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Accelerating Energy Access to the Rural Poor in Kenya through Pico-Solar Market Development

Benard O. Muok, Willis Bernard Makokha

***Abstract*-Renewable energy technologies have the potential to contribute to both economic and social development through enhance energy access. Like many other sub-Sahara Africa (SSA) countries, Kenya has abundant renewable energy resources such as biomass, solar, wind, biofuel and geothermal. Recent studies shows that Kenya has the most vibrant and fastest growing solar energy market among the developing counties. Despite the great achievement, the market is still facing enormous challenges that must be addressed to exploit the full potentials of renewable energy. It is against this background that a study was taken to identify challenges that need to be addressed to unlock the potentials of pico solar in Kenya. The study was conducted in six countries (Bungoma, Embu, Kirinyaga, Kitui, Migori, and Samburu). Both secondary and primary data were used for this study. Key challenges were identified in the following areas of Local manufacturing; Marketing and private sector involvement; Pico solar energy policy; Consumer awareness and; Waste, environment and climate change consideration. The results of the study subjected a further discussion by stakeholders during a 3-day key stakeholders' workshop held in Nakuru from 28th to 30th June 2016. The paper summarizes the discussion by the stakeholders and the key recommendations.**

***Index Terms*— Pico solar, energy access, market**

I. Introduction

Modern energy is pivotal in achieving social and economic development. Yet, out of the world's estimated 1.5 billion people who live without electricity access and 2.4 billion who rely on traditional cooking fuels, more than 95 per cent are either in sub-Saharan African (SSA) or developing Asia and 84 per cent are in rural areas (International Energy Agency [1]. The situation not only make Africa less competitive in the global market but also have a negative impact on the Human Development Index (HDI) such as life expectancy, education, and per capita income. According to recent report, approximately 200 million Africans live between the international poverty benchmarks of USD 1.25 and USD 2.00 per day [2].

A further contradiction is the fact that sub-Saharan Africa is rich in energy resources especially renewable energy resources such as solar, wind, geothermal, biomass but very poor in energy supply, making the region to have highest access deficit in electrification rate, only just managing to stay abreast of population growth. Making reliable and affordable energy widely available is therefore critical to the development of the region that accounts for 13 per cent of the world's population but only 4 per cent of its energy demand [3].

Solar and other renewable energy technologies can significantly enhance energy access thus contributing to economic and social development. This is especially true to SSA population, many of whom live in isolated areas with no access to electricity or to clean water, primary health care, education and other basic services, all of which are largely dependent on access to electricity.

In a recent report by the Kenya National Bureau of Statistics (KNBS), 6.1 million (or 69.5 per cent) of all Kenyan households use paraffin as their main source of lighting [4]. According to the report, use of paraffin for lighting is concentrated in rural areas and only 22.7 per cent of Kenyan households use electricity for lighting. Kerosene is one of the main causes of household air pollution (HAP) together with use of traditional biomass for cooking. According to World Health Organization (WHO), about 4.3 million people die worldwide annually due to cardiovascular and respiratory diseases linked to household air pollution, almost all in low and middle income countries [5]. This number is bound to go up if business-as-usual is maintained.

The primary household energy in Kenya is highly dependent on traditional biomass energy, which provides 68% of the total energy supply [6]. Fossil fuels and electricity provide 22% and 9% respectively while other sources provide 1% of the overall energy requirements. High dependency on traditional biomass has serious consequences both in the environment and health. For example approximately 14,300 people die annually due to household air pollution related diseases (UNEP, 2016). This number could be higher since a lot of death especially in the rural areas go unreported. Further, studies shows that the country's closed canopy forests which was estimated at about 12 % of the land areas at independent has been reduced to a mere 1.7% of its original size. The main drivers of this decline in forest cover include population pressure for settlements, infrastructure, and demand for wood products for timber and wood fuel and conversion to agriculture [7].

