Energy efficiency in SOUTH AFRICA:

The case of LED lighting and high-efficiency distribution transformers

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LIST OF ACRONYMS AND ABBREVIATIONS

ADAM	Approach to Distribution Asset Management
ADF	Agence Française de Développement
AMEU	Association of Municipal Electric Utilities
CAPEX	capital expenditure
CFL	compact fluorescent lamp
COMESA	Common Market for Eastern and Southern Africa
CSIR	Council for Scientific and Industrial Research
LFL	linear fluorescent lamp
CO_2	carbon dioxide
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs
DoE	Department of Energy
DPE	Department of Public Enterprises
DSM	Demand-side management
DTI	Department of Trade and Industry
EDIH	Electricity Distribution Industry Holding Company
EE	energy efficiency
EE-DSM	energy efficiency and demand-side management
EEFI	Energy Efficiency Financial Instrument
EEPIP	Energy Efficiency in Public Buildings and Infrastructure Programme (V-NAMA)
EE S&L	Market Transformation through Energy Efficiency Standards & Labelling of Appliances
EPC	energy performance contracting
ESCO	energy service company
e-WASA	e-Waste Association of South Africa
FPIC	Free Prior and Informed Consent
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GIZ	Gesellschaft für Technische Zusammenarbeit
GWh	Gigawatt-hour (billion watt-hours)
HE	high efficiency
HID	high-intensity discharge
HPS	high-pressure sodium
IDC	Industrial Development Corporation
IDM	Integrated demand management
IESSA	Illumination Engineering Society of South Africa
INDC	Intended Nationally Determined Contribution
K	Kelvin (degrees)
kVA	kilovolt-ampere
kWh	kilowatt-hour
LED	light-emitting diode
lm	lumen
LSM	Living Standard Measure
MEEDSM	Municipal Energy Efficiency and Demand-side Management Programme
MEPS	minimum energy performance standard
MFMA	Municipal Financial Management Act
MTE	mid-term review

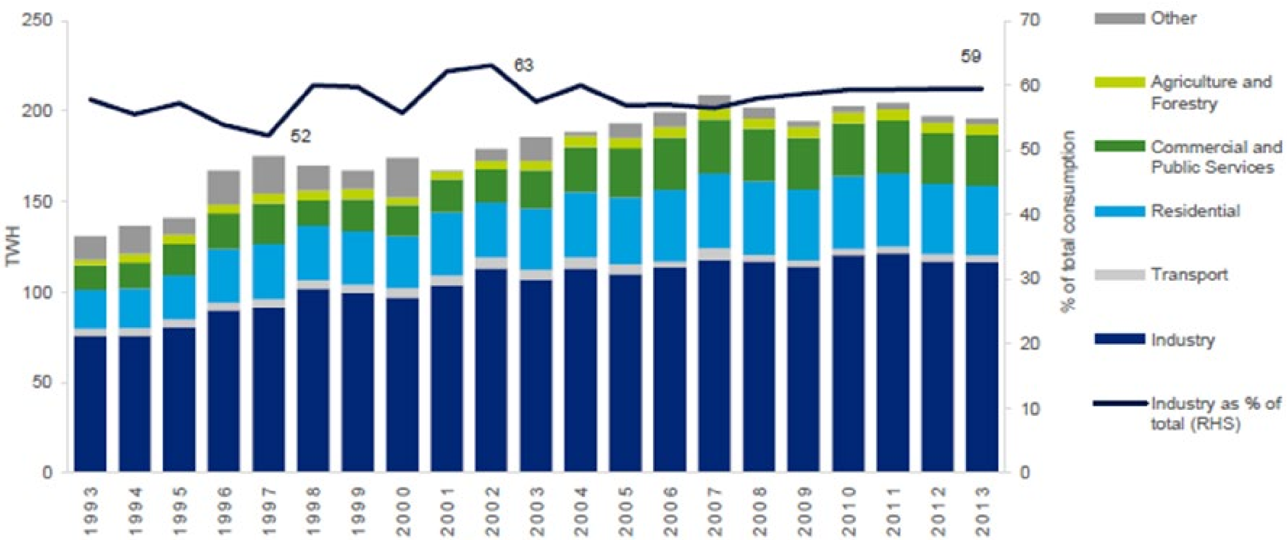
MV	mercury vapour
MVA	megavolt-ampere
MVE	monitoring, verification and enforcement
MW	megawatt (million Watt)
MWh	megawatt-hour (million Watt-hours)
NAMA	Nationally Appropriate Mitigation Actions
NBI	National Business Initiative
NCRS	National Regulator for Compulsory Specifications
NEES	National Energy Efficiency Strategy
NERSA	National Energy Regulator of South Africa
NGO	non-governmental organisation
NMISA	National Metrology Institute of South Africa
OPEX	operational expenditure
PCB	polychlorinated biphenyls
PJ	petajoules (10^{15} Joules)
PPP	public-private partnership
PPPF	Preferential Procurement Policy Framework
SABS	South Africa Bureau of Standards
SACN	South African Cities Network
SADC	Southern African Development Community
SALGA	South African Local Government Association
SANAS	South Africa National Accreditation System
SANEDI	South African National Development Institute
SAPP	Southern African Power Pool
SDG	Sustainable Development Goal
TA	technical assistance
TA	Technical Advisor
tCO_2	ton of carbon dioxide
TE	terminal evaluation
TWh	terawatt-hour (trillion watt-hours)
U4E	United for Energy
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme (UN Environment)
USD	United States dollar
V	Volt
V-NAMA	Vertical Nationally Appropriate Mitigation Actions
W	Watt
WOB	women-owned business
ZAR	Rand

1. INTRODUCTION

1.1 Context and national priorities

Total electricity consumption in South Africa has hovered around 200 TWh a up to a total of about 208 in 2015, and is projected to grow further at about 2-3% percent annually[1]. South Africa has one of the world's highest grid emission factors – about 0.94 tonnes of CO_2 emitted per MWh of electricity consumed, because of its heavy reliance on coal, which accounts for about 92% of national domestic electricity production.

Box 1 Electricity consumption, South Africa



Source: STATS SA, taken from *An overview of electricity consumption and pricing in South Africa An analysis of the historical trends and policies, key issues and outlook in 2017* (Deloitte, Eskom, 2017)

Electric appliances and equipment have become an essential part of the lives of practically all of South Africa's citizens – women and men, across all age categories, regions, and income levels. This includes lighting, which is used in all sectors, residential, commercial-productive, and in outdoor and street lighting. Lighting accounted for about 62 TWh of electricity consumption in 2016 (out of 240 TWh of electricity transmitted).

Outside of the home, electrical equipment deployed on a wide scale also has an inordinately high impact. There are about 660,000 distribution transformers deployed on the electric grid around the country, operating around the clock. Taken together, lighting and distribution transformers accounted for an estimated 72 TWh of electricity consumption in 2017, that is about 37% of the nation's total[2] and responsible for the emission of 67 million tCO_2.

The overall framework for energy efficiency is present in the form of policy documents, such as the National Energy Efficiency Strategy of (2005, reviewed in 2008) and the **Post-2015 National Energy Efficiency Strategy** (draft published in the Government Gazette in Dec 2016 for public comments), which aims for energy efficiency improvement by 2030 of 16%

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1 See Box 1 and *Electricity Generated and Available for Distribution*, STATS SA (2017) and *Integrated Resources Plan for Electricity 2010-2030*, Department of Energy. Emission factor taken from *South Africa's Grid Emission Factor*, National Business Initiative (2011).

2 Own estimates

(using a baseline of 2015) to be achieved in a number of areas, buildings, appliance & equipment, lighting, transport, industry, energy utilities.

A number of **national standards** are relevant to the Project. The standard *SANS 941* on *Energy efficiency of electrical and electronic apparatus* covers energy efficiency requirements, measurement methods and appropriate labelling of energy-efficient electrical and electronic apparatus. The *Compulsory specification for energy efficiency and labelling of electrical and electronic apparatus* (*VC 9008*) was enacted in 2014 and came into force in 2015, making the SANS 941 a compulsory standard. It requires that a range of electrical and electronic apparatus (dishwashers, washing machines, tumble dryers and/or washer-dryers, refrigerators and/or freezers, electric ovens, storage water heaters) adhere to certain minimum energy performance standards. It also requires that all appliances listed display the energy efficiency rating on the appliance. *SANS 1544 Energy performance certificates for buildings* specifies the methodology for calculating energy performance in existing buildings. It will initially be a voluntary standard but may become a mandatory standard through the NRCS regulation process (the regulations for the mandatory display of energy performance for buildings have been published). There are no energy performance standards on distribution transformers.

The **National Environmental Management** Waste Act (2008) has implications for e-waste management and makes it illegal for individuals or companies to send e-waste to landfills. DEA is considering to split the two categories, e-waste and lighting, and to be dealt with separate waste management plans. In November 2011 the National Waste Management Strategy (NWMS) was established to achieve the objects of the Act.

The **National Development Plan (NDP)** for South Africa provides a "2030 vision" to guide the country‟s development trajectory such that poverty is eliminated and inequalities are reduced by 2030. Furthermore, the NDP states that climate change is already having an impact on South Africa and recognises the need to ensure that society and the natural environment are protected from the adverse effects of climate change. South Africa aims to put in place a mitigation system, to realise the opportunities of a low-carbon economy while being mindful that a just transition requires time and careful development.

The mitigation component of South Africa's **Intended Nationally Determined Contributions (INDC)** envisages five-year periods of implementation at the national level for policy instruments under development, including a carbon tax, desired emission reduction outcomes for sectors, and company-level carbon budgets. The aspiration in the long-term is that total annual GHG emissions will be in the range of 212 to 428 million tons of CO_2 by 2050, having declined in absolute terms from 2036 onwards.

1.2 Situation analysis and barriers to high-efficiency lighting and transformers

Currently, the world consumes consume 2,900 terawatt-hours (TWh) of electricity per year for lighting. Over the next two decades, lighting services are projected to rise by approximately 50% relative to current levels of demand. UN Environment has estimated that electricity demand for lighting can be reduced by 2030 to 2,160 TWh per year, saving up to 640 TWh of electricity and thus avoiding the emission of greenhouse gases of 390 million tons of CO_2 annually. These large savings can be achieved through a global widespread shift from conventional lighting technologies like incandescent, halogen and fluorescent lamps to lighting products based on light-emitting diodes (LEDs). There are multiple advantages of energy-efficient lighting for governments Energy-efficient lighting is usually the lowest life-cycle cost option. It reduces peak loading, lowers customer bills and reduces mercury (present in fluorescent lighting).

Transformers are static devices in electricity systems that transfer electrical power between circuits through electromagnetic induction. Their application enables significant energy savings in the power transmission and distribution system by increasing the voltage and decreasing the current, since losses are proportional to the amount of current flowing through the wire. In 2017, all electric power transformers in service globally are estimated to have 1,100 TWh of losses. Although most transformers have efficiency levels greater than 98%, the energy consumed during a transformer's service life (from 15 up to 40 years), operating almost non-stop, is the dominant factor contributing to the environmental impacts over its life cycle. Technical solutions to improve the energy efficiency of transformers are commercially available, and the market penetration of highly-efficient transformers has significant room for growth.

The **development challenge,** then, is to achieve this energy efficiency potential and curtail consumption of (coal-fired) electricity and associated global environmental impact from appliances and equipment. A **long-term solution** promoted in the Project is the more widespread use of high-efficiency lighting and distribution transformers) in South Africa.

LED lamps and luminaires are rapidly expanding into general illumination applications all over the world. As LED technology improves in performance and becomes less expensive, this market expansion will accelerate, replacing traditional light sources with more efficient and better performing LED technology. LEDs are highly energy efficient when measuring light output for watts of electricity input. In the market today, the most efficacious LED lamps operate at around 130 lumens per watt. This is much better than the energy performance of a CFL and over 10 times more efficient than an incandescent lamp.. As the technology continues to evolve in the coming years, efficacy will improve and costs decline. For countries choosing to phase-out incandescent lamps and jump straight to LED, the electricity savings for consumers will be more than 85 per cent, without compromising light quality and while enjoying much longer service life. LED lighting is becoming the standard EE technology when improving lighting energy performance and addressing environmental concerns. However, most of the existing stock and even new sales of lighting equipment in South Africa does not reflect the latest LED technology, which can be used to replace conventional compact and linear fluorescent lamps, halogen lamps and high-intensity discharge lamps.

Older distribution transformers can be replaced by newer high-efficiency models that have lower (load and no-load) energy losses. A transformer can be made more energy-efficient by improving the materials of construction (e.g. better-quality core steel or winding material) and by modifying the geometric configuration of the core and winding assemblies. The most common transformer is liquid-filled with windings that are insulated and cooled with a liquid. These transformers are most often used by electric utilities and can be found in all stages of the electricity network, from generation step up through transmission and distribution. They are usually filled with mineral oil. There is large scope or replacing this with vegetable oil.

The transition to an economy with increased use of high-efficiency appliances and equipment is faced by substantial challenges and barriers. The **core problem** is that the *persistence of barriers and challenges that limit the market penetration of high-efficiency lighting and distribution transformers.* Addressing the core problem requires attention to the underlying root causes (posed by various challenges and barriers). These barriers and challenges are described in detail in Box 2, while a graphical overview is presented Box 3

One main challenge (cause) is formed by *limited planning and lack of mandatory standards and/or labelling system* (existing for a number of household appliances, but not for lighting products or distribution transformers). A second main challenge is the *weakness of market signals to consumers about the value of energy efficiency*, which arises from a *lack of awareness and information for residential users on energy-relevant characteristics* (e.g., initial and lifetime benefits and costs of lamps, performance and quality of lamps). This is linked with the above-mentioned barrier of the absence of effective labelling (energy, information and/or endorsement) for consumers.

A major barrier is formed by *insufficient human resources* (with adequate technical EE and financial skills) *and insufficient access to financial resources. Current government (national, municipal) financing alone cannot achieve a full transition towards higher efficiency LED lighting and distribution transformers.* On the other hand, it is difficult to get (conventional) debt financing for a multitude of small EE investments, due to *high transaction cost,* and *high-risk perception* of small EE investments. New modalities, such as involving energy service companies (ESCOs) are still in their infancy.

Regarding, environmentally sound management, the issue of PCB-contaminated oil in transformers is being addressed. On the other hand, the *recycling and waste separation* if used lamps can be much improved, while the *potential use of vegetable oil as a replacement for mineral oils* has not been seriously investigated yet.

Box 2 Overview of barriers and challenges

Planning and regulations
• *Lack of coherent and comprehensive data on energy performance and characteristics of lighting products (lamps) and distribution transformers* Lamp suppliers, customs, Department of Energy, municipalities all have some data on lighting products, but this is neither aggregated to a national level nor is there a consistent breakdown per type, size, capacity, energy, application, and sub-sectoral use. For example, a recent DoE study focusses on the residential sector[3], but does not cover commercial and public buildings and the industrial sector). Data exist at a local level, but for individual larger municipalities only[4]. ESKOM will have data on distribution transformers, but these are not compiled in a readily available way. There is no consistent set of information on (the energy performance) of distribution transformers in municipalities. This paucity of information hampers design of policies and complicates the evaluation of results. • *Limited planning and regulatory instruments (S&L, and (mandatory) standards and/or labelling system in particular* There are no local compulsory local standards for LED lamps. A few products are certified against voluntary standards SANS 62560 and IEC 62560 applied by suppliers and specifiers. In the absence of a compulsory standard, LED lamps performance claims, lifespan and power-consumption, by opportunistic suppliers cannot be validated by buyers. Some products appear with the European ("CE") mark as manufacturer's claim to a certain quality standard. LED lamps are not regulated by the NRCS to carry out surveillance and compliance monitoring. Consequently, many low-quality LED lamps have entered the market. There is a black market of incandescent lamps; market research found that incandescent lamps for sale at only 8-10 Rand each. Transformers have to meet the SANS 78O regulations, of which, however, the load and no-load loss specifications have not changed since the late 1960s. Transformers are prescribed by SANS 780 in its contracts with local transformer manufacturers, but municipalities may apply different standards. There may be resistance from municipal distributors and transformer suppliers, regarding MEPS as these may be clashing with their own product specifications and fear MEPS/labels will be introduced without their involvement in the process.
Challenges for residential and commercial end-users
• *Lack of awareness of and information for residential and other users on initial and lifetime benefits and costs of lamps and of performance and quality of lamps* The Eskom CFL roll-out programme started in 2005 with 64 million CFL lamps. Eskom directly procured these lamps, which were distributed for free and have mostly been delivered to the house and physically installed. Through the Eskom DSM lighting initiative CFL's have become the standard lamps used currently in South Africa; the word CFL has become synonymous to 'energy saving lamp'. LED lighting is still not commonplace in South Africa. The Eskom program focused on providing CFL lamps instead of LED due to the incipient technological development of LED lighting at that time. Low-income households were the main target group of the previous lighting replacement program from Eskom. It has helped the transition away from incandescent and halogen lamps. However, it has conditioned the (lower-income) residential users to the reception of "free" lamps and has decreased the economic benefit of transitioning to "expensive" LED lamps, even when LED prices are now approaching CFL prices. These households will replace their CFL lamp with LED lighting in the case of equipment failure, and not as retrofit of existing equipment. A large part of the lighting installed in high/middle households consists of halogen spotlights. These households tend to buy higher-quality lamps sold in the main retail chains and in this range, LEDs are still relatively expensive. Some households are reverting back to halogens given their closeness to incandescent lamps because of people like their light quality (brightness) and because the lifecycle (and monetary and energy savings) are not fully understood by all. In fact, halogens are well suited for replacement by LED lamps, and achieve attractive payback periods).

3 *Identify, Assess, and Design a Market-Based Economic Incentive(s) for Energy-Efficient Appliances in South Africa; Final Report* (Danish Embassy, Department of Energy)

4 See for example, *State of Energy in South African Cities 2015* (SACN)

In addition, due to the lack of regulation, cheaper LEDs are entering the market that gives the product a bad name. Given the broadening technical considerations applicable to LED lamps (different types of light bulbs, brands, technical standards, and price levels), consumers are often confused and conservative in their purchase decisions. Almost all LEDs on the market have a power factor of 0.5 and although this has no implications for end-users, it does have a significant impact on Eskom, especially now when there are supply shortages.
Challenges for municipalities and barriers to alternative financing modalities with ESCO involvement
• *Current government (national, municipal) financing alone cannot achieve a full transition towards higher efficiency LED lighting and distribution transformers* Government grant programmes that benefit municipalities include the MEEDSM and Integrated National Electrification Program (administered by the Department of Energy), the Municipal Infrastructure Grant (administered by the Department of Cooperative Governance) and the Urban Settlements Development grant (administered by the National Treasury). These programs, in their current form, have been important, but not sufficient to realise a full transition towards higher efficiency LED lighting and distribution transformers. Their funding is often used to reduce the backlog of issues in the infrastructure. Low-resource municipalities are accustomed to sourcing a substantial part of their revenue from grants, and they will not realise energy efficiency projects without such grant funding or a clear financial benefit. The Municipal Financial Management Act (MFMA) legislation gives substantial freedom to the municipalities on the management of their finances (for example, it does not set pre-defined limits to the amount of long-term debt that the municipalities may borrow). Their funding takes place as part of an integrated budget planning. Energy efficiency proposals will compete for funding from other capital expenditures presented by the various departments that may be more popular with the electorate. The decision of which project should be included in the budget is, therefore, a delicate balancing exercise between the various service provision mandates of the municipalities. In addition, municipalities carry out their procurements within the requirements set by National Treasury, i.e. official national-level procurement guidelines aim at 'lowest cost' rather than lifecycle or environmental considerations Metropolitan municipalities have investment-grade ratings, facilitating their borrowing processes and achieving similar borrowing costs as those of the central government. However, debt financing for capital expenditure is typically part of the annual budget planning, and not for a specific project. The MFMA requires the municipalities to engage in a broad consultative process to engage in financial obligations that span for more than three years; this hinders realization of specific energy efficiency projects through a shared-savings ESCO model. Also, the MFMA does not have any provision for the allocation of financial liabilities to ESCOs. Current trends in international financial accounting (e.g. IFRS 16) limit the situations in which organizations may record this type of projects off-balance sheet. This approach substantially limits the benefits of this model, as the projects would have to be approved through the capital expenditure process of the municipality and an associated long-term liability towards the ESCO would have to be recorded in its balance sheet. In other markets, these complexities have resulted in the issuance of a guidance note by the corresponding accounting authority (e.g. Eurostat in the European Union). The South African municipalities consulted have not received any guidance on the financial accounting of these projects. The result is that the benefit of this ESCO model for the larger and more technically capable municipalities is unclear at this point. In the case of less technically capable municipalities, the utilization of a shared-savings ESCO model may still be beneficial, as it transfers the complexities of project engineering, procurement and construction to a specialized organization. More importantly, this model allows the utilization of private financing sources to fill the gap of public funding and achieve the transition towards higher efficiency LED lighting and efficient transformers. As a result, it has the full support of the Department of Energy. A portion of the EEFI funding will be made available to support this model through a credit guarantee mechanism for loans to qualifying ESCOs. • *Under-resourced municipalities do not have the resources (skilled staff, or financial) to prepare municipal EE strategies or sound and bankable EE investment plans* Apart from having low financial resources, smaller (often, rural) municipalities have limited internal staff capacity to formulate energy projects (e.g., the economic benefits of LED lighting and high-efficiency transformers may not be well understood) and to formulate procurement requirements for lighting and other technical equipment. They often rely heavily on external

(consultancy) support and this has resulted, for example, in street lighting projects developed under the MEEDSM program with wildly varying costs and outcomes for rather similar equipment. The metropolitan municipalities do have teams of competent technical staff that are able to perform the basic engineering design of such projects and prepare tenders for the supply and installation of equipment. However, the proposals often tend to be very technical and do not reach the financial analysis that would make them a "bankable project" for (development) finance institutions.
Local production of high-efficiency lighting and transformers
• *Setting up production for new innovative products with local content (e.g. local LED lamp manufacturers or high-efficiency transformation) may be judged too high a risk* Companies interested in setting up production for new innovative products with local content (e.g. local LED product integrated lamp and luminaire for various applications) manufacturers or high-efficiency transformation face uncertainty on the market uptake. Lack of capital and short time thresholds for payback in updating production facilities - will continue to hamper investment by suppliers/manufacturers in LED lamps and in high-efficiency transformers. There is a need for staff skills enhancement and technical assistance support to local manufacturing industry and introduce new locally manufactured lamp-luminaire integrated LED products in the local market.
Environmentally sound management
• *Insufficient recycling and waste separation of used lamps* Most lamps electronic materials and HID and fluorescent lamps contain hazardous materials (mercury). Recovered quantities and types of material is highly dependent on the market demand, price and industry organised collection, buy-back, and storage systems. Households may bring to recycle points at retail chains or waste and recycling service providers. However, informal sector salvaging, both at the street level, and at the landfill, constitutes the bulk of recycling activities in South Africa. Lamps end up with other waste on municipal waste disposal and landfill facilities. Many households in low-income or rural areas these often not 'within walking distance of points of sale or retailers that can serve as a central location for collection. As a consequence, waste separation and formal recycling remain a concept foreign to many South African households. • *Vegetable oils and transformers* Most distribution transformers used in South Africa (about 80%) are of the liquid-immersed type that uses mineral oil for insulation. Vegetable-oil natural esters can be used in distribution transformers as insulating oil instead of mineral oils. Apart from its greenhouse reduction impact as a replacement for mineral oils, vegetable oils have the advantage that the transformer can be loaded at a higher rating and/or have an extended life. In addition, vegetable oils have better fire safety and reduced spread in spillage conditions. However, the use of vegetable oil has been proposed by Eskom, but not implemented.

