



SUSTAINABLE, CLEAN AND EMERGING ENERGY TECHNOLOGIES CONFERENCE (SCEETC)

UNIVERSITY OF NIGERIA, NSUKKA

IN COLLABORATION WITH

NATIONAL CENTRE FOR ENERGY RESEARCH AND DEVELOPMENT

UNIVERSITY OF NIGERIA, NSUKKA

THEME:

CLEAN ENERGY SYSTEMS FOR NET-ZERO EMISSION TARGETS

BOOK OF PROCEEDINGS



DATE: 23RD - 28TH JULY, 2023

PARTICIPATING INSTITUTIONS:



Table of contents

Lead Paper 1: SAVING OUR ENVIRONMENT AND RESOLVING CLIMATIC ISSUES THROUGH NANOSCIENCE RESEARCH, Prof Fabian Ezema,	1 – 52
Lead Paper 2: INTEGRATED RENEWABLE ENERGY AND RESOURCE NETWORK SYNTHESIS AND OPTIMISATION Prof Adeniyi J. Isafiade	53 – 78
Lead Paper 3: PROMOTING LOW CARBON ENERGY FOR SUSTAINABLE DEVELOPMENT IN SUB-SAHARAN AFRICA (SSA) Prof Sunday O. Oyedepo	79 – 138
Lead paper 3: BRUSHLESS WOUND-FIELD ELECTRICAL MACHINE FOR SUSTAINABLE CLEAN ENERGY Udochukwu B. Akuru	139 – 182
SCEETC-2023_paper_1107: MATLAB PROGRAMME ENABLED ASSESSMENT OF THE SUSTAINABILITY OF EARLY AGE HYDRATING MASS CONCRETE WITH RESPECT TO THERMAL BEHAVIOUR Donald Ugwuanyi,	183 – 187
SCEETC-2023_paper_1709: COMPARATIVE STUDY OF THE PREDICTED AND CALCULATED VALUES OF THE MONTHLY GLOBAL SOLAR RADIATION IN ENUGU USING MATLAB SIMULATION SOFTWARE, Kazim Suleman, Adegboyega Babalola, Jonathan Nwauzor, Chikodiri Ugbaja, Olawale Bosede	188 – 195
SCEETC-2023_paper_1846: DEVELOPMENT AN EFFICIENT MULTI CROP DRYER FOR DOMESTIC APPLICATION Edward Anoliefo	196 – 202
SCEETC-2023_paper_1858: ENERGY POLICY, REGULATION AND MANAGEMENT, A REVIEW Chuba Nwachukwu	203 – 207
SCEETC-2023_paper_2555: PRESET DRIVERS OF CARBON DIOXIDE (CO₂) EMISSIONS IN NIGERIA’S TEXTILE AND APPAREL INDUSTRY Oliver Inah, Bethrand Nwankwojike and Samuel Effiom	208 – 214
SCEETC-2023_paper_2776: EFFECT OF SAW DUST ASH (SDA) ADMIXED WITH MILLET HUSK ASH (MHA) ASH A STUDY OF SELF COMPACTING CONCRETE (SCC) Solomon Ayuba	215 – 222
SCEETC-2023_paper_3227: REPURPOSING PIZEO PLATES FROM E-WASTES AS ENERGY HARVESTER Matthew Olatunde Afolayan and Sallah Mohammed A..	223 – 228
SCEETC-2023_paper_3473: IMPACT OF CLEANER PRODUCTION PRACTICES IN THE NIGERIAN WOOD INDUSTRY ON SUSTAINABILITY AND ENVIRONMENTAL PERFORMANCE, David Adeniran and Temidayo Omoniyi	229 – 238
SCEETC-2023_paper_3784: A SIMPLE APPROACH TO LOAD FLOWANALYSIS OF A THREE-PHASE POWER SYSTEM MODEL Abraham Akhikpemelo, Gideon David Umoh	239 – 246
SCEETC-2023_paper_3804: UPGRADING PYROLYSIS OILS FOR TRANSPORTATION FUELS: A REVIEW Bashar Hadi Abdullahi, Salisu Muhammad Adamu, Abduljalil Mode Muhammad, Iklima Ibrahim Bandi and Samira Shehu Adamu	247 – 252
SCEETC-2023_paper_4004: MORUS ALBA EXTRACT AS SOLAR RADIATION ABSORBER Matthew Olatunde Afolayan and MUSA Hassan Ibrahim ...	253 – 257



Impact of Cleaner Production Practices in the Nigerian Wood Industry on Sustainability and Environmental Performance

Adeniran D. A., Omoniyi T. E.