As with other SSA countries, Kenya is endowed with vast renewable energy (RE) resources which can be exploited to enhance energy access especially to the poor most of who are not connected to the national grid. Most of renewable energy

Benard O. Muok, Director, Centre for Research Innovation and Technology, Jaramogi Oginga Odinga University of Science and Technology (JOOUST), P.O. Box 210-40601, Bondo, Kenya

Willis Bernard Makokha, Head of Energy Division, Kenya Industrial Research and Development Institute, Popo Road, South C, P.O

sources are based in rural areas, therefore their production and use could be is especially beneficial in rural areas where such projects can contribute to agricultural and infrastructure development, health and education services, communications and small business enterprise. Further, unlike grid electricity that can only be used where connection makes economic sense, renewable energy wind, solar, woody and non-woody biomass and small hydros can be used for both on-grid and off-grid systems. Despite the potential of renewable energy, Kenya's electricity generation is currently based on large-scale hydro power, fossil fuels, and geothermal, while other renewable energy sources play only a minor role (Draft Energy and Petroleum Policy 2015). Some of the barriers to renewable energy technology development include: technological, economic, financial, market, public acceptance, infrastructural as well as legal and administrative barriers.

Solar PV has emerged as one of the most viable option for the developing countries in enhancing energy access and rural electrification which has seen it become the fastest developing renewable energy market around the world [8]. Solar PV systems not only provide reliable, clean, and environment-friendly energy but also create employment opportunities in the vicinity of its operation [9].

Kenya has abundant solar energy resources. According to Energy Regulatory Commission (ERC), Kenya receives daily insolation of 4-6kWh/m2 which is mainly used for solar household system, thermal drying and water heating. Depending on the conversion efficiency of solar modules, 10-14 per cent of this energy can be converted to electric power [10]. Soalr system in both off-grid and mini-grid systems could therefore enahnce to energy access therefor becoming an important supplement to the electricity network expansion in the general sustainable energy electrification strategy of developing countries. Furthermore, solar market development has also been aided by the global fall in the solar PV prices over the last decade [3].

The Kenyan solar market is one of the most advanced in Eastern Africa, and indeed in Africa. Traced back through the 1980s, it is one of the classic examples of a market driven technology adoption led by the private sector. It is estimated that the overall solar market has increased by more than 100 per cent in Kenya with an estimated 300,000 solar home systems (SHS) installed and generating about 8-10MWp [11]. Lighting Africa sales results collated from manufacturers of quality tested products indicates that over 2.2 million units of solar lighting products have been sold in Kenya since 2009 and expected to grow to over 2.7 million by 2016 [12].

One of the strengths of solar PV its adaptability to provide solutions for different income levels by varying generation capacity. Solar systems vary in size, and cost, from pico- solar systems to larger home systems. While much focus has been placed on the larger systems, pico-solar has received little attention. International Energy Agency (IEA) photo voltaic pico solar (PVPS) Task 9 defines "Pico Solar PV Systems" as small PV systems with their PV panel capacity usually a few Watt peak, but can be as small as 0.3 Wp or up to 10 Wp [13]. Pico Solar PV systems design have experienced significant development ranging from use of efficient lights (mostly LEDs), charge controllers and battery technology. With these development pico solar systems now provide important services such as mobile phone charging, light and powering of radio. Lately, scalable/modular solar pico systems are now available in the market where a households could start by buying a small kit and add extras later for more services including even a small television set.

With a large segment of the Kenyan households using kerosene as their main source of lighting, pico solar home systems (PSHS) can play a big role in providing energy access especially to the bottom of the pyramid population in Kenya and substitute the use of kerosene for lighting, in addition to other crucial services. According to Lighting Africa estimates, pico solar market in Kenya is worth about USD 50 million [12].

While solar market has continues to grow rapidly to the level that is now considered as playing a big role in enhancing energy access especially in the rural areas of Kenya, there is no doubt that a large segment of the population, especially the poor, have been left out or at best forced to rely on poor and counterfeit products due to the high cost of buying quality solar solutions. It is again this background that Low Emission and Climate Resilient Project supported a study on pico-solar market in Kenya. The main objective was to undertake a baseline study to identify challenges that need to be addressed and provide information to be used for unlocking the potentials of pico solar in Kenya as a way of reducing use of kerosene for household lighting.

