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Full Length Research Paper

A REVIEW OF POLICIES, LEGISLATIONS AND PRACTICES ON OFF-GRID SOLAR ELECTRONIC WASTE MANAGEMENT IN KENYA

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ABSTRACT

Off-grid solar systems in developing countries will play a key role in the realization of sustainable development goal number seven on clean energy sources.As the uptake of solar energy systems continue to rise globally,solar electronic waste will continue to increase.Electronic solar waste is categorized as hazardous with devastating effects on the environment if poorly managed.Effective policy,legislations and practicesare key to sustainable management of this waste category.The aim of this study was to reviewthe policy,legislations and practices in solar e-waste management in Kenya.The studyexamined existing solar electronic wastemanagement policies,legal, institutional framework and management practices in Kenya.In addition, the study examined solar electronic waste governance approaches in developed and emerging economies.The study adopted a systematic literature review augmented with views from solar ectronic waste stakeholders workshop data collection method.The study established that Kenya does not have a specific solar electronic wastepolicy and legal framework andthe management of this category of waste streamis governed by thegeneral electronic waste policies and legislations.This is different fromdeveloped countriessuch as the United Kingdom and several States in USA such whohave developed specific policies and legislations to govern management of the growing solar e-waste.In addition,the study established that many emerging economies such as India are yet to develop supportive legislation for solar e-waste similar to the Kenyan scenario. The study established that there are some ongoing efforts geared towards policy and legal framework development to enhance governance of solar electronic waste in Kenya, which require to be fast-tracked due to the rising uptake of off-grid solar energy systems in the country.

Keywords: Solar Electronic Waste, Policy, Recycling, Collection, Off-grid, legislations

1. INTRODUCTION

Climate change has turned out to be a key concern of the 21st century (Thomas, *et al*, 2015). The UNFCCC COP 26 in Glasgow, Scotlandbrought together 200 countries and ended with the adoption of the Glasgow Climate Pact to keep global temperature rise under 1.5°C by 2100 (Eckersley,2022). Off-Grid Solar systems in the developing countries will play a key role in realization of Sustainable Development Goal (SDG) 7 on clean energy sources. Adoption of off-grid solar energy sources will minimize dependency on fossil fuels and this would lead to less emission of greenhouse gases (Sovacool,2012). The growing concerns regarding climate change, the health impacts of air pollution, energy accessibility and security coupled with volatile oil prices in recent years necessitate search for alternative sources of energy with low carbon emissions. Solar photovoltaic has been one of the ground-breaking renewable technologies over the years(IPCC,2018). The total mounted capacity of solar photovoltaic did hit 480 GW worldwide by the end of 2018(Chowdhury etal.,2020).Off-grid Solar power systems will definitely continue to be an essential renewable energy option in many developing countries in the coming decades. It is one of the most promising technologies for renewable energy that the world is gravitating towards due to climate change challenges.It is imperative for governments to put in place policies, legislations and best practices in order to realize sustanaible management of solar electronic waste in the backdrop of increasing uptake of off-grid solar technologies.

2. Background

According to Bodies,*etal*. (2019) the photovoltaic (PV) modules are extremely efficient solar energy generating devices with no greenhouse gas emissions, as they do not yield noise or utilize material resource. According to Wang etal.,(2021),about 70% of the world solar energy is produced by five countries in the world. These nations are China, Germany, Japan, United States, and Italy. As the uptake of both on-grid and off-grid solar energy systems continues to increase globally, the production of solar electronic waste will continue to grow, hence the need for sustainable management approaches(Abdullah,2015).The Solar electronic waste is classified differently in different jurisdiction for instance in the European Union they are recognized as electronic waste and marked as hazardous while in United State of America, different states classify them different as some categorize them as normal solid waste to be managed through landfills and others recycling their various fractions (Kumar &Turner.,2020). In broad-spectrum solar electronic waste falls under the electronic waste categories, but recent studies have shown that they are hazardous waste materials(Qi and Zhang,2017).

According toErat and Telli (2020),the world generated 53.6 metric tons of electronic waste in 2019 and this is projected to grow by 40% by the year 2030. About 80 % of general electronic waste globally in the developing countries is handled informally (Cross & Murray,2018).The main units of off-grid solar products include photovoltaic (PV) solar modules.,lamps which mainly are LED, batteries which could be lead or lithium – based,metal frames and fixtures,cables, control units with circuit board mounted electronic controls(Lunardi etal.,,2018).Photovoltaic modules for the longest time were not considered as electronic waste among the European Union members until 2012. Since the categorization of the materials as e-waste the various constituents of off -grid solar products are classified in line with their treatment and dismantling characteristics.The dismantled waste category is referred to as fractions. These fractions include the metal, screws, glass, paper, cardboard, plastics and cables(Palkova,2015).

