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South Africa's Appliance Energy Efficiency Standards and Labeling Program

Impact Assessment

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EXECUTIVE SUMMARY

Electricity consumption in South Africa comes with a hefty environmental cost to the society. For every kilowatt-hour (kWh) produced, 1 kilogram (kg) of carbon dioxide (CO₂) is emitted, 1.4 liters of water are used, and 0.37 grams of particulate emissions are released in the atmosphere. These environmental implications result from the large share of electricity produced from coal (91 percent in 2015). While planned new capacity will ramp up renewable energy, the integrated resource plan for the country still projects the share of coal to be 64 percent in 2030.

Energy savings provide environmental benefits as well as economic benefits. Energy efficiency standards and labeling (S&L) programs are a policy measure proven to save energy. Such programs have been implemented in many countries to remove inefficient technologies and transform markets to more efficient technologies. In this study, we describe the methodology, assumptions and results of a stock turnover modeling tool that estimates the energy savings achievable by South Africa's S&L program in the residential sector. We show that if regulations are passed in 2020 and effective in 2021 for 10 major end-use adopting international standards best practices, 6 terawatt-hours (TWh) will be saved in 2030 and 9.5 TWh will be saved in 2040, representing a CO₂ mitigation of 3.7 megatonnes (Mt) in 2030 and 5.8 Mt in 2040, which will contribute to the South African government's international engagement in fighting against climate change through its National Determined Contribution (NDC). Additional environmental benefits include saving of 6.5 billion liters of water in 2030, representing approximately 100 liters per capita in 2030. Air quality will also improve, as 4 kilotons (kt) of particulate emissions will be avoided, as well as 4.3 Mt of sulfur oxides (SO_x) and 23 kt of nitrogen oxides (NO_x) in 2030.

Of much importance for the nation are the benefits of saving energy, which come with significant economic benefits. By reducing energy consumption for the same level of energy services, consumers will reduce the operating costs of their electric equipment by 15.1 billion rand in 2030, representing an average annual bill savings of 683 rand per household. We also show that the cost to the government of saving 1 kWh in this program is 100 times less than the cost of supplying 1 kWh of electricity.

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GLOSSARY

AAG - average annual growth

AMPS - All Media and Products Survey

BAU - business as usual

BUENAS - Bottom-Up Energy Analysis System

CFL - Compact Fluorescent Lamp

CO₂ - carbon dioxide

DMRE - Department Of Mineral Resources and Energy

EDR - Energy Demand Resource

EJ - exajoules

GEF - Global Environmental Facility

GWh - gigawatt-hours

HVAC - heating, ventilation and air-conditioning

IEA - International Energy Agency

INEP - Integrated National Electrification Programme

LEAP - Long-Range Energy Alternatives Planning system

LBNL - Lawrence Berkeley National Laboratories

LSM - Living Standards Measure

MEPS - Minimum Energy Performance Standards

MtCO₂ - millions of CO₂

MW - Megawatt

NEES - National Energy Efficiency Strategy

NES - National Energy Savings

SAPP - South African Power Pool

SAARF - South African Advertising Research Foundation

SANEDI - South African National Energy Development Institute

S&L - Standards and Labeling

TWh - terawatt-hours

UEC - unit energy consumption

UNDP - United Nations Development Programme

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1. INTRODUCTION

South Africa has committed to pursuing improved energy efficiency to encourage a sustainable development of the energy sector, thereby minimizing the undesirable impacts of energy usage upon health and the environment and contributing toward secure and affordable energy for all. The National Energy Act, Act 34 of 2008, empowers the Minister of Energy to establish the relevant legislation and frameworks to reduce wasteful consumption of energy. Chief among them are the implementation of energy efficiency standards, regulations and labeling schemes for electrical appliances and equipment.

The South African Government, through its Department of Mineral Resources and Energy (DMRE), initially introduced the voluntary endorsement of the Energy Efficiency Standards and Labeling (S&L) program by industry in 2007. Despite many stakeholder consultations taking place during the period of voluntary participation, the uptake by industry was very low; almost nonexistent. It was the assessment of this approach that led government to consider putting in place mandatory regulations, standards and labels to drive adoption and transformation of the market. This first regulations came into effect in 2015. The program covered 10 residential appliances and equipment.¹ Lawrence Berkeley National Laboratory (LBNL) worked closely with the DMRE to assist in the implementation of this first S&L program. This collaboration has been particularly instrumental in helping to raise the efficiency levels of the water heater standard toward saving an additional 3.82 terawatt-hours (TWh) of electricity by 2030, doubling the program's impact (Van Wyngaardt 2016). The collaboration also helped the DMRE assess the energy savings achieved through the program. The projected energy savings of these new standards by 2030 are equivalent to the generation output of an 800 megawatt (MW) coal plant (de la Rue du Can and McNeil, 2018). The implementation of the S&L program has contributed to making South Africa a leader in the implementation of S&L among sub-Saharan countries.

The DMRE is now working to explore the revision and expansion of the S&L program with support from the Global Environmental Facility (GEF) and the United Nations Development Programme (UNDP) through an 18-month extension of the project that originally supported the implementation of the S&L development. Additional energy savings can be achieved by revising and expanding the current program to cover additional end uses and appliances in the residential sector. Notably, expanding the program to other major end uses such as lighting will contribute to significant energy savings in the country.

This study describes the development of a stand-alone version of an end-use electricity demand model for South Africa based on the methodology developed by LBNL in its BUENAS model for the residential sector. The South Africa Energy Demand Resource (EDR) was developed to be used by the South African government to inform the upcoming S&L program, as well as future revisions, and to help institutionalize the planning and implementation of the program within the DMRE. It will also help to inform the National Energy Efficiency Strategy (NEES) target for the residential sector and contribute in tracking savings to meet the NEES residential target of reducing electricity consumption by 23 percent in 2030.

¹ Electric water heaters, electric ovens, refrigerators, freezers, dishwashers, tumble dryers, washer-dryer combinations, washing machines, air conditioners, heat pumps, audio and video.

The model is based on assumptions of equipment penetration and unit energy consumption that were estimated based on data collected throughout the S&L program and from national statistic surveys. In this regard, the condition of the resulting EDR model analysis depends on the type and level of data collected so far. There is no doubt that as the S&L program and the tool is institutionalized at the DMRE and the South African National Energy Development Institute (SANEDI), better and more data will contribute to the improvement of the tool's analytic capabilities. However, we believe that at this point in time, the tool provides a best estimate of residential electricity savings potential and provides a solid basis for future projection of electricity consumption to be integrated at the DMRE and at SANEDI.

Additionally, it is important to note that EDR focuses on analyzing the demand of electricity and does not provide the analytics on how this demand could be supplied. Electricity can be supplied through the national electricity grid, through small generators or through solar photovoltaics. The supply of electricity in South Africa is modeled in other platforms (DMRE 2019). The objective of EDR is to understand the dynamics of energy demand and the potential for energy savings through energy efficiency programs such as S&L programs, rather than on supply.

The report first describes the methodology used in developing the EDR model for the residential sector, then details the data, source of data and assumptions made in the model. Finally, the report presents the results of two energy efficiency scenarios: the Proposed Revision and Expansion Scenario (Proposed Scenario) and the International Standards Best Practice Scenario (Best Practice Scenario).

2. METHODOLOGY

1. LBNL BUENAS Modeling Tool

LBNL developed the Bottom-Up Energy Analysis System (BUENAS) tool to enable policymakers to evaluate the potential energy savings and emissions reductions resulting from different appliance energy efficiency S&L policies (McNeil et al. 2013). BUENAS projects the energy demands and greenhouse gas emissions associated with the use of various appliances and equipment. By taking into account the changes in energy consumption resulting from efficiency improvements to different products, BUENAS provides a comprehensive forecast of the energy savings and emissions reductions that would result from implementation of different appliance energy efficiency S&L policies and programs.

