# REDUCING INDUSTRIAL AND ENVIRONMENTAL IMPACT IN NIGERIA THROUGH RESOURCE EFFICIENCY AND CLEANER PRODUCTION (RECP) METHODOLOGIES

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## A DISSERTATION

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in Pollution Management and Environmental Impact

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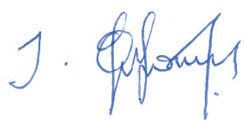
# Declaration

I certify that this thesis, “Reducing Industrial And Environmental Impact In Nigeria Through Resource Efficiency And Cleaner Production (RECP) Methodologies is entirely my original work, comprised solely of my readings, research, and analyses. Permission has been granted by all individuals and institutions referenced to include their interviews and case studies within this document.



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# Approval

This thesis is presented to the Department of Pollution Management and Environmental Impact of Selinus University to fulfil the requirement for a Philosophy Doctor (PhD) award by Research at Selinus University.

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# Dedication

This research is dedicated to my wife, Prof. Maria Jell-Ojobor, son Benjamin Ewomazino Ojobor, and daughter Philomena Evi Ojobor.

# Abstract

This research examines the effectiveness of Resource Efficiency and Cleaner Production (RECP) methods in reducing environmental impacts and improving resource use in Nigeria's industrial sector. The study focuses on four industries: textile, plastics, food and beverage, and steel, using a mixed-methods approach that combines quantitative data analysis with qualitative insights from industry stakeholders. The study selects eight companies across these industries to compare RECP-implementing firms with non-implementing ones. Data collection includes questionnaires and interviews, and the RECP Indicator System is used to assess environmental performance through various indicators.

A linear regression analysis using data from 2018 to 2022 shows that RECP-adopting companies consistently perform better across all environmental performance indicators. This analysis provides strong evidence for the long-term benefits of RECP practices. Comparison with national and international standards reveals significant room for improvement in both RECP and non-RECP companies, underscoring the urgent need for broader adoption of these methods.

The research identifies key factors driving and hindering RECP implementation. Cost savings, environmental benefits, and regulatory compliance are the main motivators, while financial constraints, lack of expertise, and resistance to change are significant barriers. The study also analyzes Nigeria's current industrial regulations to identify strengths, weaknesses, and areas for improvement.

The study proposes strategies for improvement, including technology upgrades, process optimization, and implementation of integrated resource management systems. It also recommends regulatory changes to support RECP adoption and mainstreaming. The research emphasizes the importance of self-assessment tools for companies to measure performance against various standards. A key finding is the generally low awareness of energy and resource efficiency issues among Nigerian industries. Many companies lack insight into their energy use and often don't monitor resource use, especially water

consumption. However, the research shows growing interest among companies in learning about and improving their energy and resource efficiency.

The study underscores the crucial role of government and industry bodies in supporting the transition to RECP through policies, access to green financing, and promotion of technology transfer. It recommends incorporating RECP into Nigeria's long-term planning at national and state levels, necessitating collaboration between researchers, policymakers, service providers, and other stakeholders.

This research aims to fill the knowledge gap about RECP methods in Nigeria and contribute to developing effective RECP frameworks and guidelines. By providing evidence on the benefits of RECP adoption and the challenges faced by industries, the study supports Nigeria's industrial sector's move towards a circular economy and sustainable industrial development, highlighting the shared responsibility in this transition.

The findings have important policy implications, suggesting that targeted regulations promoting RECP practices could effectively reduce the environmental impact of Nigerian industries. The study proposes various policy tools, including tax incentives, subsidies, and stricter enforcement of environmental standards, to encourage the widespread adoption of RECP methods.

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# List of abbreviations

BRIC: Brazil, Russia, India, China

CO: Carbon Monoxide

$CO_2$: Carbon Dioxide

CPA: Cleaner Production Assessment

CP: Cleaner Production

CP Centers: Cleaner Production Centers

EcoBrew: Eco-friendly Brewery (RECP practitioner)

EcoPlast: Eco-friendly Plastic Company (RECP practitioner)

EcoSteel: Eco-friendly Steel Company (RECP practitioner)

EcoTex: Eco-friendly Textile Company (RECP practitioner)

FCT: Federal Capital Territory

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GNI: Gross National Income

IPCC: Intergovernmental Panel on Climate Change

ISO: International Organization for Standardization

KPI: Key Performance Indicator

LCA: Life Cycle Assessment

MAN: Manufacturers Association of Nigeria

MJ: Megajoule

MT: Metric Ton

NBS: National Bureau of Statistics

NCPC-SA: National Cleaner Production Centre of South Africa

NNPC: Nigerian National Petroleum Corporation

NOx: Nitrogen Oxides

OECD: Organisation for Economic Co-operation and Development

SDGs: Sustainable Development Goals

SMEs: Small and Medium-sized Enterprises

SOx: Sulfur Oxides

UNEP: United Nations Environment Programme

UNIDO: United Nations Industrial Development Organization

VOCs: Volatile Organic Compounds

# Chapter 1 : Introduction

## 1.1. Introduction

The consumption of natural resources (e.g., raw material, water & energy) in industries brings welfare to society, but per unit of product from the industry is linked with the generation of environmental pollutants and emissions. The relentless pursuit of economic growth and the associated intense use of materials, energy, and water have severe implications on the extraction rates and scarcity of natural resources, environmental pollution (air, water, and soil), climate change, and human health (Szilagyi & Mocan, 2018). Industrial growth faces a significant challenge due to the looming threat of resource scarcity (World Economic Forum, 2014).

The availability of essential production elements like water, electricity, and fossil fuels is becoming increasingly limited due to climate change and economic shifts. Additionally, demographic changes and economic development further exacerbate resource limitations as populations grow and economies demand more (UNEP, 2011). By its very nature, economic activity generates waste and production processes create residuals that pollute the environment as emissions or waste (OECD, 2011). Such waste generation disrupts the ecological balance and poses significant environmental issues. The environmental problems arising from unsustainable resource use and industrial practices create a vicious cycle that hinders economic growth.

Many environmental woes can be traced back to resource extraction and processing activities. These activities are estimated to contribute roughly 50% of global greenhouse gas emissions (IPCC, 2014), over 90% of water stress (Mekonnen & Hoekstra, 2012) and substantial biodiversity loss (UNEP, 2011). Global resource use has witnessed an exponential increase, with an eightfold rise observed during the 20th century alone (Krausmann et al., 2009). This increase is further compounded by a doubling of per capita resource consumption, highlighting the intensifying pressure on the planet's finite resources.

The environmental consequences of resource extraction and processing necessitate a critical reevaluation of current industrial practices; hence, Resource Efficiency and Cleaner Production (RECP) has come as a preventive concept and measure to facilitate pollution prevention and reduce carbon intensity per unit of products along with financial profit of the industry (Hossain, 2015). RECP can be a triple-win for the economy, the environment, and society. Firms using more efficient and greener technologies and practices can have a broad range of economic, environmental, and social benefits, thus contributing to all three pillars of sustainable development (Figure 1).

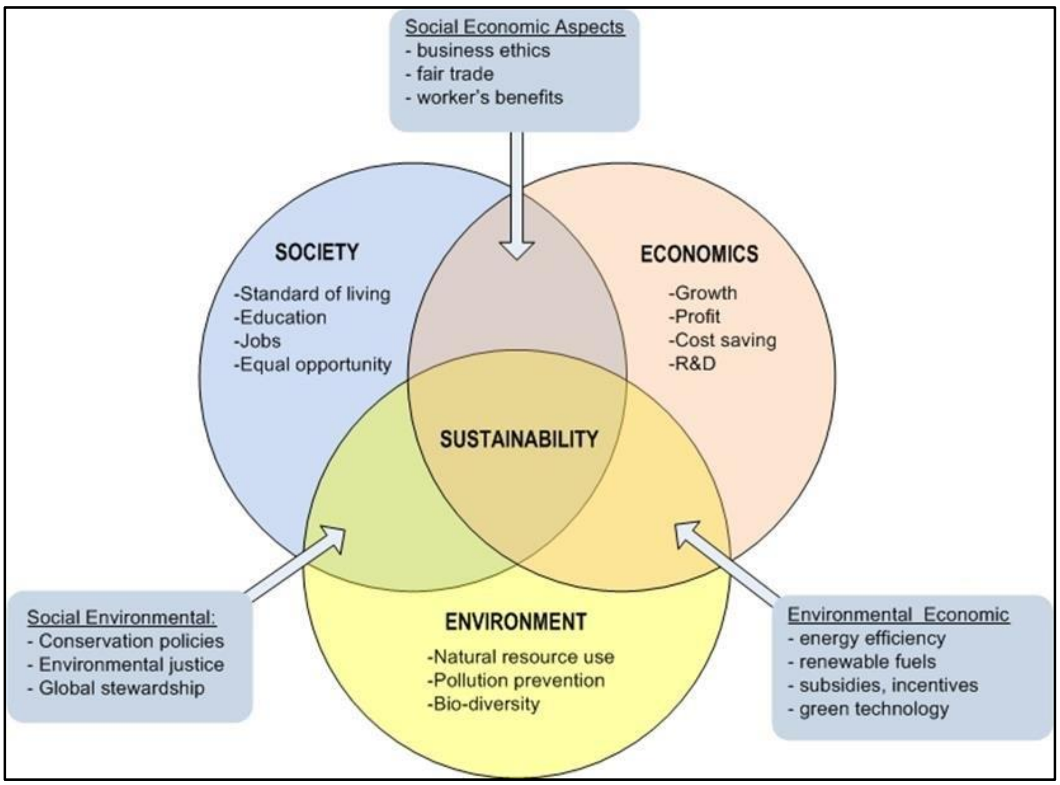


Figure 1: Interplay of the environmental, economic, and social aspects of sustainable development[1].

International evidence shows that there is generally substantial scope for individual firms in environmentally damaging sectors to improve resource efficiency and reduce

1 https://www.researchgate.net/publication/330762891_The_Political_Law_on_Coal_Mining_in_the_Fulfilment_of_People's_Welfare_in_Indonesia?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uRG93bmxvYWQiLCJwYWdlIjoiX2RpcmVjdCJ9fQ

pollution/waste (Luken & Piras, 2011). Over two decades after the concept was popularized, there is strong evidence from the literature that RECP has proven to be an effective approach, capable of generating those mentioned above environmental, economic, and social gains in many countries and sectors (van Berkel, 2007). The potential for such gains is especially large in resource-intensive and polluting sectors (e.g., leather, textile, pulp and paper) and in developing countries where production is dominated by small and medium-sized enterprises (SMEs) with low environmental management capacity (Sertyesilisik & Sertyesilisik, 2016) as these countries are more vulnerable to the impacts of resource constraints and climate change.

Although resource constraints have come into focus globally, they have also become one of the major concerns in Nigeria. At present, Nigeria uses resources three times greater than the rest of the world to generate one unit of GDP (World Bank, 2020)[2]. Adopting Resource Efficiency and Cleaner Production (RECP) practices is vital for Nigeria to address the challenges posed by resource constraints and environmental degradation while ensuring economic growth. Like many other countries, Nigeria faces significant environmental and economic pressures due to unsustainable resource use and industrial practices. By embracing RECP principles, Nigeria can mitigate these challenges and pave the way for a more sustainable and resilient future.

## 1.2. Study Area

Nigeria, located in West Africa, has a total land area of 923,768 square kilometers (356,669 square miles). Nigeria lies within the latitudes of 4° and 14° North of the Equator and longitudes 3° and 15° East of the Greenwich Meridian (Odekunle, 2006). The country shares borders with the Republic of Benin to the west, Chad and Cameroon to the east, Niger to the north, and the Gulf of Guinea to the south. Despite its location within the tropics, Nigeria's climate varies from tropical near the coast to sub-tropical further inland. There are two distinct seasons: the rainy season, which spans from April to October, and the dry season, which runs from November through March. Geologically, Nigeria's landmass comprises three main basement complexes located in the west, northwest, and

[2] https://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS?locations=NG

southeast (Tijani, 2023). Between these massifs are sedimentary basins composed of recent deposits of clay, sand, and gravel, stretching along the northeast and southwest axis from Lake Chad to the Niger Delta, following the length of the lower Niger-Benue River Systems.

Nigeria is endowed with abundant natural resources. It is blessed with wetlands, valuable forests, grassland areas, abundant sunshine and rainfall, and numerous water bodies with aquatic life and potential for hydropower generation. The country's oil reserves are estimated at 37.5 billion barrels (NNPC, 2024), while its natural gas reserves are reported to be around 206.53 trillion cubic feet as of 2021(NNPC, 2021). There are over 44 different solid minerals found in commercial quantities across the 36 states and the Federal Capital Territory (FCT) Abuja (KPMG, 2024).

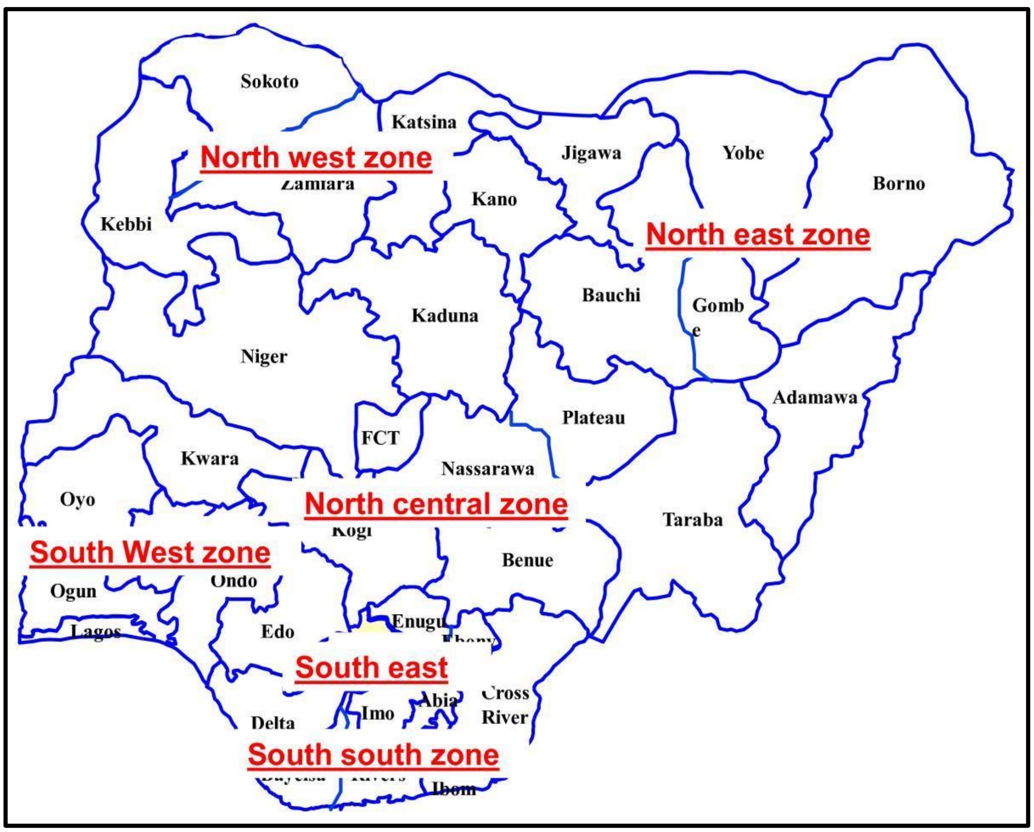


Figure 2: Map of Nigeria showing the states and geopolitical zones[3]

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https://www.researchgate.net/publication/335832704_GEOTECHNICAL_PROPERTIES_AND_STRENGTH_CHARACTERIZATION_OF_NIGERIAN_SOILS

Table 1: key socio-economic indicators for Nigeria

| Indicator | Value | Year | Reference | Link |
|---|---|---|---|---|
| Surface area | 923,768 km² | 2023 | World Bank - Nigeria Overview | https://www.worldbank.org/en/country/nigeria/overview |
| Population | 223 million | 2023 | World Bank - Nigeria Data | https://data.worldbank.org/country/nigeria |
| Population growth | 2.5% | 2023 | World Bank - Nigeria Data | https://data.worldbank.org/country/nigeria |
| Population density | 244 people/km² | 2023 | World Bank - Nigeria Data | https://data.worldbank.org/country/nigeria |
| Life expectancy at birth | 59.5 years | 2023 | World Bank - Nigeria Data | https://data.worldbank.org/country/nigeria |
| GDP | $477 billion | 2021 | World Bank - Nigeria GDP | https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=NG |
| GNI per capita | $2,330 | 2021 | World Bank - Nigeria GDP | https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=NG |
| GDP growth | 3.1% | 2023 | World Bank - Nigeria Data | https://data.worldbank.org/country/nigeria |
| Inflation (GDP deflator, annual, in %) | 17.1% | 2021 | World Bank - Nigeria GDP | https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG?locations=NG |
| Unemployment rate | 33.3% | 2023 | National Bureau of Statistics (Nigeria) - Labour Force Statistics | https://nigerianstat.gov.ng/elibrary?queries[search]=labour%20force%20statistics |
| Poverty headcount ratio at $1.90 a day | 40.1% | 2021 | World Bank - Nigeria Development Indicators | https://data.worldbank.org/indicator/SI.POV.DDAY?locations=NG |
| Access to electricity | 85.2% | 2021 | World Bank - Nigeria Development Indicators | https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NG |
| Access to improved water sources | 72.3% | 2021 | World Bank - Nigeria Development Indicators | https://data.worldbank.org/indicator/SH.H2O.SMDW.ZS?locations=NG |
| Literacy rate (ages 15 and above) | 62.1% | 2021 | World Bank - Nigeria Development Indicators | https://data.worldbank.org/indicator/SE.ADT.LITR.ZS?locations=NG |

As a country with an emerging economy, Nigeria has achieved tremendous success in industrial growth. The Government of Nigeria is ambitious to be a middle-income country by 2021. Moreover, Goldman Sachs names Nigeria in its list of "Next 11" countries (those most likely to become one of the world's largest economies after the BRIC nations) (Bhuiyan et al., 2022), and the country is one of JP Morgan's "Frontier Five" economies. These predictions are based on the rapid economic growth facilitated by the rising industrial growth.

Nigeria's energy-intensive manufacturing includes chemicals (fertilizer), ceramics, cement, paper and pulp, and iron and steel. These energy-intensive industries primarily rely on natural gas as their main energy input, fully sourced from domestic supply sources. The industrial sector is one of the largest consumers of natural gas in Nigeria. In 2022, the industry sector consumed 38% of the natural gas, while 34% was used for power generation[4].

[4] https://www.statista.com/statistics/1308588/natural-gas-demand-in-nigeria/

## 1.3. Overview of Industrial Development in Nigeria

Nigeria has a diverse and rapidly growing industrial sector that plays a crucial role in the country's economic development and job creation (Lin et al., 2015). The industrial sector encompasses many subsectors, including oil and gas, manufacturing, agriculture, mining, and construction. The Nigerian industrial sector is a significant contributor to the country's economy and a major source of employment. The industrial sector contributed approximately 30.78% to Nigeria's Gross Domestic Product (GDP) in 2022[5]. Regarding employment, the industrial sector is a crucial source of job opportunities for Nigerians. The manufacturing subsector alone employed over 2.5 million people in 2020, representing approximately 12.5% of the total workforce (NBS, 2021). The agriculture and mining subsectors also provide significant employment opportunities, particularly in rural areas. Nigeria's industrial sector comprises several key industries that play a vital role in the country's economic development. The major industrial sectors in Nigeria include:

Oil and Gas Industry: The oil and gas industry is the backbone of Nigeria's economy and the most significant industrial sector. Nigeria is Africa's leading oil producer and has vast reserves of crude oil and natural gas, which account for over 95 per cent of export earnings, 25 per cent of GDP, and about 90 per cent of government revenue (Olayungbo, 2019). Major players in the industry include the Nigerian National Petroleum Corporation (NNPC), Shell, ExxonMobil, Chevron, and Total, among others.

Manufacturing Industry: The manufacturing industry in Nigeria is diverse, encompassing sectors such as food and beverages, textiles and apparel, cement, pharmaceuticals, and consumer goods. According to the Manufacturers Association of Nigeria (MAN), the sector contributes about 9% to the country's GDP[6] and employs over 2 million people. Major manufacturing hubs are in Lagos, Ogun, Kaduna, Anambra, Abia and Kano States.

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[5] https://www.statista.com/statistics/382311/nigeria-gdp-distribution-across-economic-sectors/
[6] https://sunnewsonline.com/nigeria60-manufacturing-sector-contributes-meagre-9-to-gdp/

Agriculture and Agro-Allied Industries: Agriculture is a significant industry in Nigeria, employing over 36% of the country's labor force[7]Major agricultural products include cassava, yams, maize, rice, and sorghum, as well as livestock and fisheries. Agro-allied industries, such as food processing, are also vital parts of the industrial landscape.

Mining and Solid Minerals: Nigeria has abundant solid mineral resources, including coal, tin, iron ore, limestone, and gold, among others. The mining industry has witnessed renewed interest and investment in recent years, with the government actively promoting the sector's development.

The Nigerian industrial sector has transformed significantly, transitioning from a predominantly agricultural-based economy to a more diversified industrial landscape. Its development can be traced back to the colonial era (1882 – 1960), when the country's abundant natural resources and favourable climatic conditions attracted foreign investment in agriculture, mining, and trade.

Following independence in 1960, the Nigerian government implemented various policies and initiatives to promote industrialization, including establishing import substitution industries and creating industrial estates and free trade zones. However, the discovery and exploitation of oil reserves in the late 1950s and early 1960s significantly reshaped the industrial landscape, leading to a shift towards the oil and gas industry and a gradual decline in other sectors such as agriculture and manufacturing (Chete et al., 2014). In recent years, a renewed focus has been on diversifying the economy and revitalizing non-oil sectors to reduce the country's over-reliance on the volatile oil and gas industry.

One of the major characteristics of Nigerian industries is that they are spatially distributed and relate very closely to the sources of raw materials. Several studies, such as Ikporukpo (2002), have identified four broad areas of concentration of industries and some isolated areas, like the five industrial towns: Ajaokuta, Kainji, Sokoto, Maiduguri, and Makurdi. The major zones are as follows.

[7] https://www.pwc.com/ng/en/assets/pdf/afcfta-agribusiness-current-state-nigeria-agriculture-sector.pdf

• North-Central Zone: This zone comprises industrial towns like Kano, Zaria, Gusau, Kaduna, and Jos, where goods such as drinks, food products, textiles, car assembly, leather products, petrochemicals, breweries, ceramics, tin-smelting, and steel rolling mills abound.

• South-West Zone: This zone comprises industrial towns like Lagos, Ota, Ibadan, Ewekoro, and Shagamu, where goods such as food products, power, chemical products, Pharmaceuticals, textiles, boat building, car assembly, shoes, and steel products are available.

• Mid-South Zone: This zone comprises industrial towns like Benin City, Edo, Sapele, and Warri, where sawmills, glass factories, petroleum products, soft drinks, breweries, and power generation abound.

• South-East Zone: This zone comprises industrial towns like Port Harcourt, Aba, Onitsha, Enugu, Calabar, Nkalagu, Umuahai, and Opobo. Industries here include car assembly, petroleum products, drinks, power generation, chemical products, shoes, and heavy machine tools.

Of all the areas of concentration, the most significant are the Lagos – Ibadan axis and Kano City, which account for over 60% and 10% of all the nation's industries, respectively. The reasons for the high concentration of industries in these zones are not unconnected with the high concentration of population that provides a ready market for the products, availability of raw materials and infrastructure needed by industries, government policy, economics of agglomeration, and accessibility to all parts of the world (Maton et al., 2016).

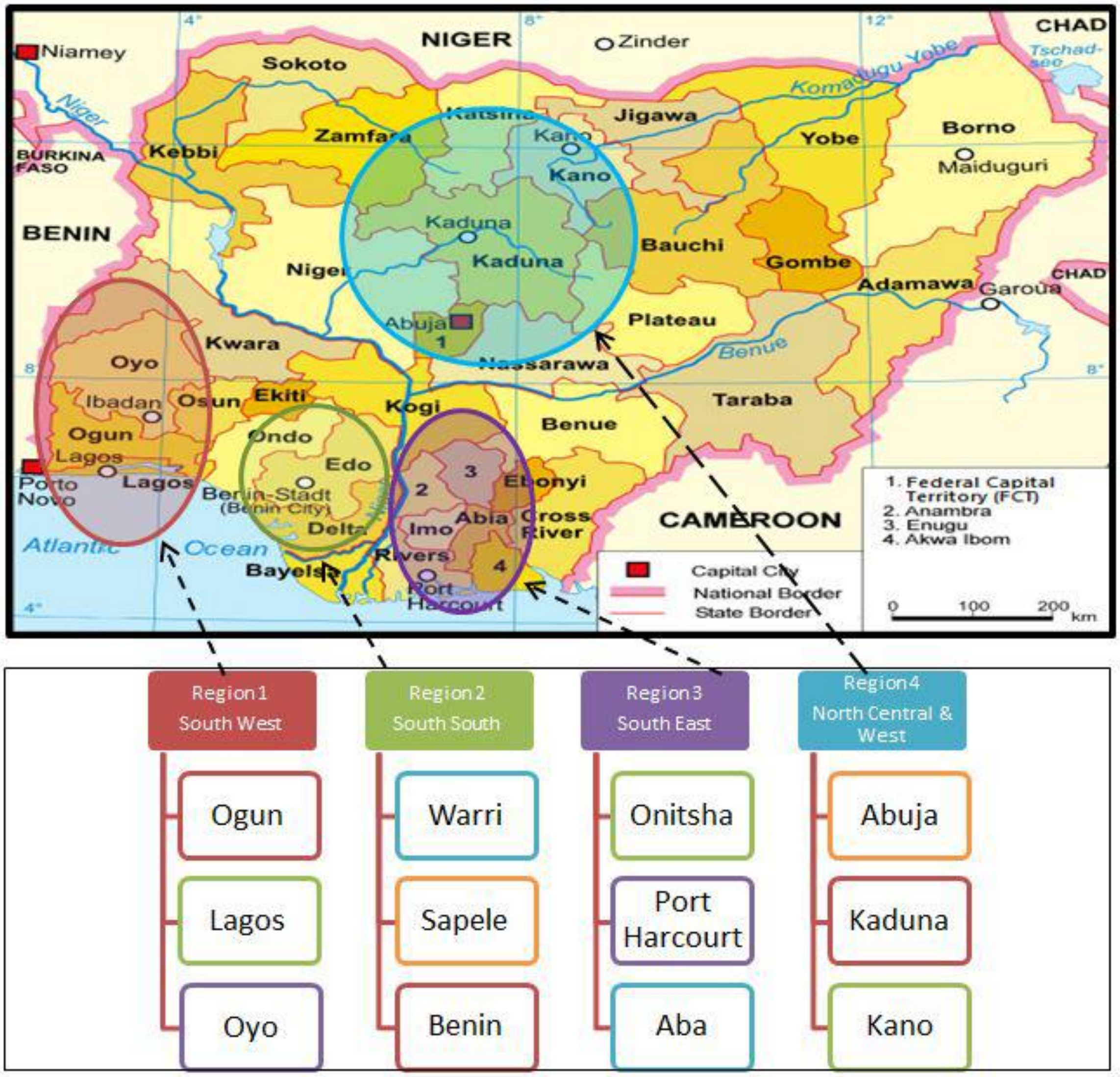


Figure 3: Map of Nigeria showing locations and activities of industrial subsectors[8]

[8] https://downloads.unido.org/ot/17/42/17426600/9714_Environmental_and_Social_Management_Plan.pdf

## 1.4. Industrial Pollution in Nigeria in the Context of RECP

### 1.4.1. Industrial Pollution and Emissions in Nigeria

Numerous studies have been conducted to assess the levels and impacts of industrial pollution in Nigeria, particularly in areas with high concentrations of manufacturing, oil and gas activities, and mining operations. These studies have employed various methodologies, including field sampling, laboratory analysis, and modelling techniques, to evaluate the extent and severity of pollution from industrial sources. For instance, Osu and Nwachukwu (2017) provided a comprehensive review of land-based sources of pollution in the Niger Delta area. Ahmad (2003) carried out research to demonstrate the need for shifting the focus of environmental policy in Africa in general, and Nigeria in particular, from the wrongful assumption of voluntary compliance by industries to a proactive strategy by agencies of active enforcement and implementation of existing rules. Also, Olayinka et al. (2019) conducted a systematic review of studies on industrial pollution in Nigeria, focusing on the oil and gas sector, and identified knowledge gaps and areas for future research.

Different industrial activities have led to multifarious pollution in Nigeria. They have extensively contaminated water bodies and land, adversely impacting aquatic ecosystems, biodiversity, air quality and natural soil properties. Untreated or inadequately treated effluents from industries like textile, food processing, and chemical manufacturing contain high levels of organic matter, heavy metals, and other toxic substances, which have seriously contaminated water sources (Ipeaiyeda & Obaje, 2017).

Furthermore, oil spills and leakages from pipelines, storage facilities, and other oil and gas operations in the Niger Delta region have severely impacted water bodies. Mining activities, particularly for solid minerals like coal and iron ore, have led to the discharge of acidic and metal-rich effluents, affecting surface and groundwater quality in surrounding areas. Moreover, improper disposal of industrial solid wastes, spillages, and leakages have resulted in land pollution and soil contamination in various industrial areas. Studies have found high levels of heavy metals, hydrocarbons, and other toxic compounds in contaminated soils across different regions of Nigeria (Ajao & Anurigwo, 2002). The indiscriminate dumping and open burning of industrial solid wastes, such as sludge, ash, and construction debris, can also release pollutants into the (air), soil and local environment (Abiona et al., 2019).

1.4.2. Geographic and Industrial Distribution of Pollution Hotspots and Industrial Zones.

Pollution hotspots and industrial zones with significant environmental impacts are concentrated in regions such as the Niger Delta, Lagos, Kaduna, Kano, and Port Harcourt, among others.

1. **Niger Delta Region**: The Niger Delta region, home to Nigeria's oil and gas industry, This region has been severely impacted by pollution from oil spills, gas flaring, and industrial effluents. Studies have documented high levels of hydrocarbons, heavy metals, and other contaminants in the soil, water, and air.
2. **Lagos and Surrounding Areas**: The Lagos metropolitan area, which hosts a large concentration of industries, including manufacturing, petrochemicals, and power generation, has experienced significant air, water, and land pollution[9]
3. **Industrial Clusters (Kaduna, Kano, Port Harcourt):** Industrial clusters in cities like Kaduna, Kano, and Port Harcourt, which are home to various manufacturing, textile, and chemical industries, have been identified as pollution hotspots. Studies report elevated levels of pollutants in the local environment.

The oil and gas industry, a significant contributor to Nigeria's economy, has been extensively studied due to its profound environmental footprint. Researchers like Bello & Nwaeke (2023), Nriagu et al. (2016), Odeyemi & Ogunseitan (1985) and Aghalino & Eyinla (2009) and several others have conducted studies on oil/gas pollution in Nigeria extensively. Their findings highlighted air emissions (greenhouse gases, particulates, volatile organic compounds - VOCs), water contamination (produced water, oil spills), and land degradation as significant concerns, especially in the Niger Delta region. In addition, petrochemical and chemical industries are major sources of volatile organic

[9] https://www.worldbank.org/en/news/feature/2022/06/03/afw-making-lagos-a-pollution-free-city-solving-the-threat-one-solution-at-a-time

compounds (VOCs), acidic emissions, greenhouse gases, hazardous liquid effluents, and solid wastes containing heavy metals and toxic organics.

The cement manufacturing sector has also been scrutinized by several researchers Etim et al. (2021), Adeniran et al. (2019) and Amah et al. (2020) due to its emissions of particulates, NOx, SOx and CO2 from fossil fuel combustion and limestone calcination. Furthermore, Steel and metallurgical industries contribute significantly to air pollution through particulates, SOx, NOx, CO and heavy metal emissions from coke ovens, blast furnaces and foundries (Ohijeagbon et al., 2022). Effluents containing oils, greases and heavy metals contaminate water bodies near steel mills (Olaleye et al., 2020). Mining, particularly coal mining, has led to severe air pollution from particulates, land degradation from overburden disposal, and water contamination from acid mine drainage rich in heavy metals and sulfates. Other sectors, like food/beverage processing, textiles, pulp/paper, etc., have also contributed significantly to water pollution through untreated organic-rich effluent discharges, depleting oxygen levels in receiving water bodies.

## 1.5. Gaps and Limitations in Current Knowledge

While resource-efficient and cleaner production (RECP) methodologies offer significant potential for promoting sustainable industrial development, several gaps and limitations in the current body of knowledge need to be addressed, particularly in the Nigerian context. One key gap is the lack of comprehensive data on resource consumption, waste generation, and environmental impacts across various industrial sectors in Nigeria. Reliable and up-to-date data is essential for conducting accurate baseline assessments, identifying improvement opportunities, and monitoring the effectiveness of implemented RECP measures.