Options to tackle the above barriers consist of an integrated approach that consists of the following main elements:

- *Regulatory-legal instruments*
  Minimum energy performance standards (MEPS) cover a collection of requirements defining which products can be sold and those that should be blocked from the market. *Energy labelling* provides information on the energy (efficiency) rating. MEPS and labels help to transform the market in concert; MEPS define a new floor, pushing the entire market of products towards higher energy efficiency, while labels define a new performance target, pulling the market towards increased innovation. The mandatory implementation of standards and labelling (S&L) depends on effective *MVE,* monitoring (i.e. check product efficiency), verification (i.e. check declarations of performance), and enforcement (i.e. actions taken against non-compliant suppliers), including testing on the energy performance.
- *Financial and support programmes*
  These are necessary to ensure a smoother implementation of standards and regulations, and to achieve a broad acceptance amongst users and suppliers. Supporting programmes include skills enhancement programmes, information and awareness campaigns that inform users, suppliers and intermediaries (finance, training, consulting) to change or modify their behaviour. Financial (and fiscal incentives) may help to address first-cost challenges in manufacturing and purchase of energy-efficient products. Financing may help address the initial cost by offering dedicated (government)

funding and debt finance, accompanied with innovative modalities (e.g. shared-savings transactions through energy service companies, ESCOs).

- *Environmentally sound management of lamps and transformers*
  Transformers already enjoy a high level of recycling due to the scrap metal value, but care should be taken to clean these if these contain polychlorinated biphenyls (PCBs) that are a hazardous substance. Fluorescent lamps contain small amounts of mercury (another hazardous substance). In general, the handling, collection of electric and electronic waste (e-waste) should be in accordance with global best practices (in particular when containing such hazardous substances).

The United Nations Development Programme (UNDP) and Development Bank of Southern Africa (DBSA) are currently implementing a programme[5] (with funding support from the Global Environment Facility, GEF) to address the barriers regarding lack of strategy, as well as the problem of insufficient knowledge, market information and awareness amongst decision-makers in decision-makers in national and local government and private sector and exposure to best practice, the Project will support:

- Capacity needs assessment of local manufacturers and suppliers and the needs assessment of institutions involved in the MVE system, including the capacity for photometric testing;
- Establishment of working groups of policy-makers, private sector representatives, and other stakeholders;
- Formulation of action plans developed with goals, strategy, work plan and key tasks of institutions involved;
- Deliver information on international best practice (in conjunction with the United for Efficiency programmem, U4E[6]) and lessons learned (including from analogous GEF-supported projects on lighting and transformers)
- Deliver technical assistance for the formulation of appropriate MEPS for lighting products and transformers and definition of energy performance categories for lamps, based on the existing EE label format;
- Support the strengthening of the existing MVE system linked with appliance standards and labelling to incorporate lighting technology and distribution transformers, including guidance to certification laboratories and organise their accreditation, and provide technical (and as needed, financial) support to properly equip test laboratories;
- Carry out a market assessment on demand and supply of lighting products in the various sectors and on distribution transformers, including consumer awareness and preferences and on current practices in municipalities (public buildings, public lighting, distribution system);
- Assess current practices and provide recommendations regarding collection, disposal, and recycling of distribution transformers and lighting products
- Conduct public-relations outreach to residential and professional-commercial consumers about the energy performance of lighting and information campaign to municipal authorities.
- Build on and cooperate with ongoing initiatives undertaken by the Government
- Support lighting product (lamps, luminaires) suppliers and transformer manufacturers in preparing bankable proposals for the financing of upgrading or setting up production lines, as well as support local authorities and commercial building owners in formulating bankable proposals to the above-mentioned DoE and Eskom grant funds as well as for financing by development and other banks;
- Set up an Energy Efficiency Financial Instrument (EEFI) with DBSA to provide partial grant financing and support new modalities for municipalities and energy service providers (credit guarantees for loans to ESCOs) and investment in EE production.

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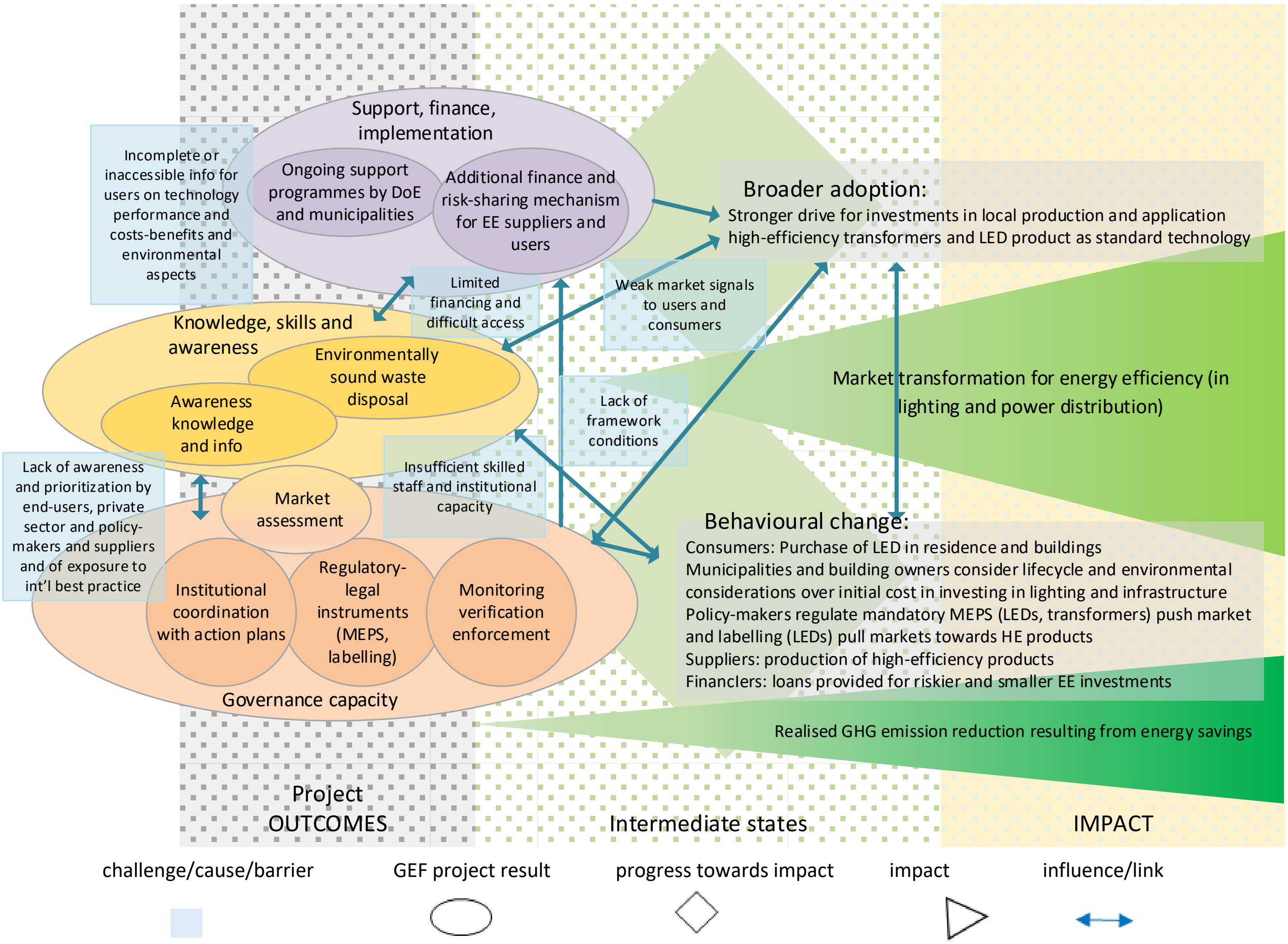
[5] *Leapfrogging South Africa's markets to high-efficiency LED lighting and high efficiency distribution transformers*. See https://www.undp.org/south-africa/projects/leapfrogging-south-africas-markets-high-efficiency-led-lighting-and-high-efficiency-distribution-transformers

[6] **United for Energy (U4E)**, funded by the GEF, with the full title *Leapfrogging Markets to High Efficiency Products (Appliances, Including Lighting, and Electrical Equipment)*. See www.united4efficiency.org

Box 3 Theory of change: addressing barriers to high-efficiency products in an integrated way



2. MARKETS, STAKEHOLDERS, POLICY AND REGULATIONS FOR LEDS AND DISTRIBUTION TRANSFORMERS

2.1 Power sector and energy efficiency institutional-regulatory framework

Electricity supply, demand, and challenges

Current electricity production in South Africa relies heavily on coal inputs with about 94% of South Africa's electricity generation comes from coal and, therefore, has a very high greenhouse gas (GHG) emission factor. Around 77% of South Africa's energy needs are directly derived from coal and 92% of coal consumed on the African continent is mined in South Africa. South Africa has 18 coal-fired power stations with an installed capacity of 40,836 MW, conventional hydroelectric power stations and hydro pumped storage schemes at 3,571 MW and gas turbine power stations with an installed capacity of 3,326 MW. Renewable energy contributes to wind energy, small hydro, solar photovoltaics and concentrated solar power with about 3,309 MW and nuclear energy 1,850 MW. Total installed capacity was 53,025 MW in 2017, to which 1,500 MW of imported hydro can be added[7].

Peak demand in 2011-12 was 37,065 MW (power produced was 49,889 MW). The energy generated in 2012 was 298,752 GWh[8]. Most of this electricity was consumed domestically, but around 13,038 GWh was exported to Swaziland, Botswana, Mozambique, Lesotho, Namibia, Zambia, Zimbabwe and other Southern African Development Community countries participating in the Southern African Power Pool. South Africa supplements its electricity supply by importing around 9,000 GWh per year from the Cahora Bassa hydroelectric generation station in Mozambique via the 1,920 MW Cahora Bassa high-voltage direct current transmission system of which 1500 MW is sold to South Africa. Electricity distributed in South Africa amounted to 229,342 gigawatt-hours (GWh) electricity in 2016[9].

In January 2008, SA experienced widespread rolling electricity blackouts due to rapid growth in demand and insufficient investment in generation capacity. To remedy to the inadequacy of supply, load shedding was carried out and lasted until early May 2009. In 2013 South Africa again approached a period of limited capacity during a winter period of higher demands. Power problems escalated in late 2014 when the coal storage silo collapsed at one of the largest coal power plants. Since then,

However, after experiencing chronic power shortages for several years, no major blackout has been experienced in South Africa. Since 2016, South Africa has had a power capacity surplus as a result of and of weaker electricity demand and of new capacity commissioned by both

Box 4 South Africa, power generation capacity

	Generation capacity (MW, 2017)			
	ESKOM	IPP	Municipal	Total
Coal	40,142	214	480	40,836
Gas	2,426	1,023		3,449
Hydro (large)	3,391		180	3,571
Hydro (small)	2	17		19
Nuclear	1,860			1,860
Wind	113	1,499		1,612
Concentrated solar (CSP)		300		300
Solar PV		1,367		1,367
Biomass/landfill gas		11		11
Total	**47,934**	**4,431**	**660**	**53,025**

Compiled from: ESKOM, *Factsheet Generation Plant Mix* (2017); Wikipedia, *List of power stations in South Africa* (2017/18); Energy Information Agency, US Department of Energy (2018)

7 See Box 18. The imported hydro comes from the Mozambique Cahora Bassa dam;

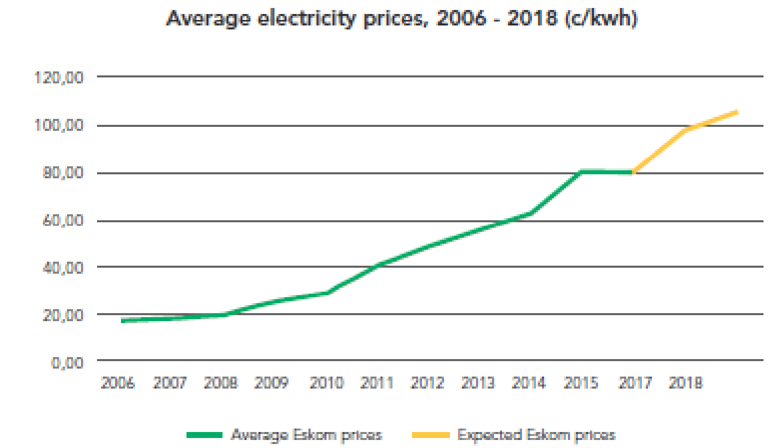
8 NERSA, *Energy Supply Statistics for South Africa 2012*

9 STATS SA, *Electricity generated and available for distribution (Preliminary)*, June 2018

public and private sectors, mainly from independent power producers (or IPPs) which added about 4.5 GW[10]. However, in 2019 the issue of power shortage returned with load shedding of about 4 GW[11].

However, the power supply remains in a critical situation. Most of Eskom's coal-based power stations are approaching the end of their lifespan, and are poorly maintained, resulting in substantial operational inefficiencies [12]. Inadequate investment during periods of increased economic growth, rising electricity demand, and mismanagement of the sector have been attributed to the power failures.

Box 5 Historic and future Eskom price trajectories



Source: GreenCape, *Market Intelligence Report* (2016)

The cost of energy from Eskom's new generation capacity will be significantly higher than its historically low energy costs. As a result of 's new build programme and the cost of essential plant maintenance, the price of electricity in South Africa has risen significantly over the past decade. This trend, coupled with market pressures for cleaner, renewable, energy sources, has been a significant driver of the growing interest in the rational use of energy. Tariffs have increased significantly. The average power tariffs were R 0.596/kWh in 2011/12 and R 0.847/kWh in 2016/17 with residential customers paying R 0.778/kWh in 2011/12 (R 1.186/kWh in 2016/17), the industrial customers R 0.401/kWh (R 0.769 in 2016/17), commercial customers R 0.639/kWh (R 1.90/kWh in 2016/17), and local authorities R. 0.483/kWh (R 0.814/kWh in 2016/17)[13]. While tariffs have increased, South Africa's electricity generation have declined overall from 2007 to 2016 by more than 4%[14]. As revenue have remained stagnant, Eskom has embarked on a large power station expansion programme for which it has had to borrow significant amounts. In 2018 the utility started teetering on the brink of financial disaster, placing the country's entire economy at risk[15].

Electricity market structure: production, transmission, distribution; regulation

Although Eskom does not have exclusive generation rights in South Africa, it does have the practical monopoly on the bulk of electricity in the country, and it maintains the national grid (operating the integrated national high-voltage transmission system). In 2002, Eskom was converted into a public company, although it is de facto a parastatal under the Department of Public Enterprises. In 2003, the Cabinet made a decision to increase private-sector participation in the electricity industry by dividing power generation between Eskom and IPPs. Currently, Eskom still has the majority of the generation rights and generates approximately 90% of the electricity. Of the capacity of 53,025 MW in 2017, about 660 MW was generated by municipalities and 4,431 MW by IPPs[16].

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10 Eskom plans to bring online over 12,000 MW of new electricity installed capacity (US Energy Information Administration, 2015), of which 8770 MW coal-fired, 2097 wind power, 400 concentrated solar, 1094 solar PV plants, 33 MW landfill gas/biomass (Wikipedia, List of power stations in South Africa (2017/18).

11 Source: UNDP/GEWF S&L Project

12 *Energy Efficiency Eskom plans to bring online almost 12,000 MW of new electricity installed capacity Country Study: Republic of South Africa,* LBNL Report 6365E, Du la Rue Can, S., Letschert, V., Leventis, G., Covary, Th., Xia (2013)

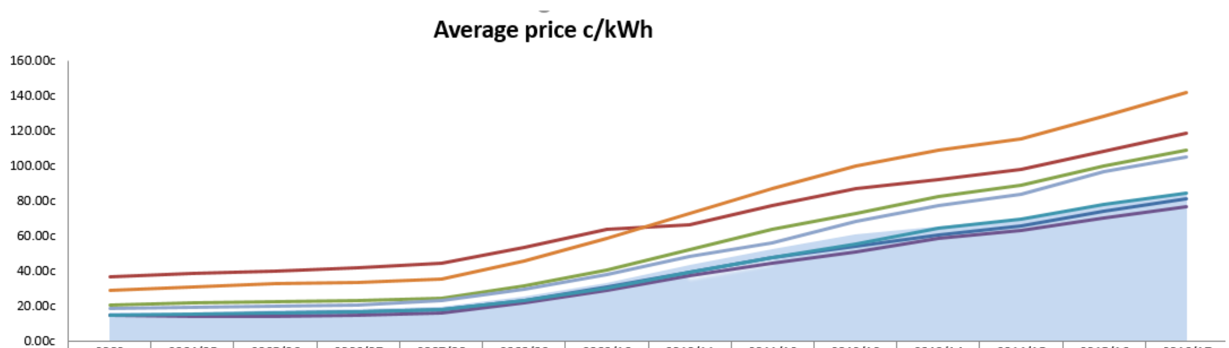
13 ESKOM website, *Historical Average Prices and Increase.* See Box 19).

14 Due to economic stagnation and downward pressures on commodity markets, rising electricity costs and energy efficiency and conservation efforts.

15 ESKOM ZAR 413 billion, of which ZAR 218.2 billion of the company's debt consist of government guarantees. http://www.creamermedia.co.za/article/electricity-2018-a-review-of-south-africas-electricity-sector-pdf-report-2018-03-14

16 Wikipedia, *List of power stations in South Africa (2017/18).* In response to chronic power shortages and the need to ensure a more diverse fuel supply, South Africa began a procurement program in 2011 to purchase power from renewable sources and lower-emitting energy

Box 6 Historic Eskom tariffs



	2003	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Average standard tariff price (Excld NPA and Int'l)	16.68c	16.82c	17.69c	18.38c	19.89c	25.65c	33.39c	43.94c	52.50c	61.25c	65.48c	70.10c	78.30c	84.70c
Local-authorities	15.25c	15.19c	16.13c	16.88c	18.21c	23.29c	30.84c	39.53c	48.03c	54.59c	60.67c	65.92c	74.11c	81.38c
Residential	36.58c	38.70c	40.08c	41.74c	44.56c	53.43c	63.98c	66.45c	77.50c	87.05c	92.41c	98.06c	108.11c	118.60c
Commercial	20.62c	21.88c	22.69c	23.50c	24.85c	31.61c	40.97c	52.63c	63.92c	73.24c	82.67c	89.16c	100.07c	109.09c
Industrial (Excl NPA)	14.73c	14.42c	14.65c	14.76c	16.30c	21.94c	29.24c	37.64c	44.44c	51.09c	58.72c	63.26c	70.52c	76.87c
Mining	15.07c	15.36c	16.19c	16.90c	17.99c	23.12c	30.25c	39.78c	48.10c	55.74c	64.66c	69.52c	78.01c	84.80c
Agriculture	29.14c	30.83c	32.86c	33.69c	35.91c	45.78c	58.96c	72.72c	87.22c	99.75c	108.75c	115.66c	128.19c	141.70c
Traction	18.98c	19.37c	20.25c	21.05c	23.31c	29.78c	38.23c	48.55c	56.24c	68.66c	77.34c	83.63c	96.60c	104.95c

Source: Eskom website (2017)

Distribution activities were unbundled from Eskom in 2003 and the creation of Regional Electricity Distributors (REDs) was begun under the newly-formed Electricity Distribution Industry Holding Company (EDIH). In 2010, after a number of issues relating to backlogs and poor performance, Cabinet decided to terminate the electricity distribution industry restructuring and to discontinue the process of creating 'regional energy distributors' with immediate effect.

Power distribution is now in the hands of Eskom (212,107 GWh in 2012), serving 4.848 million customers, private distributors (13,581 GWh), serving 2.047 customers and 178 NERSA-licensed municipal distributors, serving 26.638 million customers (96, 537 GWh)[17]. Eskom still supplies directly to large consumers (mines and large industries), commercial farmers and, through the Integrated National Electrification Programme (INEP), to a large number of residential consumers. Municipalities buy electricity from Eskom at a tariff set by the National Energy Regulator of South Africa (NERSA) and aim to offer electricity at a competitive price, with efficient service.

<u>Institutional framework for energy efficiency</u>

National government:

- *National Treasury* provides funding to all ministries, based on applications made by them.
- The *Department of Energy (DoE)* is the custodian of all energy policies and energy security in South Africa. The Department of Energy is the primary government institution responsible for energy regulation.
- The *Department of Environmental Affairs (DEA)* is responsible for protecting, conserving and improving the South African environment and natural resources. Within DEA there is one branch specifically assigned to deal with air quality and climate change.
- The *Department of Public Enterprises (DPE)* is responsible for the country's energy infrastructure, primarily through its responsibility for state-owned entities such as Eskom. The state utility *Eskom* currently owns most of the electricity production and transmission and a large part of the distribution infrastructure. It is an essential player in the electricity sector – especially as a delivery vehicle for numerous government programmes, including energy efficiency and demand-

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plants funded by IPPs. South Africa's capacity target from IPP procurement is 29 GW by 2025.

17 NERSA, *Energy Supply Statistics for South Africa 2012*

side management programmes. Eskom has set up an *Integral Demand Management (IDM) division*, formerly known as Demand-side Management (DSM) division, to make deliberate interventions in the marketplace so as to change the configuration or magnitude of the load shape in the residential, commercial, industrial and agricultural sectors.

- The *South African National Energy Development Institute (SANEDI)*, under DoE, is responsible for achieving the objectives of the National Energy Efficiency Strategy (NEES). SANEDI is the result of the merger of the two public research agencies South African National Energy Research Institute (SANERI) and National Energy Efficiency Agency (NEEA) in 2011.
- The *National Energy Regulator of South Africa (NERSA) was* established in terms of the National Energy Regulator Act of 2004, and is mandated to regulate South Africa's electricity, piped gas and petroleum industries and to collect levies from people holding title to gas and petroleum. National Energy Regulator of South Africa is of particular importance as it sets and approves the annual Eskom tariff, and issues licenses for power producers and distributors
- The *Department of Trade and Industry (DTI)* is one of the biggest government ministries, and acts as a catalyst for the transformation and the development of the economy, in support of the government's economic goals of growth, employment, and equity. DTI's mandate is to respond\ to challenges and opportunities in the economy and society as a whole and provides a predictable, competitive, equitable and socially responsible environment for investment, enterprise and trade. The following organisations fall under DTI:
    - The *South African Bureau of Standards (SABS)* is the national standardization organization, and its core function is developing national standards and maximising the benefits of international standards. Public testing facilities fall under the SABS. National measurement laboratories are housed at the *National Metrology Institute of South Africa (NMISA).*
    - The *National Regulator for Compulsory Specifications* (NCRS) was established in 2008 and its role is to ensure that all compulsory specifications, as mandated by law, are adhered to. For this purpose, it also administrates applicable legislation in an independent, effective and efficient way. The MVE (monitoring, verification, enforcement) component of any energy efficiency standards and labelling programme will fall under the NRCS mandate;
    - The *South African National Accreditation Agency (SANAS)* is recognized by the Government as the single National Accreditation Body giving formal recognition that laboratories, certification bodies, inspection bodies, and 'good laboratory practice' test facilities are competent to carry out specific tasks. SANAS is responsible for the accreditation of certification bodies under ISO 17021 and 17024; laboratories under ISO 17025; and inspection bodies under ISO 17020 standards.

