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Research/Review

Adopting Cleaner Production Technology and Green Supply Chain to Achieve Environmental Sustainability: An Applied Study

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Abstract This research aims to examine the impact of integrating cleaner production practices with green supply chain technologies as a comprehensive approach to achieving environmental sustainability. The study highlights that cleaner production and green supply chain management represent advanced, innovative strategies that have emerged as a response to the growing environmental challenges caused by the rapid expansion and diversification of industrial activities. These technologies are not only environmentally oriented but also carry significant economic implications for organizations. The findings emphasize that adopting cleaner production involves minimizing waste generation, improving production efficiency, and ensuring that processes are designed to have minimal adverse effects on the environment. On the other hand, green supply chain technologies focus on integrating environmental thinking into every stage of the supply chain—ranging from product design, material sourcing, and manufacturing processes to logistics, product delivery, and end-of-life management. The study concludes that the synergy between these two approaches provides multiple benefits. From an environmental perspective, they contribute to reducing carbon emissions, particularly from fuel-powered machinery and transportation systems. They also promote the rational use of resources, including energy, water, and raw materials, thereby helping to preserve natural resources for future generations. From an economic perspective, their implementation leads to reduced operational costs by enhancing efficiency, decreasing waste disposal expenses, and optimizing resource usage. Furthermore, the integration of cleaner production and green supply chain technologies supports compliance with environmental regulations and enhances the corporate image of economic units, enabling them to gain competitive advantages in increasingly eco-conscious markets. Overall, the research affirms that these practices are essential tools for confronting and mitigating the environmental pollution challenges of modern industries, while simultaneously fostering sustainable economic growth and long-term environmental protection.

Keywords: Cleaner Production, Environmental Sustainability, Green Supply Chain, Resource Efficiency, Sustainable Manufacturing.

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1. Introduction

In light of the increasing environmental challenges facing the world since the 1980s, the shift toward modern sustainable production and manufacturing practices has become an urgent necessity, not an option. One of the most prominent of these practices is the adoption of cleaner production technologies, which aim to reduce the negative impacts of industry by reducing waste and emissions through improved production efficiency. In parallel, green supply chain technology has emerged as a comprehensive approach that integrates

environmental considerations into all stages of the supply chain, from product design, through manufacturing and distribution, to recycling (waste) management.

From this perspective, the integration of cleaner production technologies and the green supply chain is essential to achieving environmental sustainability. This integration helps build an integrated industrial model that takes into account the balance between accelerated economic growth on the one hand and the conservation of natural resources on the other. Therefore, this research aims to demonstrate the impact of adopting cleaner production technologies and the green supply chain on achieving environmental sustainability by providing industrial models that maintain a balance between industrial growth and resource conservation.

2. Research Methodology

The Research Problem

Despite rapid industrial developments, economic units in the Iraqi production environment, particularly the General Company for Electrical and Electronic Industries, still rely on traditional production methods that contribute to water and air pollution and resource depletion. The reality of Iraqi economic units is that they do not pay attention to environmental aspects and the preservation of natural resources, and herein lies the problem. Based on the above, the research problem is to answer the following question: (Does the adoption of cleaner production technology and a green supply chain lead to achieving environmental sustainability through the manufacture of environmentally friendly products?)

Research Objectives

The primary objective of the research is to demonstrate the role played by adopting cleaner production and green supply chain technologies in achieving environmental sustainability at the General Company for Electrical and Electronic Industries through:

- Explaining the cognitive foundations of cleaner production and green supply chain technologies, their foundations, and their role in achieving environmental sustainability.
- Explaining the shortcomings of traditional production systems at the General Company for Electrical and Electronic Industries.

The Importance of the Research

The importance of the research stems from the fact that adopting cleaner production and green supply chain technologies at the General Company for Electrical and Electronic Industries leads to optimal resource utilization and reduced pollution by offering environmentally friendly products, thus achieving environmental sustainability.

The Research Hypothesis

The research is based on a main hypothesis:

(The adoption of cleaner production and green supply chain technologies helps achieve environmental sustainability, reduce pollution, and conserve resources by offering environmentally friendly products.)

