2017 Africa Unity for Renaissance International Conference South Africa, 22-24 May 2017

SOLAR MINI GRIDS IN AFRICA

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ABSTRACT

The technological advancement in telecommunications, engineering and agriculture has made electricity access a key factor for the development of any region in the world. The African continent has remained largely undeveloped because the electrification rates are low especially in Sub-Saharan African and the lack of electricity access is most acute in the rural and peri-urban areas. This research paper investigates how the availability of electricity to the rural and peri-urban areas in Africa can help in achieving sustainable development goals. Renewable energy sources specifically solar have been identified as an alternative energy solution for the generation of electricity in remote areas through the use of solar mini-grids. As national power grid extension is capital intensive and generation of electricity using fossil fuel breeds huge operation costs and greenhouse gases. An exploration of the availability of the solar recourse in the continent and the level of abundance of the solar resource, sets solar energy as an electricity generation method which is clean, cheap and sustainable. This research paper furthermore explores the financial models that can be implemented by communities to ensure that the Solar Mini Grids are economically viable and sustainable.

INTRODUCTION

More than 1.2 billion people ,16% of the global population do not have access to electricity and 95% of those people living without electricity are in countries in sub-Saharan Africa and developing Asia and they are predominantly in rural and peri-urban areas [27]. Electricity production in Africa falls far short of demand and the energy gap is increasing. Power Utility Institutions in Africa are facing various challenges from high energy tariffs to limited access to capital for development. The estimated number of people without electricity access in sub-Saharan Africa alone is 634million. [22] The International Energy Agency estimated that 60% of additional electricity generation required to achieve universal electricity access in Africa will need to come from off grid solutions.Furthermore, the IEA estimates 315 million rural and peri-

urban Africans will have access to electricity by 2040 and 140 million of those will be served mini grids. [12]. Some African countries with low rates of rural electrification are promoting affordable clean and sustainable energy versus grid extension like Kenya. The Energy Regulatory Commission(ERC)of Kenya show that total installed capacity for solar is likely to be over 20Megawatts and it is projected to grow by 15% annually [9]. There is a need to diversify the power generation mix with environmentally sustainable power generation methods to close the ever increasing energy deficit in Africa and provide energy to the rural and peri-urban population. Off-grid renewable energy systems are in many cases the most economical solution for providing electricity to these population groups [3], [21]. This paper explores the problems associated with the unavailability of electricity in rural areas and how Solar mini-grids and standalone photovoltaic solar systems are a sustainable, clean and affordable electricity solution for the un-electrified population in Africa. The paper also highlights how the availability of electricity through solar mini grids alone will help in achieving five of the eight Millennium development goals in Africa.

ELECTRICITY IN AFRICA

About 632million people in Africa do not have access to electricity [28]. Provision of electricity access in slow due to the various problems the power utility companies are facing. Electricity tariffs are high due to the dependence of the on fossil fuels for generation, high maintenance cost due to aging generation, distribution and transmission infrastructure. Furthermore, there energy deficit between generation and demand is increasing because of economic growth and rural to urban migration. Therefore, extending the grid to the rural and peri-urban areas is not a priority furthermore settlements are spacious and haphazard in the rural and peri-urban areas making grid extension capital intensive and uneconomically viable [4], [15]. EIA concludes that for the large rural population that is distant from the national power grid, mini grids provide the most viable means of access to electricity [11].

