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Coping with Solar Waste in Nigeria: Strategies for Managing Waste and Averting Environmental Pollution

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INTRODUCTION

Against the backdrop of global efforts to transition towards renewable energy sources, Nigeria has witnessed a substantial rise in the installation of solar infrastructure to meet its energy needs. This is particularly so considering epileptic power supply, rising costs of electricity bills and the purchase of carbon fuels to power electric generators. Nigeria benefits from an average solar radiation of approximately 3.5 - 7 kWh/m^2 per day, making it conducive for solar energy generation.[1]

To further broaden access, the Nigerian government has introduced initiatives like the Solar Power Naija Programme. This programme has set a target to provide 5 million off-grid solar connections to rural households, aiming to improve energy access and affordability in remote areas.[2] Additionally, with the signing of the 2023 Electricity Bill into law which further democratised energy generation with an emphasis on increasing renewable energy supply, the entire solar energy value chain in Nigeria is experiencing a boom.[3] However, this commendable progress has brought to the forefront the pressing issue of solar waste. As the country embraces solar energy solutions, the generation of solar waste poses a formidable environmental challenge that demands immediate attention.[4] This is because the environmental repercussions of inadequately addressed solar waste not only jeopardise the delicate ecological balance but also present potential health risks to the populace.[5] Therefore, managing solar waste becomes not just a practical necessity but a critical imperative for sustaining both the environment and public well-being.

In this research, we will delve into the details of solar waste generation, explore the various types of solar waste, and assess the quantitative dimensions of this challenge. Additionally, we examine the adverse consequences of inadequate waste management on the environment, and the interconnected web of factors that make this issue a pressing concern. We will also explore current approaches to solar waste management in Nigeria, identify existing challenges, and propose strategies to enhance waste management practices regarding successful international and local case studies.

[1]IRENA (2023), Renewable Energy Roadmap: Nigeria, International Renewable Energy Agency, Abu Dhabi.
[2]https://nep.rea.gov.ng/federal-governments-5milion-solar-connections-program/
[3]Izeaka, Mary (2023). Tinubu signs 2023 Electricity bill into law. Premium Times. Available at: https://www.premiumtimesng.com/news/more-news/603599-tinubu-signs-2023-electricity-bill-into-law.html
[4]IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems.
[5]UNEP, 2023, Nigeria acts to fight growing e-waste epidemic, retrieved from: https://www.unep.org/gef/news-and-stories/press-release/nigeria-acts-fight-growing-e-waste-epidemic

SOLAR WASTE GENERATION IN NIGERIA

Several factors contribute to the generation of solar waste in Nigeria. Firstly, the proliferation of solar photovoltaic (PV) systems, both grid-connected and off-grid, has led to an increased deployment of solar panels across the country. Additionally, the growth of the solar industry is accompanied by technological advancements, resulting in the phasing out of older, less efficient solar panels in favour of newer models.[6] Furthermore, factors such as improper installation, maintenance practices, and end-of-life considerations also contribute to the accumulation of solar waste.[7]

Types of Solar Waste Generated

Solar waste encompasses a wide array of materials, components, and by-products associated with the lifecycle of solar energy systems. The primary components of solar panels include photovoltaic cells, glass, aluminium frames, and various encapsulant materials. Additionally, inverters, batteries, mounting structures, and cables constitute secondary components of solar installations.[8] Each of these components pose unique challenges in terms of recycling, disposal, and environmental considerations. Moreover, the composition of solar waste may vary depending on factors such as technology, manufacturer, and installation practices.

Quantity of Solar Waste Generated Annually

The amount of solar waste generated annually varies significantly based on factors such as the scale of solar installations, technology advancements, and disposal practices. In India for example, it is estimated that approximately 200,000 tonnes of solar photovoltaic waste will be produced by 2030, with projections indicating a potential increase to 1.8 million tonnes by 2050.[9] Similarly, in Australia, it is forecasted that the cumulative amount of waste solar photovoltaic panels generated by 2047 will reach around 817,941 tons, considering historical panel installations between 2001 and 2018.[10]

The absence of robust monitoring and reporting mechanisms hampers efforts to quantify the volume of solar waste and track its disposal pathways.