The concept for BUENAS emerged from the example of the National Energy Savings (NES) component of analyses supporting U.S. federal rulemakings on Minimum Energy Performance Standards (MEPS) for residential and commercial equipment. The NES analysis forecasts equipment sales and average annual unit energy consumption (UEC) of appliances, either with or without a federal standard. Total national energy demand from the two scenarios is then compared to yield the energy saving potential of the standard. BUENAS was constructed in an attempt to replicate this type of analysis but employing much less detail for any given appliance type in a given country.

The South Africa Energy Demand Resource model was specifically developed for South Africa to run independently of any other models and to run within the DMRE and its partners. The EDR projects energy demand in order to calculate impacts of current, proposed and possible policies. Energy consumption is projected by end use from 2015 (base year) to 2040. The strategy of the model is to first project end-use

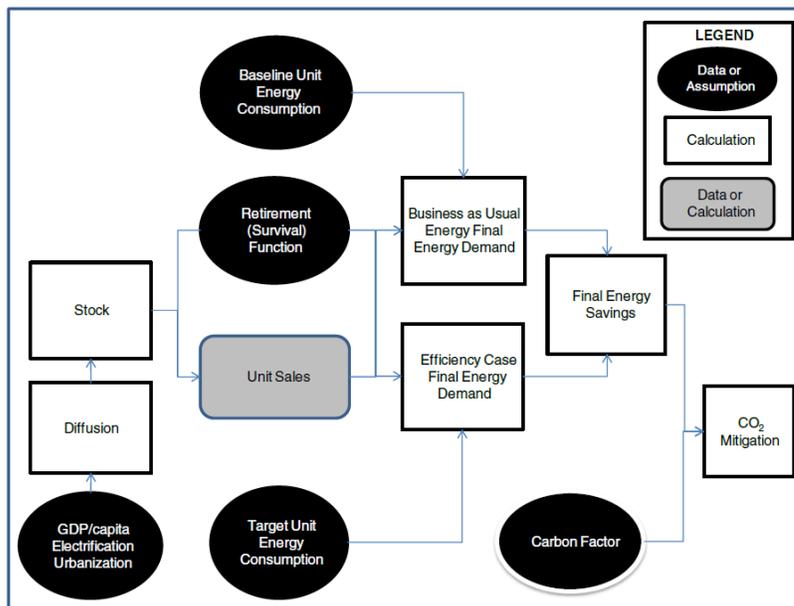
activity, which is represented by the sales of equipment driven by increased ownership of household appliances. The total stock of appliances is modeled according to penetration of ownership in the base year and then per unit sales projections. Electricity consumption or intensity of the appliance stock is then calculated according to estimates of the baseline intensity of the prevailing technology in the local market. Finally, the stock's total final energy consumption is calculated by modeling the flow of products into the stock and the marginal intensity of purchased units, either as new additions or as replacements of old units according to equipment retirement rates.

Energy efficiency scenarios are created by the assumption of increased unit efficiency relative to a business as usual (BAU) scenario starting in a certain year, when the policy comes into effect. The BAU scenario was compared with two efficiency scenarios—the proposed and the best practice scenarios—by introducing MEPS regulations to eliminate inefficient products and move the market to more efficient appliances. The BAU scenario is based on the current regulation introduced in 2016 for appliances and average estimated stock efficiency from BUENAS (Covary 2011; de la Rue du Can et al. 2013). In contrast, the proposed MEPS scenarios are based on assuming the introduction of a new regulations in 2020 that will take effect in 2021 and revisions in subsequent years as proposed by the Urban-Econ Development study (UrbanEco 2018) and described in the data sources and assumptions section below. The best practice scenario is a more aggressive scenario, based on the adoption of international best practice MEPS regulations in 2020 that take effect in 2021.

For example, if the average baseline UEC of new refrigerators is 308 kilowatt-hours (kWh)/year, and a MEPS taking effect in 2020 requires a maximum UEC of 281 kWh/year, the stock energy in the policy scenario will gradually become lower than that of the base case scenario due to increasing penetration of high-efficiency units under the standard. By 2040, the vast majority of the stock will be affected by the policy (standard).

Figure 1 represents the modeling methodology followed by EDR and BUENAS.

Figure 1. BUENAS Methodology



In Figure 1, the stock in the base year is estimated based on the penetration of equipment multiplied by the number of households. Intensity is driven by the usage and capacity of each unit, such as the size of a water heater or the number of hours a room air conditioner is used. Finally, efficiency is the technological performance of the equipment, which can be affected by government policies.

We emphasize that, while the BAU scenario used in BUENAS represents a best estimate of future demand, the focus is on energy savings from policy, not on energy demand. In particular, EDR is not comprehensive and is not calibrated to agree with top-down estimates—it only includes end-use types for which savings potential can reasonably be assessed. Having stated that, BUENAS covers a significant amount of total energy consumption. As shown in the results section, in the base year, the bottom-up energy consumption of aggregated end use modeled in EDR is 113.0 exajoules (EJ), while total residential energy consumption in South Africa was 134.9 EJ according to the International Energy Agency’s Balance for South Africa (IEA 2019).

2. LEAP and Stock Turnover in LEAP

The EDR model is implemented using the Long-Range Energy Alternatives Planning system (LEAP) developed by the Stockholm Environment Institute. LEAP is a general-purpose energy accounting model in which the model developer inputs all data and assumptions in a format that is then transparent to other users. The LEAP platform enables detailed consideration of technological development—equipment efficiency, residential appliance usage, power sector efficiency, and lighting and cooling usage—as a way to evaluate energy and emissions reduction potential. By adopting an end-use approach to energy and emissions modeling, LEAP is able to separate out and decompose different magnitudes of potential efficiency gains by end use and by technology. At the same time, scenario analysis enables the modeling of a pathway where efficiency improvements are maximized by 2040 in order to assess the combined effects of efficiency on energy and emissions reduction. This section provides details about how LEAP calculates the stock turnover.

A stock turnover analysis is particularly useful in situations where accurate simulations are required to show how a newly introduced energy efficiency standard or emissions standard affecting the sales of newly purchase technologies will translate into gradually improving average values across the entire stock of devices (as new, cleaner devices gradually replace older, less efficient or dirtier devices). A stock turnover approach is most suitable when energy-using devices have long lifetimes. In that situation, any changes to the marginal energy intensities and emission factors of newly introduced devices will thus take some time to affect the average energy intensities and emission factors of the total installed stock of devices.

Within LEAP’s user interface, the Branch Properties screen is used to set up a stock turnover analysis. There are two variations of this approach: one for conducting transportation sector stock turnover modeling, and the other for modeling all other types of energy-using technologies, such as residential appliances or heating, ventilation and air-conditioning (HVAC) systems. Given the focus of the EDR model on the buildings sector, the following sections focus on the use of stock turnover modeling for stationary equipment (e.g., appliances).

a. Overview of Stock Turnover Calculations

When using the stock turnover methodology in LEAP, energy consumption is calculated by analyzing the current and projected future stocks of energy-using devices and the UEC of each device. In the first year of the calculation (the base year) users specify the current stock of devices and the stock-average UEC

with each analyzed type of device. In future years (i.e., in scenarios) users specify future additions (sales) of devices and the UEC associated with newly added devices. LEAP then calculates the stock average energy intensity across all vintages in each future year, and ultimately the overall level of energy consumption and environmental loadings.

b. Input Variables in a LEAP Stock Turnover Model

Stock, Stock Vintage Profile, and First Sales Year

The Stock variable is used to initialize the stock turnover calculations by specifying the total number of devices in the first calculation year for each technology. The stock variable is used in conjunction with a variable called the Stock Vintage Profile, which is a vector of percentage values that describes how the total starting stock of devices is allocated among devices of each different age vintage (i.e., new devices, one-year-old devices, two-year-old devices, etc.).