Department of Wood Products Engineering, Faculty of Technology, University of Ibadan
(adenirandavidadedire@gmail.com, temidayoomoniyi@gmail.com)

Tel: +2347053352434, Tel: 2348037881122

Abstract- Wood residues generated in Nigeria amount to approximately 5.2 million tonnes annually, highlighting the resource-intensive nature of the Nigerian wood industry. Cleaner production practices, which involve the identification and implementation of strategies to reduce raw material consumption, energy use, waste generation, and pollution, have been widely adopted in many countries. However, in Nigeria, the adoption of cleaner production practices remained limited. This study aims to review the potential impact of cleaner production practices in the Nigerian wood industry on productivity and the creation of a sustainable environment. It sheds light on the unique characteristics and challenges faced in the Nigerian wood industry that influence the widespread adoption of cleaner production practices. The study delved into the different phases of cleaner production implementation, emphasising the importance of planning, implementation, monitoring, and evaluation. It highlighted the adoption of low-cost and practical cleaner production measures, debunking the misconception that cleaner production implementation is always costly. Furthermore, the study examined the prospects and challenges of implementing cleaner production measures within the specific context of Nigeria's peculiarities. It discussed comprehensive waste management strategies, noise control measures, materials modification, and substitution, as well as the application of cleaner production practices on machinery and equipment. The paper emphasised the need for stronger policies and their enforcement to ensure compliance with cleaner production practices in the wood industry. By promoting the adoption of cleaner production measures, the country can witness enhanced productivity, minimise waste, and create a sustainable and environmentally friendly wood industry sector.

Keywords Cleaner production, Wood industry, Sustainable environment, Waste management, Environmental Performance

1. Introduction

The wood industry plays a crucial role in the global economy, but its resource-intensive operations have significant environmental impacts. To address this issue, there has been a growing interest in adopting cleaner production practices aimed at reducing material consumption and environmental impact within the industry [1, 2, 3, 4]. Countries like China have incorporated environmental management tools [5]. However, in Nigeria, cleaner production advancements have received minimal attention. Cleaner production, as defined by the United Nations Environment Programme [6] refers to the application of environmental strategies to production processes and services, aiming to enhance overall productivity and efficiency while reducing potential hazards to humans, products, and the environment. It involves the identification and implementation of measures

to minimise the use of raw materials, energy, and resources, as well as the reduction of waste generation and pollutants. The objective of cleaner production is to promote sustainable development by integrating environmental considerations into industrial practices, thereby minimising environmental impacts and fostering more sustainable and environmentally friendly business models.

Although limited literature exists on the effect of cleaner production on productivity in the Nigerian wood industry, several studies have evaluated the impact of implementing environmental policies on productivity. For example, [7] highlighted the potential of the industrial cluster concept to foster collaboration and improve productivity, aligning with the principles of cleaner production. Additionally, [8] identified the challenges posed by poor electrical energy generation and rising fuel prices in the Nigerian wood



Adeniran & Omoniyi, SCEETC 2023

industry, which have adverse effects on productivity indices.

Several studies have demonstrated the potential of implementing cleaner production strategies in wood processing industries with positive outcomes. For instance, [9] explored local and international initiatives in the Canadian stakeholder community that facilitated the initiation and implementation of cleaner production practices. [10] applied cleaner production and resource efficiency practices in six pallet manufacturer sawmills, resulting in a substantial reduction in waste generation. However, there is sparse literature on the subject matter in Nigeria.

The Nigerian wood industry is characterised by some unique characteristics that affect the implementation of environmental strategies, particularly in Small and Medium Enterprises (SMEs). Factors such as limited awareness of cleaner production concepts and technologies within the industry and reliance on conventional wood processing methods passed down through generations contribute to drudgery, waste generation, and inefficient processes that may not align with cleaner production practices.

The processes involved in transforming trees into finished wood products generate significant waste, including cut crowns, left stumps, and debarked logs. To build a sustainable wood industry, optimal utilisation patterns have been proposed to achieve resource-efficient forest exploitation and reduce the frequency of return trips to the forest. Without curbing waste and carbon emissions from wood facilities, critical environmental concerns may arise.

It is against this background that this study aims to discuss the potential of cleaner production practices to enhance productivity in the wood industry, with a specific focus on the Nigerian context.

2. Discussion

2.1. Phases in cleaner production

The implementation of cleaner production typically occurs in several phases. The three critical stages in cleaner production are the planning/diagnostic phase, the selection of measures to overcome identified problems, and the implementation and evaluation of results [10].

The first phase of cleaner production is the planning phase, which involves assessing the current state of the production process, setting goals and targets for improvement, and identifying potential areas for improvement, which is sometimes referred to as diagnosis. This phase is critical for establishing the baseline for measuring progress towards cleaner production and for the selection of measures to overcome identified problems.

The second phase of cleaner production is the implementation phase, which involves identifying and implementing specific cleaner production measures that will help achieve the established goals and targets. These measures can include process modifications, equipment upgrades, and the adoption of best practices.