Another limitation is industrial stakeholders' lack of awareness and technical capacity regarding the benefits and implementation of RECP methodologies. Many Nigerian industries may be unfamiliar with resource efficiency and cleaner production or lack the necessary expertise to implement RECP strategies effectively.

Additionally, the successful implementation of RECP methodologies hinges on the presence of enabling policy frameworks and incentive structures. In many cases, the lack of robust environmental regulations, insufficient enforcement mechanisms, and the absence of incentives for sustainable practices can hinder the widespread adoption of RECP strategies. Addressing these policy gaps requires collaboration between policymakers, industry stakeholders, and environmental experts to develop and implement effective regulatory and sustainable incentive schemes.

## 1.6. Study Significance and Rationale

Nigeria's industrial sector plays a pivotal role in the country's economic development, contributing substantially to the GDP, employment generation, and export earnings. According to the National Bureau of Statistics (NBS), this sector, comprising mining and quarrying, manufacturing, and utilities, accounted for approximately 30.78% of Nigeria's GDP in 2022[10]. However, many industries within this sector are heavily energy-intensive and have the potential to generate significant environmental waste and pollution, such as cement, agro-processing industries, chemicals, pharmaceuticals, oil and gas (upstream and downstream), food processing, and other sub-manufacturing sectors.

The research holds significant implications for achieving sustainable industrial development, proper resource utilization and environmental protection in Nigeria. By promoting the adoption of Resource Efficient and Cleaner Production (RECP) methodologies, this study will contribute to mitigating the negative environmental impacts of industrialization, including soil, air, and water pollution, greenhouse gas emissions, waste generation, and resource depletion. Furthermore, it will enhance resource efficiency and productivity in Nigerian industries, leading to cost savings, increased competitiveness, and long-term economic resilience.

[10] https://www.statista.com/statistics/382311/nigeria-gdp-distribution-across-economic-sectors/#:~:text=Distribution%20of%20gross%20domestic%20product%20(GDP)%20across%20economic%20sectors%20Nigeria%202022&text=In%202022%2C%20agriculture%20contributed%20around,percent%20from%20the%20services%20sector

Moreover, this research aligns with Nigeria's transition toward a circular economy and green growth, supporting national and international sustainable development goals, such as the United Nations Sustainable Development Goals (SDGs). The generation of empirical evidence and best practices from this research will inform the development of RECP frameworks and guidelines for Nigeria and other emerging economies countries facing similar industrial and environmental challenges.

By addressing the environmental and resource efficiency concerns associated with Nigeria's significant industrial sector, this study can catalyze sustainable economic growth while preserving the nation's natural resources and mitigating the detrimental environmental impacts of industrialization. The findings and recommendations from this research can serve as a blueprint for policymakers, industry stakeholders, and international organizations to foster a more sustainable and resilient industrial landscape in Nigeria and beyond.

## 1.7. Research Objectives

i. Conduct a comprehensive assessment of the impact of RECP practices on environmental performance and resource efficiency across multiple industrial sectors in Nigeria, focusing on the textile, brewery, plastic, and steel industries.

ii. To benchmark the Resource Efficient and Cleaner Production (RECP) practices of selected Nigerian industries against international best practices and standards, focusing on identifying performance gaps, potential areas for improvement, and strategies for achieving globally competitive resource efficiency and environmental sustainability.

iii. Conduct a sector-comprehensive assessment of the current level of awareness, adoption, and potential for RECP methodologies among Nigerian industries across various

iv. Identify and analyse the barriers and enablers to implementing RECP methodologies in Nigerian industries.

v. Develop policy recommendations and strategies to promote the widespread adoption of RECP methodologies in Nigeria in alignment with national and international sustainable development goals and environmental regulations.

**Expected Outcomes**

A. A comprehensive assessment of the potential of RECP methodologies in mitigating Nigeria's industrial and environmental impact.
B. Recommendations for policymakers on strengthening the policy and regulatory environment to promote RECP adoption.

# Chapter 2 : Literature Review

## 2.1. Conceptual Basis

Cleaner production, defined as "the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment" (UNEP, 2006), forms the foundation of RECP. Resource efficiency, rooted in the concept of cleaner production, aims to optimize material use throughout the product lifecycle, including extraction, design, consumption, and disposal[11]. RECP seeks to minimize resource use, waste, and emissions while promoting sustainable industrial practices (Khalili et al., 2015). The concept emphasizes accountability in resource use, striving to reduce resources[12] and carbon emissions per unit of production. It also encompasses various methodologies to enhance resource efficiency and reduce environmental impacts across product lifecycles (Lodhia et al., 2022).

It can be surmised that resource efficiency, a key pillar of cleaner production, seeks to optimize material use throughout the entire product lifecycle, from extraction and design to consumption and disposal (Figures 4 & 5). RECP promotes "doing more with less" by efficiently using resources to prevent pollution and reduce carbon emissions (Flachenecker & Rentschler, 2019. The RECP methodology is considered essential for achieving a low-carbon industry by reducing energy intensity and greenhouse gas emissions (UNEP, 2012). The concept also stresses the importance of reducing waste and emissions at the source (Staniskis & Katiliute, 2017).

RECP's conceptual basis lies in sustainability, aiming to balance economic, social, and environmental considerations[13]. Its implementation involves principles such as a life

[11] https://www.eu4environment.org/areas-of-work/resource-efficient-and-cleaner-production/
[12] https://www.giz.de/de/downloads/giz2023_EN_WECC_Bakery%20and%20Sweets%20Guidelines.pdf
[13] https://www.unido.org/our-focus-safeguarding-environment-resource-efficient-and-low-carbon-industrial-production/resource-efficient-and-cleaner-production-recp

cycle perspective, waste hierarchy, eco-efficiency, and stakeholder engagement. RECP also recognizes the importance of a supportive policy and regulatory environment.

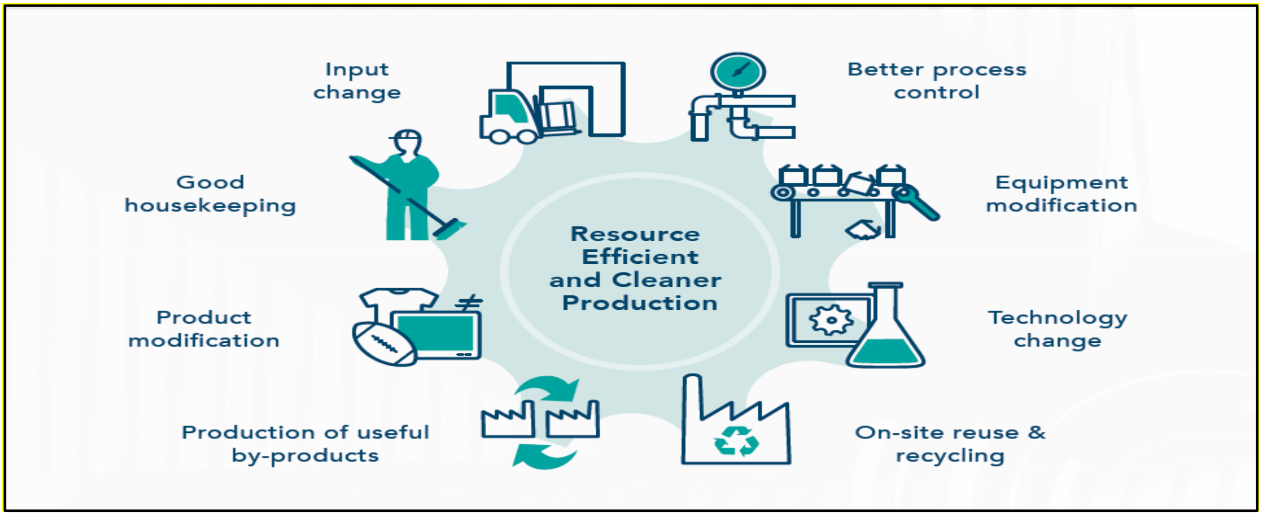


Figure 4: Conceptual image[14]

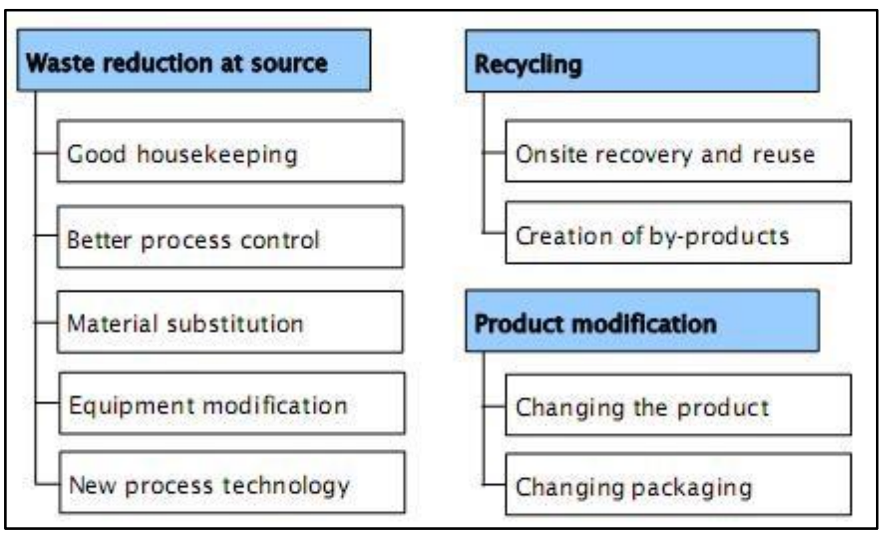


Figure 5: Resource-efficient and cleaner production options[15]

By adopting RECP methodologies, industries can achieve cost savings, improved efficiency, and increased productivity (UNIDO & UNEP, 2010); more positively, these methodologies can be tailored to different sectors and circumstances. RECP provides a

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[14] https://www.unido.org/sites/default/files/files/2020-02/IRE%20and%20Circular%20Economy.pdf
[15] UNEP,http://www.unep.org/resourceefficiency/Portals/24147/scp/presme/pdf/web_recp_indicator_peru.pdf,

comprehensive approach for industries to achieve long-term competitiveness while preserving natural resources and promoting environmental and social well-being (Asha'ari & Daud, 2019). It encompasses various strategies and techniques to improve resource efficiency and reduce environmental impacts throughout the production cycle. Adopting RECP methodologies is crucial for promoting sustainable industrial development and mitigating environmental impacts. RECP offers numerous benefits, including:

- Improved resource efficiency: By optimizing the use of raw materials, energy, and water, RECP helps industries reduce their operational costs and enhance their competitiveness.
- Reduced environmental impact: RECP techniques aim to minimize waste generation, emissions, and the depletion of natural resources, thereby reducing the industry's ecological footprint.
- Compliance with environmental regulations: Implementing RECP practices can help industries meet regulatory requirements and avoid penalties associated with non-compliance.
- Enhanced corporate image: Adopting sustainable practices through RECP can improve a company's environmental reputation and foster positive stakeholder relationships.
- Increased productivity and profitability: RECP can increase industries' productivity and profitability by optimizing processes, reducing waste, and improving efficiency.

## 2.2. History and Evolution of RECP

The 1972 United Nations Conference on the Human Environment in Stockholm first acknowledged the need for sustainable production methods. This is where one of the earliest references to cleaner production can be found. The United Nations Environment Programme (UNEP) and the International Cleaner Production Network (ICPN) both helped to develop the momentum for the idea in the 1980s and 1990s (Fresner, 1998)

(Huhtala, 1997)). According to the Brundtland Commission report (1987)[16], the excessive use of natural resources led to environmental damage and reduced quality of life. Traditional environmental protection focused on treating waste and emissions after they were created to comply with regulations. This end-of-pipe approach was prevalent in Europe until the 1980s. As industrial development increased pollution, the reactive approach involved diluting wastewater and dispersing exhaust gases. By the early 1990s, it became clear that this approach was insufficient. Legislations then demanded treatment of waste, wastewater, and emissions, although this was costly. From the 1990s onward, a preventive approach was promoted, aiming to identify and prevent sources of waste and emissions at the source (Figure 6).

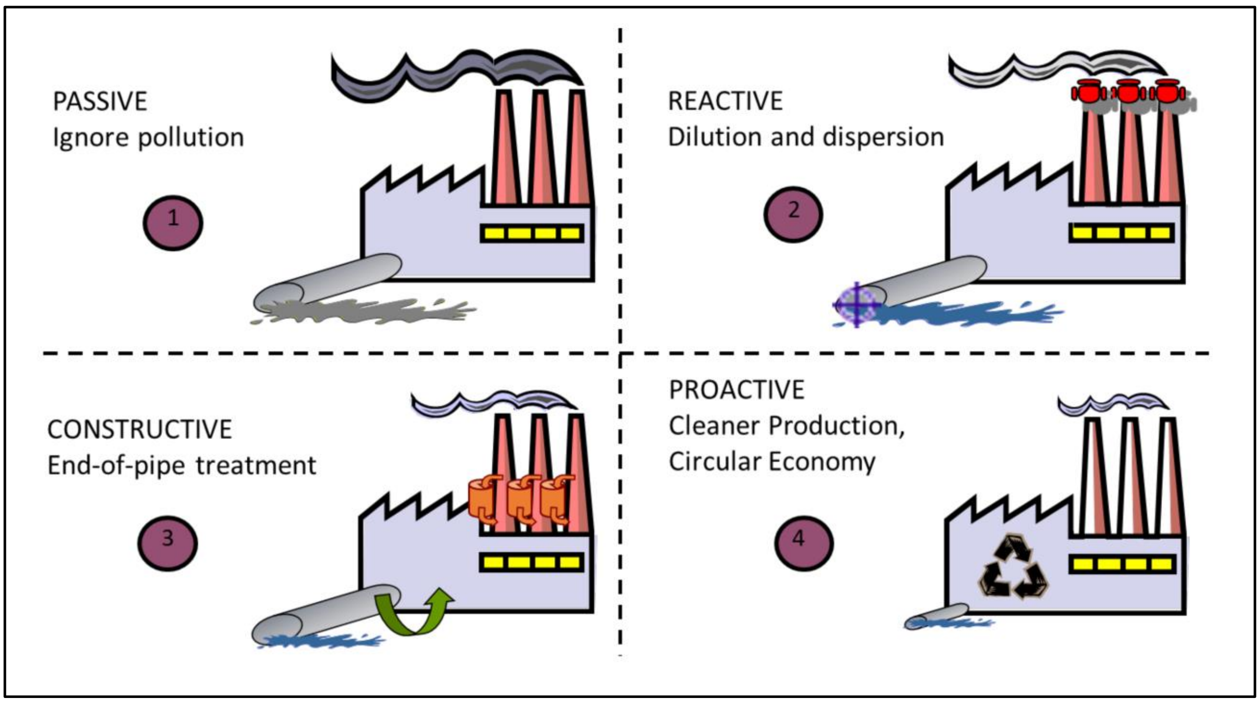



Figure 6: Progress toward RECP in the responses of businesses to pollution[17]

To counter this problem, in 1990, UNEP defined the term "cleaner production" (CP) to promote the transition toward a more sustainable industrial system and green industry (Vargas et al., 2019). The early 2000s saw a growing recognition of the need to integrate resource efficiency into cleaner production strategies. In 2002, the World Summit on

[16] https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf
[17] https://www.giz.de/de/downloads/giz2023_EN_WECC_Bakery%20and%20Sweets%20Guidelines.pdf

Sustainable Development in Johannesburg emphasized the importance of decoupling economic growth from environmental degradation through improved resource efficiency[18].

Since its conceptualization up to 2020, cleaner production has been applied in 72 countries around the globe (Ongechi & Mandala, 2021), using the experience of industrialized nations and their commitment to providing developing and transition countries with methods, practices, and techniques for more sustainable production by building national structures—the national cleaner production centers—and technical capacities—the national experts—to ensure further scaling up and replication of cleaner production applications (Van Berkel, 2015).

However, due to the global economic and environmental crisis, together with growing consumer awareness and legislative pressure in recent decades, the United Nations Industrial Development Organization (UNIDO), together with UNEP, broadened the definition of CP and included the concept of resource efficiency (RE), which is the crucial element of the transition toward sustainable industrial production (Vargas et al., 2019). In 2008, UNEP and UNIDO jointly established the Resource Efficient and Cleaner Production (RECP) program to build upon the cleaner production approach and incorporate resource efficiency principles[19].

The RECP approach gained momentum by adopting the 2030 Agenda for Sustainable Development in 2015, which included specific targets for resource efficiency, sustainable consumption, and production patterns (United Nations, 2015)[20]. The Paris Agreement on climate change, adopted in the same year, also highlighted the importance of resource efficiency in mitigating greenhouse gas emissions. Recently, RECP has been widely promoted by international organizations, national governments, and industry associations as a key strategy for achieving sustainable industrial development. UNIDO and UNEP have played a pivotal role in supporting the implementation of RECP projects

[18] https://www.un.org/en/conferences/environment/johannesburg2002
[19] https://www.unido.org/sites/default/files/2010-04/RECP%20Programme%20Flyer%20April%202010%20(2)_0.pdf
[20] https://www.un.org/en/conferences/environment/newyork2015

and initiatives worldwide, focusing on developing countries and economies in transition (UNIDO, 2020).

Furthermore, the development of national and regional policies, strategies, and action plans has supported the adoption of RECP. Many countries have established cleaner production centers and programs to promote RECP practices among industries and businesses. International organizations, such as the Organization for Economic Co-operation and Development (OECD) and the European Union, have also significantly promoted RECP through policy frameworks, guidelines, and funding mechanisms.

Generally, the history and evolution of RECP have been marked by a growing recognition of the need for sustainable production practices and the integration of resource efficiency principles into industrial processes. From its origins in cleaner production, RECP has evolved into a comprehensive approach encompassing various strategies and techniques aimed at minimizing resource use, waste, and environmental impacts throughout the product life cycle. The ongoing efforts of international organizations, national governments, and industry stakeholders have been instrumental in promoting the adoption of RECP worldwide, positioning it as a crucial pathway towards sustainable industrial development and a circular economy.

## 2.3. RECP Implementation and Methodologies

Implementing RECP methodologies often follows a structured approach, such as the Cleaner Production Assessment (CPA) methodology developed by the United Nations Environment Program (UNEP) and the United Nations Industrial Development Organization (UNIDO). The CPA methodology involves a systematic process of data collection, process analysis, identification of improvement opportunities, feasibility assessment, and implementation planning (van Berkel, 2007).

Another widely adopted implementation approach is the ISO 14001 Environmental Management System (EMS) standard, which provides a framework for organizations to manage their environmental aspects and improve their environmental performance[21].

[21] https://www.iso.org/standard/60857.html

The EMS approach incorporates RECP principles by encouraging identifying and implementing opportunities for resource efficiency, waste minimization, and pollution prevention.

Regardless of the specific implementation approach adopted, the successful implementation of RECP methodologies often involves stakeholder engagement, capacity building, and the establishment of enabling policy frameworks and incentive structures. Collaboration between industries, government agencies, research institutions, and local communities is crucial to facilitate knowledge sharing, technology transfer, and the development of context-specific RECP strategies.

The implementation of RECP methodologies typically follows a structured approach, which may include:

1. Baseline assessment: Gathering data and information on current resource usage, waste generation, and environmental impacts to establish a baseline for improvement.
2. Opportunity identification: Identifying specific opportunities for improving resource efficiency, waste minimization, and emission reduction through various RECP techniques.
3. Feasibility analysis: Evaluating identified opportunities' technical, economic, and environmental feasibility.
4. Implementation planning: Developing detailed plans for implementing selected RECP measures, including resource allocation, timelines, and responsibilities.
5. Monitoring and evaluation: Continuously monitoring and evaluating the performance of implemented RECP measures, making adjustments as necessary, and ensuring sustained improvements.

## 2.4. RECP Methodologies

RECP methodologies encompass a wide range of strategies and techniques aimed at optimizing resource utilization, minimizing waste generation, and reducing environmental impacts across the entire production cycle. These methodologies can be broadly categorized into four main areas: energy efficiency measures, waste minimization techniques, water conservation strategies, and adopting cleaner technologies and processes.

**I. Energy Efficiency Measures:** Energy efficiency is a crucial component of RECP, as industrial processes are often energy-intensive and contribute significantly to greenhouse gas emissions and climate change. RECP methodologies for energy efficiency include:

1. Process optimization: This involves analyzing and improving industrial processes to reduce energy consumption, such as through heat integration, process control optimization, and the elimination of unnecessary steps or inefficiencies[22].
2. Energy audits and management systems: Conducting comprehensive energy audits and implementing energy management systems can help identify areas for improvement and monitor energy consumption patterns, enabling targeted interventions and continuous improvement ((UNIDO, 2020)
3. Efficient equipment and technologies: Replacing outdated or inefficient equipment with energy-efficient alternatives, such as high-efficiency motors, furnaces, and lighting systems, can significantly reduce energy consumption.
4. Heat recovery systems: These systems capture and reuse waste heat generated during industrial processes, reducing energy demand and improving energy efficiency.
5. Renewable energy sources: Integrating renewable energy sources, such as solar, wind, or biomass, into industrial operations can reduce reliance on fossil fuels and associated greenhouse gas emissions.

[22] https://natural-resources.canada.ca/energy-efficiency/data-research-insights-energy-efficiency/commercial-industrial-innovation/industrial-systems-optimization/5495

**II. Waste Minimization Techniques:** Treating waste as a resource and designing a circular economy have been identified as key approaches for resource efficiency (Wilts et al., 2016). Reducing waste generation is a key objective of RECP, as waste represents an inefficient use of resources and can contribute to environmental pollution and health hazards (UNIDO, 2019). Waste minimization techniques include:

1. Applying the waste hierarchy: This principle prioritizes waste prevention, reduction, reuse, recycling, and recovery over disposal, encouraging industries to explore opportunities to minimize waste at the source.
2. Cleaner production processes: Modifying production processes to eliminate or reduce the use of hazardous materials, optimize material utilization, and minimize waste streams can significantly reduce the environmental impact of industrial operations.
3. Material substitution: Replacing hazardous or non-renewable materials with more environmentally friendly alternatives can reduce waste generation and associated environmental impacts.
4. Valorization of waste streams: Exploring opportunities to recover and reuse waste materials, by-products, or residues as inputs for other processes or products can create value from waste and contribute to a circular economy.
5. Industrial symbiosis: Establishing collaborative networks where one industry's waste or by-product becomes another industry's input can promote resource efficiency and minimize waste generation at a broader systemic level.

**III. Water Conservation Strategies:** Water is a critical resource for many industrial processes, and its efficient use and conservation are essential components of RECP. Water conservation strategies include:

1. Water audits and management systems: Conducting comprehensive water audits and implementing water management systems can help identify areas for improvement, monitor water consumption patterns, and detect leaks or inefficiencies.

2. Process modifications: Optimizing industrial processes to reduce water consumption, such as through water recycling, reuse, or the adoption of dry or low-water processes, can significantly reduce overall water demand.
3. Water-efficient technologies: Implementing water-efficient technologies, such as low-flow fixtures, high-efficiency washing systems, and water recycling systems, can reduce water consumption while maintaining or improving process efficiency.
4. Wastewater treatment and recycling: Treating and recycling wastewater for reuse in industrial processes or other applications can reduce the demand for freshwater resources and minimize the discharge of polluted effluents.
5. Rainwater harvesting: Collecting and utilizing rainwater for industrial processes or other non-potable uses can supplement and reduce the demand for freshwater resources.

**IV. Adoption of Cleaner Technologies and Processes:** Integrating cleaner technologies and processes is a fundamental aspect of RECP, enabling industries to minimize their environmental impact while maintaining or enhancing productivity and competitiveness. Cleaner technologies and methods include:

1. Environmentally sound technologies: Adopting technologies and processes that minimize resource consumption, waste generation, and environmental impacts, such as clean production processes, sustainable product design, and eco-friendly materials.
2. Green chemistry: Applying principles of green chemistry, such as using renewable or less hazardous materials, designing for energy efficiency, and minimizing waste generation, can reduce the environmental impact of chemical processes and products.
3. Eco-design: Incorporating environmental considerations into product design, including material selection, energy efficiency, recyclability, and end-of-life management, can minimize products' environmental impact throughout their life cycle.
4. Cleaner production processes: Modifying production processes to eliminate or reduce the use of hazardous materials, optimize resource utilization, and minimize

waste streams can significantly reduce the environmental impact of industrial operations.

5. Environmental management systems: Implementing structured environmental management systems, such as ISO 14001, can help industries identify and manage their environmental aspects, set objectives and targets, and continuously improve their environmental performance.

These RECP methodologies are often implemented in an integrated and holistic manner, addressing multiple aspects of resource efficiency, waste minimization, and environmental impact reduction. These methodologies' specific combination and application may vary depending on the industrial sector, production processes, and local conditions. Still, the underlying principles of RECP remain consistent: optimizing resource utilization, minimizing waste and emissions, and promoting the adoption of cleaner technologies and processes throughout the production cycle.

## 2.5. State of the Art

Thousands of companies have benefited from the adoption of sustainable solutions, which have contributed to improving their resource efficiency, increasing their productivity, and, at the same time, decreasing their environmental impact. Improving resource efficiency is one of the main pillars of industrial efforts to tackle increasing resource prices and competition for scarce resources (UNIDO, 2011)). Many companies are re-examining their core business strategies to ensure long-term survival in a greenhouse gas-regulated or carbon-constrained world.

More and more companies are embracing so-called game-changing strategies—strategies that allow a company to leapfrog its competitors by creating new markets or reshaping old ones in such a way that they generate or sustain its domination (Draper & Mbirimi, 2010). Industries are realizing the importance of applying resource-efficient methodologies to their processes, as the cost of production resources such as water, energy, and materials has increased tremendously over the past decade. Businesses rely more on increased production through resource efficiency to support their strategy and harness economic competitiveness. UNIDO has just reviewed the effectiveness of these programs with all Cleaner Production Centres across the world (van Beers et al., 2020), and the investigation showed that RECP programs in many countries across the globe have reaped remarkably successful results during and after implementation.

Research has highlighted the advantageous ramifications of Resource Efficient and Cleaner Production (RECP) implementation. For instance, the work of Henriques & Catarino (2015) showcases the successful implementation of the RECP concept in 19 small and medium-sized enterprises (SMEs) in Portugal, resulting in reductions in inputs (water, energy, and materials), emissions, and waste. In the Vietnamese craft village industry, implementing RECP practices significantly reduced water consumption, energy usage, and waste generation. For instance, in the Bat Trang ceramic village, water consumption was reduced by 30-50%, and solid waste generation was reduced by 50-70% (Yap et al., 2006). According to Hasanbeigi & Price (2012), the textile industry in Bangladesh implemented RECP practices that included energy efficiency improvements and waste reduction strategies. This led to a 15% reduction in water consumption and a 10% reduction in energy use per unit of textile produced, enhancing overall sustainability. The National Cleaner Production Centre of South Africa (NCPC-SA) has also facilitated RECP implementation in numerous metalworking companies. These efforts have substantially reduced energy and water consumption, waste generation, and environmental impact. In Peru, UNIDO[23] presented several success stories of RECP that demonstrated that improving resource productivity and reducing pollution intensity makes good business sense. For instance, Metalexacto is a small lead foundry in Peru that, by implementing RECP, attained annual savings in the region of almost USD 19,000 and improved working practices and conditions. Even though the company focused mainly on decreasing energy use, the integrated approach enabled increased materials recovery, a decrease of hazardous substances in waste, and a reduction of greenhouse gas (GHG) emissions. Also, RECP implementation in the tannery La Pisqueña led to annual savings in the region of USD 11,400, a credit reimbursement of USD 109,779, and improved product quality. While the company's initial intent was to address the problem of effluents, the RECP programme enabled the company also to improve its energy

[23] https://www.unido.org/sites/default/files/2010-12/RECP_Peru_0.pdf

productivity and reduce the quantity of GHG emissions generated per unit of production. The benefits achieved by UNIQUE, a company producing cosmetics and jewellery, after continuously applying RECP measures include a reduction of energy use by 6%, a reduction of water use by almost 30%, and a reduction of wastewater by more than 50%, accounting for savings of more than USD 79,000 per year. Additional benefits were improved working practices and reduced the company's carbon footprint.

## 2.6. Application of RECP Principles in Nigeria

RECP methodologies can and have been applied across various industrial sectors in Nigeria, including the oil and gas industry. For the oil and gas industry, RECP methodologies can help mitigate the environmental impacts associated with activities such as exploration, production, refining, and transportation. Ite & Ibok (2013) highlight the importance of implementing gas flaring reduction strategies, efficient energy management, and waste minimization techniques in Nigerian oil and gas operations.

Different studies have explored the application of RECP methodologies in various sub-sectors in the manufacturing sector. Jesuleye et al. (2020) investigated the implementation of green innovation practices in the Nigerian food and beverage industry, focusing on waste minimization and resource efficiency. In the brewery industry, Olajire (2020) reviewed some of the challenges in Breweries with a focus on key issues such as water consumption and waste generation, energy efficiency, emission management, the environmental impact of the brewing process and best environmental management practices, which do not compromise the quality of beer. Aiyedun et al. (2008) assessed the energy efficiency of Nigeria Eagle Flour Mills Limited, Ibadan. The research results showed that energy is not quite efficiently utilized because energy productivity increased substantially from 0.369 MJ/kg in 1996 to 0.716 MJ/kg in 2000.

It must be noted that RECP is still a virgin area in Nigeria, and studies on the application are still very scanty. RECP concepts and practices are still in relatively early stages of adoption and implementation across various industrial sectors in Nigeria. While the principles of RECP align with sustainability goals, the dissemination and mainstreaming of these approaches among Nigerian businesses and manufacturers seems to progress gradually. There are likely some isolated examples of companies or industrial parks that have undertaken RECP assessments or piloted cleaner production techniques. However, comprehensive case studies documenting the process, challenges, benefits and quantitative impacts appear to be scarce in the published literature.

# Chapter 3 : Research Methodology

## 3.1. Research Design

This chapter outlines the research methodology employed in this study, encompassing data collection and analysis techniques, the study sites, and the research tools utilized. The research design adopted a mixed-methods triangulation approach (Greene et al., 1989). This approach involves collecting and analyzing both quantitative and qualitative data sets. Integrating the findings from these complementary data sources can provide a comprehensive understanding of the research questions (Greene et al., 1989). The quantitative component utilized energy, material and resource consumption data from the companies assessed. The quantitative data provided a baseline upon which to assess the impact of RECP on energy, material and resource use. Furthermore, the qualitative aspect of the study involved semi-structured interviews and discussions with key stakeholders, including company managers and expert consultants.

## 3.2. Study Sites and Selection Criteria

Companies were selected based on the following criteria:

- Willingness to participate: Companies were approached through industry associations and expressed interest in participating in the research after understanding the objectives and potential benefits.
- Commitment to implementing RECP interventions: Companies demonstrated a commitment to improving resource efficiency and reducing their environmental footprint. This was assessed through their existing environmental management practices and willingness to invest in RECP interventions.
- Company managers' availability to contribute data: The research required access to company data on energy consumption and production figures. Companies with designated personnel responsible for energy management or sustainability practices were prioritized.

- Sector representation: Companies and sectors were selected to ensure adequate representation of key industrial sectors
- Environmental impact and resource consumption: Priority was given to industries with significant environmental impacts and resource consumption levels, such as energy-intensive processes, water usage, waste generation, and greenhouse gas emissions.

## 3.3. Sectors Selected for Research and the Rationale

Four industrial sectors were selected for analysis in this research, and the rationale for the selection of each of the sectors is provided below.

**Food, Beverage, and Tobacco:** This industry significantly contributes to Nigeria's GDP and employs a large workforce. However, it faces water usage, energy consumption, and waste management challenges. An RECP assessment can help identify opportunities for efficient water use, reduction of post-harvest losses, and implementation of cleaner production techniques. According to the Nigerian National Bureau of Statistics (NBS), the food, beverage, and tobacco industry accounted for 22.1% of the country's total manufacturing output in 2020[24]. Also, Nigeria is the second-largest producer of beer in Africa[25], with a growing demand for soft drinks and processed foods. The industry consumes significant amounts of water and energy, with potential for efficiency improvements. Food waste and losses are substantial, with estimates suggesting up to 30% of produce is lost post-harvest.

