United Nations
Economic Commission for Africa

PROMOTING ENERGY EFFICIENCY INVESTMENTS FOR CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

Case studies on policy reforms in Africa

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Foreword

Africa has 15 per cent of the world's population, but consumes 3 per cent of the world's energy output, as well as generating less than half of its own 74 GW peak demand requirement. Only a quarter of Africa, excluding North Africa, has access to electricity, and many countries experience daily electricity outages, costing them up to 5 per cent of gross domestic product (GDP) per annum. Africa, excluding North Africa, is the only region in the world where the number of people without access to electricity seems to be increasing.

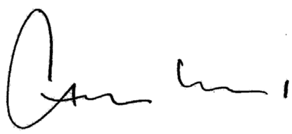
In 2011, over 70 per cent and 20 per cent of Africa's energy consumption was derived from fossil fuels and renewables, respectively. Virtually all (93 per cent) of renewable energy capacity in Africa is hydroelectric power for which its distribution is highly irregular across African states.

Energy is needed to industrialize Africa. But to avoid associating its industrialization process with increased environmental and health damage, Africa needs to diversify its energy capacity by tapping into its vast renewable energy potential and investing in energy efficiency technologies and practices. Over the years, countries have had the luxury to industrialize first and worry about the environment later. While this may have made sense in a world with 500 million people and relatively slow growth, today, it is a risky strategy when some African economies are growing at more than 8 per cent per year.

Africa has the potential to orientate the large future investments needed to scale up its energy generation towards renewable energy technologies and energy efficiency technologies. Africa can benefit from the fast technological advances in renewable energy technologies and energy efficiency technologies that are taking place globally. According to a United Nations Environment Programme (UNEP, 2012) study, global investments in renewable energy rose to $257 billion in 2011, twice as much as in 2007. However, for Africa to benefit from this global development there should be proactive regulations and legislations that allow for the facilitation of investments in energy efficiency projects which are environmentally sound; research and development (R&D) and demonstration initiatives in partnership with developed countries; and incentives for local companies to adopt energy efficiency technologies.

Africa can learn from best energy efficiency practices both on the continent and elsewhere. It needs to develop a clear understanding of its renewable energy potential, energy efficiency technologies available internationally, and the role that energy efficiency could play in its industrialization process.

This report outlines how investments, both by the private and public sector, can improve energy access in Africa. It points out that while energy generation can still be pursued in Africa in order to meet growing deficits, it is also important to pay more attention to energy efficiency, as a strategy to ensure energy security and avoid building new generation facilities in the future. The report also directly contributes to the objectives United Nations Decade for Sustainable Energy for All (SE4All), which are to ensure universal access to modern energy services, double the global rate of improvement in energy efficiency and double the share of renewable energy in the global energy mix by 2030.



Carlos Lopes
United Nations Under-Secretary General and
Executive Secretary of the Economic
Commission for Africa

Executive Summary

Overview

In recent years, both developed and developing countries have been paying greater attention to improving energy efficiency, mostly as the result of rising prices of electricity and the growing demand for finite and diminishing fossil fuel resources. Improved energy efficiency is one of the most cost-effective ways to reduce global greenhouse gas (GHG) emissions. It also enhances energy security of the countries by reducing energy demand. To date, energy efficiency has become one of the priority fields in the energy, economic and climate change policies of many countries globally.

Strategies on low-emission development make it possible for countries to advance sustainable, climate-resilient development and private sector growth while significantly reducing the GHG emissions traditionally associated with economic growth. Success in carrying out the low-emission development strategies (LEDS) is founded on the strategy being country-driven and built upon robust analysis, ranging from business-as-usual projections to financing plans. However, promotion of energy efficiency programmes might face resistance if not practically clarified.

The objective of this report is to facilitate for an improved regulatory and institutional framework for promotion of new financing mechanisms for energy efficiency projects by presenting three national case studies (Morocco, South Africa and Zambia) of policy reforms to promote energy efficiency. The case studies provide value added in which policymakers at different levels can be shown what direct social, environmental and financial benefits will be forthcoming from a specific project or series of projects, given that particular policy reforms are made. These include economic, financial, energy pricing and tariff structure, as well as institutional or comparatively simple administrative reforms. These reforms are often necessary to package energy efficiency projects and make them bankable.

A common feature about these countries is that poverty levels are high -- at 15 per cent of the 33 million people in Morocco, 31.3 per cent of the 48.4 million people in South Africa, and 60.5 per cent of the 14.64 million people in Zambia.[1] With this scenario, accessibility and affordability of energy goods and services becomes a problem. This is largely why the Moroccan government subsidises energy consumption, which for petroleum products in 2011 amounted to $4.8 billion (Lahbabi, 2013). In South Africa, under the Free Basic Alternative Energy policy programme, the government subsidises the consumption of energy such as the 50 kWh free basic electricity, paraffin, liquefied petroleum gas (LPG), and ethanol gel fuel (Tait, Merven and Senatla, 2013). In Zambia, the government cannot stop the forest-degrading production and use of wood or charcoal due to lack of an alternative affordable energy (Gumbo and others, 2013).

While most energy efficiency programmes and projects tend to leave the poor in the end-user basket, this report puts the poor at the centre, for both production and use of the energy, as part of the energy efficiency or emission saving measures. Specifically, the energy efficiency and emissions saving measures for Morocco take advantage of the very favourable irradiation of more than 2300 kWh/m^2 per year, and the adjacent European renewable energy market.

For South Africa, measures take advantage of high direct normal irradiation averaging over 7.0 kWh/m^2/day in many areas of the country, and the recent draft policy to produce biofuels (bioethanol and biodiesel) (Department of Energy of South Africa, 2012).

For Zambia, measures take advantage of the abundant use of charcoal in urban areas (Gumbo, and others, 2013; Mulenga, Tembo and Sitko,

1 Additional information is available from www.cia.gov

2013) and the favourable environment to produce bioethanol in the country.

As this was a desk study, the work involved gathering literature from ECA, web-based and physical information repositories. The information was compiled and cross-checked for discrepancies before being subjected to tools for evaluating energy efficiency, emission saving and associated outcomes. The study was presented in a seminar that consisted of African and international energy experts in Addis Ababa in June 2014.

These are the results of the analysis:

Morocco

By 2030, the estimated number of households is 7.6 million with the potential of generating 26,600 GWh of electricity in the same year, if all housing units are installed with a 5kW solar photovoltaic (PV) system. The daily consumption per household for 10 standard bulbs is 3 kWh while switching to compact fluorescent light bulbs (CFLBs) consumption would only be 0.54 kWh. The energy saved per household per day would therefore be 2.46 kWh, so that each household would sell 18,052 kWh per year, if there were only CFLBs drawing on power.

For an estimated capital cost for solar PV of $2,750/kW (Can and others, 2013), and given a $0.10 feed-in tariff (FIT), this would be an income of $1,805.20 per household. The investment would thus be recovered in about 7.6 years for the 5 kW solar PV systems, which look good for a 20-year lifespan of the system.

Historical data indicates that in 2011, there were 19.54 million metric tons of GHG emissions from power generation. These emissions are projected to increase to 28.72 million metric tons in 2030 based on the business-as-usual scenario. With a mandatory installation of solar PV systems per household instituted, an estimated 9.18 million metric tons of CO_2 would be saved.

Also, for every kWh of electricity generated from coal-fired plants, there is 0.993 kg of CO_2 equivalent emitted (Letete, Guma and Marquard, 2007). By using CFLBs, each household would avoid 2.443 kg of CO_2 per day. Thus, for a total 7.6 million households, 6.777 million tons kg of CO_2 equivalent would be avoided in 2030, due to use of CFLBs alone.

South Africa

The 16.7 million households projected in 2030 would have the potential to generate about 116,000 GWh of electricity if the policy mandates all to install 5kW solar systems. Similar to Morocco, each household would receive $1,805.20 and able to recover the investment in approximately 7.6 years for the 5 kW solar PV system.

The second policy in South Africa would be to replace paraffin with bioethanol for cooking. On the assumption that 25 per cent of the 1.78 million electrified households are using 100 per cent paraffin for cooking and heating, and that 50 per cent of the 3.47 million non-electrified households are using 100 per cent paraffin for cooking (bringing the total for the two categories to 2.18 million households using 100 per cent paraffin for cooking), this would generate a bioethanol based economy of $397.850 million annually for rural areas producing feedstock for bioethanol, based on feedstock production cost of 50 per cent of the bioethanol production cost.

For 26.6 kWh per litre of bioethanol co-generated from bagasse and 40.6 kWh co-generated from vinasse, there would be 67.2 kWh co-generated per litre of bioethanol produced. Assuming a $0.10/kWh FIT, this would generate an additional annual economy worth $5.35 billion in feedstock-producing rural communities.

Data for 2011 showed up to 229.05 million metric tons of CO_2.[2] The linear projected amount is 320.45 million metric tons by 2030. The additional 91.4 million metric tons of CO_2 would be saved if renewable energy and energy efficiency mandatory policy measures to install solar PV systems per household were instituted.

2 World Bank, "World Development Indicators", 2011. Available from http://data.worldbank.org/en/country/south-africa

Mandatory use of CFLBs in the total 16.7 million households would result in the avoidance of 14.891 million tons of CO_2 equivalent in 2030. In the case of paraffin, the business-as-usual emissions are projected to increase to 33 metric tons of CO_2 equivalent by 2030. However, using bioethanol could reduce the emissions from an estimated 19.8 metric tons in 2012 to 3.4 metric tons by 2030.

Zambia

On the assumption that a household in Zambia uses 2.5 kg of charcoal per day for cooking, if 1,126,662 out of the urban households are using bioethanol by 2030, the total annual bioethanol consumption would be 411,231,929 litres. This is based on 1 litre bioethanol charcoal equivalent consumption per household per day. Given a bioethanol producer price of $1 per litre and that 50 per cent would be the cost of feedstock supplied by rural communities, there would be $205.62 million of annual retained economy in feedstock-producing communities due to bioethanol alone. The additional economy due to power co-generation at $0.10 FIT would be $2.43 billion for the bioethanol producing communities in the year 2030. Together, it would add up to $2.635 billion of annual retained economy.

Under the business-as-usual scenario, the GHG emissions due to charcoal use for cooking by 1,126,662 urban households in Zambia would be 142,298 thousand tons of CO_2 equivalent by 2030. By introducing charcoal substitution with bioethanol, the emissions would drop down to 1,135 thousand tons of CO_2 equivalent.

Additional policy measures

Additional measures should recognize the prevailing poverty and joblessness in the three countries, the lack of affordability for the people to effectively participate in carrying out the policies; the opportunities to localize renewable energy technologies, especially in the wake of increased economies of scale; and the need for governments to use renewable industry as an opportunity for propelling citizens on the inclusive growth path. Some of these measures include offering attractive FITs, attractive mandates and producer price of bioethanol, providing incentives to lower production cost of energy, establishing local content policy, and instituting inclusive innovative financing mechanisms for energy efficiency, renewable energy and emissions saving.

Conclusions

The case studies demonstrate that by adopting low-emission development, it is possible for countries to advance a win-win sustainable, climate-resilient development for both pro-poor and private-sector growth, while significantly reducing GHG emissions. In all cases, the energy efficiency, renewable energy and emissions saving programmes can be country-driven, apart from capacity-building and technology transfer which may need external help. However, incentives are necessary to stimulate investment in the programmes.

Recommendations

The energy efficiency-renewable economies are low-hanging fruits and support sustainable development. African countries, which happen to possess either all or most of the renewable energy resources, should decide on programmes to develop green economies. To actualize the establishment of energy efficiency-based green economy, African governments should, among others, simultaneously carry out audits of the energy efficiency-emissions saving potential for various sectors and promote investment; and promote energy efficiency, renewable energy and emissions saving projects, as these are "tri-pillars" of a sustainable energy future and have synergetic benefits.

Governments should particularly prioritize energy efficiency, renewable energy and emissions saving projects (such as residential solar PVs and biofuels), which involve the poor in the value chain, as this would raise affordability for the poor, thus meaningfully promoting their access to modern clean energies and participation in economic development on a sustainable basis. To attract investment, governments should also remove operational barriers often encountered in these projects and programmes.

Development partners should help with networking energy efficiency, renewable energy and emissions saving good practices among African countries, facilitating with interregional field visits to success-story areas to gain experiences, developing information databases which will help to improve project planning and development, building capacity in national and regional stakeholder institutions and key civil society organizations, and alsohelp to raise funds for mega projects.

Acronyms and abbreviations

CEC	Copperbelt Energy Company
CFL	compact fluorescent lamp
CFLB	compact fluorescent light bulb
CH20	Formaldehyde
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
ECA	Economic Commission for Africa
FIT	feed-in tariff
GHG	Greenhouse gas
GDP	gross domestic product
LEAP	Long-range Energy Alternatives Planning
LPG	liquefied petroleum gas
MYPD	Multi-Year Price Determination
Nox	Nitrogen Oxide
ONE	Office National de l'Electricité et de l'Eau Potable
PAHs	Polycyclic aromatic hydrocarbons
PM	Particulate Matter
PV	photovoltaic
R&D	research and development
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SO2	Sulphur Oxide
TOE	ton of oil equivalent
VAT	value added tax
VOCs	Volatile Organic Compounds
ZESCO	Zambia Electricity Supply Corporation

1. Introduction

1.1. Background

Strategies on low-emission development make it possible for countries to advance sustainable, climate-resilient development and private-sector growth, while significantly reducing the GHG emissions traditionally associated with economic growth (Benioff, Cochran and Cox, 2011). A low-emission development strategy (LEDS) articulates economy-wide development scenarios, policies, programmes, financing, and implementation plans necessary to achieve those scenarios, guided by each country's development goals. The LEDS is founded on two factors: (a) the strategy must be country-driven; and (b) it must be built upon robust analysis, ranging from business-as-usual projections to financing plans.

This approach often requires a fine balancing of the autonomy of a country's economic planners and the ability of that country to access the resources necessary to conduct analysis. However, the promotion of energy efficiency programmes might face resistance, if it is not reasonably clarified. For instance, a business case for energy efficiency needs to be demonstrated to decision makers so that they understand the implications of energy efficiency programmes, such as:

- How will energy efficiency benefit governments, people and industry?
- What financing mechanisms are available?
- What country-specific barriers to energy efficiency exist and how are the solutions fashioned?
- What are the tools to demonstrate development impacts of LEDS?

In recent years, both developed and developing countries have been paying greater attention to improving energy efficiency, mostly as the result of rising prices of electricity and the growing demand for finite and diminishing fossil fuel resources. Improved energy efficiency is one of the most cost-effective ways to reduce GHG emissions. It also enhances energy security of the countries by reducing energy demand.

Energy efficiency has become one of the priority fields in the energy, economic and climate change policies of many countries globally. It has been demonstrated that energy efficiency markets are mature in developed economies such as Canada, Japan, Western European countries and the United States of America. In these countries, the energy efficiency markets are dominated by energy efficiency technologies and sustainable energy efficiency services (supply and demand) because of the specific energy efficiency policy and regulatory instruments developed and used. These instruments include awareness raising and information campaigns, and capacity building for energy efficiency experts, financial institutions staff and government officials.

Energy efficiency improvements are badly needed. For example, improving the operating efficiency of power utilities through institutional reforms would save Africa $2.7 billion a year (Global Harvest Initiative, 2011). Furthermore, if cross-border transaction costs are harmonized and lowered, the regional power trade could save Africa $2 billion per year in energy costs. Combined, the energy savings and trade give each African country an average of $88.24 million of business case, which can be targeted for energy efficiency and emission savings investment.

However, financing energy efficiency is still problematic. Projects may have high internal rates of return, but do not capture the attention of investors or commercial banks because most projects are small and unfamiliar to local lending institutions. Even high internal rates of return cannot compensate for the high transaction costs that banks incur in order to give due diligence to small projects and to establish political, financial

and institutional support for them. In addition, many national experts know the technical fixes needed to improve energy efficiency in their municipalities, power stations or factories, but they do not know how to formulate investment projects so that they meet banks rules, standards and criteria. Bearing in mind the lack of specific incentives in most of the developing countries to introduce the relevant regulatory, policy and institutional reforms in the energy sector, all these barriers represent a forbidding environment for realizing energy efficiency investments.

1.2. Objective of the study

This report is an outcome of the United Nations Development Account project whose goal is to strengthen capacities of developing countries and countries with economies in transition to attract investments in energy efficiency projects in the context of climate change mitigation and sustainable development.

The expected accomplishments of this project are:

- Improved capacity of national project developers, energy experts and mid-level managers in developing countries and countries with economies in transition to develop energy efficiency investment projects in private and public sectors.
- Improved regulatory and institutional framework for promotion of new financing mechanisms for energy efficiency projects.
- Increased financing for investments in energy efficiency projects, including through innovative financing mechanisms.

The objective of this report is therefore to achieve the second expected accomplishment of the overall project. This is done through the preparation of three national case studies of policy reforms to promote energy efficiency investments.

1.3. Description of the unit of analysis

The case studies provide value added in which policymakers at different levels can be shown the direct social, environmental and financial benefits from a specific project or series of projects given that particular policy reforms are made. These include economic, financial, energy pricing and tariff structure, institutional or comparatively simple administrative reforms. But these reforms are often necessary changes in order for economically attractive and prefeasibility study business plans to become bankable projects, which can be financed. The case studies examine the following elements:

i. Policy reforms that have transformed one or more economically attractive investment projects into a bankable project, which has been financed.

ii. Assessment of the 'scaled-up' potential environmental, economic and financial impact of the case study for selected projects or 'classes' of projects including reductions of GHG emissions.

iii. Recommendations on new reforms to introduce market-based energy systems.

Morocco, with a population of about 33 million people, has a total area of 446,550 km^2 (446,300 km^2 land and 250 km^2 water).[3] Approximately, 17.79 per cent of the land area is arable, but only 2.6 per cent is under permanent crop and about 15,000 km^2 irrigated land. The total renewable water resources amount to approximately 29 km^3 per annum, giving a per capita of 428.1 m^3 per annum. Of this, 12.61 km^3 is for domestic (12 per cent), industrial (4 per cent) and agricultural (84 per cent) use.