The Theoretical Framework of Cleaner Production and Green Supply Chain Technologies

The Theoretical Framework Of Cleaner Production Technologies

3. The Concept And Definition Of Cleaner Production Technologies

2. Preliminaries or Related W The concept of cleaner production is considered one of the components of industry in developed and developing countries, due to the productive benefits it achieves, which positively impact the environment. When widespread production led to the consumption of natural resources and energy, which generated emissions and production waste, which in turn led to harm to the environment and humans, cleaner production emerged. It eliminates or reduces these harms and contributes to the optimal utilization of energy and resource conservation, thus achieving environmental sustainability. Cleaner production also reduces waste disposal costs by addressing the sources of resource consumption and waste resulting from production processes (Paul et al., 2014: 1646).

Cleaner production technology has been defined by various authors and researchers. Patel et al. (2017:33) define it as an integrated business strategy aimed at addressing the negative impacts of manufacturing processes through continuous technology development, process improvement, optimal resource utilization, and the adoption of sustainable practices. This balances productio efficiency and profitability on the one hand, and environmental protection on the other. DaSilva Gouveia (2020:22) defines it as a comprehensive technology aimed at improving environmental performance by increasing the efficiency of production processes and reducing their negative impacts. Cleaner production relies on the application of integrated preventive measures to proactively reduce and prevent pollution .

From the above, it is possible to formulate a definition of cleaner production technology, which states: "It is a preventive strategy aimed at improving environmental performance by producing environmentally friendly products through the application of sustainable solutions that include technological development, process improvement, the adoption of green practices, and the reduction of pollution by reducing waste and emissions."

Benefits of Cleaner Production Technology

Implementing cleaner production technology achieves benefits for economic units and customers, both at the operational and product levels, as follows (Goel & Singh, 2013:169):

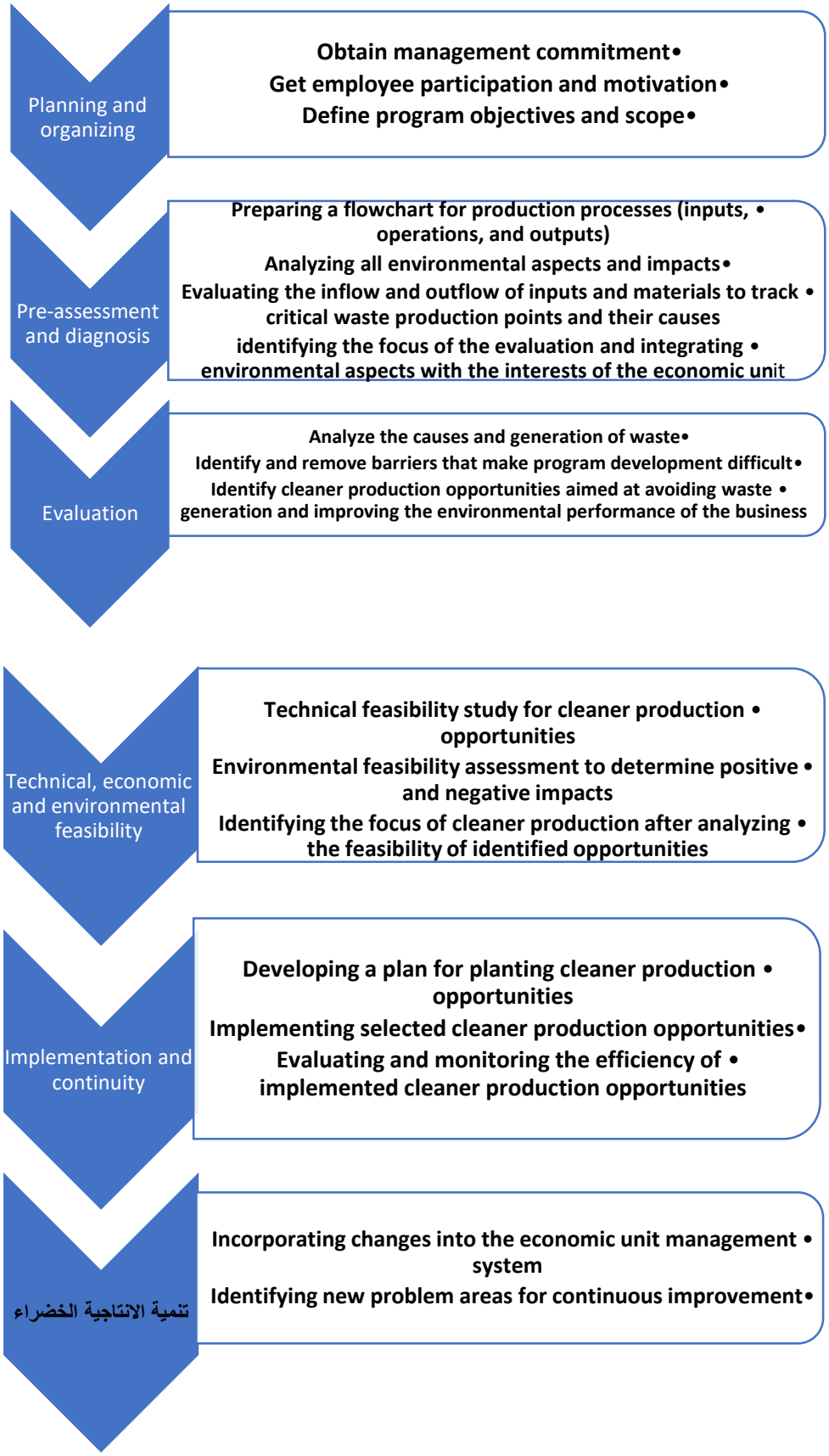
- At the operational level: It provides the basic requirements for production from raw materials by recycling and reusing the outputs of production processes, and recycling waste into materials that can be reused as inputs for secondary products, in addition to reducing the energy used in production processes.
- At the product level: Cleaner production helps optimize the use of resources and reduce costs associated with packaging, in addition to providing quality products at reasonable prices to the customer, and increasing the value of waste through resale.