Local government and organisations:

- South Africa is divided administratively into 9 *provinces*. *Local (municipal) governments* form the third tier of government (after national and provincial government), and is the arm of government closest to many electricity end-users Municipalities are responsible for a large portion of electricity distribution in the country. Local government is implemented through 8 metropolitan municipalities (comprising the largest urbanised and industrialised centres). Outside the metropolitan areas, the local government mandate is pursued by two-tier local government: 228 local municipalities that are grouped into 44 district municipalities.
- The *South African Cities Network (SACN)* is an established network of South African cities and partners that encourages the exchange of information, experience and best practices on urban development and city management. One working area of SACN is 'sustainable cities', with the focus areas of 'sustainable energy', 'waste management', 'water management' and 'climate change'. SACN has issued a number of publications regarding energy use in cities[18].
- The *Association of Municipal Electrical Utilities (AMEU)* is an association of municipal electricity distributors as well as national, parastatal, commercial, academic and other organisations that have a direct interest in the electricity supply industry in Southern Africa[19];

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[18] State of Energy in South African Cities (2015), Energy performance contracting by municipalities (2016), A case for renewable energy & energy efficiency (2014), Modelling Energy Efficiency Potential in SACN Cities (2014). Sustainable Energy Africa (SEA) has developed a handbook for South African city officials and planners titled *How to implement renewable energy and energy efficiency options: Support for South African local government*. The document was produced in partnership with North Energy Associations Ltd and funded by the Renewable Energy & Energy Efficiency Partnership (REEEP).

[19] The reader may note that the AMEU has set up a Women in Electricity Interest Group

- Municipalities have organised themselves in the *South African Local Government Association (SALGA).* SALGA has set up 'knowledge hubs' to service its members, of which one focuses on 'energy efficiency and renewable energy'.

Development and commercial banks

- The *Development Bank of South Africa (DBSA)* is a state-owned financing institution, whose main purpose is to promote economic development and growth, improve the quality of lives of people and promote regional integration in the (southern) African region through infrastructure finance and development. The DBSA provides planning, financing and implementation support to municipalities in sectors that include water and sanitation, electricity, roads, and telecommunication networks. DBSA's approach to the municipal sector is to strengthen the capacity of under-resourced municipalities in areas such as project planning, preparation, and packaging, to increase focus on areas with the biggest unfunded gap through project origination initiatives and to providing affordable funding through development subsidies to secondary municipalities and under-resourced municipalities. For this purpose, it has grouped country's municipalities in secondary (market, M2) and under-resourced (M3) municipalities, in which 'market 2' consists of about 27 large and 19 secondary cities (that generally have a moderate to strong economic base and ability to raise capital), 44 districts (that in general tend to attract little interest from commercial; banks and require support in project identification and preparation planning), and 'market 3' is formed by 190 small towns and rural municipalities (with usually a weak economic base, little ability to raise capital and requiring extensive support in all aspects of infrastructure project delivery, planning and implementation).
- The *Industrial Development Corporation* is the state-owned national development finance institution set up to promote economic growth and industrial development. The IDC's funding is generated through income from loan and equity investments and exits from mature investments, as well as borrowings from commercial banks, development finance institutions (DFIs) and other lenders. The IDC funds start-up and existing businesses with a minimum funding requirement of R1 million and a maximum of R1 billion, by means of debt, equity, guarantees, bridging finance and venture capital. Energy is one of IDC's industrial infrastructure strategic priorities. IDC has provided support to the country's Renewable Energy Independent Power Producer Programme (REIPPPP).

NGOs and private sector organisations:

- The *e-Waste Association of South Africa (eWASA)* is working with stakeholders and interested parties to establish a sustainable environmentally sound e-waste management system. Electronic and electrical waste (e-waste) includes ICT equipment, consumer electronics, small household appliances and large household appliances, including lamps and lighting devices. Some e-waste can be considered hazardous waste. For example, mercury is one of the most toxic, yet widely used metals in the production of electrical and electronic applications (mercury vapour and fluorescent lamps).
- The *National Business Initiative (NBI)*, is a voluntary coalition of South African and multinational companies, working towards sustainable growth and development in South Africa, including environmental sustainability. Its, now discontinued, Private Sector Energy Efficiency (PSEE) programme identified and facilitated the implementation of the energy saving opportunities.

International cooperation (relevant to the topics of LEDs and power distribution):

- The Swiss *Secretariat for Economic Affairs (SECO)* supports 'climate-friendly and green growth through the development of a low-carbon in South Africa with as sub-priorities a 'resource-rich private sector' and 'sustainable energy', including the promotion of sustainable and clean technologies, especially in energy, but also water and waste; energy efficiency and cleaner production.
- The German government development agency *GIZ* has launched the South African-German Energy Programme (SAGEN), in cooperation with DoE and SANEDI, focussing on renewable energy and energy efficiency. The budget for Phase 1 (2011-14) was EUR 12 million and now Phase 2 will be implemented until 2010. Regarding energy efficiency, activities have been a) institutional capacity development and support to national EE incentive programmes, such as DoE's Municipal DSM (MEESM, see further in the text), support to selected demonstration projects, such as the street lighting retrofit project (see further) and strengthening of investments in energy efficiency, for instance through the development of a market for ESCOs (energy service companies). With DEA, GIZ has been supporting the Climate Support Programme (CSP) during 2013-17. For example, the mitigation potential has been determined for different sectors of

the economy, such as energy, industry, and transport, and mitigation targets have been set and approved by the Cabinet. Supported by GIZ and the NAMA Support Facility, the V-NAMA "Energy Efficiency in Public Building and Infrastructure Programme (EEBIP)" was formulated during 2012-2015 and will be implemented during 2019-2023 with an EUR 20 million budget (discussed further in Section E.3).

- With the aim of strengthening the development of renewable and energy efficiency markets, the French *Development Agency (ADF)* has provided a EUR 120 million green credit facility (concessional loan) to the Industrial Development Corporation (IDC) and the two banks (Absa and Nedbank) for the financing of RE and EE projects. Besides, AFD is setting up a technical assistance facility with SANEDI to support the participating banks in the use of the credit facility by organizing dissemination workshops or by providing them with expertise for the savings verification for example.
- The Danish-South Africa Energy Partnership Program is being phased out. There are still a number of ongoing DANIDA projects waiting to be finalized according to the project plans, where Denmark provides support to strategic areas. The programme has provided technical assistance to DOE in renewable energy (e.g. wind energy) and, in energy efficiency, has supported the development of the Efficiency Strategy (NEES) and Action Plan, the EE awareness campaign, development of a centralized smart metering management and monitoring system, and a study to identify, assess and design a market based economic incentive(s) for energy efficiency appliances in South Africa (see further).

<u>Relevant policy, legislation and regulation</u>

In recent years South Africa developed a considerable energy policy framework, including the mandatory S&L programme for 12 appliance groups. Important with respect to energy efficiency are the following **policies and national plans**:

- *White Paper on the Energy Policy of the Republic of South Africa 1998.* Describes the government's general policy for the supply and consumption of energy until, approximately, the year 2010. This policy sets out the path for development of renewable energy and the improvement of energy efficiency with the ultimate goal of reaching a more sustainable energy mix, in order to achieve South Africa's macro-economic goals. A successor to this policy was released in September 2009 and aims to overhaul the fiscal, legislative and regulatory regimes in the energy sector, to further promote renewable energy development, and reduce carbon emissions.
- *National Energy Efficiency Strategy (NEES, 2015).* The draft post-2015 NEES Sets build on the earlier national target (as laid down in the 2008 update of the NEES, 2015) for energy efficiency improvement of 12% provides for a number of "enabling instruments"
- *Electricity Regulation Act (Act 4 of 2006*). The Act established a national regulatory framework for the electricity supply industry and NERSA as the custodian of this framework. The Act states that NERSA must encourage energy efficiency initiatives.
- The *National Energy Act (Act 34 of 2008*) was legislated to ensure that diverse energy resources are available to the South African economy, in sustainable quantities and at affordable prices, in support of economic growth and poverty alleviation. The Act takes into account environmental management requirements and interactions among economic sectors. It provides for the development of the *Integrated Energy Plan (IEP)* and the formation of SANEDI. The IRP (2010) presents scenarios that set out specific targets for renewable energy and the proposed new-build options including renewables, as well as the energy savings expected from demand-side management programmes.
- The *Industrial Policy Action Plan (IPAP) 2014/2015* includes the Production Incentive (PI) programme includes a Green Technology Upgrading Grant of between 30-50% for investments in technology and processes that improve energy efficiency and greener production processes.
- *Income Tax Act – regulations on tax allowances for energy efficiency savings*. S12L allows for additional depreciation allowances of up to 55% for greenfield projects over ZAR 200 million, with energy efficiency savings being one of the rating criteria. S12L provides a tax deduction to a taxpayer who is energy efficient, with a focus on renewable energy. Provisions S12C, S11E and S13 stipulate tax allowances for ESCOs and other compliant businesses that provide for general depreciation of asset allowances.
- The *National Environmental Management Act* (Act 107 of 1998) (NEMA) provides a principal framework for sound environmental management practices for all development activities. Waste management is provided for in the Act with principles such as 'the polluter pays'.

- It is envisaged that a *Carbon Tax* proposed by the National Treasury will be implemented, commencing in 2019 at a rate of ZAR 120 per ton of carbon dioxide equivalent (CO_2) on direct emissions, increasing by 10% per annum until 2020. Tax-free allowances of between 60% and 95% will be provided, based on trade exposure, fugitive emissions, carbon budgets compliance and other factors. See the *Carbon Tax Policy Paper* (National Treasury, 2013).

A number of **national standard**s are relevant:

- *SANS 941 - Energy efficiency of electrical and electronic apparatu*s is the national standard that covers energy efficiency requirements, measurement methods and appropriate labelling of energy-efficient electrical and electronic apparatus.
- The *Compulsory specification for energy efficiency and labelling of electrical and electronic apparatus (VC 9008)* was enacted in 2014 and came into force in 2015, making the SANS 941 a compulsory standard. It requires that a range of electrical and electronic apparatus (dishwashers, washing machines, tumble dryers and/or washer-dryers, refrigerators and/or freezers, electric ovens, storage water heaters) adhere to certain minimum energy performance standards. It also requires that all appliances listed display the energy efficiency rating on the appliance. A *Guide for Energy Efficiency Labelling*, published by DoE/DTI provides the basis for the labelling system in South Africa of above-mentioned electric appliances.
- *SANS 50010 – Measurement and verification of energy saving*s, published in 2011, specifies the methodology for calculating energy savings. This is a required tool for calculating savings for projects submitted on the 12L energy efficiency tax rebate programme.
- *SANS 10400-XA* - These construction standards require mandatory compliance on energy efficiency and energy use in the built environment, with all new buildings and extensions to buildings requiring energy efficiency initiatives before receiving municipal approval.
- SANS 1544 – Energy performance certificates *for buildings*. This is a new standard that specifies the methodology for calculating energy performance in existing buildings. It will initially be a voluntary standard but may become a mandatory standard through the NRCS regulation process.
- There exist also compulsory specifications for incandescent lamps (VC 8043) and compacts fluorescent lamp (VC 9091). These set MEPs for CFLs (according to SANS 60969 and SANS 60901) and minimum life requirements of 1000 hrs and 6000 hrs for incandescent and CFL respectively. In addition, incandescent lamps > 40 W will be phased out.

<u>Energy efficiency targets</u>

The **National Energy Efficiency Strategy (NEES)** was published in 2005 and aimed at achieving overall sectoral energy intensity reduction targets of 12% by 2015. In 2008 and 2011, the NEES was reviewed to discuss its scope and elements. The *draft Post-2015 NEES* builds on the earlier national target (as laid down in the 2008 update of the NEES, 2015) for energy efficiency improvement of 12% provides for seven priority areas: buildings, appliance & equipment, lighting, transport, industry, energy utilities, and cross-sectoral. The draft document was published for public comment in December 2016 but has not yet been finalised yet. The Post-2015 NEES sets specific targets for individual sectors:

- End-use energy consumption within the *public building sector* is expected to increase to 125.13 petajoules (PJ) in 2030 from 62.4PJ in 2012 levels (50% reduction). These increases can be curtailed by 19.7PJ, which is a decrease of roughly 16%, by conducting refurbishments and interventions in space heating, lighting and improved building practices based on the current version of the SANS10400-XA. Within *municipal services,* based on interventions in a sample of major municipalities, energy savings of 47% for bulk-water supply and water treatment, 32% for the municipal vehicle fleet, 25% for street lighting and 16% for buildings and facilities could be achieved.
- In the *residential sector*, three energy savings opportunities were identified as having sizeable potential, namely appliances, lighting, and buildings. Significant energy savings are possible if the Solar Water Heating and Mass Roll-Out programmes are continued within the residential sector. The electricity savings (12.1 TWh) proposed within the cost-effective scenario would contribute to roughly 20% of revised 2030 baselines. These savings would then translate to roughly 12.75 Mt of CO2 emissions. The proposed savings would mean a 6.8% decrease in household electricity intensity between 2010 and 2030.

Box 7 Energy efficiency standards and labelling in South Africa

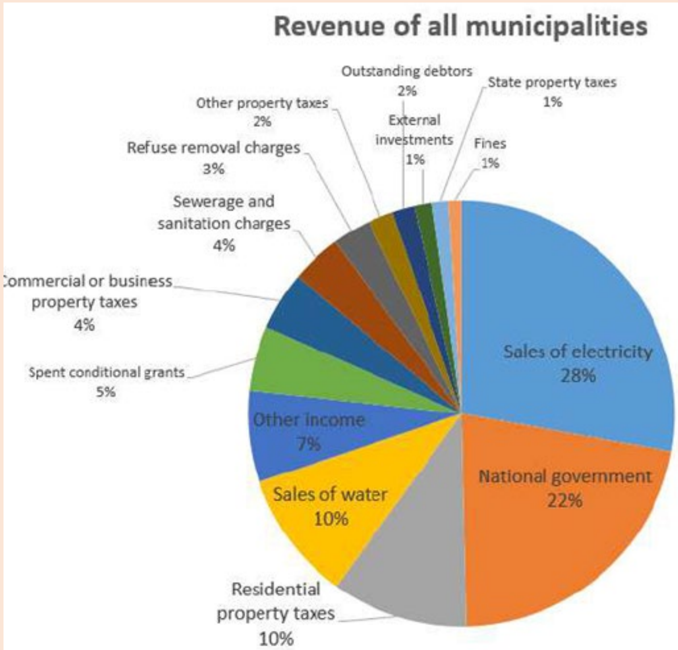
The 'Leapfrogging High-Efficiency Lighting and Distribution Transformer' Project will build on the existing infrastructure and results of the GEF-financed, UNDP-implemented project *Market Transformation through Energy Efficiency Standards & Labeling of Appliances in South Africa* (GEF 2692, UNDP PIMS 3277), implemented from 2013 to 2019. The project aims at facilitating a comprehensive transformation of the home appliance market through the introduction of a combination of two regulatory tools, minimum energy performance standards and information labels (S&L), accompanied by a series of associated awareness-building and monitoring activities. The project has focussed on a number of 12 electric appliances: refrigerators, freezers, refrigerator-freezer combinations, front-load washing machines, top-load washing machines, tumble dryers, washer-dryer combinations, dishwashers, air conditioners, electric ovens, audio-visual equipment, and electric water heaters (geysers). The following table gives a summary:

Outputs	**Main results and achievements by mid-2017**
Outcome 1 Policy and regulatory framework for the S&L programme: Strengthen structures and mechanisms for appliance EE S&L 1.1 Review of existing policies and regulations. 1.2 Evaluation of financial incentives such as the rebate program operated by the Eskom DSM for purchasing efficient appliances.	• Four studies have identified a number of incentive schemes (standards offfer for LED lights, subvention of electric geysers, swap programme, for refrigerators and a rebate system for purchasingg EE appliances), assessed cost and benefits and a fourth study (2017) will assess in the light of current situation and new government policies.
Outcome 2 Define labeling specifications and MEPS thresholds for the products considered by the DoE & DTI for S&L regulation 2.1 Conduct market and engineering analysis for the products selected for S&L regulation 2.2 Adopt labeling specifications and MEPS thresholds for the 12 products selected for S&L regulations	• Market and engineering analysis for all products has now been completed.The Minimum Energy Performance Standards (MEPS) for household electric appliances have been set and promulgated through NRCS regulations VC9008 (described in the main text), MEPS have been approved, and started to be enforced since March 2015 (audio-visual equipment); February 2016 (dishwashers, washing machines, tumble dryers and/or washer-dryers, refrigerators and freezers), August 2016 (air conditioners); and August 2017 (water heaters/geysers) • The EE label design was completed in September 2015 through a consultative process with appliance manufacturers and relevant government authorities The *Guide for Energy Efficiency Labelling*, published by DoE/DTI was launched in 2016 and provides the basis for the labelling system in South Africa of above-mentioned electric appliances. • A trial incentive programme is being designed for Gauteng (starting 2nd half 2018). This would go together with a survey on consumer attitudes and preferences, and will be linked with the presentation of endorsement labels (see also main text at the end of Section E.3)
Outcome 3 Strengthen the capacity of institutions and individuals involved in the S&L programme 3.1 Strengthen institutions (testing facilities, enforcement institution) 3.2 Strengthen employee skills	• A private laboratory (Test Africa) is accredited to test the energy efficiency of electric water heaters, ovens and standby power. SABS is accredited to test for energy efficiency of standby power (audio and visual), lighting, water heaters, ovens and refrigerators, however, only the water heater, lighting and audio/visual labs were operational by mid-2017. SANAS assessed SABS for accreditation in February 2016. The test laboratories for dishwasher and laundry will be operational in 2017. The project assisted SABS with institutional and individual capacity-building. • NRCS developed modules and training materials to training its inspectors. The modules include the learners' materials, the trainers' guide and assessment modules. Modules were completed for audio-visual equipment and white goods
Outcome 4 Awareness raising campaign for standards and labels, targeting manufacturers, distributors, retailers and end-users. 4.1 Test and adopt label design 4.2 Develop communication campaign towards manufacturers, importers, distributors, retailers and consumers about appliances' energy efficiency 4.3 Develop and deliver training programs for distributors and retailers staff.	• A one-month long market surveillance of retail floor sales staff by the NRCS in all major cities found that recognition and understanding of the label was only at 15%. A communicatoon plan was prepared in 2016. Implementation of the campaign includes stakeholder engagements, development of a training programme for retail sales personnel, messaging (through social media platforms, media releases and advertorials). After the media campaign will be completed (preparation will start in 2017), new research will ascertain the effect of the label on users and retailers. • Training will be organised 2017-18 to prepare retail sales personnel to understand and to explain the choices available to consumers when purchasing new appliances.
Outcome 5 Implementation of S&L market surveillance & compliance (MSC) regime to ensure energy performance standards is met	• The development of MCS procedures will be assigned to an independent service provider that will work with the NRCS starting 2017 • A database on S&L products developed in 2014/15 was not maintained or updated. A new product registration database is being build and due to go live in April 2019.
Outcome 6 Development of Monitoring and Evaluation (M&E) capacity	• A review of South Africa's appliance energy classes and identification of the next set of electrical equipment is planned for 2017-18

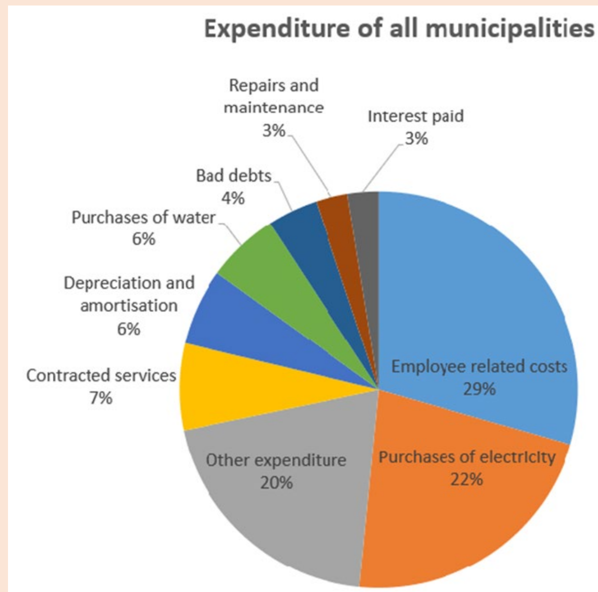
The UNDP/GEF project has been helping South Africa to embark on a more comprehensive S&L programme development. It is is now important that South Africa develops reliable and appliance-specific Measurement, Verification and Enforcement (MVE) schemes with strict sanctions to ensure that at the end the market is actually compliant with all new requirements.

Source: UNDP-GEF project Document and Project Implementation Review (2017)

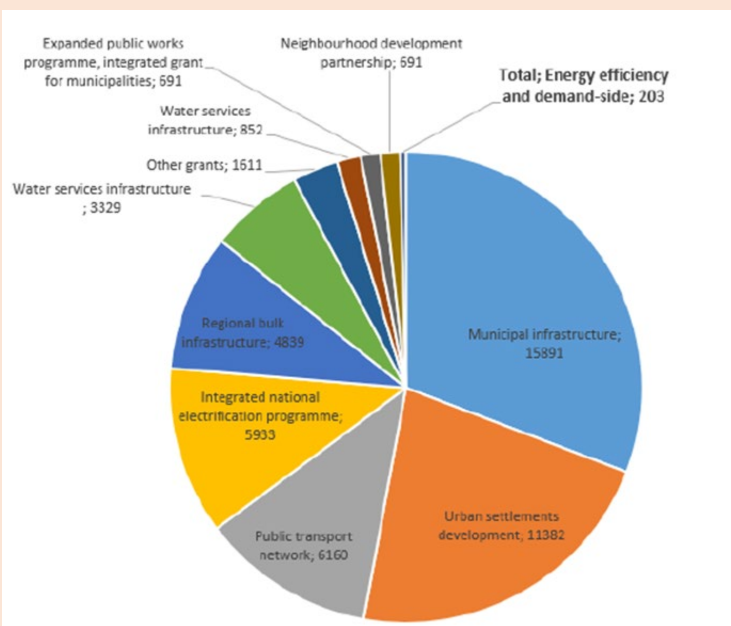
Box 8 Municipal revenues and expenditures



On average, South African municipalities obtain 28% of their income from grants and 72% from internal sources, primarily through property taxes and the sale of basic services (electricity, water, refuse collection). These figures, however, include gross income from electricity and water sales. If the total direct cost of bulk electricity and water purchases by municipalities are taken into account, the total amount of funding from grants is on average 37%. Under this same metric, metropolitan municipalities obtain 26% of their income from grants, and for all the other municipalities this figure reaches 50%.



The central government grant funding for infrastructure in the metropolitan municipalities is mainly concentrated on reducing the number of informal settlements (Urban Settlements Development Grant - ZAR 11 billion in 2018/19 budget) and on public transport (Public Transport Network Grant- ZAR 6 billion in 2018/19 budget). The Urban Settlements Development Grant may also be used for the provision of infrastructure for the settlements developed.



The Municipal Infrastructure Grant, which is the largest infrastructure transfer to municipalities (ZAR 15 billion in the 2018/19 budget) is distributed primarily to rural municipalities and some districts, while the metropolitan municipalities receive no funding from this grant program. The allocations of this program are dedicated to new infrastructure or upgrading existing infrastructure including basic water and sanitation services, central collection points for refuse, recycling facilities and solid waste disposal sites, sport and recreation facilities, street lighting, etc. A lot of the funding is understood to be spent on clearing the backlog of defective infrastructure.