The proximity to Europe (and relatively low labour costs) has helped Morocco to build a diverse, open, market-oriented economy. Industrial

3 Central Intelligence Agency, "The World Fact Book: Morocco", 20 June 2014.
Available from http://www.cia.gov/library/publications/the-world-factbook/geos/mo.html

development strategies and infrastructure improvements, including a new port and free trade zone near Tangier, are improving the country's competitiveness. Key sectors of the economy include farming, tourism, phosphates, textiles, apparel, and subcomponents. The official gross domestic product (GDP) of Morocco stood at $104.8 billion in 2013, and composed of farming (15.1 per cent), industry (31.7 per cent) and services (53.2 per cent). Notwithstanding the economic progress, the country suffers from high unemployment, which stands at 9.5 per cent, poverty (15 per cent below poverty line) and illiteracy, particularly in rural areas. In 2011 and 2012, high prices of fuel, which is subsidized and almost entirely imported, strained the government's budget and widened the country's account deficit. In the fall of 2013, Morocco capped some of its fuel subsidies, which in 2011 were $4.8 billion (Lahbabi, 2013), in an effort to gradually reduce its large budgetary deficit. Among the key economic challenges for Morocco is reforming the government's costly subsidy programme.

As of 2010, Morocco had produced about 21.13 billion kWh of electricity while its consumption stood at 23.61 billion kWh, which meant the rest had to be imported. In 2011, CO_2 emissions stood at 43.71 million tons. The per capita GHG emissions stand at 2.8 million tons of CO_2 per annum. However, more than half of these emissions are due to the energy sector, mainly from coal, fossil oil-based economic activities and power generation (Lahbabi, 2013).

By 2017, Morocco intends to increase its 6 million tons per annum of coal imports by 3.5 million tons in order to meet demand from a 1,320 MW coal-fired power plant.[4] The country has three coal-fired power plants, which produce 26.7 per cent of its total generating capacity, and wants to meet local consumption using thermal power, and export renewable energy to the European Union.

South Africa, with a population of about 48.4 million people, has an area of 1,219,090 km^2 (1,214,470 km^2 land and 4,620 km^2 water). South Africa has 9.87 per cent of arable land, but only 0.34 per cent is under permanent crop and 16,700 km^2 is under irrigation.[5] The total renewable water resources amount to 51.4 km^3, from which fresh water withdrawals are 12.5 km^3/pa for households (36 per cent), industry (7 per cent) and farming (57 per cent). The per capita withdrawal was 271.7 m^3/pa in 2005.

South Africa is a middle-income, emerging market with an abundant supply of natural resources; well-developed financial, legal, communications, energy and transport sectors; and a stock exchange that is the sixteenth largest in the world. In 2013, the estimated official GDP of South Africa stood at $534 billion, which composed of farming (2.6 per cent), industry (29 per cent) and services (68.4 per cent).

Even though the country's modern infrastructure supports a relatively efficient distribution of goods and services to major urban centres throughout the Southern African Development Community (SADC) region, unstable electricity supply retards growth. Unemployment (25 per cent), poverty (31.3 per cent) and inequality – among the highest globally – remain a challenge. Official unemployment is significantly higher among black African youth. The country's labour force is about 18.54 million people, with 9 per cent employed in farming, 26 per cent in industry and the remainder in services. The delays by Eskom (a state-owned energy utility) in the construction of two additional power plants have reduced the country's electricity margin. Economists concur that economic growth cannot exceed 3 per cent until those plants come on line. The government faces growing pressure from special interest groups to use state-owned enterprises to deliver basic services to low-income areas and to increase job growth.

According to estimates, in 2011 South Africa emitted 461.6 million metric tons of CO_2 from consumption of energy.

4 Worldcoal, "Morocco set to increase coal imports". Available from http: //

5 Central Intelligence Agency, "The World Factbook: South Africa". Available from https://www.cia.gov/library/publications/the-world-factbook/geos/sf.html.

Zambia has a population of 14.64 million people, and is also a member of SADC. The country has an area of 752,618 km^2 of which land is 743,398 km^2 and water covers 9,220 km^2. Only about 1.5 million hectares (0.04 per cent) out of 42 million hectares of the country's arable land are cultivated every year.[6] Zambia has over 40 per cent of Southern African fresh water with irrigation potential estimated to be 2.75 million hectares based on water availability and soil irrigation ability (Zambia National Farmers Union, 2014). From this potential, it is estimated that 523,000 hectares can be economically developed. However, only 340,000 hectares of land are irrigated, which is about 65 per cent of the economical irrigation potential, leaving 183,000 hectares yet to be developed. Of the 340,000 hectares, commercial irrigation is slightly above 70,000 hectares while emergent and small-scale irrigation is about 270,000 hectares.

Zambia is a tropical country modified by altitude and rainy season. In 2011, the country's total renewable water resources stood at 105.2 km^3. In 2002, fresh water withdrawals were estimated at 1.57 km^3, comprising of 18 per cent for domestic use, 8 per cent for industry and 73 per cent for farming, while the per capita withdrawals were 47m^3.

The economy of Zambia has experienced strong growth in recent years, with real GDP growth during the period 2005-13 of more than 6 per cent per year.[7] In 2013, the GDP was $22.24 billion, derived from of farming (19.8 per cent), industry (33.8 per cent) and services (46.5 per cent). Notwithstanding a strong economy, unemployment (15 per cent) and poverty (60.5 per cent below poverty line) remain significant problems in Zambia, with the latter exacerbated by a high birth rate, relatively high HIV/AIDS burden, and by market distorting farming policies.

The major sources of energy in Zambia are mainly biomass, hydropower and petroleum products. Even with its vast hydro and biomass resources, the country is experiencing power shortages. Biomass accounts for about 77 per cent of the nation's energy needs while hydropower contributes about 12 per cent. The CO_2 emissions from consumption of energy in 2011 were estimated to be 2.434 million tons.

In summary, Morocco, South Africa and Zambia are countries with diverse natural resources, geographical locations, and economic opportunities. However, what is common to all of them is high unemployment and poverty levels, notwithstanding their relatively good performance in terms of GDP (see Table 1).

Table 1: Summary of poverty and energy access indicators for case study countries

Country	Population (million)	Total area (million ha)	Land area (million ha)	Unemployment (per cent)	Poverty below datum line (per cent)	Electrification (Per cent)*	Population without electricity (per cent)*
Morocco	33	44.655	44.63	9.5	15	99 (100 urban, 97 rural)	0
South Africa	48.4	121.909	121.447	25	31.3	85 (96 urban, 67 rural)	8
Zambia	14.64	75.262	74.34	15	60.5	22 (51 urban, 3 rural)	11

* The World Factbook: World", 2014. Available from https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html

Source: **World Energy Outlook (International Energy Agency); seewww.worldenergyoutlook.org*

6 Zambia Development Agency, "Agriculture, Livestock and Fisheries - sector profile 2011", 2011. Available from http://www.zambiahc.org.uk/important_documents.html

7 Central Intelligence Agency, "The World Factbook: Zambia", 20 June 2014, Available from https://www.cia.gov/library/publications/the-world-factbook/geos/za.html

Poverty and unemployment have to be considered when suggesting policy measures for energy efficiency and emission reductions strategies. The prime question is how citizens can take advantage of the broadly available natural resources in their respective countries to participate in power generation, not only to improve its affordability (or household economies), but also accessibility to electricity using energy markets as an opportunity. Allowing the citizens to get involved in power generation (or clean fuel production) plays a role in energy markets; and access to affordable modern energy contributes to poverty reduction and inclusive growth.

Apart from a compelling, rather than voluntary, policy for identified players, it will require governments to put in place financing arrangements for those players that cannot afford their own investments, since there would be assured markets for the power generated (or fuel produced).

1.4. Outline

The next section identifies and briefly describes the renewable energy technologies discussed in the case studies. Section 3 describes the method used to analyse energy efficiency and GHG emissions in the three countries. Sections 4 to 6 describe the energy sector of the countries, and give a brief characterization of energy efficiency of the target energy producing or consuming areas, and the resulting savings of energy and GHG emissions. Section 7 gives additional policy measures to cement the promotion of investments in energy efficiency, renewable energy and emissions saving activities. Section 8 discusses results and presents conclusions, while recommendations are given in section 9.

2. Description of the Target Renewable Energy Technologies and Markets

Lack of investment in energy efficiency projects in Africa requires appropriate actions. In order to move to a more sustainable energy and economic development process, deal with (in a cost-effective manner) climate change mitigation issues, and enhance energy security those countries would need to: (a) develop skills in the private and public sectors at the local level to identify, formulate and present to financial institutions energy efficiency investment projects that are potentially bankable, and to subsequently carryout the projects; (b) introduce policy and institutional reforms needed to support energy efficiency investments; and (c) create favourable conditions for banks and commercial companies to invest in energy efficiency projects, including through the development of public-private partnerships investment funds and other innovative financial mechanisms.

It is unfortunate, save for a few countries, that energy efficiency has not been a top priority in Africa. Understandably, the priority is to increase energy generation to tackle the growing energy deficits. However, there is a strong case for a robust energy efficiency approach and investments in Africa given that:[8]

- Many African countries have been using old and dated technologies, which are energy intensive; and in almost all African countries, little new power has been put online in the past five years.

- There are at best weak or, at worst, absent competitive market forces in the energy sector, particularly in the power sector, which is vertically integrated and monopolized by governments. There is often very little private sector participation. Oftentimes, lack of competition becomes a disincentive to energy efficiency.

- As most conventional energy systems are owned or controlled by governments or the government aligned institutions, subsidies are often used to make petroleum fuels and electricity prices affordable to most people. Thus, the cost of using these fuels is not reflective of the actual price.

- Often, the governments' total monopoly in the energy sector means that financing new energy generation becomes a challenge. Increasingly, the public purse is not sufficient to finance large energy infrastructure projects. The economic climate also makes it difficult to source funding from traditional official development assistance (ODA) without stringent conditions.

- On the whole, there are very few countries that have comprehensive policies, measures and actions that encourage investments in energy efficiency initiatives.

- There is generally a dearth of in-country technical knowledge and the absence of local suppliers of energy efficiency options. If available, many of the solutions are not designed in Africa and therefore local manufacturing of whole or parts of energy efficiency technologies is challenge.

- Like any initiative, energy efficiency requires incentives, especially in the face of non-cost reflective tariffs. There is generally an absence

8 See also Hussein Elhag. "African Energy Commission's Approach to Energy Efficiency in Africa: Policy Framework and Technical Programs". Presented at the World Energy Council Regional Workshop on Energy Efficiency in Addis Ababa, Ethiopia, 29 and 30 June 2009.

of specific efficiency incentives, such as mandated energy performance codes and standards for industry and transport.

Accordingly, for Africa to realize the benefits of energy efficiency and also to be able to attract investments from in the region and externally, it needs to learn from the best experiences of countries that have undergone the energy efficiency transformation, and seek advice from them. In particular, the following sector needs to adopt energy efficiency practices, whether through adoption of new energy efficiency (or renewable energy) technologies or through behavioural change: hydrocarbon, power generation, biomass, transport, industry and buildings (see Figure 1).

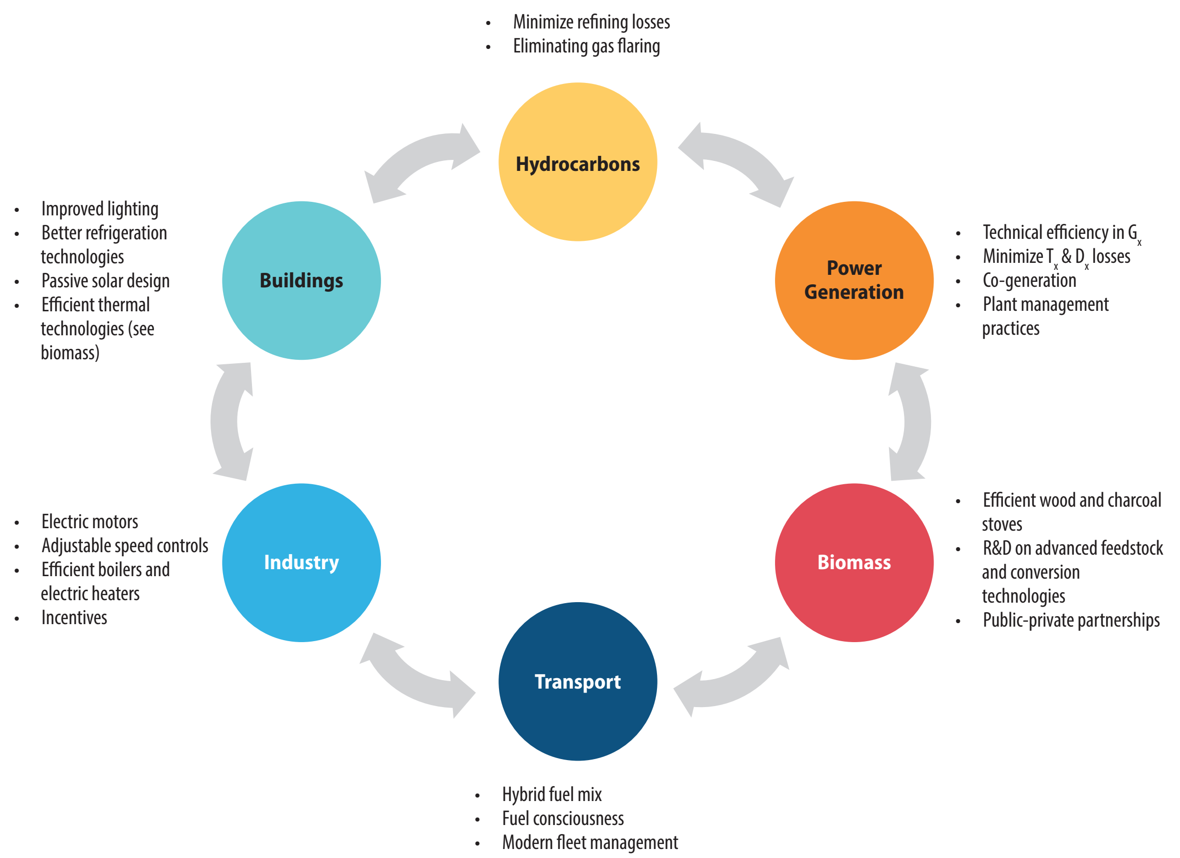
While there are several energy efficiency markets and interventions areas, this report focuses only on those areas that the selected countries have comparative advantages, and where such energy efficiency interventions could lead to inclusive wealth. These are solar PV, efficient lighting, bioethanol and efficient cookstoves.

2.1. Rooftop solar PV for electricity

A solar panel is a set of solar PV modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. A single solar module can produce only a limited amount of power, and therefore most installations contain multiple modules. A PV system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery or solar tracker and interconnection wiring. The number of solar panels depends on the solar installation goals, the roof size, the solar module efficiency and the budget.

The efficiency of solar PV panels refers to the proportion of total sunlight falling on the panel that is captured and converted into electricity (Climate Commission, 2013). The efficiency of a module determines the area of a module given

Figure 1: Energy efficiency markets and intervention areas



the same rated output. For example, an 8 per cent efficient 230-watt module will have twice the area of a 16 per cent efficient 230-watt module. The best sunlight conversion rate (solar module efficiency) is around 21.5 per cent in new commercial products. The panels can cover an entire roof and can be designed to meet a desired electrical consumption (kWh) offset or be off the grid completely.

Most of the growth in solar PV capacity has been in the residential sector. In South Africa, the Eskom estimate capital cost for solar PV is $2,750 per kW (Can, and others, 2013). Estimates for other renewable energy technologies per kW are concentrated solar power ($5,802), wind ($3,258), and nuclear ($6,131 with fuel cost of $6 per MWh). Compare these costs with coal-based power investment at $2,940 with fuel at $20 per MWh).

There are no direct GHG emissions from generating energy with solar energy systems. One MWh of solar-derived electricity avoids about one ton of CO_2, when displacing fossil fuel-based electricity (Climate Commission, 2013). At the point of electricity generation a 1.5 kW solar PV system avoids approximately 2.2 tons of CO_2 each year.

Solar energy already provides, or contributes to, a continuous supply of electricity in many parts of the world because solar energy can be used during the day and captured for use by solar energy systems at night. Solar hot water systems have in-built heat storage in the form of hot water tanks. For household-level systems, batteries can be used to store excess solar energy for later use. If accessible, the grid can serve as a back-up option. In such cases, many households therefore feed extra power into the electricity grid when they generate excess, and can then draw power from the electricity grid when the sun goes down. Industrial-scale solar storage is also already in use in a number of places.

Solar energy systems work well with a diverse range of other renewable energy sources, such as wind, where the resource may be available at different times and locations, depending on weather conditions. By having a diversified energy mix, a reliable electricity supply is more easily provided, as illustrated in box 2.1 for Germany. The variability of solar energy can also be effectively smoothed by many solar energy systems over larger areas generating electricity at different times. While the output of a single panel may vary significantly minute to minute, when the output of many panels is summed over an area the output varies much less over time. The sun does not always shine, but with effective storage, grid management and a broad electricity grid, a continuous supply of solar power can be achieved.

2.2. Bioethanol, charcoal and kerosene for cooking in households

Bioethanol (also known as ethyl or grain alcohol) is a clear, colourless liquid that can be produced by the fermentation of virtually any source of sugar (such as sugarcane and sweet sorghum) or starch (such as cassava and corn). Cellulosic biomass (e.g. grasses, woody crops, and organic wastes) can also be used to produce bioethanol through advanced processing techniques.

Box 1: Germany leads the world in solar power installed capacity

Germany receives less sunlight than Morocco, South Africa and Zambia, but has more installed capacity (7,600 MW) than any other country due to a significant programme of policy support. At maximum performance on sunny days, the country has generated enough solar electricity to supply about 35 per cent of the nation's electricity needs, and still maintains grid stability. Solar power generation in Germany coincides with peak daytime electricity demand, when electricity prices are also at their highest. In recent years the increase in solar power generation has resulted in reductions in electricity prices for large-scale users in the country, because solar-based electricity can be used instead of electricity from more expensive sources during peak demand periods.