Principles of Cleaner Production Technology

Cleaner production technology has been the subject of considerable debate among writers and researchers, but it is essentially based on four principles (Coca-Prados & Gutiérrez-Cervelló, 2012, p. 4), according to Al-Nasrawi (2023, p. 64):

- The precautionary principle: This principle concerns protecting workers from disease and protecting the economic unit from harm by utilizing all policies, knowledge, and procedures related to environmental decisions. This is achieved through a comprehensive examination of all alternatives related to environmental problems that may occur in the future and cause environmental pollution and harm to human health.
- The Preventive Principle: This principle concerns the shift from a corrective approach to **a** preventive approach. It is more effective and less costly in preventing environmental damage by examining the entire production process, from raw materials to finished products.
- The Holistic Principle: This principle adopts a comprehensive view of the production cycle through a product life cycle analysis. This principle indicates the necessity for economic units to adopt a comprehensive approach to resource use and consumption, as reliance on outdated traditional methods of production leads to water, soil, and air pollution.
- The Democratic Principle: This principle is based on a democratic system of governance that enables the formation and establishment of economic units that promote efficient production and consumption patterns in the exploitation of resources, the economy, and products, and that protect human and environmental safety.

Steps to implement cleaner production technology



Source: Costa, Nelma Penha da & Fonseca, Alberto & Filho, José Francisco Prado, (2017), "Cleaner Production Implementation in the Textile Sector: The Case of a Medium-sized Industry in Minas Gerais", Revista do Centro do Ciências Naturais e Exatas - UFSM, Santa Maria, Vol. 21, no. 3, P 149.

The theoretical framework of the green supply chain

Definition of the green supply chain

The green supply chain is a modern concept that integrates environmentally friendly practices into every stage of the supply chain, from product design and raw material flow, through production, to distribution and recycling. The green supply chain is a system of suppliers, producers, distributors, retailers, and consumers (Asrawi, 2016:11). Researchers and writers have differed in setting a specific definition for the green supply chain. Niemann et al. (2016:981) defined it as a set of organizational and environmental processes used to reduce emissions, waste, and unnecessary procedures and improve the efficiency of the traditional supply chain. Sidharath (2022:136) defined it as an interaction between various units that provides fundamental benefits across the three pillars of sustainability (economic, social, and environmental) to establish long-term partnerships, as every form of industry relies on these three pillars.

