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Policy Framework for Managing Decommissioned Solar Power Systems in the Niger Delta: A Scientometric Report

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Abstract
The Niger Delta region has experienced substantial growth in the deployment of solar power systems (SPSs) to meet the energy requirements of its populace. As these systems reach their end-of-life, appropriate management strategies are crucial to minimize environmental footprints and maximize resource recovery. This scientometrics paper was aimed at assessing government regulations for managing decommissioned SPSs in the core Niger Delta. The study adopted a quantitative approach method using questionnaire as the research instrument. Thirty six (36) government officials from the strata of 3 States were investigated on the policy framework deployed for decommissioned SPSs. Both descriptive and inferential statistics were used in the analysis of data and discussion of results. Results revealed that government officials are inept with the policy instruments that promote renewable energy and green energy technologies in the setup of SPSs and its management at their end-of-life. Among others, it was recommended that these government agencies should embrace and domesticate the key 8 policy instruments, as well as implement sustainable management strategies therein for handling wastes from SPSs for the policy framework used in the study area.
Keywords: Solar power systems (SPSs), Niger Delta, Management Strategies, Solar PV panels

1.0 Introduction

The Niger Delta region covers nearly 75,000 km², making up 7.5% of Nigeria's land mass and regarded as one of the nine most difficult deltas globally (Nwogwugwu et al., 2012). From history and early cartography, it originally consists of today's Bayelsa, Delta and Rivers States. Of the nine coastal states of the Niger Delta, these three states remain referred to as the core Niger Delta (Benefit, *et al.,* 2014). With a population growth rate at 3.2%, the Niger Delta region has an estimated population of over 42 million people (National Bureau of Statistics, NBS, 2018). Consequent to the 3.2% growth rate, the core Niger Delta has an official population of 15,650,300 for 2022 (City Population, 2022). The region has reportedly remained a rugged terrain with grips of squalor, poor sanitation services, lack of basic infrastructure, habitat loss and environmental degradation (Sahara Reporters, 2022). Today, there are waste management reports indicating continuous and unaddressed threats to the Niger Delta region biodiversity (Ogolo, 2011; Benefit, et al., 2014; Donatus et al., 2021). Okorhi (2018) and Johnson, *et al*. (2019) had reported that one of the ways degradation set into the biodiversity of the Niger Delta is through the leaching of perilous wastes into the components of the environment. Environmental and health conditions were affected from air pollution through the burning of e-wastes, leaching of perilous compounds into ground and surface water at waste disposal sites, and the persistent organic pollutants (toxins) on soil. These were partly attributed to stakeholders' poor management practices and strategies deployed in handling solid wastes. The authors concluded by identifying a "disconnect between policy and practice" for waste management in the Nigeria.

Generally, the management of decommissioned solar power systems (SPSs) is an emerging research topic in Nigeria and beyond. Several empirical studies are focused on potential environmental impacts, general waste management issues, and the need for sustainable solutions. However, there is lack of

comprehensive policies specifically tailored to the region of the Niger Delta because of its uniqueness. For instance, environmental impacts and challenges studies are characterized with highlights of various environmental concerns associated with decommissioned solar power systems, like the presence of toxins (e.g., lead and cadmium) in solar PV panels, improper disposal of wastes, and the release of greenhouse gases during the dismantling process leading to contamination of components of the environment. Besides, sparse recycling facilities, inadequate waste management infrastructure, and lack of awareness among stakeholders pose major challenges too. Secondly, resource recovery and circular economy approach which are efforts meant towards resource recovery from decommissioned SPSs were equally discussed in several studies. These researches emphasized the importance of adopting a circular economy approach to extract valuable materials and promote recycling. The recovery of metals, such as copper, silver, and silicon, is identified as economically viable and environmentally beneficial. However, all these studies fall short of specific policy perspective dedicated to the management of SPSs in the core Niger Delta. A scientometrics report on policies for managing decommissioned solar power systems in the Niger Delta would therefore add to the topic by bridging the disconnect between policy and practice.

The Africa Clean Energy (2021) had reported that Nigeria is among the 10 African countries (Egypt, Madagascar, Ivory Coast, Nigeria, Ghana, Cameroon, Rwanda, Kenya, South Africa, and Zambia) that have specific electronic waste or e-waste legislation (law, act, regulatory, statutory instruments etc.) that are legally binding for the management of end-of-life EEE. By implication, Nigeria remains considered as a leading proponent in Africa for handling disused EEE (or e-waste) because of its specific regulations targeted at several e-products. Secondly, because of some mitigating challenges in handling electronic waste from renewable facilities, the federal government of Nigeria (FGN) initiated the promotion of additional policy measures in the framework for renewable energy setups to avert wastes from the environment, and thereby improving living conditions of citizenry and the pursuit of sustainability. This paper is therefore aimed at assessing regulations of the government for managing decommissioned solar PV power systems in the Niger Delta region. We would also consider testing a null hypothesis for this study. The hypothesis (H_0) states that "The EEE regulations for handling wastes from solar power systems (SPSs) are inadequate". In particular, this study would assess the implementation of the National Environmental (Electrical/Electronics Sector) Regulations, 2022 along with other policy instruments use in the framework of renewable energy power systems in Nigeria. Also, the study intends to address reports indicating the continuous and unaddressed threats from solar power system wastes to the biodiversity of the Niger Delta region. This is in order to further ignite and reassure the citizenry that renewable energy pursuit by the FGN could be built upon and sustained.

