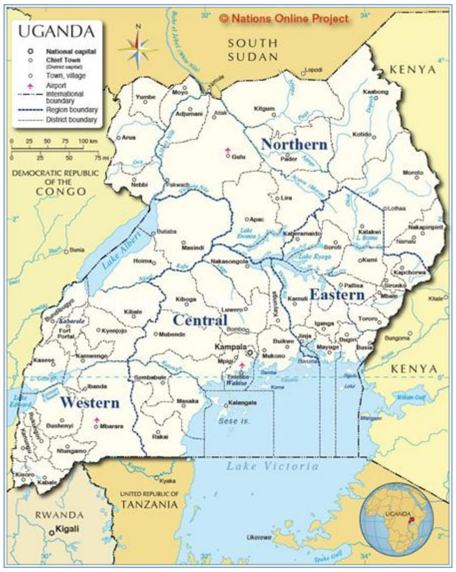
Figure 30. Annualised, Discounted LCC of Off-Grid Lighting for a South African Household

4.4 Country Profile Summary: Uganda

Capital: Kampala
Language: English, Swahili
Median age: 15 years (2014 estimate)
National currency: Ugandan Shilling (UGX/USh)

Table 36. At-a-glance Information on Uganda

Indicator	2015
Population total[1]	40,144,870
Population growth (annual %)[1]	3.32%
Urban Population, % of Total[2]	16%
Rural Population, % of Total[2]	84%
GDP (Current US$)[1]	27,102,650,472
GDP Growth (Annual %)[1]	5.19
GDP per capita (current US$)[1]	675
GDP Annual Growth Rate Forecast to 2019[2]	4.4%
Inflation, consumer prices (annual %)[1]	2%
Electrification Rate[3]	19%
Human Development Indicator (rank of 188)[2]	164
TI Corruption Index, 2017 (rank of 175)[2]	151



Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017. Note: some more recent estimates put the 2019 electrification rate for Uganda at over 25%.

Map source: Nations Online Project, 2018.

Uganda has been working for years to promote energy-efficient technology in its market. Starting with mandatory MEPS over 20 years ago, Uganda has MEPS for compact fluorescent lamps, linear fluorescent lamps and fluorescent lamp ballasts that were all updated and adopted in 2011. A new energy-efficiency and conservation bill has been drafted and is awaiting passage through parliament which will look to set MEPS on lighting and other products and appliances, while working to accelerate energy-efficiency overall.

Uganda is currently an Affiliate member of the IEC, but at the end of this financial year Uganda is planning to apply for full membership. Uganda has done some training on the Conformity Assessment packages that the IEC offers and a new member of staff has joined who is strong in the solar sector, and thus will be joining IEC TC-82, Solar Energy. And looking at energy access issues, Uganda has a joint programme with the World Bank which is conducting a 'gap analysis' in the country: https://www.lightingafrica.org/country/uganda/

4.4.1 On-Grid Lighting Market in Uganda

There are no lamp or luminaire manufacturers in Uganda, thus all lighting products are imported. Some small businesses have shown interest in starting a luminaire assembly plants, but they haven't yet started / set-up.

Most of the traders and supermarkets in Uganda import lamps, examples include (but not limited to): Transtel Ltd, Kiboko Enterprises, Ultratec Ltd, AB Matra Ltd, Appliance World Ltd, CHINT Uganda Ltd, TRONICS Ltd, Shoprite, Quality Supermarket, Mega Supermarket, Game Supermarket, House of Lights, Kampala City Traders Association (KACITA) members, etc. Any of these traders can import a mixture of lamps in different specifications including; LEDs, CFLs, fluorescent tubes, incandescent bulbs, high-intensity discharge lamps (mercury vapour, high-pressure sodium, and metal halide). Some lamp brands have local agents – for example, Vallight (with exclusive local representatives) and Philips.

The lighting market includes some products with new brand names, but the one that people seem to trust in Uganda are Vallight and Philips. It is difficult to say who has the larger share of the market, but it seems as if it would be Vallight due to their widespread availability. Philips is working to try and compete for the leading spot, and the consumer is benefitting from the competition, if the lamps being traded meet the standards.

Uganda has two manufacturer associations that relate to energy-efficient lighting. First, there is a national association of traders who are focusing on the import and sale of products, and within that association there is a division that focuses on electrical products, including lighting imports. Second, there is the Energy Efficiency Association of Uganda (EEAU) which is a non-profit, non-partisan body, whose primary aim is to promote networking, understanding, knowledge and action among different stake holders working towards promotion of efficient use of energy in Uganda. They have 25 members and include energy auditors, consultants, researchers and experts looking to grow and develop the business of energy-efficiency. By 2020, EEAU should be an accredited entity to certify Energy Efficiency Professionals in the country. EEAU link: http://unreeea.org/members/eeau/about/

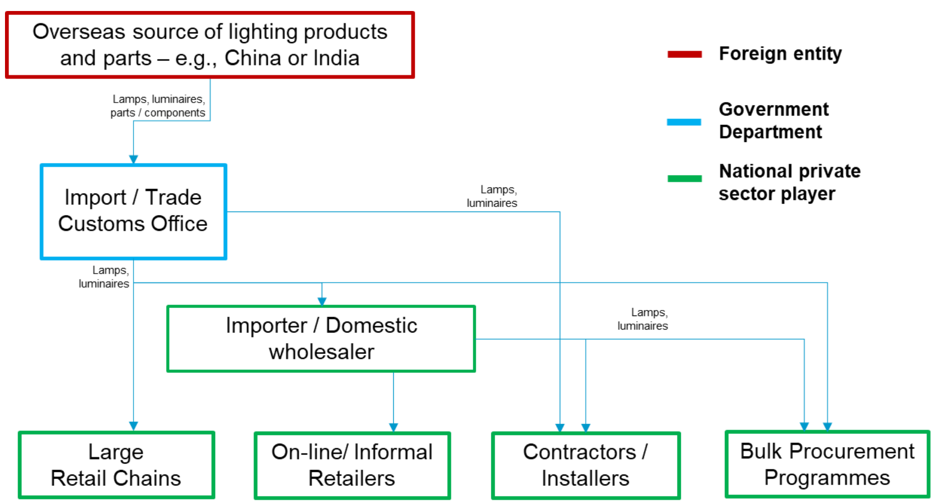


Figure 31. Illustration of the Lighting Supply Chain in Uganda

When lamps are imported, they go through customs and are taken to wholesale shops but most of them directly go to retail shops. Usually, big contractors import their lamps directly from manufacturers/overseas retailers. Small contractors can purchase directly from wholesalers or even retailers. Bulk procurement programmes are usually imported directly from manufacturers. For standards, Uganda National Bureau of standards (UNBS) relies on manufacturers' test results and sometimes on results from the PVoC (Pre-Export Verification of Conformity to Standards). The on-line system has yet to be used for importing lamps. And finally, there are informal retailers who import directly from overseas, however it should be noted that all products must be in compliance with Uganda's national standards.

Uganda's lighting market is mature and offers all the common light sources – incandescent (although now on a much smaller scale), halogen, compact fluorescent lamps, LED lamps, linear fluorescent lamps, high-intensity discharge lamps, and so-on. Typically, the following end-use sectors purchase these lamp types:

- Domestic - Compact Fluorescent, LEDs, Linear Fluorescent;
- Commercial - Compact Fluorescent, LEDs, Linear Fluorescent and sometimes incandescent;
- Industrial - Compact Fluorescent, LEDs, Halogen, Linear Fluorescent, HID Lamps; and
- Outdoor - LEDs, Linear Fluorescent, HID Lamps and halogen.

The tables below provide the estimated annual sales and installed stock of the major lamp types for Uganda, based on the United Nation's Comtrade database, spanning from 2010 through 2017 and adjusted to account for any irregularities and gaps. These data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017. Compact fluorescent lamps have remained a popular light source throughout this period.

Table 37. Estimated Total Annual Sales of Lamps for All End-Use Sectors in Uganda

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	598,188	24,792	3,120,435	1,113,369	490,565	44,035	102,250	83,347
Halogen	190,668	86,936	384,606	63,584	57,036	587,974	114,248	42,970
CFL	144,976	209,928	1,226,537	784,577	997,290	673,127	740,245	546,489
Linear Fluores.	177,193	256,579	1,499,101	958,927	1,218,910	822,710	904,743	667,931
HID Lamps	46,180	33,228	300,621	290,158	534,254	314,065	462,349	189,451
LED Lamp	-	-	-	39,231	61,796	78,308	76,539	67,281
LED Tube	-	-	-	19,179	48,756	49,363	72,379	66,793
LED Outdoor	-	-	-	5,803	21,370	18,844	36,988	18,945

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in Uganda. The table below presents this estimate, broken down by end-use sector.

Table 38. Estimated Installed Stock of Lamps by Sector in Uganda (millions of units) in 2017

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	0.205	0.019	0.004	0.228
Halogen	0.335	0.047	0.009	0.392
Compact Fluorescent	1.993	0.746	0.083	2.821
Linear Fluorescent	0.740	3.579	0.224	4.542
High Intensity Discharge	0.057	0.226	0.849	1.132
LED Omni-directional	0.111	0.060	0.008	0.179
LED Tube	0.018	0.094	0.006	0.117
LED Outdoor	0.002	0.009	0.035	0.046
Total	**3.461**	**4.779**	**1.217**	**9.457**

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in Uganda can be calculated. For the above stock of lamps, this equates to 0.803 TWh/yr of electricity consumption, or about 24.7% of the national consumption of 3.250 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

As shown in the above tables, LEDs are entering the market in Uganda and the challenge is really about ensuring the quality of the lamps imported, to make sure consumers don't have a bad experience with the technology. People are understanding the big value LEDs can offer, and they are beginning to buy them. They see the impact of the LED Lamp on their energy bills, and they are happy about the longer lifetime.

There is some awareness raising being done for the public about the higher initial price and the lower running costs, resulting in a good payback period.

There are some energy-efficient lighting policies and programmes in Uganda. MEPS were published in the gazette for CFLs, linear fluorescent lamps and fluorescent lamp ballasts:

- **US 902:2011, Self-ballasted lamps for General Lighting Services (GLS) — Performance requirements**
  This Uganda Standard specifies the performance requirements, together with the test methods and conditions required to show compliance of tubular fluorescent and other gas-discharge lamps with integrated means for controlling starting and stable operation (self-ballasted lamps), intended for domestic and similar general lighting purposes.

- **US 903-1:2011, Double-capped fluorescent lamps-performance specifications — Part 1: Minimum Energy Performance Standard (MEPS)**
  This Uganda Standard specifies Minimum Energy Performance Standard (MEPS) requirements for double-capped tubular fluorescent lamps with a nominal length of 550 mm to 1500 mm and having nominal lamp wattage of 16 watts or more. This standard covers lamps for general illumination purposes, for use in luminaires and with lamp ballasts connected to a 240 V 50 Hz single phase or similar mains supply.

- **US 904-1:2011, Performance of electrical lighting equipment-ballasts for fluorescent lamps — Part 1: Energy labelling and Minimum Energy Performance Standards requirements**
  This Uganda Standard specifies requirements for the classification of ballasts for a range of fluorescent lamp types according to their Energy Efficiency Index (EEI) and the form of labelling of the EEI, which is generally shown on the ballast rating plate.

In addition to these MEPS, Uganda has ten other energy-efficiency (i.e., quality and performance standards, not only testing standards) for household products and equipment. The complete list can be found in the Uganda National Bureau of Standards (UNBS) catalogue available on this link:

https://unbs.go.ug/content.php?src=information-resource-centre&pg=content

In addition to these standards, the Minister of Energy has been working on an Energy Efficiency and Conservation Bill has been drafted to enforce the efficient use of energy, including MEPS for lighting – but this has not yet been finalised. Uganda also has some programmes to promote energy-efficient lighting, including for example the Ministry of Energy and Mineral Development distributed free CFLs and efficient fluorescent tubes to public institutions such as schools, hospitals, universities, police barracks, and households from 2009 to 2012. The Electricity Regulatory Authority had a campaign of replacing household inefficient bulbs with LEDs in 2015/16, implemented by the utility. And currently, the Ministry of Energy and the World Bank are doing a 'gap analysis' in the country, looking to increase energy access for the rural population.

4.4.2 On-Grid Lighting Economic Analysis for Uganda

The typical prices paid for popular / common lamps in Uganda depend on the quality of the product. An incandescent lamp is about US$0.25 (1000 Shillings), a CFL is around US$1.20 and an LED lamp is about US$3.00. Electricity for the residential sector is about US$0.20 per kilowatt hour. Given these data, a socket-level economic analysis can be conducted to ascertain the value of moving toward energy-efficient lighting. The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate.

Table 39. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in Uganda

Uganda

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.

Country:	**Uganda**	UGX
Currency conversion to US$:	0.00027	Uganda Shilling
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.20	US$/kWh
Electricity price:	741	UGX/kWh
Annual change in price of Electricity	5.4%	percent
Electricity CO2 intensity:	0.616	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	Incandescent	Halogen	CFL	LED	
Lamp wattage:	60	52	15	8	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	0.25	1.00	1.20	3.00	US$/lamp
Price for one lamp (UGX):	926	3,704	4,444	11,111	UGX/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	12	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	76	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	87%	percent
Electricity cost for operating the lamps each year:	17.52	15.23	4.38	2.34	US$/year
Financial savings of electricity costs per year vs. incandescent:		2.29	13.14	15.18	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	166.60	148.69	43.82	24.87	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	17.92	122.79	141.74	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	11%	74%	85%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	6.9	7.9	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.33	0.07	0.18	years
Simple Payback period in months, compared with incandescent:	---	3.9	0.9	2.2	months
Payback period is (X) percent better than halogen payback period:	---	---	78%	45%	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	244%	1491%	598%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	539.6	469.2	134.9	71.9	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	70.4	404.7	467.7	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	564%	percent

Given the data provided for Uganda, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 2.2 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$141.74 – far exceeding the incremental first cost of US$2.75. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in Uganda. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

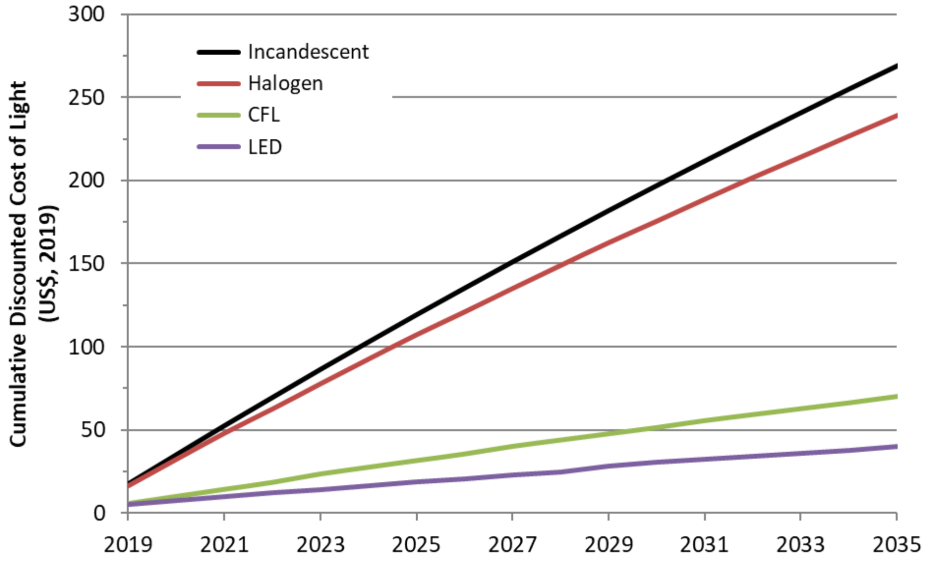


Figure 32. Cumulative Discounted Cost of Light Graph for a Lamp in a Ugandan Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

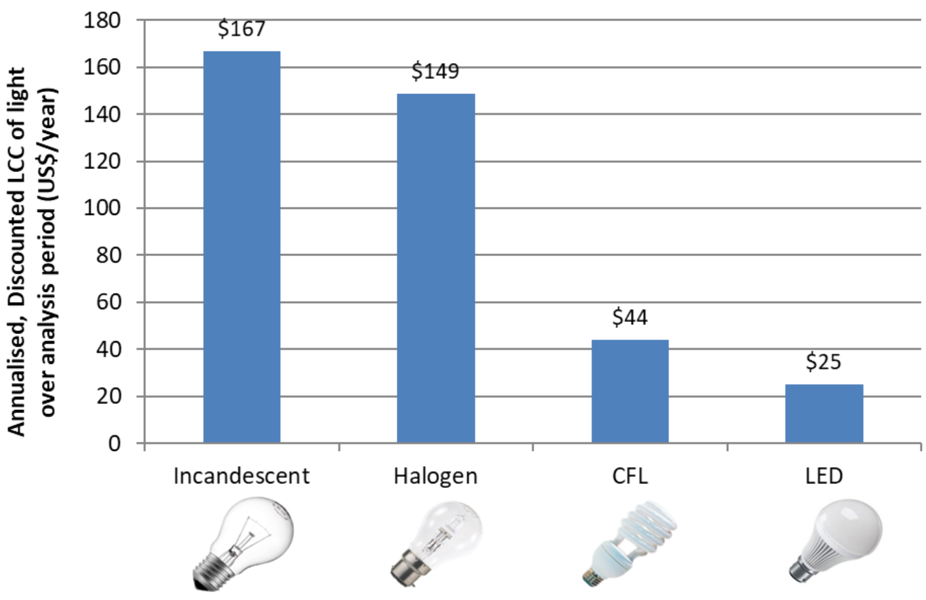


Figure 33. Annualised Discounted LCC for a Lamp over 10-years in a Ugandan Household

In Uganda, the main barrier to energy-efficient lighting is affordability – the higher up-front cost could means that the energy-efficient lamps are not selected even though they do offer the lowest life-cycle cost and payback in just a matter of months. There is also an issue of inadequate enforcement of the standards for products where there are regulations, such as for CFLs. The government is concerned too about the risk of 'technology spoiling' where a consumer has a bad experience with a new technology and then does not trust or want to use that technology again. Given the current situation where LED lamps are not regulated for quality or performance, this is a significant risk and it was noted that poor quality products are common in the market.

The decisions being made around which lighting technology is selected was not perceived in Uganda as a gender issue. The experts interviewed indicated that typically everyone decides what they want. A few people may ask for guidance from an electrical installer, but the vast majority of people just go to the store and buy a bulb that will fit in their socket at home. A wife could say to the husband, 'by the way the lamp in the living room has blown' and when he comes back in the evening, he brings a lamp with him to replace it.

4.4.3 Off-Grid Lighting Market in Uganda

There are no off-grid lighting product manufacturers in Uganda. The common importers are here – such as Village Power, Phoenix International, Solar Now Uganda, Barefoot power, M-Kopa Ltd, Solar Power Ltd, Ultratec (U) Ltd, Solar Energy For Africa Ltd. (SEFA) and many other private companies promote the use of solar power for lighting. In addition, there are KACITA Members and other small importers – many solar companies, but there is no manufacturing at this time – off-grid lighting is purely an import market.

There is also an association which includes some of these importers: Uganda Solar Energy Association (USEA) which is an independent, non-profit association dedicated to facilitating the growth and development of solar energy business in Uganda and East African region. USEA was formed in 2016 by private companies that deal in solar energy business with help from the private sector foundation, Uganda Ministry of Energy, and the Rural Electrification Agency, and it is registered under Section 10 of the Societies Act of Uganda. Link: https://unreeea.org/members/usea/ This association is actively working now to self-regulate the solar space, and with the aid of the UK Department for International Development (DFID) and United Nations Capital Development Fund (UNCDF), they are working on a quality label for solar products. The association has contracted a company called Viamo who are working with text (SMS) messages, which can provide customers with a free information service on where they can buy quality off-grid lighting products. For more information: https://viamo.io/

The supply-chain for off-grid lighting products – they are imported and go directly toward to wholesale shops or even directly to retail shops. Companies who are part of the USEA tend to test their products with the Uganda National Bureau of Standards and provide a warranty of one or two years. If the product fails in the first year, they will replace it fully at their cost. If it fails in the second year, they will repair it at no cost. The Centre for Renewable Energy at Makerere University in Uganda are contracted to train the technicians, and they also offer capacity building training to the sector.

The off-grid light sources that are used in Uganda include: kerosene, candles, batteries/torches, solar lighting, solar home systems, diesel generators and small hydro power systems. The sectors which purchase these different light sources include:

- Domestic - kerosene, candles, batteries/torches, solar lighting, solar home systems, diesel generators and small hydro power systems; and
- Commercial - solar lighting, diesel generators and small hydro power systems.

The following table provides an estimate of the off-grid lighting stock estimate for Uganda, based on analysis that was prepared by the United Nations Environment Programme (UNEP) en.lighten initiative, and published in 2015. This table provides an estimate of the millions of lamps in the installed base of households and small businesses across Uganda. Overall, it is estimated that there are approximately 17.7 million light sources for off-grid households and 1.7 million light sources for off-grid small businesses.

Table 40. Installed Stock Estimate of Off-Grid Lighting in Uganda

Light source	Households	Businesses
Kerosene lamp (glass cover)	9.0602 (51.3%)	1.2647 (72.8%)
Kerosene lamp (simple wick)	4.5301 (25.6%)	0.1180 (6.8%)
Torch (flashlight)	1.2080 (6.8%)	0.1518 (8.7%)
Candles (light points)	2.8691 (16.2%)	0.2023 (11.7%)
Total:	17.6675 million	1.7368 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in Uganda, spending around US$8.47 per month on fuel-based lighting.

Table 41. Average Household Monthly Costs, Off-Grid Lighting in Uganda

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	6.8 litres	0.90 USD / litre	6.12 USD
Candles	12.8 candles	0.15 USD / candle	1.92 USD
Batteries	0.8 batteries	0.54 USD / battery	0.43 USD
		Total:	**8.47 USD**

In Uganda, there is a tax on kerosene to try and discourage it's use for lighting purposes. The Electricity Connections Policy 2018 promotes off grid solutions and therein also promotes use of off grid products such as lighting. In addition, Uganda adopted a Renewable Energy Policy in 2007 that promotes the use of renewable energy sources in the energy mix of the country. In addition, for the Energy Efficiency Act that has been tabled in Parliament, they were tasked to carry out a Regulatory Impact Assessment of the Act before taking it back to Parliament – this should be completed by the end of 2019. The Act will include MEPS and these regulations could be extended to include off-grid lighting products.

The body responsible for testing standards for off-grid lighting products is the UNBS. They received testing equipment from the Ministry of Energy in 2016, and they are in charge of ensuring compliance while enforcing standards from other Departments.

4.4.4 Off-Grid Lighting Economic Analysis for Uganda

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for Uganda), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting and deliver far more light (higher lumens).

Table 42. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in Uganda

Uganda

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.

Country:	**Uganda**	UGX
Currency conversion to US$:	0.00027	South African Rand/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	0.90	US$/litre
Average kerosene price:	3333	MGA/litre
Annual change in price:	5.4%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	**Candle**	**Kero Lamp Sm**	**Kero Lamp Lg**	**Solar Small**	**Solar Large**	**Solar Home Sys.**	
Price for one light source (USD):	0.15	3.00	4.00	20.00	40.00	80.00	US$/product
Price for one light source (UGX):	556	11,111	14,815	74,074	148,148	296,296	UGX/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	3.00	4.00	20.00	40.00	80.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	54.75	24.97	39.42	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	303.15	159.67	235.22	52.73	72.65	80.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	250.42	230.49	223.15	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	83%	76%	74%	percent
LCC savings compared with kerosene lamp large:	---	---	---	182.50	162.57	155.22	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	40%	46%	49%	percent
Discounted, annualised LCC of light over 6 years of use:	50.52	26.61	39.20	8.79	12.11	13.33	US$/year
As above, but normalised for 1 megalumen-hour of light:	2,755	1,215	895	60	28	9	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.36	0.73	1.46	years
Simple Payback period in months, compared with candles:	---	---	---	4.4	8.7	17.5	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.41	0.91	1.93	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	4.9	11.0	23.1	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	258%	131%	71%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for Uganda, the calculation shows that the payback period of moving from candles to a solar system has a payback of 4.4 to 17.5 months, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 4.9 and 23.1 months – still less than 2 years even for the most expensive solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in Uganda is compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in Uganda. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the second year compared with the fuel-based light sources.

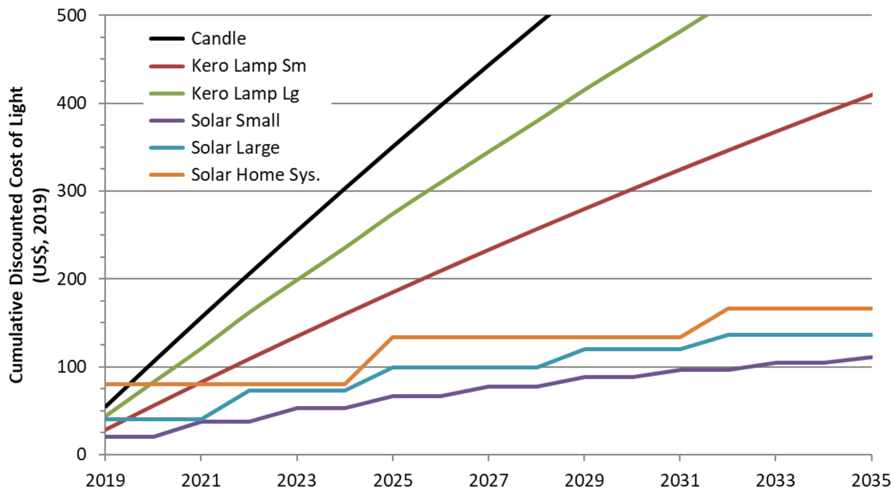


Figure 34. Cumulative Discounted Cost of Off-Grid Lighting for a Ugandan Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-5 times cheaper to own and operate compared to the kerosene and candle-based sources.