The Municipal Infrastructure Grant and the Urban Settlements Development Grant are the two largest components of the national government transfers to the municipalities. Another infrastructure grant program that addresses infrastructure relevant for this project is the Integrated National Electrification Programme Grant for municipalities. This program is funded with ZAR 5.9 billion to address the electrification backlog of households and the installation of relevant bulk infrastructure. Of this total budget the municipalities receive ZAR 2billion

Measures contemplated in NEES regarding the public and residential sector include: a) awareness raising of government employees (at national and sub-national level) and awareness raising of the public at large, b) tightening of building energy performance standards, c) mandatory display of energy performance certificates in government-owned buildings, green procurement (incorporating life-cycle considerations), d) broadening the scope of mandatory labelling and MEPS (see Box 7) , as well as introduction of endorsement labels alongside the existing comparison type of energy labelling.

Municipalities will be required to submit energy efficiency strategies, which will be informed by a comprehensive energy audit of their services and activities, and aligned with the provincial strategies. On the basis of the energy audit and municipal strategy, the DoE will assist municipalities in developing energy management plans, associated business plans and financing proposals to source financing for the measures that are prioritised. However, many municipalities have up to now identified isolated measures and do not have adequate data to understand their energy use profile. Alternative financing mechanisms could be exploited, such as energy performance contracts with private sector ESCOs, reducing the investment burden on the government and the municipality.

Considerable reductions in coal usage (22.9%), CO2 emissions (15.5%) and overall electricity usage (15.7%) can be achieved by the year 2030 within the electricity (utilities) sector, if the savings scenario that constitutes a greater share of renewable technologies, employing advanced coal technologies (high-efficiency boilers, integrated gasification combined cycle). It is 22,351 GWh were lost in 2013 in distribution and transmission. Some municipalities report losses of 30-40%. Some are non-technical losses (illegal connection, tampering with meters, etc.), other are technical (losses in transmission; use of old transformers).

2.2 The market for LED lighting in South Africa

Lighting demand and supply

The lighting market in South Africa can be described as diverse with a mix of older technologies, such as incandescent, halogen, linear and circular fluorescent lamps, high-intensity lamps (HIDs), and newer technologies, such as compact fluorescent lamps (CFLs) and light-emitting diode lamps (LEDs), all prevalent.

Box 9 Annual lamp sales in South Africa in 2016 (DoE study on residential lighting)

	Imports/sales in 2016*	Residential stock (2016)	Average price (Rand)**
Compact fluorescent lamps	5.6 million (53%)	40,322,347	31 (28-41)
Fluorescents (linear)	0.6 million (6%)	?	-
Halogen lamps	2.3 million (22%)	11,166,188	25 (11-39)
LEDs	1.4 million (13%)	8,694,813	45 (25-75)
Incandescent		1,861,031	9
Other	0.7 million (6%)	?	
	10.6 million	62,034,380	

* Period December 2015-November 2016, based on Customs and Excise data. In addition, Eskom brings about 2-3 million CFLs on the market as part of its EE-DSM programme

** Based on survey in 17 retail outlets. Price of incandescent lamp: R 9 (note that sale of most incandescents has been banned since 2015, but are nonetheless sold in 'informal' outlets)

Source: DOE (2017)

There are a number of studies available that do take into account particular market segments, municipal lighting, and street lighting (for one or municipalities) or the residential sector, but, up to now, there is not one consolidated study for the nation as a whole, encompassing all the sectors (residential buildings, commercial and industrial buildings, outdoor lighting, street lighting) and all the types of lamps. A recent Danish-supported *Identify, Assess, and Design a Market-Based Economic Incentive(s) for Energy-Efficient Appliances in South Africa; Final Report* (DOE, 2017)[20] provides market details on stock and sales of LEDs and other lamps in the residential sector (see Box 9).

[20] By Development Associates ApS for the Department of Energy, by Harris et.al (May 2017)

Box 10 Energy-efficient lighting: an overview

The following table gives an overview of various lighting technologies:

	Incandescent-type		Fluorescent lighting		Light-emiting diode (LED)	High-intensity dischrage lamps (HID)		
	Incandescent	Halogen	CFL	Fluorescent – tube (TL)		Mercury vapour	High-pressure sodium (HPS)	Metal halide
Luminous efficiency (lm/W)	8-17	11-25	60-130	80-110	60-130	45-55	105-125	80-100
Lifetime (hrs)	1000-1500	2000-3000	6000-15000	15000-30000	20000-60000	20000	15000-24000	10000-20000
CRI & colour temperature	100 (CRI) 2600-2800 K	100 (CRI) 2800-3200	70-95 2700-6500 K	60-95 (CRI) 2700-6500 K	70-95 (CRI) 2700-6500 K	15-50 (CRI) 3900-5700 K	25 (CRI) 2000-2100	65-85 (CRI) 2500-6500
Dimmable	Y	Y	if driver dimmable	if ballast dimmable	if driver dimmable	if ballast dimmable	if ballast dimmable	if ballast dimmable
	Produce light by passing electrical current through tungsten metal wire suspended in an inert tmosphere inside a glass bulb.	Halogen lamps are an improvement over incandescent Contain a small quantity of halogen that increases lamp life	The lamps incorporate an electronic ballast and phosphor-lined glass tube. An electrical arc is struck at the tube's electrodes, causing the mercury atoms to emit ultraviolet (UV) light, exciting the phosphor coating and emitting visible light. Tubular fluorescent lamps are typically classified by their diameter (most common are: T12 = 38mm, T8 = 25mm, T5 = 16mm). CFLs were developed as retrofits for incandesents, and are essentially a miniaturised version of a linear fluorescent lamp (TL). All fluorescent lamps contain mercury.		A LED is a semiconductor light source, whose p–n junction diode that emits light when activated –(electro-luminiscence). Many LED products are available that can replace the previous lamp inclduing bulbs and tubular lamps. There are also LED for street lights and outdoor applications	High intensity discharge (HID) lighting produces light from an electrical arc contained within a capsule of gas (metal vapour) which is sealed inside a bulb. HID lights require a ballast to start and operate, which regulates the voltage. HID lighting is commonly found in outdoor lighting applications such as street lighting, area flood lighting and sports stadium lighting. HID lighting is also found in-door in places such as large retail outlets, warehouses and buildings of manufacturing facilities. A ballast is a piece of equipment designed to start and properly control the flow of power to discharge light sources such as fluorescent and high intensity discharge (HID) lamps		
Incandescent comparison	- 40 W 60 W 100 W	~25% 28-29 W 41-43 W 70-72 W	~ 75% 9-11 W 13-16 W 23-27 W	40 W incandescent compares to 40 (T12)-32 (T8)	80% 5-8 W 10-13 W 20-26 W	Street lighting comparison: MV 240 W	HPS 160 W	MH 180 W LED 80 W

Compact fluorescent lamps were developed in 1970s as a replacement for the less efficient incandescent lamps and could fit in the same volume and the same fitting. However, about 52% percent of the world's total lighting market sales of 15 billion units were still incandescent in 2010. Therefore, countries around the world have started to phasing out inefficient incandescent lamps. Some countries have established effective approaches to eliminate inefficient lamps via mandatory minimum energy performance standards and energy labelling and other policy measures)

LED lamps have a lifespan and electrical efficiency which are several times greater than incandescent lamps, and are significantly more efficient than most fluorescent lamps. Recent developments have produced LEDs and new control systems that are suitable for all apllications, in buildings, traffic lights and outdoor lighting. Market share of LEDs was projected by McKinsey in 2016 (of a total of 11 billion units) to reach 22% (1% in 2010), that of CFLs 25% (up from 17% in 2010), linear fluorescent 20% (16% in 2010), HIDs 2% (also 2% in 2010), halogen 22% (20% in 2010 and incandescents down to 9% of global sales (52% in 2010).

Electricity for lighting accounts for approximately 15% of global power consumption and 5% of worldwide greenhouse gas (GHG) emissions. A switch to efficient on-grid and off-grid lighting globally would save more than USD 140 billion and reduce CO_2 emissions by 580 million tonnes every year. Worldwide, electricity accounts for about 15% of power consumption (and 5% of global greenhouse gas emissions). A reduction to the more efficient lighting would reduce global power demand for lighting by 30-40%. If countries would follow the integrated efficiency policy approach, the energy savings could reach 640,000 GWh in 2030. This is the equivalent of USD 360 billion in avoided investments in 290 large coal-fired plants, or, the savings would be enough to provide 300 million non-connected households with electric energy (assuming a consumption of 2000 kWh per household per year).

Source: Accelerating the global adoption of energy-efficient lighting, UN Environment-GEF 'United for Energy Effciiency (2016) *; BC Hydro (*www.bchydro.com)*; Lighting the way: Perspectives on the global market,* McKinsey (2011). CRI: colour rendering index

The same study also provides estimates on the stock of residential lamps in South Africa, based on the number of rooms per households in South Africa, putting the total stock of installed lamps at about 62-80 million (there are 79,084,776 rooms, according to 2012 General Household Survey). Assuming one lamp per room, this is likely to be an underestimate, as many rooms (even in lower-income households) will have more lamps than just one. On the other end of the range, there is the estimate by the UN Environment-GEF U4E/en.lighten programme (see Box 11) of about 248 million lamps in households (implying 4 lamps per room per household on average, which seems more plausible). In the remaining of this report, we will use the U4E data as an estimate for annual sales and installed stock, also because it encompasses not only households but also sectors (public, commercial and industrial).

Box 11 Estimates of annual lamps sales and installed stock in 2014

Stock (installed lamps)

(million of units)	Residential	Professional	Outdoor	Total
Incandescent	108.60	37.37	7.47	153.44
Halogen	9.82	6.22	1.24	17.29
CFL	82.88	155.57	25.93	264.38
LFL - T5	0.22	1.72	0.22	2.16
LFL - T8	34.93	117.81	16.83	169.56
LFL - T12	10.41	35.11	5.02	50.53
LED tube	0.12	0.43	0.06	0.61
LED	0.76	3.55	0.76	5.07
HID-HPS	-	2.05	4.80	6.85
HID other	0.48	2.93	5.58	8.99
	248.23	362.74	67.91	678.88

Annual lighting market

(annual sales, 2014)	Residential	Professional	Outdoor	Total
Incandescent	4,360	6,751	2,455	13,566
Halogen	330	940	347	1,617
CFL	726	6,133	2,129	8,988
LFL - T5	7	176	22	205
LFL - T8	1,224	13,760	1,966	16,949
LFL - T12	456	5,126	732	6,314
LED tube	3	39	6	48
LED	5	86	42	133
HID-HPS	-	598	1,576	2,175
HID other	135	795	2,851	3,782
	7,247	34,404	12,127	53,777

Source:
Based on UN Environment-GEF *South Africa Country Assessment* (2016)

Historically, most lamps in buildings were incandescent lamps (often 60 W or 100 W) or linear fluorescent lamps. As part of its emergency 'energy efficiency and demand-side management programme' (EE-DSM), the utility Eskom started to exchange incandescent bulbs in homes for more energy-efficient compact fluorescent lamps (CFLs) in 2008. By January 2017, more than 65 million CFLs have been distributed. The Eskom CFL roll-out programme has been one of the biggest energy-saving initiatives of its kind in the world. Eskom-appointed installers going door to door in designated areas to replace (a) energy intensive incandescent light bulbs with new energy saving CFL (Compact Fluorescent Lamps) and (b) spent CFLs with new CFLs in homes across South Africa. As a result, CFL has become synonymous to 'energy saving bulb' or just 'light'. The door-to-door programme was targeted mainly at lower-income groups[21].

In South Africa, the sale of incandescent bulbs (of 40 W or above) has effectively been banned. However, this also has favoured the sales of new halogen lamps (these operate very similar to incandescent bulbs and more efficient, but less so than CFLs) that are sold at prices below that of CFLs (see Box 9 and Box 10).

Over the past 5 years, LEDs have been entering the market in South Africa, as part of the international trend with rapid LED technology advancements (better light colouring, longevity, efficiency) and lowering of costs. Market feedback and observations of retail shelves suggest that this has shifted significantly over the preceding 12 months with a larger variety of LED bulbs available, a bigger share of shelf space allocated to LEDs and prices competing directly with the halogen and CFL alternatives[22]. Nonetheless, important factors that hinder more widespread use of LED (and other energy efficient) lamps in the market:

21 CFLs also were given to large commercial companies in South Africa to facilitate bulb replacement among employees, including at Eskom's major offices. This allowed penetration of CFLs into higher-income groups

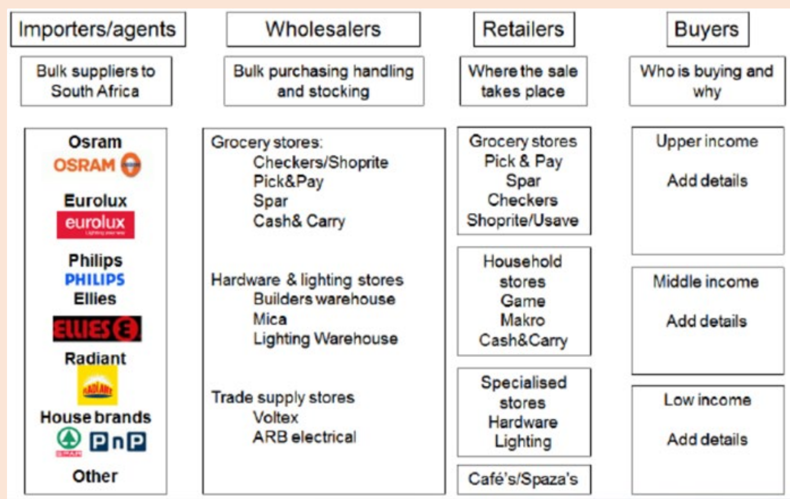
22 The report *Technical Market Review, Country Profile South Africa* (DHV-GL, 2018) mentions, based on visits to several retail stores, a

- For the lower-income households, Eskom is still distributing free CFLs and in the mindset of many households, these have become the first choice of lighting. By the end of 2016, Eskom still had some 5.9 million CFLs in stock and to be rolled out during 2017-18 (mostly as aging lamp replacements);
- For the average consumer, the comparison of lamps types, brands, performance, and energy efficiency is rather complex and confusing. This will lead to some buyer resistance regarding new LED technology and what to expect.
- Low-quality LED bulbs are being imported with three deficiencies, poor power factor (as low as 0.3), low efficiency (lumens per Watt) and low lifetime. The current lack of minimum standards leads to dumping of these lower-cost, low quality on the market. This causes competition problems for suppliers that want to provide good-quality lamps, and this is made worse by fierce competition amongst LED lamp suppliers. Especially in the higher-income households' segment, the uptake of LEDs will be hampered by the poor quality which will give the product a bad name.
- Poor quality inefficient lighting options (old stock, illegal imports of incandescent lamps) continue to find their way into homes through obscure retail outlets in the country at very low prices. Thus, the lower-end market segment is flooded with cheap, low quality imported lamps (LEDs, CFLs) and illegal incandescent bulbs that vary in terms of performance. Enforcement of lighting standards (e.g. CFLs) remains flawed due to the dysfunction in the regulatory process.

<u>Supply chain characteristics and potential for local manufacturing</u>

In South Africa, all lamps are imported (most are manufactured by in large-scale factories in China) by multinational brand companies, such as Philips, Osram, Eurolux as well as by house brands. Consumers by the lamps at grocery retailers (such as Pick 'n Pay, Shoprite, Spar), general household retailers (e.g. Makro, Cash & Carry), hardware stores (e.g. Builders, Mica) and dedicated lighting suppliers. In addition, Eskom has been providing CFLs in its residential replacement programme, as mentioned above.

Box 12 Lamp supply chain in South Africa



Source: DANIDA, DOE (2017).

Manufacture of LEDs is spread out globally, with fabrication plants operating in the United States, Germany, Malaysia, China and India. In comparison, the South African lighting industry is estimated at ZAR 5 billion a year (less than 1% of the global market), which include all types of light fittings such as street lighting, floodlighting, industrial and commercial lighting, control gear, lamps, the domestic and decorative ranges and other specialised lighting. Lamps and commercial lighting each contribute about ZAR 1 billion to the industry, while industrial lighting is estimated to be worth about ZAR 500,000 a year. South Africa has the skills, equipment and manufacturing capacity to manufacture solid-state lighting products and fluorescent lamp, but the small size of the market does not provide economies of scale (yet) in high-intensity LED components manufacturing required for solid-state lighting applications. A typical LED fabrication plant requires an investment of approximately USD 15-350 million, depending on the size, and can take up two to five years before becoming fully operational[23].

stock at the store of 38% LED, 43% CFL and FLs, and 19% halogens

23 Study to identify electronic assemblies, sub-assemblies and components that may be manufactured in South Africa (DTI, 2010). See also Box 28

Currently, there are about 18 LED suppliers in South Africa[24]. However, the market is expected to grow at a compound rate of 20% each year to reach market penetration in general lighting of well over 60% by 2020. Efficacy values of 300 lumen per Watt could be achieved and cost reduction by 20-30% each year will continue until costs are below that of conventional luminaires.

LED market developments

Globally, the lighting industry is transforming. LEDs are entering all end-use applications in the lighting market, from the non-directional household lamp, directional (or "spot") light, LED tubular lamps (to replace fluorescent tubes and dedicated LED luminaire. Also, LED street lights, flood lights, high-bay replacements, and many other luminaires and technologies are offered in the dynamic LED lighting market. In the medium to long-term, LEDs are expected by many to be the primary light source in all applications.

In the past, the lighting industry had two general distinct product segments: manufacturers of lamps (i.e. light bulbs) and manufacturers of luminaires (i.e. fixtures) The manufacturers of lamps (or commonly called "light bulbs") were a small number of large, global suppliers whose majority of business was based around the sale of replacement lamps. Manufacturers of luminaires, where there are a large number of companies, tended to be more application- and regionally focused, specialising in the production of comparatively small batches of a large variety of luminaires. Today the boundaries between the lamp and luminaire businesses have blurred. This is because of the increasing number of LED lamp-luminaire solutions. LED light sources bring the potential for ultra-long service life, which will gradually eliminate the replacement lamp business.

Street and traffic lighting

There are no nation-wide statistics that are readily available on the number of lamps used in street lighting and type of lamps used. The South African Cities Network (SACN) has carried a study on *Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN* (2014) that also include street lighting.

Street and traffic lighting usually account for between 15% and 30% of the total energy consumption within a municipality's operations and it is one of the easiest energy efficiency (EE) intervention areas. Many street lighting facilities in municipalities are outdated and therefore highly inefficient. Old lighting technology also has higher maintenance requirements. Most of the common technical measures applied to address EE in street lighting can generate between 38% to 54% energy savings per measure and these have very short payback periods.

Box 13 Street lighting characteristics in South African cities

	# of lamps	Mercury vapour (MV)	High-pressure sodium (HPS)	Metal halide
Buffalo City	128,375	82%	18%	
Cape Town	210,385	41%	59%	
Tshwane	122,638	75%	25%	
eThekwini	129,688	76%	23%	1%
Mangaung	21,123	72%	18%	9%
Total	712,209	67%	33%	1%

Source: SACN (2014). For comparsion, in the 25 states of the European Union, the share of sodium lamps was 56%, MV 32%, metal halide 3% and CFLs 8% (2004)

Mercury vapour (MV) lamps are said to have been introduced in the 1950s and were deemed a major improvement over the incandescent light bulbs. Metal halides are a newer and more efficient than MV lighting technology. HPS lamps have a high efficiency when compared to MV and MH lamps on a lumen/watt scale. CFL luminaires have improved over time although their use in street lighting is rare in South African municipalities. Inefficient MV luminaires make up 62% of the total number of installed luminaires across the nine cities. Substituting MV with LED attractive in the street lighting will result in greater savings of 71% (SACN Report 2014[25]). However, most of the municipalities have been retrofitting with HPS

[24] *Technical Market Review, Country Profile South Africa* (DHV-GL, 2018)

[25] *Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities* (SACN, 2014)

Box 14 Local production of LED street lighting luminaires

The CSIR (Council for Scientific and Industrial Research) has carried out a market assessment and feasibility study for the local production of LED luminaires for street lighting. The annual demand for LED street lighting (for new and retrofit applications) is estimated at 423,000 in municipalities and about 17,000 at national roads (managed by SANRAL). With potential exports of 9 million units to other parts of Africa, this market could make the establishment of a facility for LED street lighting manufacturing an feasible proposition. The establishment of the LED enterprises could result in the creation of sustainable job opportunities, increase local content and lead to economic growth.

The study look into the establishment of a facility that can produce 8,600 LED street light lunimaires annually (150 W for national roads and major provincial roads, 80 W for urban and 50 W for rural roads). The production facility could be set up over a 2-year period costing about ZAR 13.61 million (inclduing design and engineering, company formation, construction and office, workforce training and procurement, installation and commissioning of machinery). Lamps could be sold at slightly below the average market price for street lighting: price (150 W: ZAR 7,774; 80 W: ZAR 5,697, 50 W: ZAR 5,021). Some grant funding with soft loans would be needed to ensure the business will have a positive cash flow and attractive financial indicators.

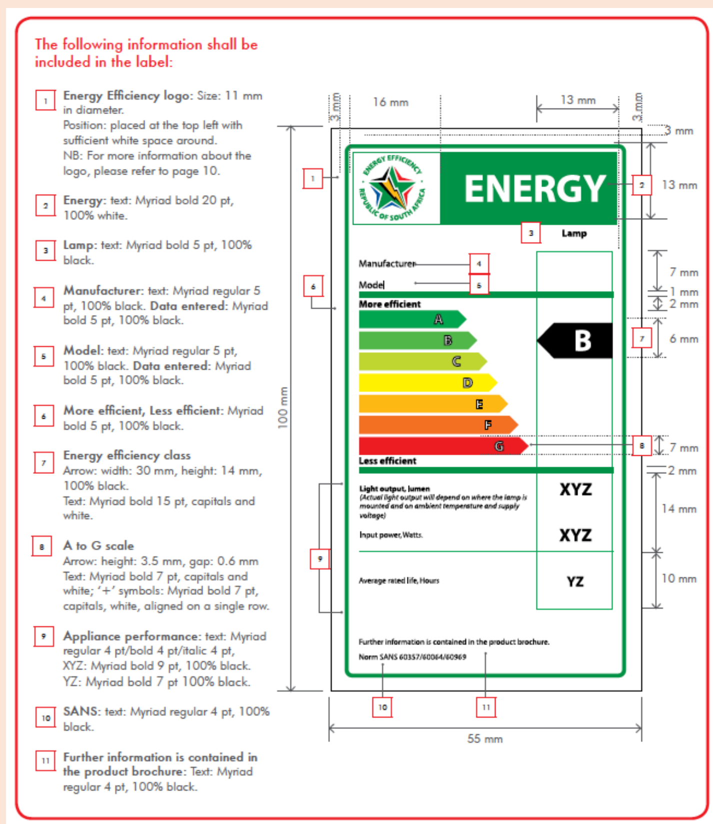
Source: CSIR Enterprise Creation for Development *Business Plan: LED Light Enterprise (2015)*

luminaires because LEDs are still regarded with some caution due to lighting characteristic, untested lifespan and costs (SEA). New lighting technologies, such as LED or induction lamps, produce at even higher lumen per watt.