According to Rathore & Panwar,(2018) photovoltaic panelsmajorly are made up of panels consisting of mixed fractions of screws, metals and crystalline silicons, glass panels and aluminum silver and ethylene vinyl acetate (EVA). A classic crystalline silicon solar panel contains 10–15% frame aluminum, 65–75% glass and 3–5% silicon. They can also contain a number of harmful carcinogenic materials such as chromium, arsenic and cadmium(Yi, *etal.*,2017).Management of off-gridend-of-life (EoL) of the photovoltaic waste modules cannot be effectively managed through landfills and this calls for technological strategies such as recycling as viable options (Adamo, etal.2017).Management approaches such as recycling immensely contribute to the virgin resource conservation of materials such as copper, semiconductor materials glass, silicon, aluminum, among others.The functioning photovoltaic panels are laminated with glass and this makes them very safe but if the glass is broken the panels do get damaged and this can cause leakage of some substances that may be very toxic to the environment (Dias,*etal.,*2017).

According to Wang etal.,(2018),the main fraction for the lead acid batteries which is a storage device for the solar energy is lead mixed with plastics and sulphuric acid. Graphite, aluminum, lithium, copper and plastics forms the main fractions in Lithium Ion batteries. If recycling approach is to be adopted in the management these batteries, their components should remain unbroken and managed as a distinct fraction while being conveyed to their ultimate recycler for safety purposes.

The key fraction for control units are printed circuit board and mixed electrical and electronic components in addition to the plastic. The cables are mostly made up of plastics insulations and copper.

Cross and Murray (2018) notes that the solar lanterns fractions are photovoltaic panels, the light emitting diode, lithium battery plastics and printed circuit boards and this implies that the fractions are a mixture of metals, glass, plastics, and mixed materials. Batteries according to the EU regulations are not included in e-waste regulations. They are classified under hazardous waste and managed under the hazardous waste regulations. It is important to observe that different types of batteries are used with solar systems with Lead acid batteries being very common for mini-grids while lithium Iron (Li-ion) batteries being found in smaller devices,such as solar lanterns and solar home systems. Lithium –Iron-Phosphate and Lithium-Manganese-Oxide are the most common off-grid batteries being used today. Lithium batteries recycling require advanced technology and a lot of resources and currently is done only in the developed countries.These fractions from off-grid technologies devices must be reclaimed from the environment. Failure to remove these waste leave the environment blemished by corroding batteries and solar panels (Jung *etal*.,2016)

Solar panel waste is expected to reach 78 million metric tons by 2050.Equally, fractions from discarded off-grid solar devices still remain a major challenge since they are produced without an intention of their dismemberment even under extreme environmental thettings. In addition, the materials are made by mixing valuable elements with those of less value hence retrieving the valuable materials is an expensive venture(Cross& Murray 2018).Globally material scientist, waste handlers and manufacturers are trying to find means of efficiently reclaiming off-grid solar devices materials. However, most of these devices are yet to reach the end of their lives to make the recycling facilities worth to invest in (Xu etal,.2018). This calls for a sustainable solar e-waste management strategy.

2.1Policies, Legislations and Practices of Solar e-waste Management Experiences from Selected Industrialized Economies

According to the IEA (2019), industrialized economies are investing heavily in the solar energy sector, and similarly, they are contributing to the generation of e-solar waste immensely. However, these economies have equally made significant investments in dealing with e-solar waste challenges facing their countries (IRENA, 2018). Leading players in developing e-solar waste management policies are the United States of America and the United Kingdom.The USA has installed solar power infrastructure supporting an estimated 17.7 million homes(Tabbassum etal.,2021). Notwithstanding the gains made in promoting clean energy, the move has created a looming e-solar waste issue on the horizon (Atasu, *et al.,* 2021). These solar panels have a lifespan of 25-30 years, meaning that at some point, they will reach the end of life and become waste. On this ground, the United States has progressively invested in policies driven towards improving e-solar waste management in the country (EPA, 2021).