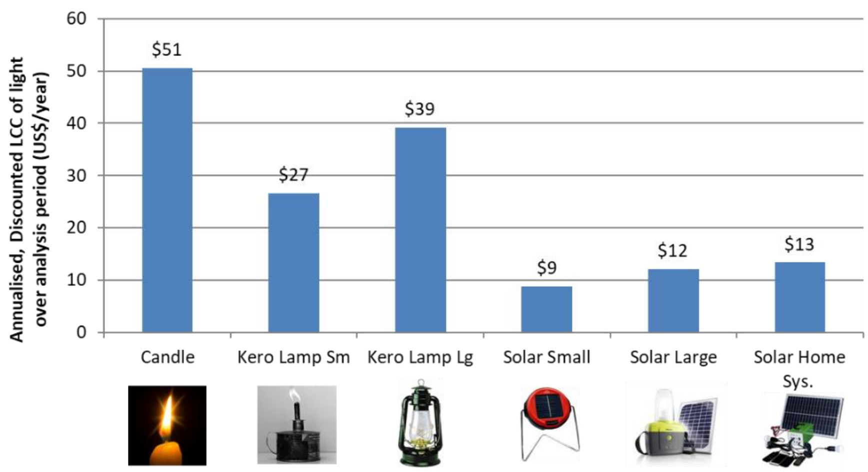


Figure 35. Annualised, Discounted LCC of Off-Grid Lighting for a Ugandan Household

A few solar companies in Uganda offer credit services but most of them offer their products primarily on a cash basis, particularly for the smaller systems. The larger systems are mainly paid for via instalments through the PAYGO system supported by mobile phone network operators.

The market for solar products is improving as prices fall. Many players are getting into the solar business and more consumers are willing to purchase the products as people need lighting in their homes. With the improvement of quality on the market – especially with the help of USEA – consumers begin to trust a brand, building faith in their product. Once that has happened, people talk to each other, convince their neighbours and the word spreads, assisting market development.

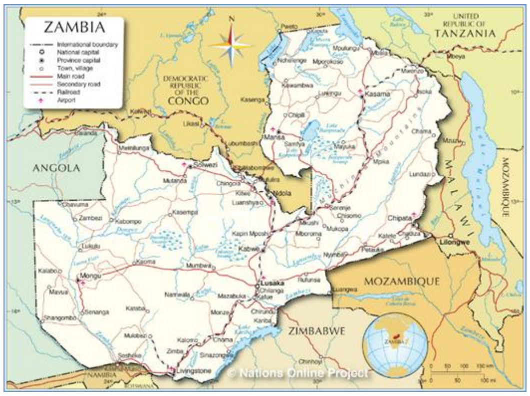
As with on-grid lighting systems, it's important that standards are enforced as these products are critical and the market has a large proportion of substandard appliances. Prices are generally too high for rural households, however there are financing schemes such as the PAYGO which can help to make them more accessible.

4.5 Country Profile Summary: Zambia

Capital: Lusaka
Language: English
Median age: 16.7 years (2016 estimate)
National currency: Kwacha, ZMW

Table 43. At-a-glance Information on Zambia

Indicator	2015
Population total[1]	17,094,130
Population growth (annual %)[1]	2.98%
Urban Population, % of Total[2]	41%
Rural Population, % of Total[2]	59%
GDP (Current US$)[1]	25,808,666,422
GDP Growth (Annual %)[1]	4.08%
GDP per capita (current US$)[1]	US$1510
GDP Annual Growth Rate Forecast to 2020[2]	5.97%
Inflation, consumer prices (annual %)[1]	6.58%
Electrification Rate[3]	34%
Human Development Indicator (rank of 188)[2]	139
TI Corruption Index, 2016 (rank of 168)[2]	76



Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017.

Map source: Nations Online Project, 2018.

4.5.1 On-Grid Lighting Market in Zambia

Zambia has an assembly plant that produces compact fluorescent lamps (CFLs). They import the parts and assemble them locally, otherwise the rest are all imported. The CFL assembly plant is called Zambia Electrometer and they are based in Ndola. The electric utility Zesco has 100% shares in this company and they have used these CFLs in their energy-efficiency programmes.

Zambia does not have luminaire manufacturing at this time.

The lamp importers – dealers – who are trading under different brands include supermarkets, some energy companies, and individual companies:

- Retailers include: Game, Shoprite, PickNPay and Chinese retailers;

- Brands are Philips, EuroLux (very popular with our chain stores here, most of them are South African stores). These are mostly what is on the market, especially in terms of energy efficient lighting; and
- Zambia Electrometer is not a big player domestically, but their products are on the shelves.

Zambia does not have a national lighting association at this time, however there is a regional association called the "Zambia Association of Manufacturers" which covers manufacturing in all sectors – cement, wood processing, metal fabrication, and so-on.

The flow diagram below depicts how products move through the lighting market in Zambia.

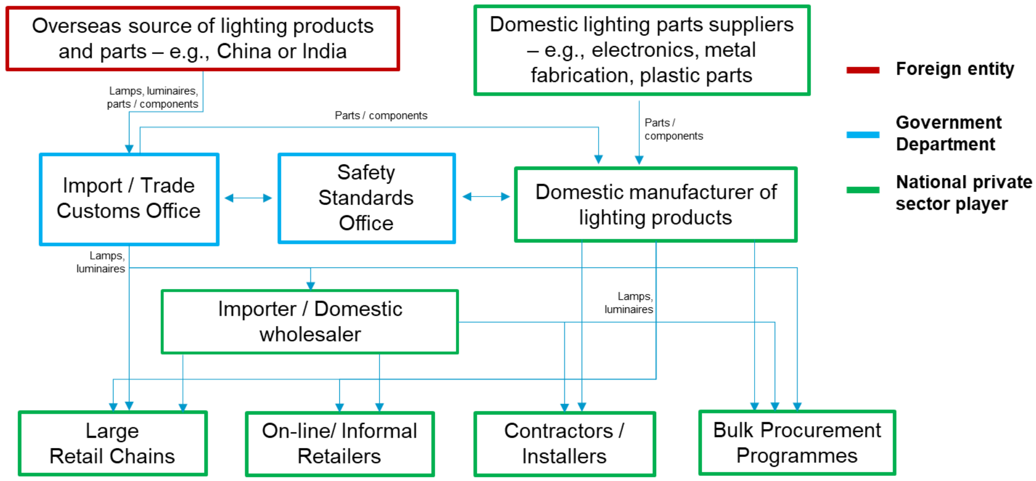


Figure 36. Illustration of the Lighting Supply Chain in Zambia

Most of the product consumed in Zambia is imported, the Zambia Revenue Authority therefore has customs officers placed at all the ports and points of entry to help ensure compliance with the regulations. There are two major ports and three border entry points – one in the north on the Tanzania border, one in the south – Kazungula on the border with Botswana and Zimbabwe and then we have Chirundu border which is another entry point from Zimbabwe. These Officers working at the ports and points of entry have to cover a whole range products, not only lighting.

In terms of lighting technologies and volumes, Zambia's lighting market includes all the technologies identified – incandescent, halogen, compact fluorescent lamps, linear fluorescent, high-intensity discharge (HID) lamps, and light emitting diode lamps and luminaires. The tables below provide the estimated annual sales and installed stock of the major lamp types for Zambia, based on the United Nation's Comtrade database, spanning from 2010 through 2017 and adjusted to account for any irregularities and gaps. These data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017. Compact fluorescent lamps have remained a popular light source throughout this period.

Table 44. Estimated Total Annual Sales of Lamps for All End-Use Sectors in Zambia

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	2,064,635	1,883,149	1,701,663	3,238,713	2,893,817	2,893,817	2,548,920	2,548,920
Halogen	1,803,914	2,669,124	2,448,990	2,524,200	2,719,629	2,740,803	2,821,402	2,902,000
CFL	615,261	1,116,311	1,486,249	2,002,633	2,197,220	1,559,381	1,716,523	1,873,665
Linear Fluores.	751,986	1,364,381	1,816,526	2,447,663	2,685,492	1,905,910	2,097,972	2,290,035
HID Lamps	101,750	261,280	200,180	127,410	188,000	95,070	99,313	103,556
LED Lamp	-	-	-	155,311	312,427	431,640	566,948	732,459
LED Tube	-	-	-	48,953	107,420	114,355	167,838	229,004
LED Outdoor	-	-	-	2,548	7,520	5,704	7,945	10,356

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in Zambia. The table below presents this estimate, broken down by end-use sector.

Table 45. Estimated Installed Stock of Lamps by Sector in Zambia (millions of units) in 2017

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	1.431	0.144	0.029	1.604
Halogen	2.766	0.337	0.067	3.170
Compact Fluorescent	3.088	2.194	0.183	5.465
Linear Fluorescent	1.646	7.766	0.485	9.897
High Intensity Discharge	0.026	0.104	0.391	0.521
LED Omni-directional	0.591	0.269	0.038	0.898
LED Tube	0.041	0.216	0.014	0.271
LED Outdoor	0.001	0.003	0.012	0.016
Total	**9.590**	**11.033**	**1.219**	**21.841**

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in Zambia can be calculated. For the above stock of lamps, this equates to 1.397 TWh/yr of electricity consumption, or about 11.8 % of the national consumption of 11.800 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

The market carries all lamp types that were presented in the questionnaire – incandescent, halogen, compact fluorescent, light emitting diode, linear fluorescent, high-intensity discharge lamps. These lamps are sold in all the sectors – domestic, commercial and industrial. LED technology is relatively new, but it has grown fast and is imported from both China and India. The awareness for energy-efficient lighting is low – this is an area that the electric utility (ZESCO) is working on to help people understand the issue. ZESCO's communications plan includes road shows, fliers, community, train stations, talking to customers – door to door, and so-on.

In terms of gender issues, generally when going door to door and speaking about energy-efficient lighting, the utility has found the mother because the father is out working. But there is no issue with the technology – the families are given the one that the utility is providing.

ZESCO has been doing a lighting campaign CFL distribution programme – they could have done about 3 million by now. They were exchanging six incandescent lamps for six CFLs for residential customers for free. That is one of the major activities. ZESCO is now expanding – with the procurement of 4 million LEDs. ZESCO had a few dry years, 3-4 years ago, and given that the utility is mostly hydro….they found that DSM really helped, particularly where feeders were overloaded. ZESCO are targeting certain feeders in 2019.

Outside of lighting, ZESCO also work on heating, promoting the use of LPG. They do this work because they have quantified in terms of lighting a household, average values that go into lighting and heating. We are trying to see solar heaters, etc. And we are going to see some of the initiatives, in terms of metering – during peak periods, we can control how much we give to our customers – besides the tariff, at peak periods, making it a little bit higher at peak periods to get people to adjust. We have not yet gone full fledge….the utility then expects to see can take savings much higher.

4.5.2 On-Grid Lighting Economic Analysis for Zambia

The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate.

Table 46. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in Zambia

Zambia

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.

Country:	**Zambia**	ZMW
Currency conversion to US$:	0.084	Zambian Kwacha/US$
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.10	US$/kWh
Electricity price:	1.2	ZMW/kWh
Annual change in price of Electricity	10.1%	percent
Electricity CO2 intensity:	0.003	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	**Incandescent**	**Halogen**	**CFL**	**LED**	
Lamp wattage:	60	52	15	7	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	0.50	1.50	2.00	3.00	US$/lamp
Price for one lamp (ZMW):	6	18	24	36	ZMW/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	10	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	77	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	88%	percent
Electricity cost for operating the lamps each year:	8.76	7.62	2.19	1.02	US$/year
Financial savings of electricity costs per year vs. incandescent:		1.14	6.57	7.74	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	105.19	96.06	29.69	14.67	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	9.13	75.50	90.53	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	9%	72%	86%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	8.3	9.9	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.88	0.23	0.32	years
Simple Payback period in months, compared with incandescent:	---	10.5	2.7	3.9	months
Payback period is (X) percent better than halogen payback period:	---	---	74%	63%	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	82%	529%	374%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	2.6	2.3	0.7	0.3	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	0.3	2.0	2.3	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	577%	percent

Given the data provided for Zambia, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 3.9 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$90.53 – far exceeding the incremental first cost of US$2.50. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in Zambia. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

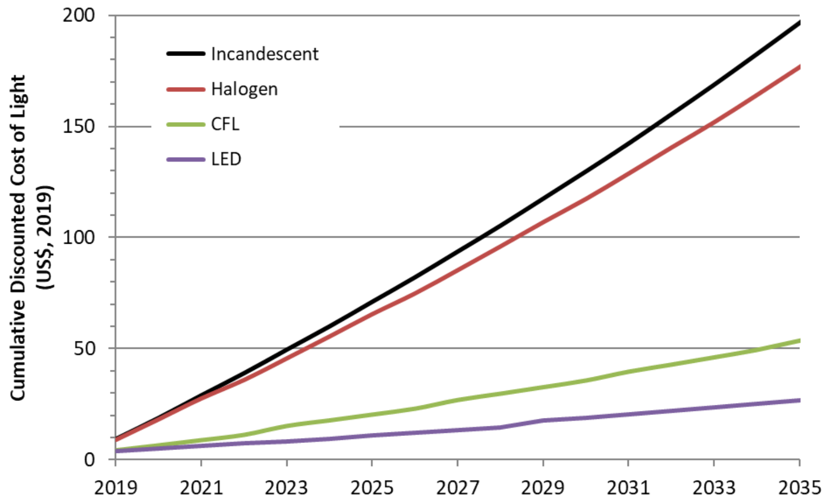


Figure 37. Cumulative Discounted Cost of Light Graph for a Lamp in a Zambia Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten-year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

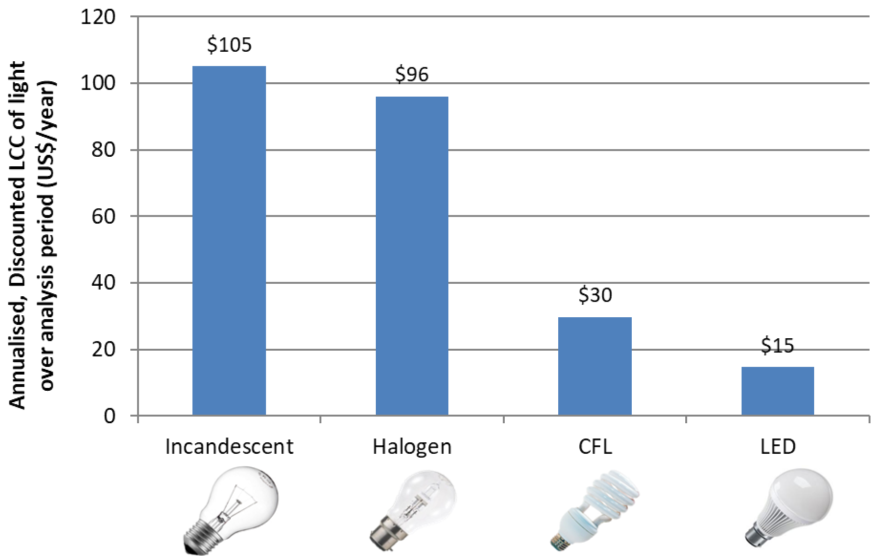


Figure 38. Annualised Discounted LCC for a Lamp over 10-years in a Zambia Household

While the above economics are compelling, there are still some market barriers in Zambia which need to be overcome for energy-efficient lighting. The following list of barriers was discussed with one of our experts:

- Awareness – LED is quite new in Zambia. The utility is running a communications campaign to raise awareness, and people remember the last one on CFLs. They are asking 'What is this again now?'
- Acceptance – in Zambia, education levels are not always high and some people are suspicious of the utility. Acceptance takes time – they need to try the lamp and see the benefits, and understand the utility is not trying to make more profit.
- Affordability – this traditional market barrier is low and will grow lower still over time. An incandescent lamp is still much cheaper than an LED lamp on a first-cost basis, but prices are coming down. The utility is setting up a revolving fund to try and address this barrier.

Overall Zambia is moving towards energy-efficient lighting in the residential and private sector. The government is even looking into a procurement specification now to encourage all government departments to procure more energy-efficient lighting for their offices.

4.5.3 Off-Grid Lighting Market in Zambia

All of the off-grid lighting technologies commonly found in the market are used in Zambia – candles, kerosene (simple and hurricane lamp), torches and solar LED lanterns and solar home systems. In terms of where these technologies can be found, the kerosene and candles are specifically for domestic use and small retailers, they are not used for larger or more formal retail establishments. For practical reasons, people tend to use candle and kerosene lamps indoors and then torches when they need to walk somewhere at night.

The off-grid lighting supply chain diagram below indicating key players, main routes to market and so-on is representative of Zambia, bearing in mind that there is no domestic manufacturing of off-grid lighting products.

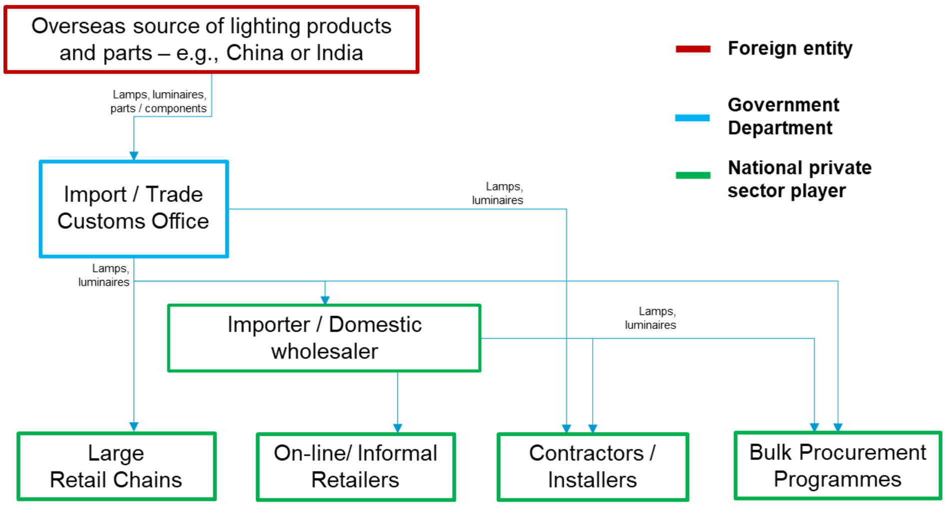


Figure 39. Flow diagram depicting the off-grid lighting supply chain in Zambia

The following table provides an estimate of the off-grid lighting stock estimate for Zambia, based on analysis that was prepared by the United Nations Environment Programme (UNEP) en.lighten initiative, and published in 2015. This table provides an estimate of the millions of lamps in the installed base of households and small businesses across Zambia. Overall, it is estimated that there are approximately 5.6 million light sources for off-grid households and 0.4 million light sources for off-grid small businesses.

Table 47. Installed Stock Estimate of Off-Grid Lighting in Zambia

Light source	Households	Businesses
Kerosene lamp (glass cover)	0.3525 (6.3%)	0.0559 (14.3%)
Kerosene lamp (simple wick)	0.4700 (8.3%)	0.0559 (14.3%)
Torch (flashlight)	0.1762 (3.1%)	0.0838 (21.4%)
Candles (light points)	4.6412 (82.3%)	0.1956 (50.0%)
Total:	5.6399 million	0.3911 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in Zambia, spending around US$5.16 per month on fuel-based lighting.

Table 48. Average Household Monthly Costs, Off-Grid Lighting in Zambia

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	1.2 litres	1.06 USD / litre	1.27 USD
Candles	60.6 candles	0.10 USD / candle	6.06 USD
Batteries	0.3 battery	0.50 USD / battery	0.16 USD
		Total:	**7.49 USD**

In the past in Zambia, off-grid solar home systems had to be paid for in cash – but now a new financing scheme has been launched where customers can pay for their system through their mobile phones. This is usually associated with a 'solar package' whereby the service provider offers the solar equipment and maintenance and the recipient pays. The Solar Industry Association of Zambia (SIAZ) offers more information about this financing programme which could also be applied to energy-efficient appliances.

Zambia is working to accelerate its engagement in the off-grid solar home system space, having recently formed an “Off Grid Task Force” which includes the Ministry of Energy, and SIDA is one of the leading partners for this supporting this platform. This work is tied into the ‘beyond the grid’ initiative, which is linked Power Africa on the USAID side and SIDA with the Swedish support. Zambia also held an investor conference in June/July 2018 with GOGLA, which is trying to push for quality assurance in the off-grid lighting space.

The impact on the Zambian Electrometer Company – a local manufacturer of CFLs – will need to be considered in the context of this regulation to phase-out inefficient lighting. If they were to move to manufacturing of LEDs, they would have to pay import tax on the parts they are using to make LED lamps whereas suppliers who are importing finished lamps will be tax exempt. This will put the local manufacturer at a competitive disadvantage. This issue will need to be addressed by the government to help ensure the local manufacturer is not penalised.

4.5.4 Off-Grid Lighting Economic Analysis for Zambia

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for Zambia), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting and deliver far more light (higher lumens).

Table 49. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in Zambia

Zambia

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.

Country:	**Zambia**	ZMW
Currency conversion to US$:	0.084	Zambian Kwacha/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	0.74	US$/litre
Average kerosene price:	9	ZMW/litre
Annual change in price:	10.1%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	Candle	Kero Lamp Sm	Kero Lamp Lg	Solar Small	Solar Large	Solar Home Sys.	
Price for one light source (USD):	0.10	2.00	7.00	30.00	40.00	90.00	US$/product
Price for one light source (ZMW):	1	24	83	357	476	1,071	ZMW/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	2.00	7.00	30.00	40.00	90.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	36.50	20.53	32.41	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	217.27	142.67	221.88	79.09	72.65	90.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	138.18	144.62	127.27	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	64%	67%	59%	percent
LCC savings compared with kerosene lamp large:	---	---	---	142.79	149.22	131.88	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	34%	31%	39%	percent
Discounted, annualised LCC of light over 6 years of use:	36.21	23.78	36.98	13.18	12.11	15.00	US$/year
As above, but normalised for 1 megalumen-hour of light:	1,975	1,086	844	90	28	10	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.82	1.09	2.46	years
Simple Payback period in months, compared with candles:	---	---	---	9.8	13.1	29.6	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.71	1.02	2.56	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	8.5	12.2	30.7	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	102%	88%	47%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for Zambia, the calculation shows that the payback period of moving from candles to a solar system has a payback of 0.82 to 2.46 years, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 0.71 and 2.56 years – around 2.5 years even for the most expensive solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in Zambia is compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in Zambia. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the third year compared with the fuel-based light sources.

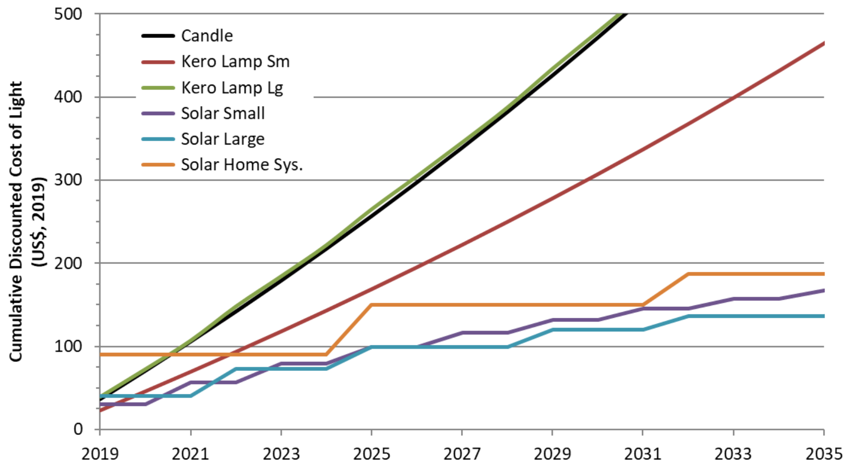


Figure 40. Cumulative Discounted Cost of Off-Grid Lighting for a Zambian Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-3 times cheaper to own and operate compared to the kerosene and candle-based sources.

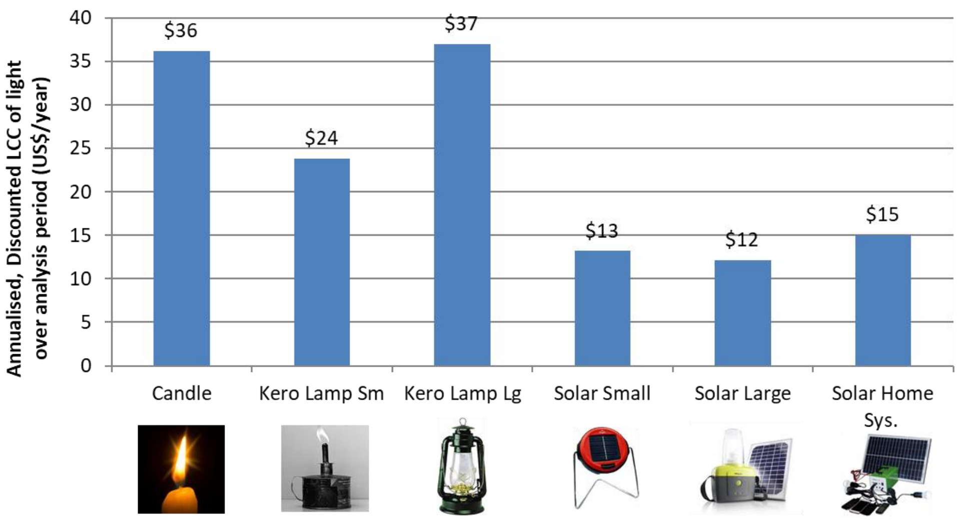


Figure 41. Annualised, Discounted LCC of Off-Grid Lighting for a Zambian Household

Off-grid solar lighting systems tend to be sold with warranty, however in most cases it is actually after sales service and repair, rather than replacement. There is a notable trend in the off-grid lighting market towards solar lighting, moving away from kerosene and candle-based lighting.