LED lighting has become the standard efficient retrofit technology for traffic lights because LED traffic light fittings last 5 to 8 years, substantially reducing maintenance cost compared to incandescent and halogen lights. Operating costs are also massively reduced due to the same level of illumination available with LED lighting, at a much lower wattage. Buffalo City, Cape Town, eThekwini and Nelson Mandela Bay, have achieved 100% penetration of EE traffic lighting. Opportunities exist for municipalities that have not achieved a 100% retrofit of their existing inefficient traffic lights with LED luminaires to expand their current programmes.

The Department of Energy's Municipal Energy Efficiency Demand Side Management (MEEDSM) programme (see Box 34) has supported municipalities in South Africa in implementing energy efficiency measures in street lighting, buildings and in the water and sewage infrastructure. During the period 2009/10-2014/15, the programme managed to replace 459,172 street lights, usually replacing HPS for MV lighting. For example, Mafube replaced 140 MV (250 W) with HPS (150 W); Buffalo City, eKurhuleni, Cape Town en eThekwini also replaced MV lamps with HPS. Nelson Mandela Bay is the only one that has been retrofitting with CFL luminaires, which do offer a considerable

Box 15 Energy label, bulbs



Source: A guide for Energy Efficiency labelling (version 2.0. DoE; 2015)

Box 16 Promotion of street lighting

A potential approach to remove these barriers is to provide dedicated support to the street lighting teams in the larger municipalities to develop high quality business cases for presentation to the budget committee, including proper financial analysis and the following aspects, to enhance the reception of these projects:

- Street lighting is highly connected to safety and has been proven to reduce both traffic accidents and crime rates. Designing a program that puts special focus on poorly lit areas with higher traffic accident and crime rates could act as a catalyst to the demand for these projects. Integration of street lighting with other initiatives, such as the installation of crime-prevention surveillance systems will also be key to the success of the program.
- Street lighting is highly connected to social activities at night, which is of particular importance in commercial and tourist areas. Designing a program that improves the street lighting quality in these areas may therefore result in an appetite by the municipalities for these projects, as a way to improve business activity and consequentially increase tax revenue.
- Illegal electricity connections, meter tampering and transformer oil theft are understood to be a common issue in the South African electricity infrastructure. The design of a program that incorporates measures addressing these issues is likely to increase the end-client demand of these projects. An example of such measures might be remote transformer monitoring to detect unusual patterns or the collaboration with the smart-meter programs of various utilities to provide LED lighting lamps to residential end-users.
- Electricity outages have also been a recurrent issue, on some occasions resulting from the illegal electricity connection or equipment theft indicated previously. Again, a transformer monitoring system that enables predictive maintenance of distribution transformers may be presented as a unique selling point of the program.

energy saving in comparison with HPS luminaires. Remarkably, Msunduzi Municipality has retrofitted HPS luminaires (i.e. already more efficient than MVs) with LED lamps.

Labelling of light bulbs

The Department of Energy, supported by the UNDP/GEF *Standards and Labelling Programme* (see Box 21), has been working on (mandatory) energy performance standards (MEPS) and energy labels. Unlike other electric appliances, there are no MEPS or labels that cover LED, CFLs, halogen and other lighting devices. An energy label does exist, but its application is on a voluntary basis. The proposed UNDP/GEF "Leapfrogging LED and HE Distribution Transformers" will build on the efforts on standards and labelling by looking at) compulsory performance standards, b) awareness and information to promote the existing energy label, and c) trial incentive programme for Gauteng area.

For LEDs, there are voluntary standards on safety and performance, but not covering energy performance considerations. The proposal is to move to mandatory to be regulated by a) DTI, or b) DoE. In the case of DTI regulation, implementation and administration (incl. certification M&V and enforcement) will reside with NRCS. In the case of DoE regulation, the implementing agency could be SANEDI. Another option is that both DTI and DOE regulate with implementation outsourced to a third entity.

A trial incentive programme is being designed for Gauteng (starting 2nd half 2018). This would go together with a survey on consumer attitudes and preferences. The primary target will be middle-higher income households, which has a high potential for savings by LED replacement of halogen downlights. This will be linked with the presentation of endorsement labels (in addition to the existing energy label), by introducing a "information label" (that compare LED, VFL, halogen and incandescent bulbs in light output, life expectancy, and energy usage) on the shelves of retailers and outlets and an "endorsement label" (for products that meet the specifications of the incentive programme). The pilot will be accompanied by awareness campaign, website (www.savingenergy.org.za) and training for retailer staff and salespeople.

2.3 Distribution transformers in South Africa

Box 17 Examples of transformers

Ground-mounted 3-phase Pole-mounted single-phase

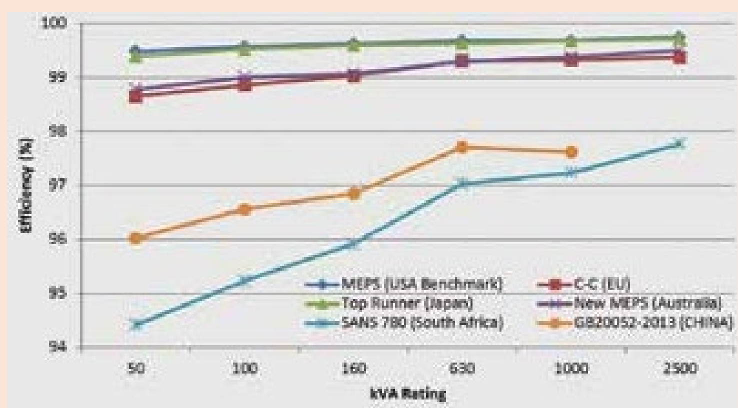
The transformers can be pole-mounted (single phase 242 V with capacities 16-25 kVA, 484 V dual-phase with capacities 31-64 kVA, or three-phase with capacities 25-500 kVA) or ground-mounted (three-phase 11 or 22 kV with capacities 50-2500 kVA).

In 2011/12, the distribution grid in South Africa had a length of 2.807 million km with 530,374.), of which 0.368 million km (and 148,984 transformers .in the hands of Eskom and 2.439 million km (with 381,390 in the hands of municipalities and private distributors. In 2017 there were about 662,655 distribution transformers installed, of which about 290,000 by Eskom.[26] An estimated 20,000-24,000 newly installed per year about half replacing old retiring transformers, and about half as newly added to the system.

Most transformers used in distribution systems in South Africa are of the liquid-immersed type made from cold-rolled grain-oriented silicon steel. The available distribution transformers are heavy pieces of electrical equipment with a weight range of 150 kg to 29,000 kg. The lifecycle cost of a transformer takes into account the initial cost and cost to operate and maintain over the product's lifetime, which could be up to 40 years. In the transformer business, this is often expressed as 'total cost of ownership (TOC)' consisting of the cost of purchasing the transformer + value of no-load losses + value of load losses. For example, the article by Amadi and De Cock (see Box 33) compares the case of a standard 315 kVA transformer in South Africa with that of a premium-efficiency transformer. With a load factor of 40%, an assumed lifetime of 40 years and cost of power of R 1.51/kWh, the conventional transformers purchase price was R 64,900 in 2014 with a TOC of R 2.253 million and that of the premium-efficiency transformer costing R 90,672 but with a TOC of R 1.184 million[27]. The investment in a high-efficiency transformer is higher but yields an attractive total cost of ownership (TOC) over the extended life of the transformer (due to lower no-load and load losses).

The first standard regarding transformers was issued in 1966 by SABS (based on IEC standards at that time), known as SANS 780. The standard has been amended several times since then, but none of these have included transformer no-load and load losses. Not surprisingly, South Africa's transformer efficiencies are trailing behind those not only those in first-world but also other BRICS countries (Brazil, Russia, China, India, and South Africa).

Box 18 South Africa transformer benchmarking



SANS 780's benchmark with respect to other international countries.

Source: Reducing South Africa' s electrical distribution transformer losses in 'Electricty and Control', by Amadi, A. and De Kock, J.

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[26] Source: Eskom, p.c.; NERSA, *Electricity Supply Statistics* 2012; DHV-GL *Country Profile: South Africa* (2018)

[27] With reduced losses of 50%, that is NLL from 0.84 to 0.42 kW and LL from 3.8 to 1.9 kW

Box 19 Efficiency, losses and transformers

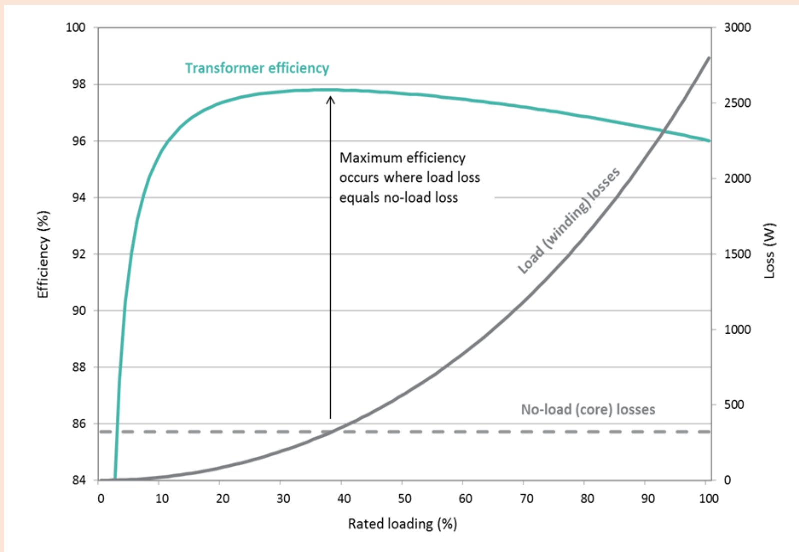
Transformers are devices in an electricity system that transfer power between circuits through electromagnetic induction (this enables energys avings in in power transport by increasing the voltage and decreasing the current). Transformers are installed at power stations to increase the voltage of the electricity to a level that will be suitable for transmission over long distances.

These transformers step up the voltage from, for example, 22 kV to 220 kV, 275 kV, 400 kV or 765 kV and feed the electricity into the national grid. Thus power is transported over large distance through the transmission grid at high voltage (110-275 kV) to the various distribution stations that are closer to the prospective users (toens, groups of villages, industry) and then tranformed by power transformers to medium voltage. When the electricity arrives at the distribution station in South Africa, bulk supplies of electricity at 22 kV are taken for primary distribution to towns and industrial areas, groups of villages, farms and similar concentrations of consumers. The lines are fed into intermediate substations where transformers reduce the voltage to 11 kV. Secondary distribution lines radiating from these substations carry the power into the areas to be supplied and terminate at distribution substations. Here the voltage is reduced to its final level of 380/220 V for use in shops, office buildings. In substations the voltage is decreased by step-down transformers.

Generally, transformers can be grouped in a) large power or high-voltage (> 245 kV), medium-power, medium power (> 36 kV and < 230 kV), medium disttibution (< 36 kV. Small power or small voltage is typically found in the distribution circuits of commercial buildings or industrial facilities. In this section, we are mainly concerned with transformers in South frica power distribution system.

'No-losses' (also called ' iron losses') in the core of a distribution transformers occur whenever the transformer is energised, but no activily transmitting a load (through hysterisis and eddy currents). ' Load losses' (also called ' wiring' or ' copper' losses) occur when the transformer supplies a load (caused by the electric resistance in the wiring, and their magnitude varies with the square of the magnetic flux, see figure). The peak efficiency of a transformers occurs at the point where no-load losses are equal to load losses. For a given efficiency, the no-load losses and load losses are generally inversely related.

A transformer can be made more efficient by improving materials (e.g. better quality core steel or winding material) and by modifying the geometric configuration of the core and windings).



Most transformers have relatively high efficiency levels of around 98%. The importance of national energy savings occurs because they operate almost non-stop over a very long service lifetime (15-40 years) and their large numbers in the distribution grid. So, even small increments (to 99%) can have a substantial impact on the national level.

Many countries around the world have estabished minumum energy performance standards (MEPS) for transformers. For example, European Union (EN50588-1:2014 and EU 548/2014, defining maximum core and coil losses at 100% load, mandatory, 3-phase 25-40,000 kVA), China (GB 20052-2013, maximum cor and coil losses at 100% load, mandatory, 1-phase 5-160 kVA and 3-phase 30-1600 kVA), Mexico (NOM-002-SEDE-1997, efficiency at 50% load, 1-phase 5-167 kVA, 3-phase 15-500 kVA) and USA (effciiency at 50% load, 10-CFR-431, mandatory, efficiency at 50% load, 1-phase: 10-833 VA, 3-phase 15-2500 Kva. Other countries have introduced comparative and/or endorsement labels on a voluntary or mandatory basis. When setting MEPS, countries usually follow IEC 60076 test methods.

Worldwide, transformer losses are about 5% of power consumption. By 2030, world energy consumption will be about 30,875 TWh/yr, including transformer losses of 1,462 TWh/yr. Adoption of MEPS could yield savings of 218 TWh/yr and in combination with best available technology (BAT) even up to 400 TWh/yr, resulting in CO_2 emission savings of 127-248 million tons (MEPS and BAT scenarios, respectively)

Source: Accelerating the Global Adoption of Energy-Efficient Transformers, UN Environment-GEF United for Efficiency (U4E, 2017); Eskom *Fact Sheet Transmission and Distribution* (2015)

High-efficiency transformers built with amorphous iron cores have 70% lower no-load losses (compared to best conventional designs using traditional core steel) and can achieve efficiencies up to 99.7% for a 100-kVA unit[28]. Such premium-efficiency transformers improve the material characteristics or the method with which these are used, and at the same time cost, size and weight of the transformer are contained. However, only a few companies can produce high-efficiency transformers and change their production lines. For example, the amorphous technology uses thin ribbons for the core, but this makes more difficult to handle during manufacturing (and the windings have a different shape). Another constraint to increasing efficiency is access to better-quality steel and copper. Also, the newer transformers have to fit into existing mounting locations, placing a physical constraint on the maximum size (and efficiency) of the new transformers.

The manufacturers[29], a mix of both foreign and local companies, will need to invest in upgrading their production facilities, while also Eskom and municipalities will not want to see a drastic change in the transformer price. To change to high-efficiency transformers the manufacturers will need to upgrade their production facilities (e.g. oil filling under vacuum, separate oil storage facilities, newer winding machines and improved paint spray booths) at an estimated cost of ZAR 8 to 10 million.

One approach will be to reduce losses requirements incrementally over time. Rather than fixing losses at a generally low level, the load factors will vary greatly in different areas or type of applications in South Africa. For example, it does not make sense to force very low loss cores for areas with high loading, where load losses dominate. This would push manufacturers and utilities towards reducing losses and raise the awareness that TOC improvements can be made with drastic changes in the upfront cost of transformers. Municipalities already struggle to keep up with the infrastructure damage caused by cable theft, and the general overloading of electricity transformers due to illegal connections.

Transformers are not typical consumer products, unlike the lighting products discussed in the previous section E.2, and in South Africa may be less suited to energy labelling[30]. ESKOM has been developing an internal efficiency standard, which is not yet published. This could be a basis for formulating the Minimum Energy Performance Standard (MEPS) for the country, not only to be followed by Eskom but by the municipal utilities as well. The MEPS might be based on voluntary agreements between the electricity companies and the government or as part of a mandatory regulatory and control framework.

The replacement of distribution transformers is typically done on an on-demand basis, as transformers fail or when networks are extended. The installation of new transformers falls under two central government programmes for electrification, one managed by ESKOM (ZAR 3.2 billion annually), another managed by the municipalities (ZAR 1.9 billion annually).

Most electricity utilities are typically regulated to some extent in terms of prices they can charge and operating costs that can be claimed. Typically, these regulatory frameworks allow system losses to be included in the overall operating costs, which are then passed on to consumers. National Treasury requires a “lowest cost” for the procurement of transformers and a certain amount of local content for qualifying equipment. Utilities therefore usually have no interest or incentive to increase the efficiency of distribution transformers that they install. Indeed, more efficient models will almost certainly have a higher capital cost, which acts as a strong disincentive for their selection. This impairs the purchase of higher efficiency equipment, and policies have to be modified to overcome this barrier. One way to provide an incentive for high-efficiency transformers may be to allow faster depreciation of high-efficiency models. This would provide some rebalancing of the financial penalties many utilities would see associated with high-efficiency transformers. Another approach would be to apply some form of tax, levy or other capital payment onto transformers that are below the target efficiency threshold to discourage their selection. However, there are no particular state or industry-funded programmes or initiatives to drive the adoption of energy efficient distribution transformers in South Africa.

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28 *Low-loss distribution transformers in a South African context,* by Stanford, G, Jones, G. and Withing (Powertech Transformers), 63rd AMEU Convention (2012)

29 There are about 17 distribution transformer manufacturers in South Africa. Brands include Actom Distribution, Revive Electrical Transformers, PowerTech Transformers, Electro Inductive Industries, WEG, Transfix, and Wegezi.

30 Some countries have introduced labelling schemes to differentiate between the performances of transformers based on the same rating, like in India (1 - 5 Star scheme), China (Grade 1 – 3 (CRGO), Australia and New Zealand (MEPS and HEPL levels), EU (Harmonised HD428: List A – C).

Use of vegetable oil

Most distribution transformers used in South Africa are of the liquid-immersed type. Worldwide, vegetable-oil natural esters are increasingly being used in distribution transformers as insulating oil. The use of vegetable oil would add an additional 10% to the cost of a transformer. Apart from its greenhouse reduction impact as a replacement for mineral oils, vegetable oils have the advantage that these have a higher maximum operating temperature, meaning that a transformer can be loaded at higher rating (run at a higher load factor and extend the transformer's life) and/or have an extended life (up to 40 years). In addition, vegetable oils have better fire safety (having a larger flash and fire point than mineral oils) and reduced spread (due to their higher viscosity) in spillage conditions.

Vegetable oils, such as rapeseed, soy or sunflower oils, are bio-degradable. The insulating oils could be recovered after the transformer's service and processed to be used as biofuel. One proposal being discussed at Eskom is for new contracts on transformers, these will incorporate 30% ester oil in the first year, 60% in the second year and 100% as of the third year onwards.

2.4 Waste management and recycling

E-waste

Informal sector salvaging, both at the street level, and at the landfill, constitutes the bulk of recycling activities in South Africa. Recovered quantities and types of material are highly dependent on the market demand, price and industry organised collection, buy-back, and redemption systems. As a consequence, waste separation and formal recycling remain a concept foreign to many South African households.

Lighting waste has internationally been incorporated under e-waste (electric and electronic waste). Fluorescent lamps have a special status as these contain small amounts of mercury[31], which is a hazardous substance. Recovery options possible are retail outlets, buy-back centres, ESKOM offices, municipal facilities, and dedicated mobile units. An ESKOM-eWASA[32] study mentions that the points of sale would constitute a central location for collection, but in low-income or rural areas these are often not 'within walking distance' and mobile units might offer a plausible solution. After collection, CFLs are taken to recycling centres. The first step of processing CFLs involves crushing the bulbs in a machine that uses negative pressure ventilation and a mercury-absorbing filter or cold trap to contain the mercury vapor. Then, the crushed glass and metal is stored in drums, ready for shipping to recycling factories. In South Africa, companies such as Reclite, Balcan Engineering, Crush Lamp, collect and/or recycle various types of lamps and separate into fractions, including the recovery of mercury.

There is currently no specific legislation that deals with e-waste in South Africa. However, the new National Environmental Management Waste Act (2008) has implications for e-waste management and makes it illegal for individuals or companies to send e-waste to landfills. DEA is considering to split the two categories, e-waste and lighting, and be dealt with separate waste management plans. In November 2011 the National Waste Management Strategy (NWMS) was established to achieve the objects of the Act.

PCBs

South Africa is a Party to the Stockholm Convention on Persistent Organic Pollutants ("Stockholm Convention"). Polychlorinated biphenyls (PCBs) form one of twelve) Persistent Organic Pollutants (POPs) governed by UNEP (United Nations Environmental Program) according to the outcome of the Basel Convention that was ratified in 2001, with South

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31 Most CFLs contain about 3-5 mg of mercury and a T12 linear fluorescent about 5 mg of mercury, which is a bio-accumulative toxicant that is easily absorbed through the skin, respiratory and gastro-intestinal tissues.

32 *Recovery of Compact Fluorescent Lamps from the general household waste stream,* eWASA, Eskom, Alakriti Consulting

Africa being a signatory. The country published in July 2014 Regulations (# 37818) on the phasing out of the use of (PCBs) and PCB-contaminated materials. The Regulations prohibit the use, production, import and export and sale of PCBs or PCB contaminated materials, during the phase-out period, without registration. The use of PCBs and PCBs contaminated materials is to be phased out by the year 2023, with a further three years provided within which PCB holders have to dispose of their stockpiled PCB materials, PCB contaminated materials and PCB waste in their possession.

PCBs were formerly used in transformer oil, since they have high dielectric strength and are not flammable. Unfortunately, they are also toxic and not at all biodegradable, and difficult to dispose of safely. When burned, they form even more toxic products, such as chlorinated dioxins and chlorinated dibenzofurans. Starting in the 1970s and 1980s, production and new uses of PCBs were banned in many countries, due to concerns about the accumulation of PCBs and toxicity of their by-products. The main electricity supplier in South Africa, Eskom, still has does have power (transmission network) transformers and capacitors with PCBs, but a programme with the aim of a getting PCB-free system is in place. Eskom has also shipped some PCB-contaminated oil overseas for monitored incineration. Batch testing of Eskom' s distribution transformers has shown that these do not contain PCBs. One can conclude that nation-wide only a small percentage of the remaining equipment contains PCBs in the oils, and these are being replaced as they become redundant. Eskom has procedures in place to prevent further contamination during transfers and maintenance.

2.5 Financing of energy efficiency and the market for energy services

The market for energy efficiency services

The energy services market uses many different definitions to reflect the varying interests of the broad spectrum of stakeholders involved. *Consultancy services* are provided by energy auditors, planning engineers, certified measurement & verification personnel (CMVPs), accountants, lawyers, and others. Payments for consultancy services are commonly agreed upon based on their inputs (hourly rates or a lump sum). *Technology suppliers* provide hardware, such as lighting, or software such as energy accounting or management packages. These are paid for the supply and/or installation or maintenance of these components, though typically not for their performance or outputs. *Energy Service Companies (ESCOs)* typically provide performance-based energy contracting, also referred to as ESCO or energy efficiency services. In the *Energy Performance Contracting (EPC*) business model, ESCOs provide energy savings measured in comparison with a previous energy cost baseline. *Engineering Procurement Contractors* provide the detailed engineering design of the project, procure all the equipment and materials necessary and then construct to deliver a functioning facility or asset to their clients.

The Department of Energy, with the Department of Public Works, has set an energy savings target of 15% for the government's portfolio of nearly 100,000 public buildings. The standards SANS 1544 *Energy performance certificates for buildings* specifies the methodology for calculating energy performance in existing buildings. This standard is mandatory for all public buildings since 2016. These Energy Performance Certificates (EPCs) will be issued by trained assessors. Although the regulations will only apply to government buildings that have a floor area greater than 1,000m^2, it is expected that the regulations will be extended to the commercial sector by 2020 (SANAS, 2016). This creates opportunities for many players in the energy efficiency value chain, including technology providers, project developers, installers, and financiers, or ESCOs offering consolidated solutions in existing buildings (i.e. retrofits) and in new buildings.