(Climate Commission, 2013)

Bioethanol is an equivalent of gasoline used in transport vehicles. Apart from transport vehicles (cars, light trucks, motor cycles and aeroplanes), bioethanol is also used in clean cookstoves, fridges, electric generators and lanterns.

2.2.1. Using bioethanol feedstock to economically empower rural communities

Feedstock for producing bioethanol can be those suitable to agro-climatic conditions in rural areas, taking into account yields and the economics of their production, and co-products to elevate backward and forward linkages to increase wealth and jobs in the production areas. As feedstock production is about 40 to 70 per cent of the cost of producing a litre of bioethanol, a large part of the bioethanol production economy would rest with ordinary people if they are directly involved or contracted to produce feedstock.

2.2.2. Decentralized bioethanol refineries

For processing, there are off-shelf decentralized modular bio-refineries that come complete with hydrolysis, fermentation, distillation and dehydration units all assembled together to produce high quality 200 proof (100 per cent) fuel grade ethanol. The plant is modularly expanded as feedstock availability, which minimizes start-up costs and improves profitability. Economical production rates can be as little as 500 litres per day (a daily equivalent of 3 tons of fresh cassava, or 1.25 tons of dry cassava, or 11 tons of sweet sorghum, or 6 tons of sugarcane).

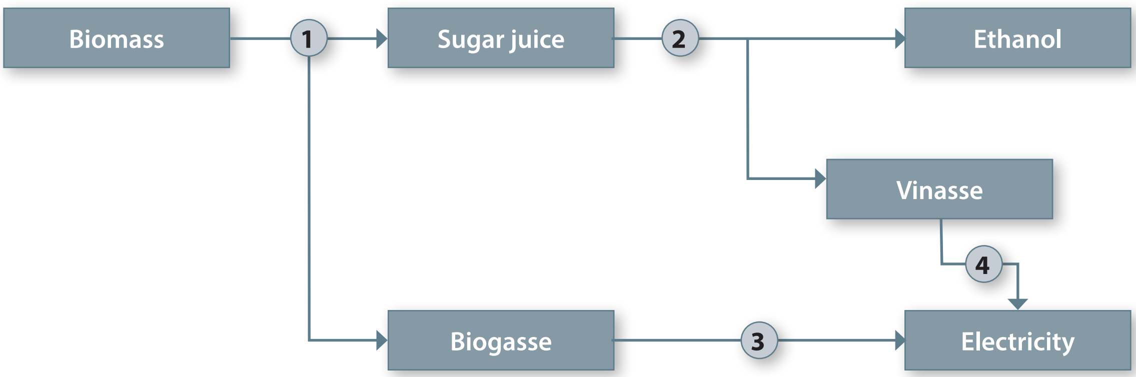
Electricity is also co-generated from vinasse and bagasse (for feedstock such as sugarcane and sweet sorghum) during processing of bioethanol (see Figure 2). Bagasse characteristics for low heat value are 17-18 MJ/kg dry-basis (db) and yield 4.7-5.0 kWh/kg db (Sweethanol, 2011). Characteristics of biogas from vinasse are 21-22 MJ/Nm^3, yielding 5.8-6.1 kWh/Nm^3.

Therefore, bioethanol producers would not only earn money from bioethanol but also from excess electricity sold to the grid.

2.2.3. Bioethanol economics for cooking versus the true cost of charcoal

Bioethanol can be used in clean cookstoves made of stainless steel or aluminium. Specifically, the bioethanol clean cookstove manufactured by the Swedish company Dometic AB has fibre-lined canisters to store bioethanol, minimizing fire hazards due to spillage or leakage.[9] The ethanol itself is easily stored and does not deteriorate in storage. Ethanol fuel is denatured, a blue dye is added to the alcohol, and the jerry cans are clearly labelled. Along with training on stove usage and care, users would receive instructions on how to store their ethanol, especially when children are around. Also, it is easy to keep pots clean with

Figure 2: Bioethanol processing and electricity co-generation - sugarcane and sweet sorghum feedstock



Source: *Sweethanol, 2011; see http://64.34.211.82/Publications/Sweethanol_Technical_Final.pdf*

9 Accenture, "Brazil Feasibility Study" – Intervention Options", Global Alliance for Clean Cookstoves, 2012.

relatively little soap after using them on a clean cookstove.

Bioethanol clean cookstoves generally come with one or two burners. A two-burner stove costs about $30 to $60, depending on whether it is locally manufactured or imported. In Nigeria, a two-burner stove has a fuel tank of 1.2 litres, which can burn for about 4.5 hours at maximum heat, up to 9 hours on low, and the stove costs about $67.[10] In Brazil, a two-burner stove costs about $60 and, on average, uses 1 litre per day for cooking for a family of five.[11] There are reported Brazilian cases of only 4 litres of bioethanol used per week to cook meals for a family of seven.[12]

A conservative estimate puts the life of the stainless steel clean cookstove at more than 10 years, while that of the aluminium-body stove at 6 years.[13] In reality, when properly cared for, these stoves can provide families with decades of clean cooking.

The Zambian government has set bioethanol producer price at $1 per litre. Since the government does not collect tax from charcoal producers, but will at least be able to collect value added tax (VAT) from bioethanol production value chain, the government could authorize the buying of bioethanol for charcoal use at this price. This would then be equivalent to what charcoal users spend today, and may thus make bioethanol competitive when benefits of clean cookstoves and bioethanol industry are considered.

2.2.4. Economics of charcoal versus bioethanol for cooking

In Zambia, a large charcoal brazier (mbaula) costs $3.6 and has a lifespan of 18 months, while a medium charcoal brazier costs about $2 with a lifespan of 12 months. To compare the costs, a two-burner clean cookstove costing from $30 to $60 with a 10-year minimum lifespan is equivalent to two small charcoal braziers together costing $4. With a one-year lifespan, a family would spend $40 on charcoal braziers in 10 years for constant dollar strength and costs, and would break-even at 7.5 to 15 years of a clean cookstove's lifespan.

In Zambia, charcoal usage costs about $32 per month. This is almost a $1 cost for charcoal per day per household. For example, with more than 210,000 households depending 100 per cent on charcoal for cooking in Lusaka alone,[14] it means there is a daily market of more than $210,000 per day, or an annual market of $76,650 million per year.

2.2.5. Economics of kerosene for cooking

In South Africa, there is no single energy carrier used, rather a range of energy carriers are used in low-income households. About 3.4 million households do not have access to electricity and rely on candles, paraffin and firewood for energy. This translates to about 25 per cent of households, of which one-third are informal households ("shack dwellers") and two-thirds formal households (Paraffin Safety Association of South Africa, 2012). In 2012, about 57 per cent of low-income households surveyed used paraffin for cooking and 23 per cent used electricity. When looking at heating, 46 per cent of households surveyed used paraffin and 18 per cent used electricity, with a similar percentage using wood (ibid).

A study by the Department of Energy of South Africa (2013a) found that cooking represents one of the most energy-intensive applications in South Africa, and about 77 per cent of households in South Africa use electricity as the main energy source for cooking. For non-electrified households, firewood (54 per cent) and paraffin (38 per cent) predominate as the main energy source for cooking purposes. The energy needs of poor households in South Africa are still inadequately met. The electrification programme has slowed (annual connection rates are now half of those a

10 Anga, Boma Simeon, "Project to promote the use of ethanol as a new household fuel for Nigeria", March 2012. Available from http://www.slideshare.net/F_Chanelle_K/10-using-ethanolfordomesticenergysupplyinwestafrica.

11 Project Gaia, "Dometic Clean Cook Brochure". Available from http://projectgaia.com/files/DometicCleanCookBROCH2010.pdf.

12 Project Gaia, "A Salinas family", 2014. Available from http://www.projectgaia.com/page.php?page=gallerybrazil/ReginaSalinaFamily.jpg.

13 Project Gaia, "What is the life of a clean cook stove?" July 2012. Available from http://www.projectgaia.com/blog/2012/07/11/what-is-the-life-of-a-cleancook-stove/.

14 Central Statistical Office, "2010 Population Census". Available from http://www.zamstats.gov.zm/.

decade ago), making the original goal of universal access by 2014 not feasible (Tait, Merven and Senatla, 2013).

The quantity of paraffin used by the average household as a primary source for cooking is 5.1 litres per week, or 20.4 litres per month (Smith, Goebel and Blignaut, 2013). In terms of appliance costs, legal stoves retail for about R100 (approximately $7) whereas the illegal ones appear to range between R85 and R100 (Tait, Merven and Senatla, 2013). In terms of the cost of cooking in South Africa, electricity is the cheapest, followed by paraffin and then by LPG. However, many households actually use paraffin heaters for cooking purposes, which cost about R400 ($29,50). This is more than either an electric two-plate or an LPG stove. Lack of affordability of appliances does not therefore seem to be a major constraining factor. Rather, it is the space heating co-benefit that paraffin stoves and heaters offer households. It means that spending on fuel for space heating is reduced; compared to if a household were using electricity or LPG, neither of which offer such a co-benefit.

The various energy sources are very useful in the home, but they are also potentially dangerous if they are not used safely and appropriately. South Africa has high rates of energy-related accidents in the home, which cause emotional, financial and physical damage to many families and communities (Paraffin Safety Association of South Africa, 2012). Whilst India, for example, has a mandatory efficiency requirement for paraffin burners as 55 per cent,[15] there was no standard for South Africa found in literature, and users could therefore be using mixed standards, some of which could be very inefficient.

2.2.6. Efficiencies and environmental issues associated with targeted cooking fuels

Inefficient cooking methods are not a trivial problem as about 2 billion cook in rudimentary stoves or over open fires. Energy conservation, green energy generation and reducing indoor air pollution are currently global mandates, not just mere needs. The relevance of improved cooking stoves is so encompassing that it can deal with at least five of the eight Millennium Development Goals (MDGs) that the United Nations is working to meet by 2015. The following are some statistics about the magnitude of the situation:[16], [17]

- CO_2, CH4 and NOx are present in biomass stove emissions.
- Black carbon, which results from incomplete combustion, is estimated to contribute the equivalent of 25 to 50 per cent of CO_2 warming globally.
- CH4 emissions are the second largest cause of climate change after CO_2..
- Stoves cause about 18 per cent of the problem of carbon emissions.
- Indoor air pollution is the fourth leading health risk in developing countries.
- There are premature deaths estimated at 1.6 million people each year due to indoor air pollution, with the most affected being women and children.
- Cooking with wood or charcoal depletes 10 per cent of wood harvested from the world's forests.

It is therefore clear that inefficient household energy use has adverse consequences for the environment, air quality and human health. There are environmental issues associated with the production and use charcoal and kerosene cooking fuels. These are briefly discussed here.

15 Servals Group, "A social enterprise in pursuit of sustainable rural energy products (energy efficient cooking stoves, water conservation, vegetable oil fuels)", March 2008. Available from http://servalsgroup.blogspot.com/2008/03/energy-efficient-kerosene-burners.html.

16 Servals Group, "Context of Servals' innovations", May 2010. Available from http://servalsgroup.blogspot.com/2010/05/context-of-sapls-innovations.html.

17 Global Alliance for Clean Cookstoves. Available from www.cleancookstoves.org.

Table 2: Estimated aboveground wood biomass at different rotation periods

Forest management phase	Wood biomass (tons/hectare) at different rotation periods				
	20 years	30 years	40 years	50 years	100 years
Good management (pre-1980s)	67 ± 40	85 ± 40	94 ± 41	98 ± 43	103 ± 51
Declining management (1980s)	45 ± 14	57 ± 15	64 ± 15	71 ± 15	90 ± 17
No management (1990s to date)	20 ± 11	27 ± 12	31 ± 13	35 ± 13	46 ± 17
Difference with good (sustainable) management (reference scenario)					
Declining management (1981 – 1989)	22	28	29	28	14
No management (1990 – 2000)	47	58	62	64	58

Source: *Determining the non-renewable portion of biomass utilized in charcoal production for Lusaka (Chidumayo, 2005).*

Harvesting of wood from forests in Zambia for wood and charcoal energy is largely under poor forest management practices and therefore not sustainable, given that areas remain deforested. Consequently, the biomass originating from forests can be considered non-renewable (Chidumayo, 2005).

The total wood biomass in virgin miombo woodlands of central Zambia is estimated at 90 tons per hectare, on average consisting of 90 per cent cord wood suitable for charcoal production and 10 per cent small stems and twigs. This amount reduces substantially depending on the subsequent nature and period of regrowth. Rotation periods for regrowth in miombo depend on the purpose of management. For aboveground wood biomass for firewood and charcoal, periods of 10-50 years and 31-50 years respectively, have been proposed. Table 2 shows wood biomass in regrowth of miombo woodlands at different rotation periods.

According to Chidumayo:

$$\text{Biomass}_{\text{non-renewable}} = \text{Biomass}_{\text{kiln-area}} + \text{Biomass}_{\text{land-use-change}} + \text{Biomass}_{\text{loss-poor management}}$$

Where:

a. Biomass $_{\text{kiln-area}}$ is biomass loss due to loss of regeneration on kiln sites found by multiplying area covered by kilns in the forest area cleared for charcoal production by above-ground wood biomass per hectare in miombo woodlands.

b. Biomass $_{\text{land-use-change}}$ is biomass loss due to land-use-change from forest to non-forest farming (about 70 per cent of area cleared for charcoal).

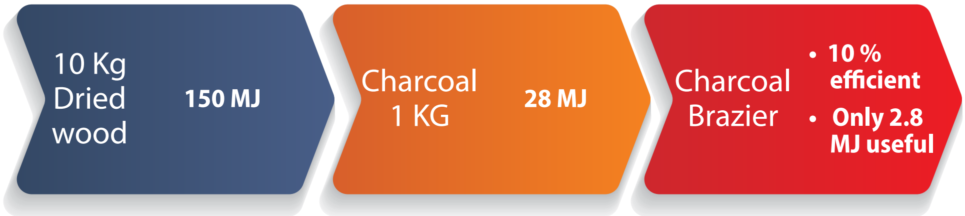
c. Biomass loss-poor management is reduction in potentially renewable biomass due to poor or lack of management at a given rotation period, in this case, a 30-year period. In the case of destructive annual late dry season fires, regrowth may remain in the "fire-trap" phase (under 2.0 m tall) indefinitely, and uncontrolled harvesting of small poles (< 8.0 cm diameter at 1.3 m above ground) in regrowth of miombo can also reduce wood biomass accumulation in such a way that the biomass stock stagnates at a certain undesirable level for charcoal production.

About 6 to 10 tons of wood is required for every 1 ton of charcoal produced, while consumers use about 1 to 1.3 tons of charcoal per household per year. For 90 tons (less 10 per cent twigs) of wood used to make charcoal per virgin hectare, only 8.1 tons of charcoal is realized per hectare, at 10 tons wood to 1 ton charcoal conversion ratio.[18]

Typically wood has an energy value of between 14 and 18 MJ/kg when burned, while charcoal has

18 But according to Table 2, yields can be as low as 1.8 tons per hectare of charcoal in unmanaged areas of 20 years regeneration.

Figure 3:Useful energy from wood to charcoal-used brazier for cooking



an energy value of around 29 MJ/kg.[19] This means that charcoal burns hotter than wood, but when not insulated or not receiving sufficient air supply (including secondary air), the absence of flames or fast flowing CO_2 gases will result in less efficient cooking due to lower heat transfer efficiency. The average conversion ratio of 10:1 means that 10kg of air-dried fuelwood is carbonized to produce 1kg of charcoal (Luwaya, 2011). The 10kg of air-dried wood is equivalent to 150 MJ, so when this produces 1kg or 28 MJ in the form of charcoal, there will be a net energy loss of 122 MJ (or about 81.33 per cent energy loss) (see Figure 3).

Accordingly, over-dependence on charcoal and wood for cooking makes it among the agents of deforestation and land degradation being experienced in sub-Saharan Africa. With an increasing population, land degradation in Africa has the potential to negatively affect the contribution of natural resources for livelihood and may drive many people into poverty.

In Zambia, an estimated 39.37 tons of carbon per hectare is lost when aboveground biomass is cleared (Kamelarczyk, 2009). When the cleared land is converted to farmland, a further 11.02 tons of carbon per hectare is lost due to belowground biomass. This brings the total 50.39 tons of carbon lost per hectare.

Wood and charcoal use, often burned indoors without chimneys or smoke hoods, has been associated with a range of health effects including lung cancer, chronic obstructive pulmonary disease, low birth weight, cataracts, pneumonia, and tuberculosis (Lam, and others, 2013). In Zambia, it is estimated that more than 2.4 million households are affected by indoor air pollution, and more than 8,600 people die every year as a result of that.[20] Justifiably, pollution from solid fuels has provoked efforts to find alternative energy sources or ways of burning biomass cleanlier.

Kerosene (also known paraffin) has numerous commercial and industrial applications including aviation fuel, general solvent, cooking, heating, and lighting. Kerosene cooking is widespread in many developing countries, especially in urban populations where biomass needs to be purchased, and electricity and LPG are expensive or unreliable.

Kerosene stove designs are broadly categorized into wick stoves (which rely on capillary transfer of fuel) and the more efficient and hotter burning pressure stoves with vapour-jet nozzles that aerosolize the fuel using manual pumping or heat. In low-income households, wick stoves are more commonly used because they are cheaper, they easily provide simmer heat for some staple foods, and they have no nozzles that can get clogged by soot.

Produced originally from coal ("coal oil"), but later from the fractional distillation of petroleum oil, kerosene is a transparent liquid fuel with a mixture of hydrocarbon chains 6 to 16 carbon atoms in length. It is a middle distillate of the petroleum refining process defined as the fraction of crude oil that boils between 145 and 300°C. Kerosene has a higher energy density than wood and generally burns more efficiently, requiring less fuel mass to complete the same cooking task. Heat of combustion of kerosene, similar to that of diesel, has a lower heating value as 43.1 MJ/kg and a higher heating value as 46.2 MJ/kg. Figure

19 Vuthisa Biochar Initiative, "Is it better to burn wood or charcoal?" September, 2010. Available from http://vuthisa.com/2010/09/05/is-it-better-to-burn-wood-or-charcoal/.