The study identified the following key areas that require urgent action: Local manufacturing; marketing and private sector involvement; pico solar energy policy; consumer awareness and; Waste management. These issues were then subjected to a further discussion at a 3-day key stakeholders' workshop held in Nakuru from 28th to 30th June 2016. The paper summarizes the discussion by the stakeholders and the key recommendations.

II. Methodology

The study which covered six countries namely Bungoma, Embu, Kirinyaga, Kitui, Migori and Samburu. The six counties were identified as among the counties where a lot pico solar promotion has been undertaken by vaeious development agents and therefore provides good case studies.

Both secondary and primary data were used for this study. Secondary data was collected through desk and case studies while primary data was collected through stakeholder interviews. Desk study involved review of published and grey literature including project reports, government policy documents among others. The stakeholders consulted during interviews include relevant government officers, local companies, development agents and household interview with communities. A stakeholders' validation workshop was conducted to review and o strengthen the findings.

Primary data was collected at three stages. First, there were consultations with relevant stake holders. There were visits to solar products dealers and companies which informed the research team on the products in the market and who was involved in marketing and distribution. Pre-designed questionnaire was developed to guide in the interviews.

The sample frame was made after consultations with organizations and companies already in the market for solar lanterns. Sample population was made from the list provided by the stakeholders. The sample was clustered around socioeconomic characteristics such as level of education, children day school, gender and household income. From each cluster a simple random sampling criteria was used to identify the respondents. A total of 460 people were interviewed of which 61 per cent were female and 39 per cent were male.

Four geographical areas within each county were selected together with relevant county officers from in which face to face interviews of households' heads were carried out. County governments as they were then did not have data suitable for this kind of research and this meant that we adopt systematic sampling approach. Geographical distribution of households is a critical factor in this approach and roads were the most appropriate.

The study was conducted from 9th November to 19th December 2015. This report does not attempt to present the whole detail of the study results especially the data here however, it is presenting the summary and recommendations of the stakeholders' discussion that emanated from the main report. The data provided here is only to support a specific course of argument.

III. Results and discussion

Manufacturing, standards and labelling

It is a known fact that manufacturing is basis of on economic. Literary no country has been able to achieve growth and accumulate wealth without developing a strong manufacturing industry. Though Africa has been slow to adopting manufacturing, the truth is that the continent must invest in manufacturing to spur industrialisation [14]. Value addition is the basis of manufacturing. In the past Africa trade has been dominated by none value added primary products. By increasingly adding value, revenues can be enhanced, thus raising average earnings.

In the solar sector, they is very little move towards local manufacturing. At the moment, there are only two companies involved in some form of production. Solinc East Africa based in Naivasha is known to locally assemble solar panels while Sunlight designed products in Kenya but manufacturing is done in China.

Among the challenges facing local manufacturing are high cost of money especially for startup companies and high cost of land. In addition, expensive and unreliable electricity supply adds to high cost of production not to mention the bureaucracy involved in setting up business and getting necessary documentation. Local manufacturing of solar products will not only create green employment but also save the country enormous amount of needed foreign exchange.

Another advantage of local manufacturing is quality control. It has been difficult to monitor quality of imported products thus resulting counterfeit products in the market. In the current study 54% of the respondents experience some problems with the products. These problems comes in different forms. For example, majority of the respondents had problems related to charging (37%), battery failure (16%), status display indicator (16%) and disconnection in the wiring for those using fixed separate or portable separate systems (15%) (Table 1). Further it is important to note that of the 54% who had encountered problems, 68% had not been able to solve their problems mainly due to lack of after sale serves forcing many to dispose the kits and either bought new ones or revert to kerosene candles.

Table 1: Problems experience in using pico solar products

Problem	% of respondents
Disconnection	15
Charging	37
Battery failure	16
Panel problem	10
Lanterns breakdown	7
Poor lighting	16

The study is in agreement with Lighting Africa's March 2016 Kenya retail report (Lighting Africa, 2016) which indicated that the top two key challenges solar retailers are grappling are low quality/counterfeit products and faulty products that lower consumer trust of solar products. A glaring short-coming against these devices was lack of maintenance and even after sales services. This supports the importance of local manufacturing of solar kits for lighting and other services.