The third phase of cleaner production is the monitoring and evaluation phase, which involves monitoring, reviewing, tracking, and measuring the performance of the implemented cleaner production measures for continuous improvement. This phase is critical for determining the effectiveness of the measures and identifying any area for further improvement and is essential for achieving long-term environmental and economic sustainability. The longitudinal approach documented by [11] which involves a systematic and continuous process of improving the environmental performance and sustainability of industrial processes over an extended period, based on assessment, planning, and implementation has been reasonably adopted in the application of CP. The CP is a continuous process, which involves continually assessing and improving the production processes to achieve even greater levels of environmental sustainability. This phase is an ongoing process that is essential for achieving long-term environmental and economic sustainability and may require revisiting and debugging other preceding stages.

A study by [3] provides a comprehensive overview of the phases of cleaner production and implementation. The study highlighted the importance of each phase and demonstrated their implementation in a small furniture industry in Brazil. The application of cleaner production resulted in a reduction of waste generation by nearly 50%. The Nigerian wood industry is predominated by small-scale furniture outlets [12]. This indicates that the applicability of low-cost cleaner production measures in the Nigerian Wood industry is probable.

Table 1: Phases of Cleaner Production

SN	Phases	Activities
1	Planning/evaluation/diagnostic phase	a) Assessing the current state of materials, processes, and equipment. b) Identifying loopholes and corresponding measures c) Setting goals and targets.



Adeniran & Omoniyi, SCEETC 2023

2	Implementation phase	Implementing Identified cleaner production measures strategized during the planning phase.
3	Monitoring and evaluation	a) Reviewing, tracking, and performance evaluation. b) Upgrading of materials, processes, and equipment. c) N/B: If the evaluation proves unsuccessful, there is the potential to return to the initial phase.

2.2. Potential of cleaner production on productivity in the Wood Industry

Cleaner production practices have been shown to improve productivity in the wood industry. Although there has been sparse literature on the effect of cleaner production on productivity in the Nigerian wood industry, a few studies have evaluated the impact of implementing environmental policies in the industry on productivity.

[7] noted that the use of the industrial cluster concept which is the geographical concentration of related firms, e.g., isolating forest-allied industries, could foster collaboration and improve productivity. While this approach may not seem to be directly linked to cleaner production, the isolation of such industries from settlements has the potential to reduce the impact of waste generation and greenhouse gas emissions on humans. This can be linked to the comprehensive or diplomatic principle of cleaner production which centres on the well-being of the residents.

In Nigeria, a study by [8] examined industrial energy transmission in the Nigerian industrial sector. Due to the poor electrical energy generation in Nigeria, industries have resorted to electromechanical generating plants, instead of hydroelectric power which was once government-owned. This may lead to continuous increases in hazardous emissions from energy plants which may escalate environmental concerns as the rate of industrialization increases if the energy issue remains unaddressed.

2.3. Environmental impact

The implementation of cleaner production practices in the wood industry, has been shown to have significant environmental benefits such as minimising the environmental impacts of wood processing activities through the adoption of a sustainability approach, and the maximising of eco-friendly production techniques.

Indiscriminate disposal of waste by open burning, dumping in water bodies, or in open locations, pollutes the environment [13]. [14] examined the strategy employed in forest waste management in Nigeria and described the recycling potential of wastes for bioenergy

production as a budding adventure. Recycling forest waste for bio-energy production could help reduce the accumulation of waste in forest areas, potentially mitigating environmental concerns associated with waste disposal. Additionally, the conversion of forest waste into bio-energy could offer an alternative and renewable energy source, which can contribute to a more sustainable energy variety. When considering the utilisation of wood waste for bio-energy production, there can be potential negative effects on air quality and human health if the processes involved are inefficient or poorly controlled. The combustion or conversion of wood waste into bio-energy can release pollutants and emissions into the atmosphere such as Volatile Organic Compounds (VOCs) emissions, Particulate Matter (PM) emissions, Carbon Monoxide (CO) emissions, Nitrogen Oxides (NOx) emissions, etc. that affect air quality and may contribute to respiratory problems [15].



Plate 1: Sawmill waste

2.3. Sustainable and green production

Cleaner production practices are a crucial component of sustainable and green production in the Nigerian and International Wood Industries. These practices seek to minimise the environmental consequences of wood processing operations by implementing sustainable and environmentally friendly manufacturing procedures. Embracing the approach, though cost-demanding, could suffice in de-escalating deleterious climatic changes.



Adeniran & Omoniyi, SCEETC 2023

[16] investigated the significance of cleaner production practices in fostering sustainable and environmentally friendly manufacturing in the Brazilian wood sector. According to the findings of the study, the adoption of cleaner production practices resulted in an all-inclusive integration of local, regional, national, and global efforts to accelerate the transition to sustainable development and societal well-being. Within the Nigerian context, it is possible to contribute to the sustainability of materials through the fervent application of cleaner production for a more sustainable and environmentally friendly business model.

2.4. Adoption of low-cost and easy-to-apply cleaner production measures

The adoption of low-cost and easy-to-apply cleaner production measures can help transform industrial systems into more sustainable and environmentally friendly initiatives both in Nigeria and globally. These measures can include the reduction of energy and water consumption, waste minimization, and the use of renewable resources. Although some reports have revealed that due to the initial cost of implementing CP measures, its profitability may not be noticeable immediately, long-term evaluations have revealed very significant cost reduction [17, 18].