[6]IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems.

[7]Osibanjo, Oladele & Nnorom, Innocent. (2008). The Challenge of Electronic Waste (E-waste) Management in Developing Countries. Waste management & research : the journal of the International Solid Wastes and Public Cleansing Association, ISWA. 25. 489-501. 10.1177/0734242X07082028.

[8]Uekert, Taylor, Christian M. Pichler, Teresa Schubert, and Erwin Reisner, 2020. "Solar-driven reforming of solid waste for a sustainable future", Nature Sustainability(5), 4:383-391. https://doi.org/10.1038/s41893-020-00650-x

[9]Rathore, N.S. and N. L. Panwar, 2021. "Strategic overview of management of future solar photovoltaic panel waste generation in the indian context", Waste Management &Amp; Research: The Journal for a Sustainable Circular Economy(5), 40:504-518. https://doi.org/10.1177/0734242x211003977

[10]Nizami, Mohammad Sohrab Hasan, Sajjad Mahmoudi, and Nazmul Huda, 2020. "Reverse logistics network design for waste solar photovoltaic panels: a case study of new south wales councils in australia", Waste Management &Amp; Research: The Journal for a Sustainable Circular Economy(2), 39:386-395. https://doi.org/10.1177/0734242x20962837

Accurate data on the quantity of solar waste generated annually in Nigeria is essential for assessing the scale of the challenge and formulating appropriate management strategies. However, comprehensive data on solar waste generation in the country remains limited. The absence of robust monitoring and reporting mechanisms hampers efforts to quantify the volume of solar waste and track its disposal pathways. Reliable estimates are further complicated by factors such as informal recycling practices, illegal dumping, and inadequate waste management infrastructure.

According to market research conducted by Deloitte in 2022 analysing the cumulative import value of solar panels in Nigeria between January 2018 and August 2021, approximately 2,618,569 to 2,894,208 units of solar panels were imported during this period, weighing between 47 to 52 million kilograms. The research found that lead acid batteries emerged as the primary source of solar waste as of 2021, with an estimated average lifespan of three to five years, and that despite the projected increase in the adoption of other battery models such as lithium-ion batteries, lead acid battery usage is expected to persist due to its affordability. However, the proportion of lead acid battery waste to total solar e-waste is projected to decline from 100% in 2021 to 82.3% by 2040.[11]

Meanwhile, the composition of solar waste is expected to evolve, reflecting changes in technology adoption and product lifespans. Lithium-ion batteries and inverters, characterised by longer lifespans of 7 to 10 years, are projected to become significant contributors to solar waste generation by 2025. By 2040, waste from lithium-ion batteries and inverters is expected to jointly account for approximately 3.1% of total waste volumes.[12] In contrast, solar panels, with an average lifespan of 20 to 25 years, are anticipated to contribute substantially to waste volumes by 2040. Solar panels will also account for approximately 14.6% of total waste volumes by that time.

[11] All On, 2022, Market research on the circular economy of the renewable energy sector in Nigeria, retrieved from: https://www.all-on.com/media/publications/_jcr_content/par/textimage_1046512014.stream/1643991469710/bd8b6c505c136f1d5a115fe1bfe67dddeb2b8ff8/project-volt-final-report.pdf
[12] Ibid.

ENVIRONMENTAL IMPACTS OF IMPROPER SOLAR WASTE MANAGEMENT

While the rapid growth of the solar energy industry has brought about significant environmental benefits by reducing greenhouse gas emissions and dependence on fossil fuels, the disposal of solar energy components at the end of their lifespan poses a potential threat to the environment if not managed properly. Solar panels, for example, are made up of various materials, including silicon, glass, metals, and plastics, some of which can be toxic if not handled and disposed of correctly. Improper disposal of solar waste can lead to various environmental impacts, including soil and water contamination, as well as the release of hazardous substances into the environment. Some of these environmental impacts are examined below.

