INTERNATIONAL REVIEW OF FINANCIAL STUDIES | IROFS
Vol 1, Issue 2;December, 2024 / visit: https://journals.unizik.edu.ng/irofs

IMPACT EVALUATION OF CARBON AND ENERGY MANAGEMENT PRACTICES ON SUSTAINABLE INNOVATION OF MANUFACTURING FIRMS IN NIGERIA

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ABSTRACT

This study examined the role of carbon and energy management practices in fostering sustainable innovation within Nigeria manufacturing sector. As global environmental concerns increase, manufacturing firms are under pressure to adopt carbon reduction and energy efficiency measures. This research investigated how these practices contribute to innovation, particularly in research and development (R&D) expenditure investments. Using data from 38 listed manufacturing firms for the years 2013 - 2023, the study finds that There is a significant and positive effect of carbon management practice on research and development (R & D) innovation expenditures of listed manufacturing companies in Nigeria (p-value 0.009; t-statistic 2.5955); and There is no significant and negative effect of energy management practice on research and development (R & D) innovation expenditures. hence, the practice of carbon management will obviously lead to the reduction in carbon emissions and improvement in energy efficiency thereby resulting in a lower operational cost. Firms implementing carbon reduction strategies and energy-efficient processes experience significant improvements in product development, operational efficiency, and regulatory compliance. The study recommended the need to incorporate carbon management considerations into decision-making processes, investment criteria, even as research and development (R & D) planning can help firms optimize resources, improve operational efficiency, and drive innovation. Secondly, transitioning to renewable energy sources such as solar, wind, or biomass, can help manufacturing firms reduce reliance on traditional fossil fuels, lower carbon emissions, and mitigate energy costs. Integrating renewable energy systems into operations can provide a sustainable and reliable source of power for R&D initiatives, while supporting environmental sustainability goals. Lastly, regular Manufacturing firms should start by conducting comprehensive energy audits to assess current energy consumption patterns, identify areas of inefficiency, and pinpoint opportunities for improvement.

Key words: *Carbon Management Practice, Energy Management Practice, Environmental Sustainability Practices, Sustainable Innovation, Research and Development Investment.*

CITE AS: Ogunmola, E.S., Nwoye, U.J. & Okafor, G.O. (2024). Impact evaluation of carbon and energy management practices on sustainable innovation of manufacturing firms in Nigeria, *International Review of Financial Studies*, 1(2), 56 - 73. Available: https://journals.unizik.edu.ng/irofs

1. INTRODUCTION

Innovation in manufacturing firms remains one of the major strategies for driving firm's growth and survival in any competitive business environment and has been used to achieve social and environmental sustainability (Ukpabio, Siyanbola, & Oyebisi, 2017; Xiao & Su, 2022). Innovation implies the development of new thoughts and ideas, items, administration and procedures that will improve technology. It provides a competitive edge to a firm, by assisting in market diversification and generating new commercial opportunities, providing a better life style by improving the standard of living in the area of production plus an unusual economic growth usually seen as encompassing product and process innovation (Caroline & Uyen, 2010; Chege, Wang & Suntu, 2019; Fayomi, Adelakun & Babaremu, 2019). Considering the environmental crises caused by industrial activities, the practice of environmental sustainability is imperative and is vital in reducing the negative impact of production activities on the environment. While we talk about environmental sustainability, we cannot overlook the implementation of carbon and energy management practices. Haffar and Searcy, (2017), submitted that companies are expected to go beyond the financial focus and extend into an encompassing economic, environmental, and social sustainability by vigorously pursuing investment in renewable energy sources, energy saving efficient technologies and developing strategies to improve and positively impact the environment in which it exists. For instance, organization can replace generator with renewable energy in warehouses, factories and offices as so on. These practices of sustainable development have the potentials to reduce communicable diseases and also drive towards an advancement in innovations which is a plus to the organisation and to the country at large. One of the crucial steps manufacturing organizations must take to protect the environment and enhance human health and well-being while conducting their manufacturing operations is to practice environmental sustainability.