The Stock variable is used in conjunction with the First Sales Year variable, which sets the year in which the stock turnover calculation begins. On this year, LEAP uses the Stock variable to specify the total stock of devices. After the First Sales Year, the stock of devices is calculated according to LEAP’s stock turnover calculations, taking into account the future sales of new devices and the retirement of older devices, as well as any forced scrappage of devices. When specifying stock data, users must enter the stock at the start of the year; i.e., NOT including any sales of devices in the first sales year. All retirements are assumed to occur at the end of each year.

Sales and Survival Profile

The Sales variable is used to specify the addition of new devices on and after the First Sales Year. Sales values can differ in each scenario analyzed. Sales are specified in conjunction with a lifecycle profile called the Survival Profile, which describes how devices are subsequently retired as they get older. The survival profile is a vector of percentage values specifying the fraction of the original sales that survives after each year (i.e., 1 year old, 2 years old, 3 years old, etc.).

Marginal UEC

Marginal UEC is the unit energy consumption of newly added devices introduced in a given year. This variable can be used in conjunction with a degradation profile that specifies how the UEC may change as devices get older. This degradation profile is a vector of percentage values specifying the relative energy intensity of surviving devices after each year (i.e., 1 year old, 2 years old, 3 years old, etc.).

c. Stock Turnover Calculations

LEAP’s stock turnover calculations are summarized by the following equations:

$$\mathbf{Stock}_{t,v,y} = \mathbf{Sales}_{t,y-v} \times \mathbf{Survival}_{t,y-v}$$

$$\mathbf{Energy\ Consumption}_{t,y} = \sum_{v=0..V} \mathbf{Stock}_{t,y,v} \times \mathbf{Unit\ Energy\ Consumption}_{t,y,v}$$

$$\mathbf{Emissions}_{y,i,p} = \mathbf{Energy\ Consumption}_{y,i} \times \mathbf{Emission\ Factor}_{p,y}$$

Where:

t is a homogenous type of technology (i.e., a LEAP branch).

v is the vintage (i.e., the age of the technology, in years from 0..V).
y is the calendar year.
i is the fuel type.
p is a pollutant (for which emission factors are defined).
V is the maximum number of vintage years.
Sales is the number of devices added in a particular year.
Stock is the number of devices existing at the end of a year before scrappage.
Final Stock is the number of devices existing at the end of year after scrappage.
Survival is the fraction of devices surviving after a number of years: entered as a lifecycle profile.
Unit Energy Consumption is the annual unit energy consumption (UEC) of a device.
Emission Factor is the annual emissions emitted per kWh of energy consumed.

3. DATA SOURCES AND ASSUMPTIONS

This section outlines the basic assumptions and data used in modeling the residential EDR model.

To conduct energy demand modeling, it is essential to know the drivers of energy demand and the input data that will go into the model, to estimate how they would evolve in the future. In this modeling process, demographic data were used as the main driver of residential energy consumption. Data variables included population rate, household size, urbanization rate and electrification rate as described in Table 1. These variables were used to calculate the number of electrified households. Population number and household size were obtained from the United Nations Population Division (United Nations 2017). Electrification rate estimates came from the Integrated National Electrification Programme (INEP) from the South Africa Department of Mineral Resources and Energy (DMRE) and include on grid and off grid electricity access.

Table 1. Macroeconomic Drivers of Residential Energy Demand

Drivers	Units	2015	2030	2040
Population	millions	55.3	64.5	69.1
Urbanization	%	64.8	72.1	76.2
Household Size	persons	3.00	2.85	2.80
Electrification Rate	%	88.0	97.5	100.0
Electrified Households	millions	16.6	22.1	24.7

Since this model is based on the stock turnover, the stock of each equipment is estimated based on the average rate of ownership of equipment per household. These penetration rates are driven by factors such as income, electrification rate and urbanization rate. Data on rate of equipment ownership were taken from the All Media and Products Survey (AMPS) from the South African Advertising Research Foundation (SAARF 2018). The SAARF AMPS collects ownership data based on the Living Standards Measure (LSM) that divides the population into 10 LSM groups, based on criteria such as their level of urbanization and ownership of major electrical appliances, representing different ranges of living standards. The wealthier households possess more electrical appliances than households in lower income quintile bands. Averages from the 10 LSM categories were used to determine the penetration rate of each appliance.

Projection of the stock is based on annual sales of equipment. Stock of equipment were estimated based on penetration of equipment in households from the AMPS of SAARF (SAARF 2018). First year sales data and average annual growth rates were obtained from a market research company called Euromonitor.² These sales data enabled us to calculate annual stock turnover.

To assess baseline efficiency and unit energy consumption of the stock and baseline sales, we used two main data sources. First, we relied on product specific analysis conducted for the S&L program by a consultant that gathers information from the market in South Africa. Specifically, one study was conducted for air conditioners (Integrated Energy Solution 2019), one was conducted for lighting (Nova Economics 2019), and one gathered information across products (UrbanEco 2018). These reports were very important data sources for helping to increase understanding of the product types available in South Africa, and for determining the baseline and assessing the growth potential of products according to different product categories. These reports were completed by a baseline study conducted in 2014 that used web-crawling techniques to gather data from online stores about the availability of products and their characteristics, including energy efficiency grading levels (Gerke, McNeil, and Tu 2017; de la Rue du Can and McNeil 2018; Unlimited Energy and Enervee 2014).

Each year products are retired and new products are purchased; such a change was modeled by the survival function. This function depends on the average age of the appliance. To determine the average age of the appliances, data can be obtained from consumer surveys. In the absence of such data, assumptions of the appliance lifetime were made based on analysis performed by LBNL using consumer surveys in the U.S. (Lutz et al. 2011) and technical support documents informing the U.S. S&L program. Table 2 provides details on the data gathered from these different sources to model the stock and sales for appliances, water heating, space conditioning and entertainment. Table 3 completes this information by providing details on the unit energy consumption of the stock and sales baselines for the two main scenarios studied in this report.

It is important to note that assumptions for UEC in the baseline and energy efficiency scenarios are based on a detailed analysis of the market share of different energy efficiency grade levels, and that an introduction of more stringent standards only removes the shares of inefficient equipment that do not meet the standard level. For example, in the case of refrigerators, market data showed that already 51 percent of refrigerators sold meet an A rating or above, so it was assumed that the efficiency improvement to an A level refrigerator would only affect 49 percent of the sales compared to the baseline. The DMRE and UNDP conducted several studies to determine the market share of the efficiency level for each piece of equipment covered by the standards implemented in 2016. The FRIDGE study undertaken in 2011 was the first attempt to collect market data on the residential appliances that were selected for the country's mandatory S&L program. The data were sourced directly from the manufacturers (Covary 2011). In 2014, this data source was furthered by a study undertaken by Unlimited Energy and Enervee, which collected detailed product information from retail websites by using web-crawling techniques (Unlimited Energy and Enervee 2014). An example of the data collected on the energy performance distribution for refrigerators is available in Figure 2, below.

² Euromonitor gathers sales data, including information regarding energy efficiency, consumption, size and price, and thus enables detailed tracking of trends in household appliances over certain years.