Soil Pollution

Improper disposal of solar waste, particularly components containing hazardous materials like cadmium and lead, poses a significant risk of soil pollution. As decomposing solar panels release toxic substances, leaching can occur, thus allowing these contaminants to seep into the soil. This process not only diminishes soil fertility but also jeopardises plant growth. This form of soil pollution extends beyond agricultural concerns as it also affects soil microorganisms, nutrient cycling, and overall ecosystem health.[13]

Studies have shown that the accumulation of heavy metals from solar panel components in the soil can lead to bioaccumulation in plants which will disrupt their growth and development. This not only affects crop productivity but also poses risks to human health through the food chain.[14]

Furthermore, the presence of hazardous materials in the soil can alter the composition and activity of soil microorganisms, which play a crucial role in nutrient cycling and soil health. Heavy metals like cadmium and lead can inhibit microbial activity, leading to imbalances in nutrient availability and affecting the overall soil ecosystem. This disruption can have cascading effects on plant communities, soil structure, and ultimately ecosystem resilience.[15]

Water Pollution

The improper handling and disposal of solar waste can result in water pollution by releasing contaminants such as heavy metals and chemicals into groundwater or surface water bodies. This pollution can have detrimental effects on aquatic ecosystems and human health by contaminating water sources. Water pollution from solar waste can also disrupt aquatic biodiversity, degrade water quality, and impede access to safe drinking water thus posing a public health challenge.[16]

Air Pollution

The disposal of solar waste, particularly through incineration or burning processes, presents significant environmental and health risks. Incineration of components containing plastics and synthetic materials found in solar panels releases harmful pollutants into the atmosphere, contributing to air pollution and its associated adverse effects on human health. The International Energy Agency (IEA) highlights that emissions from burning waste, including toxic gases and particulate matter, worsen respiratory illnesses and compromise air quality.[17]

The combustion of plastics and synthetic materials in solar panels generates hazardous compounds like dioxins, furans, and polycyclic aromatic hydrocarbons (PAHs), which have been linked to various health issues, including respiratory problems and carcinogenic effects. Additionally, the release of fine particulate matter during combustion can deeply penetrate the lungs, causing inflammation and exacerbating existing respiratory conditions.[18]

It must be noted that the impact of incineration on air quality extends beyond localised areas, affecting communities far from waste disposal sites.[19] Vulnerable populations, such as children, the elderly, and individuals with pre-existing health conditions, are particularly at risk from the adverse effects of air pollution.

The environmental impacts of improper solar waste management extend beyond pollution to encompass risks to human health and biodiversity. Direct exposure to hazardous substances leaching from decomposing solar panels or released during waste incineration can result in adverse health effects, including respiratory ailments, neurological disorders, and cancer.[20]

[13] Kowalska, Joanna Beata, Ryszard Mazurek, Michał Gąsiorek, and Tomasz Zaleski, 2018. "Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–a review", Environmental Geochemistry and Health(6), 40:2395-2420. https://doi.org/10.1007/s10653-018-0106-z

[14] McBride, Murray B., Hannah Shayler, Henry M. Spliethoff, R. G. Mitchell, Lydia G. Marquez-Bravo, Gretchen Ferenz, Jonathan Russell-Anelli et al., 2014. "Concentrations of lead, cadmium and barium in urban garden-grown vegetables: the impact of soil variables", Environmental Pollution, 194:254-261. https://doi.org/10.1016/j.envpol.2014.07.036

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[16] Ibid.

[17] Orisakwe, Orish Ebere, Chiara Frazzoli, Cajetan Elochukwu Ilo, and Benjamin Oritsemuelebi, 2019. "Public health burden of e-waste in africa", Journal of Health and Pollution(22), 9. https://doi.org/10.5696/2156-9614-9.22.190610

[18] Ibid.

[19] Ibid.

[20] Ibid.