Overtime, studies have shown how innovation can be used to achieve environmental sustainability and how these practices can affect corporate financial performance (Tuan, Nhan, Giang, & Ngoc, 2016; Ukpabio, Siyanbola, & Oyebisi, 2017; Chege, Wang, & Suntu, 2019; Ucheagwu, Akintoye & Adegbite, 2019; Xiao & Su, 2022) meanwhile sustainable innovation processes are crucial for the long-term success and competitiveness of manufacturing firms. Therefore, understanding the relationship between environmental sustainability practices and sustainable innovation of listed manufacturing firms aim to provide valuable insights for policymakers, regulators, and business leaders in Nigeria. This study tends to consider the impact of environmental sustainability practices (carbon and

energy management aspect) on innovation. This is because if there are no positive environmental initiatives in handling production processes in terms of consumption of energy, exploitation of natural resources and protecting the Eco system to support the health and well-being of persons around the company's environs the purpose of engaging in manufacturing activities has failed. The more reason why in recent years; firms are increasingly trying to find a balance between sustainable economic development and environmental damage (Tseng, Wang, Chiu, Geng & Lin, 2013; Ramayah & Rahbar, 2013; Do, Nguyen, Nguyen & Johnson, 2019). Thus, it is needful to consider the influence of carbon management practice on sustainable innovation of manufacturing companies in Nigeria and the effect of energy management practice on sustainable innovation of manufacturing company in Nigeria.

1.1 Objectives

The main objective of the study is to investigate the effect of environmental sustainability practice on innovation development of listed manufacturing firms in Nigeria. The specific objectives are to:

1. determine the effect of carbon management practice on research and development (R & D) innovation expenditures and cost incurred on machines for the process and production of new products of listed manufacturing firms in Nigeria.
2. ascertain the effect of energy management practice on research and development (R & D) innovation expenditures and cost incurred on machines for the process and production of new products of listed manufacturing firms in Nigeria.

1.2 Hypotheses

Based on the above objectives, the following hypotheses will guide the study. The hypotheses are stated below in null form:

H_{o1}: carbon management practice does not have a significant effect on research and development (R & D) innovation expenditures and cost incurred on machines for the process and production of new products of listed manufacturing companies in Nigeria.

H_{o2}: Energy management practice does not have a significant effect on research and development (R & D) innovation expenditures and cost incurred on machines for the process and production of new products of listed manufacturing company in Nigeria.

2. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Carbon Management Practice

Carbon management practice refers to the strategies and actions taken to manage and reduce carbon emissions; this strategy entails the disclosure of climate change information across its business dealings. Carbon Disclosure Project (CDP) Report in 2010 has it that several drivers are increasing the need of carbon management, some of these drivers are but not limited to, energy costs, brand reputation, energy supply risks, employee and customer expectations, risks from the physical impacts of climate change, and competitive positioning. Carbon management technologies aim to manage anthropogenic releases of greenhouse gases, such as those associated with the combustion of fossil fuel use, in an organized way. These technologies can include carbon capture and storage, renewable energy, and energy efficiency measures. The practices involved in carbon management can be classified into emission reduction commitment; product improvement; process and supply improvement; new market and business development; organisational involvement; and external relationship development. Lee (2012) in his research added that, there are six types of corporate carbon strategies which include, 'wait and see observer', 'cautious reducer', 'product enhancer', 'all round enhancer', 'emergent explorer' and 'all round explorer'. To practice carbon management in manufacturing companies, carbon emissions released in the air by some production machines, can be replaced with battery powered electric machines. Hence, sustainable practices such as switching to reusable products to reduce the dependency on single-use plastic, replacing generator with renewable energy in warehouse, factories and offices can result in increased performance through innovation. By implementing carbon management practice, firms effectively manage carbon emissions in a way that reduces environmental harm, conserves resources, and promotes sustainability. This benefits the environment but also contributes to cost savings and enhances the reputation of the organisation as a responsible and environmentally conscious entity.

2.1.2 Energy Management Practice

Firms are gradually adopting practice that reduce the negative environmental effects of their operations as knowledge of environmental sustainability rises on a worldwide scale (Alhawamdeh, Al-Saad, Almasarweh, Al-Hamad, Bani Ahmad, & Ayasrah, 2023). This decision is a shift toward the reduction of energy waste while production is ongoing effectively. It has been established by Li, Jiao and Li (2021) that Companies that take this decision are fighting against environmental degradation, to achieve more of sustainable

development, and displaying corporate social responsibility. This action has made it easier to manage energy effectively.