**Textile, Leather/Leather Footwear:** Nigeria's textile industry has experienced significant growth in recent years, with a focus on cotton production and garment manufacturing. An RECP assessment can help address environmental concerns related to water pollution, chemical usage, and waste generation, Nigeria’s annual production of cotton falls between 300,000 and 400,000MT of seed cotton or 110,000 MT of lint, which is about 607,735 bales of cotton lint produced majorly by small-scale farmers, with farm

[24] https://www.nigerianstat.gov.ng/
[25] https://www.statista.com/statistics/202411/beer-production-in-different-african-countries-in-2010/

sizes ranging from 3-5 hectares all under rain-fed ecologies[26]. The industry faces environmental challenges related to water pollution, chemical usage, and waste generation. The textile, leather, and footwear industries contributed 10.3% to the country's manufacturing output in 2020, with a growth rate of 12.1% between 2019 and 2020 (NBS). Implementing RECP practices can help reduce the industry's environmental footprint and improve competitiveness.

**Domestic/Industrial Plastics:** Nigeria's plastics industry is rapidly growing, driven by demand for packaging materials, plastic products, and construction materials. The plastic industry faces significant environmental challenges related to plastic waste, pollution, and energy consumption. Implementing RECP practices can help reduce plastic waste, minimize pollution, and improve the industry's environmental performance. The plastics manufacturing sector's growth in recent years has been driven by demand for packaging materials, plastic products, and construction materials, with a growth rate of 15.6% between 2019 and 2020 (NBS).

**Steel Industry:** According to the National Bureau of Statistics (NBS), the steel industry contributed 1.8% to Nigeria's GDP in 2020, employing over 200,000 people (NBS, 2021). The industry's growth is driven by increasing construction, manufacturing, and oil and gas demand. However, the steel industry is also one of the most energy-intensive and polluting industries, accounting for significant greenhouse gas emissions and water pollution. The steel industry in Nigeria encompasses various activities, including iron and steel production, steel rolling and processing, and foundries and forging. In 2020, Nigeria produced 2.1 million metric tons of crude steel, with a growth rate of 5.3% between 2019 and 2020 (World Steel Association, 2021). The industry also produced 1.8 million metric tons of finished steel products, with a growth rate of 6.1% between 2019 and 2020 (NBS, 2021). Additionally, the foundries and forging sub-sector contributed 0.6% to the country's manufacturing output, with a growth rate of 7.2% between 2019 and 2020 (NBS, 2021).

[26] https://businessday.ng/real-sector/article/nigeria-opportunity-to-tap-38bn-cotton-market-underexplored/

The steel industry faces a range of environmental challenges. These include high energy consumption, air emissions (particularly $CO_2$, $SO_x$, and $NO_x$), water pollution, water usage, waste generation, and waste management issues. These challenges are prevalent throughout the steel production, processing, and fabrication stages. An RECP assessment in the steel industry can help identify opportunities for improving energy efficiency, reducing air emissions, minimizing water pollution, and promoting sustainable waste management practices.

## 3.4. Data Collection and Sampling

The data collection was carried out from June 2023 to January 2024. The main objective of administering the questionnaire and conducting interviews with company managers and RECP consultants responsible for RECP implementation was to gather their perceptions and understanding of the RECP process and its benefits for reducing carbon emissions and

In this study, a purposive sampling method was employed to select eight companies from four different industries in Nigeria: textile, plastics, food and beverage, and steel. For each industry, two companies were selected: one that had implemented RECP practices and another that had not implemented or adopted the RECP methodology in their operations. This approach allowed for a comparative analysis of each industry's benefits and challenges associated with RECP implementation.

The companies that had implemented RECP practices were identified through their participation in RECP concepts such as UNIDO's Cleaner Production (CP) program or the UNEP RECPnet initiative. To ensure anonymity (which was a major concern for all the responding companies), the names of the companies have been changed. The companies that adopted RECP were labelled as "Eco" companies (e.g., EcoTex, EcoPlast, EcoBrew, and EcoSteel) to distinguish them from their non-RECP counterparts, which were labelled as "Niger" companies (e.g., NigerTex, NigerPlast, NigerBrew, and NigerSteel).

The sample size of eight companies was determined based on the following considerations. The selected companies were representative of their respective industries in size, production processes, and environmental challenges. Although seemingly small, the sample size was deemed sufficient to achieve data saturation, as the selected companies provided a comprehensive overview of the RECP implementation status within each industry. Another reason for the choice of the sample size is feasibility. Given this study's time and resource constraints, a sample size of eight companies was considered feasible for data collection and analysis.

The purposive sampling method was chosen over other sampling techniques, such as random sampling, due to the specific focus on RECP implementation. This approach ensured that the selected companies were relevant to the research objectives and provided the necessary data to address the study's research questions.

## 3.5. Questionnaire

A questionnaire was developed to gather data on the implementation of Resource Efficient and Cleaner Production (RECP) practices in the selected industries and their impact on environmental performance. The questionnaire was designed to capture the perceptions, experiences, and challenges faced by key stakeholders involved in RECP implementation. The questionnaire included a mix of closed-ended and open-ended questions. Closed-ended questions utilized Likert scales, multiple-choice options, and yes/no/not sure responses to facilitate quantitative analysis. Open-ended questions allowed respondents to provide more detailed and qualitative insights. To ensure the validity and reliability of the questionnaire, a pilot study was conducted with a small sample (2). Feedback from the pilot study was used to refine the questionnaire, clarify ambiguous questions, and improve the overall structure and flow of the survey. A template of the questionnaire is presented in the annexe section.

## 3.6. Interviews

Semi-structured interviews were conducted with key stakeholders to gather qualitative data on their perceptions of RECP implementation. Interview participants included Company managers from the participating manufacturing plants and RECP expert consultants. The interview questions were designed to explore the following aspects: stakeholder understanding of the benefits of RECP implementation, Company experiences and challenges encountered during RECP implementation and the perceptions of the effectiveness of RECP interventions in reducing resource consumption and emissions. The interview format allowed for open-ended responses to capture rich qualitative data.

## 3.7. RECP Indicator System

In this study, the Resource Efficient and Cleaner Production (RECP) Indicator System was employed as a methodology to assess the implementation and effectiveness of RECP practices in the selected companies from the textile, plastics, food and beverage, and steel industries in Nigeria.

The RECP Indicator System provides a standardized framework for measuring and monitoring the environmental performance of companies, allowing for the evaluation of RECP implementation and its impact on resource efficiency and other indicators. The RECP Indicator System utilizes both absolute and relative indicators to assess the environmental performance of companies (UNIDO & UNEP, 2010)[27].

Absolute indicators measure basic data in a given time frame, typically one year, and include metrics such as tons of Carbon Dioxide ($CO_2$) emitted annually, tons of waste generated annually, and annual production. These indicators provide a baseline understanding of the company's environmental impact and resource consumption. The absolute production indicator or reference indicator covers the product output or value created by the enterprise. It is preferably measured in a relevant physical unit (tons, kiloliters, or units) of production or service of the enterprise. However, when different products or services are created, using the economic value (sales value) as a proxy might be acceptable.

Relative indicators, on the other hand, measure the efficiency of resource use and the intensity of emissions relative to the production output or value created by the company. These indicators are derived by dividing the absolute indicator values by a reference indicator, such as the physical units of production or the economic value of sales. Relative

[27] https://www.recpnet.org/wp-content/uploads/2016/07/Enterprise-Level-Indicators.pdf

indicators allow for comparing environmental performance across different companies, industries, and periods, as they normalize the data based on the scale of production or economic activity.

Regarding environmental performance, productivity and intensity ratios are central relative indicators (Figure 7). Productivity ratios quantify the amount of product output per unit of resource use, e.g., the tons of product output per ton of materials used or the volume of services delivered per cubic meter of water used. Sustainability considerations require increasing productivity ratios over time, leading to more production per resource unit. Further, intensity ratios quantify the amount of resources used or the amount of emissions per unit of production, e.g., CO2 emissions per unit of production or waste generated per unit of production. Sustainability considerations require intensity ratios to decrease over time, leading to less pollution per production unit.

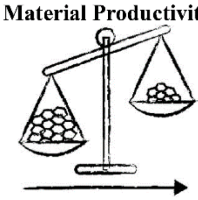
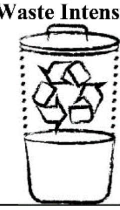
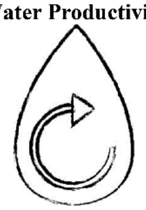
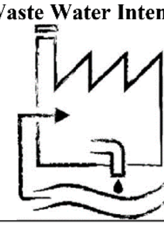
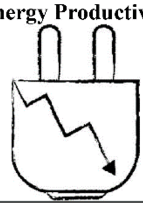
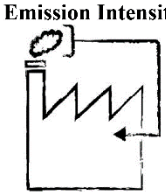
| INCREASE<br>**Resource Productivity**<br>*Through* | | DECREASE<br>**Pollution Intensity**<br>*Through* | |
|---|---|---|---|
| **Material Productivity**<br> | Selection and efficient use of materials, including chemicals | **Waste Intensity**<br> | Reduction and environmentally sound recovery, treatment and disposal of waste |
| **Water Productivity**<br> | Selection of sources for and efficient use of water | **Waste Water Intensity**<br> | Reduction and environmentally sound treatment and disposal of waste water |
| **Energy Productivity**<br> | Selection of sources for and efficient use of energy | **Emission Intensity**<br> | Reduction and environmentally sound discharge of air emissions |

Figure 7: Scope of Resource Efficient and Cleaner Production (Van Berkel, 2018)

These indicators are central to managing and evaluating the implementation of Resource Efficient and Cleaner Production (RECP) in enterprises. The indicators have been selected based on the premise that they collectively cover the most important environmental aspects of industrial operations, and improvements in these areas generally provide maximum benefits for the environment and business. Moreover, the data required for these absolute indicators should, at least in principle, be available or measurable by any company, resulting in a relatively low implementation cost in relation to the potential benefits.

These absolute indicators are used to compute five relative indicators (Table 2) - three resource-productivity indicators and two pollution-intensity indicators:

**Resource productivity**:

- Energy productivity (product output per unit of energy used)
- Materials productivity (product output per unit of material used)
- Water productivity (product output per unit of water used)

**Pollution intensity**

- Waste intensity (waste generation per unit of product output)
- Wastewater intensity (wastewater generation per unit of product output)

Together, these five relative indicators constitute the enterprise-level RECP profile. Increases in any of the productivity ratios and decreases in any of the intensity ratios over time are beneficial from the environmental and sustainability viewpoints and substantiate the successful implementation of RECP practices and technologies.

Table 2: Enterprise-level RECP indicators

| Name | Expression | Unit |
|---|---|---|
| Material Productivity | product output per unit of material used | (units of product) / (units of material) |
| Water Productivity | product output per unit of water used | (units of product) / ($m^3$ of water) |
| Energy Productivity | product output per unit of energy used | (units of product) / (units of energy) |
| Water Intensity | Total volume of water consumed in main production processes / Normalization factor | $m^3$/NF |
| Wastewater Intensity | Total volume of wastewater generation / Normalization factor | $m^3$/NF |

## 3.9. Benchmarking Analysis

The visited companies' Key Performance Indicators (KPIs) were compared with international and national benchmark values obtained from literature to determine major areas for improvement in Resource Efficient and Cleaner Production (RECP). The benchmarking study used data collected from visited companies that returned completed questionnaires. Factual data related to the companies' operations, resource consumption, and production outputs were gathered through questionnaires. International and national benchmark values for various KPIs were obtained from relevant literature sources, including industry reports, best practice guidelines, and academic publications. These benchmark values represented achievable performance standards in various industries and sectors.

The calculated KPIs of the visited companies were compared with the benchmark values obtained from the literature. This comparative analysis aimed to identify the gap between the companies' existing operating performance and the achievable performance values. The gap between the companies' existing operating performance and the achievable performance values obtained from the literature was identified for each KPI. This gap quantified the potential for improved resource efficiency and cleaner production practices.

The identified gaps were used to determine how much the performance could be improved for the selected KPIs. The benchmarks were accepted as reference values, and deviations from these were considered areas of concern regarding RECP opportunities. The benchmarking analysis allowed for a comprehensive evaluation of the visited companies' performance against established standards and best practices. By identifying the gaps and areas of concern, targeted strategies and interventions could be developed to enhance resource efficiency and promote cleaner production practices within the studied companies.

## 3.10. Data Analysis

Data collected from the questionnaire was analyzed using both quantitative and qualitative methods. Descriptive statistics, such as frequencies and percentages, were used to summarize the closed-ended responses. Thematic analysis was employed to identify patterns and insights from the open-ended responses.

# Chapter 4 : Results and Analysis

## 4.1. Descriptive Analysis

Eight companies' results regarding environmental assessments of selected indicators/parameters are presented here. All data are reported for the years 2018-2022. While these companies are similar, they have differences in housekeeping practices, management systems, etc. Table 3 presents the descriptive statistics of the eight companies selected for this study, categorized by industry and RECP status. The table includes data on the number of employees and annual revenue in Nigerian Naira (NGN). In the textile industry, EcoTex has an average of 275 employees, while NigerTex has an employee count of 400. EcoTex's annual revenue averages 1.35 billion NGN, while NigerTex has a higher annual revenue of 2 billion NGN. The plastics industry follows a similar pattern. EcoPlast, the RECP-adopting company, has an average of 373 employees, while NigerPlast has a higher employee count of 550. EcoPlast's annual revenue averages 1.5 billion NGN, while NigerPlast has a higher annual revenue of 3 billion NGN.

In the food and beverage industry, EcoBrews has an average of 463 employees, while NigerBrew has a higher employee count of 800. EcoBrews' annual revenue averages 2.35 billion NGN, while NigerBrew has a higher yearly revenue of 4 billion NGN. The steel industry exhibits the largest difference in company size and revenue. EcoSteel, the RECP-adopting company, has an average of 1,100 employees, while NigerSteel has a significantly higher employee count of 2,000. EcoSteel's annual revenue averages 16.25 billion NGN, while NigerSteel has a substantially higher yearly revenue of 25 billion NGN.

Across all four industries, the companies that have adopted RECP practices (EcoTex, EcoPlast, EcoBrews, and EcoSteel) have lower employee counts and annual revenues compared to their non-RECP counterparts (NigerTex, NigerPlast, NigerBrew, and NigerSteel). This observation suggests that smaller companies may be more likely to adopt RECP practices due to their flexibility and adaptability to change. These descriptive statistics provide a foundation for understanding the characteristics of the selected companies and their RECP status. The data suggests that company size and revenue may be factors influencing the adoption of RECP practices, with smaller companies being more likely to adopt these practices. The clear distinction in RECP adoption between the "Eco" and "Niger" companies sets the stage for further analysis of the benefits, challenges, and opportunities associated with RECP adoption in Nigeria's textile, plastics, food and beverage, and steel industries.

Table 3 : Descriptive statistic/Mean employee and revenue

| Industrial Sector | Company name | Employees (mean) | Revenue (NGN) (mean) |
|---|---|---|---|
| Textile | EcoTex | 275 | 1.35 billion |
| | NigerTex | 400 | 2 billion |
| Plastic | EcoPlast | 373 | 1.5 billion |
| | NigerPlast | 550 | 3 billion |
| Brewery | EcoBrews | 463 | 2.35 billion |
| | NigerBrew | 800 | 4 billion |
| Steel | EcoSteel | 1100 | 16.25 billion |
| | NigerSteel | 2000 | 25 billion |

## 4.2. RECP Implementation Level

Table 4 presents an overview of the Resource Efficient and Cleaner Production (RECP) implementation status of the eight companies selected for this study, categorized by industry and RECP adoption. The table includes information on the assessment tools used, awareness of RECP practices, implementation status, specific RECP practices adopted, and each company's overall level of RECP implementation.

In the textile industry, EcoTex has utilized the UNIDO Cleaner Production (CP) assessment tool to evaluate its operations and identify opportunities for RECP implementation. The company demonstrated a high level of awareness of RECP practices and has successfully implemented a range of measures, including energy efficiency, water conservation, waste reduction, cleaner production techniques, and environmental management systems (EMS). As a result, EcoTex has achieved a very high level of RECP implementation, rated as a five (5) on a scale of 1 to 5. In contrast, NigerTex has not utilized any assessment tools, lacks awareness of RECP practices, and has not implemented any RECP measures, resulting in a very low RECP implementation level of one (1).

EcoPlast, in the plastics industry, has employed the UNEP RECPnet assessment tool to evaluate its operations and identify RECP opportunities. The company has demonstrated awareness of RECP practices and has implemented measures focused on energy efficiency, waste reduction, cleaner production techniques, and EMS. EcoPlast has achieved a high level of RECP implementation, rated as a four (4) on the scale. NigerPlast, on the other hand, has not utilized any assessment tools, lacks awareness of RECP practices, and has not implemented any RECP measures, resulting in a very low RECP implementation level of one (1).

EcoBrew has used the UNIDO CP assessment tool in the food and beverage industry to evaluate its operations and identify RECP opportunities. The company has shown a high level of awareness of RECP practices. It has successfully implemented a comprehensive range of measures, including energy efficiency, water conservation, waste reduction, cleaner production techniques, and EMS. Consequently, EcoBrew has achieved a very high level of RECP implementation, rated as a five (5) on the scale. In contrast, NigerBrew has not utilized any assessment tools, lacks awareness of RECP practices, and has not implemented any RECP measures, resulting in a very low RECP implementation level of one (1).

EcoSteel, in the steel industry, has also employed the UNIDO CP assessment tool to evaluate its operations and identify RECP opportunities. The company has demonstrated a high level of awareness of RECP practices. It has successfully implemented various measures, including energy efficiency, water conservation, waste reduction, cleaner production techniques, and EMS. As a result, EcoSteel has achieved a very high level of RECP implementation, rated as a five (5) on the scale. NigerSteel, in contrast, has not utilized any assessment tools, lacks awareness of RECP practices, and has not implemented any RECP measures, resulting in a very low RECP implementation level of one (1).

The results reveal a clear pattern of RECP adoption among the selected companies. The "Eco" companies (EcoTex, EcoPlast, EcoBrew, and EcoSteel) have all utilized established assessment tools, such as UNIDO CP or UNEP RECPnet, to evaluate their operations and identify RECP opportunities. These companies have demonstrated a high awareness of RECP practices and have successfully implemented various measures across various areas, including energy efficiency, water conservation, waste reduction, cleaner production techniques, and EMS. As a result, the "Eco" companies have achieved high to very high levels of RECP implementation, with ratings of 4 or 5 on the scale. In contrast, the "Niger" companies (NigerTex, NigerPlast, NigerBrew, and NigerSteel) have not utilized any assessment tools, lacked awareness of RECP practices, and did not implement any RECP measures. Consequently, these companies have a very low level of RECP implementation, rated as a 1 on the scale.

The findings suggest that the utilization of established assessment tools, such as UNIDO CP or UNEP RECPnet, plays a crucial role in raising awareness of RECP practices and guiding companies in identifying and implementing appropriate measures. The successful adoption of RECP practices across various areas, including energy efficiency, water conservation, waste reduction, cleaner production techniques, and EMS, demonstrates the comprehensive nature of RECP implementation among the "Eco" companies.

Table 4: Overview of implementation status

| Company | Assessment Tools | Awareness | Implemented RECP | RECP Practices | RECP Level |
|---|---|---|---|---|---|
| EcoTex | UNIDO CP | Yes | Yes | Energy, Water, Waste, CP, EMS | 5 |
| NigerTex | None | No | No | None | 1 |
| EcoPlast | UNEP RECPnet | Yes | Yes | Energy, Waste, CP, EMS | 4 |
| NigerPlast | None | No | No | None | 1 |

| Company | Assessment Tools | Awareness | Implemented RECP | RECP Practices | RECP Level |
|---|---|---|---|---|---|
| EcoBrew | UNIDO CP | Yes | Yes | Energy, Water, Waste, CP, EMS | 5 |
| NigerBrew | None | No | No | None | 1 |
| EcoSteel | UNIDO CP | Yes | Yes | Energy, Water, Waste, CP, EMS | 5 |
| NigerSteel | None | No | No | None | 1 |

## 4.3. Analysis of Resource Usage and Waste Generation

The provided data presents a comprehensive analysis of the impact of implementing Resource Efficient and Cleaner Production (RECP) practices on various industrial sectors in Nigeria. The data compares the performance of companies that have adopted RECP practices (EcoTex, EcoBrews, EcoPlast, and Ecosteel) with their respective non-RECP counterparts (NigerTex, NigBrew, NigerPlast, and NigerSteel) across several key indicators, including total production, material usage, water consumption, energy use, waste generation and wastewater generation

**Textile Sector:** The data shows a clear distinction between EcoTex (RECP) and NigerTex (non-RECP) in terms of resource efficiency and environmental performance. In 2022, EcoTex produced 26,000 tons of textile products using 28,000 tons of materials, while NigerTex produced 24,000 tons using 43,000 tons of materials, indicating a significantly higher material efficiency for EcoTex. Furthermore, EcoTex consumed 800,000 cubic meters of water and 30,000,000 kWh of energy, compared to 2,600,000 cubic meters of water and 48,000,000 kWh of energy for NigerTex, demonstrating substantial savings in water and energy consumption. The waste generation and wastewater generation figures also highlight the benefits of RECP practices. In 2022, EcoTex generated 1,600 tons of waste and 400,000 cubic meters of wastewater, while NigerTex generated 8,600 tons of waste and 2,000,000 cubic meters of wastewater.

EcoTex (RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used ($m^3$) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 22000 | 24000 | 1000000 | 26000000 | 2000 | 600000 |
| 2019 | 23000 | 25000 | 950000 | 27000000 | 1900 | 550000 |
| 2020 | 24000 | 26000 | 900000 | 28000000 | 1800 | 500000 |
| 2021 | 25000 | 27000 | 850000 | 29000000 | 1700 | 450000 |
| 2022 | 26000 | 28000 | 800000 | 30000000 | 1600 | 400000 |

NigerTex (Non-RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used ($m^3$) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 20000 | 35000 | 2000000 | 40000000 | 7000 | 1400000 |
| 2019 | 21000 | 37000 | 2150000 | 42000000 | 7400 | 1550000 |
| 2020 | 22000 | 39000 | 2300000 | 44000000 | 7800 | 1700000 |
| 2021 | 23000 | 41000 | 2450000 | 46000000 | 8200 | 1850000 |
| 2022 | 24000 | 43000 | 2600000 | 48000000 | 8600 | 2000000 |

**Brewing Sector:** The data for the brewing sector follows a similar pattern, with EcoBrews (RECP) outperforming NigBrew (non-RECP) across all indicators. In 2022, EcoBrews produced 16 million litres of beverages using 37 million litres of materials, while NigBrew produced 12 million litres using 50 million litres of materials, indicating a higher material efficiency for EcoBrews. EcoBrews also consumed 90,000 cubic meters of water and 16,000,000 kWh of energy, compared to 140,000 cubic meters of water and 30,000,000 kWh of energy for NigBrew. The waste generation and wastewater generation figures for EcoBrews were significantly lower than NigBrew. In 2022, EcoBrews generated 70,000 liters of waste and 25,000 cubic meters of wastewater, while NigBrew generated 140,000 liters of waste and 50,000 cubic meters of wastewater

EcoBrews (RECP)

| Year | Total Production (million litres) | Total Material Used (million litres) | Total Water Used (cubic meters) | Total Energy Use (kWh) | Total Waste Generation (litres) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 12 | 45 | 110,000 | 22,000,000 | 110,000 | 35,000 |
| 2019 | 13 | 43 | 105,000 | 20,500,000 | 100,000 | 32,000 |
| 2020 | 14 | 41 | 100,000 | 19,000,000 | 90,000 | 30,000 |
| 2021 | 15 | 39 | 95,000 | 17,500,000 | 80,000 | 28,000 |
| 2022 | 16 | 37 | 90,000 | 16,000,000 | 70,000 | 25,000 |

NigBrew (NON-RECP)

| Year | Total Production (million liters) | Total Material Used (million liters) | Total Water Used (cubic meters) | Total Energy Use (kWh) | Total Waste Generation (liters) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 10 | 42 | 120,000 | 24,000,000 | 120,000 | 40,000 |
| 2019 | 10.5 | 44 | 125,000 | 25,500,000 | 125,000 | 42,500 |
| 2020 | 11 | 46 | 130,000 | 27,000,000 | 130,000 | 45,000 |
| 2021 | 11.5 | 48 | 135,000 | 28,500,000 | 135,000 | 47,500 |
| 2022 | 12 | 50 | 140,000 | 30,000,000 | 140,000 | 50,000 |

**Plastic Sector:** EcoPlast (RECP) exhibited superior resource efficiency and environmental performance in the plastic sector compared to NigerPlast (non-RECP). In 2022, EcoPlast produced 10,350 tons of plastic products using 2,950 tons of materials, while NigerPlast produced 9,200 tons using 4,200 tons of materials. EcoPlast consumed 12,000 cubic meters of water and 14,500,000 kWh of energy, compared to 22,000 cubic meters of water and 27,000,000 kWh of energy for NigerPlast. The waste generation and wastewater generation figures were significantly lower for EcoPlast. In 2022, EcoPlast generated 5,000 tons of waste and 17,000 cubic meters of wastewater, while NigerPlast generated 8,400 tons of waste and 37,000 cubic meters of wastewater.

EcoPlast (RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used ($m^3$) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 10,200 | 3,200 | 14,000 | 18,500,000 | 5,800 | 23,000 |
| 2019 | 10,100 | 3,100 | 13,500 | 17,500,000 | 5,600 | 21,500 |
| 2020 | 10,300 | 3,050 | 13,000 | 16,500,000 | 5,400 | 20,000 |
| 2021 | 10,250 | 3,000 | 12,500 | 15,500,000 | 5,200 | 18,500 |
| 2022 | 10,350 | 2,950 | 12,000 | 14,500,000 | 5,000 | 17,000 |

NigerPlast (Non RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used ($m^3$) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Wastewater Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 9,050 | 4,000 | 20,000 | 25,000,000 | 8,000 | 35,000 |
| 2019 | 9,150 | 4,050 | 20,500 | 25,500,000 | 8,100 | 35,500 |
| 2020 | 9,250 | 4,100 | 21,000 | 26,000,000 | 8,200 | 36,000 |
| 2021 | 9,100 | 4,150 | 21,500 | 26,500,000 | 8,300 | 36,500 |
| 2022 | 9,200 | 4,200 | 22,000 | 27,000,000 | 8,400 | 37,000 |

**Steel Sector:** The steel sector data also highlights the benefits of RECP practices. In 2022, Ecosteel (RECP) produced 108,000 tons of steel using 94,000 tons of materials, while NigerSteel (non-RECP) produced 98,000 tons using 104,000 tons of materials, indicating higher material efficiency for Ecosteel. Ecosteel consumed 460,000 cubic meters of water and 360,000,000 kWh of energy, compared to 590,000 cubic meters of water and 500,000,000 kWh of energy for NigerSteel. Ecosteel generated 16,520 tons of waste and 151,000 cubic meters of wastewater, while NigerSteel generated 25,720 tons of waste and 236,000 cubic meters of wastewater.

Ecosteel (RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used (m) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Waste Water Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 100,000 | 90,000 | 500,000 | 400,000 | 18,200 | 167,000 |
| 2019 | 102,000 | 91,000 | 490,000 | 390,000 | 17,780 | 163,000 |
| 2020 | 104,000 | 92,000 | 480,000 | 380,000 | 17,360 | 159,000 |
| 2021 | 106,000 | 93,000 | 470,000 | 370,000 | 16,940 | 155,000 |
| 2022 | 108,000 | 94,000 | 460,000 | 360,000 | 16,520 | 151,000 |

NigerSteel (NON RECP)

| Year | Total Production (tons) | Total Material Used (tons) | Total Water Used ($m^3$) | Total Energy Use (kWh) | Total Waste Generation (tons) | Total Waste Water Generation ($m^3$) |
|---|---|---|---|---|---|---|
| 2018 | 90,000 | 100,000 | 550,000 | 420,000 | 24,000 | 222,000 |
| 2019 | 92,000 | 101,000 | 560,000 | 440,000 | 24,430 | 225,500 |
| 2020 | 94,000 | 102,000 | 570,000 | 460,000 | 24,860 | 229,000 |
| 2021 | 96,000 | 103,000 | 580,000 | 480,000 | 25,290 | 232,500 |
| 2022 | 98,000 | 104,000 | 590,000 | 500,000 | 25,720 | 236,000 |

Overall, the data showcases the positive impact of RECP practices on resource efficiency, waste reduction, and environmental sustainability. Across all sectors, the RECP companies consistently demonstrate lower material usage, water consumption, energy consumption, waste generation, wastewater generation, and GHG emissions than their non-RECP counterparts. For instance, in the textile sector, EcoTex (RECP) consistently used fewer materials, consumed less water and energy, and generated less waste, wastewater, and GHG emissions compared to NigerTex (non-RECP) throughout the five-year period from 2018 to 2022. Similar trends can be observed in the brewing, plastic, and steel sectors, where the RECP companies outperformed their non-RECP counterparts regarding resource efficiency and environmental performance. It is important to note that the data presents a snapshot of the industrial performance. It does not provide detailed information about the specific RECP practices or the challenges faced during implementation.

## 4.3. Environmental Performance

This section provides a comprehensive analysis of the environmental performance of companies that have implemented RECP practices (RECP companies) compared to those that have not adopted such practices (referred to as Non-RECP companies). The analysis evaluates key environmental performance indicators, including material productivity, water productivity, energy productivity, waste intensity and wastewater intensity. A simple linear regression analysis was performed on each performance indicator for the companies in the respective sectors to assess the environmental performance of RECP and non-RECP companies. The linear regression models were developed using historical data from 2018 to 2022, allowing for the identification of trends and rates of change over time. The analysis aimed to compare the environmental performance of RECP and non-RECP companies objectively and provide insights into the effectiveness of RECP practices.

### 4.3.1. Material Productivity

**Material productivity: Textile Companies**

The regression analysis results for material productivity in different sectors are presented in Figures 8 to 11 and Equations 1 to 8. The positive slope for EcoTex indicates a slightly increasing trend in material productivity over time, while the negative slope for NigerTex suggests a slightly decreasing trend. The adoption of RECP principles by EcoTex has led to improved resource efficiency and reduced waste generation, resulting in a positive trend. NigerTex's lack of RECP implementation has resulted in a decline in material productivity, potentially due to inefficient resource use and increased waste. The results of the regression equations

*EcoTex (RECP):* $y = 0.0025x + 0.9175$ $(R^2 = 0.9286)$ *Equ. 1*

*NigerTex (Non-RECP):* $y = -0.0025x + 0.5725$ $(R^2 = 0.9286)$ *Equ. 2*

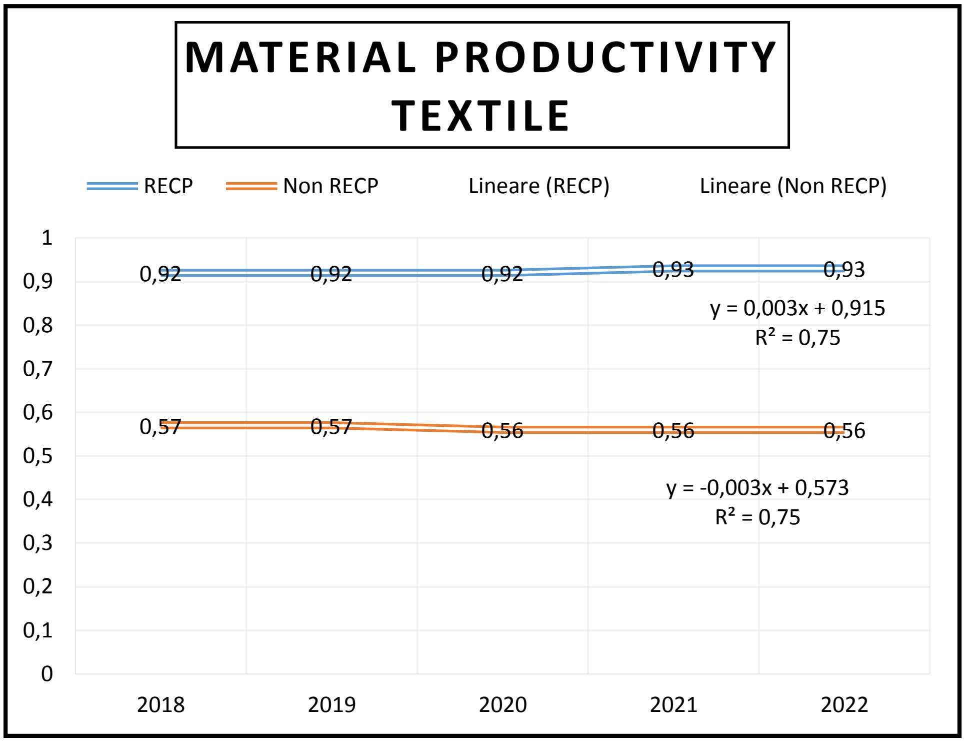



Figure 8: Regression analysis for Material productivity in the textile sector

**Material productivity: Plastic Companies**

EcoPlast shows a strong positive trend in material productivity, with a steeper slope than other sectors. This indicates that adopting RECP principles has significantly improved resource efficiency and reduced waste in the plastic industry. NigerPlast, on the other hand, exhibits a slight negative trend, suggesting that the lack of RECP implementation has resulted in a gradual decline in material productivity.