An IDC-commissioned report estimates the EE market in 2011 in South Africa as 12,993 MW, of which 939 MW in the residential, 115 MW in the commercial and 116 MW in the industrial sectors for efficient lighting. Over the period 2012-2020 another 5,500 MW would be added. Out of this potential, the market for energy efficiency service providers (ESCOs) would be 6,000 MW (at least ZAR 2.6 billion with an estimated 26 million GWh savings) [33].
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[33] See IDC (2013) *Developing a vibrant ESCO Market – Prospects for South Africa's energy efficiency future*; GreenCape *Market Intelligence Report* (2015, 2016, 2017)

Financing models

1) Standard project development – grant and debt funding

The traditional model separates the project development from the funding of energy efficiency projects. The end-client develops a set of requirements and runs a selection process for the installation of the project in a process separated from the acquisition of funding for the project. It requires the end-clients to be technically competent in the development of adequate Terms of Reference for the project and be able to analyse the technical proposals from the supplier/installer.

In grant funding cases, the funds are provided as long as the projects meet certain criteria (that can be very detailed and cumbersome to analyse for the client). The reason is that grant funding often has a higher-level objective, and the grants are only provided with a very strict set of criteria that perfectly matches this objective. This creates the risk of developing projects that are suitable for this higher-level objective but would otherwise have limited demand from the end user (uncertain 'ownership' by the client). The performance risk stays with the client.

Public sector clients typically follow very strict and regulated processes for capital expenditure projects such as energy efficiency projects. In the case of South Africa, these activities are primarily regulated by the Municipal Finance Management Act (MFMA) and the Municipal Systems Act (MSA). Important differences exist between the different types of municipalities, in areas such as their credit ratings, their revenue generating capacities and the level of financial support from the central government. The larger metropolitan municipalities (metros) generate a substantial part of their revenues from internal sources and the grants from the central government represent a much smaller portion of their funding. They also have investment-grade ratings, facilitating their borrowing processes and achieving similar borrowing costs as those of the central government.

South African municipalities have a clear incentive to reduce energy consumption from their own infrastructure, as the energy costs of street lights and distribution transformers are attributed to the municipality either indirectly (as non-chargeable electricity consumption) or directly (in the case that ESKOM manages the electricity supply to a certain area, street-light electricity bills are issued to the municipality). On the other hand, any reduction of electricity consumption from private end-users would have a negative financial impact on the municipality, due to reduced revenue from the sale of electricity. However, due to the continuous strain on the electricity system municipalities are in general supportive of energy efficiency programs if they help to reduce peak loads and increase the security of supply.

In South Africa, examples of government grant schemes are the Municipal Energy Efficiency and Demand Side Management (MEEDSM, administered by DOE), see Box 34 and the Municipal Infrastructure Grant (which excludes the metropolitan municipalities), administered by the Department of Cooperative Governance, see Box 22). Other examples are the Integrated National Electrification Program (both for municipalities and ESKOM), and the Urban Settlements Development Grant (which is focused on providing housing to reduce the numbers of informal settlements; administered by National Treasury).

These programs, in their current form, have been proven insufficient to address the transition towards higher efficiency LED lighting and distribution transformers, and funding is often used to reduce the backlog of issues in the infrastructure. Despite the insufficient grant funding available from the central government, municipalities, in particular, those from rural areas, are accustomed to sourcing a substantial part of their revenue from grants, and it is an integral part of their expectations to receive grant funding for energy efficiency projects.

Box 20 Government-sponsored schemes for energy efficiency and municipal energy efficiency

Under the **Municipal Energy Efficiency Demand-Side Management (MEEDSM) programme**, established by the Department of Energy, allocated by the National Treasury, through the Division of Revenue Act (DORA), municipalities can receive grants for the planning and implementation of energy efficient technologies ranging from traffic and street lighting to energy-efficient technologies in buildings and water service infrastructure. By means of Calls for Proposals, municipalities can submit EE and DSM proposals. The cumulative energy saved as a result of the programme based on projected targets is approximately 1.8 PJ, mainly through street lighting retrofits. The programme has delivered grants to 68 municipalities in South Africa since 2009 with a budget of ZAR 1264 million (2009-2015/16) and planned energy savings of 500 GWh (1.8 PJ), benefitting over 32 million people. With GIZ-support, DoE is implementing the *EE Street Lighting Retrofit Project (2014-2019),* which provides technical assistance, capacity building (at national and municipal level hardware infrastructure investments aiming at retrofitting about 12,000 MV as well as retrofitting HPS with LED (highways, high masts, and BRT corridors). The budget is approximately EUR 5 million, of which EUR 3.2 million for procurement (street lighting).

For the coming years, the MEEDSM programme will continue with a budget of about ZAR 200 million a year (ZAR 215 million in the 2018-19 budget). Nonetheless, the programme has reached annually just 12% of the municipalities in South Africa. To make more funding avilable to more municipalities, DoE is now discussing the possibility to reduce the level of grant funding under the MEEDSM from 100% of the project value to a lower percentage as a way to leverage the grant program, increase the number of projects and municipalities that receive funding and let the obtain funding from other sources. However, such a proposal will be opposed by many of the financially constrained municipalities.

DoE has made funds available through the **Approach to Distribution Asset Management (ADAM**) programme that will deal with the funding of the maintenance. Most of the infrastructure used by municipalities and Eskom is over 40 years old and it needs billions of Rand to be replaced or refurbished. In 2008, the maintenance backlog was ZAR 27 billion and in 2014 this had increased to ZAR 68 billion (municipalities: ZAR 32 billion and ESKOM: ZAR 36 billion). Municipalities collectively owe Eskom ZAR 11 billion over failure to pay the power utility and growing at the alarming rate of R 2.5 billion per annum (based on a study adone by Electricity Distribution Industry Holdings, EDIH). The National Energy Regulator of South Africa warned that 6% of electricity revenue of municipalities should go to the maintenance of infrastructure,

In response to the power shortage and load shedding situation (described earlier), Eskom's Energy Efficiency and Demand-side Management programme (EE-DSM, now called, **IDM, Integrated demand management**) embarked in 2008 on a campaign to exchange incandescent bulbs in homes for more energy efficient CFL bulbs (free-of-charge, primarily in the low-income households). As of January 2017, more than 65 million had been distributed to homes across South Africa, making it one of the biggest energy-saving initiatives. Eskom has directly procured these lamps for delivery to householders with a door-to-door campaign method*. The electricity supply situation has stabilised, and since 2016 there has been an over-supply. In this context and given ESKOM's funding constraints (described earlier), ESKOM is scaling back its IDM initiatives, now focussing solely on the residential CFL mass rollout and the ESCO programme.** However, the CFL exchange program will end and Eskom has no plans to continue it (with LED technology) in the foreseeable future.

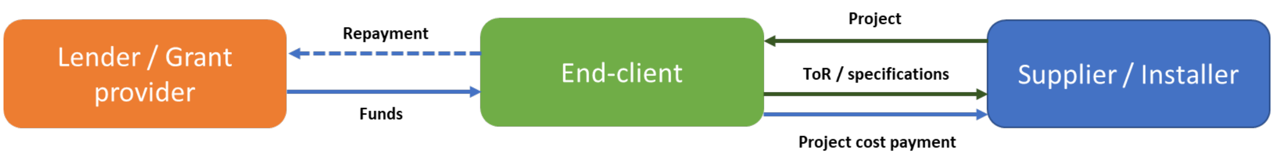
* The ESKOM EE-DSM programme also had a component that serves commercial buildings and the services are the Standard Offer (SO) and Standard Product (SP) most suited for residential and small commercial buildings, including efficient lighting (SP is for savings up to 250 kW). Eskom put the SO and SP rebate programmes on hold in 2014.

** The ESCO pgramme considered funding for commercial and industrial sector project that were able to shift electrical load outside Eskom's evening peak periods.Project proposals were invited from ESCOs, project developers, or businesses with a turnover of less than ZAR 50 million

Debt instruments include loans from a traditional (commercial) banks or a concessional loan from development banks or development partners, often through a specialized vehicle such as a sustainable energy or climate change mitigation fund. The debt funding limits the provision of funds to those clients with higher credit-worthiness. It also requires a credit analysis of the end-client, which in non-specialized lenders typically follows the same procedure as a loan for non-energy projects.

This neglects the effects that the energy efficiency project will have in the cash flow situation of the client, which, depending on the scope of the project may indeed have substantial implications to the financial situation of the end-client. A hybrid source of funding is the utilization of grant or concessional funding to provide a loan with favourable terms and conditions. In this case, the criteria to provide funds is relaxed compared to a pure grant-funding scheme, and it allows the development of a sustainable mechanism that does not require a constant replenishment of funds (particularly in the first years). Such a mechanism also provides an economic incentive to end-users to take commercial sources of debt by lowering the overall financing costs. As with grant financing, it requires 'technically competent' clients (or outside project preparation support).

For small-scale investment projects of similar type by similar end-clients (e.g. street lighting for small municipalities or LED lighting for households) this model may benefit from a joint procurement approach, whereby the aggregation of projects achieves economies of scale in the purchasing process. This approach may also be applied through an intermediary (distributor/reseller) of equipment. A graphical summary of this model is indicated below.



The Development Bank of Southern Africa (DBSA) is a development financial institution (DFI) with a focus on the public sector in Southern Africa particularly for the financing of infrastructure projects). In South Africa, DBSA's loan portfolio heavily concentrated on municipalities, with 34% of the loan portfolio and on public utilities (primarily ESKOM) with 35% of the loan portfolio. DBSA has been implementing a number of programmes:

- The *Green Fund* (and to which DEA added ZAR 800 million) has been supporting project development and investment, capacity building and policy research in green projects by means of grants, loans and equity, including energy efficiency (within its focus areas of 'green cities and towns' and 'low-carbon economy'). The Fund closed in 2018 for new proposals.
- The Bank is accredited to the Global Environment Facility (GEF) and the Green Climate Fund (GCF)
  - With GEF support, DBSA is currently implementing two energy/urban-related projects, *Cities-IAP: Building a resilient and resource-efficient Johannesburg: increased access to urban services and improved quality of life* (GEF 9415; GEF funding: USD 8.09 million) and the *SP-IPPPP: Equity Fund for the Small Projects Independent Power Producer Procurement Programme* (GEF 9085, GEF funding: USD 15 million);
  - The GCF-funded *Climate Finance Facility (CFF)* is in its latest development stages and pending finalization with the private financing providers. It was approved by GCF in October 2018 to receive a total of USD 55.6 million of funding. DBSA and other private financiers are co-funding this program which is expected to achieve a total size of ZAR 2 billion. The CFF will be structured as a self-sustaining debt facility and will evaluate and finance projects, drawing capital from multiple dedicated sources, to provide credit enhancement and debt funding (in various forms) to drive private investment The Facility targets climate-friendly (e.g., renewable energy, water, transportation and waste) projects in the four countries that comprise the common monetary area of southern Africa (South Africa, Namibia, Lesotho and Swaziland. The CFF will be structured as an independent special purpose vehicle (SPV). Funds committed to the CFF will not sit on the DBSA balance sheet, but rather within this distinct legal vehicle.[34]
  - Another GCF project is the *Public & Private Sector Energy Efficiency Programme (PPSEEP).* This program aims to provide funding (with low-interest rates) to medium-sized energy efficiency projects both for public and private clients (direct funding), as well as providing additional support to the ESCO market as a critical element of off-balance sheet funding and risk sharing. The PPSEEP is currently in its formulation stage. On a broad description, it builds on the National Business Initiative (NBI) and a large set of energy audits previously developed by the Carbon Trust.[35]

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34 For these reasons and due to its focus on larger investments, this has made it difficult to propose CFF as DBSA co-financing for the "Leapfrogging LED and Transformers" project.

35 The private sector target companies may include ESCOs performing projects for the municipalities as long as the risk is taken by the ESCO, which aligns quite well with the shared-savings model

Rural municipalities have a higher cost of external finance, are heavily dependent on central government grants and some of them are currently in debt recovery status. The funding allocation from all the infrastructure grant programs has resulted in that rural municipalities are accustomed to receiving grant funding for these projects and makes it difficult for non-grant programs to be developed. On the other hand, metropolitan municipalities receive relatively little grant funding for these purposes. The eight larger, metropolitan municipalities have good access to capital markets. They are considered investment-grade, with interest rates marginally superior to those of the national government (e.g. 10-year South African government bond currently yields 9.2%). Considering their substantially stronger revenue generation and their investment-grade status, a financial mechanism that includes a debt component may, therefore, be suitable for the metropolitan municipalities. It is worth noting that the municipalities do not typically request debt funding for specific projects once their project preparation phase is completed, rather the capital expenditures for the following three fiscal years are planned in a very well-defined budget development process. If external funding is deemed to be required for the approved budgets, the treasury department of the municipality issues a tender for the provision of such funding. DBSA regularly participates in such tenders and currently has credit lines open to most of the major municipalities.

2) ESCO models

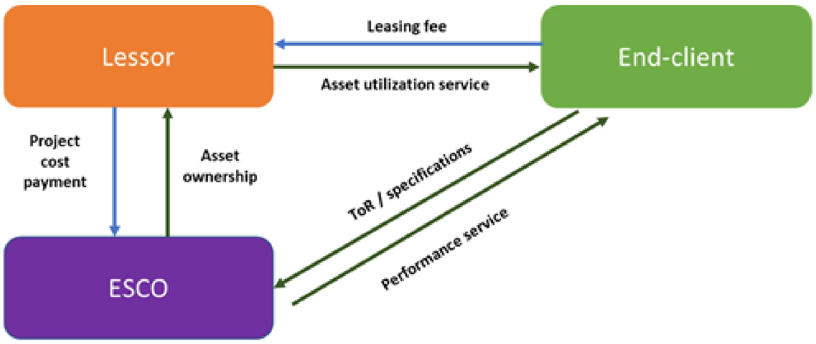
This financing model introduces the Energy Services Company (ESCO) concept. This is a special service provider that combines procurement of goods, project installation capability and a post-installation service. ESCOs work on '*energy performance contracting (EPC)*' basis, which provides energy savings measured in comparison with a previous energy cost baseline and in which the ESCO's remuneration depends on the respective outputs of the services provided. In principle, customers can have off-balance financing that will pay for the project through energy savings. A major advantage is that customers can fund the project over time and can do so with very little or no discretionary budgets and at relatively low risk. The models do require a proven ESCO presence in the energy efficiency market.

In the guaranteed savings (or performance guarantee) modality, the client makes the investment (from his own funds or the banks, or leasing) but the ESCO provides a guarantee for the energy savings realised. Based on *end-user or third-party financing*, this model has the advantage that interest rates are usually much lower and therefore more energy efficiency investment is possible. At the same time, the risk for the end-client is reduced by transferring to the ESCO the responsibility that the project will perform correctly. Penalties are applied to the ESCO should the performance of the project not meet the contractually agreed terms. A graphical summary of this model is indicated below.

This model has similar advantages and disadvantages to the standard project development but transfers part of the project performance risk to the ESCO. Typically, ESCOs build a portion of these performance risks in the project cost, increasing the capital investment requirements. Additional measurement and verification costs also need to be included which may result in the end-clients perceiving the project cost as "inflated" compared to a traditional project development case.

The more technically-competent end- clients like the metropolitan municipalities in South Africa may see a limited value on this model. The rural municipalities with less internal capacity are also more financially constrained, which means that they may not be able to access competitive sources of funding.

A variation of the modality is *lease-purchase*, in which the end-client leases the assets implemented by the ESCO and receives ownership at the end of the lease contract. Typically, the ESCO arranges the financing solution for the end-client with a leasing institution. This is a common model in energy efficiency projects in the public sector in developed ESCO markets. Despite its higher headline interest rates, it is a good alternative to traditional debt financing sources (loans, bonds) as they are much faster to deploy (it also allows the organization to pay for facility upgrades by using funds that are already allocated in its annual energy budget, which simplifies their internal approval processes). The modality does not require technically- competent client and the performance risk is transferred to the ESCO. However, it requires leasing companies to understand the ESCO model and clients to be financially competent (or have additional project preparation & post implementation support). A graphical summary is given below:



In the case of South African municipalities, the management of public finances follows an integrated plan with clearly defined processes, which would result in implementation timelines of this model similar to others. This model also requires the utilization of a specialized financial institution with deep knowledge of the ESCO model (not present currently in South Africa) and internal capacities to assess the projects and take ownership of the assets. Applying the model in the Project's Financial Instrument (EEFI) may lead to duplication of efforts with the shared-savings model for energy efficiency in public buildings implemented under the V-NAMA programme (see Box 21).

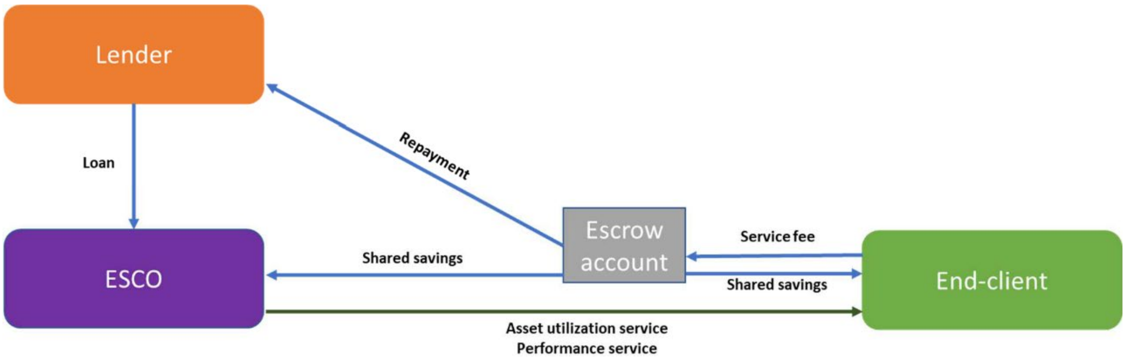
In the shared savings modality, the ESCO guarantees the performance of the installation *and* invests or provides financing, and recoups this through the contracting fee, i.e. the cost savings (due to reduced energy consumption and maintenance) are shared by the ESCO and the client at a pre-determined percentage for a fixed number of years. Thus, the ESCO guarantees a certain level of cost savings to the customer, assuming both the performance and the credit risk. Maintenance of the facilities is also typically included in the scope of the ESCO.

A regular measurement and verification (M&V) report assesses the actual savings achieved during the period analysed and determines the savings split. This report is typically performed on an annual basis and is used to reconcile the amounts due to the ESCO and the scheduled payments performed by the end-client under the contract. Depending on the result of the M&V report, an additional payment is performed by the client or by the ESCO to settle the balance. The savings split may include the allocation of excess savings to the end-client in order to align its incentives into achieving good performance.

This model has several advantages. It substantially reduces the risk for the end-client and does not require any upfront capital. It also shifts the credit assessment to the ESCO, instead of the end-client and allows the reduction of transaction costs by packaging multiple projects from one ESCO into a single loan. The main disadvantage of this model is that it increases the complexity of the program management, as payments to be made to the ESCO depend on the monitoring and verification (M&V) of the savings. In less-developed markets, ESCOs may not offer this model due to the inherent risk for them and inexperience with actual project implementation and verification of savings[36]. There are options to mitigate this complexity and potential delay in the payments, such as the establishment of a fixed annual fee (aligned with the expected savings of the project) into an escrow account, or the addition of an energy service agreement, whereby the utility bills are

[36] In the case of South Africa, all the metros and ca. 75% of the local municipalities purchase electricity in bulk from ESKOM and supply it to the local residents. This means that the electricity consumption associated with street lighting is concealed in the bulk electricity purchases and accounted either as losses or as self-consumption. In those cases, there is no "street-lighting electricity bill" to be paid to ESKOM, and clients are forced to use other M&V types. Despite the fact that the energy consumption for this infrastructure is typically hidden in the bulk electricity purchases, it still represents the largest component of own-consumption for municipalities. As example, in the case of Johannesburg, street lighting represents ca. 95% of "non-billable" electricity usage (the rest is composed of own-buildings electricity consumption and the "free-basic-electricity" subsidy). It is therefore important for the project to raise awareness within municipalities that are not conscious of this point.

channelled through the ESCO and the client pays a predetermined fee that takes into account the expected cost reductions. In both options, an annual settlement of the achieved savings is required, unless a simplified M&V option (e.g. IPMVP type A) is utilized. This M&V option determines the energy savings at the beginning of the contract and payments are based on this initial performance assessment. A graphical summary of this model with the escrow account option is indicated below:



This model represents a valuable proposition for South African municipalities with limited technical capabilities and low credit ratings. It allows the transfer of infrastructure development, performance risk and potentially maintenance costs to an external company, the ESCO. This model is also a valuable approach for industrial and commercial clients, as the small size of energy efficiency projects from these clients does not typically justify a credit assessment process. The main advantage for the metros is the possibility to finance these projects from an OPEX standpoint, which is more stable and with pre-allocated amounts, facilitating the decision-making process. Municipalities are very risk-averse with their finances and want to avoid over-indebtedness. Due to the nature of the municipal budget approval, CAPEX projects have to be approved by the city council (or funded through grants).

However, currently, there is unclarity in the accounting policies of municipalities' treasury departments regarding the shared-savings model. These contracts frequently contain at the same time elements of a rental, a service, a purchase and a loan agreement, which makes its recording complex and potentially ambiguous. The underlying reason for the ambiguity is whether the equipment installed by the ESCO is in effect municipally-owned or not. If municipal-owned, the accounting should not be different than a contract for the procurement of assets combined with a service contract and a loan liability to the ESCO. This means that these projects are considered a capital expenditure with a corresponding debt increase in the balance sheet of the municipality. This accounting approach would void one of the main potential advantages of the shared-savings model, which is the off-balance sheet financing of this infrastructure upgrade (booking it as an operational expenditure, in a similar way as an operating lease). Public sector ESCO procurement will benefit from a process being developed to allow municipalities to procure energy services for longer than three years. A standardised Request for Proposals (RFP) format is being created, funded by the GIZ. The RFP seeks to overcome the hurdle for municipalities to enter into long-term service agreements by creating a template that all municipalities can easily adopt, adapt and follow in procuring services from ESCOs.

A variation of this model introduces the role of a *Super-ESCO*, which acts as an additional agent between the ESCO, the lender and the end-client. The Super-ESCO manages most aspects of the project, including the detailed technical design, sourcing funds, providing performance guarantees to the client, selecting smaller ESCOs for project implementation, aggregating projects and overall management and coordination of the implementation and performance guarantee phases. This option greatly simplifies the program for the end-client, reduces transaction costs for the lender, and supports the development of internal competencies amongst local or more inexperienced ESCOs. It also achieves economies of scale thanks to mass procurement of energy efficiency equipment. The main disadvantage is that a Super-ESCO may grow to dominate the ESCO market, creating a monopolistic situation.