CURRENT APPROACHES TO MANAGING SOLAR WASTE IN NIGERIA

Legal and Regulatory Frameworks

Current approaches to solar waste management in Nigeria are guided by a series of legislative and regulatory frameworks aimed at addressing environmental concerns and promoting sustainable waste management practices. These frameworks include:[21]

The Harmful Waste (Special Criminal Provisions) Act Cap HI, 1988, updated in 2004

This legislation prohibits the carrying, deposition, and dumping of harmful waste on any land or territorial waters. Violators face penalties up to life imprisonment and forfeiture of vehicles or carriers involved in transporting the waste.

The National Environmental (Sanitation and Waste Control) Regulation 2009

This regulation mandates that no person engages in activities likely to generate hazardous waste without a permit from the appropriate agency. It also requires waste generators to securely store hazardous waste and ensure proper treatment before disposal. Violations may result in fines of up to N5,000,000 or imprisonment for five years.

The Guide for Importers of UEEE

This guide outlines provisions for the importation of used electrical and electronic equipment (UEEE). Importers must register with the National Environmental Standards and Regulations Enforcement Agency (NESREA) and comply with regulations banning the importation of waste electrical and electronic equipment (WEEE). Administrative fees are imposed on carriers transporting WEEE.

The National Environmental (Electrical/Electronic Sector) Regulations 2011

These regulations adopt a life cycle approach to managing electrical and electronic waste (e-waste), emphasising the 5Rs: Reduce, Repair, Reuse, Recycle, and Recover. They require permits for the export or transit of e-waste and the importation of UEEE and mandate environmentally sound management practices for e-waste.

Recycling and Disposal

The management of solar waste in Nigeria primarily relies on informal sector actors such as scavengers and informal recyclers, due to the absence of formal recycling facilities and infrastructure. These informal recycling methods often involve rudimentary processes that can pose risks to both human health and the environment. The lack of specialised facilities for processing solar waste further hampers proper recycling and disposal efforts, and is responsible for the accumulation of waste in landfills or open dumping sites. While some initiatives exist to promote recycling and recovery of valuable materials from solar panels, these efforts remain limited in scope and scale.[22]