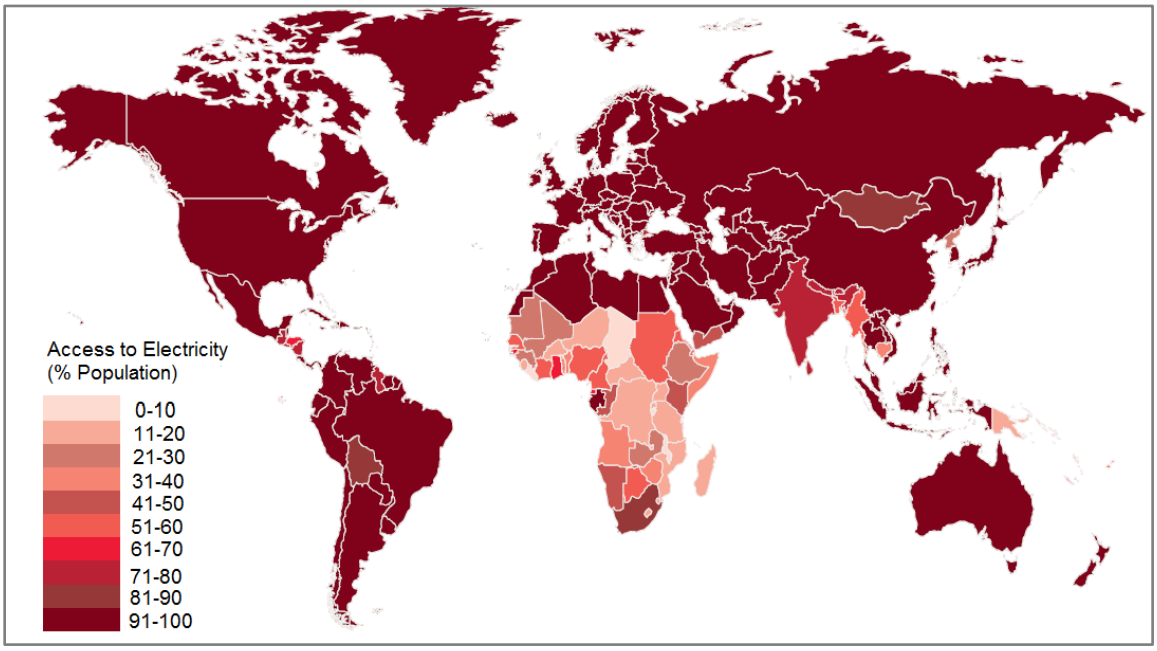

Figure 1: Level of Electrification based on region
Source: World Bank

Over 90% of the population in the Europe,America,Australia the developed countries have access to electricity. In Africa only a few countries in North Africa have countries with 90% of the population with access to electricity. The rest of the African continent has low electrification levels especially in sub-Saharan Africa namely countries like Zimbabwe with urban electrification rate of 70% and rural electrification rate of 40% , Malawi with urban electrification rate of 46% and rural electrification rate of 5% ,Botswana with urban electrification rate of 69% and rural electrification rate of 32% , DRCurban electrification rate of 42% and rural electrification rate of 0%.The electrification rates for Sub-Saharan Africa are 63% and 19% for urban and rural electrification respectively [24]. The African continent has the least level of electrification especially Sub-Saharan Africa relative to any other region in the world. Sub-Saharan Africa is the region in Africa which is lagging behind in the implementation of the Millennium Development Goals.

The lack of electricity access, modern energy services is a serious hindrance to economic and social development and must be overcome if the United Nations Millennium development goals (MDGs) are to be achieved [25]. The United Nations Millennium development goals are now being referred to as the sustainable development goals.

Table 1 : Electricity Access in 2014 – Regional Aggregates

Region	Population without electricity millions	Electrification rate %	Urban electrification rate %	Rural electrification rate %
Developing countries	1,185	79%	92%	67%
Africa	634	45%	71%	28%
North Africa	1	99%	100%	99%
Sub-Saharan Africa	632	35%	63%	19%
Developing Asia	512	86%	96%	79%
China	0	100%	100%	100%
India	244	81%	96%	74%
Latin America	22	95%	98%	85%
Middle East	18	92%	98%	78%
Transition economies & OECD	1	100%	100%	100%

WORLD	1,186	84%	95%	71%

Source: IEA: Energy Outlook 2016

PROBLEMS ASSOCIATED WITH NO ACCESS TO ELECTRICITY IN AFRICA

1. Poor Living Standards: Access to electricity improves the standard of living by providing electricity for standardlighting, entertainment, communication devices and equipment that minimise household chores e.g dishwashers and washing machines.