Energy management practice refers to the strategies and actions taken to manage and optimise energy consumption. Energy management is related with planning, monitoring, and controlling energy-associated processes with the aim to preserve energy resources and energy cost savings and to protect environment (Qamar, Malik, Qamar, Ali, & Naeem, 2021). Energy management is the usage and application of technology including planning and operation of both production and consumption of energy with a view to enhance energy efficiency of an organisation. These technological developments have had a significant impact on the organisations capacity to reduce their energy use, resulting in more sustainable practices and operations. This has also help businesses maintain their production efficiency, assuring business going concern and better financial performance. The principal objectives of energy management are conservation of resources, saving budget, preventing climate change, ensuring easy and ingrained access for all to the energy spectrum as well as implementing "technology optimization processes". These processes are to further improve these energy-efficient devices with the intention to guarantee that the current energy and technology systems are utilized to their maximum potential. To achieve this, there must be a regular check on their systems to prevent energy inefficiencies that can lead to depreciation of their systems, as well as changing current systems to keep up with developments in energy-efficient technologies.

Energy management practice (EMP) contributes to cost savings and enhances the reputation of the organisation as a responsible and environmentally conscious entity, focusing on energy conservation through enhanced maintenance procedures and lowering the energy load during non-productive times. Royston, selby and kesidou (2021) in their work submitted that effective maintenance procedures guarantee that all systems are running at their highest levels of energy efficiency and that any defects that potentially increase energy usage are quickly identified and fixed. Energy management will contribute to protecting the environment by using less energy or at least improve energy efficiency and hence combat climate change by reducing CO2 emissions (Thollander, Karlsson, Rohdin, Wollin, & Rosenqvist, 2020). It has the potential to greatly contribute to a company's sustainability goals while also ensuring operational effectiveness and competitiveness with the right direction and dedication. The management of organisations must also be committed to making investments in energy-efficient technologies and caring for them properly as the adoption and successful

implementation of EMP necessitate a thorough knowledge of the unique business processes, energy consumption trends, and resource capacities.

2.1.3 Environmental Sustainability Management

Environmental sustainability management is an aspect of sustainability that relates with maintaining the factors and practices that contribute to the quality of environment on a long-term basis. It is the responsibility taken by manufacturing companies to conserve natural resources and ensure to protect global ecosystems in order to support health and well-being now and in the future. Effendi et al. (2021), rightly put it as an environmental initiative taken by manufacturing companies to preserve the environment and improve the quality of human life while performing manufacturing activities. Considering the environmental crises caused by industrial activities today, the practice of environmental sustainability is imperative. Bocquet, Bas, Mothe and Poussing (2017), sees it as a new concept and it is related to the social impact of business enterprises on the environment in which it operates. Studies have shown that companies that support environmental community projects achieve greater financial success and social well-being beyond its economic responsibility (Zhu, Zou, & Zhang, 2018). Production carried out without environmentally sustainable practices can raise carbon dioxide emission and toxic materials which could contribute to global warming and also have a negative impact on the health of people around if not properly addressed.

Globalisation has led to the development of new technologies and discoveries, the practice of Sustainability can stipulate the achievement of these new technology and discoveries (Oladimeji, Ebodaghe, & Shobayo 2017; Joensuu-Salo, Sorama, Viljamaa, &Varameaki, 2018) and with more focus on sustainable practices, companies tend to have more capability to gain innovation performance. The practice of environmental sustainability can also suggest areas where innovation can payoff well. In the practice of environmental sustainability as penned down by Satwa, Raja, Sakundarini and Ramayah (2017), it is essential for manufacturing firms to ensure that in the process of their manufacturing activities:

i. They use renewable resources during production with minimum co2 emission. These emissions impede the natural balance of the ecosystem, are detrimental to the environment, health and well-being.
ii. They guide against overuse of resources. It is their responsibility to conserve resources for future use
iii. Waste minimisation should be implemented. According to Attah (2010), The output rule of environmental sustainability suggests that waste emissions from a

project, production or result of an organisation activity being considered should be kept within the assimilation capacity of the company, without unacceptable degradation of its future waste absorptive capacity or other important services.

iv. Reduction in energy consumption. There should be an alternative as it will lead to reduction in manufacturing cost

v. The level of usage of Hazardous substances during manufacturing processes/activities should be eliminated. Environmental sustainability includes the processes that help protecting natural resources to support human life, Shila (2015).