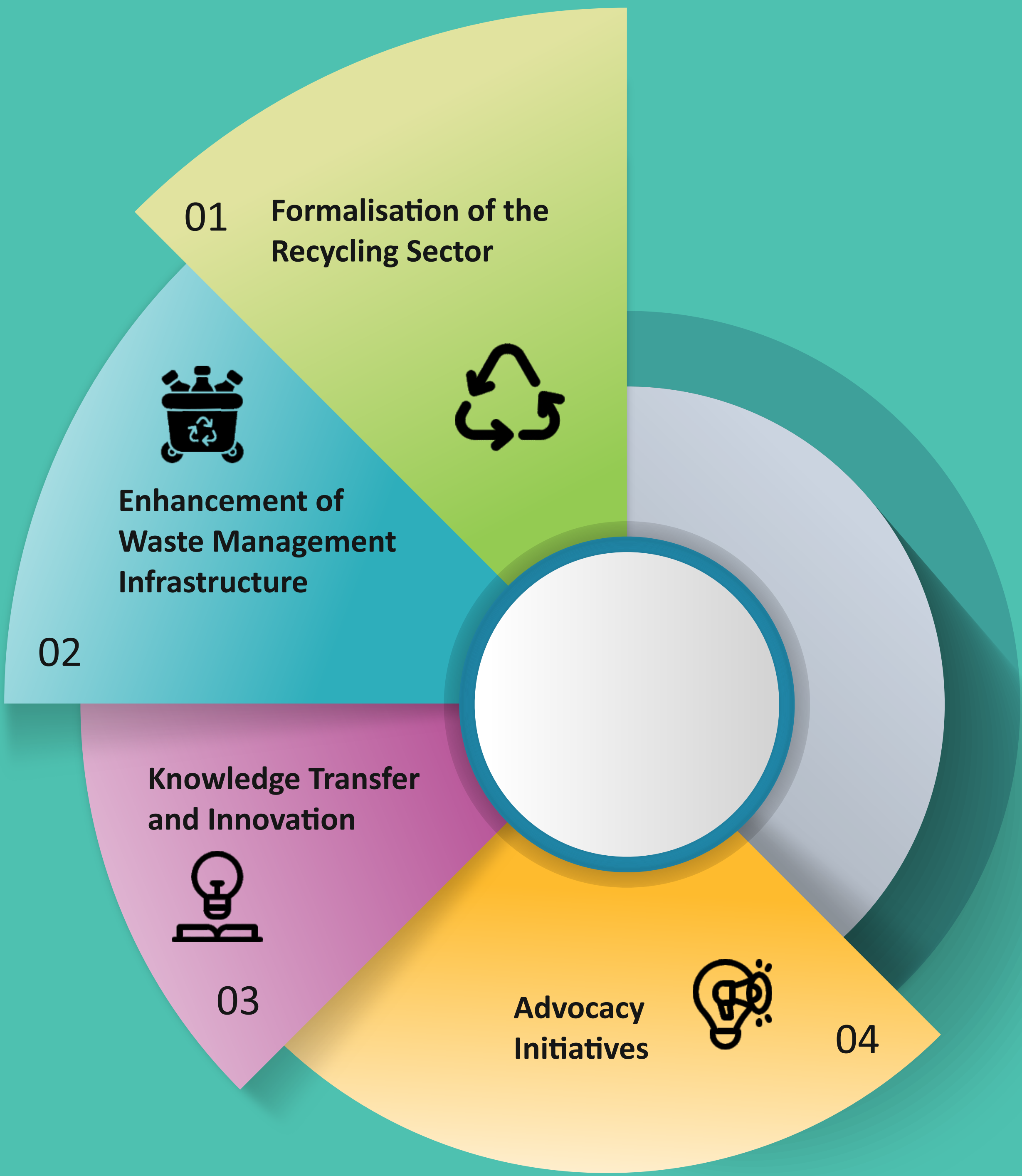
Despite efforts to manage solar waste, several challenges impede progress in Nigeria. Inadequate infrastructure, including recycling facilities and collection networks, poses logistical hurdles to proper waste management while limited public awareness and education about the hazards of improper disposal further exacerbate the problem, hence the continuation of indiscriminate dumping and informal recycling practices. Additionally, the lack of financial resources and technical capacity by regulatory bodies constrains the implementation of comprehensive waste management solutions even though regulations have been put in place to cater to some of the unique challenges of e-waste. However, some progress has been achieved through the collaboration between the Renewable Energy Association of Nigeria (REAN) and the Alliance for Responsible Battery Recycling. The Alliance has developed the Battery Stewardship Programme, aimed at enhancing sustainability within the renewable energy sector, and has extended its partnership with the Federal Ministry of Environment to formulate a National Policy on Used Batteries. This policy is focused on key sectors, including renewable energy, telecommunications, and ICT. Additionally, initiatives are underway to establish battery take-back schemes, and the Alliance has been registered by NESREA as a Producer Responsibility Organisation for the battery sector in Nigeria.[23]

[21] Amachree M. 2013, Update on E-Waste Management in Nigeria, NESREA, A Presentation made at the 3rd Annual Meeting of the Global E-Waste Management Network (GEM3), retrieved from: https://www.epa.gov/sites/default/files/2014-05/documents/nigeria.pdf

[22] Nduneseokwu, Chibuike K., Ying Qu, and Andrea Appolloni, 2017. "Factors Influencing Consumers' Intentions To Participate In A Formal E-Waste Collection System: A Case Study of Onitsha, Nigeria", Sustainability(6), 9:881. https://doi.org/10.3390/su9060881

[23] Africa Clean Energy Technical Assistance Facility, 2021, E-Waste Guide for Stand-Alone Solar in Nigeria, retrieved from: https://www.ace-taf.org/wp-content/uploads/2021/04/E-Waste-Guide-for-Stand-Alone-Solar-in-Nigeria.pdf

STRATEGIES FOR ADDRESSING THE SOLAR WASTE CHALLENGE



STRATEGIES FOR ADDRESSING THE SOLAR WASTE CHALLENGE

Formalisation of the Recycling Sector

One key strategy for formalising the recycling sector involves developing training programs to enhance the skills and knowledge of informal recyclers in safe recycling practices. For example, organisations like the Recycling Association of Nigeria (RAN) could collaborate with government agencies such as NESREA and LASEPA and educational institutions, to offer training workshops on waste management, occupational health and safety, and environmental regulations. When informal recyclers are equipped with the necessary skills and knowledge, they can transition to formalised practices while improving the quality and efficiency of their recycling operations.