20 Global Alliance for Clean Cookstoves, "Zambia", 2014. Available from http://www.cleancookstoves.org/countries/africa/zambia.html

4 shows that at the 55 per cent Indian burner efficiency standard, the useful energy per litre of kerosene is 19.38 MJ.

Although kerosene is often advocated as a cleaner alternative to solid fuels, biomass and coal for cooking, the fuel is laden with risks. Kerosene is a mixture of hundreds of chemical compounds, several with known adverse health risks. Both kerosene stoves and lamps emit various substances including PM, CO, CH20, PAHs, SO_2, and NOx. Available measurements of kitchen and personal exposure concentrations suggest that kerosene-fuelled stoves elevate indoor respirable PM concentrations above the World Health Organization (WHO) guideline and interim targets, while carbon monoxide may pose risks under some conditions (Lam, and others, 2013).

Kerosene poisonings make up a significant portion of total poisoning incidents each year, particularly in developing countries. Kerosene is also synonymous with many fires and burns, with a variety of contributing factors. Possible adverse health effects include respiratory cancer, salivary-gland cancer, respiratory symptoms and spirometry, asthma and allergic diseases, respiratory infections, and cataract effects on the eye.

In South Africa where 15.2 per cent and 14.8 per cent of the population use wood and paraffin, respectively, for cooking, it is estimated that more than 6.65 million people (about 1.4 million households) are affected by indoor air pollution and, as a result, more than 7,600 people die every year.[21] Justifiably, pollution from solid fuels has provoked efforts to find alternative energy sources or ways of burning biomass cleanlier.

Ethanol is a clean liquid biofuel that can be made from a variety of feedstock including sugary materials such as sugar cane, molasses, sugar beet, or sweet sorghum, starchy materials such as cassava, potatoes, or maize. Ethanol burns very cleanly, without the production of harmful gases and fine particulates (soot). Burning ethanol produces significantly less CO than kerosene or solid fuels, and has dramatically reduced indoor air pollution as compared to wood, charcoal and kerosene stoves. GHGs released in the production and consumption of ethanol fuel are reabsorbed during the growth cycle of the plant material used to make the fuel. Damaging GHGs such as CO and VOCs are produced in negligible amounts.

Black carbon aerosols, a potentially potent climate forcer, are essentially not produced by the combustion of ethanol and methanol. Ethanol fuel functions in a range of efficiencies when used in alcohol stoves, with gelfuel generally somewhat less efficient and liquid fuel slightly more efficient. In the most efficient alcohol stoves, ethanol is more efficient than solid fuels and kerosene, and generally comparable to LPG. The clean cookstoves, manufactured by Dometic AB of Sweden,[22] have an efficiency of more than 60 per cent. This means that of the 21.2 MJ contained in a litre of bioethanol, 12.72 MJ is directly doing work and the rest is lost. However, there is also co-production of electricity from vinasse and bagasse (for some feedstock).

Although ethanol fuel has a lower energy content by volume than kerosene, ethanol tends to combust more efficiently in a simple cook stove than kerosene does and therefore gains in efficiency what it lacks in energy. Ethanol with lower water content contains more energy; thus 95 per cent ethanol produces more heat per volume of fuel consumed than 80 per cent ethanol, although flame temperature remains reasonably constant.

The proposed bioethanol stove, known as clean cookstove, burns cleanly and safely, it cooks food quickly, and produces only low levels of GHGs. Pilot studies in Brazil, Ethiopia and Nigeria show that the clean cookstove is well liked and well used.[23]

21 https://projectgaia.com/cleancook-sweden-ab-acquires-dometics-alcohol-fuel-stove-business-division/.

22 Dometic AC, "Home page". Available from www.dometic.com/enie/International/Site/CleanCook-Alcohol-Fueled-Stoves/Download-Cleancook-Leaflet.

23 Duke University, Ethanol Cooking Fuel, "A business plan for clean stoves and ethanol production". Available from http://sites.duke.edu/adhoc_httpssitesdukeedubioethanolpro/our-product/clean-stove/.

The studies done in Ethiopia by Project Gaia have shown that women value the safety of the alcohol-fuelled stove as much as they value the clean kitchens that these stoves make possible. The stove is stable, and the fuel tank that holds the ethanol is in a special adsorptive fibre so that it cannot spill. The tanks are not pressurized so they will not flare and cannot be made to explode. The fuel tank is inserted from underneath the stove so when refilling, it has to first be removed. This makes it very safe, as it cannot be filled whilst the stove is alight. Recent laboratory safety tests showed that the clean cookstove is 'very safe,' scoring 39 out of 40 points (based on a protocol) (Johnson, 2005 and 2013).

The clean cookstove has been monitored for pollutants in both the laboratory and in a household survey. Laboratory results have shown that the stove had an average CO/CO_2 ratio of 4 per cent at high power and 5 per cent at low power; particle emissions were negligible in all tests; although CH4 emissions can be highly variable and difficult to measure, $CH4/CO_2$ ratio gas chromatograph tests recorded a range of values from 0.02 per cent to 0.35 per cent. The stoves have been used under arduous conditions in refugee camps since 2005, and no breakdown has been reported yet. In total, over 40,000 Domestic AB Clean Cookstoves are in operation globally. The stove can use ethanol, methanol or a mix of both, and the fuels themselves can be made from wastes.

In addition to the health and economic empowerment benefits associated with the use of these stoves, the stoves and bioethanol can also lead to a more sustainable and cleaner environment. They can reduce a large share of emissions from cooking with biomass, and can also bring other benefits, such as reduced indoor and outdoor pollution, less pressure on forests, and economic and time savings due to the reduced need to search for or purchase costly fuels. Since they have short life spans – a few days for black carbon, a decade for CH4 – reducing these gases would bring about a more rapid climate response than reductions in CO_2 alone.[24]

For feedstock such as sugarcane and sweet sorghum, the excess co-generated electricity sold to the grid beyond own consumption would not only make it possible for rural people to access modern energy, but for South Africa this would also reduce the requirement to use coal to generate power to meet national demands. Decentralized energy access reduces long-range energy transmission efficiency losses.

24 Global Alliance for Clean Cookstoves, "The issues". Available from http://www.cleancookstoves.org/our-work/the-issues/.

3. Methodologies to Assess Energy Efficiency and Emissions Savings

Various tools exist for analysing energy efficiency and GHG emissions calculated either separately or in combination. Some are simple[25] and web-based while others are complex and proprietary, such as LEAP. The United States National Renewable Energy Laboratory, for example, has models and tools it has developed or which it supports to assess, analyse and optimize renewable energy and energy efficiency technologies for projects.[26] Many of these tools can be applied on a global, regional, local, or project basis. It also has several models and tools that are designed for the consumer or energy professionals.

LEAP is fast becoming the *de facto* standard for countries undertaking integrated resource planning, GHG mitigation assessments and LEDS, especially in the developing world. Many countries have also chosen to use LEAP as part of their commitment to report to the United Nations Framework Convention on Climate Change (UNFCCC). LEAP works as an integrated modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can also be used to account for both energy sector and non-energy sector GHG emission sources and sinks.

In addition to tracking GHGs, LEAP can be used to analyse emissions of local and regional air pollutants, making it well suited to studies of the climate co-benefits of local air pollution reduction. LEAP has been adopted by thousands of organizations in more than 190 countries, and has been used at many different scales ranging from cities and states to national, regional and global applications (Heaps, 2012). Its users include government agencies, academics, non-governmental organizations, consulting companies and energy utilities.

Accordingly, to develop LEDS for promoting energy efficiency investments for climate change mitigation and sustainable development presented in this report, the LEAP tool and, wherever necessary and possible, Microsoft Excel spreadsheets were used to analyse and develop models that demonstrate impacts of renewable energy and energy efficiency measures on climate change mitigation. Energy models were developed for the three selected countries, and the results and associated assumptions are presented in the report.

Specifically, Microsoft Excel spreadsheets were used to develop models to demonstrate the impact of policies, which would promote installation of solar PVs and CFLs in households in Morocco and South Africa. Similarly, associated GHG emission reductions were analysed using the Excel spreadsheets. The LEAP software tool could not be used for this type of analysis due to the nature of the analysis involved, which requires data for the whole country including installed capacity, historical generation and planned installations to be available for LEAP to be used for modelling electricity generation. Furthermore, the LEAP modelling tool requires comprehensive data to develop an accurate model for energy demand and energy transformation (electricity generation and distribution). Lack of specific data for the baseline case, business-as-usual and mitigation scenarios proposed was a challenge, which hindered the use of the LEAP modelling tool.

25 Carbon offsets to alleviate poverty, "Carbon emissions calculator". Available from http://cotap.org/carbon-emissions-calculator/.

26 National Renewable Energy Laboratory, "Energy analysis: models and tools". Available from http://www.nrel.gov/analysis/models_tools.html.

The model used, focused on a sector (household) in each of the countries instead of the whole country, and Excel was therefore applied. Similarly, energy efficiency measures of installing CFLs were analysed using Excel spreadsheets in order to compare the impact of CFLs and household PV systems on electricity demand and supply, respectively.

However, the LEAP modelling tool was used to model the energy demand scenarios of household sectors in Zambia and South Africa for which all relevant data was available from the World Bank data centre and country reports. The model for South Africa considered the total number of low-income households (9,936) that use kerosene for cooking, so that the policy would be to replace kerosene with bioethanol. The key assumption was kerosene and bioethanol consumption per household per day, which was estimated at 0.5 litre and 1 litre, respectively. In Zambia, 39 per cent of the urban population used 100 per cent charcoal for cooking. The model considered then is to replace this charcoal with bioethanol in clean cookstoves.

4. Morocco - Country Case Study

The country's planned and anticipated economic projects will increase energy demand by 185 per cent, and electricity demand by 68 per cent by 2030 (Andriani and others, 2013). To support the acceleration of such projects, Morocco has developed an ambitious 2020-2030 energy strategy (the Moroccan Energy Strategy). With no oil resources and relying heavily on energy imports, Morocco intends to make the most of its wind and solar resources to become a top renewable energy producer. The country has therefore significantly reformed its legal and institutional framework to achieve this.

4.1. Morocco energy sector brief

Energy consumption in Morocco rose at an average annual rate of 5.7 per cent from 2002 to 2011, and the per capita energy consumption in 2011 was 0.52 ton of oil equivalent (Toe).[27] In 2011, the country consumed 17,262 kToe of energy, with petroleum products accounting for 61.9 per cent followed by coal (22.5 per cent), electricity trade (7.2 per cent), natural gas (4.6 per cent), hydropower (3 per cent), and wind power (1 per cent). In 2012, the country's installed electricity generation capacity was 6,677 MW, with coal-fired generation being the largest segment at 1,785 MW, followed by hydroelectric at 1,770 MW.

Rising oil prices and a rapidly growing population signify that the cost of importing energy is now seriously aggravating the country's trade deficit. Imported energy in 2011 was 95.5 per cent, the energy import bill was $10.1 billion, and subsidies for petroleum products were $4.8 billion (Lahbabi, 2013). In 2012, energy imports accounted for over a quarter of total imports, when the trade deficit grew 8 per cent to a record $23.6 billion. The long-term increase in energy needs will mainly be due to energy-intensive sectors such as the chemicals industry, building infrastructure and tourism.

Through rural electrification programme, the transmission grid owned by the State utility National Office of Electricity (ONE) covers the entire country and is connected to the Algerian and Spanish power grids via regional links.

In terms of the country's installed base, Morocco is already a regional leader, with 32 per cent of its installed capacity derived from renewables, mostly hydropower. Wind in Morocco is highly abundant in nearly all the coastal regions. Wind potential could be 25,000 MW, and the country is expected to generate more than 2,000 MW in 2020, resulting in 5.6 million tons of avoided CO_2 emissions (Lahbabi, 2013). Moroccan solar resources are significant with an extremely favourable irradiation of more than 2300 kWh/ m^2 per year, which is 30 per cent higher than the best sites in Europe, and is therefore attractive to foreign investors.

The country has a $9 billion Solar Plan to develop 2,000 MW by 2020 using 10,000 hectares of solar installations based on concentrated solar power and PV technologies, which will yield 5.6 million tons of avoided CO_2 emissions. The predominant use of biomass in Morocco is traditional fuels for cooking and heating. Forested areas are estimated at 9 million hectares, while annual consumption is estimated to be 30,000 hectares. An additional 400 MW of cogeneration potential is available in the country. Total solid bioenergy potential is estimated at 12,568 GWh/year, with a further 13,055 GWh/year from biogas and biofuels.

Significant geothermal potential exists in the northeast, in the form of hot springs, with potential for further utilization for space heating, but this resource is not being used. In 2008, 1,360 GWh were produced from hydropower, which partly comes from a 464 MW pumped storage power plant. A micro hydropower station is planned for future development.

27 Reegle, "Morocco: renewable energy", 2014. Available from http://www.reegle.info/policy-and-regulatory-overviews/MA.

For energy efficiency, the country is targeting optimization of energy use in buildings, including reducing consumption through demand-side management measures, and more efficient lighting practices; efficient use of wood in traditional heating systems in both urban and rural areas; energy efficiency knowledge, and energy use and carbon emission auditing in industry; improvement in urban transport efficiency through better governance and increased infrastructure energy performance; and appliance labelling for energy efficiency and low consumption light programme in public housing and government buildings. The energy efficiency strategy is to attain energy efficiency savings of 12 per cent by 2020 and 15 per cent by 2030, mainly from industry, tertiary and residential buildings, and transport (Lahbabi, 2013).

Morocco intends to setup support funds for energy efficiency programmes and has designated the National Agency for the Promotion of Renewable Energy and Energy Conservation to oversee the programmes. The country has also established the Moroccan Agency for Solar Energy, which is the prime contractor for solar power projects.

For energy efficiency in residential buildings, Morocco plans to incorporate several measures to incentivize the uptake of solar hot water systems, accelerate the adoption of CFLB, carry out measures related to the thermal performance of buildings, and incorporate energy efficiency labelling of appliances. For the period 2012-2014, measures include:[28]

- Solar-water heater market development aimed at reaching an installed capacity of approximately 1.7 million m^2 by 2020.

- Expanding CFLB distribution aimed at distributing some 23 million CFLBs to reduce peak load; implementation and enforcement of residential building codes for a scheme covering 400,000 houses.

- Energy saving labelling of domestic appliances, especially for refrigerators and air conditioners.

- The "20-20" initiative in which households that achieve a 20 per cent reduction in energy usage benefit from an additional 20 per cent rebate on their bill.

The measuring, reporting and verification approach still has to be developed. It will draw on the clean development mechanism whole-building methodologies, either "energy efficiency technologies or fuel switching in new buildings", or small-scale methodologies for individual actions.

The Renewable Energy Law (Law 13.09 of 11 February 2010) aims at fostering and promoting renewable energy, and regulates the commercialization and exportation of renewable energy. Furthermore, it outlines a procedure for the authorization of renewable energy installations.

In 2009, Morocco installed capacity of 6,100 MW. In order to meet the growing electricity demand, the country plans to invest more than $20 billion over a period of 10 years to increase the installed capacity by about 6,750 MW. By 2020, wind, solar and hydro would each account for 14 per cent of power supply, with the remaining sources oil (14 per cent), gas (11 per cent), nuclear (7 per cent), and coal (26 per cent). The solar and wind investment would lead to savings of 1 million to 3.7 million tons of CO_2 emissions per year.

The new energy strategy that was adopted in March 2009, and aims at diversifying the energy mix around reliable and competitive energy technologies, in order to reduce the share of oil to 40 per cent by 2030; developing the national renewable energy potential, with the objective of increasing the contribution of renewable to 10-15 per cent of primary energy demand by 2012; making energy efficiency improvements a national priority; developing indigenous energy resources by intensifying hydrocarbon exploration activities and developing conventional and non-conventional oil sources; and integrating into

28 NAMA Database, "Residential building energy efficiency in Morocco". Available from www.nama-database.org/index.php/Residential_buildings_energy_efficiency_in_Morocco.

the regional energy market, through enhanced cooperation and trade with other Arab Maghreb Union countries and European Union countries.

However, there appears to be no plan to use residential houses for power generation using solar PV and wind, a practice that is entrenched in, for example, Germany (rooftop solar PV) and the United Kingdom and Northern Ireland (rooftop wind power generation) (Climate Commission, 2013).

In 2006, ONE launched the EnergiPro programme in order to offer large industrial consumers with an incentive such as favourable tariffs to invest in renewables, and to promote independent production of electricity from renewable sources. It offers, among others, two key benefits:

Transmission of electricity produced from renewable energy throughout the grid network at fixed rate.

Guaranteed repurchase by ONE of any surplus electricity produced with a 20 per cent bonus on top of the peak, and off-peak day-ahead tariffs by ONE.

Several major firms have entered into EnergiPro agreements. Whilst EnergiPro is not limited to wind energy, the programme is primarily directed at this source. It could be used to include rooftop solar PV from residential houses to allow ordinary people to participate not only in power generation, but also as an economic empowerment tool to reduce poverty.

Morocco boasts one of the most deregulated electricity sectors in the Middle East and North Africa region. To carry out mandatory rooftop solar PV would, however, require an attractive FITs and a revolving fund or some kind of financial arrangement, which could allow households to finance solar PV installations.

4.2. Effects of energy efficiency and climate change mitigation policies on electricity scenario

Energy efficiency in Morocco is in the form of energy use of CFLBs at the point of generation (residential solar PVs) and savings from long-range grid transmission to residential houses (see Table 3). The GHG emission savings are in the form of reduced use of fossil fuels (coal, oil and gas) from either the fossil-fuel power plants or their possible future expansions.