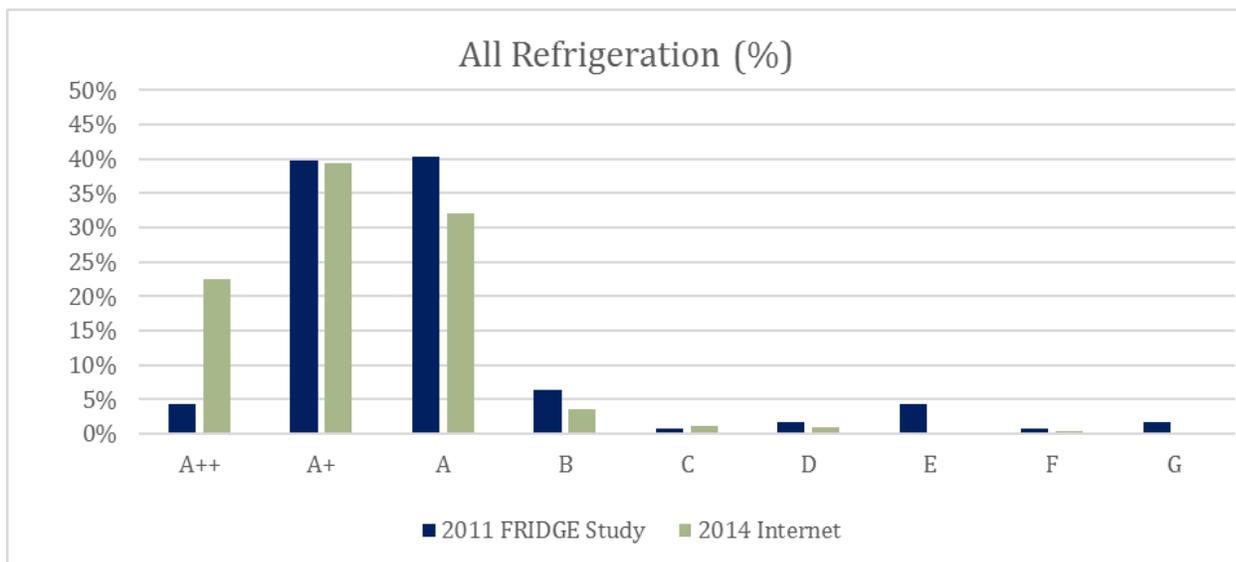
Table 2. Data Inputs and Assumptions Used in the Residential Energy Demand Resource Model

	Product Sub-Type	Penetration Rate	Source	Sales	Median Lifetime	Sales Growth	
		%		'000	years	2015–25	2025–40
Appliances	Refrigerator-Freezers	81	AMPS	1,157	17.5	2.0	1.0
	Refrigerators	4	AMPS	38	17.5	2.0	1.0
	Freezers	31	SSA	296	21	4.0	3.0
	Clothes Washers	40	AMPS	439	14.5	6.5	5.0
	Dryers	14	AMPS	19	16	6.5	5.0
	Dishwashers	14	SSA	92	15	7.1	6.0
	Ovens	88	SSA	147	14.5	0.5	0.5
Water Heating	Electric Water Heaters	42	AMPS	630	11	4.5	3.5
Space conditioning	Split cooling only	2.00	SSA	5	17.5	0	0
	Split Reversible	3.90	SSA	86.9	17.5	6.5	5.5
	Evaporative air coolers	0.10	BUENAS	2.4	17.5	6.5	5.5
Entertainment	TV	90	AMPS	535.2	18	9.3	5.0
	Stand by TV	90	AMPS	535.2	18	9.3	5.0
	Other plug load	164	AMPS	977	18	9.3	5.0

Table 3. Baseline and MEPS Scenarios Used in the Residential Energy Demand Resource Model

	Product Sub-Type	UEC Stock (KWh)	UEC Baseline (kWh)	Rating	UEC Proposed (year: kWh)	Rating	UEC Best Practice (kWh)	Rating
Appliances	Refrigerator-Freezers	344	308	B	2021: 281 2027: 243	2021: A 2027: A+	2021: 243	2021: A+
	Refrigerators	280	250	B	2021: 228 2027: 197	2021: A 2027: A+	2021: 197	2021: A+
	Freezers	423	406	C	2021: 366 2027: 330	2021: B 2027: A	2021: 274	2021: A+
	Clothes Washers	190	185	A	2023: 162	2023: A+	2023: 144	2023: A++
	Dryers	294	275	D	2021: 271	2021: C	2021: 255	2021: B
	Dishwashers	291	285	A	No change	No change	2021: 276	2021: A+
	Ovens	119	112	B	2021: 101	2021: A	2021: 101	2021: A
Water Heating	Electric Water Heaters	1,351	1,042	B	No change	No change	2021: 900	2021: A
Entertainment	TV	213	213	-	No change	No change	2021: 177	CA MEPS
	Standby TV	5.08	5.08	0.58W	2021: 4.38	0.5W	2021: 0.88	0.1W
	Other Plug Load	5.08	5.08	0.58W	2021: 4.38	0.5W	2021: 0.88	0.1W
Space Conditioning	Split Cooling Only	993	960	B	2021: 900	A	2021: 806	A+
	Split Reversible	2,056	1,988	B	2021: 1864	A	2021: 1671	A+
	Evaporative Air Coolers	804	804	-	2021: 804	-	2021: 618	-

Figure 2. Energy Efficiency Distribution for Refrigerators



Lighting

In the case of lighting, the modeling requires more details, as the source of energy savings results from the transition from various types of bulb technologies to other types that require very different levels of energy per unit of lumen produced. Lumens per watt (lm/W) is a metric used to measure the energy efficacy of a light bulb. It refers to a level of visible light produced per amount of electricity consumed. The newest lighting technology, LED (light-emitting diode), requires 10 times less energy to produce the same amount of light as a traditional 60 W incandescent bulb. Moreover, the transition also affects product stock and sales in different ways, as lifetime varies widely across technologies. While a traditional incandescent light bulb has a life of about 1,000 hours, an LED can potentially be used for 35,000 hours or more. Table 4 summarizes the main technology features of different light bulb technology options. Penetration of LEDs is still low—17 percent of the stock. However, increased use of LED bulbs will be the source of major energy savings in the residential sector, as lighting is a major source of household energy consumption; especially for low-income households, for which lighting often represents the largest portion of their electricity bills.

Table 4. Lighting Model Data Input

Bulb Technology	Stock	Stock Shares	Sales	Sales Shares	Energy Use	Lifespan	Efficacy
	Million	%	Million	%	Watt	Hours	Lumens per Watt
LED Medium Efficiency	22.6	13.3	6.2	11.5	10.0	15,000-30,000	80
LED High Efficiency	6.2	3.7	1.7	3.2	8.4	15,000-30,000	95
Compact Fluorescent	95.6	56.2	29.1	54.3	13.3	6,000-15,000	60
Halogen	43.4	25.5	15.7	29.2	53.3	2,000-3,000	15
Incandescent	2.5	1.4	0.9	1.7	60	1,000-1,500	13

Greenhouse Gas Emissions

To calculate the carbon dioxide (CO₂) emission mitigation impacts of reducing electricity consumption, we used Eskom's estimate of "environmental implications of using or saving electricity" (Eskom 2015) for the base year. In 2015, the electricity CO₂ emissions factor was 1.03 tons per MWh sold. For projecting the CO₂ electricity emissions factor, we used forecasts from the Integrated Resource Plan (IRP) from the Department of Mineral Resources and Energy (DMRE 2019). In scenario IRP 1, emissions were projected to reach 217 million of CO₂ (MtCO₂) with a total electricity generation of 321 TWh. Assuming 10 percent transmission and distribution losses, the electricity CO₂ emissions factor was estimated to reach 0.75 tonnes of CO₂ per megawatt-hour (tCO₂/MWh) in 2030. For 2040, we extrapolated the trend and estimated that the electricity CO₂ emissions factor will reach 0.6 tCO₂/MWh.

4. RESULTS

This section describes the results of the modeling scenarios. Projection of activity drivers are first described and then the BAU is described as a representation of likely residential electricity future projections if no new energy efficiency policy is implemented and standards remain as they are today. Then energy savings resulting from the two energy efficiency scenarios are described as a representation of the impacts of different MEPS options.