During the stakeholders discussion the following key issues were raised:

i. With technology ownership still dominated by the developed countries, property right issues are slowing down local manufacturing. A good example is where Sunlight products and Mibawa pico solar are being designed in Kenya but manufactured in China due to patenting of molds in China, which limits Kenya from manufacturing the products in the country.

ii. The unit cost of electricity is too expensive which is reflected in high cost of production. A part from the high cost, unreliable electricity supply characterized by regular power outages is causing enormous losses to the manufacturers. This situation is replicated almost in all sub-Sahara African countries [3]. With geothermal gradually replacing thermal generation in Kenya, was expected that the cost of electricity would gradually come down but this has not been the case.

iii. Cost of money – Most mainstream financial institutions are still reluctant to fund renewable energy projects. In cases where this funding is made available, the cost of borrowing is too high making it unaffordable to local manufacturers. The prevailing high dollar rates complicate the situation further for manufacturers who rely on imported equipment for manufacturing. Tapping into the green energy and climate funds could be an option to accessing low interest loans as long as the loans are not passed through intermediary banks who end up placing more barriers between the funds and intended beneficiaries.

v. With the high percentage of the product malfunctioning, standardization of parts would come handy in making parts available to consumers. Another issue is whether to consider standardization of parts for the pico systems which would enable the interchangeability of the parts in case on part breaks down. This would help users not to get stuck with malfunctioned pico systems if only one component is not working.

vi. Low capacity both human capital and infrastructure is a major bottleneck in local manufacturing. Capacity building for stakeholders at all level was also identified as a key area that require action for local manufacturing to thrive.

vii. Low funding of science technology and innovation has further limited innovation and commercialization of research and development outputs. Innovation is a key ingredient in local manufacturing which needs to be strengthened.

viii. The cost of land especially in large cities was identified as a major constraint to local manufacturing. The cost has sky rocketed in the last 10 years and this has been discouraging many investors who end up in neighboring countries. A possible way to address the issue is for the government to develop industrial parks where small manufacturers can do their business at a cost.

Market

As a result of the global trend towards solar energy and driven by the lowering prices, the structure of the industry, the nature and role of producers and distributors are undergoing change at multiple levels. Existing business models are at the centre of policy discussion across many countries and new players are entering the market. Attracting investments in off grid is increasingly becoming a priority, as are the strategies and enabling technologies to flexibly manage supply and demand.

Though little attention has been given to pico solar system, the reality is that the market is rapidly growing especially among the poor living in rural areas. The market is using a variety of models to reach the end customers. ICT innovation using mobile phone platform based models (e.g. Pay-As-You-Go (PAYG)) are rapidly revolutionizing the market while providing new avenues to innovate in designing new products which means the ever changing market demand. The current study observed wide use of PAYG system. The system is marketed and a pro-poor initiative for those who cannot afford one off payment for the products. The main question to be addressed is are these PAYG, which were meant for the poor bottom of the pyramid users really cheap? The current study attempted to compare the price in the market (Table 2).

Table 2: Pico solar products in the market and their prices

Product	Characteristics	Percentage of Total	Average Cost USD
D-Light	Portable integrated & separate, Metal handle, Hook for hanging, Rechargeable panel and Charging indicator	27	18
Sunking	Portable separate, Switch, Charging indicator and USB port	26	32
Solar Home System	3 - 6LED bulbs, 25Wp – 55Wp panel, 12V Battery, charge controller, Inverter and wiring	16	44
Non-Labelled	Charging indicator, Frame, USB port. Uses dry cells	13	9.8
MKOPA	Portable and fixed separate, 8Wp Panel, USB port for charging, 2 bulbs, radio and Torch	11	170
GDLite	Portable separate and fixed 4 lamps, USB port, MP3 player, Radio	4	35
Trony	Portable separate, desk lamp, Charging indicator, Phone charging and Battery charging and discharging protection	3	60

Among the fixed separate category, MKOPA was the most expensive at USD 170. MKOPA (literary meaning Mobile loan) is one of the main distribution channel using ICT supported PAYG system. The unlabeled types had the lowest average price at USD 10 but most were counterfeits as assessed by performance characteristics and user satisfaction. In terms of popularity in the portable separate and portable integrated category D-light was the most popular at 27 per cent of all that presented above followed by Sunking.