*EcoPlast (RECP):* $y = 0.02x + 0.3$ $(R^2 = 1)$ *Equ. 3*

*NigerPlast (Non-RECP):* $y = -0.0025x + 0.2275$ $(R^2 = 0.75)$ *Equ. 4*

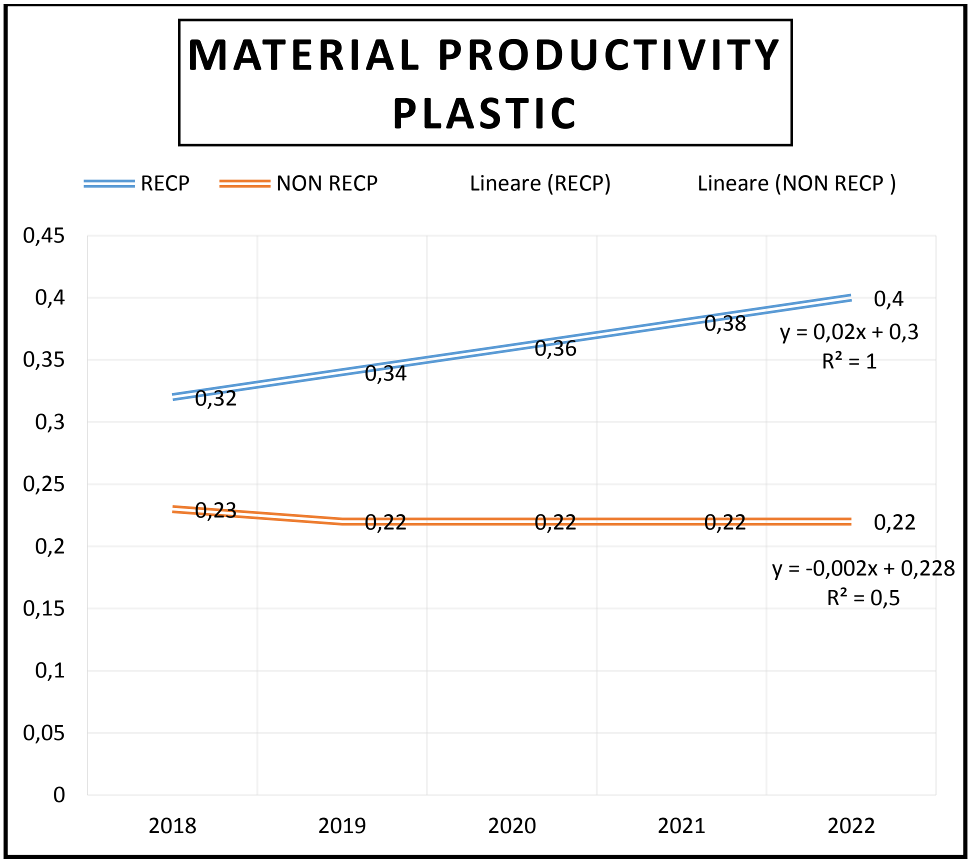



*Figure 9:* Regression analysis for Material productivity plastic sector

**Material productivity: Breweries**

EcoBrew demonstrates a slightly positive trend in material productivity, indicating that adopting RECP principles has led to improved resource efficiency and waste reduction in the brewery sector. NigerBrew, however, shows a slight negative trend, suggesting that the lack of RECP implementation has resulted in a gradual decline in material productivity.

*EcoBrew (RECP):* $y = 0.0025x + 0.9175$ $(R^2 = 0.9286)$ *Equ. 5*

*NigerBrew (Non-RECP):* $y = -0.0025x + 0.5725$ $(R^2 = 0.9286)$ *Equ. 6*

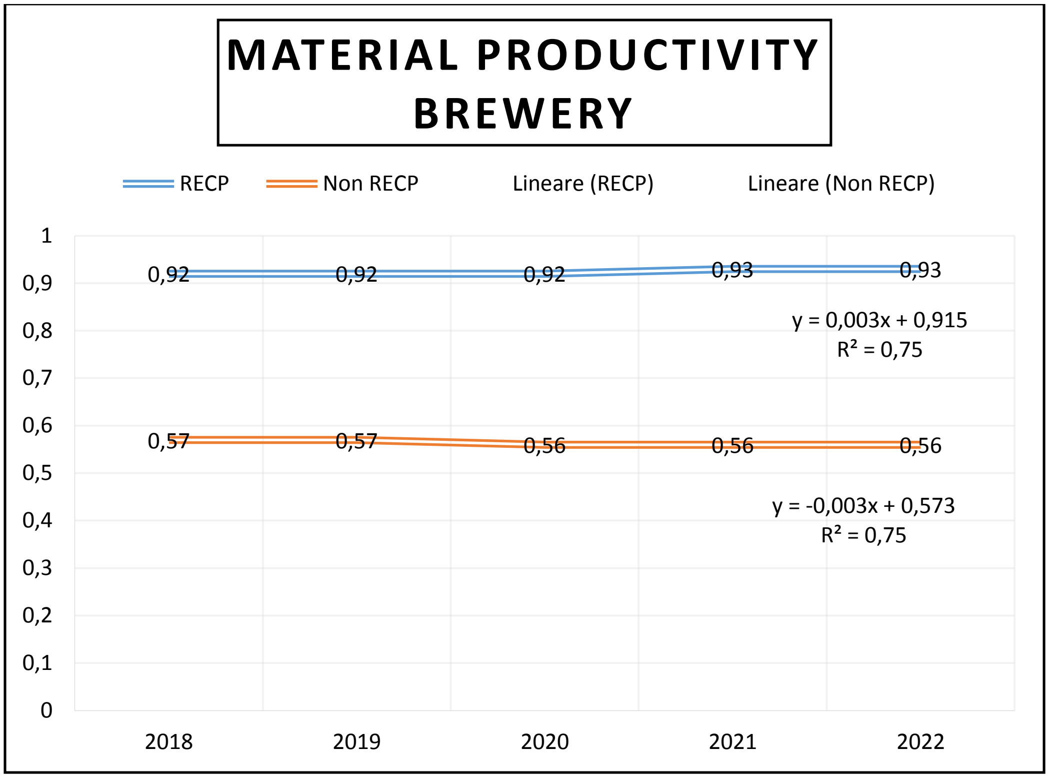



Figure 10: Regression analysis for Material productivity brewery sector

**Material productivity: Steel**

Both EcoSteel and NigerSteel exhibit positive trends in material productivity, but EcoSteel's slope is steeper, indicating a faster rate of improvement. EcoSteel's adoption of RECP principles has led to more rapid gains in resource efficiency and waste reduction compared to NigerSteel, which has not implemented RECP.

EcoSteel (RECP): $y = 0.0125x + 0.4525$ ($R^2 = 0.9821$) Equ. 7

NigerSteel (Non-RECP): $y = 0.0075x + 0.3775$ ($R^2 = 0.9643$) Equ. 8

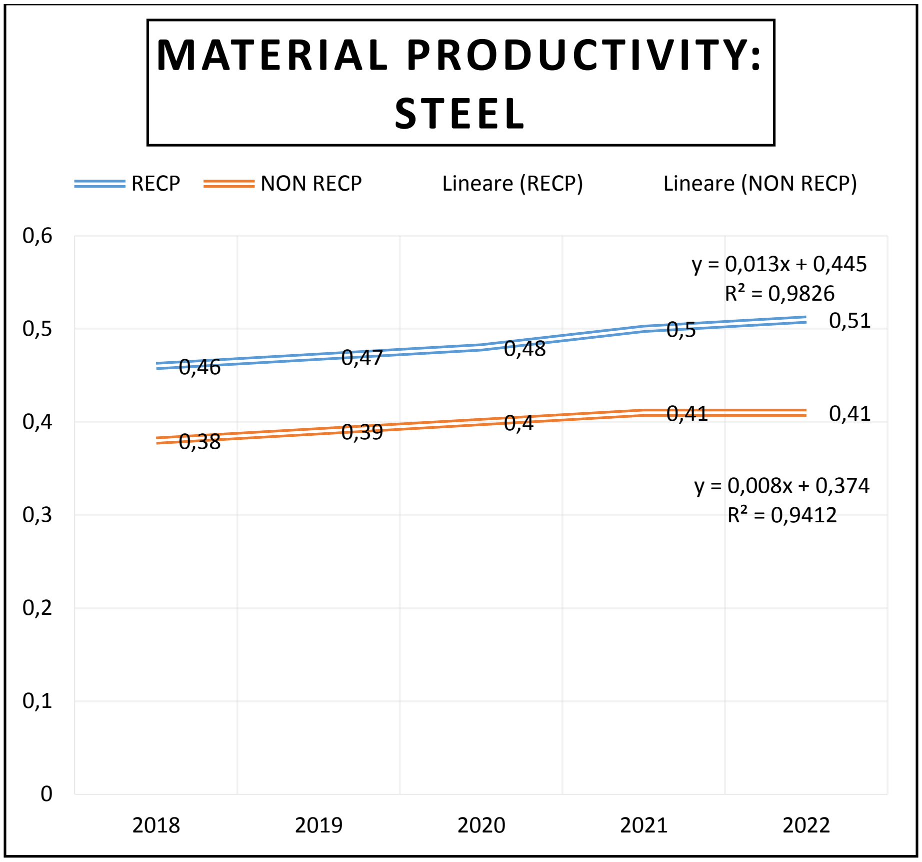



Figure 11: Regression analysis for Material productivity steel sector

**4.3.2. Water Productivity:** The regression analysis results for water productivity in different sectors are presented in figures 12 to 15 and equations 9 to 16.

**Water productivity: Textile**

EcoTex shows a positive trend in water productivity, with a slope of 0.0028, indicating a consistent improvement over time due to adopting RECP principles. This suggests that EcoTex uses water more efficiently and generates more output per unit of water consumed. NigerTex, on the other hand, exhibits a slight negative trend, with a slope of -0.0002, suggesting a gradual decline in water productivity, likely due to the lack of RECP implementation.

Textile Companies: EcoTex (RECP): $y = 0.0028x + 0.0192$ ($R^2 = 0.9892$) Equ. 9

NigerTex (Non-RECP): $y = -0.0002x + 0.0102$ ($R^2 = 0.8$) Equ. 10

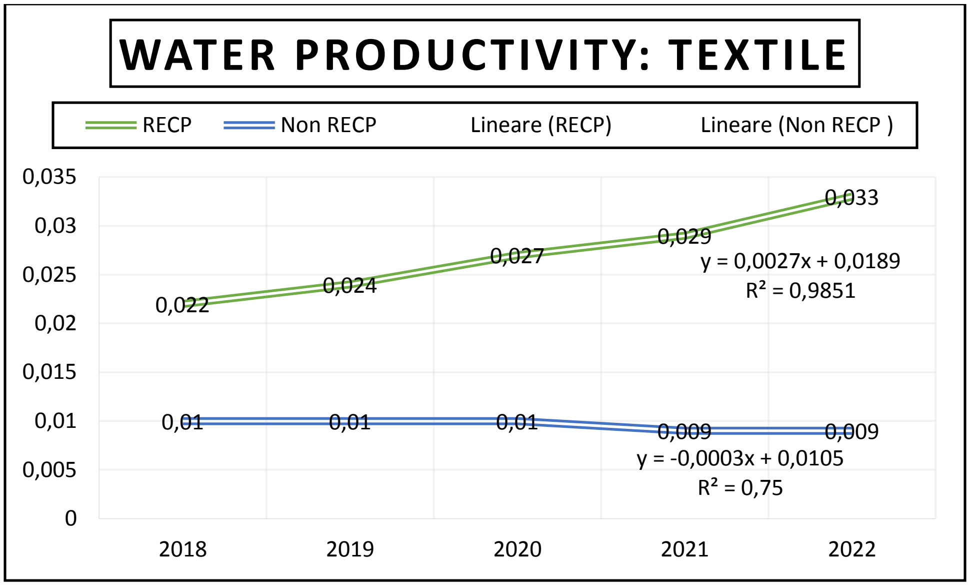



*Figure 12:* Regression analysis for water productivity textile sector

**Water productivity: Plastic**

EcoPlast demonstrates a strong positive trend in water productivity, with a slope of 0.01, indicating significant improvements in water efficiency and output generation per unit of water used. This can be attributed to the successful adoption of RECP principles in the plastic industry. NigerPlast, however, shows a negative trend, with a slope of -0.0018, suggesting a decline in water productivity over time, possibly due to the lack of RECP implementation.

Plastic Companies: EcoPlast (RECP): $y = 0.01x + 0.13$ ($R^2 = 1$) Equ. 11

NigerPlast (Non-RECP): $y = -0.0018x + 0.0918$ ($R^2 = 0.9643$) Equ. 12

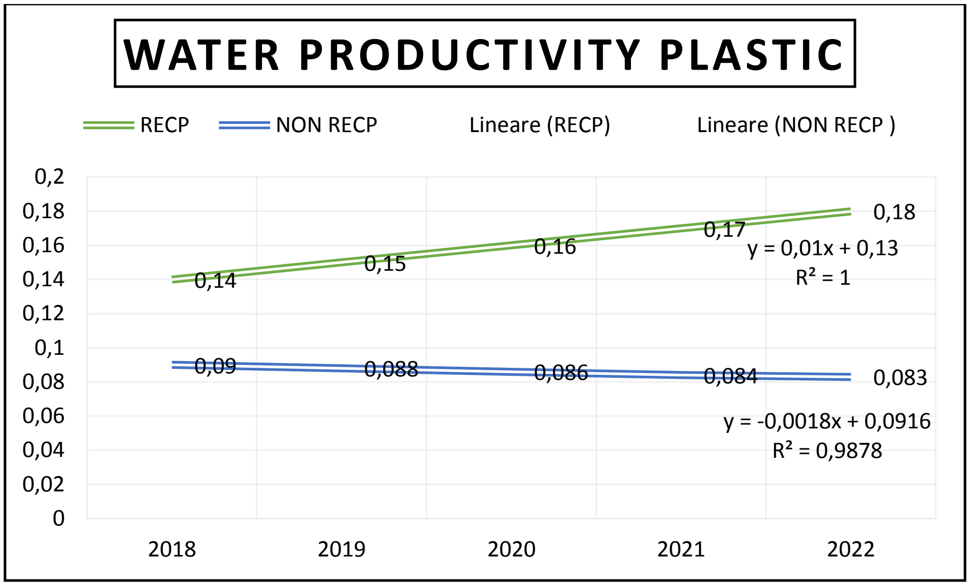



Figure 13: Regression analysis for water productivity for the plastic sector

EcoBrew exhibits a positive trend in water productivity, with a slope of 0.0028, indicating consistent improvements in water efficiency and output generation per unit of water consumed. This improvement can be attributed to adopting RECP principles in the brewery sector. NigerBrew, on the other hand, shows a slight negative trend, with a slope of -0.0002, suggesting a gradual decline in water productivity, likely due to the lack of RECP implementation.

Breweries: EcoBrew (RECP): $y = 0.0028x + 0.0192$ ($R^2 = 0.9892$) Equ. 13

NigerBrew (Non-RECP): $y = -0.0002x + 0.0102$ ($R^2 = 0.8$)Equ. 14

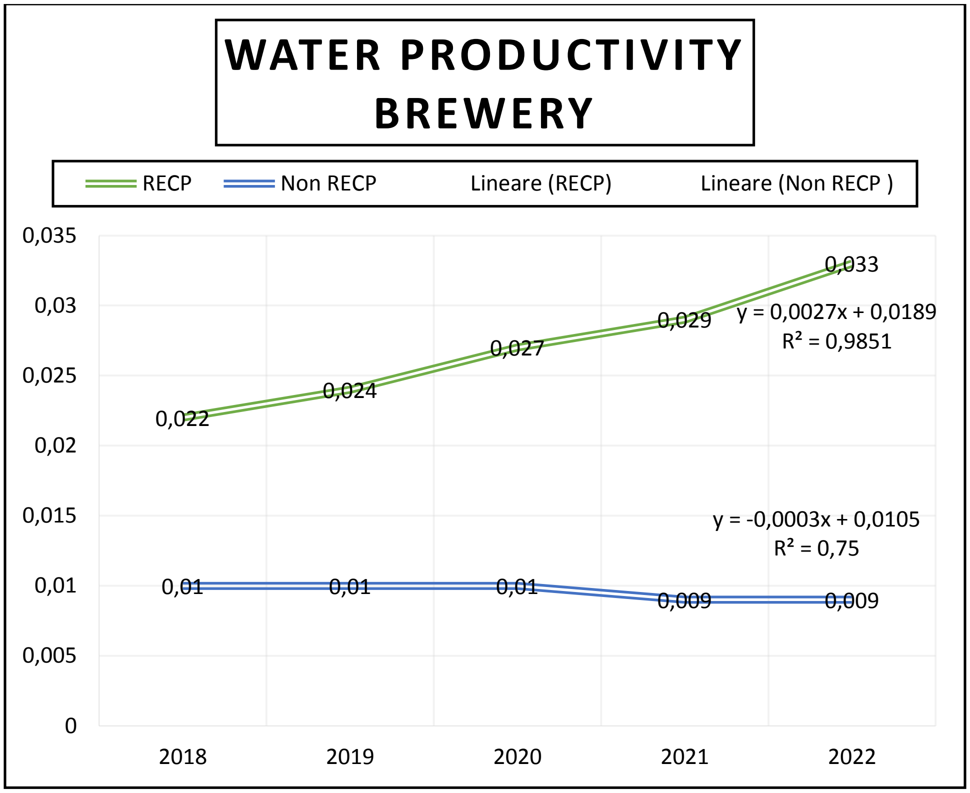



Figure 14: Regression analysis for water productivity in the brewery sector

**Water productivity: Steel**

Both EcoSteel and NigerSteel demonstrate positive trends in water productivity, but EcoSteel's slope of 0.01 is steeper than NigerSteel's slope of 0.0025. This indicates that EcoSteel, which has adopted RECP principles, is achieving faster improvements in water efficiency and output generation per unit of water used compared to NigerSteel, which has not implemented RECP.

Steel Companies: EcoSteel (RECP): $y = 0.01x + 0.17$ ($R^2 = 1$) Equ. 15

NigerSteel (Non-RECP): y = $0.0025x + 0.1575$ ($R^2 = 0.75$) Equ. 16

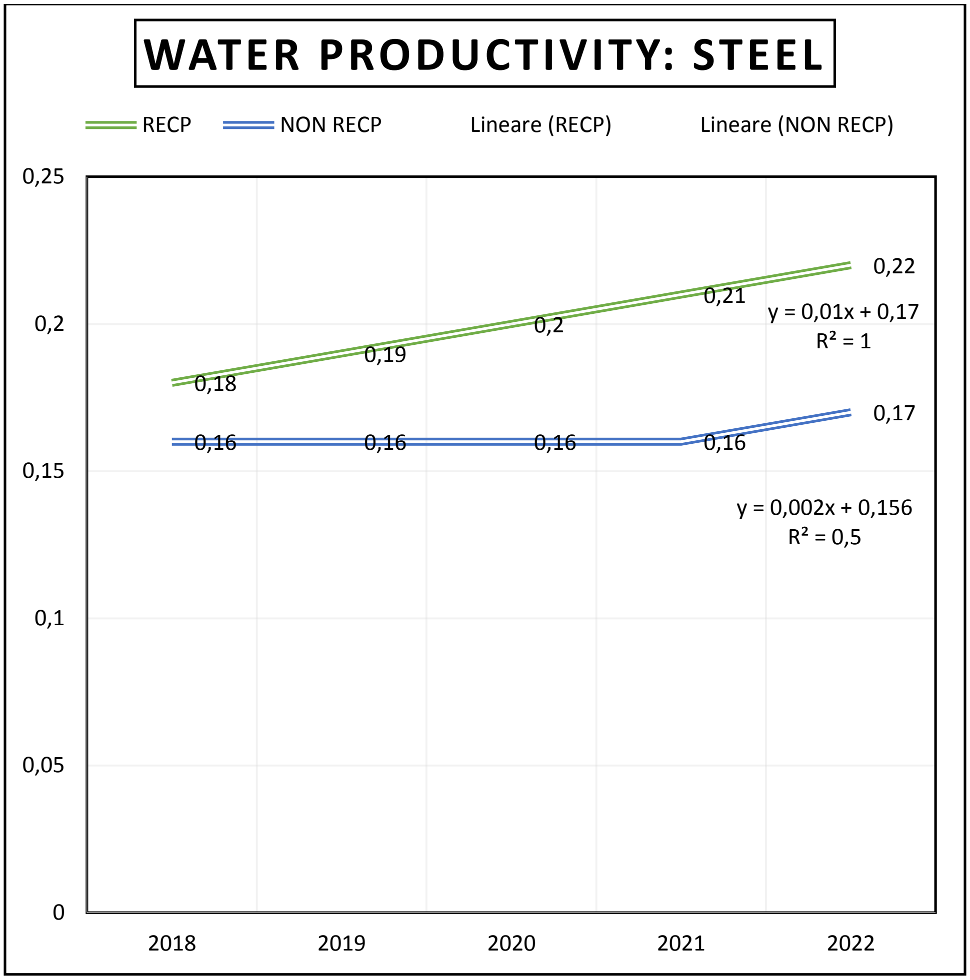



Figure 15: Regression analysis for water productivity in the steel sector

**4.3.3. Energy Productivity:** The results of the regression analysis for energy productivity in different sectors are presented in Figures 16 to 19 and Equation 17 to Equation 19.

**Energy productivity: Textile**

EcoTex shows a slight positive trend in energy productivity, with a slope of 0.00000500, indicating a gradual improvement over time due to adopting RECP principles. This suggests that EcoTex is using energy more efficiently and generating more output per unit of energy consumed. NigerTex maintains a constant energy productivity of 0.0005, indicating no improvement in energy efficiency, likely due to the lack of RECP implementation.

EcoTex (RECP): y = $0.00000500x + 0.00084750$ ($R^2 = 0.92857$) Equ. 17

NigerTex (Non-RECP): y = 0.00000000x + 0.00050000 ($R^2$ = 1.00000) Equ. 18

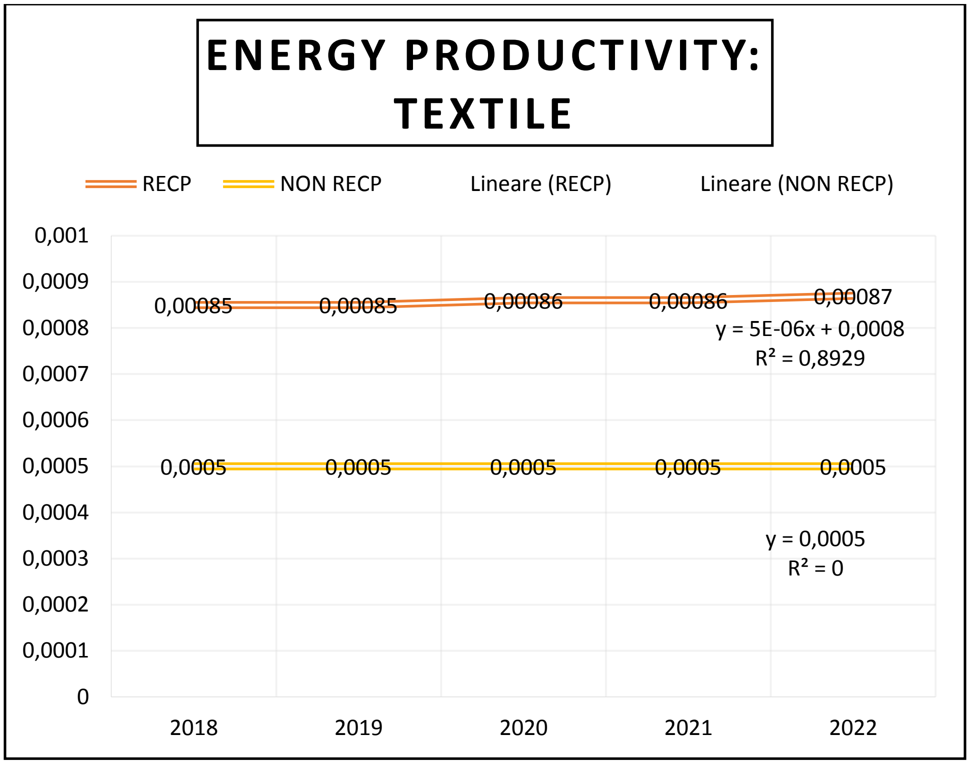



Figure 16: Regression analysis for energy productivity in the textile sector

**Energy productivity: Plastic**

EcoPlast demonstrates a strong positive trend in energy productivity, with a slope of 0.00200000, indicating significant improvements in energy efficiency and output generation per unit of energy used. This can be attributed to the successful adoption of RECP principles in the plastic industry. NigerPlast, on the other hand, shows a negative trend, with a slope of -0.00025000, suggesting a decline in energy productivity over time, possibly due to the lack of RECP implementation.

EcoPlast (RECP): $y = 0.00200000x + 0.01650000$ ($R^2 = 1.00000$)Equ. 19

NigerPlast (Non-RECP): y = -0.00025000x + 0.01075000 ($R^2$ = 0.97619) Equ. 20

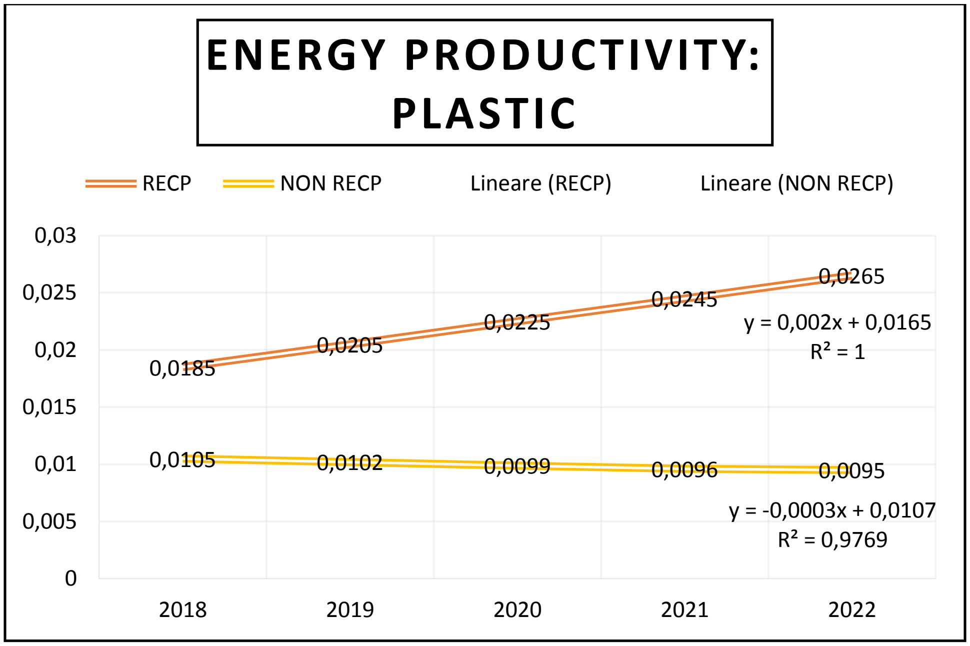



Figure 17: Regression analysis for energy productivity in the plastic sector

**Energy productivity: Breweries**

EcoBrew exhibits a slightly positive trend in energy productivity, with a slope of 0.00000500, indicating gradual improvements in energy efficiency and output generation per unit of energy consumed. This improvement can be attributed to adopting RECP principles in the brewery sector. NigerBrew maintains a constant energy productivity of 0.0005, suggesting no improvement in energy efficiency, likely due to the lack of RECP implementation.

EcoBrew (RECP): $y = 0.00000500x + 0.00084750$ ($R^2 = 0.92857$) Equ. 21

NigerBrew (Non-RECP): $y = 0.00000000x + 0.00050000$ ($R^2 = 1.00000$) Equ. 22

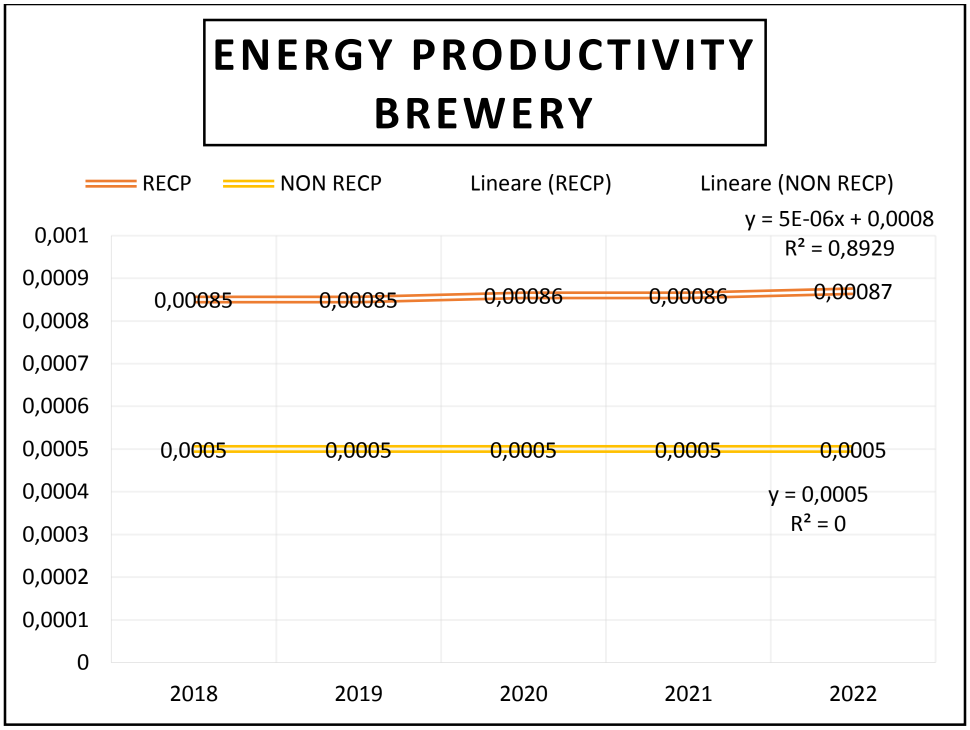



Figure 18: Regression analysis for energy productivity for Brewery

**Energy productivity: Steel**

EcoSteel demonstrates a positive trend in energy productivity, with a slope of 0.00150000, indicating consistent improvements in energy efficiency and output generation per unit of energy used. This can be attributed to the adoption of RECP principles in the steel industry. NigerSteel, however, exhibits a negative trend, with a slope of -0.00200000, suggesting a decline in energy productivity over time, likely due to the lack of RECP implementation.

EcoSteel (RECP): $y = 0.00150000x + 0.02350000$ ($R^2 = 0.98214$) Equ. 23

NigerSteel (Non-RECP): $y = -0.00200000x + 0.02400000$ ($R^2 = 1.00000$) Equ. 24

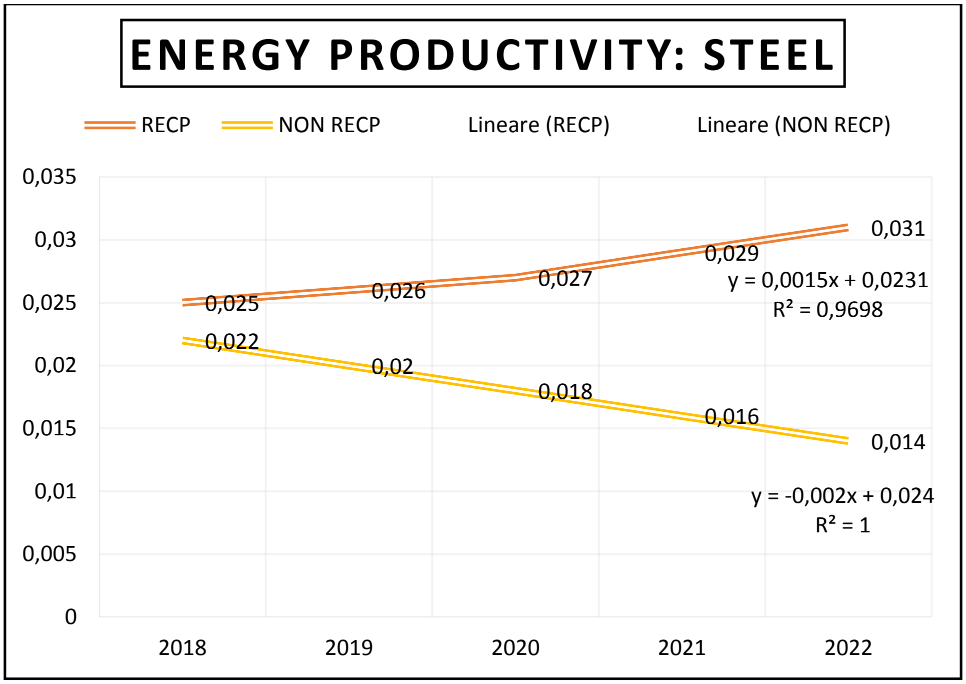



Figure 19: Regression analysis for energy productivity in the Steel sector

**4.3.4. Waste Intensity:** The results of the regression analysis for waste intensity in different sectors are presented in Figure 20 to Figure 23 and Equation 25 to Equation 32.