1. Activity Driver Projections

Ownership rate of energy-using equipment is a fundamental activity driver that influences energy demand in the residential sector. The EDR model uses sale projections based on observed current trends to forecast the growing stock of products in use among households. The EDR modeling tool has built-in indicators to show resulting projected ownership of equipment, as shown in Figure 3. South Africa projected trends in ownership in 2040 remain low compared to most industrialized countries and some emerging economies. For example, average ownership of TV per household is projected to be 132 percent in 2040 in South Africa, while it is 122 percent in China today and 230 percent in the United States today (

Table 5). These variables do not change across scenarios, as policy does not affect equipment ownership.

Figure 3. Resulting Appliance Penetration Projections

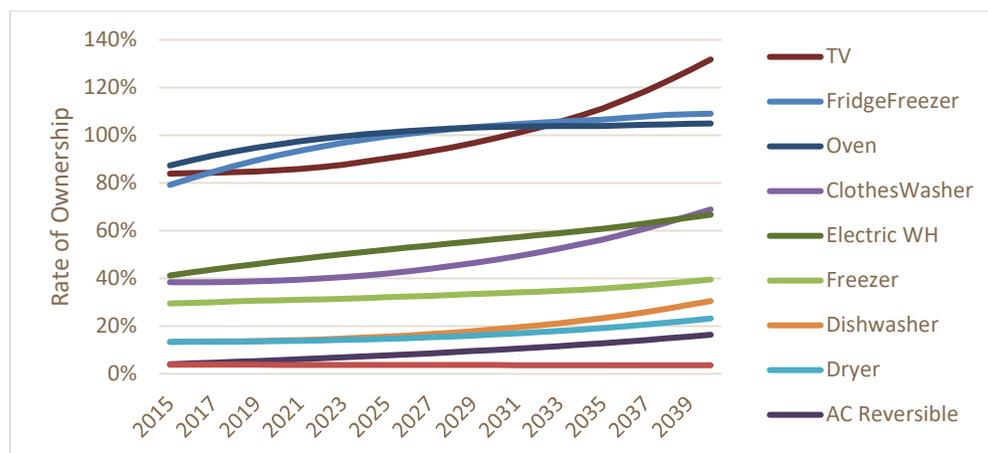


Table 5. 2040 Ownership Comparison with 2014 U.S. Trends

	SOUTH AFRICA 2040 (%)	UNITED STATES (%)	CHINA (%)
FRIDGE-FREEZER	109	129	95
FREEZER	40	36	NA
CLOTHESWASHER	69	82	91
DRYER	23	80	NA
DISHWASHER	30	67	NA
TV	132	230	122
WATER HEATER	67	100	79
ACs	16	80	96
LIGHT BULBS	11,100	29,500	NA

Source: NBSC, 2019; U.S. EIA, 2018

2. BAU Scenario Projections

In the BAU scenario, total end use electricity consumption is projected to increase from 34.1 TWh to 58.2 TWh, increasing at an average annual growth rate of 2.5 percent. It should be noted that the EDR model is a bottom-up representation of end uses that are affected by S&L policies, and that the focus of the analysis is on energy savings from policy, not on total energy demand forecast. In particular, EDR is not comprehensive and is not calibrated to agree with top-down estimates—it only includes end-use types for which savings potential can reasonably be assessed. Having stated that, EDR covers a significant amount of total energy consumption. In 2015, the bottom-up energy consumption of aggregated end uses modeled in EDR represented 84 percent of total electricity consumption estimated by the International Energy Agency’s Balance for South Africa (IEA 2019). EDR total aggregated bottom-up end use was 113.0 EJ, while total residential energy consumption in South Africa was 134.9 EJ according to the International Energy Agency (IEA). Figure 4 shows resulting electricity projections from the BAU scenario, and

Figure 5 shows detailed electricity consumption per end use.

Figure 4. BAU End-Use Energy Consumption

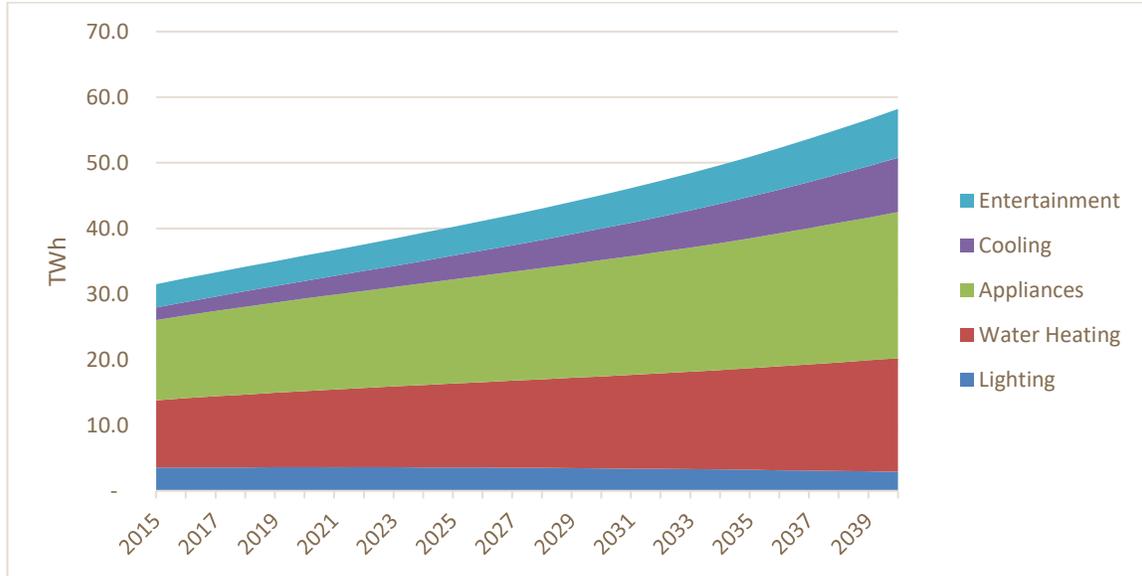
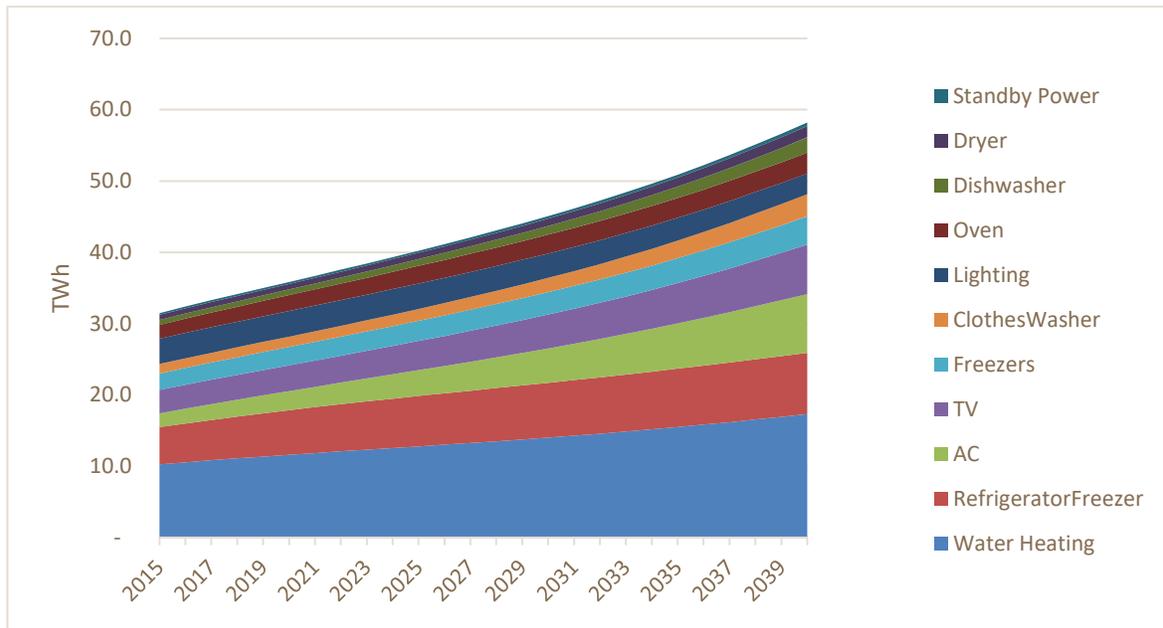