2.0 Clean energy and the significance of solar power systems option for Nigeria.

From reports, the Federal Government of Nigeria (FGN) had ensured a progressive policy direction on the diversification of the country's energy mix to promote the acceptance and usage of renewable energy as a major energy source (Adeniyi et. al, 2020; Alternative Energy Store, 2022). The government demonstrated this by creating a level playing ground, political will and commitments in developing strategies for off-grid sub-sector powered by renewable energy setup (Africa Clean Energy, 2019). The report further stated that the Nigeria Renewable Energy and Energy Efficiency Policy (NREEEP), 2015 submitted that an estimated investment of US$3.5 billion is required to accelerate the projected 30GW by 2030. In another report, the Nigeria market was considered to be among the fastest growing solar power systems (SPSs) markets around the world. This is because of the erratic and inadequate supply of electricity from government national grids to its populace. According to its operators, the growing solar PV panels market in Nigeria has been valued to be more than US$39 million, and employing over 10,000 persons (Isaac, February 26, 2018). The market is partly driven by rapid innovations in solar power devices, efficiency and reduction in prices for components of SPSs (solar panels, batteries and associated peripherals) (Netherlands Enterprise Agency, 2021). Reports of solar photovoltaic (PV) power systems setups within Nigeria by individuals, in rural dwellings and marketplaces, street lightings, etc. are overwhelming. A report by Isaac (April 6, 2018) confirmed that some of these set-ups are located in agricultural farmlands for processing, lightening and other rural purposes. An example is the Innotech 18 Meter Tunnel Solar Dryer which is said to have helped farmers in drying pepper faster within half the required normal

time. With the introduction of this innovative solar dryer, farmers' production time was cut to nearly half the normal time, and saving 40% of products that would have gone into the waste stream on the account of weather conditions and rodents damages. The solar panel system installations are locations at Kadabo and Baawa, both communities in Makarfi, Kaduna State (Isaac, April 6, 2018). Lagos State is also reckoned with installations of revolutionary solar-powered kiosks in marketplaces. These kiosks were seen strategically positioned mostly in food markets, with the traders preserving fresh vegetables and fruits in compartments of the solar-powered kiosks, while reducing food wastes. The solar powered refrigerators in kiosks were capable of elongating the shelf-life of agricultural products for between 2 to 21 days. While the high installation charges demanded upfront have deterred many of these desiring consumers within the lower segment in Nigeria, the government has equally introduced combine strategies to ignite a renewable energy pursuit using solar power systems. Some of these strategies are contained in policy framework for energy options, usage, acquisition, decommissioning and handling of obsolete solar PV power systems. For the purpose of this study, we present in Table 1 relevant policy instruments and their promoters on solar PV power systems setup.

Table 1: Framework for solar PV power systems in Nigeria

Regulations/Laws/Legislations/Acts/ for Solar PV Power Systems Management in Nigeria		**Proponents**
i	National Environmental (Energy Sector) Regulations, 2014	National Environmental Standards and Regulations Enforcement Agency (NESREA)
ii	National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015	Federal Ministry of Power
iii	National Energy Efficiency Action Plan, 2016 (NEEAP)	Federal Ministry of Power, Work and Housing
iv	National Renewable Energy Action Plan, 2016 (NREAP)	Federal Ministry of Power, Work and Housing
v	National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009	NESREA
vi	National Environmental (Electrical/Electronics Sector) Regulations, 2022	NESREA

Regardless of the framework represented in Table 1, Nigeria is still challenged with the implantation of policies in the renewable energy sector. By April, 2018, BusinessDay newspaper brought to the knowledge of the public that Nigeria's clean energy ambitions is been hampered with reported transboundary movement of decommissioned solar PV panels into Nigeria, the socioeconomic impacts, and government's huge tariffs on items for setting up renewable energy systems (Isaac, April 6, 2018). This report titled "New import duty on solar panels: How Nigeria preys on dreams" was another fact-finding article from Isaac Anyaogu. The report reckoned that the Nigerian Customs Service (NCS) had an imposed levy of 5% duty and another 5% value added tax (VAT) on all new solar PV panels imported into Nigeria. Until 2018, imported solar PV panels were exempted from duties payable to government base on Nigeria's HS Codes classification for imports. Hitherto, the NCS classified solar PV panels under the code: 85414000 classifications which attracted zero duty. In addition, the government appeared to be defiant in providing incentives for operators as part of its policy commitments for accelerating the energy transition as contained in sub-section 2.1.2, Supporting Policies and Measure, of the NREEEP (2015). These and other issues have become challenging to operators and lenders in the renewable energy sector, thereby reducing the pace for solar power systems set in Nigeria. This has equally hindering the policy drive for "generating 30% of its electricity through renewable energy and to the tune of 30GW target by 2030 from renewable energy sources, especially through solar power programme" in the Niger Delta and beyond (FMP, 2015; Isaac, April 6, 2018). Furthermore, stakeholders on the sector are apparently uninformed on the extended producer responsibility (EPR) programme for electrical and electronic equipment (EEE) at their end-of-life. The pursuit of EPR programme for solar PV devices is stipulated under Part II—General Provisions, sub-section 21 and in Schedule VI of the National Environmental (Energy Sector) Regulations, (2014). This is a key strategy to sound environmental management of decommissioned