4.6 Country Profile Summary: Zimbabwe

Capital: Harare
Language: English
Median age: 20.6 (2016 estimate)
National currency: US Dollar

Table 50. At-a-glance Information on Zimbabwe

Indicator	2015
Population total[1]	15,777,451
Population growth (annual %)[1]	2.35%
Urban Population, % of Total[2]	32.4%
Rural Population, % of Total[2]	67.6%
GDP (Current US$)[1]	16,304,667,800
GDP Growth (Annual %)[1]	1.69%
GDP per capita (current US$)[1]	US$1033
GDP Annual Growth Rate Forecast to 2020[2]	4.88%
Inflation, consumer prices (annual %)[1]	2.40%
Electrification Rate[3]	34%
Human Development Index (rank of 188)[2]	155
TI Corruption Index, 2016 (rank of 168)[2]	150

Sources: 1. World Bank Group, World Development Indicators, accessed November 2018;
2. Africa-EU Renewable Energy Cooperation Programme, accessed 10 Dec 2018;
3. IEA, Energy Access Outlook 2017.

Map source: Nations Online Project, 2018.

4.6.1 On-Grid Lighting Market in Zimbabwe

According to economists, Zimbabwe has struggled for the last two decades amidst a difficult political and social environment (SET, 2017). Between 1999 and 2008, Zimbabwe's GDP declined by 52%. Between 2009 and 2016, the economy grew at just 2.9% on average, a rate slower than its neighbours in the region.

Zimbabwe has three companies who are importing lamps and doing some limited assembly in-country – Muruwe (Pvt) Ltd. offers LED bulbs, tubes and candle lights; Global Solar offers LED bulbs and tubes; AE Electrical offers LED bulbs.

The main importers in Zimbabwe are Satewave Technologies, Lighting World, Electrosales, Amanat Electrical, Bhola Hardware, Pick & Pay (TM) supermarkets, OK (Bonnie Marche) supermarkets, and Spar supermarkets. Lighting products imported and traded include a range of Indoor and outdoor lamps, LED strips, flood lights, solar lighting, traffic lights, decorative lights, pool and fountain lights, reflectors, lighting housing, etc. The largest importers are Satewave Technologies and Amanat Electrical, followed by Lighting World and Bhola Hardware. All four of these importers are bringing in LED lamps, tubes, candle lights and spot lights. Zimbabwe doesn't have a lighting suppliers association.

The flow diagram below depicts the Supply Chain for lighting products in Zimbabwe. There is limited domestic production (most of the market is imported). Experts interviewed identified an issue with quality, in that the customs office is meant to check to ensure products meet quality standards but they aren't capacitated to perform these checks, so they are not enforced.

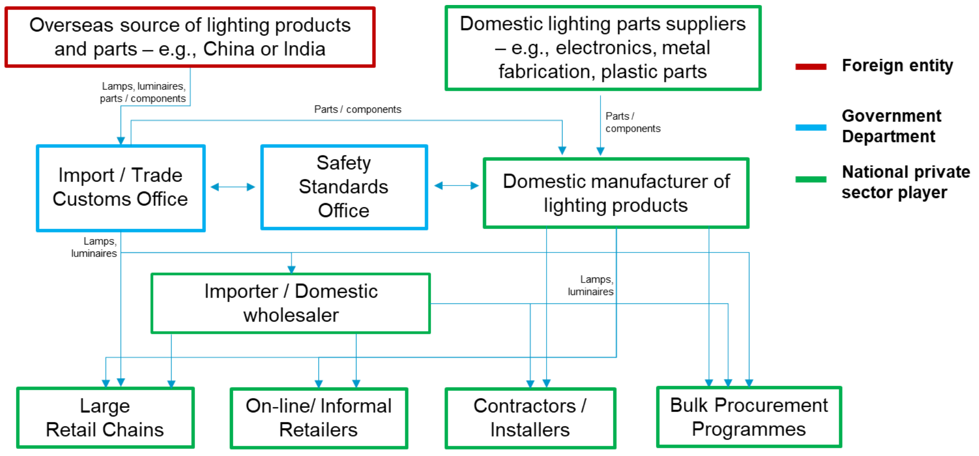


Figure 42. Flow diagram depicting the lighting supply chain in Zimbabwe

In terms of lighting technologies and volumes, Zimbabwe's lighting market includes all the technologies identified – incandescent, halogen, compact fluorescent lamps, linear fluorescent, high-intensity discharge (HID) lamps, and light emitting diode lamps and luminaires. The incandescent, halogen, compact fluorescent, LED lamps are used in domestic, commercial and offices in industrial setting. Linear fluorescent is used in commercial, industrial and municipal/outdoor settings and to e lesser extent. HID lamps and LED flood lights are used as security lights in commercial, industrial as well as in municipal settings.

The tables below provide the estimated annual sales and installed stock of the major lamp types for Zimbabwe, based on the United Nation's Comtrade database, spanning from 2010 through 2017 and adjusted to account for any irregularities and gaps. These data show a decrease in the sales of incandescent lamps from large volumes in 2012 to very small quantities in 2017.

Table 51. Estimated Total Annual Sales of Lamps for All End-Use Sectors in Zimbabwe

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	3,815,290	2,646,564	2,646,564	1,477,838	3,240,178	1,434,916	544,900	544,900
Halogen	253,312	504,593	537,758	1,148,212	1,383,234	955,746	856,322	906,034
CFL	688,635	2,350,445	1,947,988	1,913,895	1,695,714	1,601,091	1,462,397	1,531,744
Linear Fluores.	841,665	2,872,767	2,380,875	2,339,204	2,072,540	1,956,889	1,787,374	1,872,132
HID Lamps	472,408	256,110	1,023,880	141,104	17,284	88,880	240,430	164,655
LED Lamp	-	-	-	90,799	252,765	239,505	229,090	298,268
LED Tube	-	-	-	46,784	82,902	117,413	142,990	187,213
LED Outdoor	-	-	-	2,822	691	5,333	19,234	16,466

Applying assumptions to those sales data in terms of hours of use (which vary by sector) and hours of rated lifetime per product, an inventory stock model was created which provides an estimate of the total installed stock of on-grid light sources in Zimbabwe. The table below presents this estimate, broken down by end-use sector.

Table 52. Estimated Installed Stock of Lamps by Sector in Zimbabwe (millions of units)

Installed Stock of Lamps	Residential	Professional	Outdoor	Total
Incandescent	1.001	0.099	0.020	1.120
Halogen	1.103	0.132	0.026	1.262
Compact Fluorescent	3.493	2.114	0.176	5.783
Linear Fluorescent	1.870	8.513	0.532	10.914
High Intensity Discharge	0.041	0.163	0.610	0.814
LED Omni-directional	0.364	0.193	0.025	0.582
LED Tube	0.037	0.198	0.012	0.247
LED Outdoor	0.000	0.002	0.007	0.009
Total	**7.909**	**11.413**	**1.408**	**20.730**

Applying common wattages to the stock of lamps, an estimate of the total energy consumption for lighting in Zimbabwe can be calculated. For the above stock of lamps, this equates to 1.472 TWh/yr of electricity consumption, or about 18.4% of the national consumption of 8.000 TWh/yr (2015). For more information on the shipment estimates and the stock and energy consumption calculation, please see the Annex of this report.

In general, the experts interviewed indicated that most of the market is shifting towards LED. They are popular in all sectors. People have to pay for electricity before using it, and this makes them very sensitive and aware of consumption – meaning it causes many people change to LED because of the clear savings. Once a consumer has realized the savings, they spread the message and the whole Community is motivated to switch. The pre-payment meter made a lot of people to move to LED.

Street lighting – in the capital, Harare, and a few towns they also make use of LED, especially some off-grid LED pilot projects in the capital and policies are also realising it. The other municipalities, its like a policy – if a flood light fails, they will replace with LED. Those installed are being changed one-on-one.

There are some market awareness that have been run, such as one by the Zimbabwe Electricity Transmission and Distribution Company – Awareness campaigns. However there is a conflict in that the utility sees its role as producing power and selling it. Retrofitting energy-efficient lamps means a reduction in sales of electricity, so they are concerned. If there are no incentives for the utility, they see this mechanism as reducing their income and so they are not fully committed to the initiative. This is an issue that needs to be discussed with the government, who can incentivize the ZETDC to take action.

The Zimbabwe Energy Regulatory Authority worked projects of retrofitting LED lights at:

- Harare Hospital Children's Ward
- Mpilo Hospital
- Chipendeke Micro-Grid
- ZERA Headoffice

In addition, the government banned incandescent lighting through Statutory Instrument 21 of 2016 and SI 208 of 2018. Please click on this link to view the regulation.

Power quality is an issue in Zimbabwe. At the moment, they have standby generators, if the power goes off, most of the national hydro generation capacity is coming from the Zambezi river and new capacity has to be agreed with Zambia. After we agree with Zambia, then there is an issue of finance. There is one big hydro under development, and they are looking at other installations – the major problem there is how to finance those projects. Energy efficiency therefore represents a great (and cost-effective) alternative to new supply.

The majority of lamps are of poor quality due to lack of enforcement on lighting standards. The regulation is there but enforcement is weak. Although the regulator (ZERA) engaged Bureau VERITAS to assist in ensuring that we can import quality lighting products, the border check points can be porous.

4.6.2 On-Grid Lighting Economic Analysis for Zimbabwe

The illustration below shows the cost of light (including lamps and electricity only, labour is assumed to be no cost) over time. All the inputs to the calculation appear in the red-shaded areas, including the lamp cost, electricity cost, consumer price index (applied to the future cost of electricity) and the discount rate.

Table 53. Calculation of Economic Benefits of On-Grid Energy-Efficient Lighting in Zimbabwe

Zimbabwe

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures.

Country:	**Zimbabwe**	ZWD
Currency conversion to US$:	0.00028	Zimbabwe Dollar/US$
Lamp is on for hours/day:	4.00	hours/day
Electricity price:	0.10	US$/kWh
Electricity price:	357	ZWD/kWh
Annual change in price of Electricity	10.1%	percent
Electricity CO2 intensity:	0.358	kg CO2/kWh
Discount Rate	7.0%	percent

Lamp type	**Incandescent**	**Halogen**	**CFL**	**LED**	
Lamp wattage:	60	52	15	8	Watts
Rated lamp lifetime:	1000	2000	6000	15000	Hours
Price for one lamp (USD):	0.50	1.50	2.00	4.00	US$/lamp
Price for one lamp (ZWD):	1,786	5,357	7,143	14,286	ZWD/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:	88	76	22	12	kWh/year
Annual electricity savings compared to incandescent lamps:	---	11	66	76	kWh/year
Percent electricity savings compared with incandescent lamps:	---	13%	75%	87%	percent
Electricity cost for operating the lamps each year:	8.76	7.62	2.19	1.17	US$/year
Financial savings of electricity costs per year vs. incandescent:		1.14	6.57	7.59	US$/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:	10.0	10.0	10.0	10.0	years
LCC of operating lamp for 10 years, discounted to 2019:	105.19	96.06	29.69	17.33	US$ (NPV, 2019)
LCC savings of more efficient lamp compared with an incandescent:	---	9.13	75.50	87.86	US$ (NPV, 2019)
Percent LCC savings compared with incandescent lamps:	---	9%	72%	84%	percent
LCC savings are (X) times larger than halogen LCC savings:	---	---	8.3	9.6	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with incandescent:	---	0.88	0.23	0.46	years
Simple Payback period in months, compared with incandescent:	---	10.5	2.7	5.5	months
Payback period is (X) percent better than halogen payback period:	---	---	74%	47%	shorter
Internal Rate of Return (IRR), compared with incandescent:	---	82%	529%	266%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 10 years:	313.6	272.7	78.4	41.8	kg CO2/10 yrs
CO2 savings compared with an incandescent lamp:	---	40.9	235.2	271.8	kg CO2/10 yrs
CO2 savings is (X) percent more than halogen CO2 savings:	---	---	475%	564%	percent

Given the data provided for Zimbabwe, the calculation shows that the payback period of moving from incandescent lamps to an LED lamp is just 5.5 months. And the net-present value of the energy savings over a 10-year period, discounted back to 2019 is US$88 – far exceeding the incremental first cost of US$3.50. At this rate of economic savings, the case for moving to LED is extremely compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same four light sources in Zimbabwe. The first graph shows the cost of both replacement lamps and energy costs for operating the lamps over a fifteen-year time period. The energy savings gap between the tungsten-filament based incandescent and halogen lamps relative to the compact fluorescent and LED lamps is significant. It should also be noted that the incandescent and halogen lamps are already more expensive even from the first year - this is due to the high electricity cost associated with operating the lamps for several hours per day for a full year (hence the payback period for both CFL and LED is much less than one year).

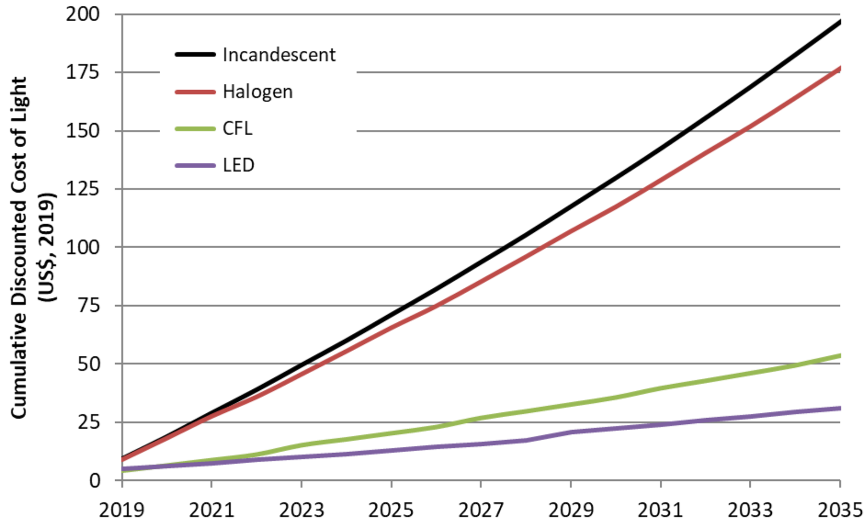


Figure 43. Cumulative Discounted Cost of Light Graph for a Lamp in a Zimbabwe Household

This comparison provides an annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of longest operating lamp), assuming lamps are used each day for the hours given, that electricity is at the cost given, and applying both the consumer price index for increasing electricity costs and the assumed discount rate.

The following graph provides a comparison of the net present value of the lighting service provided over a ten year time period, discounted back to 2019. Please note that no normalisation of light output levels are needed for this comparison as the lamps selected are all chosen to be equivalent to the light output of a 60W incandescent lamp.

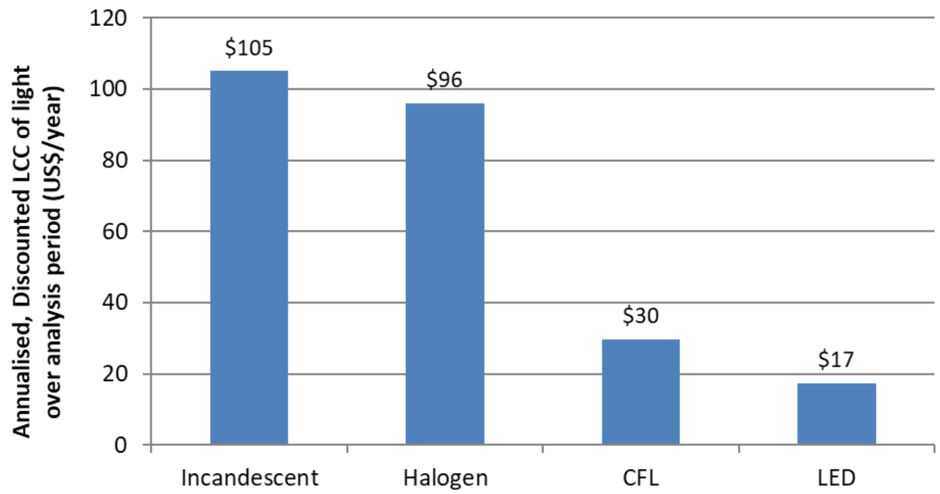


Figure 44. Annualised Discounted LCC for a Lamp over 10-years in a Zimbabwe Household

4.6.3 Off-Grid Lighting Market in Zimbabwe

There are no off-grid lighting manufacturers operating in Zimbabwe, however there is a repair market where people can get products serviced.

People can buy products from electrical hardware and retail shops, retails shops and wholesalers. The main importers include Electrosales, Amanat, Bhola and retail shops and wholesalers (Pick & Pay (TM) supermarkets, OK (Bonnie Marche) supermarkets, Spar Supermarkets, Choppers, Food World) for kerosene lamps. Lighting products include a range of solar lanterns, solar street lights, candles, kerosene lamps. Kerosene, candles, battery/torch, solar lanterns, and solar home systems are used by domestic households. Solar street lights and solar home systems are used by commercial, industrial as well as municipal sectors.

The off-grid lighting supply chain diagram below indicating key players, main routes to market and so-on is representative of Zimbabwe, bearing in mind that all lighting products are included in the flow.

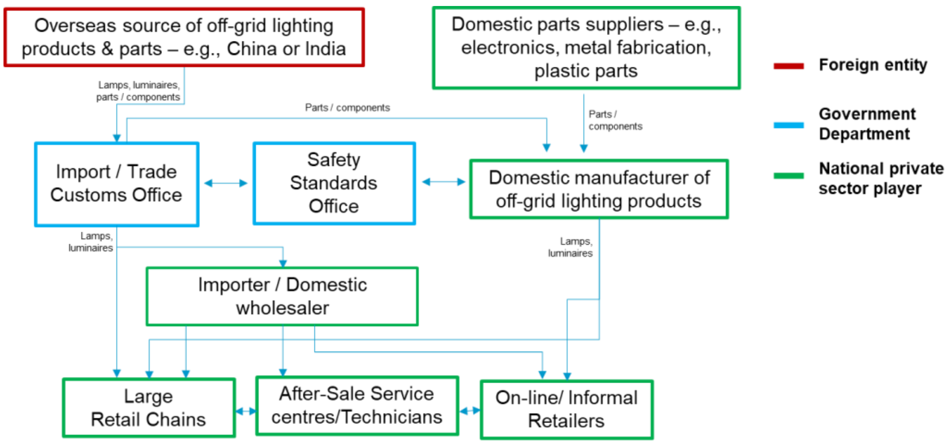


Figure 45. Flow diagram depicting the off-grid lighting supply chain in Zimbabwe

The following table provides an estimate of the off-grid lighting stock estimate for Zimbabwe, based on analysis that was prepared by the United Nations Environment Programme (UNEP) en.lighten initiative, and published in 2015. This table provides an estimate of the millions of lamps in the installed base of households and small businesses across Zimbabwe. Overall, it is estimated that there are approximately 4.4 million light sources for off-grid households and 0.3 million light sources for off-grid small businesses.

Table 54. Installed Stock Estimate of Off-Grid Lighting in Zimbabwe

Light source	Households	Businesses
Kerosene lamp (glass cover)	0.2770 (6.3%)	0.0439 (14.3%)
Kerosene lamp (simple wick)	0.3694 (8.3%)	0.0439 (14.3%)
Torch (flashlight)	0.1385 (3.1%)	0.0659 (21.4%)
Candles (light points)	3.6474 (82.3%)	0.1537 (50.0%)
Total:	4.4323 million	0.3074 million

To get an understanding of the average monthly running costs for these light sources, an estimate of the monthly fuel consumption and cost of fuel was prepared. The table below presents those estimates for the typical off-grid household in Zimbabwe, spending around US$7.22 per month on fuel-based lighting.

Table 55. Average Household Monthly Costs, Off-Grid Lighting in Zimbabwe

Energy source for light	Amount Consumed	Cost per Unit	Total
Kerosene	1.1 litres	0.73 USD / litre	1.2 USD
Candles	58.6 candles	0.10 USD / candle	5.86 USD
Batteries	0.3 battery	0.50 USD / battery	0.16 USD
		Total:	**7.22 USD**

Most shops do not give warranties on the solar lanterns products, and those few that provide them are usually for short periods, maybe one to three months. Examples of those giving warranties are Electrosales and Power Shop. Customers have to provide receipts while ensuring that they did not temper with any lighting product.

Over the last few years, LEDs have taken a greater market share. For LED is high – they are usually using LEDs and CFLs in off-grid systems. The issue of quality is a problem to some off grid lighting products. This is a problem and due to lack of technical capacity in Zimbabwe.

4.6.4 Off-Grid Lighting Economic Analysis for Zimbabwe

The table below shows the cumulative, discounted cost of off-grid light (including lamps and fuel) over time. All the inputs to the calculation appear in the red-shaded areas, including the hours per day, fuel costs, change in price over time (consumer price index for Zimbabwe), light source cost and other variables. The calculation shows that solar-based light sources are far-more cost effective than fuel-based lighting, and deliver far more light (higher lumens).

Table 56. Calculation of Economic Benefits of Off-Grid Energy-Efficient Lighting in Zimbabwe

Zimbabwe

Spreadsheet to look at cost-effectiveness of efficient lighting policy measures in the off-grid market.

Country:	**Zimbabwe**	ZWD
Currency conversion to US$:	0.00028	Zimbabwe Dollar/US$
Lamp is on for hours/day:	4.00	hours/day
Average kerosene price:	1.30	US$/litre
Average kerosene price:	4643	ZWD/litre
Annual change in price:	10.1%	percent
Candle CO2 intensity:	3.39	kg CO2/kg cand.
Kerosene CO2 intensity:	2.60	kg CO2/L keros.
Discount Rate	7.0%	percent

Light source	**Candle**	**Kero Lamp Sm**	**Kero Lamp Lg**	**Solar Small**	**Solar Large**	**Solar Home Sys.**	
Price for one light source (USD):	0.50	3.00	10.00	20.00	50.00	120.00	US$/product
Price for one light source (ZWD):	1,786	10,714	35,714	71,429	178,571	428,571	ZWD/product
Service life of the light source:	4	1000	5000	3000	5000	10000	hours
Light output of the source:	13	15	30	100	300	1000	lumens
Fuel rate (grams of candle; ml/hour kerosene):	20	19.0	30.0	---	---	---	gm ; ml/hour
Running costs and lighting service							
Annual capital cost in first year:	0.00	3.00	10.00	20.00	50.00	120.00	US$/year
Annual fuel (candle/kerosene) cost for each type:	182.50	36.06	56.94	---	---	---	US$/year
Quantity of Lighting service provided annually:	18	22	44	146	438	1,460	kilolumens/yr
Life-Cycle Cost (LCC) of one lamp over analysis period shown							
LCC time period of analysis:	6.0	6.0	6.0	6.0	6.0	6.0	years
LCC of operating lamp for 6 years, discounted to 2019:	1,086.34	248.02	385.61	52.73	90.81	120.00	US$ (NPV, 2019)
LCC savings compared with candles:	---	---	---	1,033.61	995.52	966.34	US$ (NPV, 2019)
Percent LCC savings compared with candles:	---	---	---	95%	92%	89%	percent
LCC savings compared with kerosene lamp large:	---	---	---	332.88	294.80	265.61	US$ (NPV, 2019)
Percent LCC savings compared with kerosene lamp large:	---	---	---	69%	73%	76%	percent
Discounted, annualised LCC of light over 6 years of use:	181.06	41.34	64.27	8.79	15.14	20.00	US$/year
As above, but normalised for 1 megalumen-hour of light:	9,874	1,888	1,467	60	35	14	US$/Megalumen
Payback period and Internal Rate of Return calculations							
Simple Payback period in years, compared with candles:	---	---	---	0.11	0.27	0.65	years
Simple Payback period in months, compared with candles:	---	---	---	1.3	3.3	7.9	months
Simple Payback period, compared with kerosene lamp lg:	---	---	---	0.18	0.70	1.93	years
Simple Payback in months, compared with kerosene lamp lg:	---	---	---	2.1	8.4	23.2	months
Internal Rate of Return (IRR) for each lamp type:	---	---	---	914%	372%	162%	percent
CO2 emissions calculations							
CO2 emissions from one light source over 6 years:	148.4	432.7	683.3	---	---	---	kg CO2/6 yrs
Solar lamp CO2 savings compared with a candle:	---	---	---	148.4	148.4	148.4	kg CO2/6 yrs
Solar lamp CO2 savings compared with a kerosene lamp large:	---	---	---	683.3	683.3	683.3	kg CO2/6 yrs

Given the data provided for Zimbabwe, the calculation shows that the payback period of moving from candles to a solar system has a payback of 1.3 to 8 months, depending on the system. Compared with a large kerosene lantern, the solar systems have a payback of between 2 to 23 months – still less than 2 years even for the most expensive solar home system. If the upfront capital cost can be overcome, the case for moving to solar lighting systems in Zimbabwe is compelling.