In India, the Super-ESCO model has been successfully applied and showcased in LED public lighting projects. Energy Efficiency Services Limited (EESL) is a super ESCO set up by the Ministry of Power. EESL typically operates with a government guarantee

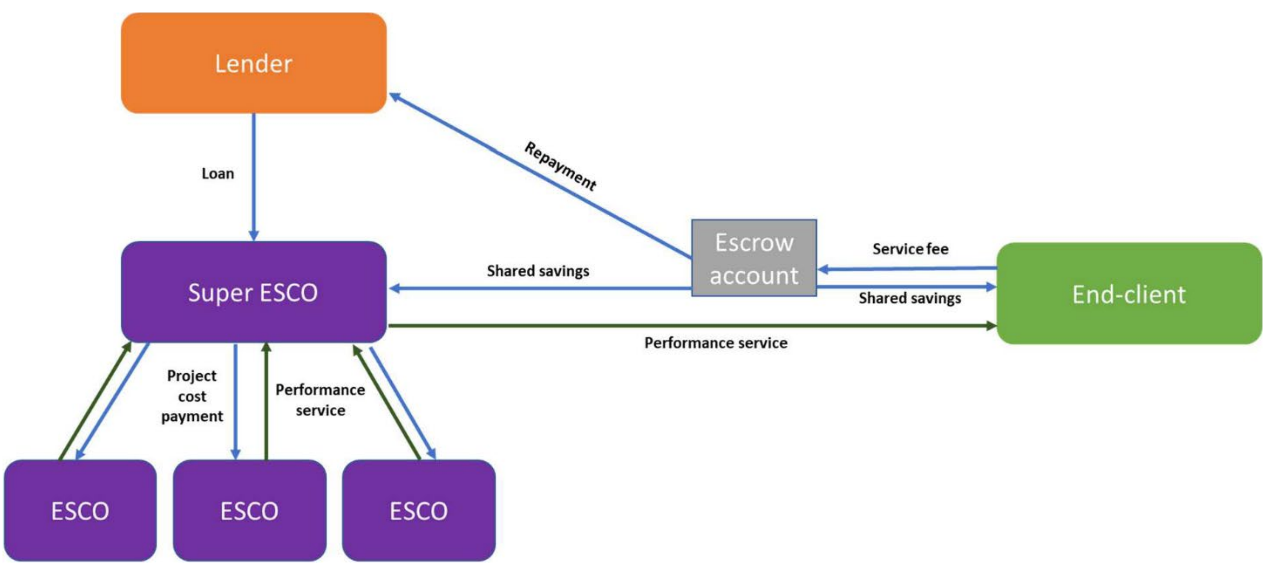
Box 21 Energy Efficiency in Public Buildings and Infrastructure Programme (EEPBIP)

The V-NAMA* **Energy Efficiency in Public Buildings and Infrastructure Programme (EEPBIP**) uses the procurement potential of the public sector to strengthen the market for energy service companies (ESCOs) in order to establish a critical mass of projects in the market, and it incorporates already existing expertise in identifying energy efficiency potentials in public buildings into which ESCOs are invited. EEPBIP will be implemented with a EUR 20 million budget during 2019-2023. In its financial component (EUR 15 million), a Project Preparation Facility enables provinces and municipalities to develop bankable energy efficiency investment plans for their public buildings. About ZAR 12.3M may be dedicated to the partial guarantee for loans. The Guarantee Fund supports private ESCOs in raising the necessary finance for entering contracts with the public owners of these buildings to finance and implement these plans (based on the "shared-savings" ESCO model, without the Super-ESCO; see main text). The financial partner may be the Industrial Development Corporation (IDC). In its technical component (EUR 5 million), a Service Desk advises provinces and municipalities on energy efficiency opportunities in public buildings by helping to raise awareness, understand the potential for energy efficiency and associated profits and carbon savings, set baselines and targets and finally identify concrete energy saving opportunities. The desk supports the government in measuring the EEPBIP's results and it supports further development of mechanisms that promote energy efficiency.

* Vertically integrated Facility funded by the German Federal Ministry for the Environment and Nature Conservation and the Department for Business, Energy and Industrial Strategy (BEIS) of the United Kingdom (UK) in 2013 with GIZ provided technical assistance. Other donors have contributed to its various Calls for Proposals (Denmark, European Union).

scheme as risk mitigation in the case of performing ESCO services. EESL replaced about 92,000 HPS and TL street lights with LED lighting, resulting in 50% energy savings and improved road illumination levels in the city of Vizag, and is working with the Indian Bureau of Efficiency in other municipalities[37]. EESL has performed a mass LED rollout program known as UJALA that as of November 2018 has distributed over 330 million LED lamps. This program heavily relies on electricity distribution companies in India (DISCOMs) to distribute the lamps to the end-consumers. These lessons and the potential role of equipment supplier could be useful for the setup of a lighting rollout program in collaboration with the municipalities in South Africa.

A graphical presentation of the Super-ESCO model is given below:

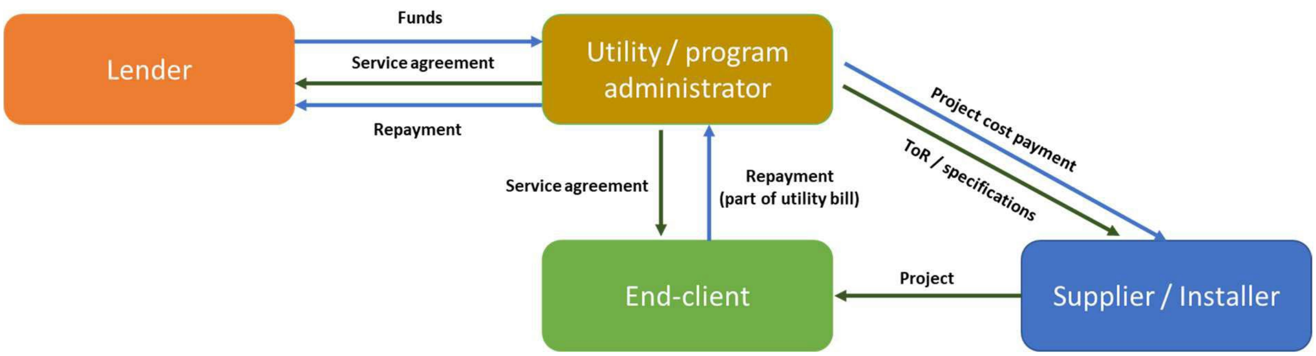


3) On-bill financing

[37] *Proven Delivery Models for LED Public Lighting: Super-ESCO Delivery Model Case Study,* World Bank, ESMAP

On-bill financing model allows end-clients to pay for energy efficiency investments through their utility bill. Typically, the range of investments is limited to a set of pre-approved technologies that the utility deems relevant for the program. Funding for the measures may be provided directly by the utility with their own funds, a revolving fund or by a third-party finance provider. As utilities already have a commercial relationship with the end-client and the projects are bundled in a credit facility, this model allows for a simplified process, reducing transaction costs for small energy efficiency investments. It also allows access to energy use profiles of the client, which may be useful for the technical project design.

This on-bill financing model reduces the risk of credit default as the contracts typically allow for disconnection of the service to customers who fail to make their loan payments. When correctly implemented this also results in a net cash-positive or at least cash-neutral financing system for the end-client, who sees in the utility bill an energy cost reduction equivalent to the loan repayment amount. These characteristics make this model suitable for large number of clients, where it is not feasible to perform individual credit assessments and cases where the electricity consumption reduction will be noticeable in the bill by the end-clients, effectively limiting its scope to private end-clients. This model has the difficulty that it requires an update the billing system of the utility to incorporate these charges as well as an information exchange platform with the financing provider if this is a third party. A graphical summary of this model is indicated below.



This model poses the challenge that municipalities obtain a substantial portion of their revenue through the sale of electricity (which they buy at bulk prices from ESKOM and supply to end-clients adding their own margin); at first look, they would not be interested in cutting this revenue by encouraging their clients to consume less. However, other considerations, such as overall peak demand reduction play an important role. For example, City Power states that peak demand reduction is the primary goal of their "energy management" efforts. The reason is that high peak demands are costly for the municipalities. Their bulk electricity purchases at peak times have the highest price per kWh and include a monthly peak demand charge. Municipalities are not able to directly pass these costs to residential users, which are instead included in a flat monthly fee based on the type of connection or blended with the unit price. High peak demands also result in high maintenance costs for municipalities as overloaded transformers fail at those times. Utilities pay a fixed price for peak capacity demanded from the network. This cost is not directly transferred to the consumers, but built into fixed charges or the kWh price.

A further LED penetration and price reduction may be achieved through a mass procurement program that channels the lamps through an existing network of distributors. Synergies with other residential energy programs such as the Shisa solar program in Durban, the smart-meter rollout in Johannesburg or the social housing programs that all municipalities manage would facilitate the deployment of this technology. This program could be deployed in collaboration with the utilities supplying electricity to these clients, which would open the possibility to include an on-bill financing program. Such a program would enable a streamlined process for the project sourcing, implementation, and fund deployment.

Let us look at municipal efficient residential lighting programme, in which the users repay the cost of the LED through a small charge in their utility bill (on-bill financing). The installation of efficient technology, i.e. LED lamps, results in a reduction of the connected load in the system, which in turns reduces the demand charges that the utilities face and that are not passed on to the residential users. This results in a positive impact in the municipal utility charges that balances the revenue sales loss. It also generates a reduction in electricity consumption that may be allocated to industrial or commercial users with a higher tariff. Together, this could allow the municipal utility to 'repay' the LED lamp programme in a period of 3-10 years.

Thus, several municipalities have supported the introduction of energy efficiency. The expected collaboration with municipalities on the development and financing of projects related to their own-consumption may be leveraged to introduce an on-bill financing mechanism for private commercial and industrial end-users once the Project is operational.

4) Public-private partnership model

The public-private partnership model consists of a long-term collaboration agreement (typically 20-30 years) between public and private entities. The contracts are typically used in large infrastructure projects, where the private sector installs and maintains the assets. The private entity also typically raises the required funding under a project-finance structure through a Special Purpose Vehicle (SPV). The public entity then pays an agreed-upon fee for the provision and utilization of the infrastructure. The aim of this model is to reduce life-cycle infrastructure costs, by gaining cost efficiencies in the design, installation and operation phases of the infrastructure, even if the financing costs are typically higher for the private sector than for the public sector. Experience has shown that this type of model is only suitable in certain situations, where a large infrastructure investment is required and supportive policy environment exists in the country.

Street lighting projects have been included in the scope of some PPPs within a municipality, but mostly PPPs are in large infrastructure development and maintenance projects such as roads, bridges, traffic signals, etc. Although South Africa has legislation that supports this type of contracts, the application to the municipal level is done through the MFMA framework with some additional requirements. The complexities of the PPP model and the tight control that the municipalities have over the electricity distribution and street lighting infrastructure makes the viability of this model questionable for the deployment of street lighting and distribution transformers in South Africa.

<u>Procurement guidelines and energy efficiency</u>

Local government often struggle to digest procurement guidelines, environmental requirements, and new procurement funding approaches. Performance contracting does not fit easily with standard procurement procedures, raising issues around asset ownership (of installed equipment) and requiring financial arrangements very different from the 'pay-on-delivery-of-a-specified-service' model. Local government finances tend to be tightly controlled by the national governments. In the case of South Africa, these are governed by the Municipal Financial Management Act (MFMA). The MFMA does not have any provision for the allocation of financial liabilities to ESCOs. It also includes a restriction to municipal finances that is key for energy efficiency project. It limits the municipalities to engage in financial obligations that span for more than three years (with some exclusions, such as long-term debt, which follows a specific procedure). Any municipality intending to enter into a service contract for a period of time longer than three years is required to follow a rather complex approval procedure. These aspects of the MFMA represent important barriers (not insurmountable, but barriers, nonetheless) to the implementation of an ESCO model where the financing for the equipment is provided to the ESCO.

In addition, electricity expenditure savings do not appear as budget line items, making the benefits of the ESCO project less apparent to the 'system'. Further to these challenges, procurement systems traditionally resist purchasing goods, which have higher capital cost, even if they have lower life-cycle costs. This is a constraint to implementing many EE options, and also has been a deterrent within individual departments as capital budgets and operating budgets are set and treated budget[38].

[38] The Public Finance Management Act (1999), National Treasury Regulations (2005), and the Municipal Finance Management Act (MFMA) of 2003, govern the financial and supply chain management functions of Local Government. One of the prescribed minimum standards of procurement is value for money in terms of acquisition cost. The National Environmental Management Act (NEMA) and policy (NEES) encourage the adoption of resource efficient procurement – value for money option taking into consideration "life-cycle cost" of product to reduce resource usage.

Box 22 Advantages and disadvantages of various financing models

Model	Advantages	Disadvantages	Assessment for South African Market
Standard project development - Grant funding.	Acceptance by end-clients. Applicable to all clients.	Requires technically competent clients or project preparation support. Requires constant replenishment of funds. Performance risk stays with the end-client. Uncertain end-client "ownership" of the project.	Feasible, requires 3rd party co-financing to achieve scale.
Standard project development - Debt funding.	Keeps end-client in control of infrastructure. Self-sustainable.	Requires technically competent-clients or project preparation support. Requires credit-worthy clients. Performance risk stays with the end-client. Funding cycles from municipalities are defined. Costly administration.	Limited to credit-worthy municipalities.
Standard project development - Concessional Debt funding.	Lowers overall cost of funding. Allows co-financing structure, leveraging public funds. Allows co-existence with other financial mechanisms. Keeps end-client in control of infrastructure. May be self-sustainable.	Requires technically competent-clients or project preparation support. Requires credit-worthy clients if external co-financing is needed. Requires repayment of funds. Funding cycles from municipalities are defined. Costly administration.	Feasible.
ESCO model, performance guarantee - Financing the end-client.	Less limited by the technical capability of end-clients. Performance risk transferred to ESCO. Self-sustainable.	Limited additional benefit for end-clients that understand the technologies. Requires credit-worthy clients. Requires the presence of ESCOs in the market.	Limited benefit.
ESCO model, performance guarantee - Lease-purchase agreement.	Does not require technically-competent clients. Performance risk transferred to ESCO. Bundles projects into a single funding recipient. Potential OPEX funding for end-client. Self-sustainable.	Requires leasing companies that understand the ESCO model. Requires the presence of ESCOs in the market. Requires financially-competent clients or project preparation & post implementation support. Public clients must be willing to transfer the operation of critical infrastructure to private company. Unclarity on municipal financial accounting in SA.	Not feasible.
ESCO model, shared savings - Financing the ESCO.	Does not require technically-competent clients. Performance risk transferred to ESCO. Potential OPEX funding for end-client. Bundles projects into a single funding recipient. Self-sustainable.	Requires sophisticated financial companies that understand the ESCO model. Requires the presence of ESCOs in the market. Requires financially-competent clients or project preparation & post implementation support. Public clients: requires acceptance to transfer the operation of critical infrastructure to private company. Unclarity on municipal financial accounting in SA. Perception that this model is associated with a whole-facility M&V model (requires main-utility bills)	Feasible, existing programs untested.
On-bill financing.	Suitable for small investments in the private sector Self-sustainable Potential for off-balance sheet financing through SPV	Complex administration. Requires adequate billing system infrastructure. May be perceived as a “commercial” activity by municipalities.	Not feasible for municipalities. Feasible but complex administration for private end-users.
Public-Private Partnership (PPP) model.	Suitable for long term infrastructure investments	Complex mechanism, not suitable for unsophisticated municipalities Limited benefit for typical EE project durations. MFMA still the governing structure for municipalities.	Limited added benefit.

2.6 Estimated energy savings and GHG impacts of market transformation

The United for Efficiency initiative (U4E) completed a Country Assessment for South Africa in December 2016. This assessment sets forth baseline conditions and potential for energy savings, avoided energy costs, and avoided GHG emissions from the adoption of minimum energy performance standards (MEPS) for refrigerators, room air conditioners, distribution transformers, industrial electric motors, and lighting. A summary of the U4E assessment is given in Box 23.

Box 23 South Africa – pathway to energy efficiency (U4E)

ANNUAL SAVINGS IN 2025 AND 2030

	Lighting		Residential Refrigerators		Room Air Conditioners		Transformers		Industrial Electric Motors	
	2025	2030	2025	2030	2025	2030	2025	2030	2025	2030
Electricity (GWh)	10,290.7	10,447.6	822.6	1,596.3	212.7	361.4	2,692.2	5,109.2	3,299.6	6,877.6
Electricity Bills (million US$)	545.4	553.7	43.6	84.6	11.3	19.2	142.7	270.8	66.0	137.6
CO2 Emissions (thousand tonnes)	10,209.2	10,364.9	816.1	1,583.7	211.1	358.6	2,425.7	4,603.4	3,273.5	6,823.2

CUMULATIVE SAVINGS (2020 - 2030)

	Lighting	Residential Refrigerators	Room Air Conditioners	Transformers	Industrial Electric Motors
Electricity (TWh)	90.3	9.0	2.2	30.0	36.9
Electricity Bills (billion US$)	4.8	0.5	0.1	1.6	0.7
CO2 Emissions (million tonnes)	89.6	8.9	2.2	27.0	36.6

The savings potential assumes minimum energy performance standards (MEPS) are implemented in 2020 at level equivalent to the present day (2015) best global MEPS that are currently implemented. The analysis uses CLASP's and Lawrence Berkeley National Laboratory's Policy Analysis Modeling System (PAMS) to forecast the impacts from implementing policies that improve the energy efficiency of new household air conditioners and refrigerators. For lighting, electric motors, and power and distribution transformers individual – models were developed, taking into account country level data, expected GDP growth, and industrialization levels

Source: U4E Country Assessment, South Africa (Dec 2016); en.lighten, United for Efficiency

UNDP has also conducted a separate analysis of potential energy savings and avoided GHG emissions using the methodology explained below. Using the same input data for lighting stock as the U4E assessment for the project (2017-2021) and similar post-project timeframes of the project (2022 up to 2030, the U4E Country Assessment's end year of 2030), the estimated energy savings and avoided GHG emissions calculated in this section are roughly the same as the U4E Country Assessment. For distribution transformers the U4E assessment does not give baseline data for transformers; the GHG calculation uses data from Eskom and NERSA reports (see Box 24)

The tables in Box 27 and Box 28 show the energy consumption in baseline (business-as-usual) and alternative scenario (with a more aggressive market penetration of LED lighting and high-efficiency transformers) or lighting products and distribution transformers, the corresponding annual energy savings and GHG emission reduction. Also, the tables provide an estimate of the peak power reduction and the avoided use of mercury and/or release into the environment.

Box 24 Assumptions and base data calculations, HE transformers, energy savings and GHG reduction

Information on the number of transformers in South Africa's distribution system is based on data from the regulator NERSA and the state utility Eskom. Unfortunately, the latest consistent set of data is from the year 2012. Data have been extrapolated to estimate the amount in Eskom's grid and the municipal power distribution grids in 2017, the base year for the scenario analysis of Box 25. According to Eskom about 10,000 new transformers are added each year and a similar number of old transformers replaced, i.e. 20,000 in total, a growth of about 3% a year. It is assumed that in the baseline that not all of these are replaced with HE (high-efficiency) equipment. In the baseline, to the stock 2,500 HE distribution transformers are added in 2019 and thereafter, in each year 2,500*(1+3%). In the alternative scenario it is assumed not only all that all the 20,000 transformers sold are high-efficient, but that the penetration rate increases also; are added; in the alternative scenario this is 20,000*(1+9%).

Distribution transformers

Number installed	**2010**	**2012**	**2017**
ESKOM	107,098	148,984	290,000
Municipalities	204,203	381,390	372,655
Total	**311,301**	**530,374**	**662,655**

Source: NERSA, *Electricity Supply Statistics* (2012), 2017 data are estimates, *ESKOM,* p.c., DHV-GL *Country Profile: South Africa* (2018)

The following table shows how the energy savings of a high-efficient transformer is calculated:

Losses of a transformer (in kWh/yr) = (P_{LL}*365*24*load factor + P_{NL}*365*24) * (cost of power)

Total owning cost (TOC) = purchase price + present value of future (no load losses + load losses).

Base data								
Exchange rate	13.17		OANDA (Jul-Sept 2017)					
Discount rate	10%							
Cost of power generation	0.061	USD/kWh	DoE Integrated Resource Plan (2010-2030)					
Grid emission factor	940	kgCO2/MWh	NBI					
Losses transmission system	2.30%		Eskom (2014)					
	Transformer (750 kVA)				**Transformer (75 kVA)**			
Load factor	0.60				0.30			
Lifetime	20				20			
Capital recovery factor	0.11746				0.1174596			
Standard distribution transformers								
No-load losses (P_{NL})	1.65	kW	7,473	USD	0.38	kW	1,698	USD
Load loss (P_L) at 75%	5.35	kW	14,538	USD	1.70	kW	2,310	USD
Purchase			10,200	USD			1,300	USD
Losses			42,574	kWh/yr			12,220	kWh/yr
TOC			**197,594**	**USD**			**35,424**	**USD**
High-efficient transformer								
No-load losses (P_{NL})	1.00	kW	4,529	USD	0.22	kW	996	USD
Load loss (P_L) at 75%	3.80	kW	10,326	USD	1.00	kW	1,359	USD
Purchase			11,118	USD			1,820	USD
Losses			28,733	kWh			7,183	kWh
TOC (eff)			**137,590**	**USD**			**21,870**	**USD**
Energy savings			**13,841**	**kWh/yr**			**5,037**	**kWh/yr**
Monetary savings			*7,156*	*USD*			*1,653*	*USD*

Estimates on transformers in DHV-GL (2018) give 662,655 with an average size of 315 kVA (11 kV/0.4 kV). Transformers come in different size, ranging from 25 to 2,500 kVA, but there are no statistics on numbers per size category. The table gives two calculation examples, for a 750 kVA and a 75 kVA transformer. Assuming that 35% are 750 kVA (or the average of 300-1500 kVA) and 65% are 75 kVA (or the average of the range 25-300 kVA) gives an average szie of 318 kVA.

The present value is calculated by dividing monetary value of the loss by the capital recovery factor*. Prices of standards and efficient transformers are based on data provided by Eskom; infon on International Copper Association (see *Introduction to Transformer Losses* from *Premium-efficiency Motors and Transformers)* and the articles *Reducing South Africa's electrical distribution transformer losses* (Amadi, DeKock, 2015) and *Low-loss transformers in a South African context* (Stanford et.al., PowerTech Transformers)

* CFF = I * $(1+i)^n$ / $((1+i)^n-1)$ with I = discount rate = 10% and n = lifetime of the transformer (20 years)

Box 25 Assumptions and base data calculations, LED lighting, market share and prices (2017)

Information on the stock of lamps is taken from the U4E country assessment for South Africa as well as information on the average wattage per lamp and the estimated usage per day of lamps. It is difficult to get reliable information on prices of lamps. These may differ per sales outlet. We have tried as much as possible use a consistent set of data (number of lamps, prices of lamps, exchange rate) with as base year 2017. Assuming the stock of lamps to grow annually with population growth (1.5%; www.ieconomics.com), the stock of lamps in 2017 is 698.39 million units (total of all sectors, residential, commercial/industrial, public sector, incl. street lighting)

(million of units)	Residential	Professional	Outdoor	Total
Incandescent	108.60	37.37	7.47	153.44
Halogen	9.82	6.22	1.24	17.29
CFL	82.88	155.57	25.93	264.38
LFL - T5	0.22	1.72	0.22	2.16
LFL - T8	34.93	117.81	16.83	169.56
LFL - T12	10.41	35.11	5.02	50.53
LED tube	0.12	0.43	0.06	0.61
LED	0.76	3.55	0.76	5.07
HID-HPS	-	2.05	4.80	6.85
HID other	0.48	2.93	5.58	8.99
	248.23	362.74	67.91	678.88

(average wattage)	Residential	Professional	Outdoor
Incandescent	55	55	100
Halogen	46	46	85
CFL	12	12	25
LFL - T5	28	28	25
LFL - T8	32	32	32
LFL - T12	40	40	40
LED tube	25	25	25
LED	7	7	17
HID-HPS	80	80	90
HID other	78	74	140

(hours/day)	Residential	Professional	Outdoor
Incandescent	2	9	9
Halogen	2	9	9
CFL	2	9	9
LFL - T5	3	10	9
LFL - T8	3	10	10
LFL - T12	3	10	10
LED tube	3	10	10
LED	3	9	9
HID-HPS	10	10	10
HID other	9	10	10

Price of lamps	Rand
Incandescent (60 W)	9.0
Halogen (50 W)	37.0
CFL (12 W)	25.0
LED (9 W)	32.0
LFL (T8-T12, 36 W)	17.0
LFL (T5, 28 W)	23.0
LED tube (12 W)	55.0

Source: U4E Country Assessment, South Africa (Dec 2016); en.lighten, United for Efficiency, South Africa_Lighting_U4E Assessment_.xlsx

Price of lamps (2018) taken from various website (makro.co.za; www.pricecheck.co.za; livecopper.za; www.builders.co.za; lightingwarehouse.za).