components of solar PV power systems and its peripherals (NESREA, 2014; Isaac, February 26, 2018).

3.0 Framework for Handling Waste from Solar Power Systems in the Niger Delta

Pursuant to assessing government regulations for managing decommissioned solar PV power systems in the Niger Delta region, we adopted a conceptual framework (Figure 1) for "Management Strategies for Handling E-Waste from Solar Devices in Selected Cities of the Niger Delta" by John (2022). It showcases the Scope, Proponents and Strategic aspects of the framework. It revealed "What" is involved, "Who" is a stakeholder and "How" the implementation of policy is dished out. In a nutshell, the management strategies for wastes from solar power systems (SPSs) could be systematically organized under six components viz.: legal and regulatory framework, institutional arrangements, strategic planning, sensitization and participation, waste scheme funding, as well as waste generation and handling (Okorhi, 2018). Because waste electrical and electronic equipment (WEEE) is a specialized waste type, the legal and regulation framework for handling waste from SPSs in the Niger Delta is mainly drawn from the policy instruments listed in Table 1. These policy instruments have sessions and stipulations that are dedicated to strategies for handling of disused devices from SPSs. These six regulations targeted at renewable energy and sustainability in power supply in Nigeria are summarized as follow:

a) The National Environmental (Energy Sector) Regulations, 2014 speaks to preventing or minimizing pollution as well as encouraging energy efficiency in all operations and ancillary undertakings of the energy sector toward achieving a sustainable economic development in Nigeria (NESREA, 2014). The sources for renewable energy should be obtained from solar, hydro, wave, wind, geothermal and biomass. Part II of the General Provisions of the regulation stipulates that the disposal of hazardous waste, like decommissioned SPSs, on land or water without prior treatment is strictly prohibited, and that every power generating facility should have a "sustainable community relations programme" as part of compliance to corporate social responsibility (CSR).

b) The National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015 was designed to remove major barriers to renewable energy and energy efficiency pursuit in Nigeria at an economic, regulatory and institutional advantages compared to other forms of energy sources. It is intended that the policy would serve as a blue print for the sustainable expansion, supply and deployment of renewable energy resources within the Nigeria economy for on-grid and off-grid energy solutions (Federal Ministry of Power, 2015). The sources of renewable energy were targeted at solar energy, biomass, wind, small and medium hydro, tide, geothermal and wave energy. Solar energy resource intensity was considered to be generally high in Nigeria and should be harnessed for agricultural processing purposes, street, homes and park lightings, among others using solar energy conversion technologies, such as photovoltaic materials (cells or modules) for setting up SPSs. The idea is also to extend the plans to the informal sector and rural communities which are inadequately captured in the national accounts for electricity supply and thereby contributing to the national accounts a minimum electricity supply of 3% by year 2020 and 6% by year 2030.

c) The National Energy Efficiency Action Plan (NEEAP) 2016 is aimed at the effective and efficient energy use and proposes key areas for energy efficiency and conservation to be considered. Also, the policy hinge on pursuing the goal for the "Solar Thermal Program (SOLTRAIN) in West Africa" that meant at contributing to a switch over from the use of fossil fuel based energy supplies to a cleaner and sustainable energy supply system that is based on renewable energies from solar power systems (Federal Ministry of Power, Work and Housing, FMPWH, 2016a).

d) The National Renewable Energy Action Plan (NREAP), 2016 is drafted for strategy implementation of the National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015. The policy provides a summary on concrete guidelines, regulations, laws, incentives and strategies to be implemented in achieving Nigeria's quest in renewable energy targets and sustainable energy supply for its citizenry. Also, Nigeria's contribution to renewable energies

to achieving its national target under the ECOWAS Renewable Energy Policy (EREP) was target at 23% by 2020 and 31% by 2030 renewable energy (FMPWH, 2016b).

e) Part II of the General Provisions, sub-section 25 in the National Environmental (Energy Sector) Regulations, 2014 had stipulated that all power generating facility shall ensure that generated wastes should be handled and disposed as recommended in the National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009. Generally, strategies for solid waste management and environmental sanitation practices for all categories of wastes are primarily drawn from the National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009 (NESREA, 2009). In the policy document, Part 2 of the Environmental Sanitation Section, Sub-section 11(a) – (II. Duties and Obligations) promotes the stratification of hazardous wastes like decommissioned solar PV panels, batteries, inverters, etc. from non-hazardous municipal wastes. Besides, Sub-section III (44-53) – "Hazardous Waste Control" was particularly dedicated to strategies for handling and disposing hazardous wastes in Nigeria. It equally classified generated hazardous waste under Schedules 13 and 14 of the regulation.