**Waste intensity: Textile**

EcoTex shows a negative trend in waste intensity, with a slope of -0.00725, indicating a consistent reduction in waste generation per output unit over time due to adopting RECP principles. This suggests that EcoTex is effectively minimizing waste and improving resource efficiency. NigerTex, on the other hand, exhibits a slight positive trend, with a slope of 0.00200, suggesting a gradual increase in waste intensity, likely due to the lack of RECP implementation.

EcoTex (RECP): $y = -0.00725x + 0.09475$ ($R^2 = 0.99835$) Equ. 25

NigerTex (Non-RECP): $y = 0.00200x + 0.34900$ ($R^2 = 0.97619$) Equ. 26

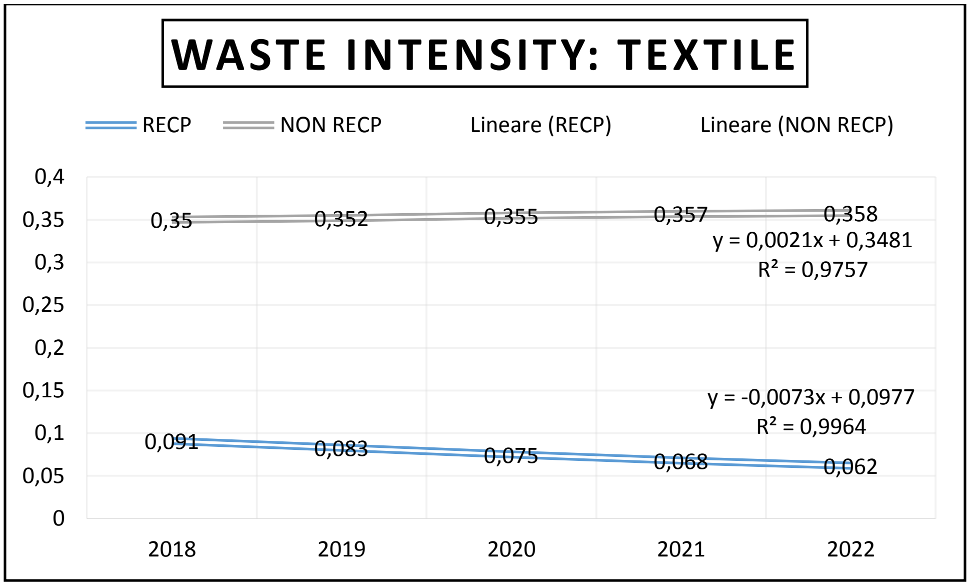



Figure 20: Regression analysis of waste intensity in the textile sector

**Waste intensity: Plastic**

EcoPlast demonstrates a strong negative trend in waste intensity, with a slope of -0.02000, indicating significant reductions in waste generation per unit of output. This can be attributed to the successful adoption of RECP principles in the plastic industry. NigerPlast, however, shows a positive trend, with a slope of 0.01325, suggesting an increase in waste intensity over time, most possibly due to the lack of RECP implementation.

EcoPlast (RECP): $y = -0.02000x + 0.60000$ ($R^2 = 1.00000$) Equ. 27

NigerPlast (Non-RECP): $y = 0.01325x + 0.87175$ ($R^2 = 0.99835$) Equ. 28

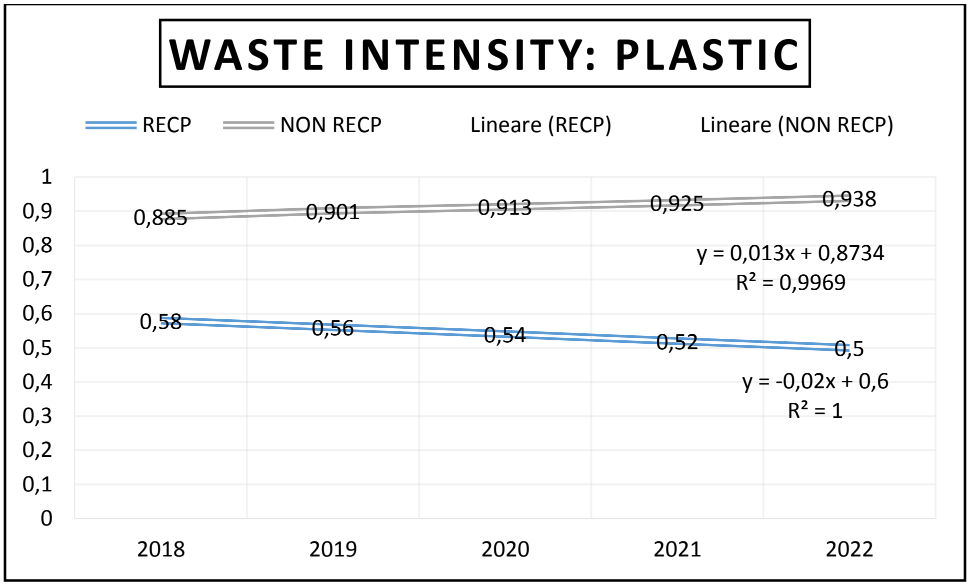



Figure 21: Regression analysis of waste intensity in the plastic sector

**Waste intensity: Breweries**

EcoBrew exhibits a negative trend in waste intensity, with a slope of -0.00725, indicating consistent reductions in waste generation per unit of output over time. This improvement can be attributed to adopting RECP principles in the brewery sector. NigerBrew, on the other hand, shows a slight positive trend, with a slope of 0.00200, suggesting a gradual increase in waste intensity, likely due to the lack of RECP implementation.

EcoBrew (RECP): $y = -0.00725x + 0.09475$ ($R^2 = 0.99835$) Equ. 29

NigerBrew (Non-RECP): $y = 0.00200x + 0.34900$ ($R^2 = 0.97619$) Equ. 30

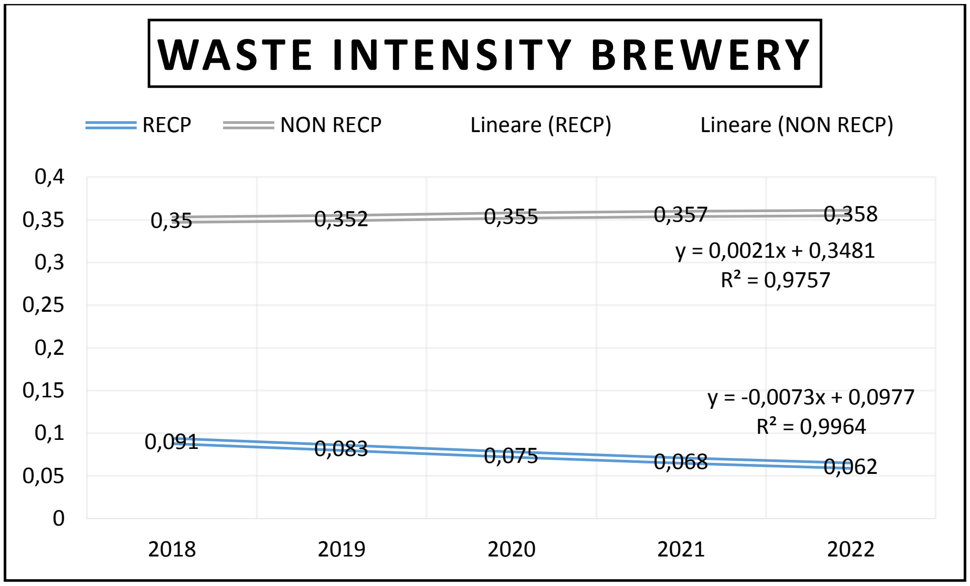



Figure 22: Regression analysis of waste intensity in the brewery sector

**Waste intensity: Steel**

EcoSteel demonstrates a negative trend in waste intensity, with a slope of -0.00475, indicating consistent reductions in waste generation per unit of output over time. This can be attributed to adopting RECP principles in the steel industry. NigerSteel, however, exhibits a positive trend, with a slope of 0.00450, suggesting an increase in waste intensity over time, likely due to the lack of RECP implementation.

EcoSteel (RECP): $y = -0.00475x + 0.18675$ ($R^2 = 0.99901$) Equ.31

NigerSteel (Non-RECP): $y = 0.00450x + 0.23550$ ($R^2 = 0.99451$) Equ 32

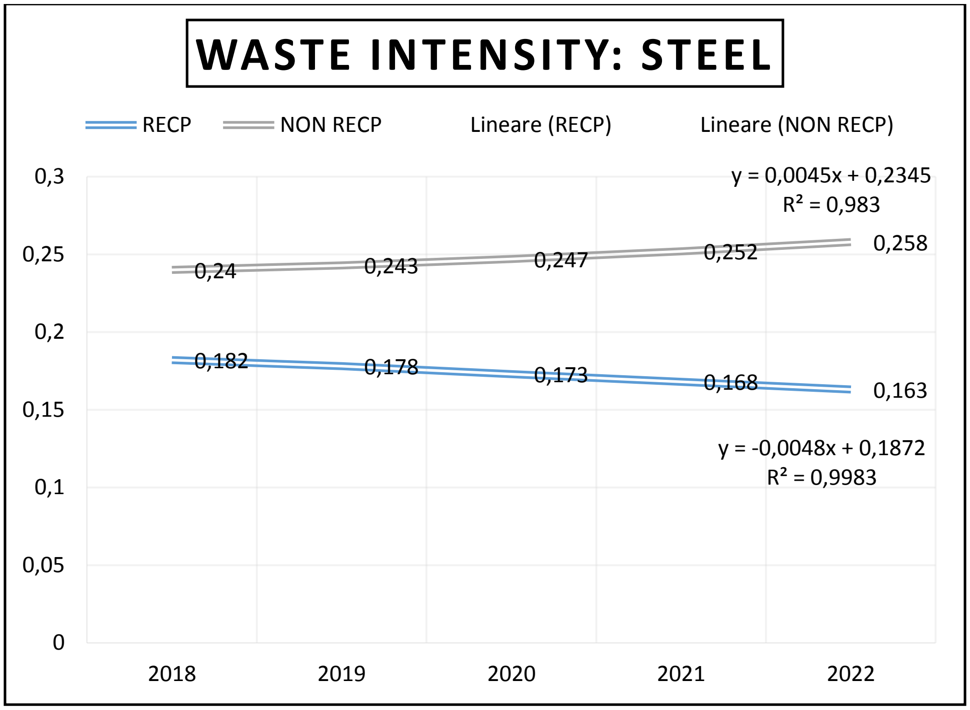



Figure 23: Regression analysis of waste intensity in the steel sector

**4.3.5. Wastewater Intensity:** The results of the regression analysis for wastewater in different sectors are presented in Figures 24 to 27 and Equation 33 to Equation 40.

**Wastewater intensity: Textile**

EcoTex shows a negative trend in wastewater intensity, with a slope of -2.9725, indicating a consistent reduction in wastewater generation per output unit over time due to adopting RECP principles. This suggests that EcoTex is effectively minimizing wastewater and improving water efficiency. NigerTex, on the other hand, exhibits a positive trend, with a slope of 3.3325, suggesting a steady increase in wastewater intensity, likely due to the lack of RECP implementation.

*EcoTex (RECP):* $y = -2.9725x + 29.8350$ $(R^2 = 0.9991)$ *Equ. 33*

*NigerTex (Non-RECP):* $y = 3.3325x + 66.6650$ $(R^2 = 1.0000)$ *Equ. 34*

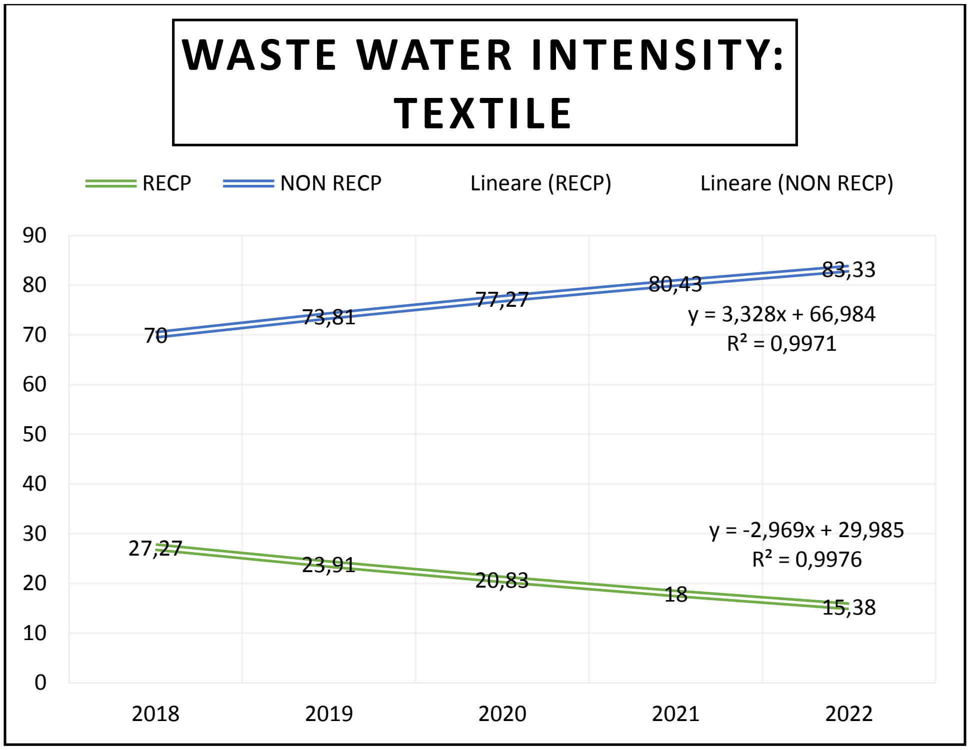



Figure 24: Regression analysis of wastewater intensity in the textile sector

**Wastewater intensity: Plastic**

EcoPlast demonstrates a negative trend in wastewater intensity, with a slope of -0.1250, indicating reductions in wastewater generation per unit of output. This can be attributed to the successful adoption of RECP principles in the plastic industry. NigerPlast, however, shows a positive trend, with a slope of 0.0550, suggesting an increase in wastewater intensity over time, possibly due to the lack of RECP implementation.

EcoPlast (RECP): $y = -0.1250x + 2.4250$ ($R^2 = 0.9934$)Equ. 35

NigerPlast (Non-RECP): $y = 0.0550x + 3.8350$ ($R^2 = 0.9967$)Equ. 36

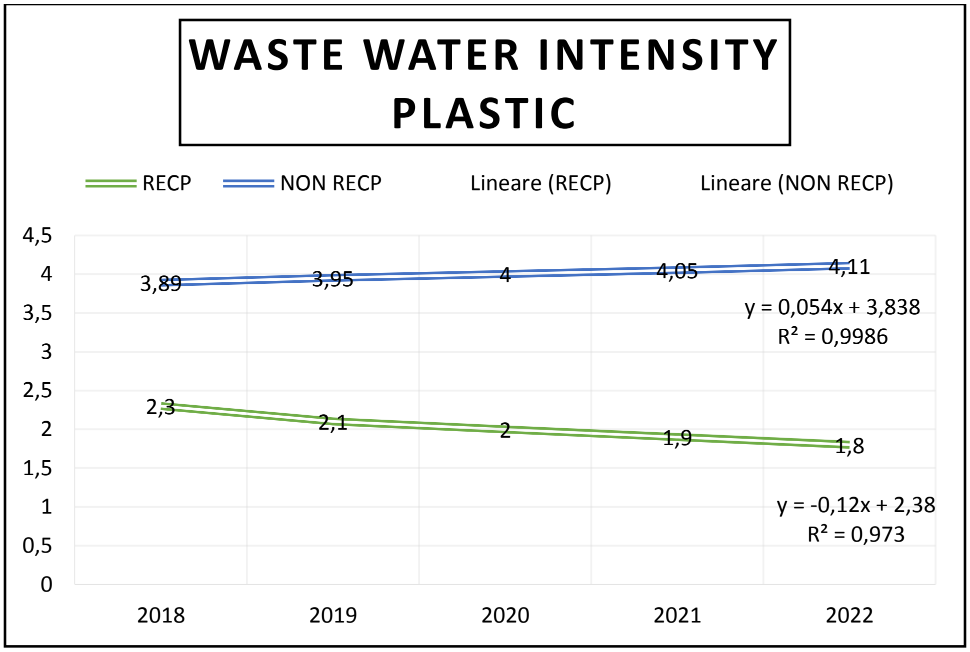



Figure 25: Regression analysis of wastewater intensity in the plastic sector

**Wastewater intensity: Breweries**

EcoBrew exhibits a negative trend in wastewater intensity, with a slope of -2.9725, indicating consistent reductions in wastewater generation per output unit over time. This improvement can be attributed to adopting RECP principles in the brewery sector. NigerBrew, on the other hand, shows a positive trend, with a slope of 3.3325, suggesting a steady increase in wastewater intensity, likely due to the lack of RECP implementation.

EcoBrew (RECP): $y = -2.9725x + 29.8350$ ($R^2 = 0.9991$)Equ. 37

NigerBrew (Non-RECP): $y = 3.3325x + 66.6650$ ($R^2 = 1.0000$)Equ. 38

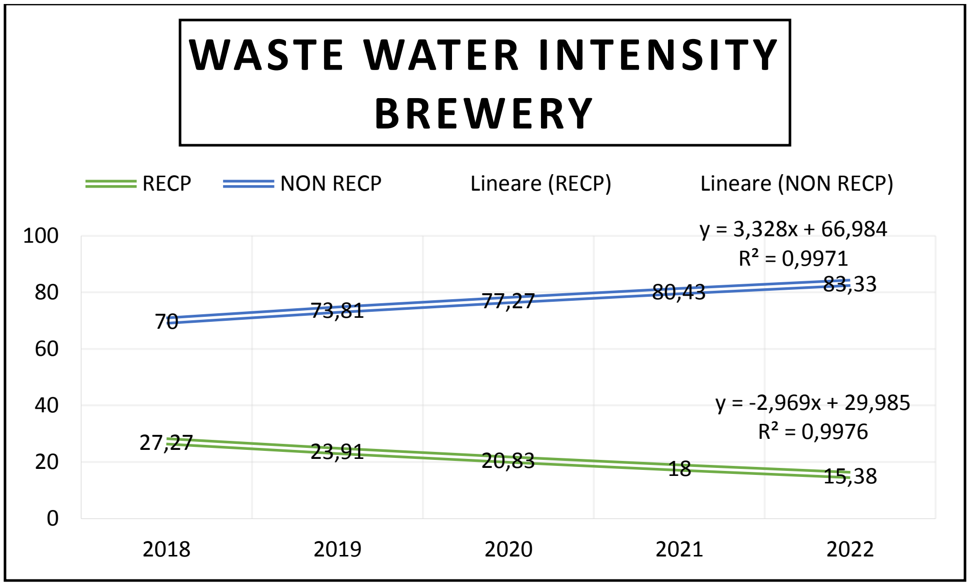



Figure 26: Regression analysis of wastewater intensity in the brewery sector

**Wastewater intensity: Steel Companies**

EcoSteel demonstrates a negative trend in wastewater intensity, with a slope of -0.0400, indicating consistent reductions in wastewater generation per unit of output over time. This can be attributed to the adoption of RECP principles in the steel industry. NigerSteel, however, exhibits a positive trend, with a slope of 0.0325, suggesting an increase in wastewater intensity over time, likely due to the lack of RECP implementation.

EcoSteel (RECP): $y = -0.0400x + 1.7100$ ($R^2 = 1.0000$)Equ. 39

NigerSteel (Non-RECP): $y = 0.0325x + 2.1875$ ($R^2 = 0.9989$)Equ. 40

The negative trends in wastewater intensity observed in companies that have adopted RECP principles (EcoTex, EcoPlast, EcoBrew, and EcoSteel) highlight the effectiveness of RECP in reducing wastewater generation and improving water efficiency across various sectors. RECP implementation leads to better wastewater management, process optimization, and the adoption of water-efficient technologies, resulting in decreased wastewater generation per unit of output and reduced environmental impact.

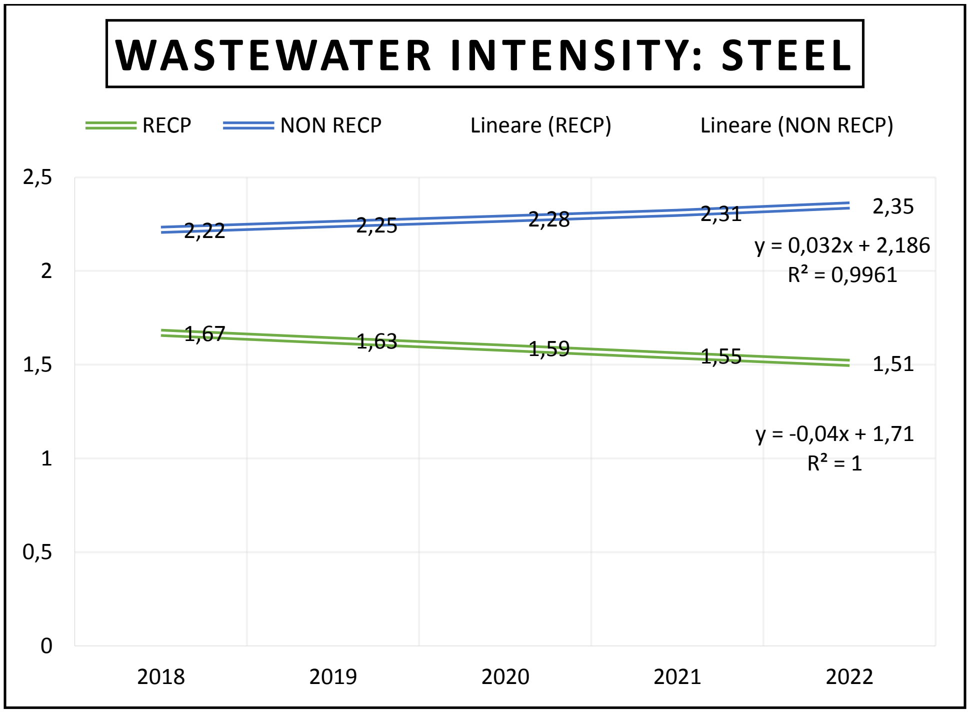



Figure 27: Regression analysis of wastewater intensity in the steel sector

**Summary**

The linear regression analysis reveals a clear distinction between companies adopting RECP principles and those that do not. RECP-adopting companies consistently outperform their non-RECP counterparts across all environmental performance indicators. These companies have significantly reduced waste and wastewater intensity, indicating a substantial decrease in their environmental footprint. Moreover, the increasing slopes in material, water, and energy productivity suggest that RECP companies have markedly improved their resource efficiency, leading to reduced consumption of raw materials, water, and energy. These improvements can be attributed to the implementation of RECP practices, including process optimization, efficient resource utilization, and effective pollution prevention measures.

In contrast, non-RECP companies have exhibited significant increases in waste intensity and wastewater intensity, pointing to a growing environmental footprint. The decreasing slopes in material, water, and energy productivity indicate that these companies have failed to improve their resource efficiency, resulting in increased raw materials, water, and energy consumption. This deterioration in performance is likely due to the absence of RECP practices, leading to inefficient resource use and inadequate pollution prevention measures.

The implications of these findings are profound for the promotion of RECP practices in Nigerian industries. The superior environmental performance of RECP companies underscores the potential benefits of adopting these practices, including improved resource efficiency, reduced waste generation, and lower greenhouse gas emissions. These benefits not only contribute to environmental sustainability but also have the potential to generate cost savings and enhance competitiveness for the companies involved. Conversely, the declining environmental performance of non-RECP companies highlights the urgent need for widespread adoption of RECP practices to mitigate environmental impact and ensure long-term sustainability.

The analysis also reveals sector-specific impacts of RECP adoption. In terms of water productivity, the plastic (EcoPlast) and steel (EcoSteel) industries showed the most significant improvements. For wastewater intensity, the textile (EcoTex) and brewery (EcoBrew) industries demonstrated substantial reductions. The plastic industry (EcoPlast) exhibited the most significant improvements in waste intensity reduction.

Companies that have not adopted RECP (NigerTex, NigerPlast, and NigerBrew) face potential risks and missed opportunities. These include increased resource consumption, higher waste generation, and higher greenhouse gas emissions. They may also incur higher costs related to water consumption, wastewater treatment, and waste disposal, as well as potential non-compliance with environmental regulations. Furthermore, these companies miss out on opportunities for improved operational efficiency and competitiveness.

The results of this analysis provide strong evidence for the effectiveness of RECP practices in improving environmental performance. These findings can inform policymakers and industry stakeholders in developing targeted strategies, incentives, and regulatory frameworks to support and encourage the implementation of RECP practices. Additionally, the linear regression models can be used to forecast future environmental performance based on observed trends, enabling companies and policymakers to anticipate potential challenges and develop proactive measures.

In conclusion, the adoption of RECP principles has a significant positive impact on environmental performance across different industries in Nigeria. Companies embracing these principles experience substantial improvements in resource efficiency and reductions in waste generation. The results underscore the importance of implementing sustainable practices and highlight the risks associated with failing to adopt RECP. As such, this analysis serves as a compelling case for the widespread adoption of RECP practices across Nigerian industries to enhance both environmental sustainability and economic competitiveness.

## 4.4: Comparative Analysis: International and National Benchmarks

This section deals with the performance metrics of the assessed companies, highlighting their current efficiency levels in material use, water and energy consumption, waste generation, and wastewater management. These metrics are compared against national and international standards to identify potential areas for improvement[28].

4.4.1. Improvement potential Textile

EcoTex (RECP) Performance (Table 5)
Material Productivity (tons/ton): EcoTex has a material productivity of 0.92-0.93 tons of fabric per ton of raw material, which is below the national standard of 1.15 and the international benchmark of 1.20. The potential improvement needed is 19-20% for national standards and 22-23% for international benchmarks. This indicates that EcoTex could enhance its material efficiency by reducing waste and optimizing processes, which would lead to better resource utilization and cost savings.

[28] the international benchmarks and best practices are based on industry averages and may vary depending on the specific industry and location.

Water Productivity ($m^3$/ton): EcoTex's water productivity is 0.022-0.033 cubic meters per ton of fabric, significantly lower than the national standard of 0.5-1.5 and the international benchmark of 0.5-2.0. The potential improvement needed ranges from 93-98% to meet the national standard and 93-99% to meet the international benchmark. This large gap suggests that EcoTex needs substantial improvements in water management, such as implementing water-saving technologies and practices to reduce water consumption and improve sustainability.

Energy Productivity (kg/kWh): EcoTex has an energy productivity of 0.00085-0.00087 kg of fabric per kilowatt-hour, which is far below the national standard of 0.005 and the international benchmark of 0.0045. The potential improvement required is 82-83% to meet national standards and 81% to meet international benchmarks. This highlights the need for significant improvements in energy efficiency, such as upgrading to energy-efficient machinery and optimizing energy use, to lower energy consumption and reduce operational costs.

Waste Intensity (ton/ton): EcoTex generates 0.062-0.091 tons of waste per ton of fabric, which is above the national standard of 0.05 and the international benchmark of 0.04. The potential improvement needed is 24-82% for national standards and 55-127% for international benchmarks. This indicates that EcoTex should focus on waste reduction strategies, such as enhancing recycling efforts and improving waste management practices, to minimize waste generation and improve environmental performance.

Wastewater Intensity ($m^3$/ton): EcoTex's wastewater intensity is 15.38-27.27 cubic meters per ton of fabric, vastly exceeding the national standard of 1.50 and the international benchmark of 1.40. The required improvement is 925-1718% for national standards and 999-1849% for international benchmarks. This massive disparity suggests that EcoTex urgently needs to improve its wastewater management, possibly through advanced treatment technologies and recycling systems, to significantly reduce its environmental impact and comply with industry standards.

Table 5: EcoTex (RECP) Improvement Potential[29]

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (tons/ton) | 1.15 | 0.92-0.93 | 19-20% | 1.20 | 22-23% |
| Water Productivity ($m^3$/ton) | 0.5-1.5 | 0.022-0.033 | 93-98% | 0.5-2.0 | 93-99% |
| Energy Productivity (kg/kWh) | 0.005 | 0.00085-0.00087 | 82-83% | 0.0045 | 81% |
| Waste Intensity (ton/ton) | 0.05 | 0.062-0.091 | 24-82% | 0.04 | 55-127% |
| Waste Water Intensity ($m^3$/ton) | 1.50 | 15.38-27.27 | 925-1718% | 1.40 | 999-1849% |

[29] Benchmark References

Federal Ministry of Industry, Trade and Investment, Nigeria. (2020). National Policy on Textile and Garment Industry.

United Nations Industrial Development Organization (UNIDO). (2019). Sustainable Textile Production - A Guide for the Textile Industry.

European Environmental Bureau (EEB). (2019). Water Management in the Textile Industry.

World Apparel and Footwear Association (WRAP). (2020). WRAP Sustainability Principles.

Table 6: NigerTex (Non-RECP) Improvement Potential

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (tons/ton) | 1.15 | 0.56-0.57 | 50-51% | 1.20 | 52-53% |
| Water Productivity ($m^3$/ton) | 0.5-1.5 | 0.009-0.010 | 98-99% | 0.5-2.0 | 98-99% |
| Energy Productivity (kg/kWh) | 0.005 | 0.00050 | 90% | 0.0045 | 89% |
| Waste Intensity (ton/ton) | 0.05 | 0.350-0.358 | 600-616% | 0.04 | 775-795% |
| Waste Water Intensity ($m^3$/ton) | 1.50 | 70.00-83.33 | 4567-5455% | 1.40 | 4900-5952% |

**NigerTex (Non-RECP) Improvement Potential (Table 6)**

Material Productivity (tons/ton): NigerTex has material productivity of 0.56-0.57 tons of fabric per ton of raw material, which is significantly below the national standard of 1.15 and the international benchmark of 1.20. The potential improvement needed is 50-51% to meet the national standard and 52-53% to meet the international benchmark. This indicates severe inefficiencies in material use, suggesting the need for adopting advanced processing techniques to reduce waste and enhance productivity.

Water Productivity ($m^3$/ton): NigerTex's water productivity is 0.009-0.010 cubic meters per ton of fabric, which is drastically below the national standard of 0.5-1.5 and the international benchmark of 0.5-2.0. The company needs to improve by 98-99% to meet both national and international standards. This large gap suggests the need for major improvements in water use efficiency, such as integrating water-saving technologies and practices to reduce water consumption and improve sustainability.

Energy Productivity (kg/kWh): NigerTex has an energy productivity of 0.00050 kg of fabric per kilowatt-hour, which is significantly below the national standard of 0.005 and the international benchmark of 0.0045. The potential improvement required is 90% to meet the national standard and 89% to meet the international benchmark. This indicates a need for energy efficiency improvements, such as adopting more efficient technologies and practices to reduce energy consumption and costs.

Waste Intensity (ton/ton): NigerTex generates 0.350-0.358 tons of waste per ton of fabric, which is far above the national standard of 0.05 and the international benchmark of 0.04. The potential improvement needed is 600-616% to meet the national standard and 775-795% to meet the international benchmark. This highlights severe inefficiencies in waste management, suggesting the need for comprehensive waste reduction strategies and improved recycling processes to align with industry standards and minimize environmental impact.

Wastewater Intensity ($m^3$/ton): NigerTex's wastewater intensity is 70.00-83.33 cubic meters per ton of fabric, far exceeding the national standard of 1.50 and the international benchmark of 1.40. The required improvement is 4567-5455% to meet the national standard and 4900-5952% to meet the international benchmark. This enormous gap indicates an urgent need for significant improvements in wastewater management, such as adopting advanced treatment technologies and water recycling systems to drastically reduce wastewater generation and comply with environmental regulations.

**Summary:** EcoTex demonstrates moderate efficiency in material productivity but has significant opportunities for improvement in water, energy, waste, and wastewater. Despite being a resource-efficient and cleaner production (RECP) practitioner, EcoTex shows substantial gaps in key metrics, indicating the need for major enhancements in operational efficiency to meet both national and international standards. By focusing on improving water and energy productivity, and reducing waste and wastewater intensity, EcoTex can enhance sustainability, reduce costs, and comply with industry benchmarks. NigerTex, on the other hand, exhibits severe inefficiencies across all metrics, including material and water productivity, energy use, waste generation and wastewater intensity. The company requires substantial improvements to align with national and international standards, with potential enhancement opportunities ranging from 50-99% for material and water productivity to over 4500% for wastewater management. Key areas for improvement include:

- Material Productivity: NigerTex needs significant enhancements to optimize material use and reduce raw material waste.
- Water Productivity: The company must invest in water recycling and conservation technologies to significantly reduce water consumption.
- Energy Efficiency: Conducting energy audits and adopting energy-efficient technologies are crucial to improve energy productivity and reduce costs.
- Waste and Wastewater Management: Implementing comprehensive waste reduction strategies and advanced wastewater treatment systems are necessary to align with industry standards and reduce environmental impact.