4.2.1. Policy: all households must have rooftop solar photovoltaics with net metres

Morocco has significant potential for electricity generation from solar PV systems. With an average insolation of 2300 kWh/m^2 per year, Morocco

Table 3:Setting for solar-based energy efficiency and climate change mitigation in Morocco

Current power sources	Coal, oil, gas, hydro, solar and wind
Energy sufficiency	Inadequate
Energy source for future expansion	Coal power for local use, renewable energy for export to the European Union
EXAMPLE natural resource to be targeted for participatory energy production and supply	Solar (high insolation levels in Morocco)
Market opportunity	Residential and national consumption, and proximity to the European Union that is importing clean energy from Morocco
Enabling participatory power generation technology	Rooftop solar PV
Energy efficiency opportunity	Decentralized power source (national) and energy efficient bulbs (household)
Rooftop to grid power sales infrastructure	99 per cent available countrywide grid connection to households
Contribution to global concern	Reduction in GHG emissions due to use of coal and petroleum fuels

has the potential to meet its electricity demand from Solar PV technology. The technology is well understood and therefore easy to replicate and scale-up from a small-scale household system to a large-scale solar power plant.

In order to realize the impact and benefits of solar systems, favourable policies need to be put in place. One such policy would be promoting the adoption of, and to carry out, a nationwide project on installing net-metered solar PV systems on rooftops of all household units which are connected to the grid. The capacity of solar PV systems suitable for household installation ranges from 2kW to 5kW. Accordingly, if the policy indicated that all household units install a 5kW solar PV system by 2030, there would be a significant increase in electricity generation, which would meet the local demand with a possibility of exporting the surplus to the region. Results of this analysis are illustrated in Figure 5.

Figure 5 also presents projected electricity generation (based on current installed capacity and assuming no additional electricity generating power plants are installed beyond 2011) and consumption projections based on a business-as-usual scenario. Assuming a gradual increase in the installation of solar PV systems so that all grid-connected households install a 5kW system by 2030, electricity generation would outstrip demand by 2016. This can be achieved by carrying out net metering where all households with solar systems can feed the surplus power into the national grid.

In 2010, the total number of households was approximately 6.3 million, and is estimated to increase to 7.6 million, with the potential of generating 26,600 GWh of electricity by 2030, if all housing units are installed with a 5kW net-metered solar PV system.

4.2.2. Policy – all households to have rooftop solar PV, net metres and CFLBs

Figure 6 below shows the impact of using CFLBs as an energy efficiency policy measure on overall electricity consumption under the household sector. Assuming a minimum of 10 bulbs per household with an average operating period of three hours per day, the impact of such a policy measure would be significant reduction in energy consumption in this sector. Also, the figure illustrates the projected impact of using CFLBs on overall electricity demand. It is clear that in the medium to long term, the use of CFLBs will contribute to substantial reduction in electricity demand.

Switching from standard lighting bulbs with an average rating of 100 Watts to energy saving CFLBs with an average rating of 18 Watts by 2030 would result in a significant reduction in the household sector's consumption of electricity. The daily consumption per household for the 10 standard bulbs is 3 kWh while that of CFLBs is 0.54

Figure 4: Power generation outlook due to residential solar photovoltaic policy

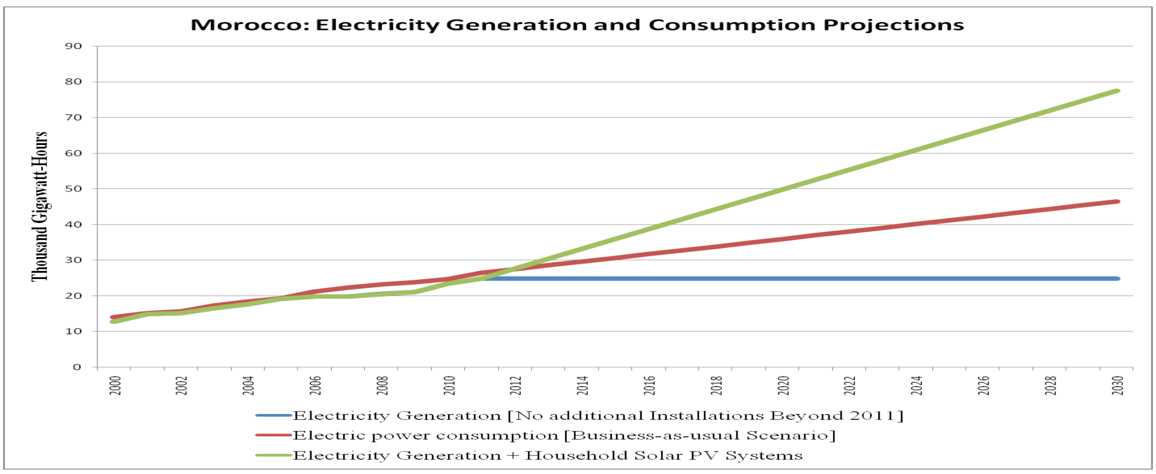
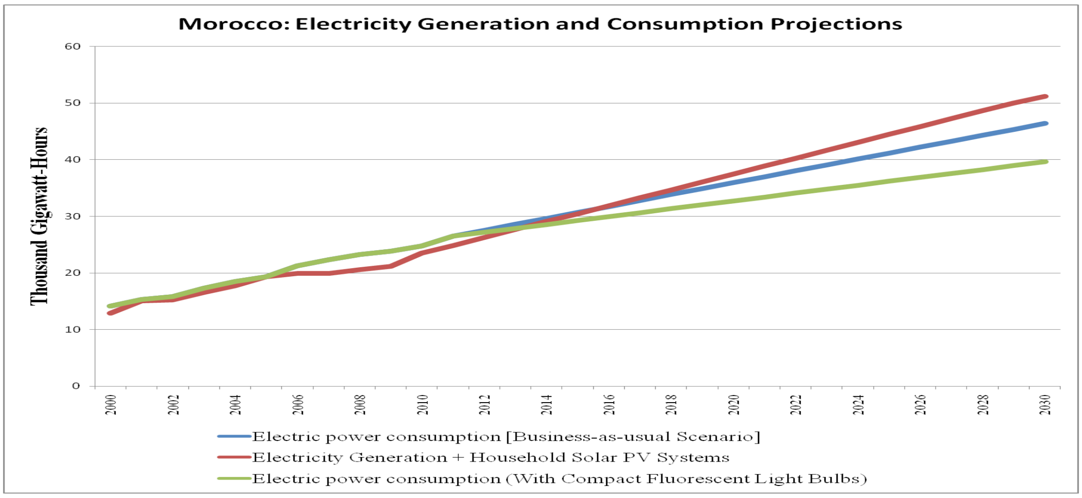


Figure 5: Energy outlook due to generation by residential solar PVs and consumption by CFLBs



kWh. The energy saved per household per day is 2.46 kWh.

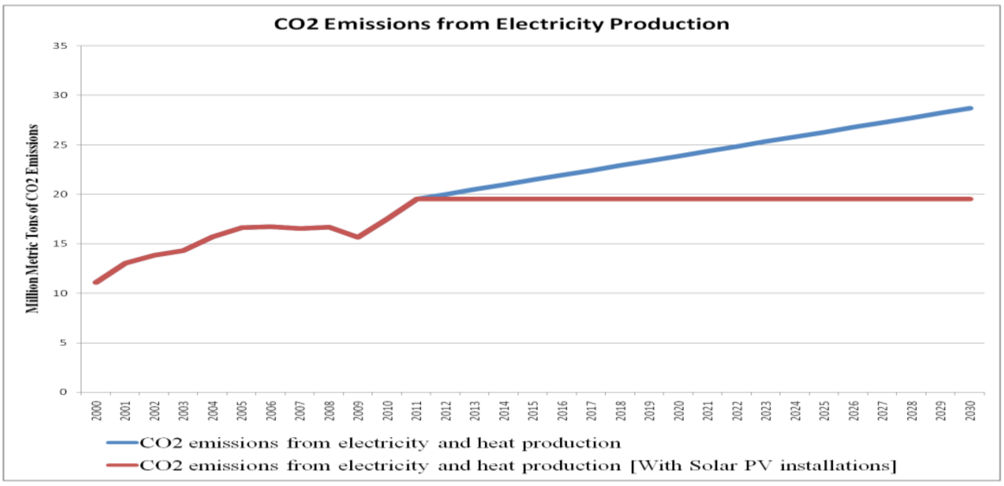
The policy measures presented in this analysis also have the economic benefit of income improvement, job creation and poverty eradication, as they would create opportunities for small and medium enterprises involved in the installation of solar PV systems and distribution of CFLBs. Specifically, out of 50 kWh (= 5 kW per solar PV X 10 hours of generation) generated per household from solar PV systems, and if only 0.540 kWh (10 bulbs X 18 W X 3 hours) is consumed by CFLBs per day, leaving 49.46 kWh extra power sold to the network per day, then each household would sell 18,052 kWh per year, if there is only CFLBs drawing on power. For an estimated capital cost for solar PV of $2,750/kW (Can, and others, 2013), and given a $0.10 FIT, this would be an income of $1,805.20. The investment would thus be recovered in about 7.6 years for the 5 kW solar PV systems, which look good for a 20-year lifespan of the system.

4.3. Carbon dioxide emission savings due to residential rooftop PV solar system policy

Figure 7 indicates a linear increase in CO_2 emissions from electricity generation using coal (which is the main energy source for electricity generation in Morocco). Historical data indicates that there were 19.54 million metric tons of GHG emissions from power generation in 2011. These emissions are projected to increase to 28.72 million metric tons in 2030, based on the business-as-usual scenario. An estimated 9.18 million metric tons of CO_2 would be saved if mandatory policy to install solar PV systems per household were instituted.

By substituting standard 100 W bulbs, 10 of which would consume 3 kWh (10 bulbs X 100 W/bulb x 3 hours) per day, with 10 X 18W CFLBs which would consume 0.54 kWh (10 bulbs X 18 W/bulb X 3 hours) per day, would result in a saving of 2.46 kWh/day. For every kWh of electricity generated from coal-fired plants, there is 0.993 kg of CO_2 equivalent emitted (Letete, Guma and Marquard, 2007). By only using CFLBs, each household would avoid 2.443 kg of CO_2 per day. Thus, for a total 7.6 million households, 6.777 million tons of CO_2 equivalents would be avoided by 2030 alone.

Figure 6: Projected emission reduction due to residential solar PVs



5. South Africa - Country Case Study

5.1. South Africa energy sector brief

The South African economy is extremely energy intensive compared to international standards, with only a handful of countries having higher intensities. In addition, South African industrial energy efficiency is on average significantly lower than in other countries. This is an important factor given that the industry and mining consume over 60 per cent of the electricity produced in the country, and the inclusion of commerce takes this figure to almost 75 per cent.[29] Accordingly, residential energy use makes up a far smaller portion of final energy demand than in other countries, and demand from poor households is even smaller. Residential consumers use only 16-18 per cent of the country's electricity, an outcome of the energy intensive nature of the economy, and the extreme income differential in the country. In South Africa, 73 percent of the population has access to electricity.

The nominal installed electricity capacity of South Africa is approximately 45,700 MW, although total net maximum capacity (nominal capacity minus the amount the power station uses to operate) is lower. Eskom supplies roughly 95 per cent of the country's electricity and the remainder comes from independent power producers and imports. Eskom buys from, and sells electricity to, countries in the SADC region.

South Africa plans to diversify its electricity generation mix. Approximately 90 per cent of the country's generation capacity is from coal-fired power stations, about 5 per cent from one nuclear power plant, and 5 per cent from hydroelectric plants, with a small amount from a wind station. The renewable energy industry is small in South Africa, but the country plans to expand renewable electricity capacity to 18,200 MW by 2030. The nuclear power plant at Koeberg has an installed capacity of 1,940 MW. The country also plans to expand nuclear power generation by 9,600 MW by 2030.

In 2012, 72 per cent of the country's total primary energy consumption came from coal, followed by oil (22 per cent), natural gas (3 per cent), nuclear (3 per cent), and renewables (less than 1 per cent, primarily from hydropower). The dependence that South Africa has on coal has led the country to become the leading CO_2 emitter in Africa and the fourteenth largest in the world.

The country's total oil consumption was 616,000 bbl. per day (or 73.45 million litres per day) in 2013. The petroleum consumed in South Africa comes mostly from its domestic refineries that import crude oil and its coal-to-liquid and gas-to-liquid plants. The country also imports petroleum products. In 2012, according to the South African Revenue Service as published by Global Trade Atlas, South Africa imported 110,000 bbl. per day (or 13.12 million litres per day) of petroleum products.

The country's electricity system is constrained, as the margin between peak demand and available electricity supply has been precariously narrow since 2008. The country's peak demand was forecast to reach 44,005 MW in 2013, exceptionally close to installed net maximum capacity. The Southern African Power Pool (SAPP) forecast has peak demand growing to almost 53,900 MW (or by 20 per cent) by 2025, and therefore Eskom plans to spend $49 billion to replace aging equipment and add new power stations to meet the growing demand.

For renewable energy, South Africa has good solar resources with direct normal irradiation averaging over 7.0 kWh per m^2 per day in many areas of the country, particularly in areas with close access

29 Reegle, "South Africa: renewable energy". vailable from http://www.reegle.info/countries/south-africa-energy-profile/ZA.

to the electricity grid, such as in the Northern Cape. The wind energy potential has average wind speeds at 10 metres range from 4-5 m/s for the majority of the coastal areas of the country, to approximately 8 m/s in some mountainous regions.

In the longer term, around 9 to 16 per cent of the total energy demand could be met by biomass sources including farming residues, cuttings from forestry operations, and dedicated energy crops. Household biogas digesters also have a large potential market share, and landfill gas on which two projects have recently been commissioned near Durban. Also, wave energy has the potential to contribute 33 TWh (terawatt hours) per year by 2050, in conjunction with other less-used renewable energy resources. Other insignificant renewable energy sources include seasonal hydropower, geothermal and waste-to-energy.

With regard to electricity, the South African White Paper on Renewable Energy set a target of 10,000 GWh of energy to be produced from renewable energy sources (mainly from biomass, wind, solar and small-scale hydro) by 2013.[30] Achieving the target was to stimulate additional income that would flow to low-income households.

For transport fuel, the regulations published in 2012 for biofuels (bioethanol and biodiesel) have set the minimum concentration to be allowed for biodiesel blending as 5 per cent v/v with diesel, while the permitted range for bioethanol blending with gasoline as 2 per cent v/v up to 10 per cent v/v (Department of Energy, 2012). For part of the South African case study in this project, this could be an avenue for adding bioethanol production targets to meet requirements to substitute paraffin with bioethanol for cooking purposes.

South Africa has also developed an Integrated Resource Plan 2010-2030, dubbed a "living plan", which was released in March 2011, and updated in 2013 (Department of Energy, 2013b). The document is to be revised every two years. Of the many forms of embedded power generation including biogas, biomass and wind, in this report only PV is demonstrated in the household policy case study as it is the most likely form of generation to be embedded in the national grid. Also, the policy only considers households in living standards measure of seven or higher, each with a capacity of 5 kWp. For the purposes of poverty reduction, here lies an opportunity for co-opting net-metered residential solar PVs as an alternative, to cover all electrified houses in South Africa.

The energy policy document plan called the "National Response to South Africa's Electricity Shortage" released in January 2008, includes work on the country's electricity distribution structure, and the fast tracking of electricity projects by independent power producers.

The National Energy Efficiency Agency, which was established in 2006, is responsible for carrying out demand-side management and energy efficiency projects in the country; the management of strategies for improving efficiency; awareness-raising campaigns and training programmes in energy efficiency; and cooperation with all agencies involved in the sector to ensure best practice.

The Energy Development Corporation, which was established in January 2004, supports the development of renewable energy and alternative fuels through investment. It targets market sectors where there is insufficient private sector activity and where the Government, for strategic reasons, believes State investment is required. The Corporation is also involved in sectors where renewable energy and energy efficiency require catalysing and development.

The South African National Energy Development Institute is an agency of the Department of Energy created to assist the country to reach its energy goals. It focuses on awareness-raising and increased uptake of "green" energy. Its portfolio includes data and knowledge management on energy, energy efficiency, fuel technology, low-carbon energy and transport, carbon capture and storage, and energy end use and infrastructure. The White Paper on Renewable Energy of

30 Department of Energy, "Renewable energy: overview". Available from www.energy.gov.za/files/renewables_frame.html.

2003 lays the foundation for the widespread functioning of renewable energy and sets a target (not mandatory, only a policy objective) of 10,000 GWh of renewable energy contribution to final energy demand by 2013.

The Energy Efficiency Strategy of 2005 sets out a national target (not mandatory, only a policy objective) for energy efficiency improvement of 12 per cent by 2015, and provides for a number of "enabling instruments". The Biofuels Industrial Strategy of 2007 proposes the adoption of a 5-year pilot programme to achieve a 2 per cent penetration level of biofuels in the national liquid fuel supply. The Strategy recommends the use of a fuel levy exemption for biodiesel and bioethanol. The National Cleaner Production Strategy of 2004 seeks to "enable South African society and industry to develop its long-term full potential by... adopting the principles of Cleaner Production... and promoting the practices of sustainable consumption."

For energy efficiency programmes, the country targets industry (energy efficient motors, energy audits, and energy management systems), utilities (rebates for energy savings), transport (extra levies on inefficient vehicles used to cross-subsidize more efficient vehicles), residential (distribution of CFLBs at subsidized prices mainly in areas with capacity bottlenecks, mandatory standards and labels for appliances, vehicles and buildings, and promoting the use of LPG as a cooking fuel rather than electricity), and public (educational campaigns and energy efficiency funding for government buildings).