f) The National Environmental (Electrical/Electronics Sector) Regulations, 2022 is a unique policy that is specifically dedicated to the managing waste from electrical and electronic equipment (EEE) in the Nigeria environment. It was first enacted in 2011 and then reviewed in 2022. The broad objective of the new regulation is to provide strategies for minimizing and preventing pollution operations and relative activities into the environment in the electrical and electronic sector (NESREA, 2022). It promoted strategies on extended producer responsibility (EPR), best practices for handling e-wastes or WEEE, restrictions on toxin effluent, WEEE handling, permit issuance and revocation, offences and penalties, among others. In the 1st Schedule [regulation 2(3)] EEE were classified into 10 categories of goods. Solar PV panel which is the principal device used in the installation of SPSs is classified under grey goods – ICT and telecommunication equipment. By implication the 2022 Electrical/Electronics Sector Regulations is the foremost guideline for handling end-of-life devices from decommissioned solar power systems (SPSs).

POLITICAL CONTEXT	
	OBJECTIVES
Scope (What?)	**PLANNING AND MANAGEMENT** • Strategic planning • Legal and regulatory framework • Public participation • Financial management • Institutional arrangements • Disposal facility Siting
	SOLAR WASTE GENERATION • Solar waste characterisation • Solar waste minimisation and source separation
	SOLAR WASTE HANDLING • Solar waste collection • Solar waste transfer, intermediate storage, treatment and disposal
Proponents	**GOVERNMENT AGENCIES** • NESREA • State Environment Protection Agencies • LGA Environmental Health office • Nigeria Customs Service • Standards Organisation of Nigeria (SON)
	BUSINESS SECTOR • Dealers/Marketers/Retailers
	INFORMAL SECTOR • Technicians/Refurbishers/Scavengers

(Who?)	**END-USERS** • Households, Government Institutions, Industries, Private Offices, • Trading/Agricultural Businesses, • Banks, Educational & Health-Care Centres
	SUPPORT AGENCIES • National Environmental Standards and Regulations Enforcement Agency (NESREA), Abuja • Federal Ministry of Power, Abuja • European Union Commission, Europe • Basel Convention Secretariat, Switzerland
Strategic Aspects (How?)	**POLITICAL** • Formulation of goals and priorities, • Determination of roles and jurisdiction, and • Establishment of Legal and Regulatory Framework.
	INSTITUTIONAL • Arrangements and Sectorial Integration
	SOCIAL • Patterns of Solar waste usage, generation and disposal of the population, and the associated Solar waste management needs and demands, • End-user participation in Solar waste management activities, and the • Ethical issues on Solar waste workers, both formal and informal.
	FINANCIAL • Budgeting and cost accounting systems, • Resource mobilisation for Solar waste funding, • Cost recovery and operational financing, • Cost control
	ECONOMICAL • Impact of Solar waste management services on the productivity and development of the economy, • The economic effectiveness of Solar waste management systems, • Conservation and efficient use of materials and resources, and • Job creation and income generation in Solar waste management activities.
	TECHNICAL • technical planning and design of Solar waste management systems, • Solar waste collection systems, • Intermediate storage and transfer systems, • Solar waste recovery, repair, reuse, recycling and disposal management
ECONOMIC CONTEXT	

Figure 1: Conceptual framework for "Management Strategies for Handling E-Waste from Solar Devices in Selected Cities of the Niger Delta" in John, 2022

4.0 Materials and Methods

The study took place in selected local government areas (LGAs) in the core Niger Delta, comprising Delta, Rivers and Bayelsa States (Kimiebi, 2010). Table 2 represents a population of the 9 purposively selected LGAs in the Core Niger Delta. Of this population, three (3) stakeholders (monitoring/regulatory agencies, recycler/technicians/traders and end-users) involved in the pursuit of renewable energy setups and management. They were investigated using distinct questionnaires for each listed group. The sample size was determined as 400 using the Yamane formulae computation, while the distribution criterion for questionnaires was informed by Ogbuene (2014). However, this report presents results from government monitoring/regulatory agencies surveyed in the study area. In

addition, Table 3 gives a schedule of questionnaire administered to these stakeholders, where government senior officials involved in policy planning and implementation for renewable energy pursuit and waste management were considered in eliciting information from the Regulatory/Monitoring Agencies sector. The choice of these officials was purposive because certain distinct data sets on the policies investigated were necessitated and could not be obtained from the other categories of respondents. For even spread, at least one urbanized LGA was picked from each strata of States in the study area. Hence, 4 questionnaires were administered to the respondents in each LGA. These 36 respondents were drawn from the federal and state environmental protection agencies, local government environmental offices and other government policing agencies. Both descriptive and inferential statistics were presented, analysed and discussed in the section that followed.