Solar lighting kits were also sold in specialized shops like other electronic products. MKOPA was the only strictly commercial network in all the areas we visited. The payment for MKOPA is USD 40 cents per day per day for 18 months (approximately USD 216) seemed to be affordable for those employed or with businesses. Many customers however, voiced problems and it looked like only those with regular or otherwise high incomes were happy with this model. This is creating a big question on the appropriateness of PAYG in serving the poor of the poor.

There is a compelling and technically feasible business case to transform the pico solar market to make it more accessible, affordable and reliable, but as with energy systems, investing in market infrastructure is capital intensive.

One of the key issue to be addressed is how to strike a balance between quality and price. Currently many good quality products are expensive and often out of range of the poor. Other resilient issues include: How do we get private investor interested? What policies/fiscal incentives should be put in place to support pico market development? What financing models are needed improve access to quality product by the poor? How to get public – private financing. Another fundamental question asked was on innovation and scaling up models, what models are working?

On the question of quality verses price – Market has a desire for quality products, as long as price gap is not prohibitive. This should never be a question of either or. Both the policy and market must ensure that all users get acceptable quality products for their basic needs. Market segmentation model as used in the smartphone market is a good example of a successful model. There are smartphones designed for different segment of the market from the top end to lower end market but all are able to access the basic services of a smartphone.

Clear and long term fiscal policies are required to jump-start the market. Incentives such as tax breaks, duty exemption or facilities providing low interest finance are necessary to develop the market. Carbon-based financing mechanisms such as the current climate technology centre network (CTCN) and other voluntary schemes can play important role in mobilizing resources for pico solar market. The problem in Kenya and indeed many African countries has been capacity to develop bankable projects that can compete internationally for the carbon-based financing. Capacity building in this field would help to create a critical mass of project developers to take advantage of carbon financing funds.

Innovation at all levels including higher institutions of learning, small and medium enterprises (SMEs) as well as grassroots innovators must be supported to play their role. There is a noted disconnect between research and innovation as they relate to the government (policy) and private sector. Triple helix structure has worked well in many countries such as Brazil (sugar/bioethanol industry) and Japan. In helix structure there is a clear linkage between research and innovation with the government and private sector.

Pico solar energy policy

Policy plays a central role in driving deployment of pico solar energy market. These policy must be long-term and predictable to create confidence in the market. Policies that changes after a short period are most likely to compromise investors' confidence. In Kenya main policies concerning energy sector are Least Cost Power Development Plan (LCPDP), Rural Electrification Master Plan, Sessional Paper No. 4 of 2004 (The energy policy document),The Energy Act of 2006, The Feed-in Tariff (FiT) Policy, The Kenya National Climate Change Response Strategy, Kenya Vision 2030 (the National economic development blueprint).

Feed-in-Tariffs (FiT introduced in 2008 and revised in 2010 and 2012) Policy has been formulated to promote renewable energy solutions (incl. wind, biomass, small hydro, geothermal, biogas and solar and municipal waste energy). Under the FiT system, investment security and market stability for investors in electricity generation from renewable energy solutions is provided whilst encouraging private investors to operate their power plants prudently and efficiently to maximize returns.

Specifically on solar, the Government published the Solar Regulation 2012 and Kenya Standard KS IEC/TS 62257-9-5 for pico-solar. The Solar Photovoltaics System Regulations, gazetted by the Kenya ERC in September 2012, requires technical capacities/ training for designing and installation of solar PV systems. The potential introduction of net metering, which is currently under active discussion, is another initiative that is expected to increase the investment on solar PV and other technologies further. Energy (Solar Water Heating) Regulations, 2012 is another important instrument. The Regulations states- All premises within the jurisdiction of a local authority with hot water requirements of a capacity exceeding one hundred liters per day shall install and use solar heating systems.