One of the significant energy efficiency investment barriers in South Africa is the low price of energy. The Government has therefore been progressively increasing the electricity tariff which by 2015 should be cost reflective, and has also included an environmental levy in electricity tariff to fund and carry out energy efficiency demand-side management (EEDSM) programmes (Can, and others, 2013). Energy efficiency is now included as a resource of choice in integrated planning for future energy resources. As part of the November 2012 revised energy efficiency strategy, for example, the Department of Energy, in collaboration with the Department of Public Works and Eskom, is retrofitting government buildings to make them more energy efficient. This contributes a saving of about R600,000 ($74,000) in electricity bills a year.[31]

South Africa is one of the pioneering emerging economies to have set up a transparent and systematic mechanism to fund energy efficiency. The National Energy Regulator of South Africa is the regulatory authority in charge of determining electricity tariff increases and energy efficiency goals. Eskom administers the energy savings programmes.

In order to carry out energy efficiency, funding is obtained through electricity tariffs. Eskom provides an EEDSM project plan in its Multi-Year Price Determination (MYPD) application to the Regulator to obtain funding to purchase energy savings and recover the reasonable costs. The Regulator makes a final determination of the EEDSM costs that Eskom provides for the MYPD application. The phase of funding allowed in the three-year MYPD 2 was R5,445 million ($674 million) with the goal of gross saving 1,037 MW and a cumulative annualized total of 4,055 GWh (about 0.67 per cent electricity savings relative to retail sales per year) from 2011 to 2013 (Can, and others, 2013).

The MYPD 2 ended in March 2013 with MYPD 3. Funding was requested of R13.9 billion ($1.7 billion) for a period of 5 years (2013 to 2018), but a new funding of R5,183 million ($641 million) was approved in the MYPD 3 (see Table 4).

The annual funding for energy efficiency under the new MPYD 3 has dropped compared to the MYPD 2, which has raised concerns about long-term commitments and about the possible under appreciation of energy efficiency as a way to meet future demand. During the MYPD 2, tariff increase by an annual average of 22.1 per cent and annual increases of 8 per cent were approved in the MYPD 3, from 65.5 c/kWh (8.1 United States cents)

31 South African Government, "Energy". Available from http://www.gov.za/node/76.

Table 4: Integrated demand management costs approved by National Energy Regulator of South Africa

ITEM	Million Rand					
	2013/14	2014/15	2015/16	2016/17	2017/18	MYPD3 Total
Return	23477	26511	26436	27657	33667	137748
Primary energy costs	51067	54966	56779	62060	68620	293492
Independent power producers	2686	5108	14826	19269	23018	64907
Depreciation	25733	27481	28564	28911	29197	139886
Integrated demand management	1455	953	819	712	1244	5183
Operating costs	45519	48565	52908	57769	60576	265337
Total allowed revenue	149937	163584	180332	196378	216322	906553

in 2013-2014 to 89.13 (11.03 United States cents) in 2018.

A total cumulative savings of 3,072 MW have been achieved through the establishment of its incentive programmes in the past 10 years (Can and others, 2013). About two thirds of these savings come from lighting energy efficiency by replacing incandescent bulbs with efficient CFLBs. South Africa has also developed solid metrics to support its savings accounting, following the International Performance Measurement and Verification Protocol (IPMVP). However, the residential sector remains difficult to reach because of its diffuse nature, and setting appropriate prices for efficiency incentives to attract investment in that sector has also been perceived as challenging.

In 2011, the South African government put forward an Integrated Resource Plan to help minimize GHG related to fossil fuels and help boost job creation. The updated Plan 2010-2030 forms a subset of the overall South African Energy Plan, calling for a total installed capacity of 17.8 GW of renewable energy and 42 per cent of all new generation capacity developed up to 2030. The planned capacity comprises 8,400 MW of wind and solar PV each, and 1,000 MW of concentrated solar thermal. Excluding hydro, this brings the renewable energy share of power supply to 9 per cent, which is far less when compared to the coal generation capacity which will continue to make up about 60 per cent of the generation fleet.

After nearly a two-year stalemate, the competitive bidding process replaced the attempted renewable energy feed-in tariff programme – renewable energy bids (REBIDs) – in August 2011, known as the Renewable Energy Independent Power Producer Procurement Programme. The Programme was designed to deliver the target of 3,625 MW of renewable energy to start and stimulate the renewable energy industry in South Africa, where bidders are required to bid on tariff and the identified socioeconomic development objectives. The government has committed to procuring 3,725 MW of renewable energy for the national grid by 2016 and to create at least 50,000 green jobs by 2020.

South Africa is a member of SAPP, which began in 1996, as the first formal international power pool in Africa with a mission to provide reliable and economical electricity supply to consumers in SAPP member countries. This creates an opportunity for the export of residentially generated power from rooftop solar PVs.

5.2. Effects of energy efficiency and climate change mitigation policies on electricity scenario

Table 5 gives a summary of energy efficiency for the South African case study: with residential solar PVs, the energy efficiency is in the form of energy use and use of CFLBs at the point of generation, and energy savings from long-range grid transmission to residential houses; by replacing kerosene with bioethanol, the energy efficiency is in the form of using improved cookstoves,

Table 5: Setting for solar and bioethanol-based energy efficiency and climate change mitigation

Current power sources	Coal, oil, gas, nuclear, hydro, biomass, solar, wind
Energy sufficiency	Inadequate
Energy source for future expansion	Coal power and Renewable energy
Example natural resources to be targeted for participatory energy production and supply	Solar (relatively high insolation levels) and biofuels (relatively high agro potential)
Market opportunity	Residential and national consumption
Enabling participatory energy production technology	Rooftop solar PV, available biofuels production technologies
Energy efficiency opportunity	Decentralized power source (national) and energy efficient bulbs (household), and replacement of inefficient household cooking energies
Rooftop to grid power sales infrastructure Ethanol distribution infrastructure	75 per cent available countrywide grid connection to households Filling stations, supermarkets, dedicated ethanol outlets distributed throughout South Africa
Contribution to global concern	Reduction in GHG emissions due to use of coal, biomass and petroleum energies

reducing indoor air pollution and health-related illness; and the switch from inefficient biomass (wood) based cooking and kerosene to electricity and bioethanol by rural communities, the GHG emission savings are in the form of reduced use of fossil fuels (coal, oil and gas) and reduced deforestation.

5.2.1. Policy: all households must have rooftop solar photovoltaics with net-meters

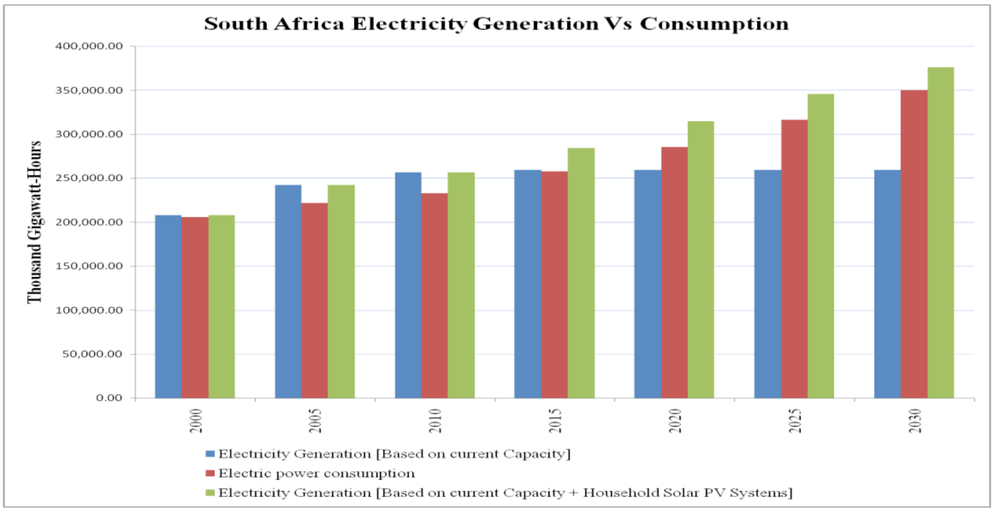
In 2012, 74.2 per cent of households in South Africa (approximately 9.8 million) were electrified. Assuming a constant electrification rate, the number of electrified households is projected to increase to 12.4 million in 2020 and 16.7 million in 2030. These are the projections considered in this analysis to illustrate the effect of the energy efficiency policy measures. The 16.7 million households would have the potential to generate about 116,000 GWh of electricity, if all installed 5kW solar systems by 2030, and the load for this source of power being only the 10 CFLBs.

Figure 8 indicates projected electricity generation. This assumes no additional installations to the current capacity, additional generation from rooftop solar PV systems installed on electrified households, and electricity consumption projected on a business-as-usual scenario. The policy measure proposed stipulates mandatory installation of a 5kW solar PV system per household, which is connected to the national grid to facilitate net metering. The policy suggests that by 2030, all households in South Africa will have installed a solar system – hence the gradual increase.

This policy measure is in line with the South African Integrated Resource Plan which assumed, for the purposes of estimating potential PV rollout in homes, that only households in living standards measure seven or higher would invest in 5 kWp rooftop Solar PV and that by 2020, about 50 per cent of these households would have installed the solar system (Department of Energy, 2013).

The results obtained indicate that projected electricity supply from current installations in South Africa would not meet the current demand. However, with investments in energy efficiency through installation of at least 5kW Solar PV systems per household, electricity demand is likely to be met and the surplus fed into the national grid and possibly exported to the region, which would provide additional revenue for the utility.

Figure 7: Power generation outlook due to residential solar PV policy in South Africa



5.2.2. Policy: all households must have rooftop solar photovoltaics, net-meters and compact fluorescent light bulbs

Figure 9 considers energy efficiency as a mitigation measure to reduce electricity consumption. With a nationwide policy of switching from standard lighting bulbs with an average rating of 100 Watts to energy saving CFLBs with an average rating of 18 Watts by 2030, there would be significant reduction in the household sector consumption of electricity. The daily power consumption per household for the 10 standard bulbs is 3 kWh, while that of CFLBs is 0.54 kWh. The energy saved per household per day is 2.46 kWh.

Similar to Morocco, the policy measures presented in this analysis also have the economic benefit of income improvement, job creation and poverty eradication, as they would create opportunities for small and medium enterprises involved in the installation of solar PV systems and distribution of CFLBs. For an estimated capital cost for solar PV of $2,750/kW (Can, and others, 2013), and given a $0.10 FIT, this would be an income of $1,805.20 per household, thus making it possible to recover capital in about 7.6 years for the 5 kW net-metered solar PV system.

5.2.3. Policy: replace kerosene with bioethanol for household cooking

Although the policy targets kerosene use in cooking and lighting in all households, the computation is only done for low-income households that use kerosene for all their cooking needs. This is a category for which segregated data was available (see figure 10 for results) from

Figure 8: Energy outlook due to generation by residential solar PV and consumption by CFLBs

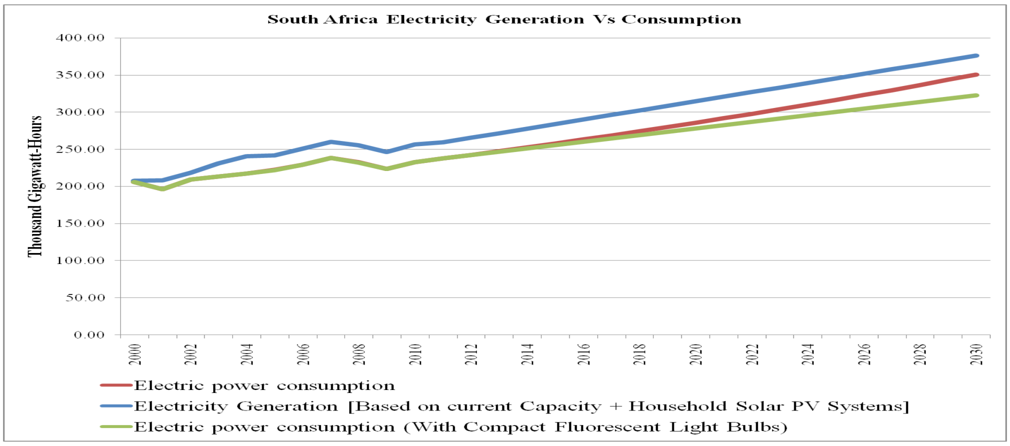
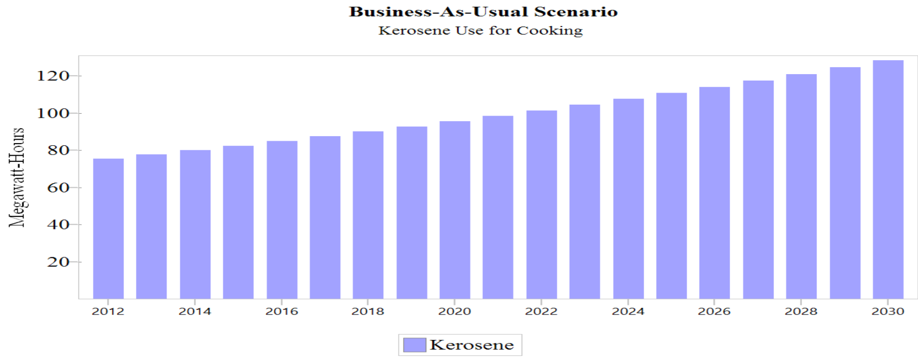


Figure 9: Projected kerosene consumption under business-as-usual scenario in South Africa



the Paraffin Safety Association of South Africa (2012) and the Department of Energy Perceptions (2013).

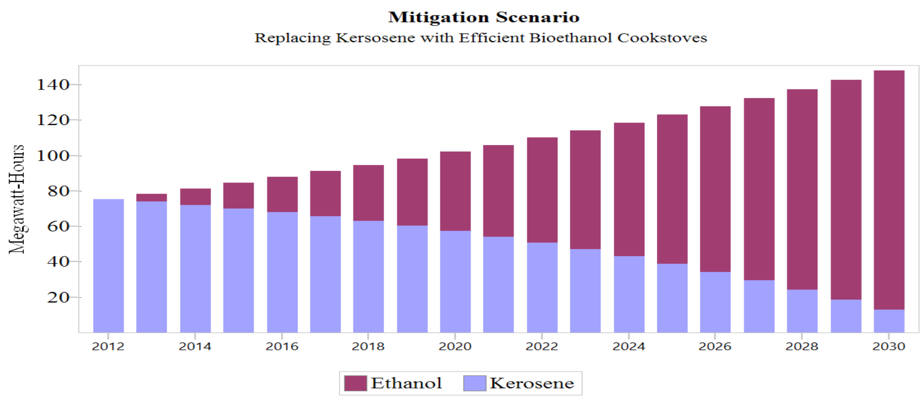
The total number of low-income households considered in this analysis is 9,936. Figure 11 shows the mitigation-projected scenario for kerosene and bioethanol consumption. The year 2012 is the baseline year while 2013–2030 are projected years. Kerosene consumption is estimated at 0.5 litres per household per day. Bioethanol consumption is estimated at maximum 1 litre per household per day. Projected growth is based on a 3 per cent low-income household growth rate for the scenario years.

Figure 11 shows the impact of a scenario with a policy, which introduces bioethanol clean cookstoves to replace the use of kerosene. The policy suggests replacing all kerosene cookstoves by 2030, although the figure shows some remnant kerosene, which is attributed to other uses such as lighting. The number of low-income households using kerosene for cooking is estimated to increase to 22,970 by 2030. This represents a demand for 22,970 litres per day of bioethanol, assuming 1 litre per day bioethanol consumption per household.

In addition to providing the needed bioethanol to replace kerosene, there is electricity generation potential of 223.02 GWh from bagasse and 272.31 GWh from vinasse, bringing the total to 495.33 GWh.

Given that the bioethanol producer price is $1 per litre and that feedstock cost is 50 per cent, there would be an annual economy of $1.8 million due to bioethanol alone injected in the households of rural communities engaged in feedstock production, to supply the 9,936 low-income households. Of the electrified households

Figure 10: Projected kerosene replacement with bioethanol for cooking in low-income households



in South Africa, 1.78 million of them also use kerosene for cooking and other purposes. On the assumption that an equivalent of 25 per cent of these 1.78 million electrified households are using 100 per cent paraffin for cooking and that 50 per cent of the 3.47 million of the non-electrified households are using 100 per cent paraffin for cooking, this brings the total for the two categories to 2.18 million households using 100 per cent. This number of households would generate a bioethanol-based economy of $397.850 million to rural areas producing feedstock for bioethanol. This is based on the assumption that feedstock costs 50 per cent of the bioethanol production cost.

For 26.6 kWh per litre of bioethanol co-generated from bagasse and 40.6 kWh co-generated from vinasse, there would be 67.2 kWh co-generated per litre of bioethanol produced. Assuming a $0.10/kWh FIT, this would generate an additional economy worth $5.35 billion (2.18 million households X 1 litre/household X 365 days X 67.2 kWh/litre X $0.10/kWh) in feedstock producing rural communities.

5.3. Carbon dioxide emission savings

5.3.1. Emission savings due to residential rooftop PV policy

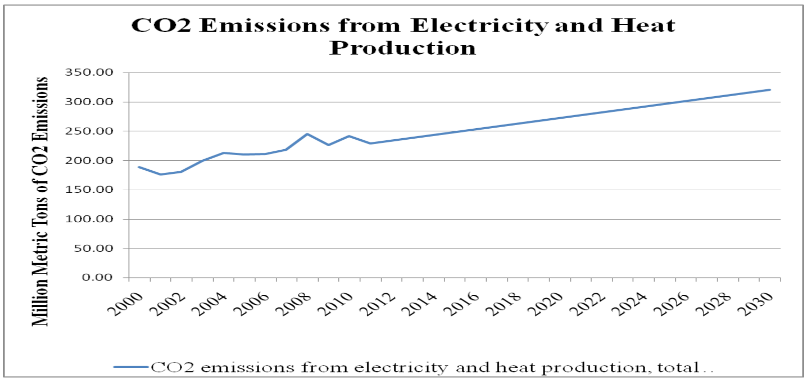
Figure 12 indicates a linear increase in CO_2 emissions from electricity and heat production. Historical data shows that it was up to 229.05 million metric tons in 2011.[32] The amount is projected to increase to 320.45 million metric tons in 2030. The additional 91.4 million metric tons of CO_2 would be saved if renewable energy and energy efficiency mandatory policy measures to install solar PV systems per household were instituted.