According to Curtis (2021) several states in the US have developed policy actions to keep solar PV panel wastes out of the landfills. For instance, California State treats solar panel wastes as hazardous Washington State developed a solar stewardship program, which makes it mandatory for manufacturers of solar PV'S to collect panels at no charge to the customer after it has come to the end of life for recycling. New York State passed Bill S2837A that requires solar PV manufacturers to collect panels once they get to end of their lives (Billy, 2019).Paiano(2015) observesin Europe, the European Union through Waste Electric and Electrical Equipment directives (WEEE Directives) 2012/19/EU regulation has banned photovoltaic panels among other electronic waste from being managed through landfills. This legislative framework calls for extended producer responsibility and the producers of photovoltaic modules are responsible for the take back and recycling of the panels they sell. Through this approach, the industry has taken up the responsibility of providing sustainable products and this has put into consideration the environment and public health (Chowdhury, *etal.*, 2020).

2.2 Experiences from the newly industrialized economies

Progressive steps have been undertaken by some of the emerging industrial economies, including China and India. According to Bhandari, *et al.* (2021), China continues to accumulate large piles of e-solar wastes. Unfortunately, the country does not have robust e-solar waste legislation.Chinese solar panels are stacking up, threatening the future of the environment. It is worth noting that China is the world's largest solar market in terms of the panels manufactured and investment made. Notwithstanding the sunny outlook of the country in regards to solar power generation, dark clouds are looming due to the absence of specific legislations on how to dispose and recycle solar wastes.Unlike Europe where the costs of collection and recycling are captured in the product price, Chinese manufacturers are yet to adopt this model. A similar trend is seen in India,where according to BTI (2020), the country has the fifth largest fleet of solar installations and this reveals the dire need for effective policies and legislations on e-solar waste to avoid environmental pollution.

2.3 Experiences from developing economies

According to Ockwell, *et al.*, (2018),many developing countries,have uneven and inadequate infrastructures for e-solar waste management.Because of the uneven e-solar waste regulation, sustainable management of these wastes continues to be a challenge. In most developing countries of Africa, the management of e-solar wastes is still a new and emerging concept since the uptake of the solar devices is gradually gaining traction and the generation of waste just like in developedand emerging economies will continue to upsurge.This studyreviewed existing policies,legislations, and practices in e-solar waste management in Kenyaandmade recommendationson policyoptionsfor a sustainable solar e-waste management.

3. METHODOLOGY

The study adopted a systematic literature review augmented with the views of key stakeholders workshopdrawnfrom the industries and sectors involved insolar electronic waste management in Kenya.The stakeholders in solar electronicwaste management in Kenyawho gave their views in the workshop includedofficials from the National Environmental Management Authority of Kenya,Ministry of Environment and Forestry of Kenya,Kenya Association of Waste Recyclers,Kenya Private Sector Association, representativesof private recycling companies such as WEEE Centre Limited,Recyckla, and research institutionsnamely Kenyatta University,JKUAT and the University of Nairobi.The stakeholdes views were transcribed and incoperated into the discussion section of this article paper.Relevant solar electronic waste government policies,legislations,published reports and journal articleswere reviewed in addition to published management practicesguidelines for solar electronic wastefrom Kenya and other jurisdictions.The findings of thisstudy willform recommendations to inform policy formulation onelectronic solar waste management in Kenya.

4. RESULTS AND DISCUSSION

4.1Constitution, policies, legislations and practices of solar e-waste management in Kenya

4.1.1 Constitutional context

Kenya has made significant progress in creating structures for environmental protection. The right to a clean and healthy environment has found its way into the bills of rights as per Article 42 of the Constitution of Kenya 2010. Article 69 (1g) obligates the government to eliminate any processes that degrade the environment. In addition, Article 1(6) states that any Convention that the Country has ratified becomes part of the national laws and a good example is the Basel Convention which prohibits transboundary movement of any hazardous material. However the constitution does not explicitly address the issue ofsolar e-waste,but article 72 of the constitution calls for development of moresubsidiary legislations to help in its operationalization.

4.4.2 Policy and legislation

This study established that Kenya is increasingly taken bold steps in policy-making to protect its people from the consequences of poor e-waste management. However, like many ofits African counterparts, Kenya lacks policy and legislation on the management of e-solar waste. The absence of a definitive law on e-solar waste management is partly because solar PV power is a relatively new concept in the country. Solar PV panels use in Kenya has become popular inthe last decade (Kairu, 2020). Notwithstanding its popularity, only few homes have solar PV panels due to the high cost of panels and installation. Lack of a specific policy and legislation on e-solar waste management is detrimental to the country's ability to address this type of waste.