The following two figures look at the longer-term running costs associated with a comparison of these same six off-grid light sources in Zimbabwe. The first graph shows the cumulative, discounted cost of light (including lamps and fuel costs, labour is assumed to be no cost) over time. Note that this graph does not account for the quantity of light delivered - it is simply the cumulative, discounted cost of light for each option. Lighting service provided by the candle is much, much lower than that provided by the solar home system. In this figure, all the solar options are less expensive by the third year compared with the fuel-based light sources.

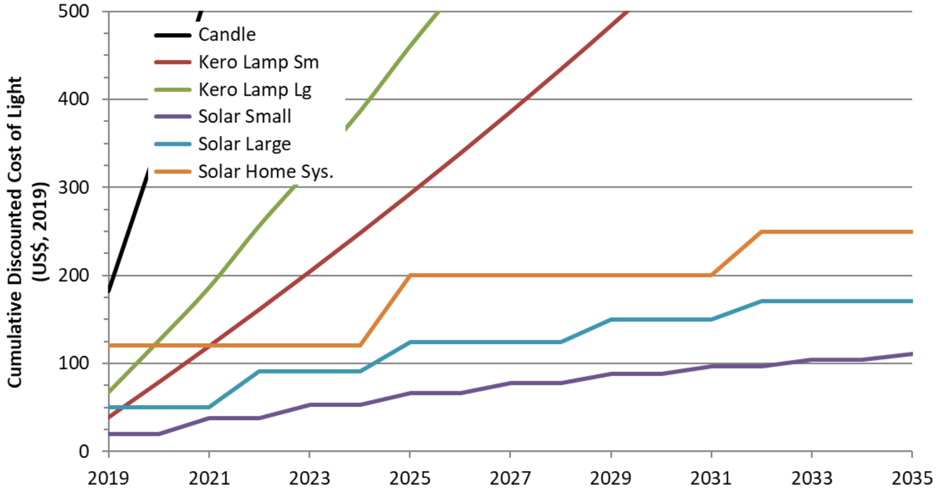


Figure 46. Cumulative Discounted Cost of Off-Grid Lighting for a Zimbabwe Household

The figure below provides a comparison of the annualised net present value life-cycle cost of light for the given analysis period (based on the lifetime of the longest operating light source). Note that light output levels are not normalised in this comparison - families with the solar lighting systems will enjoy improved light service in addition to paying less over time for lighting services in their homes. Solar lighting systems are 2-4 times cheaper to own and operate compared to the kerosene and candle-based sources.

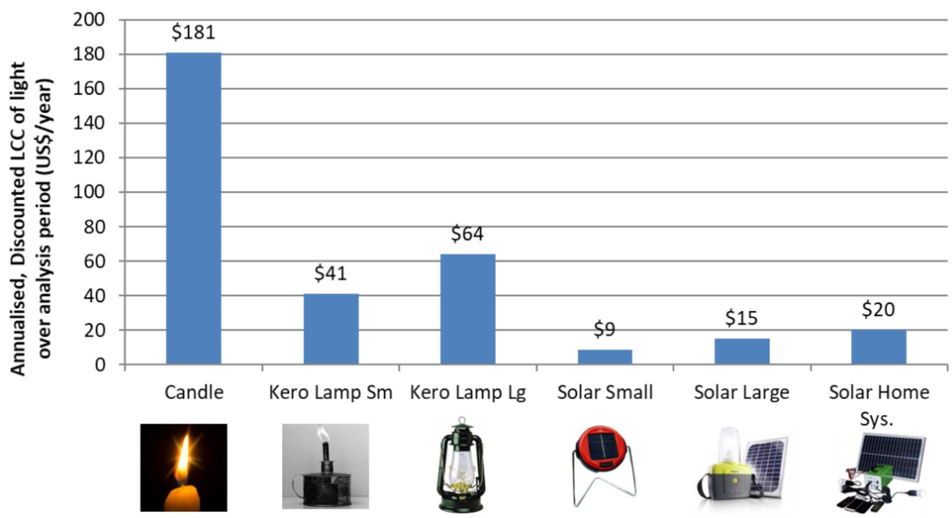


Figure 47. Annualised, Discounted LCC of Off-Grid Lighting for a Zimbabwe Household

5 Additional Input from the Countries

Several countries in the region completed the market survey instruments for on and off-grid lighting and provided information relating to their situation and readiness for transitioning their markets towards energy-efficient lighting. These countries were:

- Botswana
- Eswatini
- Mauritius
- Mozambique
- Seychelles
- South Sudan

Summaries of their contributions can be found in this chapter, and this input served to validate the findings in the focus six countries by confirming the market readiness for market transformation and need for interventions in the market to protect consumers and improve people's quality of life.

5.1 Country Profile Summary: Botswana

Capital: Gaborone
Official Languages: English and Tswana
National currency: Botswana pula (BWP)

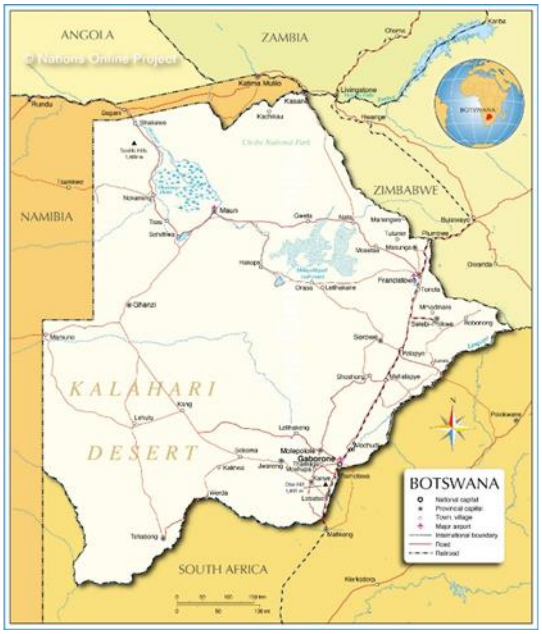


Table 57. At-a-glance Information on Botswana

Indicator	
Population total[1]	2,291,661
Population growth (annual %)[1]	1.82%
Urban Population, % of Total[1]	68.7%
Rural Population, % of Total[1]	33.1%
GDP (Current US$)[1]	17.4 Billion
GDP Growth (Annual %)[1]	2.36%
GDP per capita (current US$)[1]	US$ 7,596
Electrification Rate[2]	55%
Human Development Indicator (rank of 188)[3]	101
TI Corruption Perceptions Index, 2018 (rank of 180)[4]	34

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018 Statistical Update - Botswana, accessed January 2019; 4: Transparency International, accessed January 2019

Map source: Nations Online Project, 2019.

5.1.1 On-Grid Lighting Market in Botswana

Botswana has one lamps and luminaire manufacturer, Lesedi electrical. The main lamp and luminaire distributors are Sharp, JF Electrical, Kebo holdings, Oriental Electrical, BMS, Haskins, Omega Electrical, No 1 Electrical, Cash Build, Builder's World, Cash Build and Builders Warehouse.

All the identified lamps and luminaires are available in the market. The rate of LED penetration especially for streetlights and commercial buildings is increasing but the uptake is still low for residential applications. The government has not set any policies focused on efficient lighting. However, the Botswana Power Corporation, Botswana Institute of Technology, Research and Innovation, the Gaborone City Council and local councils are involved in some programs to promote efficient lighting. The Botswana Bureau of Standards is in charge of setting standards and testing products.

The domestic tariff ranges between 0.074 to 0.1 USD/kWh and does not vary between urban and rural users. The two main challenges to adoption of more efficient lighting is the lack of consumer awareness and affordability.

Although there are lamps and luminaires that are more energy efficient in the market, most consumers buy incandescent and low quality CFLs due to their low upfront cost.

5.1.2 Off-Grid Lighting Market in Botswana

Botswana does not have any manufacturing of off-grid lighting products. The same importers that import on-grid lighting products also import the off-grid products. Off-grid lighting importers are members of the Solar Industries Association of Botswana and the Botswana Renewable Energy Association. The Botswana market has all the off-grid products including candles, kerosene lamps and battery torches. Households and small businesses are the primary users of these products. Solar lanterns and solar home systems are available locally but most of these products are low quality. Firewood is still in use in some remote areas for heating and lighting.

Most customers purchase off-grid products on cash basis and in most cases, with no warranty. The government is developing programs to promote off-grid solar solutions.

5.2 Country Profile Summary: Eswatini

Capital: Mbabane and Lobamba
Official Languages: siSwati and English
National currency: Swazi lilangeni (SZL) and South African Rand

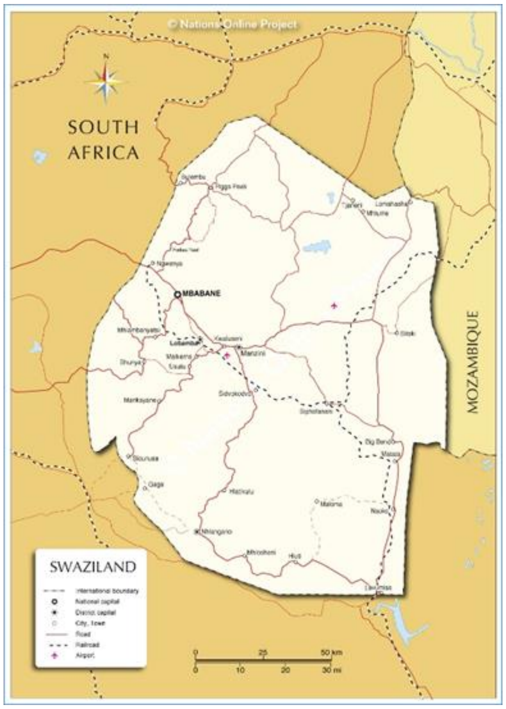


Table 58. At-a-glance Information on Eswatini

Indicator	
Population total[1]	1,367,254
Population growth (annual %)[1]	2.78%
Urban Population, % of Total[1]	23.63%
Rural Population, % of Total[1]	76.38%
GDP (Current US$)[1]	4.434 Billion
GDP Growth (Annual %)[1]	1.87%
GDP per capita (current US$)[1]	US$ 3,242
Electrification Rate[2]	84%
Human Development Indicator (rank of 188)[3]	144
TI Corruption Perceptions Index (rank of 180)[4]	89

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018

Statistical Update - Eswatini, accessed January 2019; 4: Transparency International, accessed January 2019

Map source: Nations Online Project, 2019.

5.2.1 On-Grid Lighting Market in Eswatini

The Kingdom of Eswatini does not have any domestic lamp or luminaire manufacturing. Some of the lamp importers operating in the country include:

- Large retailers
  - Spar
  - Pick & Pay
  - OK
  - Saverite
  - True Save
  - Shoprite
- Wholesalers
  - Buy & Save
  - Ruchi
  - Mass Cash and Carry
- Hardware store
  - Cashbuild
  - Build It
  - Buy Cash Hardware
  - Baceth Hardware
  - Essential Hardware
  - Hoageys
  - Mica
  - Builders Warehouse
  - Corban Hardware
  - Mormond
  - Electric Source
  - Electric Current

These importers import all the lighting technologies identified – incandescent, fluorescent tubes, CFLs, LEDs and HID lamps like mercury vapour and metal halide lamps. Overall, large retailers and wholesalers supply approximately 70% of the lamps and luminaires while the hardware stores supply the other 30%.

Electricity consumers are slowly embracing LED technologies. Most large retail shops have retrofitted to LED and installation of LEDs has become the preferred option in new commercial buildings. Adoption by domestic consumers is slower due to the high upfront cost of LEDs.

The Ministry of Natural Resources and Energy recently completed its Energy Efficiency Policy, which lays out cost-effective measures to reduce the energy demand and greenhouse gas emissions through application of energy efficient lighting systems. The policy advocates for the adoption of standards and labelling regulations in order to increase the use of energy efficient lighting systems in the country. The government and the utility company are engaged in an awareness program to promote efficient lighting systems. The awareness program includes radio shows, adverts on print media and free distribution of efficient lamps.

The Eswatini Standards Authority is mandated with setting standards and testing but it currently does not have the capacity to test lighting products.

The utility charges the same rate for both rural and urban consumers. The domestic tariff is approximately 0.13 USD/kWh. The main barriers to more energy-efficient lighting include:

- Availability of the products
- Lack of consumer awareness
- Affordability

On the market trends, the unit price of CFL units is decreasing but there has not been much change in the price of LEDs. More retailers, wholesalers and hardware stores are stocking CFLs and high frequency fluorescent tubes.

5.2.2 Off-Grid Lighting Market in Eswatini

There is limited manufacturing capacity of off-grid lighting products in Eswatini with one candle manufacturer; Swazi candle. The rest of the products are imported. Table 59 below shows the main importers and which products they import.

Table 59: Main lighting importers operating in Eswatini

Importers	Name		Type of products
Large Retailers	Spar Pick & Pay OK Saverite True Save Shoprite		• Candles • Kerosene stoves • Torches
Wholesalers	Buy & Save Ruchi Mass Cash and Carry		• Candles • Kerosene stoves • LPG lamps • Torches
Hardware stores and Contractors	Cashbuild Build It Buy Cash Hardware Baceth Hardware Essential hardware Hoageys	Mica Builders Warehouse Corban Hardware Mormond Electrical Electric Source Electric Current	• Solar lamps • Kerosene stoves • LPG lamps • Solar home systems

All the identified off-grid lighting technologies including LPG lamps are found in the Eswatini market. The government's National Energy Policy 2018 promotes the use of clean off grid lighting solutions. The National Energy Policy Implementation Strategy also provides guidance on the rollout off grid lighting solutions. Several municipalities have also introduced by-laws that encourage the use of solar energy for street lighting and lighting households.

Most off-grid lighting products are sold on a cash basis and mostly without warranty. Overall, the usage of kerosene and candles for lighting is on the decrease.

5.3 Country Profile Summary: Malawi

Capital: Lilongwe
Official Languages: English, Chichewa and regional
National currency: Kwacha (MWK)

Table 60. At-a-glance Information on Malawi

Indicator	
Population total[1]	17,573,607
Population growth (annual %)[1]	2.91%
Urban Population, % of Total[1]	17%
Rural Population, % of Total[1]	83%
GDP (Current US$)[1]	6.4 Billion
GDP Growth (Annual %)[1]	2.80%
GDP per capita (current US$)[1]	US$363
Electrification Rate[2]	11%
Human Development Indicator (rank of 188)[3]	170
TI Corruption Perceptions Index, 2018 (rank of 180)[4]	120

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018 Statistical Update; 4: Transparency International, 2019.

Map source: Nations Online Project, 2019.

5.3.1 Lighting Standards adopted in Malawi

The Malawi Bureau of Standards is a state organisation with approximately 216 employees. At the Bureau, Technical Committee 4 for Electrical and General Safety Standards has been working for over 30 years and covers all of the lighting products. In general, Malawi has adopted a number of IEC/ISO standards on lighting which are mandatory for all manufacturers, suppliers and importers. They must comply with the specifications in the following list of relevant standards:

- MS 709:2005 – Fluorescent Lights for Use in Photovoltaic (P) Systems - Specification
- MS 882:2012 – Self-Ballasted Light Emitting Diode Lamps for General Lighting Purposes – Performance Requirements
- MS 887:2012 – Self-Ballasted Light Emitting Diode Lamps for General Lighting Purposes – Safety Specification
- MS 883:2012 – Self-Ballasted Lamps for General Lighting Purposes – Safety Requirements
- MS 884:2012 – Self-Ballasted Fluorescent Lamps for General Purposes – Performance Requirements
- MS 886:2012 – Self-Ballasted Compact Fluorescent Lamps for General Lighting Purposes - Specification

The survey respondent has indicated that Malawi may consider starting a new Technical Committee on Light and Lighting, to help ensure careful consideration of all the new and specific standards relating to lighting products.

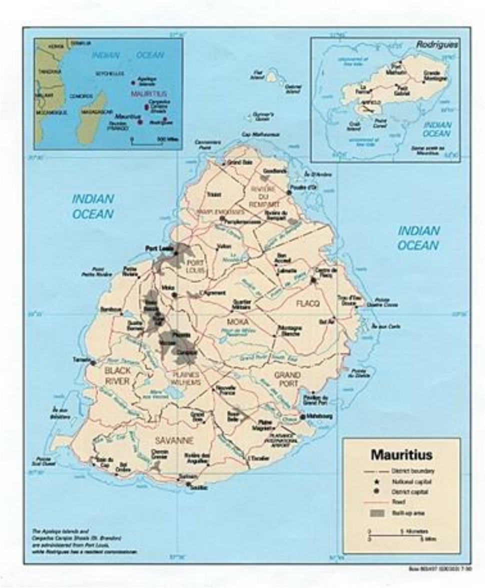
5.4 Country Profile Summary: Mauritius

Capital: Port Louis
Official Languages: English
National currency: Mauritian rupee (MUR)

Table 61. At-a-glance Information on Mauritius

Indicator	
Population total[1]	1,264,613
Population growth (annual %)[1]	0.09%
Urban Population, % of Total[1]	40.84%
Rural Population, % of Total[1]	59.16%
GDP (Current US$)[1]	13.27 Billion
GDP Growth (Annual %)[1]	3.82%
GDP per capita (current US$)[1]	US$ 10,491
Electrification Rate[2]	100%
Human Development Indicator (rank of 188)[3]	65
TI Corruption Perceptions Index, 2018 (rank of 180)[4]	56

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018 Statistical Update - Mauritius, accessed January 2019; 4: Transparency International, accessed January 2019



Map source: [Nations Online Project](), 2019.

5.4.1 On-Grid Lighting Market in Mauritius

Mauritius does not have any domestic manufacturing of lamps and luminaires. All the identified lamps and luminaires are available in the market. The penetration of LED lighting is low compared to other lighting technologies.

The government banned the importation of incandescent lamps of 75W and above. There is also a voluntary energy-labelling scheme that has been in place since 2014. The Energy Efficiency Management Office undertakes consumer awareness campaigns to promote efficient use of energy. The Mauritius Standards Bureau sets standards but does not have the laboratory capacity to test the energy consumption of lamps and luminaires.

The main barrier to adoption of more energy-efficient lighting products is the high cost of the products.

5.5 Country Profile Summary: Mozambique

Capital: Maputo
Official Languages: Portuguese
National currency: Metical (MZM)

Table 62. At-a-glance Information on Mozambique

Indicator	
Population total[1]	29,668,834
Population growth (annual %)[1]	2.87%
Urban Population, % of Total[1]	35.45%
Rural Population, % of Total[1]	64.55%
GDP (Current US$)[1]	12.646 Billion
GDP Growth (Annual %)[1]	3.74%
GDP per capita (current US$)[1]	US$ 1,248
Electrification Rate[2]	29%
Human Development Indicator (rank of 189)[3]	180
TI Corruption Perceptions Index, 2018 (rank of 180)[4]	158

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018 Statistical Update - Mozambique, accessed January 2019; 4: Transparency International, accessed January 2019

Map source: Nations Online Project, 2019.

5.5.1 Off-Grid Lighting Market in Mozambique

Most off-grid lighting products are imported. However, there is one solar panel manufacturing plant in the country. There are several importers of off-grid lighting products. These include Aberdare, Ellies, and Tecnoelectrica among others. The country does not have a local association representing manufacturers and importers of off-grid lighting products.

All off-grid lighting technologies are in use in Mozambique including candles, battery torches, kerosene, solar lighting and solar home systems. These products are often purchased for domestic or small commercial use. The organisation in charge of testing and developing standards for lighting products is the Quality and Standardization National Institute (INNOQ).

The main policy guiding the development of the off-grid lighting sector is the National Electrification Strategy: 2018-2010. There are currently no initiatives by the regional or municipal governments or the utility company to increase the uptake of off-grid solar lighting.

Most customers purchase solar lights on a cash basis and the products are sold with warranty. The uptake of solar lights has increased in recent years although the market is not yet mature and is mostly informal. The people's knowledge on the potential benefits and uses of off-grid solar products is also minimal.

5.6 Country Profile Summary: Seychelles

Capital: Victoria
Official Languages: Seychelles Creole, English, and French
National currency: Seychelles Rupee (SCR)

Table 63. At-a-glance Information on Seychelles

Indicator	2015
Population total[1]	95,843
Population growth (annual %)[1]	1.224%
Urban Population, % of Total[1]	56.26%
Rural Population, % of Total[1]	43.74%
GDP (Current US$)[1]	1.489 Billion
GDP Growth (Annual %)[1]	5.285%
GDP per capita (current US$)[1]	US$29,265
Electrification Rate	97%
Human Development Indicator (rank of 188)[2]	62
TI Corruption Perceptions Index, 2018 (rank of 180)[3]	76

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. Human Development Indices and Indicators: 2018 Statistical Update - Seychelles, accessed January 2019; 3: Transparency International, accessed January 2019

Map source: Nations Online Project, 2019.

5.6.1 On-Grid Lighting Market in Seychelles

All the lamps and luminaires in the Seychelles are imported; the country does not have any lamp or luminaire manufacturing capacity. There are several main lamp and luminaire importers and dealers in Seychelles. Some of the main ones include:

- Luminous trading
- Happy house
- Swiss LED
- Soho surveillance

Seychelles does not have a lighting manufacturer's association since the country does not have any domestic manufacturing.

The flow diagram below depicts how products move through the lighting market in Seychelles.

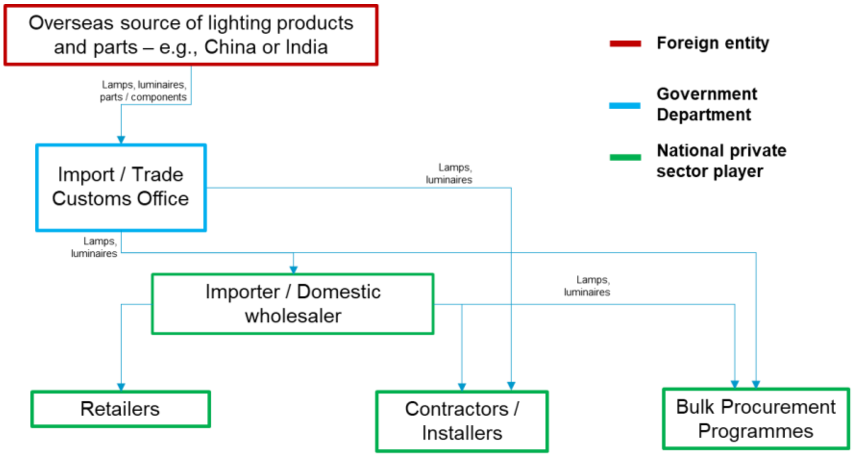


Figure 48: Illustration of the Lighting Supply Chain in the Seychelles

Most lighting products in the Seychelles are imported from China, India, the UAE, the UK and some come from other African countries like Kenya and South Africa. The customs office processes all imports but they do not check for compliance of the products with any safety or performance standards. Instead, the Seychelles Energy Commission check for compliance with the country's minimum energy performance standards and advice customs on whether the products meet the standards to allow for VAT exemption.

The Seychelles' lighting market has all the technologies identified - incandescent, halogen, compact fluorescent lamps, linear fluorescent, high-intensity discharge (HID) lamps, and light emitting diode lamps and luminaires. The sodium/mercury vapour lamps are used for street lighting and in some industrial lighting applications. However, more and more streetlights are now LED as the sodium/mercury vapour lamps are replaced. All sectors use LED, linear fluorescent and CFL lighting with some residential use of incandescent lights. Commercial, industrial and municipal lighting is mostly HID, whose use is being reduced, and halogen lights.

As per the VAT Act 2010, energy efficient products can be VAT-exempt. As a result, the Seychelles Energy Commission (SEC) has established the MEPS to screen products that are eligible for exemption. An energy-labelling program is still at the initial stages of discussion and an energy efficiency policy has been proposed to support the initiatives.

There has been an increase in the rate of penetration of LEDs in the Seychelles market. Several initiatives are causing this increase. For example, the municipals replace worn out lamps on their grounds with LED lamps. Awareness campaigns on efficient lighting and the VAT exemption discussed above has also increased the use of LEDs. The "Switch to LED Campaign" initiated on Earth Day 2017 aims to give electricity consumers two LED bulbs in exchange for two non-LED lamps. The main target of the campaign is incandescent bulbs. The campaign has been carried out in different islands and regions of the Seychelles.

The electric utility charges a subsidized flat domestic electricity tariff of 0.17 US$/unit across both urban and rural areas.

The main challenges of transitioning to more efficient lighting in the Seychelles include:

- Difficulty in sourcing products compliant with the efficiency standards. Since the Seychelles is a small market, importers have a hard time sourcing for compliant products.
- The efficiency regulations are only interim and enforcement has been a challenge
- Lack of affordability of efficient lighting products
- Some people are skeptical of the new lighting technologies

Overall, the market for efficient lighting in the Seychelles is growing with the fiscal incentives and more consumer awareness contributing to this growth.

5.6.2 Off-Grid Lighting Market in the Seychelles

The electrification rate in the Seychelles is 97 %. Most of the areas that are not connected are outer islands managed by the Island Development Company and islands for conservation and research managed by Seychelles National Parks Authority/ Seychelles Island foundation/Nature Seychelles and others. There are also some big hotels and other establishments on the mainland that have power generation systems. The off-grid lighting market in the Seychelles is therefore not as large as in other African countries.