Table 2: Population of selected LGAs in the Core Niger Delta

Metropolis (City)	**State**	**Local Government Area**	**Population in 2006 (NBS, 2013)**	**Estimated population in 2022**	**Estimated population by City**	**Percentage**	**Number of Questionnaire**
Asaba	Delta	Oshimili South	150,032	214,846	214,846	06.08%	024
Warri metropolis	Delta	Warri South West	116,538	166,882	1,087,913	30.80%	123
	Delta	Warri South	311,970	446,741			
	Delta	Uvwie	188,728	270,259			
	Delta	Udu	142,480	204,031			
Port Harcourt metropolis	Rivers	Obio-Akpor	462,350	662,085	1,705,658	48.29%	193
	Rivers	Eleme	190,194	272,358			
	Rivers	Port Harcourt City	538,558	771,215			
Yenegoa	Bayelsa	Yenegoa	*(395,615)	523,794	523,794	14.83%	060
Total				**3,532,211**	**3,532,211**	**100%**	**400**

**Estimated population in 2010 for Yenegoa is 395,615*

Source: Extrapolated from National Bureau of Statistics, NBS (2013)

Table 3: Schedule of Questionnaire Administered

Stakeholders	Number Administered	Number Retrieved	% of Number Retrieved	Number of Valid Retrieved Questionnaire	% of Valid Retrieved Questionnaire
Regulatory/Monitoring Agencies	36	36	100.00	34	94.44
Distributors/ Recyclers	90	82	91.11	69	76.67
Consumers/End-Users	274	252	91.97	206	75.18
Total	**400**	**370**	**92.50%**	**309**	**77.25%**

Source: Field Survey, 2022

5.0 Results

Sequel to Table 2 representation of number of questionnaires administered (36), number of questionnaires retrieved (36) and number of valuable questionnaires retrieved (34), we present an analysis of the respondents with Table A1 and Figure A1. The respondents from the Regulatory and Monitoring Agencies were drawn from government agencies like the Federal Ministry of Environment, National Environmental Standards and Regulations Enforcement Agency (NESREA), State Environmental Protection Agencies from Bayelsa, Rivers and Delta, Local Government Area Health Offices, Government/Private Waste Management Firms, Nigerian Custom Service, as well as Federal Ministry of Power.

Table A1: Analysis of the Respondents

Organization/ Occupation	**Frequency**	**Cumulative Frequency**	**%**
REGULATORS/MONITORING AGENCIES: (Federal Ministry of Environment, NESREA, State Environmental Protection Agencies, Local Government Health Offices, Government/Private Waste	34	34	100

Management Firms, Nigerian Custom Service, Federal Ministry of Power)		
Total	**34**	**100**

Source: Field Survey, 2022

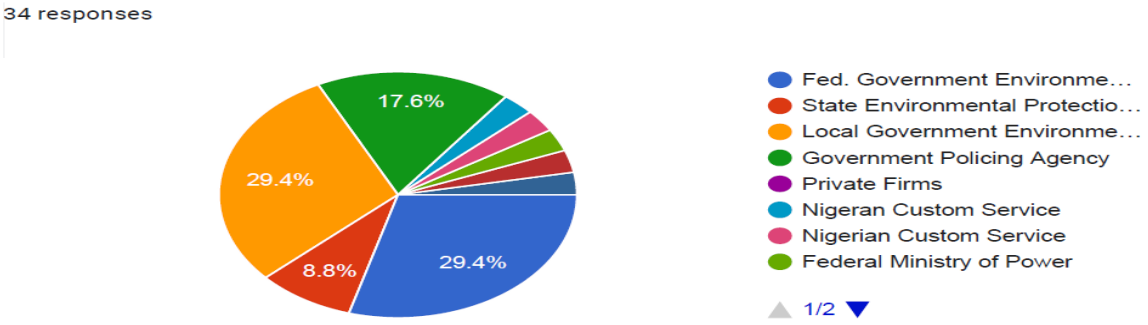

Figure A1: Schema of respondents (Regulatory and Monitoring Agencies (36))

The respondents for this study were primarily senior government officers who are responsible for the planning, execute, monitor and regulating strategies for the policy framework deployed for managing wastes from Solar PV Systems in the study area. These officials subsequently suggest improvements, adoption and promotion of frontier measures that are sustainable for the management of WEEE in Nigeria. We discuss this framework by first analysing the applicable guideline(s) adopted and promoted by these agencies for conducting routine management of wastes from SPSs, and thereafter assessing the strategies deployed for implementation in the Niger Delta region. Table 1 had a listing of six (6) national policy instruments approved for use by the regulatory and legislative agencies.