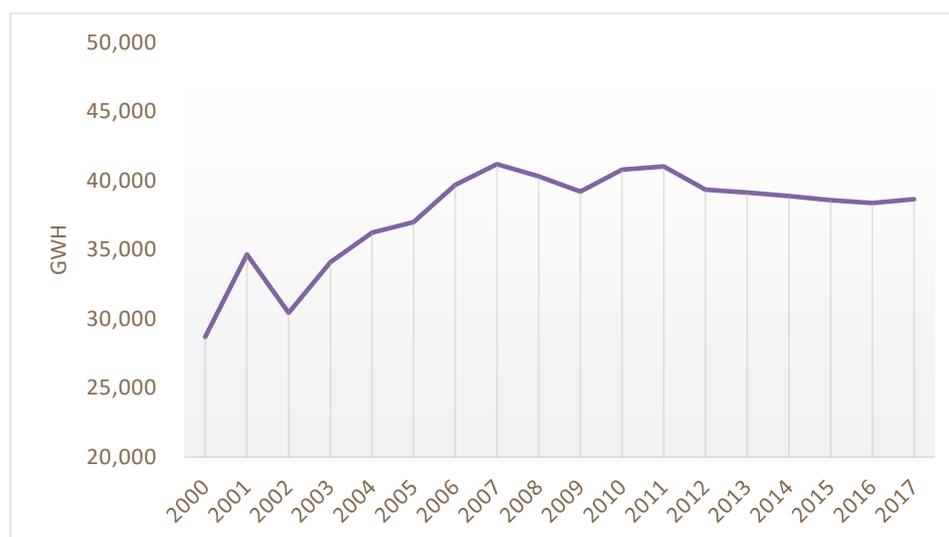
Figure 5. BAU Detailed End-Use Consumption



While it is a delicate task to forecast the future, scenario-based projection helps to depict possible outlooks by taking into account assumptions and methods. In order to appraise the electricity projection

resulting from the BAU scenario we contextualize it with past trends and other model projections of electricity consumption. Looking over the last 15-year period, residential electricity consumption has increased by an average growth rate of 1.8 percent according to the South Africa energy balance compiled by the IEA (2019). However, this trend has not been even, growing at an average rate of 4.3 percent over the period 2000–2008 and then declining at an average rate of 1.0 percent after the global financial crisis of 2008 and up to 2015 (Figure 6). Similarly, the rate of change over the period 2015 to 2040 will not be even, but the BAU projections provide a leveled projected outlook based on most likely conditions in the absence of new energy efficiency policy and major technological or economic disruption.

Figure 6. Residential Electricity Consumption 2000–2017



Source: IEA, 2019

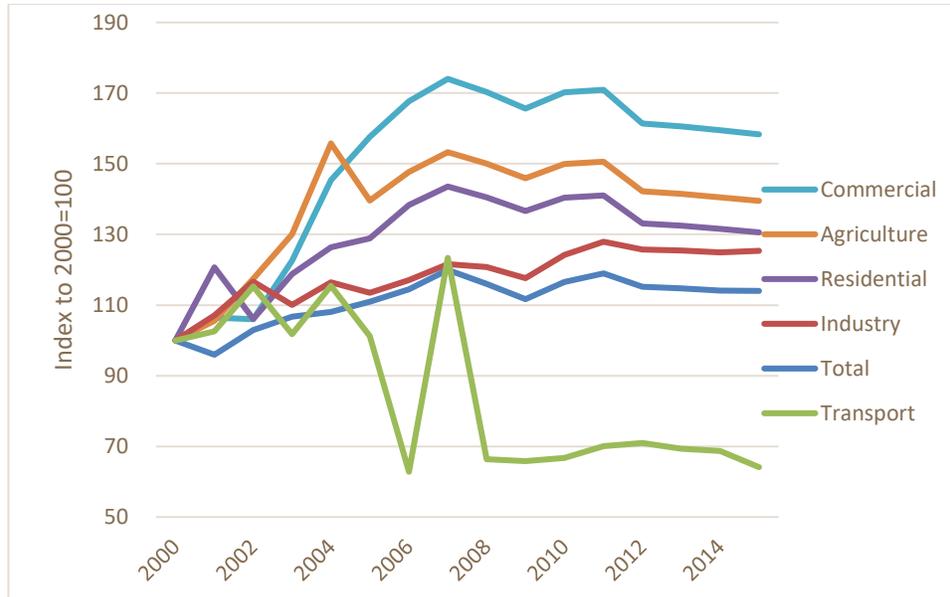
Electricity consumption at the sector level is rarely projected for South Africa. The IEA Africa Energy Outlook is the only source that provides country level estimates (IEA 2014) for the residential sector. In their New Policies Scenario, residential electricity consumption is projected to grow to 116,300 gigawatt-hours (GWh) in 2040, representing an average annual growth (AAG) of 4.5 percent over the period 2015–2040. This is considerably higher than our BAU scenario of 2.5 percent AAG.

A few national estimates are available for the projection of all sectors’ electricity consumption. The Southern Africa Power Pool master plan provides estimates received from ESKOM, recently supplemented to take into account of lower expected economic growth. In the base demand forecast, average annual growth is projected at 2.5 percent, and in the low economic forecast, this is reduced to 1.9 percent per annum. The IRP also provides forecasts for all sector electricity demand. In the median forecast scenario, average annual electricity demand growth is projected at 1.8 percent by 2030 and 1.4 percent by 2050 based on an average 4.3 percent GDP growth by 2030 and significant change in the structure of the economy (DMRE 2019).

Electricity rate of changes vary across sectors, as can be seen over time for South Africa, and depends on many factors (Figure 7). In the residential sector, the main drivers are equipment penetration, equipment energy efficiency, usage pattern, household size, urbanization and electricity access, among the most important. Compared to other scenarios, EDR’s BAU projections for residential consumption align with

the base demand forecast of Eskom for total electricity supplied in the South African Power Pool (SAPP) master plan (SAPP 2017). However, it is worth noting that EDR’s projection included all types of electricity, off grid and on grid.

Figure 7. Electricity Sectors Growth Trend, 2000 base year



Source: IEA, 2019

3. Proposed MEPS Scenario

Figure 8 shows the estimated annual energy savings resulting from the implementation of the currently proposed MEPS. For 2040, it is estimated that about 4.5 TWh of electricity consumption would be saved, representing the equivalent of a 700 MW thermal power plant (or the equivalent of almost 2 GW of wind capacity) and a reduction of 8 percent of residential electricity consumption. Appliances show the largest source of energy savings potential, followed by lighting. Figure 9 shows the details of the energy savings per end use. Refrigerators are the largest energy savings after lighting, followed by freezers. These energy savings are estimated to result in 3.3 MtCO₂, a reduction of 8 percent compared to BAU energy use, and the equivalent of today’s direct³ emissions from the chemical and petrochemical industry in South Africa.

³ Direct emissions include only emissions from fuel combustion and do not include indirect emissions from electricity consumption or process emissions.