Candles are mainly used for decorative purposes with torchlights and solar lights more common for off-grid applications.

5.7 Country Profile Summary: South Sudan

Capital: Juba
Official Languages: English
National currency: South Sudanese Pound (SSP)

Table 64. At-a-glance Information on South Sudan

Indicator	
Population total[1]	12,575,714
Population growth (annual %)[1]	2.78%
Urban Population, % of Total[1]	19.35%
Rural Population, % of Total[1]	80.65%
GDP (Current US$)[1]	2.904 Billion
GDP Growth (Annual %)[1]	-13%
GDP per capita (current US$)[1]	US$ 1,693
Electrification Rate[2]	1%
Human Development Indicator (rank of 188)[3]	187
TI Corruption Perceptions Index, 2018 (rank of 180)[4]	178

Sources: 1. World Bank Group, World Development Indicators, accessed January 2019; 2. IEA World Energy Outlook 2017; 3. Human Development Indices and Indicators: 2018 Statistical Update – South Sudan, accessed January 2019; 4: Transparency International, accessed January 2019

Map source: On the World Map, 2019.

5.7.1 On-Grid Lighting Market in South Sudan

South Sudan does not have any domestic lamps and luminaires manufacturing and therefore all the products in the country are imported. Most the lighting products are imported from China, India and Malaysia.

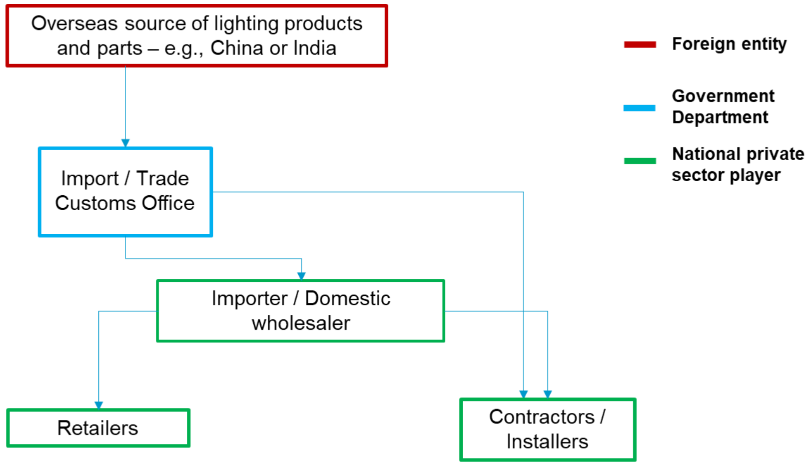


Figure 49: Illustration of the Lighting Supply Chain in South Sudan

The lighting technologies found in the South Sudan market include incandescent, CFLs, linear fluorescent and LEDs. Incandescent, linear fluorescent and CFL lamps and luminaires are mainly used in domestic, commercial and industrial applications while LED lamps are used by municipals for outdoor lighting.

South Sudan has not yet put in place any energy efficiency policies and there are currently no programs promoting the adoption of efficient lighting. The South Sudan National Bureau of Standards (SSNBS) is in charge of setting lighting standards and testing.

The average residential electricity tariff 0.47 USD/kwh is higher than most countries in the regions covered by this report. The barriers to more efficient lighting include:

- Lack of access to the products
- Affordability
- Lack of consumer awareness

5.7.2 Off-Grid Lighting Market in South Sudan

Due to the low electrification rate, off-grid lighting products are prevalent in South Sudan. Kerosene, candles, solar lanterns are used in domestic applications while solar home systems are used in small commercial settings. Solar LED lamps are mostly used for outdoor lighting.

There are currently no policies or government initiatives promoting off-grid lighting products. However, the government through the Ministry of Electricity and Dams has plans to initiate such programs. Most off-grid lighting products are purchased on cash basis and without warranty.

6 Conclusions and Recommendations

Based on the findings of the market assessment in this region, we make the following recommendations for consideration:

Interventions 1-3 are considered foundational, that all countries should undertake if they have not already, thereby ensuring a consistent, level playing field across the region. Interventions 4-7 are designed to be no-regrets market-pull initiatives, which will incentivise or facilitate a transition to more energy-efficient products. These market-pull interventions are not mandatory, but they open markets, lower cost barriers and generally raise awareness in the supply chain of more efficient technologies and products. Interventions 8 and 9 are market push approaches, which apply regulatory pressure and requirements to national markets. Intervention 8 would ideally be a harmonised regulatory measure, and it is recommended that governments start with a domestic lighting regulation (Bångens, 2016) to gain experience with the process and the timing of each stage.

Table 65. Recommended Intervention Actions to Support Market Transformation

#	Intervention Action	Type of Intervention and Description
1	Build Laboratory Capacity	Regional action. Facilitate the expansion and strengthening of the test laboratory capacity throughout the region. Consider conducting an Interlaboratory Comparison of lighting laboratories to help promote accreditation and ensure labs are calibrated to the same international standards (for both on-grid and off-grid lighting products). Consult with Dr. Franz Hengstberger from the National Metrology Institute of Ethiopia, a former president of the CIE and regional lighting metrology expert, for advice on efforts to build laboratory capacity in the region. Consider a bulk-purchase of the LightSpion test instruments and training work to build government capacity for testing and enforcing regulations. These recommendations are especially important for countries who have (or seek to develop) local manufacturing and/or product assembly.
2	Legislative Framework	National action. Ensure the government has created the legislative framework that grants authority to a Ministry for establishing mandatory standards and labelling (S&L) on consumer products and commercial equipment. S&L are the cornerstone of national programmes to transform markets towards more energy-efficient products.
3	Participate in Regional Energy-Efficiency Centres	National level action for regional benefit. Engagement with the regional energy-efficiency centres, SACREEE / EACREEE and participating in the dialogue and planning to establish programmes designed to support market transformation, including harmonised performance standards, bulk procurements, product specifications, policy recommendations and much more.
4	Green Procurement Specification	Regional action (potentially led by SACREEE and EACREEE) Develop a specification for the public sector to lead by example – Ministries, Parliament, Municipalities and other public entities would purchase from the green procurement specification which sets regional product purchasing criteria for a range of products – from street lights to office refrigerators; consider offering tax incentives to encourage the private sector to utilise the same list when making procurements for their facilities. One model for this bulk procurement that could be organised and implemented regionally is the successful joint venture in India called Energy Efficiency Services Limited (EESL).

#	Intervention Action	Type of Intervention and Description
5	Develop ESCOs and Funding Scheme	National / Regional action. Energy Service Companies (ESCOs) are an excellent way to unleash the power of the private sector to deliver energy savings in a given market. EACREEE and SACREEE could work together with national governments to develop a training programmes, case studies, spreadsheet tools, reference documents and resources that would stimulate entrepreneurs in the region to create ESCOs. If needed, a low interest fund which they can use, governments will enable them to more easily sign-up new clients and implement change, upgrading lighting, HVAC, appliances, equipment, building envelope and other solutions. ESCOs can specialise in commercial buildings, industries (e.g., mining, processes), or other market niche. By establishing a fund (e.g., with a local financial institution), this intervention would encourage more ESCOs to be formed and for those that already exist, it would enable them to expand their portfolio of business.
6	Electric Utility Engagement	National action. Electric utilities offer another avenue for market intervention because of their pivotal role between the end-user and their energy-supply. It is suggested that governments consider employing market-based instruments (MBIs) such as white-certificates which would obligate utilities to save energy but not prescribe the methodology they must follow. This could result, for example, in a change in the utility regulatory language requiring it to engage in end-user DSM initiatives. Those initiatives could trigger a range of different energy-efficiency initiatives. DSM programmes can then be launched that would promote efficient products and provide energy savings.
7	Stimulating Development of Energy-Efficiency Businesses	National / Regional action. Working with the regional energy efficiency centres and national ministries of trade and industry, help to develop a pipeline of green-tech projects and businesses that can stimulate and facilitate the development of environmentally sustainable businesses across the region. These businesses would seek to establish themselves, build local expertise, employment and create value-added products in the region. Examples of projects could include: LED luminaire manufacturing, micro-solar home systems, ceiling fans, and much more. If green finance is needed, establish a loan facility, potentially modelled after the Beyond the Grid Fund for Africa (BGFA), that provides grants to existing or start-up green-technology companies who are seeking to establish domestic production of products that are more efficient than the standard products on the market.
8	Quality and Performance Regulations	Regional action, adopted nationally. Minimum energy performance standards (MEPS) are the most sustainable option for achieving high levels of energy efficiency and for phasing out less efficient technologies. MEPS apply to both energy and performance-related characteristics, and should be developed in consultation with stakeholders' input and economic analysis, taking into account regional harmonisation. MEPS programmes need to be monitored, evaluated, updated, reviewed and revised. Lighting – both on-grid and off-grid lighting is an excellent starting point as it would enable processes to be trialled and understood, and once established, other products can be regulated through the same process. CLASP suggests a possible set of products for consideration and encourages the formation of an inclusive process where stakeholders can have a say: tertiary sector lighting, air-conditioning, domestic refrigeration, electric motors and televisions. Discussion on all of these products can be found in Chapter 6.

#	Intervention Action	Type of Intervention and Description
9	Market Surveillance	Regional and National Action. To ensure the MEPS are successful, governments need to a functional system of monitoring, verification and enforcement capable of ensuring full compliance of products with any regulatory measures. This Team within the government would be dedicated to Market Surveillance and would work in partnership with domestic industry as well as the customs office to monitor, inspect, test and ultimately accept or reject products from the market based on their compliance with the national regulations.

Country governments reviewing this study and these recommendations should consider harmonising their policies and actions with those of neighbouring states. Harmonising policy measures would mean adopting the same requirements, test standards and/or other requirement as another country (or countries) in a region. Through harmonisation, consumers benefit from lower prices and better product choice because the supplier's administrative trade barriers are reduced, and testing and compliance certification reporting costs are lower. The compliance costs are spread across a larger number of products, enabling consumers in those markets to enjoy better prices and choice of goods associated with the other (generally larger) economies with which they are harmonised.

Harmonisation of test standards enables multiple national markets to be accessible for the cost of only one test. Testing standards underpin all lamp MEPS and energy labelling programmes because they are the means by which a product's performance is measured and compared. Harmonisation of test procedures facilitates: trade; comparison of performance levels; technology transfer; and encourages replication of best practices. The most widely used test methods today for measuring the performance of lamps are those of the International Electrotechnical Commission (IEC) and the Commission Internationale de l'Eclairage (CIE). To ensure that they have an opportunity to participate in the development of these test methods, countries are encouraged to join the IEC.

The following subsections provide some more information and discussion on each of the ideas outlined in Table 65.

6.1 Build Laboratory Capacity

Note: This intervention would be undertaken at a regional level – across EAC and SADC.

Regional action. This recommendation revolves around three actions which are suggested to help build expand and strengthen test laboratory capacity throughout EAC and SADC, especially for countries who have (or seek to develop) local manufacturing and/or lighting product assembly:

(1) consider conducting an Interlaboratory Comparison of lighting laboratories to help promote accreditation and ensure labs are calibrated to the same international standards (for both on-grid and off-grid lighting products);
(2) consult with Dr. Franz Hengstberger from the National Metrology Institute of Ethiopia, a former president of the CIE and regional lighting metrology expert, for advice on efforts to build laboratory capacity in the region; and
(3) consider a bulk-purchase of the LightSpion test instruments and training work to build government capacity for testing and enforcing regulations.

6.1.1 African Regional Interlaboratory Comparison

A regional interlaboratory performance assessment scheme could be designed to help support harmonisation of SSL testing across Southern and Eastern Africa, and potentially across the whole continent. This initiative could be designed to establish a proficiency test (PT) to help participating labs gain accreditation to the international standard for measuring LED lamps, luminaires and modules – CIE S 025/E:2015. This work would be very useful for governments and market surveillance authorities in the region because it would strengthen the existing capacity by improving the reliability of results. Knowing that governments can trust laboratory test reports is really at the core of any regulatory and market surveillance work.

It is recommended this work be conducted in such a way that the Interlaboratory Comparison (IC) is focused on lighting products, and offers participants testing to both on-grid and off-grid lighting products:

- On-grid: CIE S 025/E:2015 – Test Method for LED Lamps, LED Luminaires and LED Modules http://www.cie.co.at/publications/test-method-led-lamps-led-luminaires-and-led-modules

- Off-grid: IEC TS 62257-9-5:2018 Recommendations for renewable energy and hybrid systems for rural electrification - Part 9-5: Integrated systems - Laboratory evaluation of stand-alone renewable energy products for rural electrification https://webstore.iec.ch/publication/59747

This intervention would revolve around the design and implementation regional Interlaboratory Comparison of lighting laboratories to help promote accreditation and ensure labs are calibrated to the same international standards. This activity is especially important for countries who have (or seek to develop) local manufacturing and/or product assembly.

Case Study: IEA 4E SSL Annex Interlaboratory Comparison (IC 2013)

The IEA 4E SSL Annex's Interlaboratory Comparison 2013 (IC 2013) was conducted between October 2012 and August 2013, and involved 110 laboratories comparing measurements of photometric, colorimetric, and electrical quantities of several different types of SSL products. More than 50 laboratories participated in the study directly while others were 'linked' to IC 2013 through existing proficiency test schemes in North America and the Asia Pacific region. The sample of products tested by the laboratories varied slightly, taking into account the most important products in the regional markets – but all test samples included both LED retrofit lamps and luminaires.

The comparison looked at the measured values of luminous flux, luminous efficacy, active power, RMS current, power factor, chromaticity x and y, correlated colour temperature, and colour rendering index. The study found that while most of the laboratories were within the expected levels of agreement, a few extreme outliers were observed. Dr Yoshi Ohno at the US National Institute of Standards and Technology (NIST), lead author of the IC2013 report note that identifying these large deviations by a small group of laboratories demonstrates the importance of proficiency testing, as these laboratories would not have been aware of their problems without participating in IC 2013.

The uncertainties reported by the participants were found to have a very large range (often more than two orders of magnitude), and some were significantly underestimated. Still other laboratories did not report uncertainties at all or for any colour quantities (i.e., chromaticity x, y, CCT, CRI). Dr. Ohno noted that the 2013 IC helped to understand that uncertainty evaluation, especially for colour quantities, which was noted as being difficult for the SSL industry, and the study also found that reported uncertainties are often not reliable. The report concluded that practical methods and tools for uncertainty evaluation of measurements, as well as educational documents and training for the SSL industry on practical uncertainty evaluation were urgently needed. Click on this link for more information.

6.1.2 Dr. Franz Hengstberger from the National Metrology Institute of Ethiopia

In the course of their regional market research, the Swedish Energy Agency met with the National Metrology Institute of Ethiopia (NMIE) and met a Resident Advisor named Dr. Franz Hengstberger. Formerly from Austria, Dr. Hengstberger is currently working on establishing a test lab for lighting quality for the Ministry of Trade and Industry, but has worked across many countries in the region over the last four decades, including some projects with UNIDO. He worked for 37 years as a manager of the lighting metrology department of the National Metrology Institute of South Africa (NMISA). He was president of the Commission Internationale de l'Eclairage (CIE) and thus has wide knowledge of test standards. This background of work could mean that he'd make an excellent advisor to the EELA project on the best approach for developing and expanding lighting test laboratory capacity in Africa. His linked-in profile can be found here: https://www.linkedin.com/in/fhrsa/?originalSubdomain=za

6.1.3 LightSpion Test Suitcase – for Product Screening

One possible way to strengthen the testing capacity for future regulatory enforcement would be to invest in a relatively low-cost solution which offers an indicative / red-flag test of lighting products. This product would not replace measurement in an accredited laboratory (such as those participating in the recommended regional interlaboratory comparison), but it would offer customs officials and trade inspectors an opportunity to conduct product screening tests for regulatory compliance with several regulatory requirements, including: lumens, colour temperature, colour rendering index, beam angle, power, power factor, efficacy (lumens per watt). Information on the LightSpion test suitcase can be found here: http://www.visosystems.com/products/lightspion/

Figure 50. Photograph of the LightSpion test suitcase testing an LED lamp

The Australian government has been exploring the potential for this product to be useful for import inspections and identified a list of additional equipment that is either essential or desirable depending on the desired level of accuracy of the measurement. These include the following:

- Low voltage power supply and digital multimeter
- Mains voltage uninterruptable power supply (to deal with any local voltage fluctuations at the test site)
- Gloves, sunglasses, marker pens, protractor
- Ageing rack - testing a lamp right out of the box is not very reliable, it should be seasoned for at least 100 hours (i.e., slightly more than 4 days)
- Special housing to hold MR16 lamps
- A small room or office with black cloth for walls
- Data processing spreadsheet
- Laptop to host the LightSpion software and possible drivers for the LV Power supply (note: it is possible to obtain one that can interact with the LightSpion software)

The Australian government is in the process of developing a brief step by step instruction manual for testing incandescent/halogen and CFL lamps, and these guidelines could probably easily be extended to LEDs. They have also developed a spreadsheet that allows for data entry from the LightSpion software so that the spreadsheet can process the data and provide the findings of the measurement.

6.2 Legislative Framework

Note: This intervention is conducted at the national level – not all countries will need it.

In order to establish a national MEPS programme which constitutes the cornerstone of any market-transformation initiative, governments typically follow a process of setting out framework legislation and then having individual regulatory measures on products. In the framework legislation, the overall policy-making process is laid out, identifying which existing government agency is responsible for the implementation of mandatory product quality and performance standards and/or energy labels. The legislation may mandate such programmes, prescribe which products are to be addressed (i.e. scope of coverage), and can even prescribe some initial regulatory requirements. Once the framework legislation is in place, the second stage involves the process of establishing policies on products through the application of the authority granted under the framework legislation. In this stage, the appointed implementing agency works on establishing, and setting, MEPS for specific product types, such as lighting, or more specifically, for categories of lamp products. A summary of the process to follow under this recommendation can be found in Annex I to this report, which contains a two-page summary of a UNEP publication: “Developing Minimum Energy Performance Standards for Lighting Products: Guidance Note for Policymakers” by Michael Scholand, United Nations Environment Programme. (UNEP, 2015)

Framework legislation is a better solution because it avoids the need to constantly seek approval from the legislative body of government for each new regulatory measure. Framework legislation delegates responsibility for developing product-specific legislative measures, provided the implementing agency follows the procedure set out in the framework. Framework legislation often identifies key stakeholders and defines roles, responsibilities and obligations under the law. It also designates a government body as the implementing agency and authorises that agency to issue product-specific MEPS. Ideally, framework legislation would establish:

a) Defined programme objectives;
b) Authorised types of intervention (mandatory standards and/or voluntary targets);
c) Criteria for determining which lamps are covered;
d) Criteria for the level of technical intervention (based on payback periods, life-cycle cost, harmonisation with trading partners);
e) The schedule of implementation;
f) Procedural rules and deadlines;
g) The requirement to evaluate the programme’s impact, including effects on manufacturers, consumers and the country.

An example of a legislative framework for establishing MEPS today is the European Parliament’s Ecodesign Directive, which sets out a process that the European Commission must follow when establishing mandatory quality and performance regulations on consumer products and commercial and industrial equipment. Here is a link to the regulation: Ecodesign legislation, Framework directive, Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, recast of Directive 2005/32/EC amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council.

6.3 Participate in Regional Energy-Efficiency Centres

Note: This intervention is conducted at the national level, but rolls-up to regional benefits.

Countries can benefit by strengthening their engagement with the regional energy-efficiency centres, the East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREEE) and the Southern African Development Community (SADC) Centre for Renewable Energy and Energy Efficiency (SACREEE). These Centres were established to conceive and implement regional and national programmes to accelerate the adoption of renewable energy and increase the market penetration of energy-efficient products and services. Country governments can engage in the dialogue and participate in planning programmes designed to support market transformation, including harmonised performance standards, bulk procurements, product specifications, policy recommendations and much, much more.

SACREEE - the Southern African Development Community (SADC) Centre for Renewable Energy and Energy Efficiency (SACREEE) was established by the SADC Member States in 2015 to contribute towards increased access to modern energy services and improved energy security across the SADC Region through the promotion of market based uptake of renewable energy (RE) and energy efficient (EE) technologies and energy services. The SACREEE Secretariat is based in Windhoek, Namibia.

SACREEE develops and executes regional programs and projects in order to support SADC Member States

- To increase access to sustainable energy services;
- To develop sustainable energy markets;
- To improve the legal and regulatory framework and ensure policy coherence and alignment of RE & EE activities with national/regional and international policies;
- To align the national actions with international commitments and climate change actions (e.g. NDCs)
- To support donor harmonization, coordination and to create synergies with other ongoing initiatives;
- To strengthen local capacities through capacity building activities
- To foster networks between research and training institutions (Network of Energy Excellence for Development (NEED), SOLTRAIN, etc) as well as organize train-the-trainers workshops;
- To improve the availability of quality energy data and information for sound decision making on policy and investment

For more information about SACREEE, please visit their website by clicking here.

EACREEE – the goals of the East African Centre of Excellence for Renewable Energy and Energy Efficiency are to facilitate the creation of an enabling environment for renewable energy and energy efficiency markets and investments, in order to contribute to:

- increased access of modern, affordable and reliable energy services;
- energy security; and
- mitigation of negative effects (e.g. local pollution and GHG emissions).

The EACREEE will play a key role in promoting renewable energies and energy efficiency in the EAC region. Through its activities in the areas of policy, capacity development, knowledge management, and awareness raising, as well as business and investment promotion, the EACREEE centre aims to create an enabling environment by mitigating existing barriers and in promoting a competitive sustainable energy market, as well as economies of scale in the EAC region. Moreover, the EACREEE will execute regional projects programmes and activities in the above areas and in addition showing leadership in the coordination and harmonisation of donor activities and acting as a regional hub for the SE4ALL initiative. For more information about EACREEE, please visit their website by clicking here.

In addition to considering helping to facilitate some of the recommendations in this report, SACREEE and EACREEE will conduct other activities that will help to support market transformation towards more energy-efficient products. Some of these activities may include:

- Promoting the full adoption of CIE S 025 and IEC TS 62257-9-5:2018 by the Country Standard Bureaus and Regional bodies EAC and SADC;
- Strengthening representation by small and medium sized enterprises in the business associations and renewable energy bodies at the national and regional level;
- Encouraging business capacity across the whole region by facilitating forums for engagement between key local players to unlock last mile distribution and financing and to consider new technology adoption like PAYGO roll-out and local manufacturing or full production and assembly of kits; and
- Support on how to incorporate end-of-life management for on and off-grid lighting products to allow for repair, reuse and recycle of products, including for example the GOGLA solar-waste management strategy https://www.gogla.org/about-us/blogs/industry-agrees-it-is-time-to-tackle-off-grid-solar-electronic-waste

6.4 Green Procurement Specification

Note: This intervention is regional and could be conducted by EACREEE and SACREEE.

Public authorities – including national government, municipalities, the military and other public organisations – are major consumers of products and equipment. The concept behind 'green procurement' is to develop a quality and performance specification for products that are commonly purchased – including replacement lamps, computers, televisions, street lights, refrigerators and more. The development and communication of these draft specifications could be conducted by the two regional energy-efficiency centres, EACREEE and SACREEE, in partnership with the other technical and international experts involved in the EELA project. These specifications typically call for products to be more energy-efficient than the average products on the market, stimulating the interest of private sector suppliers to be quality providers of green procurement specification equipment. In defining and using these green procurement specifications, public entities will be helping to accelerate the market, drawing in new and more efficient products to the market while simultaneously benefitting from the reduced power consumption.

Although green procurement is a voluntary policy mechanism, it can play a key role in facilitating market transformation for products that are within scope. The product specification, coupled with procurement contracts gathered from multiple entities, can stimulate the market by creating a critical mass of demand for more sustainable products and equipment which could otherwise have been difficult to get onto the market. Green procurement can be a strong stimulus for market transformation.

To maximise its impact, green procurement specifications require clear and verifiable environmental criteria for products. Governments in Europe, North America and elsewhere have developed these specifications which could be a starting point for consideration. And, to extend the impact of the specification beyond the public sector, governments may consider using other policy instruments such as tax breaks and incentives to encourage private sector players in their markets to utilise the same green procurement list when making purchases for their facilities.

These procurement specifications can function as voluntary codes of conduct, setting requirements that will be recognised and adopted by leading market players and institutions. These programme participants can then claim the economic, environmental and social benefits that comes with being a progressive market leader and agent of change.

Case Study: Energy Star Computers Saturate the USA Market
The US Federal Government is one of the largest purchasers of computers in the world. In 1993, President Bill Clinton signed Executive Order 12845 that required all Federal agencies to purchase computer equipment – including personal computers, monitors and printers – that met the Environmental Protection Agency's Energy Star requirements for energy efficiency. Due to the purchasing power of the Federal Government, this Executive Order resulted in a major market shift towards Energy Star computers. Executives from six computer manufacturers were interviewed who all stated that they moved their entire production lines to be Energy Star compliant. Thus, this 'green procurement' in the form of an Executive Order requiring the purchase of Energy Star computer equipment, transformed the US computer market in the mid 1990's towards Energy Star. Source: de Bruijn, T. and V. Norberg-Bohm, 2005. Click on this link for more information.