[19] highlighted the importance of adopting low-cost and easy-to-apply cleaner production measures in promoting sustainable production in Nigeria. The study was designed to process bamboo waste, which was used as scaffolding, recovered from construction sites into furniture items. These waste scaffolds, after being used in construction sites, are often left to pollute the environment. However, another study by [20] reported a significant loss in physicomachanical properties of wood recovered from construction sites. Most times, low-cost and easy-to-apply measures are tactful management initiatives such as routine checks, maintenance, and optimization processes.

2.6. Waste management

Waste management is an important consideration for industries worldwide, including the wood industry. One of the significances of cleaner production is to reduce waste, which is related to the concept of lean production.

In the wood industry, cleaner production can be applied to reduce waste generated during the manufacturing process. For example, generating optimised cutting lists for cutting out patterns from boards has been shown to reduce waste from converted boards [21]. In China, the

application of advanced technology, such as the implementation of artificial intelligence and computer-aided design and manufacturing, has been employed as a CP option for ensuring the precision of operations and reducing waste and potential errors [22]. However, in Nigeria, the high cost of procurement, importation, installation, and maintenance of sophisticated machinery has limited their availability and widespread use.

Another aspect of cleaner production in the wood industry is the use of sustainable materials. Sustainable materials, such as bamboo and recycled wood, have been used as alternatives to traditional lumber, reducing the environmental impact of the manufacturing process [23], [24]. This can also lead to economic benefits. For example, reducing waste can lead to cost savings through decreased material usage and reduced disposal costs. Additionally, implementing sustainable practices can enhance a company's reputation and increase its market value [25].

2.7. Noise control

Noise control is an important aspect of workplace safety in the wood industry, as excessive noise exposure can cause hearing loss, stress, and other health issues among workers. Cleaner production approaches have helped to reduce noise levels in the wood industry by minimising the use of noisy machinery and improving production processes.

One effective approach for noise control in the wood industry is to replace or upgrade noisy equipment and machine components with quieter alternatives. For example, using sewing machines with low noise emissions can significantly reduce noise levels in sawmills [26]. Modern and newer machines used in wood processing generate less noise compared to older machines. This is because technology has been improved upon to make them operate with less friction [27]. [28] also observed that newer diesel engines emit fewer GreenHouse Gases (GHGs) than the older models.

The advent of laser cutters has also helped to address the concern of high noise levels in wood conversion. However, only a few facilities in Nigeria can afford such luxury. Also, due to the epileptic power supply in Nigeria, most wood conversion and manufacturing facilities employ the use of mechanical generators, that emit disturbing noise alongside volatile organic compounds, to power conversion equipment.

Another approach for noise control in the wood industry is to implement process modifications that reduce noise levels. For example, optimising certain cutting parameters such as blade speed and feed rate can reduce noise levels during sawing operations [29]. Additionally, using vibration-damping materials in the



Adeniran & Omoniyi, SCEETC 2023

production line can also help to reduce noise levels, as they absorb and dissipate vibrations that would otherwise generate noise [30].

Furthermore, training and educating workers on noise hazards and proper hearing protection can also contribute to noise control and safety in the wood industry. Workers should be aware of the risks associated with noise exposure and should be provided with appropriate Hearing Protection Devices (HPDs) such as earmuffs or earplugs. Proper use of HPDs can reduce noise levels to safe levels and protect workers from hearing loss [31].

2.8. Materials modification and substitution

The utilisation of materials that are eco-friendly and less toxic to humans and the environment is one way of implementing cleaner production. Some studies have looked into the development of cleaner materials for wood-based industries. A study by [32] applied phosphorus/calcium-cottonseed protein adhesive for the production of 3-ply strips plywood. The study revealed that the water resistance of the plywood passed all the set criteria indicating that the adhesive under optimal conditions can be used as a green and environment-friendly adhesive resource in the wood industry and an apt alternative to synthetic adhesives.

Streamlining material flow by the implementation of cleaner production is also an essential strategy for reducing waste and minimising the environmental impact of industrial processes. In the wood industry, material streamlining can be achieved through various approaches, including reducing material use, improving process efficiency, and recycling waste materials.

According to [33], streamlining material flow in wood factories can be achieved by the use of simulation and optimization tools to reduce raw materials wastage of wood fibre during manufacturing, and increase the recovery of by-products. The authors revealed that these measures can lead to significant cost savings and environmental benefits, including reduced greenhouse gas emissions, water consumption, and land use.

Another strategy for improving wood volume recovery and reducing waste in the wood industry is through the use of circular economy principles [34]. According to [35], the circular economy concept involves reusing and recycling materials as well as by-products, reducing waste, and promoting resource efficiency.

[1] investigated the application of cleaner production in the Chinese wood industry and found that the implementation of cleaner production practices led to a 26.8% reduction in raw material consumption.