Objectives of the Green Supply Chain

The green supply chain aims to reduce waste and improve the quality of the ecosystem, including waste recycling, in addition to providing measures in terms of knowledge, technology, and individual development, enabling them to achieve profits through a focus on environmental efficiency (Novitasari et al., 2021:393). The green supply chain achieves several objectives that play a fundamental role in motivating economic units to implement them. The following are some of the objectives of this chain (Kadam et al., 2017:39). (Ali, 2023, p. 52)

- The green supply chain focuses on making industrial operations environmentally friendly
- Achieving environmental sustainability and efficient performance through the application of green supply chain practices.
- Integrating the supply chain into public policies within the economic unit for streamlined operation.
- Using environmental analysis as a catalyst for innovation.

Green Supply Chain Activities

- Green Procurement: A strategic environmental initiative aimed at selecting materials that comply with environmental standards, enhancing sustainability. This approach relies on reducing waste and emissions at the source, encouraging recycling and reuse, and adopting environmentally friendly alternatives. (Hidayat et al., 2020: 470)

- Green Design: An environmentally friendly design adopted by an economic unit throughout the product life cycle. The primary motivation for green design is that it enables economic units to understand how to make design decisions, which in turn helps make products more environmentally compatible. The green design approach involves replacing potentially unwanted (hazardous) materials or reprocessing them with less problematic materials (Audo, 2012: 19).

- Green Manufacturing: A set of processes focused on transforming inputs into an environmentally friendly and desirable product. This reduces emissions and hazardous waste that impact humans and the environment, while economically maintaining product quality (Dubey et al., 2017: 29).

- Green Marketing: Marketing that promotes products that are environmentally friendly. It can be said that green marketing reflects the planning, development, and promotion of products and services that satisfy customer needs in terms of quality, price, performance, and available services, without any negative impact on the environment. It also emphasizes the rational use and quality of raw materials and energy (Ali, 2023, p. 52).

- Reverse Logistics: This is defined as the process of retrieving a product from the end consumer to obtain value or proper disposal. It includes collection, inspection, joint sorting, reprocessing, direct recovery, redistribution, and disposal activities (Ninlawan et al., 2010: 3).

Steps for Implementing the Green Supply Chain

The green supply chain is implemented in economic units through five steps, as follows (Wallerius & Zakrisson, 2010: 29-30), (Al-Taie, 2018: 40), (Al-Sayed, 2018: 678):

- Definition: In this step, the economic unit's maturity is determined, and current procedures are tracked by creating an early picture of the unit's position and market position, i.e., the overall picture in various areas such as metrics, tracking values and objectives, leadership, technology, etc.

- Planning: Planning is done to reduce waste by evaluating the changes that are likely to achieve cost savings and reduce environmental impacts.

- Reporting: This step requires the cooperation of all employees in the economic unit to preserve the environment, as well as a commitment from management to support this idea, conduct a market research program, and gather information to understand customer demands and identify the other environmental impacts of these products.

- Implementation: This step entails implementing training and educational programs for administrative levels. Furthermore, it is necessary to raise awareness among employees and workers about this concept and foster a team spirit to achieve this goal for the economic unit.

- Monitoring: Maintaining all the achievements made through the previous green supply chain steps requires diligent work to conduct ongoing monitoring and evaluation to ensure environmental sustainability.

Applying Cleaner Production Technology and the Green Supply Chain to Achieve Environmental Sustainability

This section will address two main themes: the first is an introductory overview of the State Company for Electrical and Electronic Industries, the subject of this research, and the second discusses the mechanism of the electric generator.

A Brief Overview of the State Company for Electrical and Electronic Industries

The State Company was established in 1965, and its founding was published in Issue No. 367 of 1967 in the Al-Waqa'i' Gazette. Construction of the project began in 1963, covering an area of 108,000 square meters. The company was officially inaugurated in 1967 with a capital of 4,249,337,252 dinars. The company employs 2,637 people, in addition to 1,080 temporary contract workers. Its locations are distributed between Tajiat and Al-Waziriyah in Baghdad.