From the end-user or customer perspective, the green procurement specifications should be presented as taking into consideration the total cost of ownership associated with the product – in this case, lighting. Spreadsheets would need to be prepared that show the cost-effectiveness of participating in the green procurement specification compared with the incumbent / baseline technology. Again, this work could be readily prepared and implemented by the regional energy-efficiency centres, EACREEE and SACREEE.

Another approach that could be considered by EACREEE and EACREEE would be to study the success of the joint-venture started by the government of India called Energy-Efficiency Services Limited (EESL). EESL is a joint venture of four national public-sector agencies: NTPC Limited, Power Finance Corporation Limited, Rural Electrification Corporation Limited and PowerGrid Corporation of India Limited. This organisation was designed to promote energy-efficiency across India and was the first company in South Asia to focus exclusively on energy efficiency implementation. EESL is responsible for facilitating bulk procurement of both LED household lamps and LED street lights 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, EESL had helped to deliver 155 million household LED lamps and 1.2 million LED streetlights. As a direct result of the bulk procurement scheme implemented by EESL on this scale, the wholesale price of a 7 Watt household LED lamp came down from US$4.65 to US$0.84 in 2016 as shown in the following figure (UNEP, 2017). The retail price of LED lamps dropped as well, tracking the wholesale cost reduction. EESL works with Utilities through on-bill financing with residential consumers and classic pay-as-you-save model or with manufacturers and vendors through annuity-based financing for municipal street lighting. For more information about EESL, visit their website https://eeslindia.org/content/raj/eesl/en/home.html (EESL, 2019).

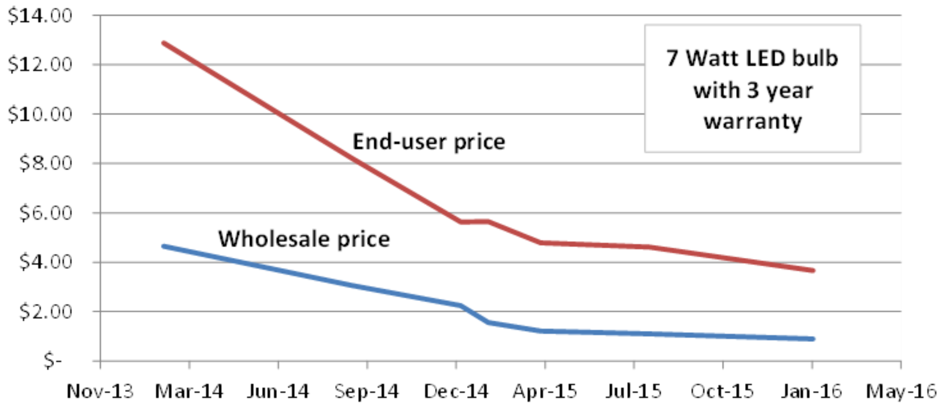


Figure 51. Wholesale and end-user price reduction of 7 Watt LED lamps in India

6.5 Develop ESCOs and Funding Scheme

Note: This intervention could be national or regional, depending on the need and scope.

This intervention recommends that the two energy-efficiency centres work with national governments to help establish energy service companies (ESCOs) that will work across the region to promote the installation of energy-efficient lighting and other products and equipment. ESCOs are businesses that promote energy-efficiency in the market. These companies serve as project developers where they bring together project design (i.e., technology), financing, installation/retrofit, and operational commissioning. ESCOs are different from other energy-efficiency contractors because they guarantee the energy savings as a specified part of the energy savings performance contract. The building owner (or other end-use energy consumer) takes no risk – instead the ESCO finances the equipment, installs it and only recovers their investment from the recipient as the energy savings are realised – a 'pay as you save' approach.

ESCOs typically present an energy-efficiency plan that is designed around and optimised for the given site. ESCOs usually bundle together more than one technology upgrade into a project, such as doing the lighting, HVAC system, escalators and transformers at one site. Drawing on a range of expertise encompassing engineering, financial, and technology, typical service offerings from ESCOs are as follows:

- Provide a detailed and robust energy audit of the whole facility
- Give guidance on the overall project, including appropriate size and scope
- Locate financing and assist the organization in understanding financing options
- Specify, purchase and install the more energy-efficient equipment
- Install smart meters / metering to monitor savings for the duration of the contract term
- Provide operations and maintenance support if contracted
- Prepare reports that show energy and financial savings relative to the business as usual case

Energy Service Companies (ESCOs) are an excellent way to unleash the power of the private sector to deliver energy savings in a given market. However, no energy-service companies were found in this market assessment in the six focus countries. It is recommended therefore that the two energy-efficiency centres (EACREEE and SACREEE) would work together cooperatively with national governments to help create training programmes, case studies, spreadsheet tools, reference documents and resources that would stimulate entrepreneurs in the region to create ESCOs.

If this work establishing ESCOs is successful, it may be necessary to establish a special (low interest) load fund that is held especially as a collateral guarantee to help finance Energy Service Companies. In serving as a guarantee against commercial finance borrowed for energy-efficiency upgrades, the same amount of money can be stretched much further and support many more projects. In establishing a low interest fund which they can use, governments will enable them to more easily sign-up new clients and implement change, upgrading lighting, HVAC, appliances, equipment, building envelope and other solutions.

ESCOs can specialise in commercial buildings, industries (e.g., mining, processes), or other market niche. By establishing a fund (e.g., with a local financial institution), this intervention would encourage more ESCOs to be formed and for those that already exist, it would enable them to expand their portfolio of business. For more information on ESCOs in Developing countries, read this publication from the International Institute for Sustainable Development.

6.6 Electric Utility Engagement

Note: This intervention would be national level, working with the national and municipal utilities.
Electric utilities are one of the best channels for reaching end-use customers, particularly households. Electric utilities that are experiencing electricity shortages and brown/black-outs are likely to be interested in engaging in demand side management (DSM) programmes that will reduce electricity consumption, freeing up capacity to be used elsewhere. Very often, these DSM programmes are designed around energy-efficient lighting as this end-use is found in all homes with electricity, and energy-efficient light sources can reduce consumption by 80-90 percent over conventional technologies. The experts and implementers of these programmes could be trained to handle other products eventually (e.g., refrigerators, air-conditioners) and perform more advanced services (e.g., whole building retrofits, industrial energy-efficiency).

Electric utilities are already engaged across the region in actively promoting energy-efficiency programmes for customers, focusing largely on lighting. Indeed, the South African utility Eskom has been running demand-side management programmes for over 20 years, including hot water/geyser ripple control and the “ElectroWISE” campaign.

Another approach for engaging electric utilities would be to establish a programme of Market-based Instruments (MBIs) that promote energy-efficiency. MBIs are able to use market forces to minimise the cost of saving energy by setting a policy framework specifying the outcome (i.e., reduction in energy, level of cost-effective measures to take) to be delivered by the market actors, but without setting requirements for the delivery mechanisms or the measures to be used (IEA, 2017b). One of the broad MBI programme types which could apply to electric utilities are energy-efficiency obligations, including white-certificate programmes and energy-efficiency resource standards. These obligations require electric utilities to carried out a prescribed level of activity to promote energy-savings in their jurisdiction, but crucially the obligations do not specify how those savings should be achieved. The utility is then free to determine how to best capture those savings, on which they must later report to their regulator demonstrating their compliance with the obligation. For more information on MBIs and utility obligations like white certificates, please see the IEA publication, ‘Market-based instruments for energy-efficiency, policy choice and design’ (IEA, 2017b).

While the type of programme implemented by the utility can vary depending on the motivation behind the initiative, there is one approach which has been successful all over the world in engaging utilities to participate in energy-efficiency initiatives: amending the utility’s regulatory framework to require it to engage in demand side management. The electric utility regulator has the ability to establish new requirements in the regulatory language that the utility must conduct demand side management activities on the customer side of the meter. This approach ensures that the utility will undertake to identify cost-effective energy-saving opportunities for their customers and implement programmes that will deliver those savings.

During the review of the focus countries, an example of this best practice was identified in Zambia, where ZESCO is currently running a lighting trade-in scheme to fulfil the requirements imposed on them by the Electricity Regulatory Board of Zambia, which will help them with power shortages that occur during times of peak demand. This programme is a trade-in scheme where 3 million LED lamps are installed by contractors working for ZESCO directly into the sockets in people's homes, replacing incandescent lamps. Typical savings are on the order of 35 watts per socket, with incandescent lamps at 40W being replaced by LEDs that use only 5W and last much longer. When fully deployed, this programme is projected to free-up more than 100MW of generating capacity at peak times, improving grid reliability and customer service. For more information about the ZESCO scheme, click on this link.

In addition to Zambia, Namibia has also run a trade-in / retrofit scheme where contractors working for the utility NamPower install LED lamps directly into people's homes – and there are other examples from across the region. However, in some countries, there is a culture in the utility which sees itself as selling kilowatt-hours, and any measures that reduce those sales undercuts its core business. For these utilities, the management team typically resists DSM schemes as they are perceived as reducing sales. In order to address that barrier, a better utility regulatory environment as described above would be helpful because it could require and/or incentivise investment in DSM for its customers.

6.7 Stimulating Development of Energy-Efficiency Businesses

Note: This intervention could be national or regional, depending on the need and scope.

This initiative will be conducted by EACREEE and SACREEE, through the national governments, to develop a pipeline of bankable energy-efficiency projects in the region. These could include businesses that focus on the provision of energy-efficient products such as the conversion of CFL manufacturing facilities to become LED lamp and luminaire facilities, or the manufacturing of solar water heaters. The bankable projects could also focus on the provision of services, such businesses that illuminate streets under contract to a municipality or building audit and upgrade services (like an ESCO). The development of this pipeline would be established by the two regional centres engaging with national and regional private sector associations such as the national lighting associations to offer webinars, training, expert advice and so-on to stimulate and develop green-tech and environmentally sustainable ideas into bankable projects and businesses.

Once the energy-efficient project ideas have been developed, EACREEE and SACREEE would work to help them identify the best 'green investment fund' that could provide loan guarantees or co-finance investments for green businesses and start-ups. This function of tying together the entrepreneur and the finance can be difficult for companies if they are operating in a non-traditional investment space, such as energy efficiency or the manufacturing of energy-efficient products. The work of the centres would be to overcome that barrier, by identifying (or promoting) green finance facilities that provides loans to companies who are seeking to establish domestic production of products that are more efficient than the traditional ones on the market. Some of the funds that could be accessed include Innovations Against Poverty (IAP) and the Renewable Energy Challenge Fund in Uganda.

Working with the regional energy efficiency centres and national ministries of trade and industry, these businesses would seek to establish themselves, build local expertise, employment and create value-added products in the region. Ultimately, the objective of this initiative would be to establish a robust player in the national and regional market for that product or technology. Examples could include: LED luminaire manufacturing, micro-solar home systems, ceiling fans, and much more. Note too that this fund could also be linked to service provision as opposed to product manufacturing, such as the ESCOs described in section 6.5.

If green finance is needed to support the bankable green tech investments identified, the regional energy-efficiency centres may work with sources of finance to set up a facility similar to the Beyond the Grid Fund for Africa[6] (BGFA) which is focused on engaging the private sector to help facilitate the process of delivering

[6] Beyond the Grid Fund for Africa (BGFA) aims to increase access to energy, improve poor people's livelihoods and catalyze economic activity in rural areas and slums in Burkina Faso, Liberia, Mozambique

sustainable, small-scale electricity to off-grid households (SIDA, 2019). In Zambia, a preliminary version of this Fund was piloted with a goal of connecting 1 million people over a five-year period. Roughly halfway through the project, Beyond the Grid Fund for Zambia has already provided access to electricity for 450,000 people, which corresponds to double the expected connections for that time. When the project is complete in 2021, it is estimated that 1.6 million people will be connected to affordable and sustainable electricity. Applying a business model such as the Beyond the Grid Funds to incentivise and stimulate investment and innovation in promoting energy-efficient products and services in the region could have a significant impact, unleashing the power of the private sector in the SADC and EAC markets.

6.8 Quality and Performance Regulations

Note: This intervention would be harmonised regionally but adopted nationally.

Our assessment of the market shows that all countries across the region should adopt minimum energy performance standards (MEPS) for the typical lamps used in households and small businesses throughout the region – including both on-grid (one-third of the population) and off-grid (two-thirds of the population). MEPS are among the most cost-effective policy measures for transforming markets, they typically apply to both energy and performance / quality-related characteristics, and are developed in consultation with stakeholders' input and economic analysis, and should take into account regional harmonisation. Household lighting is an excellent starting point as it would enable this policy instrument to be established and applied, and once it is understood, other products can be regulated through the same process – air conditioning, refrigerators, electric motors, televisions, and so-on.

In Europe and North America, the MEPS policies set efficiency requirements in a 'technology neutral' way, meaning the requirements apply to all lighting products that can operate in the same application (e.g., incandescent, halogen, CFL and LED lamps in the same 230V socket). This 'technology neutral' approach is generally favoured by governments because it allows flexibility in the supply chain and ensures a level playing field in terms of the degree of ambition of the requirements. The other quality aspects of a lighting regulation – such as colour quality, lifetime, power characteristics – are generally technology-specific, such as a limit on the amount of mercury in a CFL. A 'technology neutral' scope, allows for competition between different technologies, encouraging innovation and the introduction of new products, and stimulating the market to develop more energy-efficient products. Consider for example the technologies in the following table which all produce light when installed in a mains-voltage screw-base socket.

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and Zambia. The goal is that between five and fifteen million poor consumers - who already make a large part of their disposable income on substandard forms of energy - will have access to economically affordable and reliable renewable energy services. BGFA is part of the Power Africa initiative.

Table 66. Examples of non-directional general service lamps, screw-base, mains-voltage (230V)

Characteristic	Incandescent	Halogen	Compact Fluorescent	Light Emitting Diode Lamp
				
Efficacy	10-15 lm/W	12-18 lm/W	55-65 lm/W	70-145 lm/W
Lifetime	1000-1500 hrs	2000-3000 hrs	6000-12,000 hrs	5000-40,000 hrs
Colour rendering index	100	100	70-90	70-95
Cost to buy*	$	$$	$$$	$$ - $$$
Cost to run*	$$$$$	$$$$	$$	$

* Note: LED technology is getting less expensive to buy and operate, as it continues to improve its efficacy.

Domestic lighting – both on-grid and off-grid – is an excellent product group for EAC and SADC countries to start on. LED technology is rapidly expanding into these markets, however in the absence of any regulation, the quality of products is not guaranteed, and consumers could be at risk. Due to the urgent need to establish quality and performance requirements for the lighting market, it is suggested that this product moves first, followed by a second regulation for the tertiary sector – including street lights and office / industrial lighting products. This approach would follow the way the European Commission initiated lighting regulations, with one measure on domestic lighting (EC No 244/2009) and a second measure on tertiary lighting (EC No 245/2009). In Annex I to this Market Assessment report, we have included some guidance from a 2015 publication about the steps to following when setting MEPS for lighting products.

In parallel with the tertiary sector lighting regulation, it is suggested that country governments start work on an air conditioning regulation as the second product group. This second group is a rapidly expanding product in the region and is a significant contributor to peak power demand. By moving quickly to set quality and performance regulations on air-conditioning products, governments can help limit the growth in power demand while also ensuring consumers and businesses benefit from cost-effective requirements that are harmonised across the region and take into account regulations on these same products elsewhere in the world. This work on air-conditioning could tie in well with the efforts currently underway globally by the Kigali Cooling Efficiency Programme (https://www.k-cep.org/).

After lighting and air-conditioning, there are three other 'priority' products that stakeholders in the region may wish to consider: (1) Domestic refrigeration (i.e., refrigerators, freezers and refrigerator-freezer combinations); (2) Electric Motors and (3) Televisions. These products are suggested for consideration due to their high level of market penetration across the region and large energy-savings potential.

Domestic refrigeration is important because this product has been regulated widely for decades around the world and product performance has improved substantially. However, countries that do not establish regulations may not benefit from these improvements and could instead become a 'dumping ground' for older, inefficient designs which were phased-out of other markets. Furthermore, domestic refrigeration is a baseload demand, operating 24/7 and so is coincident with peak power demand.

Electric motors, similar to domestic refrigeration, are also widely regulated around the world and represent an opportunity to save energy in the industrial sector. Electric motors are comfortably the largest single electrical end-use and are estimated to consume between 43 and 46% of all global electricity demand (Scholand, 2011). Most of the energy savings opportunities reside in optimising aspects of the motor driven systems but there are still significant cost-effective energy savings to be had from the use of more efficient electric motors themselves. A growing proportion of the world's economies have adopted MEPS for electric motors. A broadly accepted international energy efficiency test method (IEC 60034-2-1) is now used in most of the major economies and building on that, IEC introduced two performance standards: IEC 60034-30 that establishes a three tier classification system: IE1, IE2 and IE3 and IEC 60034-31 which set a "super premium" efficiency level known as IE4. This product group could therefore be introduced into the EAC and SADC markets, harmonising with global standards and facilitating energy savings.

Televisions are suggested as they are another popular consumer product with increasing levels of market penetration in the region. This product is regulated in Europe and there are a number of efficiency requirements which could be considered by regulators that would protect consumers and help to ensure they benefit from high-efficiency, both on and off-grid.

It is recommended therefore that after lighting, the regional energy-efficiency centres – EACREEE and SACREEE – work together to conduct an inclusive process where African end-users can have a say in the prioritisation of the next products to regulate (CTCN, 2017). This process should be supported by an evidence-based market assessment – called a 'prioritisation study' – that looks at a range of products across the region, similar to the scope of this lighting market assessment. The prioritisation study would consider a wide range of energy-using products and take into consideration the supply chain (including local manufacturing), typical baseline efficiencies, barriers to higher efficiency, economic justification and payback periods, product lifetime, rates of replacement, and so-on. Products would then be ranked and thereby provide a robust basis for stakeholders to discuss and decide the way forward. Of course, it is important that this prioritisation study consider which products would be required for the national economic and industrial development. The work of the energy-efficiency centres will be to launch a pro-active dialogue/process for discussing what products should be regulated in the future.

6.9 Market Surveillance

Note: This is both national or regional, depending on what surveillance is being conducted.

Energy efficiency regulatory policies are the cornerstone of successful national market transformation programmes, however without monitoring, verification and enforcement (MVE) schemes, Product performance standards and labelling initiatives risk being marginalised and may not have any impact. Establishing a robust monitoring, verification, and enforcement (MVE) infrastructure ensures credibility and market impact of standards and labelling activities. Consistent, effective and visible MVE of product energy consumption and performance helps realise the benefits expected from standards and labelling programmes. In establishing a fair and level playing field, a robust MVE programme encourages greater levels of investment and innovation in energy-efficient products.

A robust compliance programme requires three main components – monitoring, verification and enforcement - to be the most effective and impactful:

- **Monitoring** involves comprehensive monitoring or surveillance of the market to give an accurate picture of products available on the market which informs analysis of the progress of the standards and labelling programme and compliance of the programme. This process is essential for two different purposes. Firstly, it ensures that timely and accurate market information is used to set appropriate, cost effective efficiency requirements through collaboration with regulators and public authorities, acting in cooperation with industry, civil society and other key stakeholders. Secondly, it helps identify cases of potential non-compliance that require further verification.
- **Verification** is about the understanding, selection and testing of products – the ability to develop, measure and ensure regulatory compliance. Testing activities and related services are therefore a key element in programmes' abilities to accurately assess product performance and quality. Testing activities can also support manufacturing and ensure market protection as part of an integrated, comprehensive MVE framework. Where verification testing identifies cases of non-compliance, these should be followed up by proportionate enforcement actions.
- **Enforcement** refers to the actions taken by an authority in response to investigated and confirmed incidents of non-compliance using a suite of timely and appropriate actions. These actions are taken within the rules of an energy-efficiency programme, are built on rigorous testing, and will yield a

high return in terms of market and consumer protection. Enforcement actions safeguard the benefits of standards and labelling policies by ensuring that non-compliant products are removed from the market and that non-compliant manufacturers, importers and retailers are held accountable for their actions.

Through investment in MVE, governments help to ensure they maintain high compliance rates which in turn safeguard the credibility of standards and labelling policies and programmes. If governments fail to address issues of non-compliance, it can lead to serious long-term consequences through the erosion of consumer confidence. Instances of non-compliance, which can mean that consumers pay for performance that they do not receive, erodes credibility and can lead to lawsuits and compensation claims.

Ensuring high compliance rates also protects the investments made by responsible, compliant industry participants who manufacture and supply energy-efficient products. Without adequate enforcement, the compliant industry participant is penalised through a loss of economic returns and competitive advantage, creating a disincentive for companies to invest in innovation.

Thus, improving compliance rates will help secure the objectives of standards and labelling policies and programmes - greater energy savings and reduced emissions of greenhouse gases. Developing and maintaining a strong compliance regime may appear difficult and resource intensive, however the benefits identified show that investment in compliance and enforcement regimes has a major impact on the success of programmes.

One possible approach for consideration by governments in the region would be to establish a new group of SADC and EAC market inspectors who work at the ports that service the region and are responsible for monitoring and checking the compliance certification of products entering the region. Due to the high degree of imported products, and the fact that most of the products entering the region do so through a limited number of ports, a targeted initiative that places inspectors at these market entry-points could offer regional benefit by preventing entry of non-compliant products into the supply chain. These inspectors could be recruited by SACREEE for SADC and EACREEE for EAC, trained through a rigorous regional training initiative on market surveillance and inspection, and then supported in the field with test equipment and laboratories, compliance certification check-lists, and other tools that will enable them to ensure that products entering the market comply with the harmonised regional regulations. These inspectors would be donor-financed initially, but would be transitioned over to local sources of funding over a five year period.

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Annex A. Madagascar Lighting Market Estimates

Draft Estimate for: **Madagascar** MDG

	2018 estimate		
Total Electricity Consumption:	2.170	TWh/yr	*Source: U4E, 2015*
Total Consumption for lighting:	0.295	TWh/yr	*Source: calculated from data below*
Percentage:	13.6%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	*(units)*
Incandescent	0.550	0.056	0.011	0.616	millions of lamps
Halogen	0.444	0.057	0.011	0.512	millions of lamps
Compact Fluorescent	0.878	0.310	0.034	1.222	millions of lamps
Linear Fluorescent	0.327	1.557	0.097	1.981	millions of lamps
High Intensity Discharge	0.007	0.029	0.109	0.146	millions of lamps
LED Omni-directional	0.165	0.052	0.009	0.226	millions of lamps
LED Tube	0.007	0.039	0.002	0.049	millions of lamps
LED Outdoor	0.000	0.001	0.003	0.004	millions of lamps
Total	2.378	2.100	0.278	4.757	

Average Lamp Wattage	Residential	Professional	Outdoor	*(units)*
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	*(units)*
Incandescent	2.0	5.0	5.0	*hours/day*
Halogen	2.0	5.0	5.0	*hours/day*
Compact Fluorescent	3.0	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	3.0	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	*(units)*
Incandescent	18.05	4.56	2.03	24.644	*GWh/yr*
Halogen	12.00	3.83	1.76	17.585	*GWh/yr*
Compact Fluorescent	9.61	13.59	2.01	25.208	*GWh/yr*
Linear Fluorescent	8.59	163.63	14.77	186.992	*GWh/yr*
High Intensity Discharge	1.60	6.39	27.97	35.957	*GWh/yr*
LED Omni-directional	0.90	0.48	0.24	1.623	*GWh/yr*
LED Tube	0.11	2.28	0.21	2.605	*GWh/yr*
LED Outdoor	0.01	0.09	0.32	0.414	*GWh/yr*
Total	50.872	194.842	49.315	295.029	*GWh/yr*

Lamp shipments: Madagascar Years: 2010-2017

Annual sales based on UN Comtrade data. Adjustments made: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) increasing HID shipments by a factor of 10 due to values being too low relative to U4E 2015 stock estimates; (3) increased Linear Fluorescent shipments for a few years to smooth shipments and avoid volatility of published Comtrade data; (4) estimating LED sales as a small and slowly increasing percentage of lamp technologies they are replacing, starting in 2013

Table MDG.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	476,563	591,355	591,355	706,147	937,577	937,577	1,169,007	997,148
Halogen	98,431	233,636	198,522	163,409	311,901	360,072	595,369	800,892
Compact Fluorescent	56,966	64,725	181,536	298,347	167,166	122,706	133,385	114,131
Linear Fluorescent	20,888	23,733	66,563	109,394	61,294	44,992	48,908	41,848
High Intensity Discharge	13,999	2,773	2,056	1,339	1,626	1,733	1,733	1,733
LED Omni-directional	-	-	-	23,358	56,666	85,221	151,821	191,217
LED Tube	-	-	-	2,188	2,452	2,700	3,913	4,185
LED Outdoor	-	-	-	27	65	104	139	173

Table MDG.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	93,261	115,725	115,725	138,189	183,479	183,479	228,768	195,137
Halogen	35,154	83,441	70,901	58,360	111,393	128,597	212,632	286,033
Compact Fluorescent	51,269	58,253	163,383	268,513	150,449	110,436	120,046	102,718
Linear Fluorescent	111,400	126,574	355,004	583,435	326,902	239,959	260,842	223,189
High Intensity Discharge	55,996	11,090	8,222	5,354	6,504	6,930	6,930	6,930
LED Omni-directional	-	-	-	9,301	17,813	25,351	44,916	58,389
LED Tube	-	-	-	11,669	13,076	14,398	20,867	22,319
LED Outdoor	-	-	-	107	260	416	554	693