By substituting standard 100W bulbs, 10 of which would consume 3 kWh (10 bulbs X 100W/bulb X 3 hours) per day, with 10 X 18W CFLBs, which would consume 0.54 kWh (10 bulbs X 18 W/bulb X 3 hours) per day, would result in a saving of 2.46 kWh/day. For every kWh of electricity generated from coal – fired plants, there is 0.993 kg of CO_2 equivalent emitted. By using only CFLBs, each household would avoid 2.443 kg of CO_2 per day and thus, for a total 16.7 million households in 2030, 14.891 million tons of CO_2 equivalents would be avoided in that year.

5.3.2. Savings due to replacement of kerosene by bioethanol

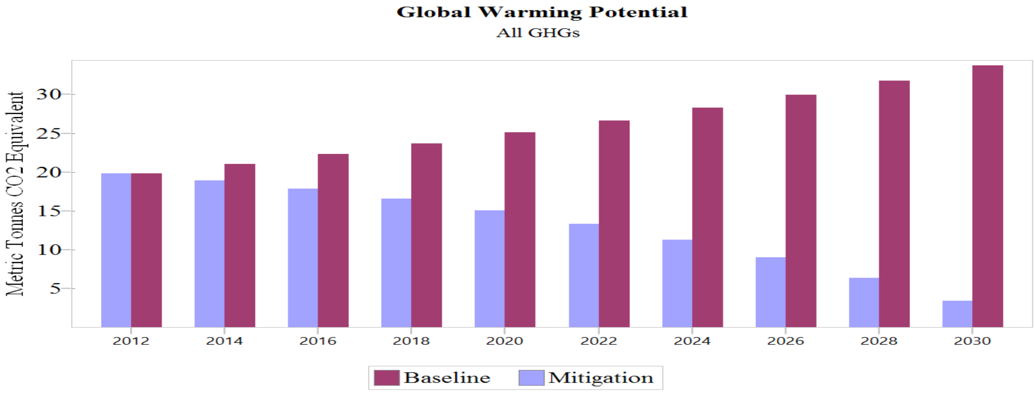
Figure 13 shows the environmental impact of the two scenarios in terms of GHG emissions. Replacement of kerosene by bioethanol used in clean cookstoves will significantly reduce these emissions. The business-as-usual scenario (baseline) indicates an increase in net GHG emissions from low-income households from kerosene consumption. The emissions are projected to increase to 33 tons of CO_2 equivalent in 2030. However, using bioethanol reduces the emissions from an estimated 19.8 tons in 2012 to 3.4 tons in 2030.

Figure 11: Projected CO_2 emissions from production of electricity and heat



32 World Bank, "Data: South Africa". Available from http://data.worldbank.org/country/south-africa.

Figure 12: Projections of emissions reduction due to kerosene replacement policy in South Africa



6. Zambia – Country Case Study

6.1. Zambia energy sector brief

The total installed electricity capacity of Zambia is 1,967 MW, of which hydro is 95.9 per cent and thermal 4.1 per cent.[33] The total primary energy supply in 2009 was 7,856 kToe, which comprised of biomass 80.9 per cent, hydroelectric 11.3 per cent, crude oil 6.6 per cent, petroleum products 1 per cent, electricity imports 0.2 per cent, coal and peat less than 0.01 per cent.

Zambia has a range of primary energy sources, including hydropower, coal, forest biomass and renewable sources of energy. Proven coal reserves exceed 30 million tons. Zambia is self-sufficient in all its energy sources with the exception of petroleum. Petroleum products supply approximately 26 per cent of the country's commercial energy needs, the balance being provided by hydroelectricity and coal. Total oil imports, estimated in 2009, were 17,570 bbl. per day (2.10 million litres per day), and by 2012, fuel consumption rose to 1.2 million litres per day for gasoline and 2 million litres per day for diesel. In 2009, Zambia imported 661 kToe of energy resources (net total), or 8.4 per cent of the total primary energy supply. For the same period, net electricity imports were 179 GWh.

Approximately, only 19 per cent of the country has access to electricity. The majority of electrified households live in urban areas, while only 2.2 per cent of rural people have access to electricity. Zambia is heavily reliant on imported petroleum products, which supply 37 per cent of the energy needs of the country. In 2010, fuel imports accounted for 11.6 per cent of total merchandize imports into Zambia. Biomass (mostly primary solid biofuels) provides the largest contribution to primary energy supply in the country. Other potential renewable energy options include modern bioenergy, solar energy, wind energy and increased hydroelectricity production.

The major power stations are linked via a transmission and distribution network of 2,008 km of 330 kV lines, 548 km of 220 kV lines, 85 km of 132 kV lines, 704 km of 88 kV lines and 3,014 km of 66 kV lines. Further distribution occurs on over 6,500 km of 33 kV and 11 kV lines.

The country's total demand exceeds internal generation, as a result of the thriving mining sector. Zambia is also faced with the challenge of satisfying the demand of more than 80 per cent of its population with modern forms of energy. Inadequate investment, in recent years, in generation and transmission infrastructure has led to deterioration in the power network. Sub-economic power tariffs have been blamed as a reason for the lack in financial mobilization. The sale of electric power tariffs in Zambia is among the lowest in the region. Due to power deficit, load-management is practiced to maintain the balance of supply and demand. Transmission and distribution losses in 2009 were 23 per cent, or approximately 2,407 GWh.

With regard to renewable energy, average solar insolation is roughly 5.5 kWh per m^2 per day, with approximately 3,000 sunshine hours annually, providing good potential for solar thermal and PV exploitation. Wind speeds average 2.5 m/s at 10m above the ground, a speed that is mainly suitable for mechanical applications. Seven areas have been identified as viable for off-grid wind power generation, although little development has since occurred. There is high potential for biomass-based energy, as the woodlands and forests of Zambia are estimated to cover about 50 million hectares or 66 per cent of country's total land area.

About 341,000 units of biogas digesters are operational in the country. Sugar cane is being grown in three provinces, and processed by three different companies with a projected capacity of 483,000 tons of sugar per year. At present no ethanol is being produced by the main sugar growing companies.

33 Reegle, "Energy profile in Zambia". Available from http://www.reegle.info/countries/zambia-energy-profile/ZM.

Zambia has geothermal energy potential, although it has not been examined in great detail. A geothermal power installation has been constructed at Kapisha, totalling some 200 kW, but only as a means for assessing potential. Over 80 hot springs exist in the country. Small hydro potential stands at 4 MW while large hydropower potential is 6,000 MW, of which less than 2,000 MW has been harnessed. Sites yet to be developed include Kafue Gorge Lower, Itezhi Tezhi, Kalungwishi, Mambilima, Batoka Gorge, Devil's Gorge and Kabompo.

The Energy Regulation Board is involved in Regional and Country Energy Efficiency, through promoting energy awareness and disseminating useful information on energy efficiency measures; carrying out technical audits on businesses such as farming; and developing appropriate license conditions on energy efficiency such as metering all customers.

In response to rising industrial consumption and stagnating infrastructure development, demand-side management is seen as a key short-term strategy, and Zambia Electricity Supply Corporation (ZESCO), which is government-owned and the largest power utility, identified the potential for several measures, including increasing CFLB use in all sectors through tax breaks and retail partnerships; a prepaid meter installation programme; and public sector energy efficiency measures, for example, a metal halide street lighting programme.

Copperbelt Energy Corporation (CEC) is a privately owned company that operates and maintains transmission, distribution and generation assets, and a control centre on the copper-belt. Lunsemfwa Hydro Power Corporation is a privately owned independent power producer, which was created after the privatization of the Zambian mining conglomerate, Zambia Consolidated Copper Mines. Lunsemfwa has an installed capacity of about 40 MW, and sells all its power to ZESCO under a power purchase agreement.

As the three operators in the electricity sector in Zambia, ZESCO is engaged in generation (ZESCO 94 per cent, CEC 4 per cent, and Lunsemfwa 2 per cent) and transmission activities (ZESCO 69 per cent, CEC 29 per cent, and Lunsemfwa 2 per cent). ZESCO and the Zambian electricity market are vertically integrated, with the State Company engaging in all sectors of the market.

ZESCO has also completed feasibility studies for the development of two hydropower stations with a combined capacity of 870 MW, and construction is set to begin soon. Both ZESCO and CEC are members of SAPP, which takes measures to create a common market for electricity in the SADC region, and to let their customers benefit from the advantages associated with this market. This is an opportunity for Zambia to export excess power.

Since the dissolution of the former parastatal monopoly, the Zambian Oil Company, private sector participation in the sector has grown, and the number oil distribution companies operating in the country have risen from five to 19.

The development plans based on the Energy Policy of 1994, and the succeeding policy in May 2008, have put more emphasis on grid hydroelectricity compared to other renewable energy options. These plans include the Poverty Reduction Strategy Paper, Transitional National Development Plan (2002-2005), the Fifth National Development Plan (2006-2010), and the Sixth National Development Plan (2011-2015).

The Poverty Reduction Strategy Paper acknowledges the importance of harnessing renewable energy resources to meet the country's energy needs. However, no investment strategy or targets for renewable energy technologies are defined in the Paper, and the main focus is on hydropower. The Sixth National Development Plan sets out specific goals for the energy sector, including increasing capacity by 1,000 MW compared to 2010 levels, improving rural and national electrification to 15 per cent and 40 per cent respectively, and increasing the capacity of petroleum bulk storage facilities to allow for the storage of 30 days of strategic stock.

Programme goals under the Sixth National Development Plan include: carrying out a cost-effective electricity tariff regime; establishing an open and non-discriminatory transmission access regime in the sector; introducing an appropriate and cost-effective renewable energy feed-in tariff programme; promoting the use of biogas for cooking, lighting and electricity generation; increasing biofuel substitution for mineral oil (E10 and B5); and developing a biomass energy strategy to improve the sustainability and effectiveness of the biomass supply.

Also covered under the Sixth National Development Plan are plans to further carry out the Rural Electrification Master Plan, build capacity in the engineering sector for energy efficiency and develop an energy efficiency plan, and further develop the environmental technology industry in the country, with an incentive framework.

The National Energy Policy 2008 also sets out a number of policy measures for renewable energy, including the assessment of renewable energy potentials, the strengthening of the institutional framework for renewable energy R&D, and the provision of financial and fiscal implements for the stimulation of renewable energy deployment.

The Global Village Energy Partnership, in association with the Department of Energy and the Ministry of Energy and Water Development, are working on a mechanism to increase access to reliable, affordable, and environmentally sustainable energy services as a means of enhancing economic and social development. The Ministry has the overall responsibility to develop and carry out policy on energy.

Major bottlenecks in applying renewable energy technologies in rural settings relate to low level of income of communities, policy and planning implications, the nature of the supply networks, and information on renewable energy technologies. Lack of information on these and other factors inhibits the application of RETs to move forward.

The Ministry of Tourism, Environment and Natural Resources is responsible for the formulation of policy on forestry and the environment, and works with the Ministry of Energy on issues of biomass, especially on the energy supply side.

The Rural Electrification Authority, which was established through an Act of Parliament in 2003, is in charge of developing and carrying out master plans for the systematic electrification of rural areas, including developing mechanisms for the operation of a grid extension network for rural electrification, and applying a subsidy for capital costs on projects designed to supply energy in rural areas.

The Energy Sector Advisory Group is a committee formed under the Ministry of Energy and Water Development, which contains representatives from government ministries and authorities, development agencies, and commercial enterprises. Its purpose is to encourage harmony between all sectors of the economy in terms of energy policy, and provide an informed opinion on energy matters to policymakers.

The Ministry has a long-term Energy Strategy (2009-2030) focusing on electricity, petroleum and renewable energy. In addition, there are plans for the formulation of a renewable energy strategy that will focus on solar energy, small hydropower, energy crops, biomass, and an environmental framework for biofuels.

The Government investigated renewable energy options through a number of different plans. A position paper on FIT was to be published in June 2012. However, there is no specific regulatory framework for renewable energy in the country, and the Energy Regulation Act makes limited mention of renewable energy sources. Through the 2008 National Energy Policy, the creation of a FIT system is nearing completion. Solar energy regulation is more developed than that of any other source. To date, a licensing regime for solar power operators has been developed, allowing the licensee to engage in the manufacture, supply, installation and maintenance of solar systems.

In 2008, the Zambian government revised the energy policy to include biofuels in the national fuel mix. Since then, the Government has issued a Statutory Instrument SI 42 of 2008 which lawfully recognizes biofuels in the national energy mix, B5 and E10 blending targets, Standards ZS E100 (for Bioethanol) and ZS B100 (for Biodiesel), and Guidelines and Regulations for biofuels. The Government has also recently announced producer prices for bioethanol and biodiesel.

The Zambian government's overall energy policy objectives and measures aim at creating "conditions that will ensure the availability of adequate supply of energy from various sources, which are dependable, at the lowest economic, financial, social and environmental cost consistent with national development goals."

In relation to biomass resources, the policy states, "to improve the standard of living there is need to switch from these low quality energy sources to better quality energy resources". By introducing biofuels, the intentions of the government is to mitigate climate change, improve energy security, conserve the environment, promote rural development, foster technological development, create jobs, alleviate poverty, co-generate electricity, empower citizens, and enhance food security, among others. Here lies an opportunity for the production of bioethanol for clean cooking.

The Energy Regulation Board is responsible for ensuring that utilities earn a reasonable rate of return on their investments, which is necessary to provide a quality service at affordable prices to the consumer; and ensuring that all energy utilities in the sector are licensed, and monitoring levels and structures of competition, including investigations and remedies if necessary. Tariff setting for the sale of electricity is also the responsibility of the Board.

The Board safeguards the interests of the consumer, licenses energy undertakings, and receives and investigates complaints from consumers on prices and services. It also regulates the refining and marketing of importation and transportation of crude and finished petroleum products. Applying renewable energy technologies in order to showcase their viability in the country has been limited, with only a few small-scale demonstration projects in operation.

Table 6: Setting for bioethanol-based energy efficiency and climate change mitigation in Zambia

Current power sources	Biomass, hydro, oil, and coal
Energy sufficiency	Inadequate
Energy sources for future expansion	Hydro, renewable energy, and coal
Example natural resource to be targeted for participatory energy production and supply	Biofuels (high agro potential)
Market opportunity	Residential for cooking and excess for transport fuel
Allowing for participatory energy production technology	Available biofuels production technologies
Energy efficiency opportunity	Replacement of inefficient household cooking energies
Biofuels distribution infrastructure	Pump stations and shops distributed throughout urban areas in Zambia
Contribution to global concern	Reduction in GHG emissions due to use of wood, charcoal and petroleum energies for cooking.

6.2. Effects of energy efficiency and climate change mitigation policies on electricity scenario

In the country's case study of replacing charcoal with bioethanol (see Table 6), the energy efficiency is in the form of using improved cookstoves; reduced indoor air pollution and health-related energy use risks; and the switch from inefficient biomass (wood, charcoal, etc.) based cooking to electricity and bioethanol by rural communities producing bioethanol, which is made possible by their newly acquired affluence. The GHG savings are in the form of reduced use of charcoal, fossil fuels and deforestation.

6.2.1. Policy: replace charcoal with bioethanol for household cooking

Assumptions on energy sources for cooking in 2010, the baseline year, include charcoal consumption of 2.5 kg per day per household, a corresponding bioethanol consumption of 1 litre per day per household, Electricity consumption of 8.3 kWh per day per household (estimated based on the assumption that electricity consumption per household per month is 500 kWh of which 50 per cent is used for cooking).

In 2010, the country's total population was 13,088,570, making up 2,617,714 households based on five persons per household. The number of households is estimated to increase to 4,896,000 in 2030. Urban population is 39 per cent and in this analysis, it is assumed constant throughout the projected years up to 2013. By 2030, 59 per cent of the 39 per cent urban households, which is approximately 1,126,662 (= 4,896,000 X 0.39 X 0.59) households, are estimated to be using bioethanol for cooking.

In 2010, the number of urban households using charcoal was 1,020,906 (= 39 per cent of 2,617,714), which represents 39 per cent of the total number of urban households in Zambia in 2010. Figure 15 gives projections for the business-as-usual scenario up to 2030, and Figure 16 gives projected results up to 2030 for the policy of substituting charcoal with bioethanol. There is a very significant reduction in charcoal use.

Figure 13: : Projections for the business-as-usual energy type consumption in Zambia

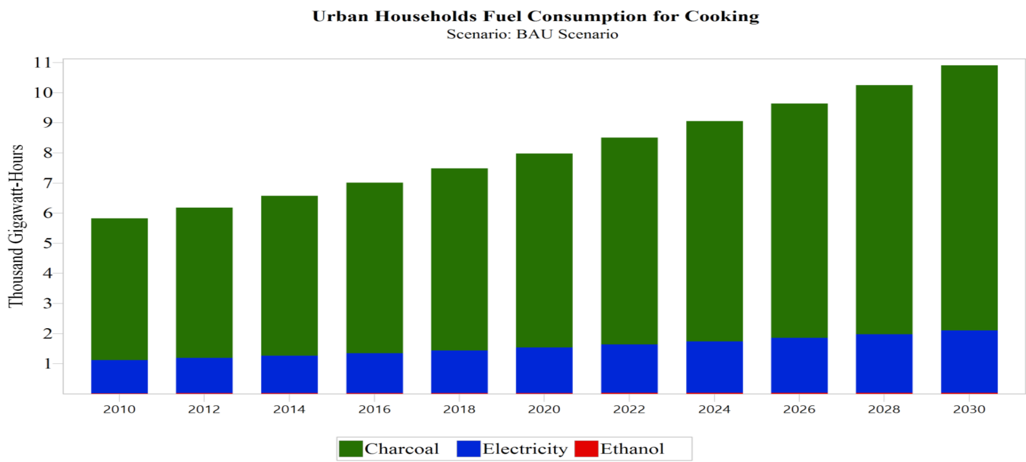
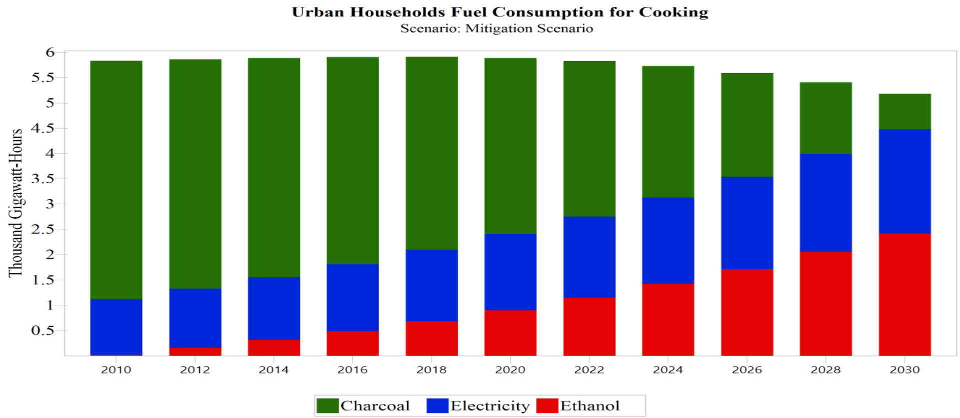


Figure 14: Projected proportions of households using bioethanol, charcoal and electricity in Zambia



During production of bioethanol, there is an opportunity to co-generate electricity from feedstock stove/bagasse and vinasse from the refinery. The assumption here is that if 1,126,662 urban households were using bioethanol by 2030, the total annual bioethanol consumption would be 411,231,929 litres, for the 1 litre consumption per household per day. The power generation potential at a rate of 26.6 kWh per litre for the 411,231,929.3 litres amounts to about 10,939 GWh. Given a bioethanol producer price of $1 per litre and that 50 per cent would be the cost of feedstock supplied by rural communities, there would be $205.62 million of annual retained economy due to bioethanol alone.