2. Poor Health Service Delivery: Rural motility rate is significantly high in Africa relative to the motility rate in Urban Area. Electricity improves services at the hospital, improving standards

3. Poor lighting methods: Kerosene lamps have significant hazards which range from respiratory diseases due to the soot produced, eye problems due to the poor light they produce and the risk of fires.

4. Poor Education standards: Modern learning methods are now supported by Information Technology systems. Therefore, in most rural and peri-urban area there is no electricity to support internet and internet based learning methods.

ELECTRICITY GENERATION AND THE CARBON FOOTPRINT

There is growing scientific evidence that burning fossil fuels for electricity generation by thermal power plants contributes to rising temperatures and extreme weather [15]. The burning of fossil fuels produces greenhouse gases which lead to global warming leading and climate change. The leaders and decision makers recognize the need for action to mitigate global warming [1]. Policy makers have been urged to seek ways to reduce greenhouse gases in response to growing concern about climate change.

Carbon foot print is a set of greenhouse gas emissions caused directly and indirectly by individuals or organizations.Thegreenhouse gasses are expressed in units of carbon dioxide equivalent (CO2e). Some of the greenhouse gases identified by the Kyto Protocol are carbon dioxide,methane, nitrous oxide.Energy generation methods generate greenhouse gases and national power grid extension increases the load and leads to the increase in the generation of greenhouse gases.

Policy makers are encouraged to champion policies which minimize generation of greenhouse gases. Therefore, alternative electricity generation methods should be explored.Some African countries have embraced alternative energy generation methods a good example is Kenya in Africa and India in Asia. The Energy Regulatory Commission(ERC)of Kenya show that total installed capacity for solar is likely to be over 20Megawatts and it is projected to grow by 15% annually. [9]. In India the government seeks to balance the need for electricity with environmental concerns from the use of fossil fuels to generate electricity [13]. The current emissions of greenhouse gases of the poorest countries notably in Sub-Saharan Africa and in rural

areas of developing countries, are negligible due to the low levels of Industrialisation. If the fossil fuel consumption of the countries grows at a high rate until year 2030 the per capita level of emissions will still remain low relative to those in high income countries [23].However, Africa should also establish such policies which balance electricity generation with environmental concerns, so that the whole world has a holistic approach in dealing with climate change.

Every Kilowatt of energy supplied using renewable energy resources contribute significantly to minimising the generation of greenhouse gases. Solar Mini-grids and standalone photovoltaic solar systems generate electricity using energy from the sun, thus solar energy can be utilised to provide electricity to remote areas in an environmentally friendly manner. The table below was developed by the Clean Development Mechanism (CDM). The methodology relates the emission of greenhouse gases to the electricity consumed by households and the reduction in green house emission if the household was using electricity generated by a renewable energy source.

Emission Reduction using CDM Methodology AMSIII.BB. Electrification of Communities through Grid Extension or Construction of new Mini-Grids

Emission Factor for first 55kWh of Household consumption	6.82	tCO2/MWh
Emission Factor for 55kWh -250kWh of Household consumption	1.3	tC02/MWh
Emission Factor beyond 250kWh of Household Consumption	1.0	tC02/MWh
Electricity Used Per Household per year	584	KWh/year
Emission reductions for first 55kWh with Renewable Energy	0.281	tC02e
Emission reduction for 55 to 250kWh with Renewable Energy	0.190	tC02e
Emission reduction for beyond 250kWh with Renewable Energy	0.00025	tC02e
Total Emission reduction her household for year 1	0.472	tC02e
Total emission reduction per household for 2years to 20 years	0.438	tC02e/year
Annual Emission reduction from program	65953	tC02e/year
Total Emission reductions from Program (20 year lifetime)	1319055	tC02e

Source:http://cdm.unfccc.int/

SOLAR MINI GRID

Mini grids are local producer networks that use distributed energy resources and manage local electricity supply and demand [20]. A micro-grid is a grid that transfers a capacity of less than

50Kilo volt-amperes (KVA) and is powered by a micro-power plant [10]. The word mini grid is often used interchangeably with the word micro-grid [20].