Figure 8. Energy Savings from the Proposed MEPS

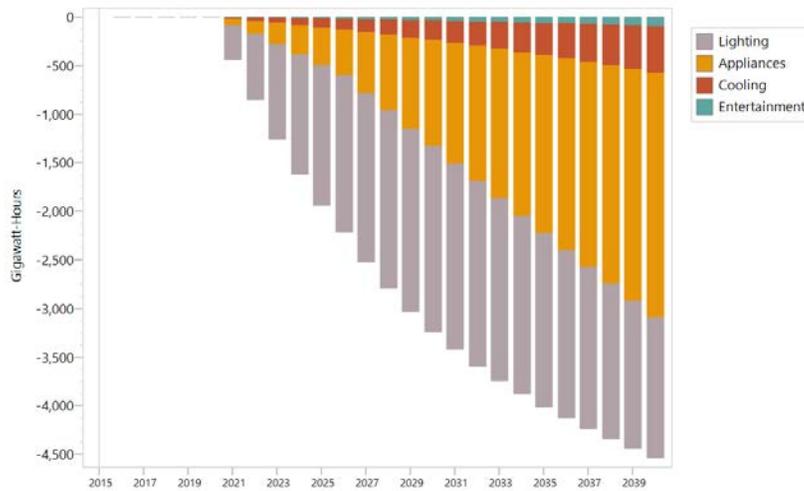
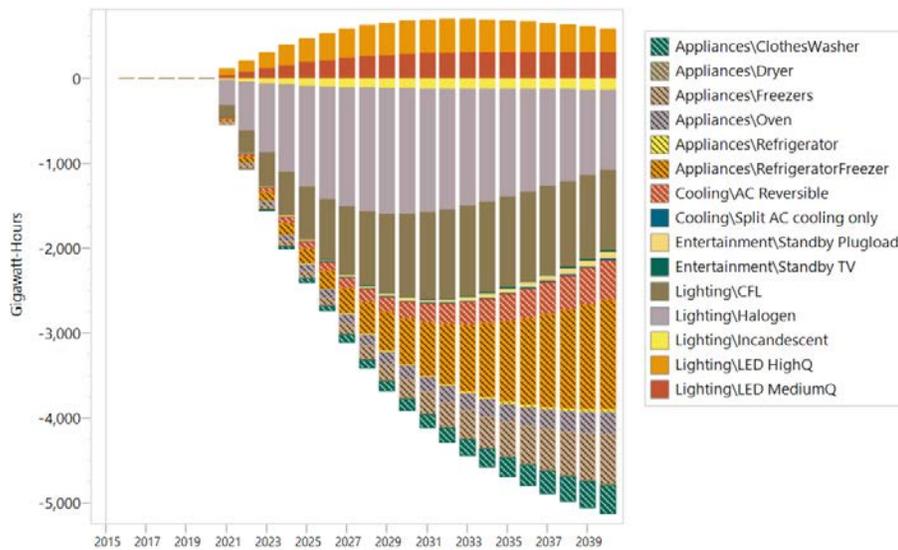


Figure 9. Detailed End-Use Energy Savings from the Proposed MEPS Scenario



4. Best Practices MEPS Scenario

The best practices scenario shows the potential to push the energy efficiency boundary a bit further to align with currently implemented international best practices standards. In this case, most of the standards are considered to take effect by 2021, and additional end uses, such as water heating and TVs, are considered, which were not considered in the Proposed Scenario. Figure 10 shows the annual energy savings per main end use, and Figure 11 provides additional details per end use. In this scenario, energy savings reach 9.6 TWh, representing a reduction of 17 percent of the electricity consumption. This is equivalent to avoiding the development of a 1.5 GW thermal power plant or 4.0 GW wind farm. The

implementation of the best practice scenario would result in 7.0 MtCO₂ in 2040, which is more than the equivalent of direct emissions from the mining industry today in South Africa.

Figure 10. Best Practice Scenario Energy Savings

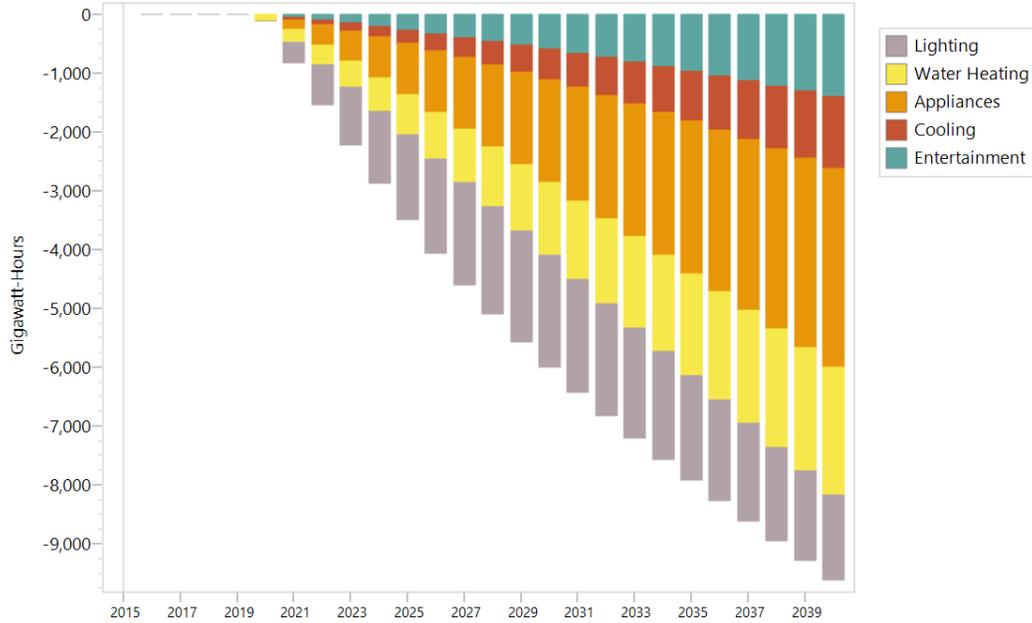
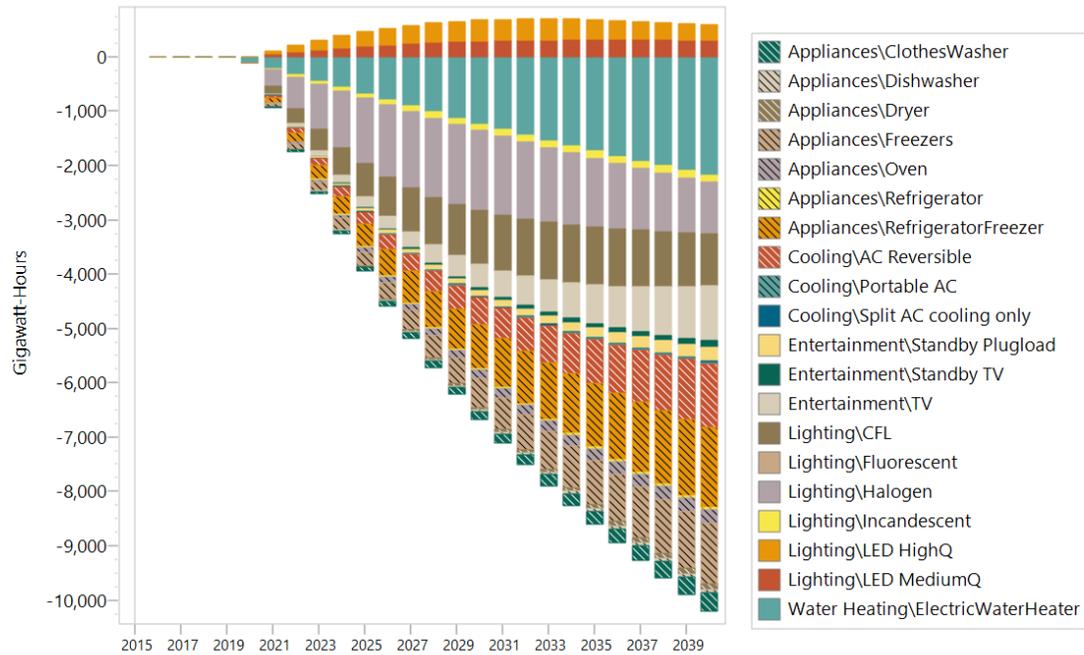


Figure 11. Detailed End Use Energy Savings from the Best Practice Scenario



5. MULTI-BENEFITS OF THE S&L ENERGY EFFICIENCY PROGRAM

Investments in energy efficiency bring multiple benefits, including increased access to energy services, enhanced reliability of a country's energy system, mitigation of environmental and other harm from fuel combustion and contributions to economic development.