To obtain the amount of power co-generated from vinasse, the assumption is 7 litres of vinasse for every litre of bioethanol produced (Sweethanol, 2011).[34] The 411,231,929.3 litres produced will therefore result in 2,878,623,505.1 litres of vinasse. The rate of power co-generation from vinasse is 5.8 kWh per litre.[35] If this is multiplied by the amount of bioethanol and assume 80 per cent of the result to take into account volatile matter,[36] it will yield 13,357 GWh.

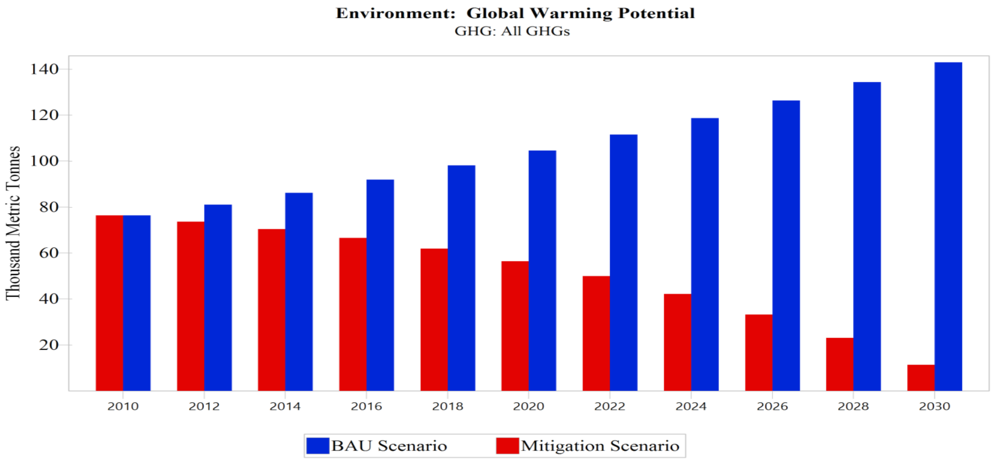
Overall, the power co-generated from both bagasse and vinasse is 24,296 (13,357 + 10,939) GWh, which at a FIT of $0.10/kWh would inject an economy of $2.43 billion for the bioethanol producing rural communities in the year 2030. Together with bioethanol at $205.62 million per year, would add up to 2.635 billion of annual retained economy in feedstock producer rural communities.

6.2.2. Carbon dioxide emission savings due to replacement of charcoal by bioethanol

Under the business-as-usual scenario, the GHG emissions due to charcoal use for cooking by the 1,126,662 urban households in Zambia would be 142.298 thousand tons of CO_2 equivalent by 2030 (see Figure 17). By substituting charcoal with bioethanol, the emissions would drop to 1 135 000 tons of CO_2 equivalent.

34 Page 49 of Sweethanol 2011 report.
35 Ibid (page 50).
36 Ibid (page 49).

Figure 15: Emission projections for the business-as-usual and under bioethanol mitigation policy



7. Additional Policy Measures

The policy pronouncements to have all residential houses in Morocco and South Africa fitted with net-metered solar PV systems and to have kerosene in South Africa and charcoal in Zambia replaced by bioethanol are not sufficient unless other practical measures are put in place. The measures should recognize the prevailing poverty and joblessness in the three countries; the lack of affordability for the people to effectively participate in carrying out the policies; the lack of opportunities to localize renewable energy technologies, especially in the wake of created increased economies of scale; and the need for Governments to use renewable industry as an opportunity for propelling citizens on the inclusive growth path. Some of these measures are outlined below.

7.1. Attractive feed-in tariffs and cost of bioethanol

The cost of power from residential rooftop solar PV should be lower than the grid power cost. Overall, here is how the system should work:

7.1.1. Attractive feed-in tariffs

If targeted communities install electricity-generating technology from a renewable or low-carbon source such as solar PV or wind turbine, the FITs scheme should mean that the targeted producers get money from energy suppliers (e.g. energy service companies), similar to measures used in, for example, the United Kingdom.[37] In the United Kingdom, you can be paid for the electricity you generate, even if you use it yourself, and for any surplus electricity you export to the grid, and you will also save money on your electricity bill because you will be using your own electricity. Most domestic technologies qualify for the scheme, including solar electricity (roof mounted PV or stand-alone), wind turbines (building mounted or free standing), hydroelectricity, anaerobic digesters and micro combined heat and power.

7.1.2. Attractive cost of ethanol

The cost of bioethanol comprises the cost of production, producer's mark-up, retailers' mark-up and government taxes. The Government of Zambia does not collect taxes for charcoal while the Government of South Africa, through the Free Basic Alternative Energy policy programme, subsidizes the consumption of energy sources such as paraffin, LPG and ethanol gel fuel (Tait, Merven and Senatla, 2013).

The selling price of bioethanol, which would be denatured for use in clean cookstoves, can therefore be kept at retailer's mark-up, with a government set maximum, so that the bioethanol price remains more attractive. Government would collect VAT from bioethanol producers. At the same time, the price of kerosene should be raised to an unsubsidized value while charcoal should be taxed so that they become economically unattractive. The latter is justified owing to the need to reduce deaths and ailments related to indoor air pollution, accidents and deaths, GHG emissions related to cooking and lighting, and deforestation in relation to wood and charcoal.

7.2. Lowering production cost of energy

To lower the cost of energy production, policy measures can include instituting incentives such as lowering import duties for solar and biorefinery equipment, promoting local manufacturing of production equipment, and investing in R&D to improve production efficiencies.

7.3. Job creation and local content policy

The policies as stated above would create increased and predictable market volumes enough to warrant local manufacturing of renewable energy technology equipment. The incentives here can therefore include lowering

37 Energy Saving Trust, "Feed-in Tariff scheme", 20 September 2013. Available from www.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Feed-In-Tariffs-scheme-FITs.

of the cost of nationally made renewable energy products, and increase jobs in renewable energy manufacturing supply chains, renewable energy manufacturing, design engineering, installation and all the miscellaneous jobs created when a renewable energy array is established. This would further promote forward and backward industrial linkages in national economies (Sinkala, 2014).

7.4. Inclusive innovative financing

Barriers to financing mean that, in the past, energy efficiency has not been able to attract significant amounts of private capital. These barriers take a range of well-recognized forms and include the initial cost barrier, high transaction costs, long payback time, and risk exposure. Furthermore, lack of knowledge among finance providers about energy efficiency prevents customers from accessing capital, and the absence of standardized measurement and verification practices further increases transaction costs. Various innovative ways of financing energy efficiency and clean energy programmes exist (Association for the Conservation of Energy, 2013) and they are crafted in various forms including the following options:

7.4.1. Soft loans

These are loans that are enhanced or "softened", for example, with low interest rates and interest-free periods at the start of the loan term (also called preferential loans). In most cases, preferential loans are delivered through public-private partnerships where the Government provides a financial support to the bank, which in turn offers a preferential interest rate to its customers. Loans may be provided to an individual residential or non-residential customer, or to a group of customers, such as an apartment association or a microfinance group.

7.4.2. On-bill repayment

This approach uses utility or third party capital to pay for energy efficiency or renewable energy retrofits in a building. The customer repays the cost of this through an additional charge on their utility bill.

7.4.3. Guarantee programmes

Energy efficiency projects can be structured with various guarantees. Guarantee mechanisms seek to engage financial institutions by supporting and sharing the credit risk of energy efficiency investments. In this way they help financiers to accept the risk for debt lending and act as a catalyst to scale-up private investment in energy efficiency.

7.4.4. Property-assessed repayment

This is an approach developed in the United States, from 2007, that allows local governments to finance energy efficiency improvements using land-secured special assessment or 'improvement district' structures. Under such authority, local governments issue bonds to finance local improvements that have a public purpose. They then collect the money to repay the bond through assessments levied against properties that receive a benefit from the improvements. In a typical Property Assessed Clean Energy (PACE) programme, the municipal improvement district authority is expanded to include energy efficiency or renewable energy improvements on private property. Property owners voluntarily agree to have assessments levied against their property in exchange for receiving the up-front capital for the energy efficiency improvements.

7.4.5. Energy service companies

These are generally companies which offer energy demand reduction services, often financed through so-called 'performance contracting', where the energy savings generate cash flow which pays for the installation of the equipment plus a margin. In most developed markets, the energy service company assumes the cost of the equipment, process replacement and building retrofit through an energy performance contract. Payback is defined as a percentage of energy savings as stipulated in the contract.

Establishing a clean energy rate can be justified in various ways. A value of renewable energy (VoRE) is a rate that includes all of the environmental and financial benefits of establishing renewable

energy.[38] For example, what is the value of not burning charcoal to cook, or coal and oil to create electricity? What is the value of eliminating high cost infrastructure upgrades such as high voltage transmission lines or more power plant upgrades? The VoRE rate will put a true value on all those benefits accrued when a renewable energy system is established. The VoRE rate will do two things:

- It will allow for a guaranteed rate of return for the next XX years of production of a renewable energy system.

- The VoRE rate encourages lending from financing companies to allow for the establishment of renewable energy at little to no up-front cost.

38 TruNorth Solar, "The New Minnesota Solar Rebate Menu – What you need to know". Available from www.trunorthsolar.com/2013/09/the-new-minnesota-solar-rebate-menu-what-you-need-to-know.

8. Discussion and Conclusions

This study has demonstrated that by adopting a low-emission development, it is possible for countries to advance a win-win sustainable, climate-resilient development for both pro-poor and private sector growth, while significantly reducing GHG emissions.

For Morocco, it has been demonstrated how the country can involve citizens to economically participate in independently generating power using residential net-metered solar PVs, which would contribute to meeting power, needs for their households and the country as a whole, beyond which there is also an export potential. This policy approach allows people to earn money by selling their excess power to the national grid, thereby reducing poverty. The efficiency is achieved through on-site power generation for residential use, thus avoiding long-range power transmission losses. Furthermore, there is power savings through the use of CFLBs.

For South Africa, a similar analysis has been demonstrated with residential solar PVs. But, in addition, there is also an illustration where kerosene use for cooking is replaced by bioethanol use in clean cookstoves. Here again, the emphasis is on involvement of people in this substitution programme as a way of providing jobs and reducing poverty. People would earn money from selling excess power from their net-metered residential solar PVs, and they would also participate in the bioethanol production and supply value chain. Since South Africa has issued blending mandates for biofuels, the excess bioethanol produced would be sold for motor transport energy mix.

For Zambia where biomass, mainly wood and charcoal, accounts for approximately 77 per cent of the nation's energy needs, the demonstration in this study has been to replace charcoal and charcoal braziers with bioethanol use in efficient and clean cookstoves. The example shows that the country can allow people to gain access to modern clean energy as they also get economically empowered through participation in the value chain of the bioethanol industry. In particular, as much as 50 to 60 per cent of the cost of producing a litre of bioethanol is attributed to feedstock production. This is the minimum size of the economy that would be possessed by peoples in rural areas who would be participating in feedstock production and supply to bioethanol refineries.

In the cases of Morocco and South Africa, use of solar PVs residential houses would significantly save GHG emissions by reducing the amount of coal that would be required to generate power to meet household demands, especially for lighting. In South Africa, the emissions related to kerosene use would significantly reduce GHG emissions and the high levels of accidents, which are sometimes fatal. In Zambia, there would be significant carbon savings both due to reduced charcoal use and deforestation.

In the cases of South Africa and Zambia that would be producing bioethanol to replace kerosene and charcoal use for cooking in households respectively, producers of bioethanol would also be generating electricity to meet production and other local energy demands, while exporting the excess to national grids. The raised affordability for rural people and the decentralized availability of electricity would increase accessibility to modern energy, which for Zambia would reduce deforestation due to decreased use of wood and charcoal in households and for South Africa would reduce the use of paraffin.

In all cases, the energy efficiency, renewable energy and emissions saving programmes can be country-driven, apart from capacity-building and technology transfer which may need external help.

In addition to clean energy substitution policies, supporting policies that include access to finance,

incentives to promote the energy efficiency, renewable energy and emissions saving industry, promotion of local content for enhancing forward and backward industrial linkages, and attractive FITs and innovative lowering of bioethanol prices, would be important for these policies to be effective.

9. Recommendations

The energy efficiency and renewable energy economies are low hanging fruits and support sustainable development. African countries, which happen to possess either all or some of the renewable energy resources, should decide on programmes to develop green economies. To actualize the establishment of energy efficiency, renewable energy and emissions saving-based green economies, the following are recommended:

9.1. Actions by governments and development partners

African governments should carry out audits of the energy efficiency, renewable energy and emissions saving potential for various sectors and promote investment; concurrently promote the projects as these are "tri-pillars" of a sustainable energy future, and have synergetic benefits; and particularly prioritize projects such as residential solar PVs and biofuels which involve the poor in the value chain as this would raise affordability by the poor, thus meaningfully promoting their access to modern clean energies and participation in economic development on sustainable basis. To attract investment, Governments should remove the operational barriers often encountered in energy efficiency, renewable energy and emissions saving programmes and projects.

Development partners should help with networking energy efficiency, renewable energy and emissions saving good practices among African countries, facilitating with interregional field visits to success-story areas to gain experiences, developing information databases which will help to improve the programmes and projects' planning and development, building capacity in national and regional stakeholder institutions and key civil society organizations, and helping to raise funds for mega projects.

9.2. Project target areas with high energy efficiency-emission saving impacts

Project target areas with high energy efficiency-emission saving impacts that can be carried out, include lighting (energy saving bulbs and renewable energy systems), household appliances and equipment (improved cookstoves, promoting pre-paid meters, and installing renewable energy systems), buildings envelope (retrofitting, refurbishing, design standards for energy-efficient buildings, and installation of renewable energy systems), large industries and small and medium-sized enterprises (use of energy-efficient processes, installing better meters and sub meters, fixing leaking steam pipes, reducing use of compressed air, and incentivizing renewable energy consumption), transport (use of public transport and use of biofuels (bioethanol, biodiesel and biogas), electricity utilities and power services companies (installation of energy-efficient power generation and distribution facilities), off-grid power generation and supply (decentralized energy systems), and research, development, demonstration and deployment to provide local solutions for energy efficiency, renewable energy and emissions saving (ECA, 2012).

9.3. Potential energy efficiency-renewable energy-emission saving programmes and projects

Taking into account Africa's regional situation (the availability of energy resources, their distribution, their affordability, on-going renewable energy and energy efficiency programmes, and regional energy disparity factors) the energy efficiency-emissions saving programmes and projects can be based on energy sources including: solar (popular solar PV systems, or solar home systems); biofuels (using participatory and drought tolerant feedstock such cassava and sweet sorghum for multiple clean energies and economic empowerment of the rural and peri-urban population to improve affordability of energy efficiency-emissions saving measures);

mini-grids based on PV and hybrid systems (including small hydro and wind); improved cookstoves with use of biomass-waste briquettes, biogas and ethanol); geothermal heat and power, biomass power plants (e.g. use of bagasse); small-scale hydropower plants to exploit the enormous potential that exists mostly in sub-Saharan Africa, biogas digesters (small and large, especially in rural and peri-urban areas).

9.4. Financing energy efficiency-renewable energy-emission saving programmes and projects

Governments should provide an environment for establishing funds to support development of energy efficiency-renewable energy industries; incentivize banks and other financial institutions to consider energy efficiency savings and off-take agreements as tangible collateral since they can be measured and costed over time; facilitate use of part of the energy efficiency savings made by energy service companies for (i) expansion of services for renewable energy development, and emissions saving projects, and (ii) soft loans or similar to be accessed for small to medium energy efficiency, renewable energy and emissions saving projects.

9.5. Technologies and research and development

All basic energy efficiency, renewable energy and emissions saving technologies are mature and their costs are progressively decreasing, thus improving affordability. However, their promotion should be country-specific, depending on the energy efficiency-renewable energy mix available or viable, as evidence from the three case study countries shows. R&D needs to be supported to internalize the energy efficiency, renewable energy and emissions saving industry in Africa, and to also progressively reduce the cost of technologies. Sub-regional and international partnerships should be encouraged to reduce R&D costs, and to avoid costs of “re-inventing the wheel”. Sectoral best-practice networks should be promoted to improve information flow and development of sectoral databases, which will also help in monitoring progress when carrying out energy efficiency, renewable energy and emissions saving projects.

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