This electricity generation, transmission and distribution method is an ideal alternative for providing electricity to remote areas. Compared to the national power grid extension solar mini grids can be less expensive due to the low capital cost of distribution and transmission infrastructure and low cost of operation by avoiding electricity transmission and distribution losses [15]. The power plants generate electricity using light energy from the sun, through the use of photovoltaic cells which convert light energy into electricity. This technology can be used where there is sun. It is evident that solar energy is a practical method of providing electricity to remote areas, since photovoltaic systems have been used to operate broadcasting equipment in remote areas [24] [6]. Furthermore, mini grids are used to supply remote industrial sites, telecommunication facilities, lighthouses, national parks and schools with electricity [20]. The block diagram shows a solar mini grid with photovoltaic modules distributing electricity to the different electrical loads.

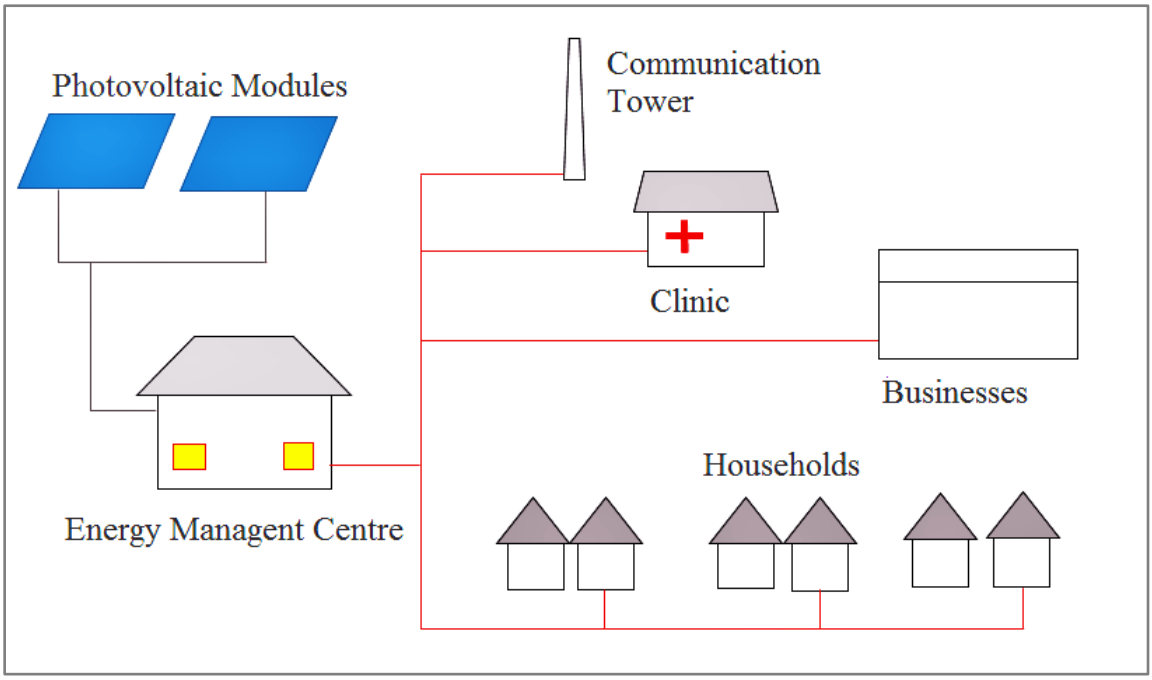

Figure 3: Solar Mini-Grid Block Diagram

ELECTRICITY SOLUTIONS FOR RURAL AND PERI URBAN AREAS

Electricity in a rural areas and peri-urban areas can be distributed to different areas in a number of ways which are cost effective in terms of investment for infrastructure for distribution and transmission. A localized electricity generation, transmission and distribution system like a solar mini grid reduces transmission and distribution costs therefore making electricity affordable. To achieve universal electricity access, electricity can be distributed through two methods.