By addressing these areas, NigerTex can significantly enhance its operational efficiency, align with industry standards, and improve its sustainability and competitiveness in the textile industry. Adopting resource-efficient and cleaner production practices not only improves productivity and competitiveness but also contributes to broader environmental and sustainability goals, benefiting both the company and the community.

4.4.2. Improvement potential: Breweries

EcoBrew (RECP) performance (Table 7)

Material Productivity (kg/kg): EcoBrew achieves a material productivity of 260-300 kg of beer per kg of raw material, which exceeds the national standard of 220-280 and meets the international benchmark of 250-300. This performance indicates no need for improvement. The high material productivity reflects EcoBrew's effective use of raw materials, ensuring minimal wastage and maximizing output, aligning with the company's sustainable practices and operational efficiency.

Water Productivity (kg/m³): EcoBrew's water productivity is between 110 and 150 kg of beer per cubic meter of water. While this meets the international benchmark of 100-150, it falls short of the national standard of 120-180, suggesting a potential improvement of 17-39% to align with national requirements. The current performance indicates good water management practices, but there is room for further optimization to enhance water use efficiency and reduce consumption, crucial in an industry where water is a key input.

Energy Productivity (kg/MJ): EcoBrew's energy productivity ranges from 0.55 to 0.65 kg of beer per megajoule of energy, meeting both the national standard of 0.45-0.65 and the international benchmark of 0.50-0.60. No improvement is needed in this area, as the company demonstrates efficient energy use. This high energy productivity is vital in minimizing operational costs and environmental impact, highlighting EcoBrew's commitment to energy-efficient production processes.

Waste Intensity (kg/kg): The waste intensity at EcoBrew is 0.007-0.009 kg of waste per kg of beer, which falls well within both the national standard of 0.006-0.012 and the international benchmark of 0.008-0.012. This indicates that EcoBrew's waste generation is minimal and in line with best practices in waste management. No improvements are required, underscoring EcoBrew's effectiveness in waste reduction and its role as a responsible industry player.

Wastewater Intensity (m³/kg): EcoBrew has a wastewater intensity of 0.0028-0.0032 m³ per kg of beer produced, meeting both the national standard of 0.002-0.004 and the international benchmark of 0.0025-0.0035. The company's effective wastewater management practices mean no improvement is necessary. This performance highlights EcoBrew's commitment to minimizing its environmental footprint through efficient water use and wastewater treatment.

Table 7: EcoBrew (RECP) Improvement potential[30]

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 220-280 | 260-300 | No improvement needed | 250-300 | No improvement needed |
| Water Productivity (kg/m³) | 120-180 | 110-150 | 17-39% | 100-150 | No improvement needed |
| Energy Productivity (kg/MJ) | 0.45-0.65 | 0.55-0.65 | No improvement needed | 0.50-0.60 | No improvement needed |
| Waste Intensity (kg/kg) | 0.006-0.012 | 0.007-0.009 | No improvement needed | 0.008-0.012 | No improvement needed |
| Waste Water Intensity (m³/kg) | 0.002-0.004 | 0.0028-0.0032 | No improvement needed | 0.0025-0.0035 | No improvement needed |

[30] References for benchmarks in Annex section

Table 8: NigerBrew (Non-RECP) Improvement potential

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 220-280 | 200-240 | 14-29% | 250-300 | 20-33% |
| Water Productivity ($kg/m^3$) | 120-180 | 70-90 | 50-61% | 100-150 | 40-53% |
| Energy Productivity (kg/MJ) | 0.45-0.65 | 0.42-0.50 | 23-35% | 0.50-0.60 | 17-30% |
| Waste Intensity (kg/kg) | 0.006-0.012 | 0.012-0.014 | -17% | 0.008-0.012 | -75% |
| Waste Water Intensity ($m^3/kg$) | 0.002-0.004 | 0.0033-0.0037 | 7-18% | 0.0025-0.0035 | -6-6% |

NigerBrew (Non-RECP) Improvement potential (Table 8)

Material Productivity (kg/kg): NigerBrew's material productivity is between 200 and 240 kg of beer per kg of raw material, which is below the national standard of 220-280 and the international benchmark of 250-300. There is significant room for improvement, with a potential increase of 14-29% to meet the national standard and 20-33% to reach the international benchmark. This suggests that NigerBrew needs to enhance its raw material utilization to reduce waste and improve output efficiency.

Water Productivity (kg/m³): NigerBrew's water productivity is 70-90 kg of beer per cubic meter of water, far below the national standard of 120-180 and the international benchmark of 100-150. This reflects a potential improvement of 50-61% to meet the national standard and 40-53% to align with international benchmarks. The company's high water consumption indicates inefficient water use practices, highlighting the need for significant investment in water management technologies and practices to enhance water efficiency and sustainability.

Energy Productivity (kg/MJ): NigerBrew's energy productivity ranges from 0.42 to 0.50 kg of (produced) beer per megajoule, falling short of the national standard of 0.45-0.65 and the international benchmark of 0.50-0.60. The potential for improvement is 23-35% to meet national standards and 17-30% for international benchmarks. This indicates significant energy inefficiencies, suggesting that NigerBrew should conduct energy audits and adopt more energy-efficient technologies to reduce energy consumption and improve overall productivity.

Waste Intensity (kg/kg): NigerBrew has a waste intensity of 0.012-0.014 kg of waste per kg of beer, which exceeds the national standard of 0.006-0.012 and falls within the international benchmark of 0.008-0.012. The potential for improvement is -17% to meet national standards, while it meets the international benchmark. The high waste intensity points to inefficiencies in waste management, indicating that NigerBrew should implement waste reduction and recycling strategies to minimize waste generation and comply with national standards.

Wastewater Intensity (m³/kg): NigerBrew's wastewater intensity is 0.0033-0.0037 m³ per kg of beer, which exceeds the national standard of 0.002-0.004 and slightly aligns with the international benchmark of 0.0025-0.0035. There is a potential improvement of 7-18% to meet national standards and a mixed potential of -6% to 6% for the international benchmark. This high wastewater generation suggests the need for improved water management and wastewater treatment practices to reduce wastewater output and align with national and international standards.

**Summary:** EcoBrew shows high efficiency across most metrics, exceeding or meeting both national and international standards in material, energy, waste, and wastewater productivity. However, there is room for improvement in water productivity to meet the national standard. EcoBrew's strong performance reflects effective sustainable practices, ensuring minimal waste and high operational efficiency. NigerBrew, on the other hand, displays inefficiencies across all metrics, with significant improvement needed in material, water, and energy productivity. The company needs to adopt comprehensive strategies for waste and wastewater management to meet national and international standards. Key improvement areas for NigerBrew include:

- Material Productivity: Enhance raw material utilization to reduce waste and increase output efficiency.
- Water Productivity: Invest in water management technologies to improve water use efficiency and sustainability.
- Energy Efficiency: Conduct energy audits and adopt energy-efficient technologies to reduce energy consumption and costs.
- Waste and Wastewater Management: Implement waste reduction strategies and improve wastewater treatment to minimize environmental impact.

By addressing these areas, NigerBrew can improve its sustainability, align with industry standards, and enhance its competitiveness in the brewing industry. Adopting resource-efficient and cleaner production practices not only boosts productivity but also contributes to environmental and sustainability goals, benefiting both the company and the broader community.

4.4.3. Improvement potential: Plastic

EcoPlast (RECP) Improvement potential (Table 9)

<u>Material Productivity (kg/kg):</u> EcoPlast achieves a material productivity of 0.32-0.40 kg of plastic per kg of raw material. This is well within the national standard of 0.30-0.40 and meets the international benchmark of 0.35-0.45. The company shows no significant need for improvement, with the potential for a 0-20% increase to reach the upper national limit and up to a 28.9% increase to meet the highest international standards. This

indicates that EcoPlast is efficiently utilizing its raw materials, minimizing waste, and optimizing resource use, which aligns with its commitment to sustainability and cost reduction.

Water Productivity (kg/m³): EcoPlast's water productivity is between 0.14 and 0.18 kg of plastic per cubic meter of water, meeting the national standard of 0.10-0.20 and aligning closely with the international benchmark of 0.12-0.22. There is potential for a 10-30% improvement to meet the upper limit of the national standard and a 10-36.4% improvement to reach the highest international benchmark. This suggests EcoPlast has good practices in water management, but there is room for enhancement to further reduce water use and improve sustainability.

Energy Productivity (kg/MJ): EcoPlast's energy productivity ranges from 0.0185 to 0.0265 kg of plastic per megajoule of energy, within the national standard of 0.015-0.030 and the international benchmark of 0.020-0.035. The company has a potential improvement of 0-38.3% to meet the upper national limit and 0-47.1% to reach the international benchmark. This high energy productivity is crucial in reducing energy costs and environmental impact, indicating that EcoPlast effectively manages its energy resources. Further improvements could enhance operational efficiency and sustainability.

Waste Intensity (kg/kg): EcoPlast has a waste intensity of 0.50-0.58 kg of waste per kg of plastic, which is within the national standard of 0.40-0.60 and the international benchmark of 0.45-0.65. Potential improvements are 0-16.7% for national standards and 0-23.1% for international benchmarks. Lower waste intensity indicates that EcoPlast generates less waste relative to its output, reflecting effective waste reduction strategies. This positions the company as a leader in environmental stewardship, although there is room for minor improvements.

Wastewater Intensity (m³/kg): With a wastewater intensity of 1.8-2.3 m³ per kg of plastic, EcoPlast falls within the national standard of 1.5-3.0 and the international benchmark of 1.8-3.2. There is potential for a 23.3-40% improvement to meet the upper national limit and a 28.1-43.8% improvement for international benchmarks. Effective wastewater management practices indicate EcoPlast is likely employing good practices in water treatment and reuse, which helps in reducing environmental impacts and ensuring regulatory compliance

Table 9: EcoPlast (RECP) improvement potential

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 0.30-0.40 | 0.32-0.40 | 0-20% | 0.35-0.45 | 0-28.9% |
| Water Productivity ($kg/m^3$) | 0.10-0.20 | 0.14-0.18 | 10-30% | 0.12-0.22 | 10-36.4% |
| Energy Productivity (kg/MJ) | 0.015-0.030 | 0.0185-0.0265 | 0-38.3% | 0.020-0.035 | 0-47.1% |
| Waste Intensity (kg/kg) | 0.40-0.60 | 0.50-0.58 | 0-16.7% | 0.45-0.65 | 0-23.1% |
| Waste Water Intensity ($m^3/kg$) | 1.5-3.0 | 1.8-2.3 | 23.3-40% | 1.8-3.2 | 28.1-43.8% |

Table 10: NigerPlast (Non-RECP)

| Metric | National Standard | Current | Potential Improvement (%) to National Standard | International Benchmark | Potential Improvement (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 0.30-0.40 | 0.15-0.20 | 50-62.5% | 0.35-0.45 | 55.6-66.7% |
| Water Productivity ($kg/m^3$) | 0.10-0.20 | 0.05-0.08 | 60-75% | 0.12-0.22 | 63.6-77.3% |
| Energy Productivity (kg/MJ) | 0.015-0.030 | 0.010-0.012 | 60-66.7% | 0.020-0.035 | 65.7-71.4% |
| Waste Intensity (kg/kg) | 0.40-0.60 | 0.65-0.70 | -16.7 to -8.3% | 0.45-0.65 | No improvement needed |
| Waste Water Intensity ($m^3/kg$) | 1.5-3.0 | 3.5-4.0 | -33.3 to -16.7% | 1.8-3.2 | -25 to -9.4% |

NigerPlast (Non-RECP) Improvement potential (Table 10)

<u>Material Productivity (kg/kg):</u> NigerPlast achieves a material productivity of 0.15-0.20 kg of plastic per kg of raw material, which falls significantly below the national standard of 0.30-0.40 and the international benchmark of 0.35-0.45. There is substantial potential for improvement, with a need for a 50-62.5% increase to meet the national standard and a 55.6-66.7% increase to reach the international benchmark. This indicates significant inefficiencies in material use, suggesting the need for adopting advanced material handling and processing techniques to reduce waste and improve productivity.

Water Productivity (kg/m³): NigerPlast's water productivity is 0.05-0.08 kg of plastic per cubic meter of water, well below the national standard of 0.10-0.20 and the international benchmark of 0.12-0.22. This reflects a 60-75% improvement potential to meet national standards and a 63.6-77.3% improvement to reach international benchmarks. Excessive water usage suggests the need for more efficient water management practices. Investing in water recycling and conservation technologies could significantly reduce water use, lower operational costs, and minimize environmental impact.

Energy Productivity (kg/MJ): NigerPlast's energy productivity is between 0.010 and 0.012 kg of plastic per megajoule of energy, falling below the national standard of 0.015-0.030 and the international benchmark of 0.020-0.035. The potential for improvement is 60-66.7% to meet national standards and 65.7-71.4% to reach international benchmarks. This indicates significant energy inefficiencies, suggesting the need for energy audits and the adoption of more energy-efficient technologies. Improved energy management would reduce costs and environmental impact, aligning the company with industry standards.

Waste Intensity (kg/kg): NigerPlast has a waste intensity of 0.65-0.70 kg of waste per kg of plastic, exceeding the national standard of 0.40-0.60 and within the international benchmark of 0.45-0.65. This requires a reduction of -16.7 to -8.3% to meet national standards, while no improvement is needed for international benchmarks. High waste generation indicates inefficient processes and poor waste management practices. Improvements could include better recycling and waste reduction strategies to align with national standards and reduce disposal costs.

Wastewater Intensity (m³/kg): With a wastewater intensity of 3.5-4.0 m³ per kg of plastic, NigerPlast exceeds both the national standard of 1.5-3.0 and the international benchmark of 1.8-3.2. Improvement potential ranges from -33.3 to -16.7% to meet national standards and -25 to -9.4% for international benchmarks. High wastewater generation suggests the need for better water management and treatment practices. Investing in advanced wastewater treatment technologies and water recycling systems would help reduce wastewater output and environmental impact.

**Summary:** EcoPlast demonstrates strong performance across key indicators, meeting or exceeding both national and international standards. The company's efficient resource management, high productivity, and commitment to minimizing waste reflect its dedication to sustainability and operational excellence. While there is some room for improvement, particularly in water and energy productivity, EcoPlast's practices already position it as a competitive and environmentally responsible player in the plastics industry. This exemplary performance highlights the benefits of adopting resource-efficient and cleaner production practices. NigerPlast's performance falls significantly short of both national and international benchmarks in several key areas, including material and water productivity, energy use, and wastewater management. The company shows significant room for improvement, particularly in adopting more efficient resource management practices. Key areas for improvement include:

- Material Productivity: Significant enhancements are needed to optimize material use and reduce waste.
- Water Productivity: Investing in water recycling and conservation technologies to reduce excessive water consumption is crucial.
- Energy Efficiency: Conducting energy audits and adopting energy-efficient technologies to improve energy productivity.
- Waste and Wastewater Management: Implementing comprehensive waste reduction and advanced wastewater treatment strategies to align with industry standards.

By addressing these areas, NigerPlast can improve its operational efficiency, align with national and international benchmarks, and enhance its sustainability and competitiveness in the plastics industry. Adopting resource-efficient and cleaner production practices not only improves productivity and competitiveness but also contributes to broader environmental and sustainability goals, benefiting both the company and the community.

### 4.4.4. Improvement potential: Steel

EcoSteel (RECP) improvement potential (Table 11)

Material Productivity: EcoSteel demonstrates excellent material productivity, achieving between 0.91 and 0.94 kg of steel per kg of raw material. This performance is comfortably within the national standard of 0.90-1.00 and aligns with the international benchmark of 0.92-1.02. This high level of material utilization indicates efficient use of raw materials, minimizing waste and optimizing input. EcoSteel's strong material productivity showcases its commitment to reducing costs and enhancing sustainability by maximizing the use of resources.

Water Productivity: In terms of water productivity, EcoSteel produces 460-500 kg of steel per cubic meter of water. This performance meets the national standard of 450-550 and is closely aligned with the international benchmark of 400-500. Effective water management is critical in the steel industry due to its high water usage. EcoSteel's performance suggests effective water recycling and conservation practices, reducing dependence on freshwater and minimizing environmental impact. This indicates strong operational practices that balance efficiency with environmental stewardship.

Energy Productivity: EcoSteel's energy productivity stands at 380-400 kg of steel per megajoule of energy, which is within the national standard of 350-450 and aligns with the international benchmark of 380-480. High energy productivity is essential in the steel industry, which is notoriously energy-intensive. EcoSteel's ability to maintain such productivity reflects its effective management of energy resources, leading to reduced operational costs and environmental benefits. This performance highlights EcoSteel's commitment to operational efficiency and sustainability.

Waste Intensity: EcoSteel also excels in waste management, with a waste intensity of 0.172-0.182 kg of waste per kg of steel. This is better than the national standard of 0.15-0.25 and the international benchmark of 0.18-0.28. Lower waste intensity indicates minimal waste generation relative to steel output, reflecting effective waste reduction strategies and a commitment to environmental sustainability.

Wastewater Intensity: EcoSteel's wastewater intensity is 155-167 $m^3$ per kg of steel, well within both national and international standards. This indicates robust practices in wastewater treatment and reuse, contributing to reduced environmental impacts and regulatory compliance.

Table 11: EcoSteel (RECP) improvement potential

| Category | National Standards (Nigeria) | International Benchmarks | EcoSteel (RECP) | Potential Improvement for EcoSteel (%) to National Standard | Potential Improvement for EcoSteel (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 0.90-1.00 | 0.92-1.02 | 0.91-0.94 | 0-6.4% | 0-8.5% |
| Water Productivity (kg/$m^3$) | 450-550 | 400-500 | 460-500 | 0-16.3% | 0-8.0% |
| Energy Productivity (kg/MJ) | 350-450 | 380-480 | 380-400 | 0-15.6% | 0-20.0% |
| Waste Intensity (kg/kg) | 0.15-0.25 | 0.18-0.28 | 0.172-0.182 | 0-31.2% | 0-35.0% |
| Wastewater Intensity ($m^3$/kg) | 150-250 | 160-260 | 155-167 | 0-35.6% | 0-35.8% |

Table 12: NigerSteel (Non-RECP) improvement potential

| Category | National Standards (Nigeria) | International Benchmarks | NigerSteel (Non-RECP) | Potential Improvement for NigerSteel (%) to National Standard | Potential Improvement for NigerSteel (%) to International Benchmark |
|---|---|---|---|---|---|
| Material Productivity (kg/kg) | 0.90-1.00 | 0.92-1.02 | 0.90-0.92 | 0-10% | 0-9.8% |
| Water Productivity (kg/m³) | 450-550 | 400-500 | 550-590 | 0-9.1% | 10-18% |
| Energy Productivity (kg/MJ) | 350-450 | 380-480 | 420-500 | 0-6.7% | 4.2-12.5% |
| Waste Intensity (kg/kg) | 0.15-0.25 | 0.18-0.28 | 0.24-0.257 | 4.3-8.6% | 14.3-21.4% |
| Wastewater Intensity (m³/kg) | 150-250 | 160-260 | 222-236 | 0-11.8% | 10.2-27.1% |

NigerSteel (Non-RECP) Improvement Potential

Material Productivity: NigerSteel achieves a material productivity of 0.90-0.92 kg of steel per kg of raw material, which meets the national standard of 0.90-1.00 but falls short of the international benchmark of 0.92-1.02. While its material utilization is adequate, there is room for improvement to optimize material use. Potential improvements could involve adopting advanced processing techniques or better quality control measures to reduce material waste and enhance efficiency.

Water Productivity: In terms of water productivity, NigerSteel produces 550-590 kg of steel per cubic meter of water, exceeding the national standard of 450-550 and the international benchmark of 400-500. This indicates excessive water usage and suggests inefficiencies in water management. To address this, NigerSteel could implement water recycling and conservation measures, and invest in more efficient water management technologies to reduce its water footprint and operational costs. Improved water management is critical for aligning with both national and international standards and reducing environmental impacts.

Energy Productivity: NigerSteel's energy productivity ranges from 420-500 kg of steel per megajoule, meeting the national standard of 350-450 but only partially aligning with the international benchmark of 380-480. The higher end of this range suggests potential inefficiencies in energy use. To improve, NigerSteel could benefit from conducting energy audits and adopting energy-efficient technologies. Enhancing energy efficiency would reduce operational costs and environmental impacts, making the company more competitive and sustainable.

Waste Intensity: NigerSteel's waste intensity is 0.24-0.257 kg of waste per kg of steel, within the national standard of 0.15-0.25 but higher than the international benchmark of 0.18-0.28. High waste generation points to the need for better waste management practices. NigerSteel could enhance its waste reduction efforts by recycling by-products and implementing comprehensive waste reduction programs.

Wastewater Intensity: NigerSteel's wastewater intensity of 222-236 $m^3$ per kg of steel exceeds both national and international standards, indicating a need for improved wastewater management. Investing in advanced wastewater treatment technologies and water recycling systems would help reduce wastewater output and its environmental impact.

## 4.5. Summary

The comparative analysis of resource-efficient and cleaner production (RECP) and non-RECP companies across Nigeria's textile, brewery, plastics, and steel industries reveals significant potentials for improvement and highlights the need for targeted strategies to enhance sustainability and efficiency.

Despite their overall strong performance, most RECP firms still have room for enhancement, particularly in aligning with top-tier international benchmarks. Areas such as water productivity (EcoTex: 93-99%, EcoBrew: 17-39%) and energy productivity (EcoPlast: up to 47.1%) present opportunities for further optimization. However, it's noteworthy that EcoSteel demonstrates exemplary performance across all key indicators, meeting or exceeding both national and international standards. EcoSteel's efficient resource management, high water and energy productivity, and commitment to minimizing waste reflect a strong dedication to operational efficiency and sustainability. This positions EcoSteel as a competitive and environmentally responsible player in the steel industry, with no significant improvements required at this time.

Non-RECP Companies (NigerTex, NigerBrew, NigerPlast, NigerSteel) exhibit substantial improvement potential across most metrics. Critical areas include material productivity (NigerTex: 50-53%, NigerPlast: 55.6-66.7%), water productivity (NigerBrew: 40-61%, NigerPlast: 63.6-77.3%), energy efficiency (NigerTex: 89-90%, NigerBrew: 17-35%), and wastewater management (NigerTex: 4900-5952%, NigerBrew: 7-18%). While NigerSteel meets some national standards, it falls short of several international benchmarks, particularly in water and energy productivity, and waste and wastewater management. NigerSteel has significant room for improvement in waste intensity (14.3-21.4%) and wastewater intensity (10.2-27.1%).

Strategies for Improvement: RECP Companies:

1. Technological Upgrades: Invest in cutting-edge technologies to further enhance resource efficiency, particularly in water recycling, energy cogeneration, and advanced wastewater treatment.
2. Process Optimization: Continuously refine production processes to minimize waste generation and maximize output per unit of input.
3. Renewable Energy Integration: Increase the share of renewable energy sources to improve energy productivity and reduce carbon footprint.

4. Closed-loop Systems: Implement circular economy principles to reuse byproducts and minimize waste.
5. Employee Training: Regular upskilling in sustainable practices to maintain high operational standards.

Non-RECP Companies:

1. Resource Management Systems: Urgently implement integrated resource management systems to track and optimize material, water, and energy use (e.g., Enterprise Resource Planning systems).
2. Water Conservation: Adopt water-saving technologies such as rainwater harvesting, process water recycling, and efficient cooling systems to dramatically improve water productivity.
3. Energy Audits and Retrofits: Conduct comprehensive energy audits followed by retrofitting with energy-efficient equipment and improved insulation to boost energy productivity.
4. Waste Reduction Programs: Establish waste sorting, recycling, and upcycling initiatives to reduce waste intensity and potentially create new revenue streams from byproducts.
5. Wastewater Treatment: Invest in modern wastewater treatment facilities capable of treating and recycling process water to significantly reduce wastewater intensity.
6. Lean Manufacturing: Implement lean principles to minimize waste, improve process flow, and enhance overall productivity.
7. Strategic Partnerships: Collaborate with RECP companies, research institutions, or international organizations for knowledge transfer and capacity building in sustainable practices.
8. Incremental Adoption: Phase in RECP practices gradually, starting with low-hanging fruit to build momentum and reinvest savings into more capital-intensive improvements.

The disparities in performance underscore the transformative potential of RECP strategies. For RECP companies like EcoTex, EcoBrew, and EcoPlast, the focus should be on refining existing systems to achieve best-in-class global standards, following EcoSteel's lead in exemplary performance. Non-RECP firms, facing more significant gaps, need to prioritize foundational changes in resource management, often requiring substantial investment and organizational shifts.

For instance, NigerSteel should focus on enhancing water management by investing in water recycling and conservation technologies, improving energy efficiency through energy audits and the adoption of efficient technologies, and reducing waste generation through comprehensive waste management practices. By addressing these areas, NigerSteel can improve its operational efficiency, align with international benchmarks, and enhance its sustainability and competitiveness in the steel industry.

Government and industry bodies have a crucial role in facilitating this transition through policies that incentivize sustainable practices, provide access to green financing, and support technology transfer. Additionally, creating platforms for inter-company learning and benchmarking can accelerate the diffusion of best practices.

In conclusion, the deviations from national and international benchmarks across all four sectors highlight the urgent need for comprehensive RECP measures. By implementing targeted strategies for water conservation, material and energy efficiency, waste minimization, wastewater treatment, and emission reduction, these companies can not only improve their environmental performance but also enhance their competitiveness, comply with regulatory standards, and contribute to sustainable development goals. While the path to improvement varies in scale and complexity between RECP and non-RECP companies, the end goal remains the same: a manufacturing sector that balances productivity with environmental stewardship. By strategically addressing their respective improvement potentials, Nigerian industries can position themselves favourably in an increasingly eco-conscious global market.

# Chapter 5 : Dynamics and Regulatory Landscape

## 5.1. Companies' Perception of Drivers and Barriers of RECP

It is essential to examine the industrial perception of drivers and barriers that influence the adoption of RECP measures. Understanding these factors can help policymakers and industry stakeholders develop more effective strategies to overcome barriers and leverage the identified drivers. The data presents the perceptions of different companies regarding the drivers and barriers to implementing Resource Efficient and Cleaner Production (RECP) measures. The drivers are ranked on a scale of 1 to 5, with 5 being the most significant driver, while the barriers are also ranked from 1 to 5, with 5 being the most significant barrier.

Table 13: Perception of drivers and barriers of RECP in Nigeria[31]

| Company | Drivers | Barriers |
|---|---|---|
| EcoTex | Cost 5, Compliance 3, Env 4, Comp 3, CSR 4 | Fin 2, Expertise 1, Resist 2, Regs 3, Aware 2 |
| NigerTex | - | - |
| EcoPlast | Cost 5, Compliance 4, Env 3, Comp 4, CSR 3 | Fin 3, Expertise 2, Resist 3, Regs 2, Aware 4 |
| NigerPlast | - | - |
| EcoBrews | Cost 5, Compliance 4, Env 5, Comp 4, CSR 5 | Fin 2, Expertise 3, Resist 2, Regs 4, Aware 1 |
| NigerBrew | - | - |
| EcoSteel | Cost 5, Compliance 4, Env 4, Comp 5, CSR 3 | Fin 3, Expertise 2, Resist 4, Regs 3, Aware 2 |
| NigerSteel | Cost 4, Compliance 5, Env 3, Comp 4, CSR 4 | Fin 4, Expertise 3, Resist 2, Regs 4, Aware 3 |

[31] It's important to note that not all companies provided data for both drivers and barriers, which may indicate a lack of awareness or prioritization of RECP measures within those companies.

### 5.1.1. Drivers of RECP implementation

Figure 28 provides a breakdown of the perception of the drivers to RECP implementation in Nigeria. Among the companies that provided data, cost savings (Cost) emerged as the most significant driver for implementing RECP measures, with 83.3% (5 out of 6) of the companies, including EcoTex, EcoPlast, EcoBrew, EcoSteel, and NigerSteel, ranking it as the highest driver (5 on a scale of 1 to 5). This indicates that these companies perceive the potential for cost reduction through improved resource efficiency and cleaner production as a strong motivating factor, making a compelling economic case for their adoption.

Environmental benefits (Env) were also recognized as a significant driver, with 33.3% (2 out of 6) of the companies (EcoBrew and EcoSteel) ranking it as the highest driver (5), and another 33.3% (EcoTex and EcoPlast) ranking it as a strong driver (4 and 3, respectively). This suggests that these companies acknowledge the positive environmental impacts of RECP measures, are driven by a desire to reduce their ecological footprint, and contribute to sustainable development goals.

Compliance with regulations (Compliance) was another important driver, with 16.7% (1 out of 6) of the companies (NigerSteel) ranking it as the highest driver (5), and 50% (EcoPlast, EcoBrew, and EcoSteel) ranking it as a strong driver (4). This highlights the importance of adhering to environmental regulations and standards as a motivating factor for implementing RECP measures, emphasizing the role of regulatory frameworks in driving their adoption.

Competitiveness (Comp) was also seen as a significant driver, with 16.7% (1 out of 6) of the companies (EcoSteel) ranking it as the highest driver (5), and 50% (EcoPlast, EcoBrew, and NigerSteel) ranking it as a strong driver (4). These companies likely perceive RECP measures as a means to enhance their competitiveness by improving efficiency, reducing costs, and aligning with sustainability trends in the market.

Corporate Social Responsibility (CSR) was considered a driver by most companies, with 16.7% (1 out of 6) of the companies (EcoBrew) ranking it as the highest driver (5), 33.3%

(EcoTex and EcoSteel) ranking it as a strong driver (4), and 33.3% (EcoPlast and NigerSteel) ranking it as a moderate driver (3). This suggests that these companies recognize the importance of demonstrating environmental and social responsibility through RECP initiatives, which can enhance their reputation and stakeholder relations.

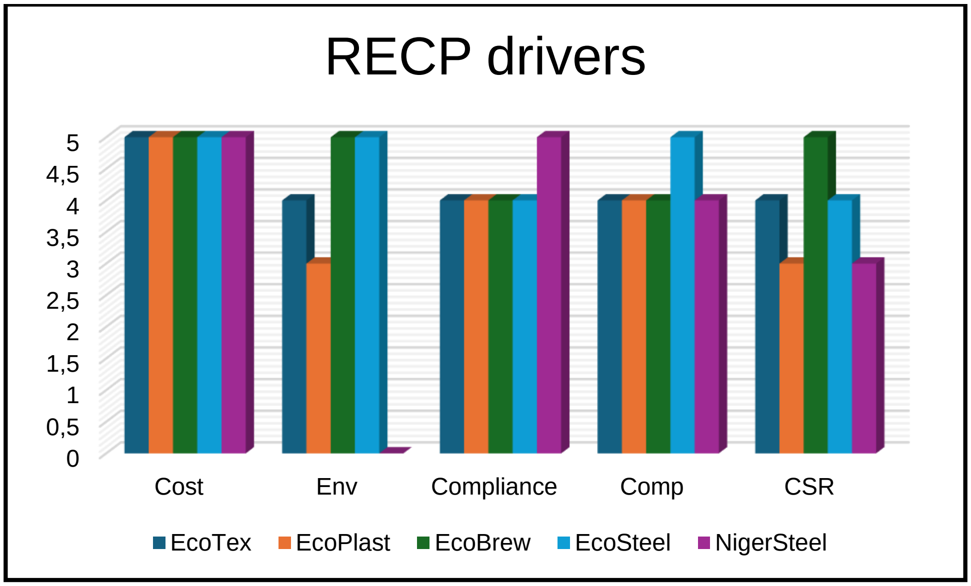



*Figure 28: RECP Drivers*

5.1.2. Barriers to RECP Implementation

While the drivers provide motivation for implementing RECP measures, companies also face various barriers that hinder their adoption. Financial constraints were identified as a barrier by 66.7% (4 out of 6) of the companies (EcoTex, EcoBrew, EcoSteel, and NigerSteel), with rankings ranging from 2 to 3 on the scale of 1 to 5. This suggests that the initial investment required for RECP measures may be perceived as a significant obstacle, particularly for companies with limited financial resources.