Plate 2: Recyclable sawdust at a sawmill

The authors suggested that this reduction was primarily due to process optimization and improved production efficiency.

Similarly, [2] examined the impact of cleaner production practices on certain parameters in the wood industry in Brazil. The study found that the implementation of cleaner production practices provided a detailed characterization of the waste, resulting in a potential for material usage reduction by 30%, a reduction in waste by 49%, and a reduction in energy by 36% as a result of the simplification of the manufacturing processes.

A couple of other studies suggested that the implementation of cleaner production practices in the wood industry can lead to a significant reduction in material consumption [9, 22, 36]. These reductions are primarily due to improved production efficiency, the adoption of sustainable production methods, and the recycling of waste materials which is usually termed “waste to wealth.”

2.9. Application of cleaner production measures on machineries and equipment

The application of cleaner production best practices often involves a holistic and incessant approach and the measures are often prone to modifications as need demands. The measures are applied to all factors of production, including machinery and equipment. Adopting CP on machinery and equipment in the wood industry can have several benefits.

The widespread use of more efficient sawing machines and equipment via the application of cleaner production practices could lead to a reduction in energy consumption and in greenhouse gas emissions and can significantly reduce the environmental impact of the wood industry if policies that account for that are properly developed and enforced [37].



Adeniran & Omoniyi, SCEETC 2023

In the Department of Wood Products Engineering, University of Ibadan, a solar kiln was built, and it has been demonstrated to be a cleaner drying option as it led to a reduction in energy consumption, and waste generation with no carbon emission, as there is no need for gas-powered generating plants. The implementation of cleaner production practices on a wider scale in drying processes can improve the sustainability of the wood industry. The use of more efficient machines and equipment, as well as process optimization, can lead to a reduction in energy consumption and greenhouse gas emissions [38]. These reductions are primarily due to the use of more efficient machines and equipment, process optimization, and the adoption of sustainable production methods.

2.10. Impact of cleaner production on health

The condition of the working environment can affect the health of staff. Cleaner production practices in the wood industry can have a positive impact on the health and safety of workers by reducing exposure to hazardous chemicals and improving working conditions. One study by [39] investigated the impact of wooden casket production and finishing in Owerri on ambient air quality. All the air quality parameters sampled did not meet the standards for clean air, designating the area as a non-attainment spot with a high risk of occupational health hazards for the casket woodworkers, most of whom work without personal protective equipment.

Similarly, another study by [40] examined the air quality index from charcoal production sites, carboxyhemoglobin and lung function among occupationally exposed charcoal workers in South Western Nigeria. The study revealed that charcoal workers are exposed to high levels of CO and PM_{2.5} which induces lowered respiratory functions. The study recommended routine respiratory and carboxyhemoglobin assessment of charcoal production workers.

[41] investigated the hazards of sawmilling activities in wood sawmills in three Nigerian cities. The study revealed that timber sawmills located across the cities may have contributed to the health and environmental challenges of the people living in the neighbourhood. The study stressed the role of the fourth industrial revolution in cubing environmental hazards. However, it may be necessary to adopt the democratic principle of cleaner production [42] which aims at strategically locating industries to prevent pollution and other hazards that may affect the residents.

In terms of health and safety concerns, some studies have shown that the implementation of cleaner production practices led to a reduction in the risk of work-related accidents and injuries, as well as a reduction in the

exposure of workers to hazardous chemicals and have suggested that the implementation of cleaner production practices can improve the health and safety of workers in the wood industry and contribute to the sustainable development of the industry and the overall well-being of workers. [43, 44, 45, 46].

2.11. Challenges of cleaner production application in Nigerian wood-based industries

The Nigerian wood industry plays a significant role in the country's economy, contributing to employment, income generation and exports. However, the industry is also associated with environmental and health impacts due to unsustainable practices and inadequate pollution control measures. Cleaner production approaches have been proposed as a way to reduce waste, emissions, and resource use while improving efficiency and competitiveness [5]. However, the implementation of CP in Nigerian wood industries may be daunting with several challenges.

Most wood industry workers in Nigeria are tied to conventional methods of processing. This resistance to change in technology and working conditions is relatively widespread.

One major challenge of CP in Nigerian wood industries is the lack of awareness and knowledge about CP principles and practices among industry stakeholders, including managers, workers, and regulators [36]. The low level of awareness and implementation may be attributed to a lack of training, technical assistance, and incentives. As a result, many wood firms continue to rely on traditional, inefficient, and polluting technologies and practices, such as open burning, inefficient techniques, and inadequate waste management.

Another challenge of CP in the Nigerian wood industry is the high cost of implementing CP measures, which can deter firms from adopting them, especially small and medium-sized enterprises (SMEs) with limited financial resources. It could be necessary for government and development partners to provide financial and technical support to SMEs to overcome this barrier. However, the adoption of low-cost and practical cleaner production measures may suffice in this regard because cleaner production implementation is not always costly.