Though energy polices has evolved over the years since the first policy in 1969 to the current Draft Energy and Petroleum Bill 2015, these policies are not specifically targeted to pico solar. Pico solar is targeting the poor especially in rural areas which at the moment are not the main focus of the current energy policies.

The appropriate policy and regulatory environment should help reduce solar energy investment barriers and increase investors' confidence in the sector. A good example is the Energy (Local Content) Regulation 2014 which if well applied can promote local assembly of quality pico solar products substantially. The real or perceived risk, the relatively short track record of many solar energy technologies, the relatively small size of many solar energy projects and the limited experience of project developers all act as barriers to investment. Further analysis is necessary to understand the most effective use of financing instruments required to scale-up investment, including those that de-risk investments and improve access to affordable capital for projects.

Increased transparency of investment statistics and trends is necessary to enable policy makers to identify available options, examine the strengths and weaknesses of different approaches and implement the most appropriate mechanisms.

Some key issues that were identified in building supportive policy environment include: building comprehensive, up-to-dated and freely accessible database of pico solar statistics through the continued collection of pico solar country statistics.

This could include strengthening collaboration with other data-collecting organizations, consolidating and standardizing data currently collected by different agencies, and presenting this data in more accessible and user-friendly forms. Ministry of Energy and Petroleum is the chief custodian, on the other hand all players must do their responsibility in collecting and availing this information. There is need for a clear to developed pico solar energy strategy with clear targets and timelines to guide market development and monitoring of progress.

Consumer awareness

While scholars have always argued that low penetration of clean energy is associated with high poverty levels in Africa, lessons learnt from development of mobile phone market gives a different picture. The rapid adoption of mobile phones in some of the poorest countries in the world has far exceeded expectations. Mobile phone subscriptions on the continent have risen from 16 million in 2000 to 376 million in 2008 [15]. This suggests that the problem may not be poverty per se, considering that at least 50 percent of the entire populations in 38 of the 49 sub-Saharan countries live without electricity, the question is why are the same poor Africa population able to acquire mobile phone sets but not solar lanterns? These are issues that need to be addressed by the industry players with a view to coming up with long term strategies. One could argue that the packaging of the message to consumers need to be thought through to identify the real issues that will appeal to consumers.

Awareness, perceptions and user expectations regarding use, benefits and impact of solar lighting is a prerequisite for adoption and sustained use. Solar solutions offer several benefits to consumer including income and fuel savings. A question that need to be asked is does the consumer understand the ‘triple benefits” (economic, social and environmental) including their role in household health, livelihoods, local environmental quality and regional climate benefits? The proposers of solar solutions must bring out this message at a level that the customers can identify with. We have to look at the benefits from consumers’ perspectives and not ours. Consumers seldom adopt innovations without good reasons.

The study established that though majority (76%) were happy with the solar kits they purchased, almost all respondents concurred that they would love to have solar kits that can perform other functions which their current solar kits configuration (lanterns) could not satisfy. Especially those that would provide for radio and multiple phone charging followed by solar products that lights more rooms.

Table 3: Attributes of solar products required by users

Attributes	Percentage
Superior Lanterns with brighter lights	66
Should include aesthetics	60
Would prefer system to light more rooms	53.
Lantern with powerful battery	82
One that charges phone and radio	78

The importance of the battery where 83 per cent preferred solar kits with a more powerful batteries cannot be overstated given that many of those with problems related to the battery (Table 3). This should be one of the most important factors to consider when manufacturing the local solar kits – not only powerful and durable batteries but that these should also be accessible for after sales replacement since batteries have shorter life generally than the system electronics and solar panels. Phone charging and radio are equally important attributes.

An important aspect of the transformation of the solar market will be for the manufacturers to identify the needs of the rural poor people and provide products that include important services such lighting, radio and phone charging as a unit. This should include clear guidelines on operation, services centres and a channel for complains.

Waste management

Scholars are in agreement that solar power facilities reduce the environmental impacts of combustion used in fossil fuel power generation, such as impacts from greenhouse gases and other air pollution emissions [16]. Unlike fossil fuel power generating facilities, solar facilities have very low air emissions of air pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, and the greenhouse gas carbon dioxide during operations. In addition to these benefits of solar development, construction and operation of solar facilities creates both direct and indirect employment and additional income in the regions where the development occurs.