2.1.4 Concept of Product and Process Innovation.

Product and process innovation are seen as crucial for firm competitiveness, particularly in a global market. Product innovation can be seen as any good or services that is understood by an individual or a firm as new. it is the one that allows a better product to be offer than the ones currently on the market, in the sense that it offers more functions or performs better. Ukpabio et al (2017) noted that its product innovation is the introduction of new products or services in order to create new markets or customers or satisfying the existing ones. Through product innovation, company can gain a competitive advantage by differentiating its production and increasing the quality and variety of goods that allow it to grow demand and open new growth opportunities (Vadastreanu, 2015: Maier, 2018). When the quality of goods and services of a firm is improved upon, it enhances competitive advantage to the firm. Product innovation is the process of creating a new productor improving an existing one to meet customers' needs in a novel way. Product innovations are new products or services introduced to meet an external user need. They are embodied in the outputs of an organisation and may result in product differentiation or an increase in product quality (Ester, 2019). Jain (2023), documented Product innovation as developing novel products or enhancing existing ones to meet evolving market demands and customer expectations. Stating further that it encompasses advancements in functionality, design, performance, and user experience.

Process innovation on the other hand describes the new or improved way of doing things, it is essential to the operations of a company. It is a change in the ways of producing or manufacturing or developing certain products. This could be in form of new logistics, new materials, replacing outdated production machines with sophisticated ones, (ukpabio et al 2017). Some of the benefits derived from the implementation of process innovation are reduction in costs, efficiency in business operations, and increased productivity. Process

innovation revolves around optimizing internal workflows, systems, and technologies to streamline operations, boost efficiency, and reduce costs as it enhances organizational agility and competitiveness. It should be noted that process innovation does not stand alone, it is often as a result of product innovation.

2.2 Theoretical Review

2.2.1 Technology Organisation Environment (TOE) Model

Technology-Organisation-Environment (TOE) model was developed by Tornatzky, Fleischer, and Chakrabarti (1990). This model allows organisations to integrate the wider use of technology (Chege & Wang, 2020). It suggests that the capabilities of the firm to adopt and implement technological innovation depends on three main factors in organisations, namely technological factors, organisational factors and environmental factors. The technological factors in firms can be internal and external, for instance, their internal IT infrastructure or the wider external communication infrastructure such as suitable Internet access etc., while the organisational factors can be described as internal, such as management support, size of the firm and ICT innovation intensity, whereas the environmental factors are external such as government regulations, green technologies support infrastructure and pressure from consumer and environment campaigners (Chege & Wang, 2020).

2.3 Empirical Review

Rahmani, Naeini, Mashayekh, Aboojafari, Daim and Yalcin (2024), in their work green innovation for a green future; a meta- analysis of the impact on environmental performance carried out in Iran discovered that the climate change and industrial pollution forced all enterprises to identify and adopt sustainable practices to enhance positive environmental effects and contribute to economic recovery. Nonetheless, they realized that the effect of green innovation with all its dimensions on environmental performance, assessed in many studies have obtained different results. using a meta-analysis approach to determine the overall effect of green innovation (GI), green product innovation (GPRI), and green process innovation (GPCI) on environmental performance (EP), they revealed that green innovation has a positive and significant impact on environmental performance.

Suendarti (2023) Protecting Our Planet: The Vital Role of Carbon Sequestration in Combating Threats to Environmental Sustainability, a study carried out in Indonesia. This research study examined the impacts of eutrophication, human footprints, and economic growth on environmental sustainability through the underlying mechanism of biodiversity

loss and the moderating role of carbon sequestration in the relationship between loss of biodiversity and environmental sustainability. A total of 553 farmers from different regions of Indonesia participated in the study, and the data collected was analyzed using Smart PLS software. The findings revealed a significant negative impact of eutrophication and human footprints on environmental sustainability through biodiversity loss. The moderating role of carbon sequestration was found to be significant in the relationship between biodiversity and environmental sustainability.

Irani and Kilic (2022) in their work, an assessment of implementing green HRM practices on environmental performance: The moderating role of green process innovation revealed that various organisations' employees are crucial in mitigating carbon monoxide emissions. The study explores how to enhance hotels' environmental performance (EP) by adopting green human resource management (HRM) practices. They developed and investigated a moderation model which examined the green process innovation (GPI) as a moderator onto the relationship between green HRM and environmental process through the lens of Ability-Motivation-Opportunity theory (AMO). using SmartPLS software to analyze the data from 220 full-time employees of, 4-, and 5-stars green hotels in Turkey. They found out the importance of adopting green practices in advancing organisational performance, especially the environmental aspect.