5.1 Waste management policies for solar power systems (SPSs) in the Niger Delta

From Table B1, it is revealed that 20 (59%) respondents opined that they deploy 2 state environmental edicts from Delta and Rivers in addition to the 6 FGN regulatory instruments in the management of decommissioned solar PV systems. Together, eight (8) regulations are deployed in the study area. The number of guidelines falls short of the waste management by-laws for Bayelsa State, owing to government officials' restriction, show of confidentiality and unwillingness to release the State's by-law before and during the survey.

Table B1: Policy instruments used by government officials in managing decommissioned solar PV systems in the Niger Delta

Regulation/Law/Legislations/Acts/ in carrying out routine management of decommissioned solar PV systems		Very Great Extent	Great Extent	Small Extent	Very Small Extent	Not At ALL	Total No. of Respondents
I	National Environmental (Energy Sector) Regulations, 2014	9	11	11	2	1	34
Ii	National Energy Efficiency Action Plan, 2016 (NEEAP)	4	10	6	12	2	34
Iii	National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015	1	13	7	11	2	34
Iv	National Renewable Energy Action Plan, 2016 (NREAP)	2	12	8	10	2	34
V	The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011	7	13	8	3	3	34
Vi	The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009	11	12	6	3	2	34
Vii	Others	Delta State Waste Management law Rivers State Waste Management Authority Law					34
Statistics							

		National Environmental (Energy Sector) Regulations, 2014	National Energy Efficiency Action Plan, 2016 (NEEAP)]	National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015	National Renewable Energy Action Plan, 2016 (NREAP)	The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011	The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009
N	Valid	34	34	34	34	34	34
	Missing	0	0	0	0	0	0
Mean		3.74	3.06	3.00	3.06	3.53	3.79
Median		4.00	3.00	3.00	3.00	4.00	4.00
Std. Deviation		1.024	1.179	1.044	1.071	1.187	1.175
Range		4	4	4	4	4	4
Minimum		1	1	1	1	1	1
Maximum		5	5	5	5	5	5

Other legislative provisions (including State edits) that form part of the policy framework adopted and applicable in managing disused wastes from solar devices in the Niger Delta

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Rivers State Waste Management Authority Law	17	50.0	50.0	50.0
	Delta State Waste Management Board Law	3	8.8	8.8	58.8
	Nil	14	41.2	41.2	100.0
	Total	34	100.0	100.0	

Source: Field Survey, 2022

5.2 Waste management plans and strategies for decommissioned solar power systems (SPSs)

Table B2 further assessed the appropriateness of adopted regulations for the management of end-of-life solar PV system setups.

Table B2: Adequacy of adopted legislations deployed by government officials

Are these additional national guidelines - "Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991" relevant to decommissioned solar PV systems management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	1	2.9	2.9	2.9
	Very small	7	20.6	20.6	23.5
	Small	8	23.5	23.5	47.1
	Great	10	29.4	29.4	76.5
	Very Great	8	23.5	23.5	100.0
	Total	34	100.0	100.0	

Are the management strategies in the regulatory framework adequate for the effective handling of end-of-life solar PV systems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very small	5	14.7	14.7	14.7
	Small	12	35.3	35.3	50.0
	Great	15	44.1	44.1	94.1
	Very Great	2	5.9	5.9	100.0
	Total	34	100.0	100.0	

From the existing national regulations, is there a minimum collection targets and handling expertise defined for the States in the Niger Delta to be followed for the management of wastes from solar devices?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	12	35.3	35.3	35.3
	Very small	6	17.6	17.6	52.9
	Small	5	14.7	14.7	67.6
	Great	10	29.4	29.4	97.1
	Very Great	1	2.9	2.9	100.0
	Total	34	100.0	100.0	

Are there provisions in the policy documents that promotes cascaded application and second life for end-of-life solar PV devices?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	6	17.6	17.6	17.6
	Very small	8	23.5	23.5	41.2
	Small	11	32.4	32.4	73.5
	Great	9	26.5	26.5	100.0
	Total	34	100.0	100.0	

When it becomes necessary, do you adopt any foreign regulations in the management process of solar device wastes?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	23.5	23.5	23.5
	Very small	9	26.5	26.5	50.0
	Small	11	32.4	32.4	82.4
	Great	6	17.6	17.6	100.0
	Total	34	100.0	100.0	

Are there financing mechanisms or reward for formal recycling of solar PV systems included in the integrated policy framework?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	7	20.6	20.6	20.6
	Very small	9	26.5	26.5	47.1
	Small	8	23.5	23.5	70.6
	Great	6	17.6	17.6	88.2
	Very Great	4	11.8	11.8	100.0
	Total	34	100.0	100.0	

Statistics

		Are these additional national guidelines - Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991 â€“ relevant to decommissioned solar PV systems management	Are the management strategies in the regulatory framework adequate for the effective handling of end-of-life solar PV systems?	From the existing national regulations, is there a minimum collection targets and handling expertise defined for the States in the Niger Delta to be followed for the management of wastes from solar devices?	Are there provisions in the policy documents that promotes cascaded application and second life for end-of-life solar PV devices?	When it becomes necessary, do you adopt any foreign regulations in the management process of solar device wastes?	Are there financing mechanisms or reward for formal recycling of solar PV systems included in the integrated policy framework?
N	Valid	34	34	34	34	34	34
	Missing	0	0	0	0	0	0
Mean		3.50	3.41	2.47	2.68	2.44	2.74
Median		4.00	3.50	2.00	3.00	2.50	3.00
Std. Deviation		1.161	.821	1.331	1.065	1.050	1.310
Range		4	3	4	3	3	4
Minimum		1	2	1	1	1	1
Maximum		5	5	5	4	4	5