1. Electricity from solar mini grids can be distribute through Low voltage which directly distributes single phase AC electricity to each household.

2. Standalone solar photovoltaic systems for isolated households

The electricity supplied by solar mini grids and the standalone solar photovoltaic systems should be adequate to power 3 energy efficient lights, a radio, a phone charger and a television to satisfy some of the modern needs of a person.

SOLAR ENERGY RESOURCE

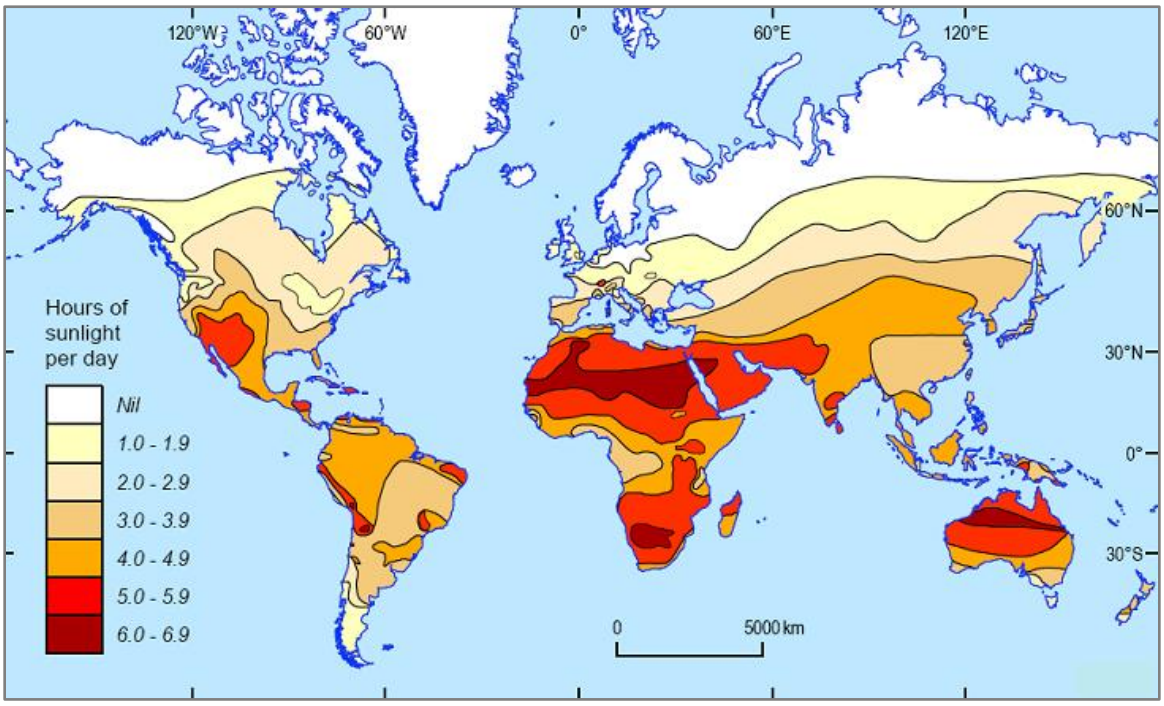

Figure 4: Minimum Sun Hours
Source: Sunwise Technologies 2008

The map highlights that the African Continents has the most abundant solar resource. The average solar hours for the continent are between 5 hours to 6hours in the worst case. The availability of the solar resource in Africa makes solar technology an ideal alternative for electricity generation and solar water heating. Kenya has abundant solarresources, its daily average solar insolation is estimated to be about 4 to 6 kilowatt hour per square meter, which is considered to be one of the best solar electric energy production in Sun-Saharan Arica [5].