The most relevant policy that closely relates to solar e-waste in the country is the National ICT Policy of 2006. This policy requires electric and electronic equipment's dealersto demonstrate their readiness to contain the effects of their PV infrastructure on the environment to qualify for licenses from the Kenyan Authorities. The goal of this policy is to ensure that the companies producing solar electronic equipment take full responsibility for the solar e-wastegenerated at the end life. These producers should take responsibility to conserve and protect the environment (MoEF,2019). This policycan help in containing malpractices of dumping of e-waste. However, because of its lack of specificity on solar PV e-waste, it has not addressed real issues in this sector. The other policy addressing electronic waste in general in Kenya includes Kenya Vision 2030(2008-2030).This polict recognizes that Kenya cannot attain high economic and social development without prioritizing environmental management. Waste management including electronic waste is a priority flagship project in the policy. The policy prioritizese-waste as an emerging waste category with an emphasis on support to Small and Medium Scale Enterprises (SME) to improve waste management.However the policy still does not address the solar e-waste and all the fractions whose poor management can lead to tremendous environmental pollution.

Anotherinstrument addressing management of electronic waste in Kenya is National E-Waste Guidelines 2010.The guideline was developed by National Environment Management Authority of Kenya to assist the government, private sector, learning institutions and other stakeholders to effectively manage e-waste. The guideline prescribes approaches to enhance environmental protection; awareness; categories of e-waste and target groups; e-waste treatment technologies and disposal procedures.The guideline too does not address the solar e-waste and their fractions there of.The government has also finalized the National E-Waste Strategy 2019 to guide the country's interventions in the management of e-waste. The Strategy aims to address e-waste management through the development of policies, guidelines and standards. Thee-waste management strategy awaits publication and implementation.It is important to note that Kenya has already developed theNational Environmental Policy 2013.The policy calls for a clean and healthy environment (Section 6),however all these policies and strategies too have a lacuna in addressing solar e-waste management and the fractions therein.

In regard to legislations that are closely addressing solar e-waste in Kenya, the Government has enacted several laws and others are still being developed. However, there is no specific solar e-waste legislation in Kenya. The main legislation guiding e-waste management in Kenya is the Environmental and Management Coordination Act (EMCA) of 1999, CAP 387 and EMC Waste Management Regulations (2006). These laws prohibit handling, transportation and disposal of waste without valid licenses issued by NEMA.In addition to the above legislations ,the Kenya National Sustainable Waste Management Act 2022,proposes a transition from linear to circular economy with increased recovery of value from waste material. Another legislation relating to solar e-waste management is the Public Procurement and Asset Disposal Act of 2015 that governs disposal of goods and services in public institutions. Under this law, the public institutions have to bind and invite competitive tenders for disposal of computers and other EEE as scrap in line with procurement procedures.

The Government of Kenya has just finalized development of e-waste regulations under EMCA CAP 387. However all these legislations are not specific to addressing solar e-waste and its fractions.It is worthy to note that similar to the approach being used in industrialized economies such as USA and European countries, the Government of Kenya has developed Extended Producer Responsibility (EPR) Regulations(Bill) 2021 which is currently in its final stagesof enactment. The EPR Regulations Bill (2021) identifies e-waste as one of the products subject to extended producer responsibility. Upon its enactment all producers of electrical and electronic equipment's shall establish or join a Producer Responsibility Organization(PRO) as shareholders and operationalize an extended producer responsibility scheme collectively. The law borrows from a similar regulations in Europe. Iis based on the principle that producers are solely responsible for what they produce.

However, if the Kenyan Extended Producer Responsibility Regulation (2021) is enacted in its current form it may not solve solar electronic waste problem in the country even upon the piling up of this stream of waste category. This is because despite the fact that this study through stakeholders workshop views and systematic literature review established that 80% of the electronic waste in Kenya is collected and managed by the informal sector,the regulation does not protect vulnerable groups such as the pickers.Putting up a Producer Responsibility Organizations without allocating a proportion of fees paid by the dealers and producers to Producer Responsibility Organisations to the waste pickers and handlers may mean locking them out of the e-waste management loop. There is a need to set up solar e – waste management fund with a clear provision for waste pickers to improve their wellbeing.

4.4.3 Management practices

According to Cross&Murray (2018),information about the management and organization ofsolar e-waste in Kenya is scanty. The study established that there is a wide range of substandard solar energy products.These products represented an estimated 71% of pico-solar sales in Kenyan market in 2018 .In addition 20%of solar energy products in Kenya stop working within 18 months of purchase.This implies speedy entry into e-solar waste chain, which represents a serious threat to environmental sustainability.This study established that there is an estimated 750,000 solar home systems in Kenya. Unfortunately, despite the various hazardous components found in solar electronic waste such as Chromium, Arsenic, Cadmium, Lithium, Silicon, among others. In most cases,the e-waste including solar e-waste ,ends up being mixed with ordinary waste in dumpsites and landfills. Further, little recycling of electronic waste is done in the country.In Kenya and Africa in general,less than 0.1% e-waste gets recycled annually.Through the views of the stakeholders workshop,the study established that in Kenya, electronic waste is mostly handled by the private sector.in addition most of the companies dealing with these types of waste are transfer stations because they lack capacity and infrustructures to recycle. Those engaged in recycling only handle certain fractions and ship the rest to their partners abroad.However there is insufficient data on how much solar electronic waste is being generated in the country making it difficult to make informedsolar ewaste management decisions.Furthermore there is little engagement in policy making process of the stakeholders and this has led to limited awareness of the effects of solar devices e-waste and prolonged policy and legislations making process.