Formal recycling companies can also provide support and resources to informal recyclers, such as access to collection infrastructure, sorting facilities, and market linkages.[24] For instance, initiatives like the Waste Management Society of Nigeria (WAMASON) and Renewable Energy Association of Nigeria (REAN) could partner with established recycling firms to create mentorship programs that guide informal recyclers through the transition to formalised operations. These partnerships benefit both parties by expanding the reach of recycling efforts and promoting sustainable waste management practices, particularly for solar waste recycling. They could design niche initiatives around specific and popular e-waste products in the sustainability context, such as mobile phones, batteries and generators, so that they are manageable, achievable and scalable.

Furthermore, certification programmes can play a crucial role in incentivising compliance with formal recycling standards among recyclers. Regulators can establish clear criteria for certification, such as adherence to safety protocols, environmental regulations, and material recovery targets which will help informal recyclers to demonstrate their commitment to responsible recycling practices and certify them to carry out their operations. Examples of successful certification programmes include the Responsible Recycling ("R2") Standard for Electronics Recyclers and the e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment, both of which provide formal recognition and market access to certified recyclers in the U.S.A.[25] Similar initiatives tailored to the Nigerian context can encourage the widespread adoption of formalised recycling practices.

Enhancement of Waste Management Infrastructure

The construction of specialised recycling facilities equipped with advanced technologies is crucial for efficiently processing solar waste. In the United States, the Solar Energy Industries Association (SEIA) collaborates with recycling firms like METech Recycling to provide infrastructural capacity for recycling solar panels.[26] These facilities utilise innovative processes such as mechanical shredding and thermal treatment to recover valuable materials from end-of-life solar panels and promote resource conservation and circular economy principles.

Additionally, robust waste collection systems are essential to ensure the proper segregation and transportation of solar waste to designated recycling facilities. In Europe, the Waste Electrical and Electronic Equipment Directive (WEEE Directive) mandates the separate collection of electronic waste, including solar panels, through established collection points and recycling centers. Municipalities also partner with waste management companies to implement efficient collection routes and educate residents on proper disposal practices, which have yielded relatively high recycling rates and minimal landfilling of solar waste.

Alongside waste collection systems, monitoring and tracking systems will play a vital role in enhancing transparency and accountability in the solar waste management process which is where technology like IoT and blockchain can be leveraged to monitor the responsible disposal and recycling of solar waste.[27]

[24] Velis, Costas A., David C. Wilson, Ondina Rocca, Stephen R. Smith, Antonis Mavropoulos, and Christopher R. Cheeseman, 2012. "An analytical framework and tool ('intera') for integrating the informal recycling sector in waste and resource management systems in developing countries", Waste Management &Amp; Research: The Journal for a Sustainable Circular Economy(9_suppl), 30:43-66. https://doi.org/10.1177/0734242x12454934

[25] United States Environmental Protection Agency (EPA), Certified Electronics Recyclers, retrieved from: https://www.epa.gov/smm-electronics/certified-electronics-recyclers

[26] Solar Energy Industries Association (SEIA), SEIA National PV Recycling Program, retrieved from: https://www.seia.org/initiatives/seia-national-pv-recycling-program

[27] Bošnjaković, Mladen, Mato Galović, Jasmin Kuprešak, and Tomislav Bošnjaković. 2023. "The End of Life of PV Systems: Is Europe Ready for It?" Sustainability 15, no. 23: 16466. https://doi.org/10.3390/su152316466