ECONOMIC SUSTAINIBILITY OF SOLAR MINI GRIDS

Solar mini grids are designed to be able to self-sufficient that is the Solar Mini Grids should generate adequate revenue to cater for overhead costs and variable costs. To

insure a successful development of solar mini grid sector in a country, human resource training and capacity development are essential for all stakeholders project developers, government officials, regulators, local distribution utility officials, financing service providers and the community [2].[1]. A good initiation of the project and adequate operator model guarantees the sustainability of the Mini grid. The business models of solar mini grid vary widely particularly with regard to funding and operation. Funding for renewable energy projects come in form of Non-Governmental Organizations' grants, loans, Government Allocations and Equity. The Solar Mini grid can be managed by Utility operator, private operator, community operator.

1. Utility Operator
   The Government of a wholly government owned company manages all aspects of the solar mini grid generation and maintenance of the Solar Power Plant.

2. Private Operator
   A privately owned company manages all aspects of the solar mini grid. The Private operator operates the power plant in a manner which is regulated by law.

3. Community Operator
   The community members organizes to manage the generation, distribution and maintenance of the Solar Mini Grid with the guidance of the power utility company of the private operator.

Utility operated mini grids have suffered from low development due to bureaucracy and inflexibility regarding ownership, billing and customer relations. The private operator lead approach is able to establish and connect the population to the solar mini grid quickly and efficiently than models of business [16]. The private operator is flexible in terms of financing, billing and ownership.The most effective approach to the development of solar mini grids and the most effective solar Mini grids are designed with the local context in mind structured with sustainable finance models that meet all the fixed and variable overheads and supported by government policies [19].

BENEFITS OF SOLAR MINI-GRIDS

1. Affordable and Clean Energy: Solar mini-grids generate electricity which is cheap and clean using light energy form the sun. Power Utility companies generate electricity using fossil fuels which is expensive.

2. Environmentally Friendly: Solar Mini-Grids use the sun to generate electricity. The electricity generation method does not generated noise and does not produce greenhouse gases.

3. Eradication of Poverty: Availability of electricity in a community opens up opportunities for the population to be productive and the community can start income generating projects.

4. Reliable: The Power plants are reliable in that any power interruptions and outages are attended to in a swift name because the power plant and the transmission and distribution system is localized.

5. Improved standard of living: Kerosene lamps which pose a number of safety and health risks of respiratory diseases and fires are eliminated and the lamps are substituted by energy efficient electrical bulbs which produce standard lighting.

6. Quality Education: Electricity can be utilized to power tools which are being used for modern learning methods. Access to the internet and other electronic learning resources is possible.

7. Improved Health Service Delivery: Electricity improves health services delivery and this will help to minimize child mortality and improve maternal health. Model medical equipment, communication systems and management systems can be used.

8. Clean water: safe drinking water can be supplied from deep boreholes. Boreholes which are mechanism and powered by solar energy.

9. Employment creation: Where a solar Mini-grid is constructed and operated there are likely to be 30 jobs created directly and 60 jobs created indirectly for every megawatt installed on the solar mini grid [20]. Which achieves one of the Millennium Development goals of eradication of poverty.

Access to modern forms of energy is essential for the provision of clean water, sanitation and heath care and provides benefits to development through the provision of efficient lighting, heating, cooking, mechanical power, transport and telecommunication services [26].

CHALLENGES OF SOLAR MINI GRIDS

There are many challenges involved in the implementation of Solar Mini-Grids in Africa the challenges include political, economic, environmental social and technological

1. No investor interest for the Solar Mini Grids in Africa due to inadequate business cases to support investments towards solar mini grids. Investors require robust financial models which guarantees consistent income to support operations which break even, which are able to breakeven.