The best practice scenario projects energy savings of 6.0 TWh in 2030 and 9.6 TWh in 2040, which represent reductions of total residential electricity consumption of 13 percent in 2030 and 17 percent in 2040. These electricity savings constitute major electricity cost savings for consumers. Considering an electricity price of 2.5 rand per kilowatt-hour, consumers would save 15.1 billion rand in 2030 and 24.3 billion rand in 2040 in operating costs. Even with the savings, they would receive the same level of energy services (e.g., the same level of luminosity, the same level of refrigeration) that they would if there were no energy efficiency standard. On average, households would save 683 rand in 2030 and 978 rand in 2040 in operating costs as a result of residential energy efficiency standards.

A reduction in the amount of electricity produced as the result of energy efficiency offers additional environmental benefits, even when cleaner electricity production is considered, as in the case in IRP 1. In this scenario, the proportion of coal would be 64 percent in 2030 compared to 91 percent today. The implementation of energy efficiency standards would reduce CO₂ emissions by 3.7 Mt in 2030 and 5.8 Mt in 2040 in the best practice scenario. About 2.5 and 3.2 million tons of coal would be avoided in the electricity generation in 2030 and 2040, respectively, resulting in avoiding 4 kilotons (kt) of particulate emissions, 4.3 Mt of sulfur oxide (SO_x) emissions, and 25 kt of nitrogen oxide (NO_x) emissions in 2030; and 6 kt of particulate emissions, 5.0 Mt of SO_x emissions, and 29 kt of NO_x emissions in 2040. The improvement of air quality characterized by the inhalable fraction of particulate matter (PM₁₀) and other pollutants is very important, as it contributes to reduce a country's morbidity and mortality rates. The country would also save 6.5 billion liters of water in 2030 and 8.3 billion liters in 2040.

Table 6 summarizes the main benefits of implementing Best Practice standards using Eskom environmental implications of saving electricity (Eskom 2015) extrapolated to 2040, based on South Africa DMRE's IRP projection of electricity mix.

Table 6. Best Practice Scenario’s Multiple Benefits in 2030 and 2040

	2030	2040
	6.0 TWh of annual electricity savings	9.6 TWh of annual electricity savings
	15.1 billion rand of annual energy bill savings, representing an average annual bill saving of 683 rand per household	24 billion rand of annual energy bill savings, representing an average annual bill saving of 978 rand per household
	Reduction of 3.7 million tons of CO ₂ emissions	Reduction of 5.8 million tons of CO ₂ emissions
	Water savings of 6.5 billion litres	Water savings of 8.3 billion litres
	Reduction of 2.5 million tons of coal burned	Reduction of 3.2 million tons of coal burned
	Avoiding emissions of the following atmospheric pollutants: <ul style="list-style-type: none"> • 4 kt of particulate • 4.3 Mt of SO_x emissions • 23 kt of NO_x emissions 	Avoiding emissions of the following atmospheric pollutants: <ul style="list-style-type: none"> • 6 kt of particulate • 5.0 Mt of SO_x emissions • 25 kt of NO_x emissions

6. THE COST OF SAVING KILOWATT-HOURS

The DMRE initiated its S&L program following the adoption in 2005 of the National Energy Efficiency Strategy. Following a number of stakeholder consultations and the decisions on the final approach, it was in 2011 when a successful funding application to the Global Environment Facility (GEF), through the UNDP, was endorsed and allocated a budget of US\$4.4 million to implement the project “Market Transformation through the Introduction of Energy Efficiency Standards and the Labelling of Household Appliances in South Africa.” This project resulted in the promulgation of standards and labeling regulations in February 2014 (which came into effect in August 2015 for white goods and audio-visual equipment) and in February 2016 for electric water heaters (which came into effect in August 2017). The set of MEPS, which were approved under South Africa’s Compulsory Specification for Energy Efficiency and Labeling of Electrical and Electronic Apparatus (VC 9008), are expected to achieve 2.15 TWh of savings by 2020 and 5.55 TWh by 2030 (de la Rue du Can and McNeil 2018).

Considering a similar budget for revising the standards and expanding the program to include lighting, the cost to the government of saving one unit of electricity is extremely low. It is estimated to be 2 cents of a rand per kWh (c/kWh) in the Proposed MEPS scenario and 1 c/kWh in the case of the Best Practice

scenario. This compares very favorably with the cost to supply a kilowatt-hour, which is in the order of 115 c/kWh in IRP 1. The cost of supplying 1 kWh costs the government⁴ 100 times more than saving 1 kWh. Because the investment in saving 1 kWh of electricity is much cheaper than the cost of meeting electricity needs with new power plants, energy efficiency contributes to reducing electricity tariffs, and therefore increases the affordability of electricity to all. Therefore, the government of South Africa should prioritize the implementation of the S&L program to save energy and reduce costs.

7. CONCLUSION

Energy efficiency standards and labeling (EESL) programs are highly effective policy instruments to save energy and support growing markets for energy-efficient products. They are the cornerstone of energy efficiency programs worldwide and have been implemented in more than 80 countries, covering more than 50 different types of energy-using products in the commercial, industrial and residential sectors. These programs encourage removal of inefficient technologies from the market; avoid dumping of older, less-efficient technologies from more advanced economies; and empower consumers to make informed purchasing choices. These programs are essential to transform markets toward more advanced technologies and foster innovation, contributing to the improvement of technology in a country. Energy efficiency standards should be regularly revised to more stringent levels to reflect rapid changes in markets.

The South African government launched its S&L program in 2011 and has made tremendous progress since then, with the implementation of mandatory standards in 2016 covering 10 products; the development of tools to facilitate compliance, monitoring and verification; and a communication campaign to inform households about the benefits of buying more efficient products. However, MEPS are becoming obsolete as market appliance efficiencies are improved. This report shows that by adopting new standards that are common in other parts of the world, significant additional energy savings are possible. Implementation of standards that are in line with international best practice would enable South Africa to reduce residential electricity consumption by 13 percent in 2030 and 17 percent in 2040.

Consumers would save 15.1 billion rand in 2030 and 24.3 billion rand in 2040 in operating costs and still enjoy the same level of energy services. This represents a per household average of 683 rand in 2030 and 978 rand in 2040. Environmental benefits also would be large, including saving 6.5 billion liters of water in 2030 and 8.3 billion liters in 2040; reducing CO₂ emissions by 3.7 Mt in 2030 and 5.8 Mt in 2040; and avoiding 4 kt of particulate emissions, 4.3 Mt of SO_x emissions, and 25 kt of NO_x emissions in 2030; and 6 kt of particulate emissions, 5.0 Mt of SO_x emissions, and 29 kt of NO_x emissions in 2040. The air quality improvement would help reduce the incidence of premature mortality and chronic respiratory diseases. The program's CO₂ emission reductions also would contribute to South Africa's nationally determined contribution (NDC) commitment. The government committed to hold greenhouse gas emissions between 398 and 614 MtCO₂ per year from 2025 to 2030 in its NDC to the 2015 United Nations Framework Convention on Climate Change (UNFCCC) Paris agreement.

⁴ In this analysis we did not include the incremental cost to the consumers of purchasing more efficient equipment. However, this cost is estimated to be small, as all standards considered have been already implemented in other countries and are largely compensated for by the operating costs savings.

South Africa's S&L program is still developing. The current project has provided a solid foundation for the program to grow and improve, and it is now running and operating with well-established tools and resources, as well as a good understanding from consumers and other stakeholders of the value of the program and energy efficiency standards and labels. It is now important that the South African government builds on this robust foundation and values the benefits that provide the program to consumers by providing dedicated resources to institutionalize the program in the long term and allow its expansion.

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