Knowledge Transfer and Innovation

Forums for knowledge exchange are essential for disseminating best practices and innovative solutions in solar waste management. These platforms can facilitate collaboration, and allow stakeholders to learn from each other's experiences and implement proven strategies in their respective regions. Consequently, research and development are critical for driving innovation in solar waste recycling technologies and processes. For example, Horizon Europe, the European Union's funding programme for research and innovation with a budget of €95.5 billion, funds research projects focused on advancing recycling methods for solar panels.[28]

Collaboration between academia, industry, and government agencies is also essential to accelerate innovation in solar waste management. Expertise from academia and industry will drive research initiatives aimed at improving the efficiency and sustainability of solar waste recycling processes. The European Photovoltaic Industry Association (EPIA) is one of such bodies that facilitates collaboration between academia, industry, and policymakers to promote the development and adoption of sustainable practices in the photovoltaic industry. The Global Solar Council (GSC) also fosters collaboration among industry associations and research organisations worldwide to promote innovation in solar waste recycling and sharing of global best practices. The Telecommunication and Technology Sustainability Working Group (TTSWG), a coalition for industry businesses intentionally imbibing sustainability-thinking, for example, published a Telecoms and Technology Citizenship Awareness Roadmap (TATCAR) which provides practical recommendations and guidance for stakeholders in the Nigerian ICT sector on how to proactively address sustainability matters including e-waste.[29] Alongside the National Environmental (Electrical and Electronic Sector) Regulations 2022, these resources provide practical guidance and regulations that can help stakeholders in the ICT sector align with sustainable practices in e-waste management.

Advocacy Initiatives

Public awareness campaigns play a vital role in educating the public about the importance of proper waste management practices and the impact of solar waste on the environment and public health. Already NESREA and state agencies, including Lagos Waste Management Authority (LAWMA), collaborate with local NGOs and community leaders to organise awareness campaigns on responsible waste disposal in urban and rural areas. These campaigns can be taken a notch further to highlight the benefits of recycling and proper disposal of solar panels by leveraging various communication channels, including social media, radio broadcasts, and community events, to reach diverse audiences and promote behaviour change.

Community organisations, youth groups and women associations included, also play a crucial role in grassroots outreach and engagement, and can be funded by private sector stakeholders to encourage communities to take action and support local waste management initiatives.

Advocacy for the operationalisation of waste management regulations, including extended producer responsibility (EPR) schemes for solar panel manufacturers and importers, is also key. There is also the need for civil society groups to collaborate with government agencies and lawmakers to lobby for increased funding for waste management programmes, research and development, infrastructure development, and community-based recycling. Rwanda for example has established 16 e-waste collection points and has a goal to increase this to cover the 30 districts of the country.[30]

[28] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2022-d3-03-09

[29] Telecoms and Technology Citizenship Awareness Roadmap (TATCAR), retrieved from: https://www.ttswg.org/tatcar/

[30] All On, 2022, Market research on the circular economy of the renewable energy sector in Nigeria, retrieved from: https://www.all-on.com/media/publications/_jcr_content/par/textimage_1046512014.stream/1643991469710/bd8b6c505c136f1d5a115fe1bfe67dddeb2b8ff8/project-volt-final-report.pdf

CONCLUSION

Through the analysis of the foregoing strategies and instances for coping with solar waste, several key insights and implications emerge for enhancing solar waste management in Nigeria. First is the fact that collaboration between government, industry, and communities cannot be overstated. Synergistic efforts facilitate the mobilisation of resources, expertise, and stakeholder engagement necessary for effective waste management initiatives. Secondly, innovation and technological advancements play a crucial role in developing sustainable waste management solutions. Adopting innovative technologies and best practices from successful initiatives can inform the design and implementation of tailored interventions in Nigeria. Lastly, community engagement and awareness-raising efforts are essential for fostering a culture of responsible waste management and promoting behavioural change among stakeholders.

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[12] Ibid.

[13] Kowalska, Joanna Beata, Ryszard Mazurek, Michał Gąsiorek, and Tomasz Zaleski, 2018. "Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination–a review", Environmental Geochemistry and Health(6), 40:2395-2420. https://doi.org/10.1007/s10653-018-0106-z

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