2. There are no policies to champion new energy generation methods through renewable energy in mostAfrica Countries. In some countries where policy is there it is vague and does not have specific timelines. Many government policies for African countries support rural electrification through power grid extension versus the use of renewable energy

3. Solar Mini grids are treated as pre-electrification processes which are meant to provide electricity on a temporary basis to remote areas waiting for the national power grid connection, however the grid extension in Africa is slow.

4. Land Acquisition is a major problem in Africa Land is mainly dedicated for farming, wildlife and cattle ranching. No land is dedicated for the development of Solar Mini Grids

5. The development of the solar mini grid is a human intervention. This intervention disturbs the environment, the animal's life cycles the food chain and disturbs the entire ecosystem.

6. Limited knowledge in solar photovoltaic systems and thermal solar systems. The Kenyan Renewable Energy Association highlights that the solar energy sector has been affected by poor quality products, poor designs, installations and maintenance services [11].

7. The Solar Mini –Grids is supposed to serve very low income earners. Affordability should be of great importance when designing mini grids.However Solar Mini Grids eventually become expensive to develop and operate because of limited knowledge in solar photovoltaics in the continent.

RECOMMENDATIONS

1. Solar Mini Grids projects should establish effective business cases before the implementation of the project. An effective business model should be established to ensure that the Solar Mini Grid is sustainable. The ABC Business Model is one of the financial models which are effective in making the solar mini grids sustainable.

   ABC Business Model

   The financial sustainability of the Solar Mini grid depends on the ABC (Anchor Business Consumer) model. Anchor this is normally a large business that provides a constant demand of electricity and the revenue is constant. Anchor loads include telecommunications towers and aviation beacons. Businesses usually provide medium load demands and the demand of electricity is erratic. Community has the less demand of electricity and the electricity demand is not constant and the ability

to pay is inconsistent [25]. The ABC model guarantees that the Solar Mini Grid will generate adequate income to sustain the operation of the solar mini grid. The Anchor load ensure that the Solar Mini grid generates adequate revenue to meet operational costs even if the businesses and the community revenue is inconsistent.

2. Countries in the continent should have a set of renewable energy targets which are specific, measureable, achievable, realistic and time bound. The targets should specify the deliverables and the timeline in the different renewable energy technologies namely solar, wind and hydro-power. The responsible department should be accountable to the President.

3. African governments should invest in the development of land banks. African Governments should invest resources in the identification of land which can be used for renewable energy electricity generation projects.This information should be made available for use by investors, non-governmental organizations and businessesthrough the relevant government departments.

4. Government policiesshould encourage investments towards alternative energy through government Policy. Policies which provides subsidies, incentives and rebates to solar energy companies, entrepreneurs and individuals.African governments should establish Renewable Energy Funds. The fund will be used to offer incentives, subsidies to businesses and entrepreneurs' in renewable energy

5. African governments through rural district council should control the development of new settlements in the peri-urban, rural or communal areas. Settlements should be designed in a less spacious manner which is compact which will make transmission and distribution infrastructure less capital intensive.

6. African countries should develop energy access maps and energy developmental plans. Energy access maps showing areas which should be electrified and the preferred method of electrification. The developmental plan showing the time lines and the required levels of investment to achieve universal electricity access.

CONCLUSION

The peri-urban and rural population in Africa have remain largely unelectrified, uneconomically active and with low standards of living experiencing the harsh effects of climate change. Global warming which is a result of greenhouse gases produced by energy producing process has led to climate change and extreme weather patterns. Disasters and environmental uncertainties are a hindrance to the achievement of the sustainable development goals. Solar Mini Grids on their own present an ever growing opportunity for the development of sustainable, clean and affordable energy. Provision of

electricity in the peri urban and rural areas through solar mini grids, eradicates poverty, reduces child mortality, improves maternal health,improves child education, provides clean and affordable energy. The future of Sub-Saharan Africa will depend on how the continent will make use of its resources ranging from the extractive energy industries oil, coal and gas to the more reliable cheap clean and sustainable renewable energy resources.

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