Yunzhao (2022) in his work titled Modeling the role of Eco innovation, renewable energy, and environmental taxes in carbon emissions reduction in E−7 economies: Evidence from advance panel estimations submitted that Carbon emissions are considered as the major factor of environmental deterioration which makes environmental sustainability vulnerable and risky. He further stated that Global warming is a severe challenge for most of the economies and the emerging seven (E7) economies are not exempted from this challenge. The study estimated the role of Eco-innovation, renewable energy, and environmental taxes for E−7 economies over 1995–2018 period. This was done by employing three different cross-sectional dependence (CSD) tests, it was revealed that renewable energy, Eco-innovations, and environmental taxes have positive contributions towards carbon emission reduction. Moreover, a feedback or bi-directional causal relationship is found to be present between a forementioned variables and carbon emissions. The study also revealed the different policy implications that are helpful to control carbon emissions and their damaging environmental impacts.

Bai, Song, Jiao, and Yang (2019) in their work titled The impacts of government R&D subsidies on green innovation: Evidence from Chinese energy-intensive firms explored the impacts of government R&D subsidies on the green innovation of energy-intensive firms by employing propensity score matching with 527 samples of listed companies from 2010 to 2015, the empirical results showed that government R&D subsidies increase the green innovation of energy-intensive firms, specifically their tendency and performance, by 107.3% and 54.1%, respectively. Heterogeneity analyses show that the impact is stronger in state-owned enterprises and in small and medium enterprises. Finally, some practical implications are put forward that may help to improve the efficiency of government R&D subsidies and promote the green innovation of energy-intensive firms.

Hau (2019), in his work, SMEs' External Technology R&D Cooperation Network Diversity and their Greenhouse Gas Emission Reduction and Energy Saving: A Moderated Mediation Analysis carried out in south Korean empirically revealed the effect of external technology R&D cooperation network diversity (ETRDCND) on the greenhouse gas (GHG) emission reduction and energy saving of small and medium-sized enterprises (SMEs). Furthermore, this study aimed at analyzing the roles of production time reduction and absorptive capacity in the relationship between SMEs' ETRDCND and their GHG emission reduction and energy saving. Ordinary least squares regression was performed with the data of 3300 South Korean SMEs, their research revealed four points. First, ETRDCND positively influences SMEs' GHG emission reduction and energy saving. Second, production time reduction perfectly mediates the relationship between SMEs' ETRDCND and their GHG emission reduction and energy saving. Third, the mediating role of production time reduction in this relationship is moderated by SMEs' absorptive capacity. Fourth, ETRDCND significantly influences SMEs' GHG emission reduction and their energy saving only if SMEs possess their own absorptive capacity.

3. MATERIAL AND METHODS

The study adopted the quasi- experiment. The study used secondary data which was collected from the selected listed manufacturing firms in Nigeria Exchange Group, NSE Fact book and related firm's annual financial reports for the period of ten years covering year 2013 to 2023. The dependent variable sustainable innovation was proxy with research and development innovation expenditure of new product and process innovation. The independent variables are: carbon management practice, energy management practice of listed manufacturing firms in Nigeria. The secondary data collected was analysed using descriptive statistics, multiple

regression analysis. The descriptive statistics was use to evaluate the characteristics of the data: mean maximum, minimum, and standard deviation and also check for normality of variables and to check for multi-collinearity, variance inflation factor analysis was conducted to confirm the multi-collinearity result. Multiple regression analysis was used to evaluate the effect of the independent variables on the dependent variable to reveal and predict the degree of effect the independent variables have on the dependent variables. In order to estimate the model and examine the proposed hypotheses, the following regression model were estimated:

RDE = f (CMP, EMP, FS) ……. Eqn 1.

The model is stated explicitly as follows:

$RDE_{it} = \alpha_0 + \beta_1 CMP_{it} + \beta_2 EMP_{it} + \beta_3 FS_{it} + \varepsilon$…….Eqn 2

Where:

RDE - Research & Development (R & D) Innovation Expenditures;

CMP - Carbon Management Practice

EMP - Energy Management Practice

FS - Firm Size.

$\beta_1 - \beta_3$ -represent the coefficient of the explanatory variables.

i - denote the number of firm in the panel.

t - denote the time period of the panel data.

ε - the error term.

Accept the alternate hypothesis if p-value is less than 0.05, otherwise reject the null hypotheses

4. RESULT AND DISCUSSIONS

4.1 Data Analysis

4.1.1 Descriptive Analysis of Data

The descriptive statistics for both the independent and dependent variables of interest was examined. Each variable was examined based on the mean, median, maximum and minimum.