Despite these benefits, the primary environmental concern arising from solar technologies is the disposal of batteries, in addition to certain heavy metals in the electronic components and mother board. Batteries are required to store electricity produced by solar panels so the power can be used at night and on cloudy days. They are an essential component of any passive solar installation. Some of these batteries contain lead acid, which makes them difficult to recycle and a threat to the environment if they are disposed of improperly. The primary concern is that developing countries may not have the means for properly disposing of or recycling lead acid batteries. Used lead acid batteries (ULABs) from photo-voltaic solar system are hazardous waste. In Kenya the study identified one company Chloride Exide that recycles ULABs and has collection centers in most parts of the counties. It also has a payback scheme of 5% on a new battery and sends regular short messages (SMS) to the end users for maximum collection of ULABs. In addition, they manufacturer lead acid batteries that has warrant of 2 years. This is a good attempt on batteries and the same could be explored for solar batteries.

The other issues that may not be a problem now but may be a problem in the very near future are solar pannels. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds (32g and 82g) of carbon dioxide equivalent per kilowatt-hour (Union of Concerned Scientists, 2013)

Solar modules contain some potentially dangerous materials found in other electronics, including silicon tetrachloride, cadmium, selenium, and sulphur hexafluoride (a potent greenhouse gas). So as solar moves from the fringe to the mainstream, insiders and watchdog groups are beginning to talk about producer responsibility and recycling in an attempt to sidestep the pitfalls of electronic waste and retain the industry's green credibility. Kenya standard KS 2542 as well as the Lighting Africa, Kenya has attempted to draw a line on the maximum concentrations of these chemicals allowable. However enforcement has not been strong enough.

Solar modules have an expected lifespan of at least 20 years so most have not yet reached the end of their useful lives. With 35% malfunctioning rate and with ever increasing solar product entering the market, it is a matter of time before e-waste from pico solar becomes an environmental threat. Key issues addressed by stakeholders include: Status of solar waste in the country; Legal and regulation framework on management of e-waste and this has a close relation with issues of standards and quality assurance; Waste management options and; e-waste management progress tracking, monitoring and evaluation.

Currently the recycling of solar panels faces a big issue, specifically, there are not enough locations to recycle old solar panels, and there are not enough non-operational solar panels to make recycling them economically attractive. Recycling of solar panels is particularly important because the materials used to make the panels are rare or precious metals, all of them being composed of silver, tellurium, or indium. Due to the limitability of recycling the panels, those recoverable metals may be going to waste which may result in resource scarcity issues in the future. Looking at silicon for example, one resource that is needed to make the majority of present day photovoltaic cells and which there is currently an abundance of, however a silicon-based solar cell requires a lot of energy input in its manufacturing process, the source of that energy, which is often coal, determining how large the cell's carbon footprint is.

There is need to consider extended producer and stakeholder responsibility that will aid the take-back-schemes for pico-solar products that are no longer in use. This should be considered hand in hand with design for disassembly so that it becomes easier to promote recovery, reuse, and recycling.

The lack of awareness regarding the manufacturing process of solar panels and to the issue of recycling these, as well as the absence of much external pressure are the causes of the insufficiency in driving significant change in the recycling of the materials used in solar panel manufacturing, a business that, from a power-generation standpoint, already has great environmental credibility.

The problem of e-waste can only be address through a multi-stakeholder approach where each stakeholder plays its role. Even in absence of enforceable regulations some companies such as Safaricom, WEEE centre, Communication Authority of Kenya, East Africa Compliant and other key stakeholders have been participating in sustainable management of e-waste.

Some legal and regulatory frameworks on management of E-waste already exist, these frameworks are inadequate and poorly enforced therefore there is need for enforcement of the frameworks, as well as revising them to match with the current trends. E-waste management board should be established to implement guidelines on E-waste management

Some of the existing legal and regulatory framework include; EMCA, 1999/EMCA (Amendment), 2015 on management of environment; Environmental Management and Coordination (Waste Management) Regulations of 2006, Waste Management Guidelines, The National Solid Waste Management, and; Draft Environmental Management and Coordination (E-waste) Regulations, awaiting approval by the parliament.