Applying Cleaner Production and the Green Supply Chain to Electric Generators (500 and 1000 KVA)

- The Mechanism of Operation of Conventional Electric Generators

A generator is a machine that converts kinetic energy generated by an external source (diesel and gasoline engines) into electrical energy via the magnetic field that generates the kinetic energy. Conventional generators rely on fossil fuels, which cause noise pollution due to noise, high carbon emissions, and high operating and maintenance costs.

Research Proposal to Achieve Environmental Sustainability: A Self-Powered Electric Generator (Hybrid System) by developing a hybrid generator that relies on a starter powered by rechargeable batteries, an electric motor as an alternative to a mechanical one, and a

magnetic field to reduce dependence on fuel. This proposal will reduce noise pollution from mechanical engines and carbon emissions by 100% due to the elimination of the need for fuel, in addition to reducing operating and maintenance costs and increasing energy production efficiency. We will analyze the green supply chain and cleaner production.

• Green purchasing activity: replacing fuel-powered mechanical engines with environmentally friendly electric ones. We will calculate the required horsepower for each generator using the following equation:

Horsepower (HP) = Apparent Power (KAV) * 0.8 * 1000 / 746

Applying the above equation to calculate the power for each generator:

500 KAV generator: 500 * 0.8 * 1000 / 746 = 536 HP

1000 KAV generator: 1000 * 0.8 * 1000 / 746 = 1072 HP

Table 1 below shows the prices of electric motors (according to the market).

Table 1: Electric Motor Prices

Generator Category: KAV	Horsepower, HP	Price in Dinars
500	600	18000000
1000	1100	27000000

Source: Prepared by the researcher

From the table above, it can be said that the green purchasing activity has achieved an important factor in achieving sustainability by purchasing electric motors and replacing mechanical ones.

• Green design activity: We will eliminate the silencer due to the lack of sound in the electric motor. The table below shows the cost of the silencer.

Table 2: Silencer Prices

Details	Silencer Price	Number of Units	Total
500 KAV Silencer	7,500,000	14	105,000,000
1000 KAV Silencer	19,000,000	8	152,000,000
Total			257,000,000

Source: Prepared by the researcher

From Table (2), it is noted that an amount of 257,000,000 was reduced due to the exclusion of the silencer.

• Green Manufacturing Activity: This activity is carried out by redesigning the base by adjusting the dimensions to fit the size of the electric motor, making it smaller in size, thus saving space and costing 800,000 for the 500 KAV generator and 1,250,000 for the 1000 KAV generator, according to experts.

• Green marketing activity: Advertising and publicity expenses will be significantly reduced as a result of increased demand due to the environmental and economic advantages offered by the product.

• Reverse logistics (cleaner production): This involves recycling or selling scrap, thereby generating revenue for the factory and disposing of waste to reduce pollution. The factory generates revenues of 450,000 dinars from the sale of recycled metal waste, selling 1.5 tons annually for 300,000 dinars per ton annually. Based on the above, it can be said that the implementation of cleaner production and the green supply chain represents a qualitative shift in industry, particularly in the electric generator industry, as it achieves numerous competitive advantages through quality, efficiency, and increased profitability by reducing costs and increasing sales. Furthermore, it achieves environmental sustainability by reducing waste and emissions.

4. Conclusions

- Cleaner production and green supply chain technologies are modern technologies that have been used to address environmental pollution caused by multiple industries. They are also important in economic units in confronting and mitigating environmental pollution challenges.

- Adopting cleaner production and green supply chain technologies represents an integrated framework for achieving environmental sustainability, as each complements the other. Environmental performance is improved by reducing carbon emissions from fuel-powered engines, rationalizing resource consumption, and achieving economic benefits through cost reductions.

- Cleaner production focuses on preventing pollution at the source by improving internal processes, such as the procurement of electric motors in the factory. Green supply chain, on the other hand, expands the scope to include the entire product lifecycle, from raw material procurement to final disposal.

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