Table 1 Summary statistics of dependent, independent and control variable

	RDE	CMP	EMP	FS
Mean	2.34E+08	0.232614	0.278177	1.44E+08
Median	1.13E+08	0.000000	0.000000	61121470
Maximum	1.63E+09	11.00000	1.000000	9.96E+08
Minimum	10000000	0.000000	0.000000	10000000
Std. Dev.	2.80E+08	0.665850	0.448640	2.01E+08
Skewness	1.976204	10.46019	0.990055	2.293590
Kurtosis	7.105081	165.1495	1.980210	7.806042
Jarque-Bera	564.2221	464436.1	86.19409	766.9370
Probability	0.000000	0.000000	0.000000	0.000000
Sum	9.77E+10	97.00000	116.0000	6.02E+10
Sum Sq. Dev.	3.26E+19	184.4365	83.73141	1.68E+19
Observations	417	417	417	417

Source: E-Views 11

Key: CMP-Carbon Management Practices; EMP-Energy Management Practices; FS-Firm Size, RDE- Research & Development (R & D) Innovation Expenditures

Carbon Management Practice (CMP) measures the degree to which firms manage their carbon emissions. The mean value of CMP is 0.232614; and, the median value was 0.00. The mean (0.232614) and median (0) show that most firms have low or no engagement in carbon management. The extremely high skewness (10.46019) and kurtosis (165.1495) indicate that only a few firms report higher values, possibly due to stricter environmental regulations or proactive sustainability strategies.

EMP reflects the implementation of energy management strategies, with values typically between 0 and 1. The mean value of EMP is 0.278177; and, the median value is 0.00. Similar to WMP, the median (0) and high standard deviation (0.448640) show that many firms either have minimal or no EMP. The positive skewness (0.990055) suggests a potential increase in adoption.

Conclusively, the variables show a significant difference between the mean and the median, indicating a skewed distribution. All variables are positively skewed, with CMP having the highest skewness (10.46019), suggesting a long tail on the right side of the distribution. All variables have high kurtosis values, especially for CMP (165.1495). High kurtosis in other variables also suggests that data points are more concentrated around the mean. The standard deviations of the variables were mostly relatively large, which is consistent with the high variability observed in the data. Finally, the probability values for the J-B test are all 0.000000, which means the null hypothesis of a normal distribution is rejected for all variables, confirming non-normality.

Table 2 Correlation analysis of dependent, independent and control variable

	RDE	**CMP**	**EMP**	**FS**
RDE	1.0000			
CMP	0.1074	1.0000		
EMP	0.0193	0.5473	1.0000	
FS	0.7303	0.1021	-0.0476	1.0000

Source: E-Views 11

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
R & D	0.270322	0.167351	1.615293	0.1073
CMP	0.022254	0.008574	2.595582	0.0099
EMP	-0.048448	0.049147	-0.985775	0.3250
FS	0.663179	0.024912	26.62132	0.0000

Key: RDE- Research & Development (R & D) Innovation Expenditures; CMP-Carbon Management Practices; EMP-Energy Management Practices; FS-Firm Size.

The t-statistic of CMP is 2.595582; is highly significant positive effect on R&D expenditures. Since the p-value is 0.0000 is less than .05; we reject the null and accept the alternate: carbon management practice has a significant influence on research and development (R&D) innovation expenditures and cost incurred on machines of listed manufacturing companies in Nigeria. The t-statistic of EMP is -0.985775; is highly not significant negative effect on R&D expenditures. Since the p-value is 0.0000 is greater than .05; we reject the alternate and accept the null: energy management practice does not have a significant effect on research and development (R & D) innovation expenditures and cost incurred on machines of listed manufacturing company in Nigeria.

4.2 Test of hypotheses

Table 3 Regression Analysis Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.270322	0.167351	1.615293	0.1073
CMP	0.022254	0.008574	2.595582	0.0099
EMP	-0.048448	0.049147	-0.985775	0.3250
FS	0.663179	0.024912	26.62132	0.0000

4.2.1 Hypothesis One

H_{o1}: carbon management practice does not have a significant influence on research and development (R & D) innovation expenditures and cost incurred on machines of listed manufacturing companies in Nigeria.

From table 3, the t-statistic of EMP is -0.985775; is highly not significant negative effect on R&D expenditures. Since the p-value (0.0099) is less than .05; we reject the null and accept the alternate: there is a significant effect of carbon management practice on research and development (R & D) innovation expenditures of listed manufacturing companies in Nigeria.