A related challenge is the lack of regulatory incentives and enforcement for CP in Nigerian wood industries. Although Nigeria has environmental regulations and standards for various industries, including the wood industry, their implementation and enforcement are weak, inconsistent, and often compromised by corruption and political interference [47]. This situation creates a disincentive for firms to invest in CP, as they may not face penalties or sanctions for non-



Adeniran & Omoniyi, SCEETC 2023

compliance or may face unfair competition from non-compliant firms.

2.16. Prospects of cleaner production in the Nigerian Wood Industry

Cleaner production practices have received more attention in many countries of the world in recent years; possibly due to their potential benefits for both the environment and the economy.

One major advantage of implementing CP in Nigeria is its potential to aid the reduction of pollution and environmental degradation to its barest minimum. Nigeria has been contending with the negative impact of industrial activities on its environment, particularly in the Wood Industry. The implementation of CP can also suffice in this area [48]. This can help to mitigate the negative impact of industrial activities on the environment and protect public health.

The potential to increase efficiency and reduce costs of production is another advantage of implementing CP in Nigeria. Although, due to naivety, most enterprises may be resistant to adopting CP because the initial cost of implementation may be deterring, whereas, over a long period of time, it has the potential of saving on cost. The adoption of cleaner production technologies and processes can help industries cut down on their energy and resource consumption, leading to reduced production costs and other economic benefits [49]. This can improve the competitiveness of Nigerian industries and contribute to economic growth and development.

Widespread acceptance and practice of CP in Nigeria can also create opportunities for innovation and technology transfer. As industries adopt cleaner technologies and processes, there is a need for research and development of new technologies and practices. This can lead to the creation of new industries and job opportunities in Nigeria. Additionally, the adoption of CP can also attract foreign investment and partnerships, leading to knowledge transfer and technology exchange [50].

3. Conclusion

This study has been able to assess the potential of cleaner production practices in the Nigerian wood industry, with a focus on enhancing productivity and sustainability. It highlighted the potential benefits of adopting cleaner production practices in the Nigerian wood industry. By implementing strategies to minimise resource consumption, waste generation, and pollution, the industry can enhance productivity and create a sustainable and environmentally friendly sector. It also identified the challenges and unique factors that hinder the widespread adoption of cleaner production practices in Nigeria. The findings

underscore the need for concerted efforts from stakeholders, including policymakers, industry players, and researchers, to promote the adoption of cleaner production practices and strengthen the regulatory framework. By doing so, Nigeria can pave the way for a more sustainable and environmentally conscious wood industry, contributing to the nation's overall development and environmental well-being.

References

- [1] Y. Geng, J. Fu, J. Sarkis, B. Xue, and Q. Zhang, "Towards a national circular economy indicator system in China: an evaluation and critical analysis," *Journal of Cleaner Production*, vol. 23, no. 1, pp. 216-224, 2012.
- [2] C. Massote and A. Santi, "Implementation of a cleaner production program in a Brazilian wooden furniture factory," *Journal of Cleaner Production*, vol. 46, pp. 89-97, 2013.
- [3] C. Gutiérrez Aguilar, R. Panameño, A. Perez Velazquez, B. Angel Alvarez, A. Kiperstok, and S. César, "Cleaner production applied in a small furniture industry in Brazil: Addressing focused changes in design to reduce waste," *Sustainability*, vol. 9, no. 10, pp. 1867, 2017.
- [4] P. da Silva, G. de Oliveira Neto, J. Correia, and H. Tucci, "Evaluation of economic, environmental and operational performance of the adoption of cleaner production: Survey in large textile industries," *Journal of Cleaner Production*, <https://doi.org/10.1016/j.jclepro.2020.123855>, vol. 278, pp. 1-17, 2021.
- [5] C. Hicks and R. Dietmar, "Improving cleaner production through the application of environmental management tools in China," *Journal of Cleaner Production*, vol. 15, no. 5, pp. 395-408, 2007.
- [6] UNEP, "Environmental agreements and cleaner production," UNEP, 2023. [Online]. Available: <https://www.unep.org/resources/report/environmental-agreements-and-cleaner-production>. [Accessed: March 2, 2023].
- [7] A. Ogunwusi and I. Olife, "Enhancing productivity of forest industry through industrial clusters concept," *Industrial Engineering Letters*, vol. 2, no. 8, pp.1-19, 2012.
- [8] N. Edomah, "Governing sustainable industrial energy use: Energy transitions in Nigeria's manufacturing sector," *Journal of Cleaner Production*, vol. 210, pp. 620-629, 2019.
- [9] B. Taylor, "Encouraging industry to assess and implement cleaner production measures,"



Adeniran & Omoniyi, SCEETC 2023

Journal of cleaner production, vol. 14, no. 6-7, pp. 601-609, 2006.

[10] B. Vargas, G. Miño, P. Vega, and J. Mariño, "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*, vol. 21, no. 3, pp. 367-380, 2019.