Lack of expertise was also seen as a barrier, with 50% (3 out of 6) of the companies (EcoPlast, EcoSteel, and NigerSteel) ranking it as a moderate barrier (2 or 3). This indicates that these companies may lack the necessary technical knowledge or skilled personnel to implement and maintain RECP measures effectively, highlighting the need for capacity-building and knowledge-sharing initiatives. EcoTex ranked it as 1, further emphasizing the expertise gap.

Resistance to change was identified as a barrier by 66.7% (4 out of 6) of the companies, with rankings ranging from 2 to 4. EcoTex ranked it as a moderate barrier (2), EcoPlast and NigerSteel ranked it as a moderate barrier (3), while EcoSteel ranked it as a significant barrier (4). This suggests that some companies may face internal resistance or inertia when it comes to adopting new practices or technologies associated with RECP measures, which could stem from organizational culture, fear of change, or lack of awareness.

Regulatory constraints were perceived as a barrier by 66.7% (4 out of 6) of the companies, with rankings ranging from 3 to 4. EcoTex ranked it as a moderate barrier (3), EcoBrew and NigerSteel ranked it as a significant barrier (4), and EcoSteel ranked it as a moderate barrier (3). This could indicate that these companies perceive existing regulations or policies as hindering or not adequately supporting the implementation of RECP measures, potentially due to complex bureaucratic processes, inconsistent enforcement, or a lack of clarity in the regulatory framework.

Lack of awareness was identified as a barrier by 50% (3 out of 6) of the companies, with rankings ranging from 1 to 4. EcoTex ranked it as a moderate barrier (2), EcoPlast ranked it as a significant barrier (4), NigerSteel ranked it as a moderate barrier (3), and EcoBrew ranked it as the lowest barrier (1). This suggests that some companies may lack sufficient awareness or understanding of the benefits and practices associated with RECP measures, hindering their adoption and highlighting the need for awareness campaigns and knowledge dissemination efforts.

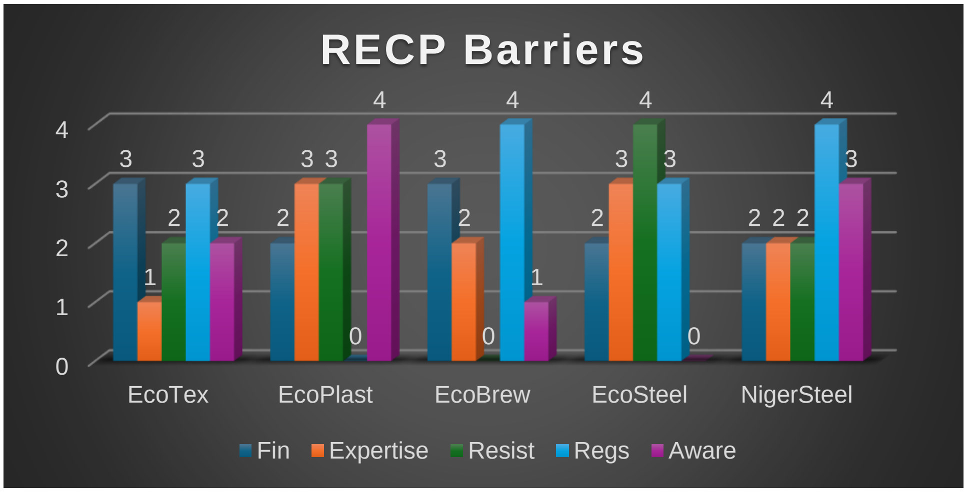



Figure 29: Barriers to RECP implementation in Nigeria

Overall, this data provides valuable insights into the industrial perception of drivers and barriers related to RECP implementation. By understanding these perceptions, policymakers, industry associations, and relevant stakeholders can develop targeted strategies to address the barriers and leverage the identified drivers to facilitate the widespread adoption of RECP measures across various industrial sector

By understanding these drivers and barriers, policymakers and industry stakeholders can develop targeted strategies to leverage the identified drivers and address the specific barriers faced by companies in different sectors. This could involve providing financial incentives, facilitating technology transfer, promoting capacity-building initiatives, streamlining regulatory processes, and enhancing awareness and knowledge-sharing efforts. A comprehensive approach that addresses drivers and barriers will be crucial in fostering the widespread adoption of RECP measures across various industrial sectors.

## 5.2. Analysis of Regulatory Framework in the Context of RECP

This section covers the key aspects of the regulatory framework analysis, including an overview of existing regulations, legal frameworks governing industrial activities, alignment with international conventions, strengths and weaknesses of the current system, opportunities for improvement, and recommendations for regulatory reform and RECP mainstreaming. The analysis provides a comprehensive and critical assessment of the regulatory landscape, identifies gaps and challenges, and proposes actionable measures to strengthen the regulatory framework and promote the adoption of RECP principles and practices in Nigerian industries.

### 5.2.1 Legal Frameworks Governing Industrial Activities

Nigeria has established a comprehensive legal framework to regulate industrial activities and their environmental impacts. This framework includes regulations on industrial emissions, effluent discharge, waste management, environmental permitting and licensing requirements, and environmental impact assessment procedures. These legal instruments aim to promote sustainable industrial development, protect public health and the environment, and ensure compliance with national and international environmental standards.

Environmental Impact Assessment (EIA) Act (1992)

The Environmental Impact Assessment (EIA) Act (1992) is a cornerstone of Nigeria's environmental legislation, mandating the conduct of environmental impact assessments for proposed projects and activities with potential adverse environmental impacts.

- The EIA Act makes it mandatory to conduct an environmental impact assessment for all public and private projects with potential adverse environmental impacts.

- It establishes the legal and administrative procedures for conducting EIAs, including the preparation of environmental impact statements, public participation, and decision-making processes (Olokesusi, 1998)
- The Act covers a wide range of projects across various sectors, such as agriculture, mining, manufacturing, oil and gas, transportation, and infrastructure development (Echefu & Akpofure, 2003).
- The Federal Ministry of Environment and state environmental protection agencies are responsible for administering the EIA process and ensuring compliance with the Act.

National Environmental Standards and Regulations Enforcement Agency (NESREA) Act (2007)

- The NESREA Act established the National Environmental Standards and Regulations Enforcement Agency (NESREA) as the primary enforcement agency for environmental laws and regulations in Nigeria.
- NESREA is responsible for setting and enforcing environmental standards, regulations, and guidelines for air quality, noise, effluent limitations, chemical management, and other environmental aspects (NESREA, 2007)[32].
- The agency oversees environmental compliance monitoring, permitting, and enforcement actions, including sanctions for violations of environmental laws and regulations
- NESREA has developed various regulations and guidelines, such as the National Environmental (Surface and Groundwater Quality Control) Regulations (2011), National Environmental (Soil Erosion and Flood Control) Regulations (2011), and National Environmental (Noise Standards and Control) Regulations (2009).

National Policy on the Environment (Revised 2016)[33]

- The National Policy on the Environment provides a comprehensive framework for environmental management in Nigeria, outlining guiding principles, sectoral strategies, and implementation plans.
- The policy covers a wide range of environmental issues, including biodiversity conservation, pollution control, sustainable resource use, environmental education and awareness, and the application of environmental standards and regulations.
- It promotes the integration of environmental considerations into development planning, stakeholder participation, and the use of economic instruments for environmental protection.

[32] https://www.nesrea.gov.ng/wp-content/uploads/2020/04/NESREA-ACT.pdf
[33] https://www.nesrea.gov.ng/wp-content/uploads/2017/09/National-Policy-on-Environment.pdf

- The policy also emphasizes the need for institutional strengthening, capacity building, and effective enforcement of environmental laws and regulations.

<u>Regulations on Industrial Emissions, Effluent Discharge, and Waste Management</u>

The National Environmental (Air Quality Control) Regulations (2014) and the National Environmental (Surface and Groundwater Quality Control) Regulations (2011), issued by NESREA, set standards and guidelines for air emissions and effluent discharge from industrial activities. These regulations establish permissible limits for various air pollutants, such as particulate matter, sulfur oxides, nitrogen oxides, and volatile organic compound. They also specify maximum allowable concentrations of pollutants in surface and groundwater bodies, as well as requirements for effluent treatment and discharge monitoring.

The National Environmental (Sanitation and Waste Control) Regulations (2009) provide a legal framework for waste management, including industrial waste, hazardous waste, and sewage. These regulations mandate the implementation of waste minimization, recycling, and proper disposal practices, as well as the treatment and handling of hazardous waste in accordance with international standards and best practices

Other relevant policies and regulations:

1. National Forestry Policy (2006) - This policy aims to achieve sustainable forest management, conservation of forest biodiversity, and the promotion of forest-based economic activities.
2. National Biodiversity Strategy and Action Plan (2016-2020) - The plan outlines strategies and actions for the conservation and sustainable use of biological resources, including the protection of ecosystems, species, and genetic diversity.
3. Harmful Waste (Special Criminal Provisions, etc.) Act (2004) - This Act regulates the handling, treatment, and disposal of harmful waste, including hazardous waste generated by industries.

4. National Gas Policy (2017) - The policy aims to reduce gas flaring, promote gas utilization, and develop gas infrastructure in Nigeria, addressing environmental and economic concerns associated with gas flaring in the oil and gas industry.
5. National Environmental (Sanitation and Waste Control) Regulations (2009) - These regulations, issued by NESREA, establish standards and guidelines for waste management, including industrial waste, hazardous waste, and sewage.

The existing environmental laws and policies in Nigeria provide a comprehensive regulatory framework for conducting environmental assessments, setting standards for pollution prevention and control, promoting sustainable resource use, and defining compliance and enforcement mechanisms across various sectors, including industries. However, challenges persist in the implementation, coordination among agencies, capacity building, and stakeholder engagement, which will be discussed further in subsequent sections.

## 5.3. Alignment with International Conventions and Agreements

Although, Nigeria as a non-Annex-1 country[34] has no GHG-emission reduction commitments within the frameworks of the international agreements, however, Nigeria's environmental regulations and policies are designed to align with various international conventions and agreements aimed at promoting sustainable development, combating climate change, and protecting the environment. This alignment demonstrates Nigeria's commitment to addressing global environmental challenges and adhering to internationally recognized standards and best practices. Nigeria ratified the Paris Agreement on Climate Change in 2017[35], committing to taking ambitious measures to mitigate greenhouse gas (GHG) emissions and adapt to the impacts of climate change.

The country's Nationally Determined Contribution (NDC) under the Paris Agreement outlines specific targets and actions to reduce GHG emissions across various sectors, including industry. The National Climate Change Policy (2021)[36] and the Nationally

[34] https://climatechange.gov.ng/wp-content/uploads/2020/09/nigeria-1st-biennial-update-report.pdf
[35] https://unfccc.int/sites/default/files/resource/Nigeria_LTS1.pdf
[36] https://climatechange.gov.ng/wp-content/uploads/2021/08/NCCP_NIGERIA_REVISED_2-JUNE-2021.pdf

Determined Contribution (NDC) (2021)[37] provide a policy framework and roadmap for Nigeria to achieve its climate change mitigation and adaptation goals. These documents emphasize the need for transitioning towards low-carbon and climate-resilient development pathways, promoting energy efficiency, and adopting cleaner production technologies in industries.

In line with the Paris Agreement, Nigeria's environmental regulations, such as the National Environmental (Air Quality Control) Regulations (2014) and the National Environmental (Sanitation and Waste Control) Regulations (2009), aim to reduce industrial emissions and promote sustainable waste management practices, thereby contributing to climate change mitigation efforts.

Furthermore, Nigeria is a signatory to the United Nations 2030 Agenda for Sustainable Development, which outlines 17 Sustainable Development Goals (SDGs) to be achieved by 2030 (United Nations, 2015). Nigeria's National Policy on the Environment (Revised 2016) and the Economic Recovery and Growth Plan (2017-2020) align with the SDGs by promoting sustainable industrial development, resource efficiency, pollution prevention, and environmental protection.

Other Relevant International Treaties and Conventions

Nigeria is a party to several other international treaties and conventions related to environmental protection and sustainable development, which have influenced the country's environmental regulations and policies:

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1992): Regulates the transboundary movement and disposal of hazardous wastes, aligning with Nigeria's Harmful Waste (Special Criminal Provisions) Act (2004).
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (2004): Promotes shared responsibility and cooperative efforts in the international trade of

[37] https://unfccc.int/documents/497790

hazardous chemicals and pesticides, aligning with Nigeria's National Environmental (Chemical, Pharmaceutical, Soap and Detergent Manufacturing Industries) Regulations (2009).

- Stockholm Convention on Persistent Organic Pollutants (2004): Aims to eliminate or restrict the production and use of persistent organic pollutants (POPs), aligning with Nigeria's National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants (2010).
- Convention on Biological Diversity (CBD) (1992): Promotes the conservation and sustainable use of biodiversity, aligning with Nigeria's National Biodiversity Strategy and Action Plan (2016-2020) and the Environmental Impact Assessment (EIA) Act (1992).

By aligning its environmental regulations and policies with these international conventions and agreements, Nigeria demonstrates its commitment to addressing global environmental challenges, promoting sustainable development, and adhering to internationally recognized standards and best practices.

## 5.4. Strengths of the Existing Regulatory Framework

Nigeria's environmental regulatory framework has several strengths that contribute to its effectiveness in promoting sustainable development and environmental protection. The Nigerian legal framework encompasses a wide range of environmental aspects, including air quality, water quality, waste management, biodiversity conservation, and environmental impact assessment, providing a holistic approach to environmental regulation.

Specific regulations, such as the National Environmental (Air Quality Control) Regulations (2014) and the National Environmental (Surface and Groundwater Quality Control) Regulations (2011), establish comprehensive standards and guidelines for controlling industrial emissions and effluent discharge. As mentioned earlier. Nigeria's environmental regulations and policies are aligned with various international conventions and agreements, such as the Paris Agreement on Climate Change, the United

Nations Sustainable Development Goals (SDGs), and the Basel Convention on Hazardous Wastes, ensuring compatibility with globally recognized standards and best practices.

The Environmental Impact Assessment (EIA) Act (1992) and its procedures are consistent with the principles and guidelines of the International Association for Impact Assessment (IAIA) and the World Bank's Environmental Assessment Sourcebook, promoting international best practices in environmental impact assessment. There is also provision for public participation and stakeholder engagement. For example, the EIA Act (1992) mandates public consultations and stakeholder engagement throughout the environmental impact assessment process, ensuring transparency and consideration of public concerns. Also, The National Policy on the Environment emphasizes the importance of stakeholder participation, environmental education, and public awareness in environmental decision-making processes. These strengths provide a solid foundation for effective environmental regulation and contribute to Nigeria's sustainable industrial development and environmental protection efforts.

## 5.5. Weaknesses and Challenges of legal and policy frameworks

While Nigeria has a robust environmental legal and policy framework, implementing and enforcing these regulations has faced significant challenges. Several studies, such as Oruonye ED & Ahmed YM (2020), Ijaiya & Joseph (2014), and Olokesusi (1998), highlighted the weak enforcement of environmental laws and regulations as a major barrier to effective environmental management in the country. The reasons adduced for poor implementation include inadequate funding, lack of trained personnel, corruption, and limited political will Abdullateef Abdullahi Ibrahim (et al., 2020). Ogunba, (2004) andOsuizugbo & Nnodu (2023).

For instance, the Environmental Impact Assessment (EIA) process has been criticized for its bureaucratic bottlenecks, lack of transparency, and inadequate public participation. Further, the environmental governance structure in Nigeria involves multiple agencies and institutions at the federal, state, and local levels, often leading to overlapping jurisdictions, conflicts of interest, and poor coordination (Ogbodo, 2009). For example, while NESREA is the primary enforcement agency, other agencies like the Department of

Petroleum Resources (DPR) and state environmental protection agencies also have regulatory roles, leading to potential conflicts and duplication of efforts (Olokesusi et al., 2015).

Effective implementation of environmental regulations requires adequate human and institutional capacity, which has been a significant challenge in Nigeria. Ogbodo (2009) highlighted the lack of skilled personnel, inadequate training, and outdated equipment as major constraints environmental regulatory agencies face. Furthermore, industries often lack the technical expertise and resources to adopt cleaner production technologies and comply with environmental standards (Emoyan et al., 2008). There is often limited awareness and understanding of environmental regulations and sustainable practices among industries, particularly small and medium-sized enterprises (SMEs), leading to low levels of compliance. Lack of effective stakeholder engagement and public awareness campaigns can contribute to resistance and non-compliance with environmental policies and regulations.

Nigeria's environmental regulations may not adequately address emerging environmental challenges, such as climate change adaptation, circular economy principles, and the management of electronic waste (e-waste) and microplastics, requiring updates and revisions to remain relevant and effective. Last but not least. There may be gaps in the regulatory framework regarding adopting new technologies, such as renewable energy sources and cleaner production technologies, hindering the transition towards a more sustainable industrial sector.

Addressing these challenges will require concerted efforts to strengthen institutional capacities, streamline coordination mechanisms, promote capacity-building initiatives, and enhance stakeholder engagement processes. Subsequent sections will explore these aspects further, with recommendations for improving the regulatory framework and promoting resource-efficient and cleaner production (RECP) practices in Nigerian industries.

## 5.6. Opportunities for Improvement and RECP Integration

Despite the challenges faced in implementing and enforcing environmental regulations in Nigeria, there are significant opportunities for improvement and integration of resource-efficient and cleaner production (RECP) principles and practices. These opportunities include:

1. Streamlining and harmonization of regulations:
    - Conducting a comprehensive review of existing environmental laws and regulations to identify overlaps, gaps, and inconsistencies.
    - Harmonizing and consolidating regulations to improve clarity, reduce duplication, and enhance coordination among agencies
    - Establishing a central coordinating body or inter-agency committee to oversee implementing and enforcing environmental regulations across various sectors.
2. Capacity building for enforcement agencies and industries:
    - Providing training and professional development programs for regulatory agency personnel to enhance their technical expertise, enforcement capabilities, and understanding of RECP concepts.
    - Developing industry-specific guidelines and toolkits to assist companies in implementing RECP practices, such as resource efficiency, waste minimization, and cleaner production technologies.
    - Encouraging knowledge-sharing and partnerships between industries, research institutions, and regulatory agencies to facilitate the adoption of RECP practices.
3. Promoting cleaner production technologies and practices:
    - Providing incentives, such as tax credits, subsidies, or preferential financing, for industries that invest in cleaner production technologies and RECP initiatives.
    - Establishing voluntary environmental management programs, such as eco-labelling or environmental certification schemes, to recognize and promote industries with exemplary environmental performance.

    - Encouraging the development and adoption of green technologies, renewable energy sources, and eco-industrial parks that promote resource efficiency and waste valorization.
4. Incentives for the adoption of RECP principles and practices:
    - Introducing market-based instruments, such as emissions trading schemes, pollution taxes, or deposit-refund systems, to encourage industries to reduce their environmental footprint and adopt RECP practices.
    - Providing financial incentives, such as grants or low-interest loans, to support small and medium-sized enterprises (SMEs) implementing RECP initiatives.
    - Offering technical assistance and consulting services to help industries identify and implement RECP opportunities within their operations.
5. Strengthening stakeholder engagement and public participation:
    - Enhancing transparency and access to environmental information by establishing public registers, online databases, and environmental reporting mechanisms.
    - Promoting public consultations and stakeholder dialogues while developing and reviewing environmental policies, regulations, and RECP initiatives.
    - Encouraging the formation of industry associations, civil society organizations, and community-based monitoring groups to participate in environmental decision-making processes.
    - Raising public awareness about the benefits of RECP and the importance of sustainable industrial development through educational campaigns and outreach programs.

By embracing these opportunities, Nigeria can strengthen its environmental governance framework, foster a compliance and continuous improvement culture, and support the transition towards a more resource-efficient and sustainable industrial sector.

## 5.7. Perception and Awareness of Relevant Policies

This section provides valuable insights into the companies' awareness of relevant policies, perceptions of policy effectiveness, and suggestions for improving policy implementation to promote RECP adoption (Table 14). By considering these insights, policymakers and relevant authorities can address the identified gaps, strengthen enforcement mechanisms, and develop targeted support programs to facilitate the widespread adoption of RECP measures across different industrial sectors.

Table 14: Perception and Awareness of relevant policies

| Company | Policy Awareness | Policies Known | Policy Effect | Policy Suggestions |
|---|---|---|---|---|
| EcoTex | Yes | EIA Act | 3 | Incentives, Enforcement |
| NigerTex | Yes | EIA Act | 4 | Training, Financial support. |
| Ecoplast | Yes | Extended Producer Responsibility | 4 | Strict enforcement and public awareness. |
| NigerPlast | No | Plastic Waste Management Policy | - | - |
| EcoBrews | Yes | National Breweries Policy, Environmental Regulations | 4 | Tax incentives, Technical support |
| NigerBrew | Yes | Water Resources Act, Food Safety Standards | 3 | Streamlined permitting, Capacity building |
| EcoSteel | Yes | National Steel Policy, Env. Regulations | 3 | Financial incentives, R&D support |
| NigerSteel | Yes | Mineral & Metal Policy, Air Quality Standards | 4 | Strict monitoring, Technology transfer |

**Awareness:** Most companies surveyed demonstrated awareness of relevant policies and regulations related to their respective industries and environmental management practices. Specifically, 87.5% (7 out of 8) of the companies indicated policy awareness, while only 12.5% (NigerPlast) reported a lack of policy awareness. This lack of awareness could pose a significant barrier to implementing Resource Efficient and Cleaner Production (RECP) measures for NigerPlast.

**Policies Known:** The companies were familiar with a range of national policies, acts, and regulations to promote sustainable practices and environmental protection. Among the textile companies, 100% (EcoTex and NigerTex) were aware of the Environmental Impact Assessment (EIA) Act. In the plastics industry, 50% (Ecoplast) recognized the Extended Producer Responsibility policy, while the other 50% (NigerPlast) acknowledged the Plastic Waste Management Policy. The brewery sector companies, EcoBrews (100%) and NigerBrew (100%), demonstrated knowledge of industry-specific policies such as the environmental regulations, the Water Resources Act, and Food Safety standards. Both EcoSteel (100%) and NigerSteel (100%) were familiar with national environmental regulations, mineral and metal Policies, and air quality standards in the steel sector.

**Policy Effect:** The companies provided subjective ratings on the perceived effectiveness of the policies in promoting RECP practices, using a scale of 1 to 5 (with 5 being the highest). The average rating across all companies was 3.625, indicating a moderate to high level of perceived policy effectiveness. However, there were variations among the companies. Ecoplast, EcoBrews, and NigerSteel rated the policy effect as 4, suggesting a relatively high level of effectiveness. On the other hand, EcoTex, NigerBrew, and EcoSteel rated the policy effect as 3, indicating a moderate level of effectiveness.

**Policy Suggestions:** The companies offered various suggestions to improve policy implementation and promote RECP adoption:

- 37.5% (EcoTex, Ecoplast, and NigerSteel) emphasized stronger enforcement measures, strict monitoring, and public awareness campaigns to ensure compliance with RECP policies.

- 25% (NigerTex and EcoSteel) highlighted the importance of providing financial incentives, such as tax breaks and R&D support, to encourage companies to invest in RECP initiatives.
- 25% (NigerTex and NigerBrew) suggested offering training programs and capacity-building initiatives to equip companies with the necessary expertise and skills for RECP implementation.
- 25% (EcoBrews and NigerBrew) recommended streamlining permitting processes and providing technical support to facilitate the adoption of RECP measures.
- 12.5% (Ecoplast) advocated technology transfer programs to facilitate access to cleaner and more efficient production technologies.

This analysis provides valuable insights into the companies' awareness of relevant policies, their perceptions of policy effectiveness, and their suggestions for improving policy implementation to promote RECP adoption. By considering these insights, policymakers and relevant authorities can address the identified gaps, strengthen enforcement mechanisms, and develop targeted support programs, such as financial incentives, training initiatives, and technology transfer programs, to facilitate the widespread adoption of RECP measures across different industrial sectors.

# Chapter 6 : Conclusion

## Recommendations

To effectively mainstream resource-efficient and cleaner production (RECP) in the Nigerian industrial sector, a comprehensive regulatory reform that addresses the existing challenges and creates an enabling environment for adopting sustainable practices is crucial. The following recommendations are proposed.

- Propose amendments to existing laws and regulations: for instance, review and update the Environmental Impact Assessment (EIA) Act by incorporating RECP principles and requirements into the EIA process, such as evaluating resource efficiency, cleaner technology options, and life-cycle impacts.

- Establish an inter-agency coordination mechanism, such as a national environmental council or committee, to harmonize policies and ensure effective collaboration.
- Revise emission standards, effluent discharge limits, and waste management guidelines to reflect RECP principles, such as promoting waste minimization, resource recovery, and cleaner production technologies.
- Introduce sector-specific RECP guidelines and industry best practice manuals, based on international standards and best available techniques (BAT).
- Mandate implementation of environmental management systems (EMS), such as ISO 14001, for industries to systematically identify, manage, and improve their environmental performance.
- Develop a national RECP policy framework, which might involve establishing a multi-stakeholder task force or committee to develop the policy, involving representatives from government agencies, industries, academia, and civil society organizations.
- Define clear objectives, targets, and action plans for promoting RECP in different industrial sectors, aligned with national and international sustainable development goals.

- Outline strategies for capacity building, technology transfer, financial incentives, and awareness-raising campaigns to support RECP adoption.
- Create a specialized unit within NESREA or the Federal Ministry of Environment to coordinate RECP initiatives, provide technical assistance, and facilitate knowledge sharing.
- Develop a network of RECP experts, consultants, and service providers to support industries conducting resource efficiency audits, implementing cleaner technologies, and optimizing processes.
- Collaborate with international organizations, such as the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP), to access funding, technical expertise, and best practices in RECP implementation.
- Develop criteria and standards for eco-labels or environmental certifications based on RECP principles, such as resource efficiency, waste minimization, and cleaner production.
- Provide incentives, such as tax benefits, preferential public procurement, or marketing advantages, for industries that obtain eco-labels or environmental certifications.
- Develop a robust monitoring and evaluation framework by establishing a set of performance indicators and benchmarks for resource efficiency, emissions reduction, waste minimization, and other RECP parameters in different industrial sectors.
- Implement regular monitoring and reporting requirements for industries, including self-monitoring, third-party audits, and public disclosure of environmental performance data. Conduct periodic compliance inspections and enforcement actions by regulatory agencies, supported by modern monitoring equipment and analytical capabilities.
- Introducing market-based instruments, such as emissions trading schemes, pollution taxes, or deposit-refund systems, to create economic incentives for industries to reduce their environmental footprint and adopt RECP practices.

- Promote public consultations and stakeholder dialogues during developing, reviewing, and implementing environmental policies, regulations, and RECP initiatives, ensuring that diverse perspectives and concerns are considered.

## Conclusion

This research investigated the impact of Resource Efficiency and Cleaner Production (RECP) methodologies on reducing industrial and environmental impact in Nigeria. The study employed a mixed-methods approach, combining quantitative and qualitative data to comprehensively understand the current state of RECP adoption in Nigerian industries and its potential benefits. The literature review revealed that Nigeria's industrial sector faces significant challenges related to inefficient resource consumption and environmental degradation. The growing demand for energy, water, and raw materials has put increasing pressure on the country's resources, impacting various industrial sectors and communities. RECP methods have been identified as a potential solution to address these issues, but substantial financial and institutional resources are required for widespread implementation. The analysis covered four sectors: textile, brewery, plastics, and steel, and evaluated key environmental performance indicators, including material productivity, water productivity, energy productivity, waste intensity, wastewater intensity, and emission intensity.

A simple linear regression analysis was performed on each performance indicator for the companies in the respective sectors to assess the environmental performance of RECP and non-RECP companies. The linear regression models were developed using historical data from 2018 to 2022, allowing for the identification of trends and rates of change over time. The analysis aimed to objectively compare the environmental performance of RECP and non-RECP companies and provide insights into the effectiveness of RECP practices.

By comparing the performance of RECP and non-RECP companies across various sectors, this study provides a compelling case for the widespread implementation of RECP methodologies in Nigeria's industrial landscape. The assessment confirmed that while initial steps have been taken in some industries to improve energy efficiency, awareness of energy and resource efficiency issues is generally very low. Many companies have insufficient insight into their energy use, and resource use (such as water consumption) is often not monitored at all. However, all companies visited expressed interest in learning more about these issues and improving their energy and resource efficiency.

The outcomes of the assessments from these companies provided valuable insights into the technological and environmental challenges faced by Nigeria's industrial sector. This research's findings underscore the importance of adopting RECP practices to improve environmental performance and mitigate the negative impacts of industrial activities on the environment.

The study also highlighted the importance of self-assessment frameworks for benchmarking environmental and social performance against international, national, and corporate requirements. The assessment was found to be particularly useful for identifying areas of improvement in adopting RECP methodologies.

The results of this study also suggest that policies and regulations promoting the adoption of RECP practices could effectively reduce the environmental impact of industries in Nigeria. Governments and regulatory bodies could incentivize companies to adopt RECP practices through tax breaks, subsidies, or other measures. Stricter regulations and enforcement could also be implemented to ensure companies adhere to environmental standards and adopt sustainable practices. To support the widespread adoption of RECP in Nigeria, policymakers should consider integrating RECP into the country's long-term planning documents at both the national and state levels. This holistic approach would require collaboration between researchers, policymakers, service providers, and other stakeholders to build trust, identify knowledge gaps, and establish accountability mechanisms.

## Study Limitations

The research confirmed that while initial steps have been taken in some industries to improve energy efficiency, in general, awareness of the issues related to energy and resource efficiency is very low among the companies studied for this PhD thesis in Nigeria.

It was gathered that many companies have insufficient insight into their energy use, and resource use, such as water consumption, is often not monitored at all.

The study's scope was restricted to a limited number of companies, and the findings may not wholly represent Nigeria's entire industrial sector. Secondly, the data collection process may have been affected by companies' willingness to disclose information, the accuracy of self-reported data, and the availability of comprehensive records on resource consumption and waste generation.

Additionally, the study focused primarily on assessing energy and resource efficiency challenges. Still, implementing proposed solutions or the long-term monitoring of their effectiveness was beyond the scope of this PhD research. Furthermore, the study was conducted within a specific time frame and geographic region, which may influence the findings and limit the generalizability of the results to other contexts or time periods.

Another significant limitation of the study was the inability to calculate or include greenhouse gas (GHG) emissions in the analysis. This was because the participating companies either did not have the necessary data or could not provide it. Including GHG emissions data would have provided a more comprehensive understanding of the environmental impact of the companies' operations and the potential benefits of RECP adoption in climate change mitigation. The absence of this data highlights the need for improved data collection and monitoring systems within the Nigerian industrial sector to support future research and decision-making related to sustainability and environmental performance.

Despite these limitations, the study provides valuable insights into the current energy and resource efficiency state in the Nigerian industrial sector, highlighting the need for increased awareness, monitoring, and implementation of sustainable practices. The findings can serve as a foundation for future research, policy development, and targeted interventions to address the identified challenges and promote a more sustainable and resource-efficient industrial landscape in Nigeria.

## Future Research Directions

While this study provides valuable insights into the impact of RECP methodologies on reducing industrial and environmental impact in Nigeria, there are several avenues for future research. Further studies could investigate the specific RECP practices adopted by companies and their effectiveness in reducing environmental impact, such as quantifying reductions in waste generation, water consumption, energy usage, and greenhouse gas emissions. Researchers could also explore the economic benefits of RECP adoption, such as cost savings, reduced operational expenses, increased competitiveness, and social implications, including job creation, skill development, and community engagement.

Additional research directions include:

- Comprehensive Sector-Wide Assessments: Investigating the RECP practices adopted by a larger sample of companies across various industrial sectors in Nigeria to provide a more representative and holistic understanding, allowing for identifying sector-specific challenges and best practices.
- Comparative Studies and Best Practice Sharing: Benchmarking the RECP practices and performance of Nigerian companies against regional and international counterparts to facilitate the identification of best practices and enable knowledge-sharing and technology transfer opportunities.
- Policy Evaluation and Regulatory Framework Analysis: Evaluating the effectiveness of existing policies, regulations, and incentive structures in promoting RECP adoption to inform policy revisions and the development of more robust and supportive regulatory frameworks.
- Stakeholder Engagement and Capacity Building: Exploring strategies for enhancing stakeholder engagement, fostering public-private partnerships, and developing capacity-building programs to address identified barriers, such as lack of awareness and expertise.
- Additionally, future research could examine the role of environmental information disclosure in encouraging businesses to adopt RECP practices by involving

communities and customers. This alternative tool could complement regulatory efforts and market-based initiatives in promoting sustainable industrial practices.