Table MDG.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	18,652	23,145	23,145	27,638	36,696	36,696	45,754	39,027
Halogen	7,031	16,688	14,180	11,672	22,279	25,719	42,526	57,207
Compact Fluorescent	5,697	6,473	18,154	29,835	16,717	12,271	13,338	11,413
Linear Fluorescent	6,963	7,911	22,188	36,465	20,431	14,997	16,303	13,949
High Intensity Discharge	209,985	41,588	30,833	20,078	24,390	25,988	25,988	25,988
LED Omni-directional	-	-	-	1,383	3,028	4,481	8,129	10,765
LED Tube	-	-	-	729	817	900	1,304	1,395
LED Outdoor	-	-	-	402	976	1,559	2,079	2,599

Table MDG.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	588,476	730,225	730,225	871,974	1,157,751	1,157,751	1,443,529	1,231,312
Halogen	140,615	333,765	283,603	233,441	445,573	514,388	850,527	1,144,131
Compact Fluorescent	113,932	129,451	363,073	596,695	334,332	245,413	266,770	228,262
Linear Fluorescent	139,250	158,217	443,755	729,293	408,628	299,949	326,052	278,986
High Intensity Discharge	279,980	55,450	41,110	26,770	32,520	34,650	34,650	34,650
LED Omni-directional	-	-	-	34,042	77,506	115,053	204,866	260,370
LED Tube	-	-	-	14,586	16,345	17,997	26,084	27,899
LED Outdoor	-	-	-	535	1,301	2,079	2,772	3,465

Annex B. Namibia Lighting Market Estimates

Draft Estimate for: **Nambia** NAM

	2018 estimate		
Total Electricity Consumption:	3.800	TWh/yr	*Source: IEA, 2017*
Total Consumption for lighting:	0.615	TWh/yr	*Source: calculated from data below*
Percentage:	16.2%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	*(units)*
Incandescent	0.268	0.027	0.005	0.301	millions of lamps
Halogen	0.457	0.060	0.012	0.529	millions of lamps
Compact Fluorescent	2.201	0.894	0.099	3.194	millions of lamps
Linear Fluorescent	0.830	3.697	0.231	4.758	millions of lamps
High Intensity Discharge	0.012	0.048	0.179	0.239	millions of lamps
LED Omni-directional	0.159	0.084	0.011	0.254	millions of lamps
LED Tube	0.024	0.130	0.008	0.162	millions of lamps
LED Outdoor	0.000	0.002	0.007	0.009	millions of lamps
Total	3.952	4.941	0.554	9.447	

Average Lamp Wattage	Residential	Professional	Outdoor	*(units)*
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	*(units)*
Incandescent	2.0	5.0	5.0	*hours/day*
Halogen	2.0	5.0	5.0	*hours/day*
Compact Fluorescent	3.0	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	3.0	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	*(units)*
Incandescent	8.81	2.22	0.99	12.010	*GWh/yr*
Halogen	12.34	4.08	1.87	18.295	*GWh/yr*
Compact Fluorescent	24.10	39.15	5.80	69.048	*GWh/yr*
Linear Fluorescent	21.82	388.58	35.08	445.480	*GWh/yr*
High Intensity Discharge	2.62	10.48	45.83	58.922	*GWh/yr*
LED Omni-directional	0.87	0.77	0.31	1.948	*GWh/yr*
LED Tube	0.36	7.58	0.71	8.651	*GWh/yr*
LED Outdoor	0.02	0.21	0.77	0.992	*GWh/yr*
Total	70.932	453.053	91.362	615.346	*GWh/yr*

Lamp shipments: Namibia Years: 2010-2017

Annual sales based on UN Comtrade data. Adjustments made: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) increasing fluorescent lamp shipments by a factor of 10 due to values being too low relative to U4E 2015 stock estimates; (3) smoothed HID shipments out over time period, as one year was excessively high and some years were nil, avoiding volatility of published Comtrade data and maintaining same values overall; (4) estimating LED sales as a small and slowly increasing percentage of lamp technologies they are replacing, starting in 2013.

Table NAM.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	985,281	566,773	148,266	437,453	441,797	441,797	446,141	446,141
Halogen	163,416	238,903	91,783	118,719	289,482	421,054	607,831	758,771
Compact Fluorescent	396,632	396,632	142,110	171,882	320,868	836,123	616,208	1,103,531
Linear Fluorescent	145,432	145,432	52,107	63,023	117,652	306,578	225,943	404,628
High Intensity Discharge	2,422	1,695	3,860	1,851	5,110	3,790	3,847	3,847
LED Omni-directional	-	-	-	14,561	42,086	101,938	133,614	230,844
LED Tube	-	-	-	1,260	4,706	18,395	18,075	40,463
LED Outdoor	-	-	-	37	204	227	308	385

Table NAM.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	192,814	110,915	29,015	85,607	86,457	86,457	87,307	87,307
Halogen	58,363	85,323	32,780	42,400	103,386	150,376	217,083	270,990
Compact Fluorescent	356,969	356,969	127,899	154,694	288,781	752,510	554,587	993,177
Linear Fluorescent	775,636	775,636	277,904	336,125	627,475	1,635,084	1,205,028	2,158,015
High Intensity Discharge	9,686	6,778	15,442	7,404	20,438	15,160	15,388	15,388
LED Omni-directional	-	-	-	5,654	19,145	59,361	68,718	135,147
LED Tube	-	-	-	6,722	25,099	98,105	96,402	215,802
LED Outdoor	-	-	-	148	818	910	1,231	1,539

Table NAM.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	38,563	22,183	5,803	17,121	17,291	17,291	17,461	17,461
Halogen	11,673	17,065	6,556	8,480	20,677	30,075	43,417	54,198
Compact Fluorescent	39,663	39,663	14,211	17,188	32,087	83,612	61,621	110,353
Linear Fluorescent	48,477	48,477	17,369	21,008	39,217	102,193	75,314	134,876
High Intensity Discharge	36,323	25,418	57,907	27,765	76,643	56,850	57,705	57,705
LED Omni-directional	-	-	-	856	2,802	7,859	9,800	18,201
LED Tube	-	-	-	420	1,569	6,132	6,025	13,488
LED Outdoor	-	-	-	555	3,066	3,411	4,616	5,771

Table NAM.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	1,216,658	699,871	183,083	540,182	545,546	545,546	550,910	550,910
Halogen	233,451	341,290	131,118	169,599	413,545	601,505	868,330	1,083,958
Compact Fluorescent	793,265	793,265	284,220	343,764	641,736	1,672,245	1,232,415	2,207,061
Linear Fluorescent	969,546	969,546	347,380	420,156	784,344	2,043,855	1,506,285	2,697,519
High Intensity Discharge	48,430	33,890	77,209	37,020	102,190	75,800	76,940	76,940
LED Omni-directional	-	-	-	21,071	64,033	169,158	212,132	384,193
LED Tube	-	-	-	8,403	31,374	122,631	120,503	269,752
LED Outdoor	-	-	-	740	4,088	4,548	6,155	7,694

Annex C. South Africa Lighting Market Estimates

Draft Estimate for: **South Africa** ZAF

2018 estimate

Total Electricity Consumption:	228.2	TWh/yr	Source: IEA, 2017
Total Consumption for lighting:	26.2	TWh/yr	
Percentage:	11.5%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	(units)
Incandescent	2.8	0.2	0.0	3.1	millions of lamps
Halogen	88.1	7.0	1.4	96.5	millions of lamps
Compact Fluorescent	100.4	31.4	3.5	135.3	millions of lamps
Linear Fluorescent	36.8	162.0	10.1	209.0	millions of lamps
High Intensity Discharge	0.3	1.3	4.8	6.4	millions of lamps
LED Omni-directional	9.6	4.0	0.6	14.2	millions of lamps
LED Tube	0.8	4.1	0.3	5.1	millions of lamps
LED Outdoor	0.0	0.0	0.2	0.2	millions of lamps
Total	238.8	210.1	20.9	469.8	

Average Lamp Wattage	Residential	Professional	Outdoor	(units)
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	(units)
Incandescent	1.5	5.0	5.0	*hours/day*
Halogen	1.5	5.0	5.0	*hours/day*
Compact Fluorescent	1.5	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	1.5	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	(units)
Incandescent	70.2	16.2	7.2	93.6	*GWh/yr*
Halogen	1,784.7	471.3	216.5	2,472.5	*GWh/yr*
Compact Fluorescent	549.6	1,376.5	203.9	2,130.0	*GWh/yr*
Linear Fluorescent	967.2	17,032.6	1,537.7	19,537.5	*GWh/yr*
High Intensity Discharge	69.7	278.6	1,219.0	1,567.3	*GWh/yr*
LED Omni-directional	26.2	36.7	17.5	80.4	*GWh/yr*
LED Tube	11.2	238.4	22.4	272.0	*GWh/yr*
LED Outdoor	0.4	5.1	19.1	24.6	*GWh/yr*
Total	3,479.2	19,455.4	3,243.2	26,177.8	*GWh/yr*

Lamp shipments: South Africa Years: 2010-2017 UN ComTrade Data

Adjustments made to UN Comtrade data included: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) increased incandescent and halogen shipments slightly to smooth volatility and address a deficit relative to U4E 2015 stock estimates; (3) minor adjustments to align calibration better with market data from Impact Assessment.

Table ZAF.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	6,921,890	6,315,760	5,709,631	4,756,401	3,803,171	2,409,237	2,219,921	1,966,840
Halogen	81,074,087	88,709,821	50,496,296	56,213,023	60,953,987	59,046,624	57,852,992	54,895,809
Compact Fluorescent	16,165,899	18,361,171	14,098,127	16,700,820	17,397,821	17,654,067	19,155,130	19,957,904
Linear Fluorescent	5,927,496	6,732,429	5,169,313	6,123,634	6,379,201	6,473,158	7,023,548	7,317,898
High Intensity Discharge	89,811	102,007	78,323	92,782	96,655	98,078	106,417	110,877
LED Omni-directional	-	-	-	1,553,405	3,286,199	4,746,596	6,338,244	7,682,055
LED Tube	-	-	-	122,473	255,168	388,389	561,884	731,790
LED Outdoor	-	-	-	1,856	3,866	5,885	8,513	11,088

Table ZAF.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	1,354,577	1,235,961	1,117,345	930,802	744,260	471,475	434,427	384,900
Halogen	23,798,656	26,040,065	14,822,787	16,500,887	17,892,560	17,332,668	16,982,287	16,114,230
Compact Fluorescent	14,549,309	16,525,054	12,688,314	15,030,738	15,658,039	15,888,660	17,239,617	17,962,114
Linear Fluorescent	31,613,314	35,906,290	27,569,670	32,659,381	34,022,406	34,523,509	37,458,921	39,028,790
High Intensity Discharge	359,242	408,026	313,292	371,129	386,618	392,313	425,670	443,509
LED Omni-directional	-	-	-	649,249	1,371,794	2,021,568	2,772,507	3,446,124
LED Tube	-	-	-	653,188	1,360,896	2,071,411	2,996,714	3,902,879
LED Outdoor	-	-	-	7,423	15,465	23,539	34,054	44,351

Table ZAF.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	270,915	247,192	223,469	186,160	148,852	94,295	86,885	76,980
Halogen	4,759,731	5,208,013	2,964,557	3,300,177	3,578,512	3,466,534	3,396,457	3,222,846
Compact Fluorescent	1,616,590	1,836,117	1,409,813	1,670,082	1,739,782	1,765,407	1,915,513	1,995,790
Linear Fluorescent	1,975,832	2,244,143	1,723,104	2,041,211	2,126,400	2,157,719	2,341,183	2,439,299
High Intensity Discharge	1,347,158	1,530,098	1,174,844	1,391,735	1,449,818	1,471,172	1,596,261	1,663,159
LED Omni-directional	-	-	-	103,128	218,686	319,574	431,908	529,562
LED Tube	-	-	-	40,824	85,056	129,463	187,295	243,930
LED Outdoor	-	-	-	27,835	57,993	88,270	127,701	166,316

Table ZAF.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	8,547,383	7,798,913	7,050,444	5,873,364	4,696,283	2,975,007	2,741,233	2,428,721
Halogen	109,632,474	119,957,899	68,283,640	76,014,087	82,425,058	79,845,826	78,231,737	74,232,885
Compact Fluorescent	32,331,798	36,722,342	28,196,253	33,401,639	34,795,643	35,308,134	38,310,260	39,915,808
Linear Fluorescent	39,516,642	44,882,863	34,462,087	40,824,226	42,528,008	43,154,386	46,823,652	48,785,988
High Intensity Discharge	1,796,211	2,040,130	1,566,459	1,855,647	1,933,091	1,961,563	2,128,348	2,217,545
LED Omni-directional	-	-	-	2,305,782	4,876,679	7,087,738	9,542,658	11,657,741
LED Tube	-	-	-	816,485	1,701,120	2,589,263	3,745,892	4,878,599
LED Outdoor	-	-	-	37,113	77,324	117,694	170,268	221,754

Annex D. Uganda Lighting Market Estimates

Draft Estimate for: **Uganda** UGA

	2018 estimate		
Total Electricity Consumption:	3.250	TWh/yr	*Source: U4E, 2015*
Total Consumption for lighting:	0.803	TWh/yr	*Source: calculated from data below*
Percentage:	24.7%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	*(units)*
Incandescent	0.205	0.019	0.004	0.228	millions of lamps
Halogen	0.335	0.047	0.009	0.392	millions of lamps
Compact Fluorescent	1.993	0.746	0.083	2.821	millions of lamps
Linear Fluorescent	0.740	3.579	0.224	4.542	millions of lamps
High Intensity Discharge	0.057	0.226	0.849	1.132	millions of lamps
LED Omni-directional	0.111	0.060	0.008	0.179	millions of lamps
LED Tube	0.018	0.094	0.006	0.117	millions of lamps
LED Outdoor	0.002	0.009	0.035	0.046	millions of lamps
Total	3.461	4.779	1.217	9.457	

Average Lamp Wattage	Residential	Professional	Outdoor	*(units)*
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	*(units)*
Incandescent	2.0	5.0	5.0	*hours/day*
Halogen	2.0	5.0	5.0	*hours/day*
Compact Fluorescent	3.0	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	3.0	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	*(units)*
Incandescent	6.74	1.54	0.69	8.970	*GWh/yr*
Halogen	9.06	3.19	1.47	13.713	*GWh/yr*
Compact Fluorescent	21.82	32.66	4.84	59.321	*GWh/yr*
Linear Fluorescent	19.45	376.18	33.96	429.587	*GWh/yr*
High Intensity Discharge	12.39	49.57	216.88	278.845	*GWh/yr*
LED Omni-directional	0.61	0.54	0.22	1.375	*GWh/yr*
LED Tube	0.26	5.48	0.51	6.247	*GWh/yr*
LED Outdoor	0.08	1.01	3.78	4.869	*GWh/yr*
Total	70.413	470.171	262.342	802.926	*GWh/yr*

Lamp shipments: Uganda Years: 2010-2017

Annual sales based on UN Comtrade data. Adjustments made: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) reduced fluorescent lamp shipments by a factor of 2 due to values being too high relative to U4E 2015 stock estimates; (3) reduced HID shipments by a factor of 10 due to values being too high relative to U4E 2015 stock estimates; (4) estimating LED sales as a small and slowly increasing percentage of lamp technologies they are replacing, starting in 2013.

Table UGA.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	484,428	20,077	2,527,008	901,635	397,272	35,661	82,804	67,497
Halogen	133,468	60,855	269,224	44,509	39,925	411,582	79,974	30,079
Compact Fluorescent	72,488	104,964	613,268	392,288	498,645	336,563	370,122	273,245
Linear Fluorescent	26,579	38,487	224,865	143,839	182,837	123,407	135,712	100,190
High Intensity Discharge	2,309	1,661	15,031	14,508	26,713	15,703	23,117	9,473
LED Omni-directional	-	-	-	26,769	37,434	47,028	42,632	37,082
LED Tube	-	-	-	2,877	7,313	7,404	10,857	10,019
LED Outdoor	-	-	-	290	1,069	942	1,849	947

Table UGA.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	94,800	3,929	494,522	176,445	77,744	6,979	16,204	13,209
Halogen	47,667	21,734	96,152	15,896	14,259	146,994	28,562	10,743
Compact Fluorescent	65,239	94,468	551,942	353,060	448,781	302,907	333,110	245,920
Linear Fluorescent	141,755	205,263	1,199,280	767,142	975,128	658,168	723,795	534,345
High Intensity Discharge	9,236	6,646	60,124	58,032	106,851	62,813	92,470	37,890
LED Omni-directional	-	-	-	10,908	21,631	27,413	30,230	26,987
LED Tube	-	-	-	15,343	39,005	39,490	57,904	53,434
LED Outdoor	-	-	-	1,161	4,274	3,769	7,398	3,789

Table UGA.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	18,960	786	98,904	35,289	15,549	1,396	3,241	2,642
Halogen	9,533	4,347	19,230	3,179	2,852	29,399	5,712	2,149
Compact Fluorescent	7,249	10,496	61,327	39,229	49,865	33,656	37,012	27,324
Linear Fluorescent	8,860	12,829	74,955	47,946	60,946	41,136	45,237	33,397
High Intensity Discharge	34,635	24,921	225,466	217,619	400,691	235,548	346,762	142,088
LED Omni-directional	-	-	-	1,554	2,731	3,867	3,677	3,211
LED Tube	-	-	-	959	2,438	2,468	3,619	3,340
LED Outdoor	-	-	-	4,352	16,028	14,133	27,741	14,209

Table UGA.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	598,188	24,792	3,120,435	1,113,369	490,565	44,035	102,250	83,347
Halogen	190,668	86,936	384,606	63,584	57,036	587,974	114,248	42,970
Compact Fluorescent	144,976	209,928	1,226,537	784,577	997,290	673,127	740,245	546,489
Linear Fluorescent	177,193	256,579	1,499,101	958,927	1,218,910	822,710	904,743	667,931
High Intensity Discharge	46,180	33,228	300,621	290,158	534,254	314,065	462,349	189,451
LED Omni-directional	-	-	-	39,231	61,796	78,308	76,539	67,281
LED Tube	-	-	-	19,179	48,756	49,363	72,379	66,793
LED Outdoor	-	-	-	5,803	21,370	18,844	36,988	18,945

Annex E. Zambia Lighting Market Estimates

Draft Estimate for: **Zambia** ZMB

	2018 estimate		
Total Electricity Consumption:	11.800	TWh/yr	*Source: IEA, 2017*
Total Consumption for lighting:	1.397	TWh/yr	*Source: calculated from data below*
Percentage:	11.8%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	(units)
Incandescent	1.431	0.144	0.029	1.604	millions of lamps
Halogen	2.766	0.337	0.067	3.170	millions of lamps
Compact Fluorescent	3.088	2.194	0.183	5.465	millions of lamps
Linear Fluorescent	1.646	7.766	0.485	9.897	millions of lamps
High Intensity Discharge	0.026	0.104	0.391	0.521	millions of lamps
LED Omni-directional	0.591	0.269	0.038	0.898	millions of lamps
LED Tube	0.041	0.216	0.014	0.271	millions of lamps
LED Outdoor	0.001	0.003	0.012	0.016	millions of lamps
Total	9.590	11.033	1.219	21.841	

Average Lamp Wattage	Residential	Professional	Outdoor	(units)
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	(units)
Incandescent	2.0	5.0	5.0	*hours/day*
Halogen	2.0	5.0	5.0	*hours/day*
Compact Fluorescent	3.0	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	3.0	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	(units)
Incandescent	47.00	11.83	5.26	64.086	*GWh/yr*
Halogen	74.72	22.73	10.44	107.896	*GWh/yr*
Compact Fluorescent	33.82	96.10	10.68	140.600	*GWh/yr*
Linear Fluorescent	43.25	816.34	73.70	933.290	*GWh/yr*
High Intensity Discharge	5.70	22.81	99.79	128.299	*GWh/yr*
LED Omni-directional	3.24	2.45	1.05	6.733	*GWh/yr*
LED Tube	0.59	12.64	1.18	14.417	*GWh/yr*
LED Outdoor	0.03	0.35	1.29	1.669	*GWh/yr*
Total	208.351	985.247	203.393	1,396.991	*GWh/yr*

Lamp shipments: Zambia   Years: 2010-2017

Annual sales based on UN Comtrade data. Adjustments made: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) increased incandescent and halogen shipments slightly to smooth volatility and address a deficit relative to U4E 2015 stock estimates; (3) increased fluorescent lamp shipments to smooth trend for increasing sales over the time period and to align with U4E; (4) increased HID shipments by a factor of 10 due to values being too low relative to U4E 2015 stock estimates; (5) estimating LED sales as a small and slowly increasing percentage of lamp technologies they are replacing, starting in 2013.

Table ZMB.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	1,671,994	1,525,022	1,378,050	2,622,793	2,343,487	2,343,487	2,064,181	2,064,181
Halogen	1,262,740	1,868,387	1,714,293	1,766,940	1,903,740	1,918,562	1,974,981	2,031,400
Compact Fluorescent	215,341	390,709	520,187	700,922	769,027	545,783	600,783	655,783
Linear Fluorescent	112,798	204,657	272,479	367,149	402,824	285,886	314,696	343,505
High Intensity Discharge	5,088	13,064	10,009	6,371	9,400	4,754	4,966	5,178
LED Omni-directional	-	-	-	101,813	200,650	288,470	371,196	475,136
LED Tube	-	-	-	7,343	16,113	17,153	25,176	34,351
LED Outdoor	-	-	-	127	376	285	397	518

Table ZMB.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	327,200	298,439	269,677	513,267	458,608	458,608	403,949	403,949
Halogen	450,979	667,281	612,248	631,050	679,907	685,201	705,350	725,500
Compact Fluorescent	369,157	669,787	891,749	1,201,580	1,318,332	935,628	1,029,914	1,124,199
Linear Fluorescent	601,589	1,091,504	1,453,221	1,958,130	2,148,393	1,524,728	1,678,378	1,832,028
High Intensity Discharge	20,350	52,256	40,036	25,482	37,600	19,014	19,863	20,711
LED Omni-directional	-	-	-	46,918	98,274	124,766	171,137	225,365
LED Tube	-	-	-	39,163	85,936	91,484	134,270	183,203
LED Outdoor	-	-	-	510	1,504	1,141	1,589	2,071

Table ZMB.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	65,440	59,688	53,935	102,653	91,722	91,722	80,790	80,790
Halogen	90,196	133,456	122,450	126,210	135,981	137,040	141,070	145,100
Compact Fluorescent	30,763	55,816	74,312	100,132	109,861	77,969	85,826	93,683
Linear Fluorescent	37,599	68,219	90,826	122,383	134,275	95,295	104,899	114,502
High Intensity Discharge	76,313	195,960	150,135	95,558	141,000	71,303	74,485	77,667
LED Omni-directional	-	-	-	6,580	13,503	18,404	24,615	31,957
LED Tube	-	-	-	2,448	5,371	5,718	8,392	11,450
LED Outdoor	-	-	-	1,911	5,640	4,278	5,959	7,767

Table ZMB.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	2,064,635	1,883,149	1,701,663	3,238,713	2,893,817	2,893,817	2,548,920	2,548,920
Halogen	1,803,914	2,669,124	2,448,990	2,524,200	2,719,629	2,740,803	2,821,402	2,902,000
Compact Fluorescent	615,261	1,116,311	1,486,249	2,002,633	2,197,220	1,559,381	1,716,523	1,873,665
Linear Fluorescent	751,986	1,364,381	1,816,526	2,447,663	2,685,492	1,905,910	2,097,972	2,290,035
High Intensity Discharge	101,750	261,280	200,180	127,410	188,000	95,070	99,313	103,556
LED Omni-directional	-	-	-	155,311	312,427	431,640	566,948	732,459
LED Tube	-	-	-	48,953	107,420	114,355	167,838	229,004
LED Outdoor	-	-	-	2,548	7,520	5,704	7,945	10,356

Annex F. Zimbabwe Lighting Market Estimates

Draft Estimate for: **Zimbabwe** ZWE

	2018 estimate		
Total Electricity Consumption:	8.000	TWh/yr	*Source: IEA, 2017*
Total Consumption for lighting:	1.472	TWh/yr	*Source: calculated from data below*
Percentage:	18.4%	Percent	

Installed Stock of Lamps	Residential	Professional	Outdoor	Total	*(units)*
Incandescent	1.001	0.099	0.020	1.120	millions of lamps
Halogen	1.103	0.132	0.026	1.262	millions of lamps
Compact Fluorescent	3.493	2.114	0.176	5.783	millions of lamps
Linear Fluorescent	1.870	8.513	0.532	10.914	millions of lamps
High Intensity Discharge	0.041	0.163	0.610	0.814	millions of lamps
LED Omni-directional	0.364	0.193	0.025	0.582	millions of lamps
LED Tube	0.037	0.198	0.012	0.247	millions of lamps
LED Outdoor	0.000	0.002	0.007	0.009	millions of lamps
Total	7.909	11.413	1.408	20.730	

Average Lamp Wattage	Residential	Professional	Outdoor	*(units)*
Incandescent	45	45	100	*Watts*
Halogen	37	37	85	*Watts*
Compact Fluorescent	10	15	20	*Watts*
Linear Fluorescent	36	36	52	*Watts*
High Intensity Discharge	60	60	70	*Watts*
LED Omni-directional	5	5	15	*Watts*
LED Tube	20	20	30	*Watts*
LED Outdoor	10	30	30	*Watts*

Average Operating Hours	Residential	Professional	Outdoor	*(units)*
Incandescent	2.0	5.0	5.0	*hours/day*
Halogen	2.0	5.0	5.0	*hours/day*
Compact Fluorescent	3.0	8.0	8.0	*hours/day*
Linear Fluorescent	2.0	8.0	8.0	*hours/day*
High Intensity Discharge	10.0	10.0	10.0	*hours/day*
LED Omni-directional	3.0	5.0	5.0	*hours/day*
LED Tube	2.0	8.0	8.0	*hours/day*
LED Outdoor	10.0	10.0	10.0	*hours/day*

Annual Lighting Energy (2018)	Residential	Professional	Outdoor	TOTAL	*(units)*
Incandescent	32.89	8.10	3.60	44.587	*GWh/yr*
Halogen	29.79	8.94	4.11	42.837	*GWh/yr*
Compact Fluorescent	38.25	92.61	10.29	141.143	*GWh/yr*
Linear Fluorescent	49.13	894.84	80.78	1,024.761	*GWh/yr*
High Intensity Discharge	8.91	35.64	155.91	200.452	*GWh/yr*
LED Omni-directional	1.99	1.76	0.67	4.427	*GWh/yr*
LED Tube	0.54	11.54	1.08	13.159	*GWh/yr*
LED Outdoor	0.02	0.19	0.73	0.936	*GWh/yr*
Total	161.522	1,053.615	257.167	1,472.303	*GWh/yr*

Lamp shipments: Zimbabwe Years: 2010-2017

Annual sales based on UN Comtrade data. Adjustments made: (1) Filling in 'gap years' in data by averaging unit shipments on years before and after; (2) increased incandescent lamp shipments slightly to maintain trend but avoid volatility relative to U4E 2015 estimates; (3) swapped reported data of HID and Fluorescent lamps as they appeared to be mis-classified; (4) After swapping, reduced fluorescent lamp shipments by a factor of 2 to better align with U4E 2015 estimates; (5) estimating LED sales as a small and slowly increasing percentage of lamp technologies they are replacing, starting in 2013.