[11] R. Hernández, C. Fernández, and M. Baptista, *Metodología de la Investigación. Sexta Edición*, McGraw-Hill, México, 2014.

[12] A. Olorunnisola, "The Past, Present and Future Outlook of the Wood Industry in Nigeria," in *Wood Industry-Past, Present and Future Outlook*, IntechOpen, 2023.

[13] A. Aiyelaja, A. Oladele, and S. Hassan, "Sustainable Wood Processing for National Economic Development," *Journal of Energy Technologies and Policy*, vol. 4, no. 4, pp. 20-29, 2014.

[14] O. Onabanjo, "Cleaner Production in the Pulp and Paper Industry: A Case Study of Green Cape Paper Mill Limited, Nigeria," *International Journal of Environmental Science and Development*, vol. 5, no. 3, p. 270, 2014.

[15] I. Kularathne, C. Gunathilake, A. Rathneweera, C. Kalpage, and S. Rajapakse, "The effect of use of biofuels on environmental pollution—A review," *International Journal of Renewable Energy Research*, vol. 9, pp. 1355-1367, 2019.

[16] C. Almeida, F. Agostinho, B. Giannetti, and D. Huisingh, "Integrating cleaner production into sustainability strategies: an introduction to this special volume." *Journal of Cleaner Production*, vol. 96, pp. 1-9, 2015.

[17] J. Park, J. Sarkis, and Z. Wu, "Creating integrated business and environmental value within the context of China's circular economy and ecological modernization." *Journal of Cleaner Production*, vol. 18, pp. 1494-1501, 2010.

[18] M. Jänicke, "Ecological modernisation: new perspectives." *Journal of cleaner production*, vol. 16, pp. 557-565, 2008.

[19] N. Adewole and K. Bello, "Recycling of Bamboo (*Bambusa vulgaris* Schrad) recovered from scaffold into material for furniture production." *Innovative Systems Design and Engineering*, vol. 4, pp. 73-78, 2013.

[20] N. Adewole and A. Icha, "Preliminary evaluation of loss in physico-mechanical properties of woods recovered from construction site." *African Journal of Agriculture, Technology and Environment*, vol. 10, pp. 1-7, 2021.

[21] J. Manrique, M. Al-Hussein, A. Bouferguene, H. Safouhi, and R. Nasser, "Combinatorial algorithm for optimising wood waste in framing designs." *Journal of construction engineering and management*, vol. 137, pp. 188-197, 2011.

[22] Y. Van Fan, H. Chin, J. Klemeš, P. Varbanov, and X. Liu, "Optimisation and process design tools for cleaner production." *Journal of Cleaner Production*, vol. 247, pp. 119181, 2020.

[23] A. Aniegbuna and K. Okolie, "Exploring the Potentials in Bamboo as A Sustainable Building Material for Construction in South East Nigeria." *Environmental Review*, vol. 8, pp. 2, 2021.

[24] A. Olorunnisola, "Potentials of Wood, Bamboo and Natural Fibre-Reinforced Composite Products as Substitute Materials for Fabricating Affordable Agricultural Equipment and Processing Machines in Africa." In *Technology in Agriculture*. IntechOpen.

[25] S. Chege and D. Wang, "The influence of technology innovation on SME performance through environmental sustainability practices in Kenya." *Technology in Society*, <https://doi.org/10.1016/j.techsoc.2019.101210>, vol. 60, pp. 1-12, 2020.

[26] R. Licow, D. Chuchala, M. Deja, K. A. Orlowski, and P. Taube, "Effect of pine impregnation and feed speed on sound level and cutting power in wood sawing." *Journal of Cleaner Production*, <https://doi.org/10.1016/j.jclepro.2020.122833>, vol. 272, pp. 1-10, 2020.

[27] C. Lupupa and K. kaleji, "The Impact of a Three Axis Computer Numerical Control (CNC) Shaping Machine on Designing." *The International Journal of Multi-Disciplinary Research*, vol. 1, pp. 1-37, 2019.

[28] D. Quiros, J. Smith, A. Thiruvengadam, T. Huai, and S. Hu, "Greenhouse gas emissions from heavy-duty natural gas, hybrid, and conventional diesel on-road trucks during freight transport." *Atmospheric Environment*, vol. 168, pp. 36-45, 2017.

[29] V. Nasir, J. Cool, and F. Sassani, "Acoustic emission monitoring of sawing process: artificial intelligence approach for optimal sensory feature selection." *The International Journal of Advanced Manufacturing Technology*, vol. 102, pp. 4179-4197, 2019.