Yunzhao (2022) examined the role of eco-innovation, renewable energy, and environmental taxes in reducing carbon emissions across E−7 economies, highlighting the positive contributions of carbon management practice to environmental sustainability. Wu et al. (2022) explored the impact of environmental regulations on green innovation in Chinese companies, showing that formal and informal regulation pressures positively influence green innovation, with political connections moderating these effects. Bai et al. (2019) explored the impacts of government R&D subsidies on green innovation in Chinese energy-intensive firms, using a sample of 527 listed companies. Their empirical results showed that subsidies significantly increased green innovation, particularly in state-owned and small-to-medium enterprises. The study highlighted the importance of carbon management practice in reducing emissions and promoting sustainable innovation, demonstrating a significant positive effect on R&D expenditures. Huang et al. (2016) examined the influence of regulatory and customer pressure on green organizational responses and green innovation performance in a sample of 427 manufacturing organizations in China. Their results indicated that regulatory pressure promotes green organizational responses, enhancing green innovation performance, including

carbon management practices. This underscores the role of external pressures in driving firms to adopt carbon management practices that boost innovation and efficiency.

4.2.2 Hypothesis Two

H_{o2}: Energy management practice does not have a significant effect on research and development (R & D) innovation expenditures and cost incurred on machines of listed manufacturing company in Nigeria.

From table 3, the t-statistic of EMP is -0.985775; is highly not significant negative effect on R&D expenditures. Since the p-value (0.3250) is greater than .05; we reject the alternate and accept the null: energy management practice does not have a significant effect on research and development (R & D) innovation expenditures and cost incurred on machines of listed manufacturing company in Nigeria.

Khan et al. (2022) investigated the relationship between Green Supply Chain Management practices, technological innovation, and operational performance in Pakistani manufacturing firms, indicating that energy management practice significantly affect operational performance through innovation. Lundgren and Zhou (2017) analyzed the interactions between productivity, energy efficiency, and environmental performance using a panel vector auto-regression methodology. Their study found that energy efficiency and environmental performance are integrated, with energy efficiency positively reinforcing productivity. Hassan et al. (2016) investigated the implementation of green supply chain management practice and their impact on corporate performance. They found that green purchasing and environmental cooperation significantly impact operational performance but did not find a direct effect of energy management practices on R&D innovation expenditures.

5. CONCLUSION AND RECOMMENDATIONS

There is a significant and positive effect of carbon management practice on research and development (R & D) innovation expenditures of listed manufacturing companies in Nigeria (p-value 0.009; t-statistic 2.5955); and There is no significant and negative effect of energy management practice on research and development (R & D) innovation expenditures and of listed manufacturing company in Nigeria (p-value 0.022; t-statistic 0.9857). hence, this is telling us that The practice of carbon management will obviously lead to the reduction in carbon emissions and improvement in energy efficiency thereby resulting in a lower operational cost. This result may compel the organization to invest more in R&D innovation

expenditure to develop new technologies for new product and production processes. When carbon footprint is reduced in manufacturing activities, manufacturing firms can avoid penalties which can encourage them to invest more in R&D innovation expenditures. It should be noted that energy management practice alone cannot be a major factor in the decision of an organization's investment in R&D innovation expenditures. meaning, manufacturing firms may not prioritise this practice when making decision on innovation development but it should be noted this practice can still contribute to organizational sustainability goals. It is therefore recommended that:

1. companies should invest in Clean Technologies and Renewable Energy. Transitioning to clean technologies and integrating renewable energy sources into manufacturing operations can significantly reduce carbon emissions and reliance on fossil fuels. Investing in solar panels, wind turbines, or other renewable energy systems can not only lower energy costs but also position firms as leaders in sustainable manufacturing practices. Clean technologies can drive innovation in R&D projects by enabling the development of greener products and processes, contributing to competitive advantage and market differentiation. Also, manufacturing firms should develop a comprehensive carbon management strategy that aligns with their business goals, R&D priorities, and sustainability objectives. Incorporating carbon management considerations into decision-making processes, investment criteria, and R&D planning can help firms optimize resources, improve operational efficiency, and drive innovation. Moreover, Employee Training and Engagement should be prioritized.