Source: Field Survey, 2022

Eighteen 18 (53%) respondents admitted that the national guidelines like the "Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and "National Environmental Protection (Waste Management) Regulations S.I.15 of 1991" were also pertinent to 6 FGN key policy instruments listed in Table B1 for the management of decommissioned SPSs in the Niger Delta. But half of the FGN respondents (17(50%)) admitted that the deployed management strategies in the policy framework for obsolete solar PV systems were inadequate or ineffective. Besides, it was revealed that the minimum set targets in the national regulations as management strategies for the collection of wastes for solar devices as well as handling expertise stipulated for States of the Niger Delta is not adhered to. Eighteen (18) (53%) respondents confirmed that set targets for collecting and handling of solar PV system wastes were not followed through. However, 11(32%) respondents admitted to a small extent that there are strategies in the policy framework that promotes the recovery and recycling of decommissioned solar PV devices, while another 8(24%) respondents debunked this position to be at a very small extent, and 6(18%) respondents further opined that the strategies promoting recovery and recycling for such wastes are not tenable in the study area. More so, 11 (32%) respondents agreed to a small extent that they adopt foreign regulations as part of the management strategies for solar device wastes generated. With 6(18%) respondents affirmed strongly to incorporating foreign management strategies during implementation. Nevertheless, there are close indifferences in adjudging inclusion of government financial mechanisms in the integrated policy framework to promote formal recycling of decommissioned SPSs. From Table B2, 7(21%) respondents strongly disagree, 9 (27%) respondents slightly disagreed, 8(24%) respondents agreed to a small extent, 6(18%) respondents agreed, and 4(14%) respondents totally agreed to the inclusion of financial mechanisms during the implementation process.

5.3 Hypothesis Test and Interpretation (H_o1)

A regression statistical was used to test the relationship between the dependent variable (response Y) and independent variables (predictors k) on the main research question: What are the standard government regulations deployed for managing decommissioned SPSs in the Niger Delta region? The null hypothesis H_o1 is stated as: "The EEE regulations for handling wastes from solar power systems (SPSs) are inadequate". Here, the dependent variable is considered as "the extent of knowledge and

participation of regulatory and monitoring agencies in the formulated policies, laws/legislatures, guidelines and regulations relating to wastes from SPSs". And the independent variables include the quantitative responses on management standards and disposal strategies deployed in the study area. Table B3 reveals analysis on questions for hypothesis H_0 (1). Here A linear multiple regression test was carried out on questions relating to government policies, regulations, laws, acts, legislations, edits, guidelines, standards etc. for handling wastes from SPSs.

Table B3: Linear multiple regression test for hypothesis $H_0$1

Regression

Notes		
Output Created		15-JAN-2023 18:40:05
Comments		
Input	Data	
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	34
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT @1.AreyouawareofanyspecificRegulationsLawsLegislationsActsforsol /METHOD=ENTER @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesusedb @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesuse_A @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesuse_B @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesuse_C @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesuse_D @1.Amongtheprovisionslistedbelowticktheapplicableguidelinesuse_E @2.Otherthanthoselistedinquestion1abovepleaseindicateotherlegisl v2.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.05
	Memory Required	38416 bytes
	Additional Memory Required for Residual Plots	0 bytes

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Are these additional national guidelines â€“ Harmful Waste (Special Criminal Provisions). Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991 â€“ relevant to decommissioned solar PV systems management, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Environmental (Energy Sector) Regulations, 2014], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Energy Efficiency Action Plan, 2016 (NEEAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011, Other than those listed in question 1 above, please indicate other legislative provisions (including State edits) that form part of the policy framework adopted and applicable in managing disused wastes from solar devices in your jurisdiction of work, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy Action Plan, 2016 (NREAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015][b]		Enter

a. Dependent Variable: Are you aware of any specific Regulations/Laws/Legislations/Acts for solar PV components management in the Niger Delta?
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.577[a]	.333	.120	1.297

a. Predictors: (Constant), Are these additional national guidelines “Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991“ relevant to decommissioned solar PV systems management, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Environmental (Energy Sector) Regulations, 2014], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Energy Efficiency Action Plan, 2016 (NEEAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011, Other than those listed in question 1 above, please indicate other legislative provisions (including State edits) that form part of the policy framework adopted and applicable in managing disused wastes from solar devices in your jurisdiction of work, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy Action Plan, 2016 (NREAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015]