The alternative scenario differs from the baseline scenario by calculating the market share of LEDs in the years 2022 and 2030 for three categories, a. incandescent, CFLs, halogen lamps and LEDs, b. tubular lamps (LFLs and LED tubes) and c. high-power, outdoor and street lighting lamps (HID-MV, HID-HPS and LEDs). The shares of the intermediate years 2018-2021 and 2023-2029 are determined by interpolation. One can observe that the total number of lighting points (i.e. installed lamps) in the baseline and the alternative scenario is the same, but that the distribution of lamps is shifted towards more energy efficient products in the alternative scenario.

As fewer fluorescent lamps are installed in the alternative scenario, this will result in **avoided mercury content** (compact, linear and circular fluorescent lamps contain small amounts of mercury), starting with 3.13 tons in 2018 up to 5.03 tons of mercury in 2030 that would otherwise have been deposited into the environment (unless the mercury of these lamps is recovered in recycling facilities). Coal contains some small amounts of mercury, so the avoided use of coal (due to lower electricity consumption) implies that less mercury is released into the environment. Many lamps will be used during hours of **peak power demand** (the proportion of time used during peak hours and off-peak is expressed by the 'peak coincidence factor'), so the use of more efficient lamp technology will result in lowering the maximum power peak demand, an estimated 117 MW in 2018 (over the baseline) to about 559 MW in 2028, i.e. equivalent to the avoided construction and operation of a power plant.

Box 26 Assumptions and base data calculations, LED lighting, energy consumption per device

Assumptions

Grid			Source:
Grid emission factor (2013-2020)	940	kgCO2/MWh	NBI
Lamps-on peak coincidence factor (incand; CFL)		80%	Own estimate
Lamps-on peak coincidence factor (TL; outdoor)		50%	
Losses, transmission and distribution		8.8%	Eskom (2014)
Tariff			
Average residential tariff	0.090	USD/kWh	Eskom (2016/17)
Average commercial tariff	0.083	USD/kWh	
Average local authority	0.062	USD/kWh	
Average industry tariff	0.058		
Mercury			
- coal-based	0.11	g/MWh	En.lighten
- coal content South Africa fuel mix	92.6%		DoE PowerPoint 2016
Discount rate, annualized cost calculations	10%		
Exchange rate	13.17		OANDA (Jul-Sept17)

Incandescents, CFLs and LEDs		
Hours of operation	6.5	hrs/day
Average wattage incandescent	62	W
Corresponding wattage CFL	12.0	W
Corresponding wattage LED	9.0	W
Incandescent		
- Life	0.50	yr
- Retail price	0.68	USD
- Annual energy consumption	148.01	kWh/yr
- Peak power at plant's gate	0.0540	kW
CFL		
- Life	4.19	yr
- Retail price	1.90	USD
- Annual energy consumption	28.65	kWh/yr
- Peak power at plant's gate	0.0104	kW
- Mercury content	4	mg
LED		
- Life	12.57	yr
- Retail price	2.43	USD
- Annual energy consumption	21.49	kWh/yr
- Peak power at plant's gate	0.0078	kW

Tubular fluorescent (TL)		
Hours of operation	6.5	hrs/day
Average wattage TL (T8-T12)	36	W
Corresponding wattage TL-T5	28.0	W
Corresponding LED wattage	18.0	W
TL		
- Life	6.91	yr
- Retail price	1.29	USD
- Annual energy consumption	85.94	kWh/ryr
- Peak power at plant's gate	0.0196	kW
- Mercury content	10	mg
Efficient TL (T5)		
- Life	8.38	yr
- Retail price (plus fitting)	1.75	USD
- Annual energy consumption	66.84	kWh/yr
- Peak power at plant's gate	0.0152	kW
- Mercury content	5	mg
Tubular LED		
- Life	16.76	yr
- Retail price	4.18	USD
- Annual energy consumption	42.97	kWh/yr
- Peak power at plant's gate	0.0098	kW

Outdoor/street, MV, HPS and LED		
Hours of operation	12	hrs/day
Average wattage	200	W
Corresponding wattage HID-HPS	125	W
Corresponding wattage LED	65	W
HID-MV		
- Life	4.1	yr
- Retail price	6.83	USD
- Annual energy consumption	876.0	kWh/yr
- Peak power at plant's gate	0.1088	kW
HID-HPS		
- Life	4.6	yr
- Retail price	9.11	USD
- Annual energy consumption	547.50	kWh/yr
- Peak power at plant's gate	0.068	kW
LED		
- Life	10.3	yr
- Retail price	50	USD
- Annual energy consumption	284.7	kWh/yr
- Peak power at plant's gate	0.03536	kW

Halogen lamp and LED		
Hours of operation	6.5	
Average wattage	55	W
Corresponding wattage LED	9.0	W
Halogen		
- Life	0.92	yr
- Retail price	2.81	USD
- Annual energy consumption	131.30	kWh/yr
- Peak power at plant's gate	0.0479	kW
LED		
- Life	10.47	yr
- Retail price	2.43	USD
- Annual energy consumption	21.49	kWh/yr
- Peak power at plant's gate	0.0078	kW

Source: ESKOM website, Historical average price and increase (2017), transmission and distribution losses (2014). Exchange rates from OANDA website; *South Africa's Grid Emission Factor,* National Business Initiative (2013).

Using the market data of Box 42, and assumptions on lifetime and average wattage of the lamp, the tables show the calculation of energy and monetary savings per type of replacement: a) LED replacing CFL and incandescent, b) tubular LED replacing fluorescent tubular lamps (TLs), c) LED replacing a halogen lamp, and d) LED replacing HPS (high-pressure sodium) and mercury vapour (MV) lamps, used in street lighting and other applications. The annual consunmption data are used as input fort the annual energy consumption calculations of **Box 44** (= consumption per lamps x number of lamps in yr 20XY)

Box 27 LED and other lamps stock South Africa – energy consumption and GHG emissions in baseline and GEF alternative scenario over 2017-2030

Baseline	Share	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Share '22	Share '30
Incandescent	29%	129.73	108.67	87.61	66.55	45.49	24.4	12.20	0.00	0.00	0.00	0.00	0.00	0.00	0	5%	0%
Halogen	6%	28.90	36.80	44.70	52.60	60.49	68.39	66.72	65.05	63.38	61.71	60.04	58.37	56.70	55.03	14%	10%
CFL	60%	272.37	271.64	270.90	270.16	269.43	268.69	255.74	242.79	229.84	216.89	203.94	191.00	178.05	165.10	55%	30%
LED	5%	22.48	43.38	64.29	85.20	106.11	127.02	161.59	196.13	218.47	240.82	263.16	285.51	307.85	330.19	26%	60%
LFL	99%	226.75	216.03	205.31	194.58	183.86	173.14	161.95	150.75	139.56	128.37	117.17	105.98	94.78	83.59	70%	30%
LFL-T5	1%	2.23	11.68	21.12	30.57	40.02	49.47	57.22	64.97	72.71	80.46	88.21	95.96	103.71	111.45	20%	40%
LED tube	0%	0.63	5.45	10.27	15.09	19.91	24.73	32.09	39.45	46.81	54.16	61.52	68.88	76.23	83.59	10%	30%
HID-HPS	46%	7.05	8.12	9.18	10.24	11.30	12.37	12.45	12.53	12.61	12.68	12.76	12.84	12.92	13.00	75%	70%
HID-MV	54%	8.24	6.92	5.60	4.29	2.97	1.65	1.44	1.24	1.03	0.82	0.62	0.41	0.21	0.00	10%	0%
LED outdoor	0%	0.01	0.50	1.00	1.49	1.98	2.47	2.86	3.25	3.64	4.02	4.41	4.80	5.19	5.57	15%	30%
Total		**698.39**	**709.18**	**719.98**	**730.77**	**741.57**	**752.36**	**764.26**	**776.16**	**788.05**	**799.95**	**811.84**	**823.74**	**835.64**	**847.53**		
Alternative																	
Incandescent		129.73	108.67	81.50	54.34	27.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0%
Halogen		28.90	36.80	38.59	40.38	42.17	43.97	38.47	32.98	27.48	21.98	16.49	10.99	5.50	0.00	9%	0%
CFL		272.37	271.64	247.70	223.75	199.81	175.87	167.64	159.42	151.19	142.97	134.74	126.52	118.29	110.06	36%	20%
LED		22.48	43.38	99.71	156.04	212.36	268.69	290.14	311.58	333.03	354.47	375.92	397.37	418.81	440.26	55%	80%
LFL		226.75	216.03	186.75	157.48	128.21	98.94	86.57	74.20	61.84	49.47	37.10	24.73	12.37	0.00	40%	0%
LFL-T5		2.23	11.68	30.40	49.12	67.85	86.57	87.94	89.31	90.68	92.05	93.42	94.78	96.15	97.52	35%	35%
LED tube		0.63	5.45	19.55	33.64	47.74	61.84	76.75	91.66	106.57	121.47	136.38	151.29	166.20	181.11	25%	65%
HID-HPS		7.05	8.12	8.97	9.83	10.69	11.5	11.26	10.98	10.70	10.42	10.13	9.85	9.57	9.29	70%	50%
HID-MV		8.24	6.92	5.19	3.46	1.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%	0%
LED outdoor/street		0.01	0.50	1.61	2.72	3.84	4.95	5.49	6.03	6.57	7.12	7.66	8.20	8.75	9.29	30%	50%
Total		**698.39**	**709.18**	**719.98**	**730.77**	**741.57**	**752.36**	**764.26**	**776.16**	**788.05**	**799.95**	**811.84**	**823.74**	**835.64**	**847.53**		
Difference																	
Incandescent		0.00	0.00	-6.11	-12.21	-18.32	-24.43	-12.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Halogen		0.00	0.00	-6.11	-12.21	-18.32	-24.43	-28.25	-32.08	-35.90	-39.73	-43.56	-47.38	-51.21	-55.03		
CFL		0.00	0.00	-23.21	-46.41	-69.62	-92.82	-88.10	-83.37	-78.65	-73.93	-69.20	-64.48	-59.76	-55.03		
LED		0.00	0.00	35.42	70.84	106.25	141.67	128.55	115.45	114.55	113.66	112.76	111.86	110.96	110.06		
LFL		0.00	0.00	-18.55	-37.10	-55.65	-74.20	-75.38	-76.55	-77.72	-78.90	-80.07	-81.24	-82.42	-83.59		
LFL-T5		0.00	0.00	9.28	18.55	27.83	37.10	30.72	24.34	17.96	11.59	5.21	-1.17	-7.55	-13.93		
LED tube		0.00	0.00	9.28	18.55	27.83	37.10	44.65	52.21	59.76	67.31	74.86	82.42	89.97	97.52		
HID-HPS		0.00	0.00	-0.21	-0.41	-0.62	-0.82	-1.19	-1.55	-1.91	-2.27	-2.63	-2.99	-3.35	-3.72		
HID-MV		0.00	0.00	-0.41	-0.82	-1.24	-1.65	-1.44	-1.24	-1.03	-0.82	-0.62	-0.41	-0.21	0.00		
LED outdoor/street		0.00	0.00	0.62	1.24	1.86	2.47	2.63	2.78	2.94	3.09	3.25	3.40	3.56	3.72		
Total		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
Energy savings																	
Incandescent			0	904	1,808	2,712	3,615	1,806	0	0	0	0	0	0	0		
Halogen			0	802	1,604	2,405	3,207	3,710	4,212	4,714	5,216	5,719	6,221	6,723	7,226		
CFL			0	665	1,330	1,994	2,659	2,524	2,388	2,253	2,118	1,982	1,847	1,712	1,577		
LED			0	-761	-1,522	-2,283	-3,044	-2,762	-2,481	-2,461	-2,442	-2,423	-2,403	-2,384	-2,365		
LFL			0	1,594	3,189	4,783	6,377	6,478	6,579	6,680	6,781	6,881	6,982	7,083	7,184		
LFL-T5			0	-620	-1,240	-1,860	-2,480	-2,054	-1,627	-1,201	-774	-348	78	505	931		
LED tube			0	-399	-797	-1,196	-1,594	-1,919	-2,243	-2,568	-2,892	-3,217	-3,542	-3,866	-4,191		
HPS			0	113	226	339	451	649	847	1,045	1,243	1,441	1,638	1,836	2,034		
HID-MV			0	361	722	1,083	1,444	1,264	1,083	903	722	542	361	181	0		
LED outdoor/street			0	-176	-352	-528	-704	-748	-793	-837	-881	-925	-969	-1,013	-1,058		
Total energy savings (GWh/yr)			0	2,483	4,966	7,449	9,932	8,947	7,966	8,528	9,090	9,652	10,214	10,776	11,338		
Plant gate's savings (GWh/yr)			**0**	**2,702**	**5,403**	**8,105**	**10,806**	**9,735**	**8,667**	**9,278**	**9,890**	**10,502**	**11,113**	**11,725**	**12,336**		
Emission factor (kgCO_2/MWh)			940	934	928	922	916	910	903	897	891	885	879	873	867		
GHG emission reduction ktCO_2/yr			**0**	**2,523**	**5,013**	**7,470**	**9,895**	**8,854**	**7,830**	**8,326**	**8,814**	**9,296**	**9,769**	**10,235**	**10,694**		

Note: In the calculation the following lifetime of lamps is assumed: incandescent, 1200 hours; CFL: 10000 hours; halogen: 2200 hours, LFL: 16500 hours; LFL-T5: 20000 hours; LED: 30000 hours; LED tube: 40000 hours, HID-mercury vapour: 18000 hours; HID-HPS: 20000 hours.

Box 28 Distribution transformers stock South Africa – energy consumption and GHG emissions in baseline and GEF alternative scenario, 2017-2030

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Transformers, total	682,535	703,011	724,101	745,824	768,199	791,245	814,982	839,432	864,614	890,553	917,269	944,788	973,131
No. installed HE transformers, baseline	0	2,500	5,075	7,650	10,225	12,800	15,375	17,950	20,525	23,100	25,675	28,250	30,825
No. installed HE transformers, alternative	0	2,500	7,500	15,000	35,000	61,160	87,320	113,480	139,640	165,800	191,960	218,120	244,280
Difference, HE transformers	**0**	**0**	**2,425**	**7,350**	**24,775**	**48,360**	**71,945**	**95,530**	**119,115**	**142,700**	**166,285**	**189,870**	**213,455**
Energy savings (GWh/yr)	0	0	36	110	370	723	1,075	1,427	1,780	2,132	2,484	2,837	3,189
At plant's gate (GWh/yr)	**0**	**0**	**37**	**112**	**379**	**739**	**1,100**	**1,460**	**1,821**	**2,181**	**2,542**	**2,902**	**3,263**
Emission factor (kgCO_2/MWh)	940	934	928	922	916	910	903	897	891	885	879	873	867
Reduced CO_2 emissions (ktCO_2/yr)	**0**	**0**	**34**	**104**	**347**	**672**	**993**	**1,310**	**1,623**	**1,931**	**2,234**	**2,533**	**2,828**

Note: The energy savings at plant's gate follow from multiplying the calculated annual energy savings by (1+T) for transformers and (1+T+D) for the lighting products, where T: % transmission losses and D: distribution losses.

Box 29 Peak power demand reduction and avoided mercury content

Peak power impact

	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Incandescent	MW	0.0	48.8	97.6	146.3	195.1	97.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Halogen		0.0	38.4	76.8	115.2	153.5	177.6	201.6	225.7	249.7	273.8	297.8	321.9	345.9
CFL		0.0	6.9	13.9	20.8	27.8	26.4	24.9	23.5	22.1	20.7	19.3	17.9	16.5
LED		0.0	-6.0	-11.9	-17.9	-23.8	-21.6	-19.4	-19.3	-19.1	-19.0	-18.8	-18.7	-18.5
LFL		0.0	31.2	62.4	93.7	124.9	126.9	128.8	130.8	132.8	134.8	136.7	138.7	140.7
LFL-T5		0.0	-9.4	-18.9	-28.3	-37.8	-31.3	-24.8	-18.3	-11.8	-5.3	1.2	7.7	14.2
LED tube		0.0	-3.9	-7.8	-11.7	-15.6	-18.8	-22.0	-25.1	-28.3	-31.5	-34.7	-37.9	-41.0
HID-HPS		0.0	7.7	15.3	23.0	30.7	44.1	57.6	71.1	84.5	98.0	111.4	124.9	138.3
HID-MV		0.0	39.3	78.6	117.9	157.2	137.5	117.9	98.2	78.6	58.9	39.3	19.6	0.0
LED outdoor		0.0	-6.2	-12.4	-18.7	-24.9	-26.5	-28.0	-29.6	-31.1	-32.7	-34.3	-35.8	-37.4
Net impact	MW	0.0	146.8	293.5	440.3	587.0	511.7	436.7	457.0	477.3	497.6	518.0	538.3	558.6

Mercury content - baseline

Alternative	Unit	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CFL		1,086.6	990.8	895.0	799.2	703.5	670.6	637.7	604.8	571.9	539.0	506.1	473.2	440.3
LFL		2,160.3	1,867.5	1,574.8	1,282.1	989.4	865.7	742.0	618.4	494.7	371.0	247.3	123.7	0.0
LFL-T5		58.4	152.0	245.6	339.2	432.9	439.7	446.5	453.4	460.2	467.1	473.9	480.8	487.6
TOTAL	*kg*	*3,305.2*	*3,010.3*	*2,715.5*	*2,420.6*	*2,125.7*	*1,976.0*	*1,826.3*	*1,676.5*	*1,526.8*	*1,377.1*	*1,227.3*	*1,077.6*	*927.9*
Business-as-usual														
CFL		1,086.6	1,083.6	1,080.7	1,077.7	1,074.8	1,023.0	971.2	919.4	867.6	815.8	764.0	712.2	660.4
LFL		2,160.3	2,053.1	1,945.8	1,838.6	1,731.4	1,619.5	1,507.5	1,395.6	1,283.7	1,171.7	1,059.8	947.8	835.9
LFL-T5		2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0	2,765.0
TOTAL	*kg*	*6,011.8*	*5,901.7*	*5,791.5*	*5,681.3*	*5,571.2*	*5,407.5*	*5,243.7*	*5,080.0*	*4,916.2*	*4,752.5*	*4,588.8*	*4,425.0*	*4,261.3*
Difference in Hg content - stock		**-2,707**	**-2,891**	**-3,076**	**-3,261**	**-3,445**	**-3,431**	**-3,417**	**-3,403**	**-3,389**	**-3,375**	**-3,361**	**-3,347**	**-3,333**
Avoided Hg in coal burning - LED		0	-275	-550	-826	-1,101	-992	-883	-945	-1,007	-1,070	-1,132	-1,194	-1,257
Avoided Hg in coal burning - dist. trans.		0	0	-4	-11	-39	-75	-112	-149	-185	-222	-259	-296	-332
TOTAL - Hg content		**-2,707**	**-3,167**	**-3,630**	**-4,098**	**-4,585**	**-4,498**	**-4,412**	**-4,497**	**-4,582**	**-4,667**	**-4,752**	**-4,837**	**-4,922**

For the **emission factor** of the electricity grid, 0.94 $kgCO_2/MWh$ is used for the base year 2017[39]. Following the baseline scenario of the *Integrated Resource Plan for Electricity 2010-2030* of the Department of Energy, emission factors are used that slightly decline from year to year, which can be attributed to the slight increase of renewables in South Africa's power mix. he calculations yield estimates of the potential electricity savings and avoided emissions similar to those of the U4E country assessment by the year 2030 (lighting: 12.3 TWh and 10.69 million tCO_2 in comparison with U4E's 10.45 TWh and 10.2 million tCO_2; transformers: 4.36 TWh and 3.78 million tCO_2 in comparison with U4E's 5.1 TWh and 4.6 million tCO_2), assuming a compliance rate of 100 percent.

Box 30 Monetary savings due to replacement per type of lamp

Replacing 60 W incandescent with 12 W CFL	USD	Replacing TL with efficient LED tube	USD
Cost		*Cost*	
Purchase lamp (annualized)	0.54	Purchase lamp (annualized)	0.52
Benefit		*Benefit*	
Avoided purchase IL (annualized)	1.46	Avoided purchase TL (annualized)	0.27
Savings energy bill	10.75	Savings energy bill	3.87
Annual net benefits	**11.67**	**Annual net benefits**	**3.61**

Replacing 60 W incandescent with 9 W LED	USD	Replacing HPS street light with LED	
Cost		*Cost*	
Purchase lamp (annualized)	0.35	Purchase luminaire (annualized)	44.91
Benefit		*Benefit*	
Avoided purchase IL (annualized)	1.46	Avoided purchase HPS (annualized)	34.42
Savings energy bill	11.39	Savings energy bill	16.23
Annual net benefits	**12.50**	**Annual net benefits**	**5.74**

Replacing 55 W halogen lamp with 9 W LED	USD	Replacing MV street light with LED	
Cost		*Cost*	
Purchase lamp (annualized)	0.38	Purchase luminaire (annualized)	44.91
Benefit		*Benefit*	
Avoided purchase IL (annualized)	3.34	Avoided purchase HID-MV	36.57
Savings energy bill	9.89	Savings energy bill	36.53
Annual net benefits	**12.84**	**Annual net benefits**	**28.19**

Based on the energy consumption estimates, lifetime, and tariff assumptions and calculations of Box 43, the table above provides estimates of **monetary savings** of switching an efficient lamp for a less efficient one (in USD per lamp per year) for different lamp replacement combinations.

es:

For comparing lamps, the residential Eskom tariff is used, for street lighting the public tariff

Annualised cost are calculated by multiplying the purchase price with the capital recovery factor CFF = I * $(1+i)^n$ / $((1+i)^n-1)$ with I = discount rate = 10% and n = lifetime of the lamp

Street lighting is compared not by using the cost of the lamp, but the cost of the luminaire (plus lamp). Cost data are based on the before-mentioned CSA *Public Lighting Guide* (2012) and the calculations in the table on the left.

Street lighting		
Hours of operation	12	
Average wattage (HID-MV)	200	W
Corresponding wattage induction	71	W
Corresponding wattage HID-HPS	125	W
Corresponding wattage LED	65	W
HID-MV		
- Life	4.57	yr
- Retail price (lamp+luminaire)	129.05	USD
- Annual energy consumption	876.00	kWh/yr
- Peak power at plant's gate	0.1088	kW
Induction		
- Life	9.13	yr
- Retail price (lamp+luminaire)	201.16	USD
- Annual energy consumption	310.32	kWh/yr
- Peak power at plant's gate	0.0385	kW
HID-HPS		
- Life	4.57	yr
- Retail price (lamp+luminaire)	121.46	USD
- Annual energy consumption	547.50	kWh/yr
- Peak power at plant's gate	0.0680	kW
LED		
- Life	15.00	yr
- Retail price (lamp+luminaire)	356.78	USD
- Annual energy consumption	284.70	kWh/yr
- Peak power at plant's gate	0.0354	kW

[39] National Business Initiative, *South Africa's Grid Emission Factor* (2013).

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