5. DiISCUSSION AND CONCLUSION

The finding of this study shows that solar e-solar waste management represents a serious challenge in the developing economies including Kenya due to the hazardous elements found in their various fractions. Failure to effectively manage solar e-solar waste is a threat to sustainable development in the face of increasing uptake off-grid systems. Significant progress is being made by the developed economies such as USA and European countries to manage solar electronic waste as established by this study. Europe has strong policies and legislations specific to solar electronic waste management where extended producer responsibility has been implemented in these countries. UK and USA solar PV producers work under the 'Take-Back' rule where producers have to collect the solar PV panels they sold after they reach the end of life for recycling and appropriate disposal is done. The study has also established that industrialized economies have physical infrastructure and facilities in place to collect, treat and recycle electronic waste materials fractions, a challenge that is facing Kenyan government and many African countries where some fractions have to be shipped abroad for recycling. There is insufficient data on solar e-waste stock, flows and routes in Kenya. About 80 % of the collection and handling of electronic waste /solar e-waste in Kenya is done by the informal sector. The study has also established thata small proportion of the electronic waste/solar e-waste is being recycled or shipped abroad for recycling by the private sector due to lack of the necessary infrustructures. Furthermore, there is limited awareness on the solar e-waste hazards at various levels – policymakers, government officials, developers, traders and consumers as noted from the stakeholders workshop.The study observes that there has been insufficient stakeholder engagement in solar e-solar management leading to weak policies with glaring gaps or prolonged policy preparation.

Furthermore there is a challenge of poor waste collection infrastructure, lack of specific solar e-waste end of life policy andlegal frameworks.The study noted that the general electronic waste legislations drafts awaiting enactment are not customized to the local needs, for example the

Extended Producer Responsibility does not fully respond to the informality of electronic waste collectors/handlers in the country.However, off-grid solar products are increasingly found mainly in developing countries such as Kenya. The context in the industrial economies is very different from that in the developing countries. Therefore, there is need for effective stakeholders' participation in policy making to take into consideration the local context in solar e-solar waste management. It is also important to underscore the challenges posed by increased counterfeit solar energy systems in the implementation of Extended Producer Responsibility regulation upon its passage. As the uptake of solar energy systems continues to grow, there is need for an integrated participatory approach in the management of solar e-waste in Kenya and developing countries in general.

With increased focus on the development of solar energy globally, investment in the subsector is bound to increase. Similarly, solar e-wasteis bound to increase. Unfortunately, Kenya does not have explicit policies and legislations on solar e-waste making it difficult to create functioning structures and processes for effective management of solar e – waste. There is need for a policy and legislative framework that explicitly addresses solar e – wastemanagement in the country. Such policy and legal instruments can either be stand alone or fused into existing policies and legislations. The policy and legal framework should among others focus on extended producer responsibility which will ensure that the cost of solar e-waste management is internalized in the cost of the product. Also, the producer takes responsibility to collect and managesolar e – waste at the end of the product's life.The policy and legislative framework will provide a mechanism for effective management of solar e – waste, specifically retrieval, collection, transportation, storage, recycling and safe disposal of residues. This will be important in safeguarding the environment from adverse effects of solar energy development.Through policy and legislative framework recycling and reuse of solar e-waste can be staggered at different scales and locations, including source, volumes, and market chain of the fractions.This will create room for stakeholders engagement at all levels. The study through the stakeholders in solar e-waste workshop established that active stakeholders' engagement is very critical in effective management of solar e-waste.This will provide room for networking, cost – benefit sharing, information sharing, skills transfer and awareness–raisingon solar e-waste phenomenon. There are many actors in the production, distribution and use of solar energy products as well as management of e - waste. The actors also include policymakers, regulatory agencies, and enforcement agencies.Research and data management of solar e-waste is very important for better response to the emerging waste management challenges. At the moment, data on solar e-waste and its management is scanty. Further, the impact of solar e – waste on the environment is largely unknown. So, there is need to promote research on this sub-sector for informed decision making.

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