There is need to have a structure to guide the end user, manufactures, importers and the dealers to keep inventory and monitoring of e-waste. This will help to: encourage segregating at source; create collection mechanisms such as take back schemes and collection centers; provide temporary storage and returns mechanism to the dealers or collection centers; conduct massive creation of awareness to the end users on e-waste management; provide incentives to encourage the dealers, manufacturers and end users to develop e-waste buy back schemes. In addition there is need to have a policy that harmonize the data collected, so that they can know the date of manufacture and the lifespan of the products.

Conclusion and Recommendations

The study has succeeded in isolating the main issues in the development of pico solar market in Kenya. Further the stakeholders have come up with strong recommendations to support the market. The recommendations are as follows:

1. Building on the experience to date, there is need to focus on awareness creation and capacity building of stakeholders (policy makers, entrepreneurs, financiers and consumers) as well as institutional and infrastructure needed to support pico solar market. There should be inter-agency coordination to avoid duplication of roles and conflicts. The coordination infrastructure could use an online platform, periodic stakeholder review and stakeholder analysis and consultations.
2. Develop a system to build a comprehensive, up-to-date, and freely accessible database of renewable energy statistics through the continued collection of renewable energy country statistics, by strengthening collaboration with other data-collecting organisations, by consolidating and standardising data currently collected by different agencies, and by presenting this data in more accessible and user-friendly forms.
3. There is need to promote local manufacturing of quality products to protect the consumers from poor quality products mainly originating out of the country. This should be supported by strong innovation networks and forward looking in-depth technology analysis that will result in design, prototyping and reverse engineering to adapt current technologies to end-user needs.
4. There is need for the Government to set aside a specific percentage of finances for funding off-grid solutions as a priority in line with the last mile connectivity e.g. solutions for subsidies; need for revolving funds to buy off-grid solutions to support distributors and low end users. Focus should also be placed on promoting

accessibility to pico-solar products especially in the marginalized areas through innovative financial mechanisms. This should include a deliberate attempt to attract private sector financing and also to provide a framework for research to contribute to pico solar development.

5. Though it does not pose a high risk level, e-waste from solar energy components is a potential problem that must be addressed by all stakeholders developing appropriate policies and standards. For example, digital innovations (e.g. GPS, GSM, SMS) should be incorporated in the pico solar home systems to help in traceability, warranty, e-waste management and emission estimation.
6. The draft Energy Policy 2015 and Bill as well as the Energy (Local Content) Regulation and Kenya Standard KS IEC/TS 62257-9-5 are important policies that should be used to promote development of pico solar energy. Considering the role pico solar systems play in energy access especially to the poor communities in rural areas, what is require now is a pico solar energy strategy with clear targets to guide and drive the development of this market in Kenya. The policies also need to be accompanied with attractive fiscal incentives to attract investment in the sector. The current fiscal incentives are biased towards large solar systems.

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Benard Muok, PhD holds a PhD in Tropical Agriculture from Kyoto University, Japan and a post-doc in Renewable and Climate Change from University of Edinburgh, UK. He also holds MSc and BSc degrees in Forestry from Moi University, Eldoret, Kenya; Certificate in Environmental Impact Assessment and Environmental Audit from Jomo Kenyatta University of Agriculture and Technology (JKUAT); and International Certificate in Plant Conservation at the Royal Botanical Garden, Kew, United Kingdom/National Museums of Kenya. Dr. Muok has worked for over 20 years in research focusing on renewable energy, energy access and policy in Africa, science technology innovation, environmental conservation and climate change adaptation and mitigation. He is currently the Director Centre for Research, Innovation and Technology (CRIT) at Jaramogi Oginga Odinga University of Science and Technology.

Willis Bernard Makokha holds as master degree in Energy, Climate Change & Sustainable development. Mr. Makokha is the Head of Energy Division at Kenya Industrial Research and Development Institute.