Adeniran & Omoniyi, SCEETC 2023

- [30] M. Crocker (Ed.), Handbook of noise and vibration control. 2007, John Wiley & Sons.
- [31] S. Tak, R. Davis, and G. Calvert, "Exposure to hazardous workplace noise and use of hearing protection devices among US workers—NHANES, 1999–2004." American journal of industrial medicine, vol. 52, no. 5, pp. 358-371.
- [32] J. Li, S. Pradyawong, Z. He, X. Sun, D. Wang, H. Cheng, and J. Zhong, "Assessment and application of phosphorus/calcium-cottonseed protein adhesive for plywood production." Journal of Cleaner Production, vol. 229, pp. 454-462.
- [33] H. Heräjärvi, J. Kunttu, E. Hurmekoski, and T. Hujala, "Outlook for modified wood use and regulations in circular economy." Holzforschung, vol. 74, no. 4, pp. 334-343.
- [34] A. Susanty, B. Tjahjono, and R. Sulistyani, "An investigation into circular economy practices in the traditional wooden furniture industry." Production Planning & Control, vol. 31, no. 16, pp. 1336-1348.
- [35] O. Ogunmakinde, "A review of circular economy development models in China, Germany and Japan." Recycling, vol. 4, no. 3, pp. 27, 2019.
- [36] L. Oyenpemi, A. Tijani, and A. Kehinde, "What determines a sustained use of approved pesticides for cleaner production and its impact on yield? Evidence from the cocoa industry in Osun State, Nigeria." Cleaner and Responsible Consumption, vol. 9, pp. 100-113, 2023.
- [37] D. Xuan, X. Ma, and Y. Shang, "Can China's policy of carbon emission trading promote carbon emission reduction?" Journal of Cleaner Production, <https://doi.org/10.1016/j.jclepro.2020.122383>, vol. 270, pp. 1-9, 2020.
- [38] F. Mostashari-Rad, A. Nabavi-Pelesaraei, F. Soheilifard, F. Hosseini-Fashami, and K. W. Chau, "Energy optimization and greenhouse gas emissions mitigation for agricultural and horticultural systems in Northern Iran." Energy, <https://doi.org/10.1016/j.energy.2019.07.175>, vol. 186, pp. 1-15, 2019.
- [39] E. Ubuoh, F. Nwogu, and E. Biose, "Environmental Implication of Wooden Casket Production on Ambient Air Quality in Part of Owerri Municipal, South Eastern Nigeria." African Journal of Health, Safety and Environment, vol. 3, no. 1, pp. 71-95.
- [40] O. Olujimi, G. Ana, O. Ogunseye, and V. Fabunmi, "Air quality index from charcoal production sites, carboxyhaemoglobin and lung function among occupationally exposed charcoal workers in South Western Nigeria." Springerplus, vol. 5, no. 1, pp. 1-18.
- [41] A. Ebekoziem, M. Aigbedion, O. Duru, O. Udeagwu, and I. Aginah, "Hazards of wood sawmills in Nigeria's cities: the role of fourth industrial revolution technologies." Journal of Facilities Management, vol. 21, no. 1, pp. 84-101.
- [42] B. Thorpe, Citizen's guide to clean production, University of Massachusetts, 1999, Lowell Center for Sustainable Production.
- [43] D. Ramos, P. Afonso, and M. Rodrigues, "Integrated management systems as a key facilitator of occupational health and safety risk management: A case study in a medium sized waste management firm." Journal of Cleaner Production, vol. 262, pp. 121346, 2020.
- [44] A. Alsamawi, J. Murray, M. Lenzen, and R. Reyes, "Trade in occupational safety and health: Tracing the embodied human and economic harm in labor along the global supply chain." Journal of cleaner production, vol. 147, pp. 187-196.
- [45] O. Chyhryn, N. Artiukhova, and T. Vasylyna, "Cleaner production as a driver of green competitiveness."
- [46] V. Veleva and M. Ellenbecker, "Indicators of sustainable production: framework and methodology." Journal of cleaner production, vol. 9, no. 6, pp. 519-549.
- [47] A. Momenirad and P. Ghanbari, "The role of governments' practice in the possibility of applying global jurisdiction in dealing with pollution and international environmental crimes." Journal of Positive School Psychology, pp. 9812-9829, 2022.
- [48] G. Neto, R. Leite, W. Lucato, R. Vanalle, M. Amorim, J. Matias, and V. Kumar, "Overcoming Barriers to the Implementation of Cleaner Production in Small Enterprises in the Mechanics Industry: Exploring Economic Gains and Contributions for Sustainable Development Goals." Sustainability, vol. 14, no. 5, pp. 2944, 2022.
- [49] G. de Oliveira Neto, J. Santana, M. Godinho Filho, and C. J. Chiappetta Jabbour, "Assessment of the environmental impact and economic benefits of the adoption of cleaner production in a Brazilian metal finishing industry." Environmental technology, vol. 41, no. 14, pp. 1814-1828.
- [50] L. Cheng, Y. Liu, X. Lou, Z. Chen, and Y. Yang, "Does technology conglomeration promote innovative outcomes of new energy vehicle enterprises?"



Adeniran & Omoniyi, SCEETC 2023

The moderating effect of divisive faultlines." Journal of
Cleaner Production, vol. 324, pp. 129-232, 2021.

UNIVERSITY OF IBADAN LIBRARY