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.028	8	2.629	1.563	.186[b]
	Residual	42.030	25	1.681		
	Total	63.059	33			

a. Dependent Variable: Are you aware of any specific Regulations/Laws/Legislations/Acts for solar PV components management in the Niger Delta?

b. Predictors: (Constant), Are these additional national guidelines "Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991" relevant to decommissioned solar PV systems management, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Environmental (Energy Sector) Regulations, 2014], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Energy Efficiency Action Plan, 2016 (NEEAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011, Other than those listed in question 1 above, please indicate other legislative provisions (including State edits) that form part of the policy framework adopted and applicable in managing disused wastes from solar devices in your jurisdiction of work, Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy Action Plan, 2016 (NREAP)], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009], Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015]

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.450	2.647		.170	.866
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Environmental (Energy Sector) Regulations, 2014]	.583	.292	.432	1.997	.057
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Energy Efficiency Action Plan, 2016 (NEEAP)]	.211	.571	.180	.369	.715
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy and Energy Efficiency Policy (NREEEP), 2015]	-.260	.908	-.196	-.286	.777
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Renewable Energy Action Plan, 2016 (NREAP)]	.333	.515	.258	.647	.523
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011	.189	.279	.162	.678	.504
	Among the provisions listed below, tick the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [The National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009]	.063	.400	.053	.157	.876

Other than those listed in question 1 above, please indicate other legislative provisions (including State edits) that form part of the policy framework adopted and applicable in managing disused wastes from solar devices in your jurisdiction of work	.213	.339	.149	.630	.535
Are these additional national guidelines â€“ Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004 and the National Environmental Protection (Waste Management) Regulations S.I.15 of 1991 â€“ relevant to decommissioned solar PV systems management	-.605	.282	-.509	-2.144	.042

a. Dependent Variable: Are you aware of any specific Regulations/Laws/Legislations/Acts for solar PV components management in the Niger Delta?

Source: Field Survey, 2022

The Regression Criteria = $P < 0.05$ implies we reject the null hypothesis. The comparable values for regression inferential statistics are the Beta, β coefficients: $H_0 1$ are $\beta_1 = 0.432$; $\beta_2 = 0.180$; $\beta_3 = -0.196$; $\beta_4 = 0.258$; $\beta_5 = 0.162$; $\beta_6 = 0.053$; $\beta_7 = 0.149$ and $\beta_8 = -0.509$. The R-square is given as 0.333 or R^2 = (33%). The question "…the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Environmental (Energy Sector) Regulations, 2014]" has Beta (β_1) = 0.432 when compared with the tabulated p-value (P_1) = 0.057. This result reveals that the variable is significant. Next, the question "the applicable guideline(s) used by your firm/business in carrying out routine management of end-of-life lithium batteries: [National Energy Efficiency Action Plan, 2016 (NEEAP)]" has Beta (β_2) = 0.180 which is comparably (P_2) = 0.715. However, this result implies that the variable tested is insignificant. We compute and compare for the others as follow for $\beta_3 - \beta_8$ and $P_3 - P_8$: $\beta_3 = -0.196$: $P_3 = 0.777$, $\beta_4 = 0.258$: $P_4 = 0.523$, $\beta_5 = 0.162$: $P_5 = 0.504$, $\beta_6 = 0.053$: $P_6 = 0.876$, $\beta_7 = 0.149$: $P_7 = 0.535$, and $\beta_8 = -0.509$: $P_8 = 0.042$. From the above results, the P-values ($P_3 - P_8$) are found to be greater than the comparable Beta coefficient (β) significant values. Therefore the tested variables become insignificant. So, we are to accept the null hypothesis $H_0 1$: "The EEE regulations for handling wastes from solar power systems (SPSs) are inadequate", since most p-values (except P_8) were greater than P = 0.05. These findings agrees with field observations and anecdotal claims by stakeholders that there remain inadequate action of management functions that starts with proper planning, organising, leading, handling and control of wastes from decommissioned SPSs.

6.0 Conclusions and Recommendations

This scientometrics report highlights the emerging issue of managing decommissioned solar power systems (SPSs) in the core Niger Delta, and emphasizes the need for comprehensive policies to operate. Following data elicited, processed and analyzed for the study "…policies for managing decommissioned solar power systems in the Niger Delta", the discussions and tested hypothesis confirmed that officials from government regulatory/monitoring agencies are unaware of key regulations/guidelines that promotes renewable energy and green energy technologies, including SPSs setup and management at their end-of-life. Some of the important regulations listed in Table 1 remain key to promoting the setup of solar PV power systems and in handling wastes from decommission SPSs. To ensure environmental sustainability, resource use and recovery, as well as circular economy principles, it is pertinent for stakeholders to collaborate and implement recommended policies. Therefore, we recommend to the regulatory/monitoring agencies that they should urgently embrace, domesticate and implement sustainable management strategies in handling waste from SPSs as contained in the 6 policy instruments listed in Table 1, along with individual state environmental edicts (region-specific policies), the Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004, and the National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009. Furthermore, additional research and continuous monitoring are needed to evaluate the effectiveness of these policies and refine them over time.

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