Table ZWE.1 Estimated Lamp Sales Annually by Technology in the Residential Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	3,089,720	2,143,255	2,143,255	1,196,791	2,623,979	1,162,032	441,274	441,274
Halogen	177,318	353,215	376,431	803,748	968,264	669,022	599,425	634,224
Compact Fluorescent	241,022	822,656	681,796	669,863	593,500	560,382	511,839	536,110
Linear Fluorescent	126,250	430,915	357,131	350,881	310,881	293,533	268,106	280,820
High Intensity Discharge	23,620	12,806	51,194	7,055	864	4,444	12,022	8,233
LED Omni-directional	-	-	-	53,408	167,430	143,486	124,203	161,161
LED Tube	-	-	-	7,018	12,435	17,612	21,448	28,082
LED Outdoor	-	-	-	141	35	267	962	823

Table ZWE.2 Estimated Lamp Sales Annually by Technology in the Professional (Commercial + Industrial) Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	604,642	419,424	419,424	234,206	513,499	227,404	86,355	86,355
Halogen	63,328	126,148	134,440	287,053	345,809	238,937	214,080	226,508
Compact Fluorescent	413,181	1,410,267	1,168,793	1,148,337	1,017,429	960,655	877,438	919,046
Linear Fluorescent	673,332	2,298,213	1,904,700	1,871,364	1,658,032	1,565,511	1,429,900	1,497,705
High Intensity Discharge	94,482	51,222	204,776	28,221	3,457	17,776	48,086	32,931
LED Omni-directional	-	-	-	33,392	75,069	85,620	94,230	123,191
LED Tube	-	-	-	37,427	66,321	93,931	114,392	149,771
LED Outdoor	-	-	-	564	138	1,067	3,847	3,293

Table ZWE.3 Estimated Lamp Sales Annually by Technology in the Outdoor Sector

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	120,928	83,885	83,885	46,841	102,700	45,481	17,271	17,271
Halogen	12,666	25,230	26,888	57,411	69,162	47,787	42,816	45,302
Compact Fluorescent	34,432	117,522	97,399	95,695	84,786	80,055	73,120	76,587
Linear Fluorescent	42,083	143,638	119,044	116,960	103,627	97,844	89,369	93,607
High Intensity Discharge	354,306	192,083	767,910	105,828	12,963	66,660	180,323	123,491
LED Omni-directional	-	-	-	3,999	10,266	10,399	10,657	13,916
LED Tube	-	-	-	2,339	4,145	5,871	7,149	9,361
LED Outdoor	-	-	-	2,117	519	4,000	14,426	12,349

Table ZWE.4 Estimated Total Annual Sales of Lamps for Residential, Professional and Outdoor Sectors

Lamp Type	2010	2011	2012	2013	2014	2015	2016	2017
Incandescent	3,815,290	2,646,564	2,646,564	1,477,838	3,240,178	1,434,916	544,900	544,900
Halogen	253,312	504,593	537,758	1,148,212	1,383,234	955,746	856,322	906,034
Compact Fluorescent	688,635	2,350,445	1,947,988	1,913,895	1,695,714	1,601,091	1,462,397	1,531,744
Linear Fluorescent	841,665	2,872,767	2,380,875	2,339,204	2,072,540	1,956,889	1,787,374	1,872,132
High Intensity Discharge	472,408	256,110	1,023,880	141,104	17,284	88,880	240,430	164,655
LED Omni-directional	-	-	-	90,799	252,765	239,505	229,090	298,268
LED Tube	-	-	-	46,784	82,902	117,413	142,990	187,213
LED Outdoor	-	-	-	2,822	691	5,333	19,234	16,466

Annex G. Lamp Type Descriptions

This section provides a brief description and illustration of each of the lamp types discussed in this report.

Lamp Type	Lamp description (not a definition)	Image
Incandescent	A lamp with a wire filament heated by passing an electric current through it to such a high temperature that it glows with visible light (i.e., “incandescence”)	
Halogen reflector	A lamp that contains a halogen capsule built into a small enclosure with a reflective surface behind the capsule so it produces a forward beam of light. These lamps do not need additional reflectors to be incorporated into the light fixture.	
Halogen omnidirectional	An incandescent lamp with a small amount of a halogen gas such as iodine or bromine added to a small capsule surrounding the filament. Halogen is about 20% more efficient than incandescent.	
Halogen other	Other types of halogen lamps, such as double-ended lamps found in outdoor wall-mounted flood lights and torchieres; also small capsule low-voltage halogen lamps.	
Compact fluorescent lamp without integral ballast	A lamp where the ballast operating the lamp is contained in the fixture into which the pin-base CFLni lamp is inserted. The “ni” stands for non-integrated, meaning the ballast is not integrated with the lamp. CFLni’s are also commonly known as “PL lamps”.	
Compact fluorescent lamp with integral ballast	A miniaturised fluorescent lamp designed to replace an incandescent lamp. Consists of a fluorescent tube that is curved, twisted or folded to fit into the space of an incandescent lamp, and incorporates an electronic ballast in the base of the lamp. CFLs are about 75% more efficient than incandescent.	

Lamp Type	Lamp description (not a definition)	Image
Linear fluorescent lamp T5	A linear fluorescent lamp is a type of gas-discharge lamp whereby an electrical arc emitting UV light is sustained inside the tube, and the white phosphors on the inside surface of the glass tube down-convert the UV light into the visible spectrum. T5 denotes the diameter of the bulb, at 5/8 of an inch (16mm).	
Linear fluorescent lamp T8	A fluorescent lamp similar to the T5 lamp, except with a larger diameter – one inch (26 mm).	
Linear fluorescent lamp T12	A fluorescent lamp similar to the T5 and T8 lamp, however with a larger diameter 1.5 inches (38 mm) and generally with a lower efficiency than T5 and T8.	
Light emitting diode tubular lamp (retrofit for LFL)	A tubular replacement lamp that looks like a LFL and retrofits into a LFL fixture. It produces light from LEDs distributed along the interior surface of the tube, which serves as a diffuser.	
Light emitting diode omnidirectional lamp	An LED lamp that can be retrofit directly into mains-voltage sockets and which emit light in all directions, like an incandescent lamp. Can be clear or frosted at the bulb surface. Typically 75% to 90% more efficient than incandescent.	
Light emitting diode reflector lamp	An LED lamp that is designed as a retrofit replacement for a reflector lamp. Commonly found in PAR/MR-16 format (pictured), but also larger diameters with higher light output levels.	
Light emitting diode outdoor luminaire	An LED luminaire that is used outdoors, meaning it is designed for the weather and temperature swings experienced by outdoor fixtures.	

Lamp Type	Lamp description (not a definition)	Image
Light emitting diode downlight luminaire	An LED luminaire that is designed to work as an indoor recessed downlight luminaire. One example is pictured, but can be many different designs.	
High intensity discharge lamp – indoor applications	A type of electrical gas-discharge lamp that produces light by maintaining an electric arc between two electrodes housed inside a fused quartz or ceramic arc tube. This tube is filled with both gas and metal salts. Indoor HID applications typically use ceramic metal halide lamps.	
High intensity discharge lamp – high pressure sodium lamp	An HID lamp that is based on sodium, and is very commonly found in street lighting applications (emits an orange light).	
High-intensity discharge – other types	Other HID lamps that can be found, e.g., stadium lighting, white-light area and street lighting, etc.	

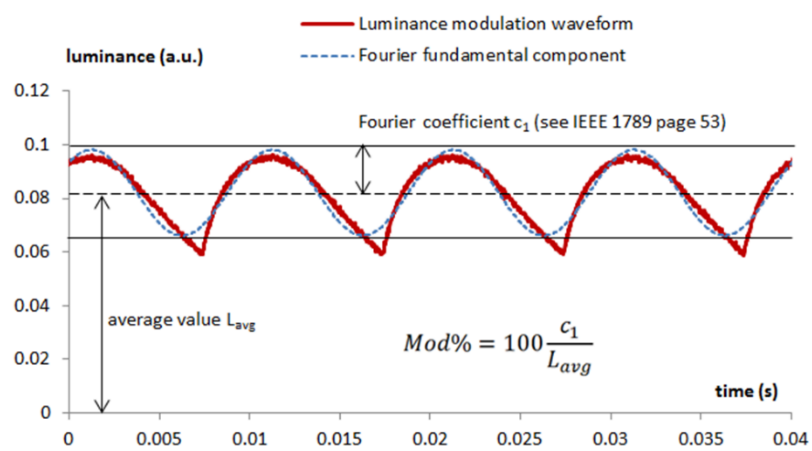
Annex H. Performance Criteria for Non-Directional Lamps

Source: IEA 4E SSL Annex, Quality and Performance Tiers, Non-Directional Lamps, November 2016

Criterion	What is it?	Why is it included?	Test Method
Minimum lamp luminous efficacy (lm/watt)	The ratio of the total light output of a lamp compared to power consumed (lm/watt). The higher the efficacy value, the more energy-efficient the lighting product.	This criterion is of highest importance for the consumer and society to save energy and money.	CIE S 025/E (or IES LM-79)
Maximum Standby Power	Maximum Standby Power applies to the default (factory setting) mode of smart lamps and other modes that provide a lighting control function, and which remain 'on' when emitting no light. The IEA/G20 will continue to research this topic plus other types of smart lighting and provide advice to governments.	As wireless control of lighting expands in the market, this criterion is important for the consumer and society so as to ensure minimal additional power consumption associated with new lighting control features.	IEC 62301
Claimed incandescent equivalent wattage (W) and minimal initial light output (lumens)	These levels will also assist in evaluating manufacturer claims that a given SSL product is an equivalent replacement for a typical wattage incandescent light product. These light levels are different in 120V and 230/240V markets (defined by equations). The Annex also proposes a transition to a harmonised set of lumen bins, based on an approximate averaging of the light output.	Acceptable light output levels are of highest importance for safe working and living conditions. Accurate equivalency comparison with the products that are being replaced is also important. This importance will diminish over time as manufacturers stop selling products according to claimed equivalencies and consumers select lamps on the basis of light output (lumens) rather than wattage.	
Luminous flux maintenance	The percentage of a lighting product's measured light output after a period of time compared to that light product's initial total light output	Luminous flux maintenance helps the consumer determine how long it will take a lighting product to degrade to the point that it is no longer useable. High lumen maintenance over time helps to justify the higher initial cost of SSL lighting products.	IES LM-80/TM-21 or IES LM-84/TM-28. It is expected from 2017 onwards only LM-84 / TM-28 may be accepted
Early failure rate (maximum)	The percentage of lamps in a sample that fail at a specified point in time (6000 hours).	Early failure rates should be as low as possible in order to minimise the risk that new customers to LED lighting will have a bad experience and the lamp itself will fail to achieve its full potential of energy savings. It is also an alternative indicator of longevity in the absence of a practical lifetime test.	IES LM-80

Criterion	What is it?	Why is it included?	Test Method
Minimum rated lamp lifetime (F_{50})	Lifetime is typically defined as the amount of time that it takes for 50% of a statistically significant sample to fail.	It is unrealistic to measure very long lifetimes for SSL products. Having a credible F_{50} estimation is very important, as LED lighting products must have longer lifetimes to justify the high initial cost of LED lighting. If SSL products are able to meet their lifetime claims, they can cut long-term energy consumption and save the consumer money.	
Endurance test	This criterion requires that a SSL product is rapidly switched on and off to simulate how a product will be used over its lifetime.	This criterion requires that a test is carried out to stress a SSL product over a short period of time to determine the failure rates of a product. Often, if one electronic subcomponent in a SSL product fails, the whole product fails. A stress test like this one can help verify that an SSL product will not fail when installed and used in a consumer application.	IEC 62612
Colour rendering index (CRI)	Colour rendering is a measure of how similar object colours appear under one light source as compared to the object colours under a reference light source (usually an incandescent light or daylight). Colour rendering is very important for consumer satisfaction with a lighting product. Often, a CRI of 80 is required for office work, and recommended for use in residential applications. A CRI of 90 is recommended for tasks that require high colour discrimination.	The IEA SSL Annex is aware of current investigations and discussions of shortcomings of the CRI metric that limit its ability to fully represent how humans perceive colour for SSL technology; and the potential need for both a colour fidelity metric and a colour preference metric. The IEA SSL annex is monitoring the work of the IES (in particular the release of TM-30) as well as the ongoing work in CIE, and will take this work into account in future updates of the SSL Annex performance specifications.	CIE 13.3-1995
Colour maintenance (Δ u',v' at 6,000h)	This criterion specifies the allowable shift of the light colour of a SSL package as it ages, based on either using IESNA LM-80/TM-21 or IESNA LM-84/TM-28.	This criterion ensures that as a light product ages, the perceived colour of light does not shift from warm- white to cool-white or develop a green or pink tint. If an SSL lamp or luminaire in a large installation is replaced by a new light product of the same model, this criterion ensures that the new product's colour will be similar to those installed around it.	IES LM-80/TM-21 or IES LM-84/TM-28. It is expected from 2017 onwards only LM-84 / TM-28 may be accepted

Criterion	What is it?	Why is it included?	Test Method
Chromaticity tolerance	This criterion specifies the allowable deviation in light's colour. Technically, it is the distance of a light's chromaticity from the Planckian (black body) locus and target CCT.	This criterion is of high importance to ensure that the light from an LED product does not have an unacceptable pink or green tint. This criterion attempts to ensure that all lamps and luminaires of the same claimed colour temperature appear to be the same colour when installed.	ANSI C78.377-2015
Luminous intensity distribution 0-180°	This criterion describes the measured distribution of light of a lighting product.	It is of high importance to measure this as many LED products being sold now poorly approximate the light distribution of the conventional products they claim to replace.	CIE S 025/E
Dimmer compatibility	This criterion evaluates whether a SSL light source will operate well with the current stock of installed dimmers.	Dimmer compatibility is of high importance for the consumer as many SSL products are often not completely compatible with commonly available dimmers. As manufacturers are still trying to define and adopt a new dimming standard, the dimmer compatibility of SSL products is likely to continue to be a problem.	
Power factor	Power factor is the ratio of the active power flowing to the load over the apparent power of the circuit (see IEC IEV ref 131-11-46). We recognise that in many cases the IEC requirements on total harmonic distortion (THD) will lead to a higher power factor (PF) than the minimum level required in the performance tiers, but we follow IEC standards and believe the most critical electrotechnical requirements are set through the THD requirements.	For the Electrical power supplier, power factor is of high importance. For street lighting and commercial or industrial lighting; customers may be subject to a penalty charge if power factor is below 0.9. The importance of high power factor may vary depending on the nature of the power distribution network.	IEC 61000-3-2
Harmonic distortion	The total harmonic distortion of the current is the RMS-sum of all the harmonic currents divided by the current at the fundamental frequency (50 Hz or 60 Hz). $THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^2}}{I_1}$	Harmonic distortion measures how the lighting product might affect the quality and safety of the electrical utility's grid. The total harmonic distortion is important to maintain the quality and safety of the electrical grid. High frequency harmonic currents emitted by electrical devices such as lamps may trigger circuit breakers, may cause overheating in cables (lost energy) and electrical distribution devices and may cause a loss of reliability of switch pulse information.	IEC 61000-4-7

Criterion	What is it?	Why is it included?	Test Method
Dominant light modulation frequency (*f*) Modulation percent at this frequency (Mod%) (Includes Flicker effects)	The criteria here are based on the IEEE 1789 standard, section 8. The criteria are related to fast periodic changes - less than 1 second - of the luminance of a light source (including flicker). The dominant light modulation frequency is usually the Fourier fundamental frequency of the luminance modulation waveform. (Please see diagram and Mod% equation below; also see the spreadsheet on the SSL Annex website to facilitate the Fourier calculation)	This is an important item for both consumer satisfaction and consumer acceptance of SSL products. Some consumer may have severe health reactions to flickering light sources of certain frequencies ranging from low-grade headaches to extreme seizures. Modulated light can also alter the perception of the motion of objects and produce ghost images in the visual field. The requirements minimize these effects. While more research is required on health effects at non visible modulation frequencies beyond 90 Hz, the priority here is on restricting flicker, occurring at modulation frequencies less than 90 Hz.	There is no standard test method at this time. IEEE 1789 is not a test standard. CIE TN 006:2016 Section 4 gives a useful indication of the experimental determination of the light modulation waveform and the calculation of its Fourier spectrum.
			
Photo-biological risk group (blue light and UV hazard)	Photobiological 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. The criterion sets a limit to the blue light dose that the retina can receive.	This criterion is very important for consumer safety. Blue light can cause irreparable damage to eyesight at high doses. Products need to be evaluated to determine their appropriate photobiological risk group.	IEC 62471-2/ CIE S 009 and IEC TR 62778
Safety	This criterion specifies that a product meets mechanical and electrical safety requirements and marking requirements.	All products must meet all safety regulations in an economy.	IEC 60598 series
Warranty duration	This criterion specifies the duration in years from the date of installation of a SSL product.	It is very important that consumers have a guarantee that SSL products will perform as claimed.	

Criterion	What is it?	Why is it included?	Test Method
RoHS compliant	The EU's Regulation of Hazardous Substances (RoHS), Delegated Directive (EU) 2015/863 of 31 March 2015, prevents the use of certain hazardous materials in new electrical and electronic equipment placed on the European market.	This criterion requires products meet requirements that limit the use of certain hazardous materials when sold in the EU. Non-EU countries may use other, similar requirements.	
Recyclable content (%)	This criterion defines how much of the SSL product must be recyclable: • Recyclable content, expressed in percentage by weight (wt%) • The nature of the recyclable materials, stated by recycling codes or recycling symbols	This criterion is important to manage electronic equipment waste and reduce the environmental burden of these products. Ideally, products would be designed to be easily recycled when they fail.	ISO 14021; ISO 14025:2006

Annex I. Minimum Energy Performance Specifications for Lighting

This Annex is an excerpt from UNEP publication from 2015 titled: “Developing Minimum Energy Performance Standards for Lighting Products: Guidance Note for Policymakers” by Michael Scholand, United Nations Environment Programme, June 2015.
Link: https://united4efficiency.org/wp-content/uploads/2016/09/Developing_MEPS_for_Lighting_Products_web_14-07-15.pdf

MEPS are regulatory tools that increase the energy efficiency of products. For lighting, they contribute to the phasing out of the least efficient lamps in a market by setting the minimum levels of energy efficiency that a lamp in a given class must meet before it can be sold. When effectively applied, MEPS, in conjunction with supporting policies, encourage manufacturers to improve the efficiency of their products or to introduce more efficient replacements. However, before MEPS are adopted, cost/benefit analyses must be performed to ensure that the associated regulatory measures provide a positive economic benefit to consumers. MEPS should be developed in consultation with all of the stakeholders involved in the manufacturing, sale and use of the products to which they apply.

Generally, policymakers have designed the energy efficiency performance MEPS for lamps around one of two different options:

TECHNOLOGY-NEUTRAL approaches that establish MEPS for lamps without specifying the light source technology. For example, the European Union (EU) phase out strategy allows any lamp to be sold if it meets the energy performance and other requirements of the MEPS.

TECHNOLOGY-SPECIFIC approaches that establish MEPS for lamps, but that only apply to certain light sources or technologies.

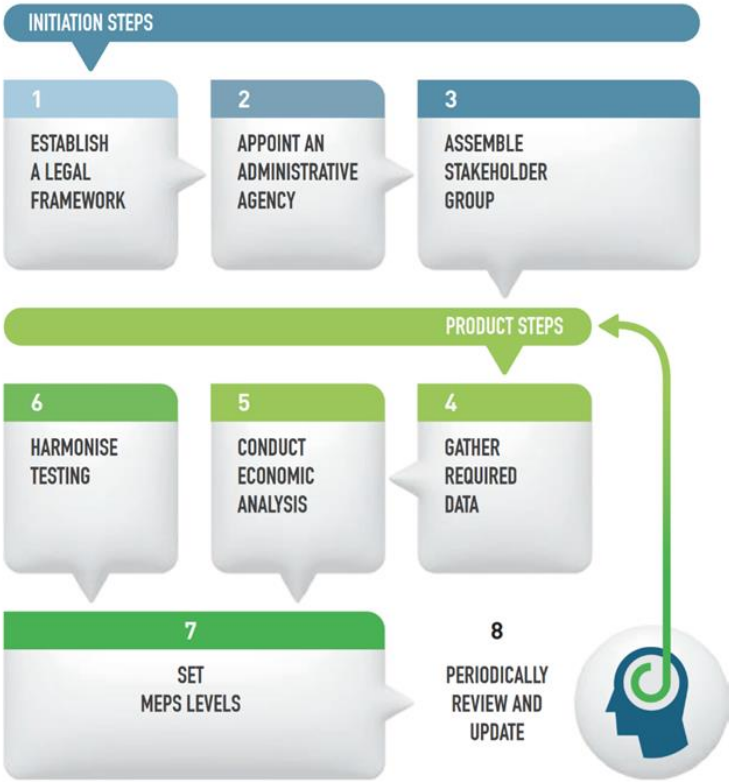
Successful market transformation strategies are designed for the long term, to ensure a complete and permanent phase out of inefficient lamps. Although MEPS offer a powerful tool in the transition to energy efficient lighting, they are just one component of an overall strategy required to ensure this complete and permanent phase out of inefficient lamps. The UNEP-GEF en.lighten initiative therefore recommends that MEPS be implemented as part of an integrated policy approach, as detailed in, Achieving the Global Transition to Energy Efficient Lighting Toolkit.

MEPS are the most sustainable option for achieving high levels of energy efficiency and for phasing out less efficient lamps. To be effective, MEPS must be carefully implemented. Performance levels and programme requirements must be developed with stakeholders’ input to obtain maximum buy-in and participation. Once implemented, MEPS programmes need to be monitored, evaluated, updated, reviewed and revised. The most important factor for programme success is a functional system of monitoring, verification and enforcement capable of ensuring full compliance of products with any regulatory measures.

It is strongly recommended that a structured, multistep approach is followed when developing MEPS – with ’initiation steps’ which need be conducted only once, and ’product steps’ which are repeated for each category of lamp (or other product) to be regulated.

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 your economy who would be interested and invite them to participate in the process. PRODUCT STEPS

4. 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.
5. Conduct an economic analysis: Use cost-effectiveness analysis to determine the appropriate level of ambition for the regulatory measure(s).
6. 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.
7. 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.
8. Review and update: Plan to periodically review and update the standards every few years to ensure they remain appropriate and relevant.



If MEPS are to be adopted in a country or regional market, stakeholders should consider whether to harmonise with the existing lamp MEPS on those same products in their region, or with the lamp MEPS of a large trading partner. If one country in a trading region chooses to adopt MEPS that are not compatible with its neighbouring markets, this decision could increase cost and restrict the availability of energy efficient lamps. Manufacturers may need to perform different, or additional lamp tests; create unique labels and catalogue numbers for each market; and track, keep inventory and ship country-specific lamp products.

Harmonisation of MEPS offers many benefits that allow countries and the private sector to avoid the costs of duplicating testing and of non-comparable 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. Harmonisation of test standards enables multiple national markets to be accessible for the cost of only one test.

The success of any lamp MEPS programme depends on the selection and combination of other policies to meet the specific needs of a country and the particular objectives of a phase-out scheme. Other policy options should be used to support the implementation of MEPS in order to reduce the use of inefficient lamps while promoting the demand for MEPS-compliant high efficiency lamps. An integrated policy approach positions MEPS as the cornerstone of a sustainable national efficient lighting strategy.