2. Engaging employees in energy management practices and providing training on energy-efficient behaviors can foster a culture of sustainability within manufacturing firms. Empowering employees to identify energy-saving opportunities, implement best practices, and participate in energy conservation initiatives can lead to continuous improvements in energy efficiency. Secondly, transitioning to renewable energy sources, such as solar, wind, or biomass, can help manufacturing firms reduce reliance on traditional fossil fuels, lower carbon emissions, and mitigate energy costs. Integrating renewable energy systems into operations can provide a sustainable and reliable source of power for R&D initiatives, while supporting environmental sustainability goals. Lastly, regular Manufacturing firms should start by conducting comprehensive energy audits to assess current energy consumption patterns, identify areas of inefficiency, and pinpoint opportunities for improvement. Energy audits

provide valuable insights that can guide decision-making and investment in energy-saving technologies.

REFERENCES

Albort-Morant,G., Henseler,J., Leal-Millan,A., Cepeda-Carrion,G. (2017). Developing green innovation performance by fostering of organizational knowledge and competitive relations. *Journal of review of managerial science 12, 499-517*

Alhawamdeh, H., Al-Saad, S. A., Almasarweh, M. S., Al-Hamad, A. A.-S. A., Bani Ahmad, A. Y. A. B., & Ayasrah, F. T. M. (2023). The Role of Energy Management Practices in Sustainable Tourism Development: A Case Study of Jerash, Jordan. *International Journal of Energy Economics and Policy*, 13 (6), 321–333.

Alraja, M. N., Imran, R., Khashab, B. M., & Shah, M. (2022). Technological innovation, sustainable green practices and SMEs sustainable performance in times of crisis (COVID-19 pandemic). *Information Systems Frontiers*, 24(4), 1081-1105.

Bai, Y., Song, S., Jiao, J., & Yang, R. (2019). The impacts of government R&D subsidies on green innovation: Evidence from Chinese energy-intensive firms explored the impacts of government R&D subsidies on the green innovation of energy-intensive firms. *Journal of cleaner production, 233*, 818-829

Banerjee, R., & Gupta, K. (2019). The Effect of Environmentally Sustainability Practices on Firm R&D: International evidence. *Journal of economic modelling, 78, 262-274*

Chege, S. M., & Wang, D. (2020). The influence of technology innovation on SME performance through environmental sustainability practices in Kenya. *Technology in Society*, *60*, 101210.

Gloria, J.R., & Ebele, A. (2023). The Role of Research & Development (R&D) Investment on Economic Transformation in Nigeria. *International Journal of economics, commerce and management, 11(4)*

Hau, Y.S. (2019). SMEs' External Technology R&D Cooperation Network Diversity and Their Greenhouse Gas Emission Reduction and Energy Saving: A Moderated Mediation Analysis. Journal of sustainability, 11(1), 115

Rahmani, A., Naeini, A.B., Mashayekh, J., Aboojafari, B., Daim, T., & Yalcin, H. (2024). Green Innovation for Greener Future: A Meta-Analysis of the Impact on Environmental Performance. *Journal of Cleaner Production, 140, 142547*

Sarpong, D., Boakye, D., Ofosu, G., & Botchie, D. (2023). The Three Pointers of Research and Development (R&D) for Growth-Boosting Sustainable Innovation System. *Journal of technovation, 122(3) :102581.*

Simionescu, L. N., Gherghina, Ș. C., Sheikha, Z., & Tawil, H. (2020). Does water, waste, and energy consumption influence firm performance? Panel data evidence from S&P 500 information technology sector. *International Journal of Environmental Research and Public Health, 17(14), 5206*.

Suendarti, M. (2023). Protecting Our Planet: The Vital Role of Carbon Sequestration in Combating Threats to Environmental Sustainability. *Pakistan Journal of Life and Social Sciences, 21(1): 23-36.*

Thollander, P., Karlsson, M., Rohdin, P., Wollin, J., & Rosenqvist, J. (2020). *Introduction to industrial energy efficiency: energy auditing, energy management, and policy issues*. Academic Press.

Xu, J., Wang, X., & Liu, F. (2021). Government subsidies, R&D investment, and innovation performance: analysis from pharmaceutical sector in China *Technol. Anal. Strat. Manag., 33 (5), 535-553*

Yunzhao, L. (2022). Modelling the role of Eco innovation, Renewable energy and environmental taxes in carbon emissions reduction in E-7 economies; Evidence from advance panel estimations. *Journal of renewable energy, 190, 309-318*

Yussupov,U.B., Aliyev, M.K., Kazhmukhameotova, A.A., Aitkhozhina, L.Z., & Zhumatayeva, B.A. (2023). The Impact of R&D on Sustainable Development: a Literature Review. *Journal of the economy strategy and practice 18(3) 68-83*