# References

Abdullateef Abdullahi Ibrahim, Abbas Sani, Ali Mustapha Gado, Muhammad Abdullahi Ibrahim, Mustapha Said Sulaiman, & Idris Umar Zungum. (2020). Environmental impact assessment in Nigeria- A review. *World Journal of Advanced Research and Reviews*, *8*(3), 330–336. https://doi.org/10.30574/wjarr.2020.8.3.0487

Adeniran, J. A., Yusuf, R. O., Fakinle, B. S., & Sonibare, J. A. (2019). Air quality assessment and modelling of pollutants emission from a major cement plant complex in Nigeria. *Atmospheric Pollution Research*, *10*(1), 257–266. https://doi.org/10.1016/j.apr.2018.07.010

Aghalino, S. O., & Eyinla, B. (2009). Oil Exploitation and Marine Pollution: Evidence from the Niger Delta, Nigeria. *Journal of Human Ecology*, *28*(3), 177–182. https://doi.org/10.1080/09709274.2009.11906236

Ahmad, A. (2003). Policing Industrial Pollution in Nigeria. In *International Environmental Law and Policy in Africa* (pp. 131–150). Springer Netherlands. https://doi.org/10.1007/978-94-017-0135-8_7

Aiyedun, P. O., Adeyemi, O. A., & Bolaji, B. O. (2008). Energy Efficiency of a Manufacturing Industry: A Case Study of Nigeria Eagle Flour Mills Limited, Ibadan. *ASSET An International Journal*, *7*(2).

Amah, V. E., Udeh, N., & Effiong, B. O. (2020). Particulate Matter Pollution around a Cement Industry and its Potential Effect. *Journal of Scientific Research and Reports*, 130–140. https://doi.org/10.9734/jsrr/2020/v26i1030328

Asha'ari, M. J., & Daud, S. (2019). The influence of cleaner production and resource efficiency on corporate sustainability performance: the moderating role of organisation size. *International Journal of Environmental Technology and Management*, *22*(4/5), 364. https://doi.org/10.1504/IJETM.2019.10026431

Bello, A. T., & Nwaeke, T. (2023). Impacts of Oil Exploration (Oil and Gas Conflicts; Niger Delta as a Case Study). *Journal of Geoscience and Environment Protection*, *11*(03), 189–200. https://doi.org/10.4236/gep.2023.113013

Bhuiyan, M. A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., & Huang, X. (2022). Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.878394

Chete, L. N., Adeoti, J. O., Adeyinka, F. M., & Ogundele, O. O. (2014). *Industrial development and growth in Nigeria: Lessons and challenges* (Vol. 2014). UNU-WIDER. https://doi.org/10.35188/UNU-WIDER/2014/740-0

Draper, P., & Mbirimi, I. (2010). *Climate Change and Trade: The Challenges for Southern Africa*.

E. Ite, A., & J. Ibok, U. (2013). Gas Flaring and Venting Associated with Petroleum Exploration and Production in the Nigeria's Niger Delta. *American Journal of Environmental Protection*, *1*(4), 70–77. https://doi.org/10.12691/env-1-4-1

Echefu, N., & Akpofure, E. (2003). Environmental impact assessment in Nigeria: Regulatory background and procedural framework. In Sadler B & McCabe M. (Eds.), *United Nations Environment Programme Environmental Impact Assessment Training Resource Manual* (pp. 63–74).

Emoyan, O. O., Akpoborie, I. A., & Akporhonor, E. E. (2008). The Oil and Gas Industry and the Niger Delta: Implications for the Environment. *J. Appl. Sci. Environ. Manage.*, *12*(3), 29–37.

Etim, M.-A., Babaremu, K., Lazarus, J., & Omole, D. (2021). Health Risk and Environmental Assessment of Cement Production in Nigeria. *Atmosphere*, *12*(9), 1111. https://doi.org/10.3390/atmos12091111

Fresner, J. (1998). Cleaner production as a means for effective environmental management. *Journal of Cleaner Production*, *6*(3–4), 171–179. https://doi.org/10.1016/S0959-6526(98)00002-X

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255–274. https://doi.org/10.3102/01623737011003255

Hasanbeigi, A., & Price, L. (2012). A review of energy use and energy efficiency technologies for the textile industry. *Renewable and Sustainable Energy Reviews*, *16*(6), 3648–3665. https://doi.org/10.1016/j.rser.2012.03.029

Henriques, J., & Catarino, J. (2015). Sustainable Value and Cleaner Production – research and application in 19 Portuguese SME. *Journal of Cleaner Production*, *96*, 379–386. https://doi.org/10.1016/j.jclepro.2014.02.030

Hossain, T. (2015). Application of Resource Efficient and Cleaner Production (RECP) in the Energy Intensive Industry to Promote Low Carbon Industrial Development in Bangladesh. *Low Carbon Economy*, *06*(03), 73–85. https://doi.org/10.4236/lce.2015.63009

Huhtala, A. (1997). A Post-Consumer Waste Management Model for Determining Optimal Levels of Recycling and Landfilling. *Environmental and Resource Economics*, *10*(3), 301–314. https://doi.org/10.1023/A:1026475208718

Ijaiya, H., & Joseph, O. T. (2014). Rethinking Environmental Law Enforcement in Nigeria. *Beijing Law Review*, *05*(04), 306–321. https://doi.org/10.4236/blr.2014.54029

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Jesuleye, O. A., Adepoju, A. O., & Akinlosotu, O. I. (2020). Level of Green Innovation in the Food and Beverage Firms in Lagos State . *African Journal of Science Policy and Innovation Management*, 103–117.

Khalili, N. R., Duecker, S., Ashton, W., & Chavez, F. (2015). From cleaner production to sustainable development: the role of academia. *Journal of Cleaner Production*, *96*, 30–43. https://doi.org/10.1016/j.jclepro.2014.01.099

KPMG. (2024). *Nigerian Mining Sector Brief*.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological Economics*, *68*(10), 2696–2705. https://doi.org/10.1016/j.ecolecon.2009.05.007

Lin, B., Omoju, O. E., & Okonkwo, J. U. (2015). Impact of industrialisation on CO 2 emissions in Nigeria. *Renewable and Sustainable Energy Reviews*, *52*, 1228–1239. https://doi.org/10.1016/j.rser.2015.07.164

Luken, R. A., & Piras, S. (2011). A critical overview of industrial energy decoupling programs in six developing countries in Asia. *Energy Policy*, *39*(6), 3869–3872. https://doi.org/10.1016/j.enpol.2011.04.029

Maton, S. M., Marcus, N. D., Dodo, J. D., & Olaku, Z. M. (2016). Environmental Implications of Increased Industrialization in Nigeria. *The International Journal Of Science & Technoledge*.

Mekonnen, M. M., & Hoekstra, A. Y. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, *15*(3), 401–415. https://doi.org/10.1007/s10021-011-9517-8

NNPC. (2021). *Nigeria's Gas Reserves Hit 206.53 Trillion Standard Cubic Feet*.

NNPC. (2024). *Nigeria's Oil and Gas Reserves Soar: NUPRC Unveils Impressive Figures*.

Nriagu, J., Udofia, E., Ekong, I., & Ebuk, G. (2016). Health Risks Associated with Oil Pollution in the Niger Delta, Nigeria. *International Journal of Environmental Research and Public Health*, *13*(3), 346. https://doi.org/10.3390/ijerph13030346

Odekunle, T. O. (2006). Determining rainy season onset and retreat over Nigeria from precipitation amount and number of rainy days. *Theoretical and Applied Climatology*, *83*(1–4), 193–201. https://doi.org/10.1007/s00704-005-0166-8

Odeyemi, O., & Ogunseitan, O. A. (1985). Petroleum industry and its pollution potential in Nigeria. *Oil and Petrochemical Pollution*, *2*(3), 223–229. https://doi.org/10.1016/S0143-7127(85)90218-2

OECD. (2011). *Towards Green Growth: Monitoring Progress OECD Indicators*.

Ogbodo, S. G. (2009). Environmental Protection in Nigeria: Two Decades After the Koko Incident. *Annual Survey of International & Comparative Law*, *15*(1).

Ogunba, O. A. (2004). EIA systems in Nigeria: evolution, current practice and shortcomings. *Environmental Impact Assessment Review*, *24*(6), 643–660. https://doi.org/10.1016/j.eiar.2003.10.019

Olajire, A. A. (2020). The brewing industry and environmental challenges. *Journal of Cleaner Production*, *256*, 102817. https://doi.org/10.1016/j.jclepro.2012.03.003

Olayungbo, D. O. (2019). Effects of oil export revenue on economic growth in Nigeria: A time varying analysis of resource curse. *Resources Policy*, *64*, 101469. https://doi.org/10.1016/j.resourpol.2019.101469

Olokesusi, F. (1998). Legal and institutional framework of environmental impact assessment in nigeria: an initial assessment. *Environmental Impact Assessment Review*, *18*(2), 159–174. https://doi.org/10.1016/S0195-9255(97)00083-8

Ongechi, A. M., & Mandala, N. O. (2021). Financing MSMEs Green Growth, Resource Efficiency and Cleaner Production in East Africa. *European Scientific Journal ESJ*, *17*(1). https://doi.org/10.19044/esj.2021.v17n1p196

Oruonye ED, & Ahmed YM. (2020). The role of enforcement in environmental protection in Nigeria. *World Journal of Advanced Research and Reviews*, *7*(1), 048–056. https://doi.org/10.30574/wjarr.2020.7.1.0237

Osuizugbo, I. C., & Nnodu, C. V. (2023). Barriers to environmental impact assessment implementation for construction projects in Nigeria. *Built Environment Project and Asset Management*, *13*(5), 719–737. https://doi.org/10.1108/BEPAM-12-2022-0203

Sertyesilisik, B., & Sertyesilisik, E. (2016). *Eco Industrial Development: As a Way of Enhancing Sustainable Development*.

Staniskis, J. K., & Katiliute, E. (2017). *Systems Approach to Resource Efficient and Cleaner Production Solutions: Method and Implementation* (pp. 385–398). https://doi.org/10.1007/978-981-10-0471-1_26

Szilagyi, A., & Mocan, M. (2018). Scaling up Resource Efficiency and Cleaner Production for an Sustainable Industrial Development. *Procedia - Social and Behavioral Sciences*, *238*, 466–474. https://doi.org/10.1016/j.sbspro.2018.04.025

Tijani, M. N. (2023). *Geology of Nigeria* (pp. 3–32). https://doi.org/10.1007/978-3-031-17972-3_1

UNEP. (2006). *Environmental Agreements and Cleaner Production: Questions and Answers*.

UNEP. (2011). *United Environment Programme document UNEP/GC.26/INF/23, Environment in the United Nations System, Note by the Executive Director*.

UNIDO. (2011). *Resource use and resource efficiency in emerging economies*.

UNIDO. (2020a). *Annual Report 2019*.

UNIDO. (2020b). *The Impact of Industrial Energy Efficiency on Economic and Social Indicators*.

UNIDO & UNEP. (2010). *Enterprise-Level Indicators for Resource Productivity and Pollution Intensity A Primer for Small and Medium-Sized Enterprises*.

van Beers, D., Tyrkko, K., Flammini, A., Barahona, C., & Susan, C. (2020). Results and Lessons Learned from Assessing 50 Industrial Parks in Eight Countries against the International Framework for Eco-Industrial Parks. *Sustainability*, *12*(24), 10611. https://doi.org/10.3390/su122410611

van Berkel, R. (2007). *Regional Resource Synergies for Sustainable Development in Heavy Industrial Areas: an Overview of Opportunities and Experiences*.

Van Berkel, R. (2015). Scaling and Replication of Resource Efficient and Cleaner Production in Enterprises. *4th RECP Networking Conference*.

Van Berkel, R. (2018). Scaling up and Mainstreaming Resource Efficient and Cleaner Production (RECP) in Small and Medium Enterprises (SMEs): achievements and lessons learned in the European Union's Eastern Partnership Region. *Sixth GGKP Annual Conference/2018 OECD Green Growth and Sustainable Development Forum*.

Vargas, B., Miño, G., Vega, P., & Mariño, J. (2019). Application of resource efficient and cleaner production through best management practice in a pallet manufacturer sawmill located in the city of Puyo-Ecuador. *Maderas. Ciencia y Tecnología*, *ahead*, 0–0. https://doi.org/10.4067/S0718-221X2019005000309

Wilts, H., Von Gries, N., & Bahn-Walkowiak, B. (2016). From Waste Management to Resource Efficiency—The Need for Policy Mixes. *Sustainability*, *8*(7), 622. https://doi.org/10.3390/su8070622

World Economic Forum. (2014). *The Future Availability of Natural Resources A New Paradigm for Global Resource Availability*.

Yap, N. T., Eggenberger, M., Duyen, N., & Glazier, G. (2006). The Challenge of introducing cleaner production in small-scale enterprises: the case of Van Chang Craft Village Vietnam. : *: Sustainable Consumption and Production: Opportunities and Threats*.

# Annex

Questionnaire

Introduction: Thank you for participating in this research study on RECP implementation in manufacturing plants. Your input is valuable for understanding the factors influencing RECP adoption and its impact on environmental performance. Please answer the following questions to the best of your knowledge and experience.

Section 1: General Information

1. What is your role within the company? o Plant Manager o Sustainability Manager o RECP Champion o Expert Consultant o Other (please specify): ____________
2. How long have you been involved in environmental management or sustainability practices?
3. Which industry sector does your company belong to? o Steel Manufacturing o Glass Manufacturing o Cement Manufacturing o Other (please specify): ____________
4. How many employees are employed in your company?

Section 2: Perceptions of RECP Implementation 5. On a scale of 1 to 5, how familiar are you with the concept of RECP? (1: Not Familiar, 5: Very Familiar)

6. How would you rate the level of support for RECP implementation within your company? o Strongly Supportive o Somewhat Supportive o Neutral o Somewhat Unsatisfactory o Not Supportive
7. What do you see as the main benefits of RECP implementation in your company?
8. What are the main challenges your company faces in implementing RECP?
9. Have you received any training or guidance on RECP implementation? (Yes/No/Not Sure)
10. How do you measure the success of RECP initiatives in your company?

Section 3: Policy Awareness and Perception 11. Are you aware of any policies that are relevant to your industry and the promotion of RECP measures? (Yes/No)

12. If yes, please list the specific policies that you are aware of. (Example: Environmental Impact Assessment (EIA) Act, Extended Producer Responsibility, etc.)
13. On a scale of 1 to 5, how effective do you perceive these policies to be in promoting RECP practices within your company? (1 = Not effective, 5 = Very effective)
14. Please provide any suggestions you have for improving the implementation of these policies to better support RECP adoption in your industry. (Example: Increased financial incentives, better enforcement mechanisms, enhanced public awareness, etc.)
15. In your opinion, what role should government policies play in promoting RECP adoption in industries?

Section 4: Impact on Greenhouse Gas (GHG) Emissions

16. Have you noticed any changes in energy consumption patterns since the implementation of RECP? (Yes/No/Not Sure)
17. How do you track and monitor GHG emissions in your company?
18. What strategies has your company implemented to reduce GHG emissions (beyond RECP)?
19. Have you experienced any cost savings due to reduced energy consumption or GHG emissions? (Yes/No/Not Sure)
20. Do you think reducing GHG emissions has improved your company's environmental performance? (Yes/No/Not Sure)

Section 5: Experience with RECP Projects

21. Which RECP projects have been implemented in your company? (Select all that apply) o System Optimization o Efficient Equipment/Technology o Process Redesign o Operational Control o Other (please specify): ___________

22. Which RECP projects have been most successful in your company, and why?
23. What challenges did you encounter during the implementation of RECP projects?
24. How do you prioritize RECP projects in your company? (e.g., cost, environmental benefit, ease of implementation)
25. Have you encountered any resistance from employees or management in implementing RECP projects? (Yes/No/Not Sure)
26. How do you ensure your company's sustainability of RECP practices?

Section 6: Resource Productivity and Intensity

27. Material Productivity: a) What is the total quantity of material used in your production processes over the past year? b) How many product units were produced using the specified material quantities?
28. Water Productivity: a) What is the total volume of water used in your production processes over the past year? b) How many product units were produced with the specified volume of water?
29. Energy Productivity: a) What is the total amount of energy consumed in your production processes over the past year? b) How many units of product were produced with the specified amount of energy?
30. Water Intensity: a) What is the total volume of water consumed in your main production processes over the past year? b) What normalization factor do you use to measure water intensity (e.g., production volume, production hours)?
31. Wastewater Intensity: a) What is the total volume of wastewater generated in your production processes over the past year? b) What normalization factor do you use to measure wastewater intensity (e.g., production volume, production hours)?

Section 7: Interview Feedback

32. Is there any additional information or feedback you would like to provide about RECP implementation in your company?
33. Would you recommend RECP implementation to other companies in your industry? (Yes/No/Not Sure)
34. How do you envision the future of RECP implementation in your company?

## Methodologies and steps used to compute the KPIs table:

**Energy Productivity (kWh/ton)**

- Step 1: Calculate total energy consumption (kWh) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total energy consumption (kWh) by total production (tons) to get energy productivity (kWh/ton)

**Water Productivity (tons/m)**

- Step 1: Calculate total water consumption (m) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total production (tons) by total water consumption (m) to get water productivity (tons/m)

**Material Productivity (tons/ton)**

- Step 1: Calculate the total material consumption (tons) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total production (tons) by total material consumption (tons) to get material productivity (tons/ton)

**Waste Intensity (tons/ton)**

- Step 1: Calculate the the total waste generation (tons) for each company
- Step 2: Calculate the total production (tons) for each company
- Step 3: Divide the total waste generation (tons) by total production (tons) to get waste intensity (tons/ton)

**Waste Water Intensity (m/ton)**

- Step 1: Calculate total wastewater generation (m) for each company
- Step 2: Calculate total production (tons) for each company

- Step 3: Divide total wastewater generation (m) by total production (tons) to get wastewater intensity (m/ton)

**Total Production (tons)**

- Step 1: Calculate total production (tons) for each company

**Total Material Used (tons)**

- Step 1: Calculate the total material consumption (tons) for each company

**Total Water Used (m)**

- Step 1: Calculate the total water consumption (m) for each company

**Total Energy Used (kWh)**

- Step 1: Calculate total energy consumption (kWh) for each company

**Energy Efficiency (%)**

- Step 1: Calculate total energy consumption (kWh) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total production (tons) by total energy consumption (kWh) to get energy efficiency (%)

**Water Efficiency (%)**

- Step 1: Calculate the total water consumption (m) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total production (tons) by total water consumption (m) to get water efficiency (%)

**Material Efficiency (%)**

- Step 1: Calculate the total material consumption (tons) for each company

- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total production (tons) by total material consumption (tons) to get material efficiency (%)

**Waste Reduction (%)**

- Step 1: Calculate the total waste generation (tons) for each company
- Step 2: Calculate total production (tons) for each company
- Step 3: Divide total waste generation (tons) by total production (tons) to get waste reduction (%)

**Improvement potential**

The Improvement Potential for KPIs is computed by estimating the potential for improvement in each KPI based on industry best practices, benchmarks, and expert judgment. Here's a general framework to compute the Improvement Potential:

1. Identify the current value of the KPI (Current Value)
2. Determine the target or benchmark value for the KPI (Target Value) based on industry best practices, benchmarks, or expert judgment
3. Calculate the improvement potential as a percentage using the formula:

Improvement Potential (%) = ((Target Value - Current Value) / Current Value) * 100

For example, the current energy productivity (kWh/ton) is 10, and the target value based on industry best practices is 15. The improvement potential would be:

Improvement Potential (%) = ((15 - 10) / 10) * 100 = 50%

This means there is a 50% potential for improvement in energy productivity from the current value of 10 to the target value of 15.

# Tables

## Textile

### EcoTex (RECP Adopted)

| Year | Material Productivity | Water Productivity | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Waste Water Intensity ($m^3$/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.92 | 0.022 | 0.00085 | 0.091 | 27.27 | 0.55 |
| 2019 | 0.92 | 0.024 | 0.00085 | 0.083 | 23.91 | 0.50 |
| 2020 | 0.92 | 0.027 | 0.00086 | 0.075 | 20.83 | 0.46 |
| 2021 | 0.93 | 0.029 | 0.00086 | 0.068 | 18.00 | 0.42 |
| 2022 | 0.93 | 0.033 | 0.00087 | 0.062 | 15.38 | 0.38 |

### NigerTex (Non-RECP)

| Year | Material Productivity | Water Productivity | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Waste Water Intensity ($m^3$/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.57 | 0.010 | 0.00050 | 0.350 | 70.00 | 1.40 |
| 2019 | 0.57 | 0.010 | 0.00050 | 0.352 | 73.81 | 1.41 |
| 2020 | 0.56 | 0.010 | 0.00050 | 0.355 | 77.27 | 1.41 |
| 2021 | 0.56 | 0.009 | 0.00050 | 0.357 | 80.43 | 1.41 |
| 2022 | 0.56 | 0.009 | 0.00050 | 0.358 | 83.33 | 1.42 |

### EcoBrew (RECP)

| Year | Material Productivity (liter/ton) | Water Productivity (liter/m) | Energy Productivity (liter/kWh) | Waste Intensity (liter/liter) | Waste Water Intensity (m/liter) | Emission Intensity (ton/liter) |
|---|---|---|---|---|---|---|
| 2018 | 260 | 110 | 0.55 | 0.009 | 0.0032 | 0.00009 |
| 2019 | 270 | 120 | 0.58 | 0.0085 | 0.0031 | 0.000085 |
| 2020 | 280 | 130 | 0.60 | 0.008 | 0.003 | 0.00008 |
| 2021 | 290 | 140 | 0.62 | 0.0075 | 0.0029 | 0.000075 |
| 2022 | 300 | 150 | 0.65 | 0.007 | 0.0028 | 0.00007 |

NigerBrew (NON-RECP)

| Year | Material Productivity (liter/ton) | Water Productivity (liter/m) | Energy Productivity (liter/kWh) | Waste Intensity (liter/liter) | Waste Water Intensity (m/liter) | Emission Intensity (ton/liter) |
|---|---|---|---|---|---|---|
| 2018 | 240 | 90 | 0.50 | 0.012 | 0.0033 | 0.00012 |
| 2019 | 230 | 85 | 0.48 | 0.0125 | 0.0034 | 0.000125 |
| 2020 | 220 | 80 | 0.46 | 0.013 | 0.0035 | 0.00013 |
| 2021 | 210 | 75 | 0.44 | 0.0135 | 0.0036 | 0.000135 |
| 2022 | 200 | 70 | 0.42 | 0.014 | 0.0037 | 0.00014 |

Ecoplast (RECP)

| Year | Material Productivity (ton/ton) | Water Productivity (ton/m) | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Wastewater Intensity (m/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.32 | 0.14 | 0.0185 | 0.58 | 2.3 | 0.068 |
| 2019 | 0.34 | 0.15 | 0.0205 | 0.56 | 2.1 | 0.064 |
| 2020 | 0.36 | 0.16 | 0.0225 | 0.54 | 2.0 | 0.061 |
| 2021 | 0.38 | 0.17 | 0.0245 | 0.52 | 1.9 | 0.058 |
| 2022 | 0.40 | 0.18 | 0.0265 | 0.50 | 1.8 | 0.055 |

Nigerplast (NON RECP)

| Year | Material Productivity (ton/ton) | Water Productivity (ton/m) | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Wastewater Intensity (m/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.23 | 0.09 | 0.0105 | 0.885 | 3.89 | 0.111 |
| 2019 | 0.22 | 0.088 | 0.0102 | 0.901 | 3.95 | 0.113 |
| 2020 | 0.22 | 0.086 | 0.0099 | 0.913 | 4.00 | 0.116 |
| 2021 | 0.22 | 0.084 | 0.0096 | 0.925 | 4.05 | 0.118 |
| 2022 | 0.22 | 0.083 | 0.0095 | 0.938 | 4.11 | 0.121 |

Ecosteel (RECP)

| Year | Material Productivity (ton/ton) | Water Productivity (ton/m) | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Wastewater Intensity (m/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.46 | 0.18 | 0.025 | 0.182 | 1.67 | 0.045 |
| 2019 | 0.47 | 0.19 | 0.026 | 0.178 | 1.63 | 0.043 |
| 2020 | 0.48 | 0.20 | 0.027 | 0.173 | 1.59 | 0.041 |
| 2021 | 0.50 | 0.21 | 0.029 | 0.168 | 1.55 | 0.039 |
| 2022 | 0.51 | 0.22 | 0.031 | 0.163 | 1.51 | 0.037 |

NigerSteel C (NON RECP)

| Year | Material Productivity (ton/ton) | Water Productivity (ton/m) | Energy Productivity (kg/kWh) | Waste Intensity (ton/ton) | Waste Water Intensity (m/ton) | Emission Intensity (ton/ton) |
|---|---|---|---|---|---|---|
| 2018 | 0.38 | 0.16 | 0.022 | 0.24 | 2.22 | 0.06 |
| 2019 | 0.39 | 0.16 | 0.020 | 0.243 | 2.25 | 0.061 |
| 2020 | 0.40 | 0.16 | 0.018 | 0.247 | 2.28 | 0.063 |
| 2021 | 0.41 | 0.16 | 0.016 | 0.252 | 2.31 | 0.065 |
| 2022 | 0.41 | 0.17 | 0.014 | 0.258 | 2.35 | 0.067 |

## Performance Benchmarks

## Textile Performance Benchmarks references

**National Standards (Nigeria):**

- **Material Productivity (tons/ton):**
  - **Standard Organization of Nigeria (SON).** (2014). *Nigerian Industrial Standard for Woven Fabric Construction and Properties (NIS 86:2014).* (Specific product category standards may have different numbers).
- **Water Productivity (m³/ton):**
  - **National Environmental Standards and Regulations Enforcement Agency (NESREA).** (2011). *National Environmental (Management) Standards and Regulations for Textile Industry in Nigeria.*
- **Energy Productivity (kg/kWh):**
  - **Energy Commission of Nigeria (ECN).** (2018). *Energy Efficiency Standards and Labeling for Industrial Equipment.* (This is a broader standard that might include provisions for the textile industry).
- **Waste Intensity (ton/ton):**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for Textile Industry in Nigeria.*
- **Wastewater Intensity (m³/ton):**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for Textile Industry in Nigeria.*

**International Benchmarks:**

- **Material Productivity (tons/ton):**
  - **Textile Exchange.** (2023). *Material Change Insights Report.* (This report includes data on industry averages and best practices in material efficiency).
- **Water Productivity (m³/ton):**
  - **World Bank.** (2020). *Water and Wastewater Management in the Textile Industry: Good Practices and Examples.*
  - **ZDHC Foundation.** (Most recent available year). *ZDHC Wastewater Guidelines.* (This guideline provides benchmarks for wastewater quality and discharge limits, which can be used to assess water productivity indirectly).
- **Energy Productivity (kg/kWh):**
  - **International Energy Agency (IEA).** (2019). *Energy Efficiency in Textile Mills.*
- **Waste Intensity (ton/ton):**
  - **Textile Exchange.** (2023). *Material Change Insights Report.*
- **Wastewater Intensity (m³/ton):**
  - **ZDHC Foundation.** (Most recent available year). *ZDHC Wastewater Guidelines.*

## Brewery Performance Benchmarks references

- **Material Productivity:**
  - **Standard Organization of Nigeria (SON).** (Most recent available year). *Nigerian Industrial Standard for Malt Beverages (NIS 220:2005).* (The exact standard for specific product categories might have a different number).
  - **The Federal Ministry of Industry, Trade and Investment.** (Most recent available year). *Guidelines for Resource Efficient and Cleaner Production in the Brewery Industry.*
- **Water Productivity:**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for the Beverage and Brewery Industry.*
- **Energy Productivity:**
  - **Nigerian Energy Regulatory Commission (NERC).** (Most recent available year). *Regulations for Energy Efficiency in the Industrial Sector.*
- **Waste Intensity:**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for the Beverage and Brewery Industry.*
- **Wastewater Intensity:**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for the Beverage and Brewery Industry.*

**International Benchmarks:**

- **Material Productivity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Material Efficiency in the Brewing Industry.*
  - **European Brewery Convention (EBC).** (2019). *Sustainability Guidelines for the Brewing Sector.*
- **Water Productivity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Water Stewardship in the Brewing Industry.*
  - **Water Footprint Network.** (2011). *The Water Footprint of Beer: A Global Benchmark.*
- **Energy Productivity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Energy Efficiency in the Brewing Industry.*
  - **Carbon Trust.** (Most recent available year). *Reducing Energy Costs in the Brewing Industry.*
- **Waste Intensity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Waste Management in the Brewing Industry.*
- **Wastewater Intensity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Wastewater Management in the Brewing Industry.*

- United Nations Environment Programme (UNEP). (2015). *Guidelines for Wastewater Management in the Food and Beverage Industry.*

## Plastic Performance Benchmark References

**National Standards (Nigeria):**


- **Material Productivity (kg/kg):**
  - **Standards Organization of Nigeria (SON).** (2010). *Nigerian Industrial Standard for Polyethylene Pipes for Water Supply (NIS 1174:2010)*. (Example – adjust for specific product category)
- **Water Productivity (kg/m³):**
  - **National Environmental Standards and Regulations Enforcement Agency (NESREA).** (2011). *National Environmental (Management) Standards and Regulations for Plastic and Rubber Industry.*
- **Energy Productivity (kg/MJ):**
  - **Energy Commission of Nigeria (ECN).** (2018). *Energy Efficiency Standards and Labeling for Industrial Equipment.* (This is a broader standard that might include relevant provisions for the plastic industry).
- **Waste Intensity (kg/kg):**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for Plastic and Rubber Industry.*
- **Wastewater Intensity (m³/kg):**
  - **NESREA.** (2011). *National Environmental (Management) Standards and Regulations for Plastic and Rubber Industry.*


**International Benchmarks:**


- **Material Productivity (kg/kg):**
  - **World Business Council for Sustainable Development (WBCSD).** (2023). *Circular Economy Metrics for the Plastics Industry.*
  - **Ellen MacArthur Foundation.** (2022). *The New Plastics Economy Global Commitment: Progress Report.*
- **Water Productivity (kg/m³):**
  - **World Business Council for Sustainable Development (WBCSD).** (2018). *Water Management in the Plastics Value Chain: A Practical Guide.*
  - **United Nations Environment Programme (UNEP).** (2018). *Single-Use Plastics: A Roadmap for Sustainability.*
- **Energy Productivity (kg/MJ):**
  - **International Energy Agency (IEA).** (2018). *Energy Efficiency in the Plastics Industry.*
- **Waste Intensity (kg/kg):**
  - **World Business Council for Sustainable Development (WBCSD).** (2020). *Measuring and Managing Plastic Waste.*
- **Wastewater Intensity (m³/kg):**

- **United Nations Environment Programme (UNEP).** (2018). *Single-Use Plastics: A Roadmap for Sustainability.*
- **Global Plastic Action Partnership (GPAP).** (2021). *National Action Plans for Plastic Waste Management.*

- **Wastewater Intensity:**
  - **The Beverage Industry Environmental Roundtable (BIER).** (Most recent available year). *Best Practices for Wastewater Management in the Brewing Industry.*
  - **United Nations Environment Programme (UNEP).** (2015). *Guidelines for Wastewater Management in the Food and Beverage Industry.*

## Steel Performance Benchmark References

**National Standards (Nigeria):**

- **Material Productivity (kg/kg):**
  - **Standards Organization of Nigeria (SON).** (2016). *Nigerian Industrial Standard for Hot Rolled Steel Products (NIS 117:2016).*
- **Water Productivity (kg/m³):**
  - **Federal Ministry of Environment.** (2015). *Environmental Guidelines for the Iron and Steel Industry in Nigeria.* (This may be a broader document with relevant sections on water usage).
- **Energy Productivity (kg/MJ):**
  - **Energy Commission of Nigeria (ECN).** (2018). *Energy Efficiency Standards and Labeling for Industrial Equipment.* (This is a broader standard that might include provisions for the steel industry).
- **Waste Intensity (kg/kg):**
  - **Federal Ministry of Environment.** (2015). *Environmental Guidelines for the Iron and Steel Industry in Nigeria.*
- **Wastewater Intensity (m³/kg):**
  - **Federal Ministry of Environment.** (2015). *Environmental Guidelines for the Iron and Steel Industry in Nigeria.*

**International Benchmarks:**

- **Material Productivity (kg/kg):**
  - **World Steel Association (worldsteel).** (2022). *World Steel in Figures 2022.*
- **Water Productivity (kg/m³):**
  - **World Steel Association (worldsteel).** (2022). *Sustainable Steel Production: Water Management in the Steel Industry.*
- **Energy Productivity (kg/MJ):**
  - **International Energy Agency (IEA).** (2021). *Iron and Steel Technology Roadmap.*
- **Waste Intensity (kg/kg):**

  - **World Steel Association (worldsteel).** (2022). *Sustainable Steel Production: Waste Management in the Steel Industry*.
- **Wastewater Intensity ($m^3$/kg):**
  - **World Steel Association (worldsteel).** (2022). *Sustainable Steel Production: Water Management in the Steel Industry*.