



Cleaner Production Strategy: A Path Toward the Sustainability of Economic Institutions within the Framework of Sustainable Development

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Abstract

The cleaner production strategy is considered one of the most important contemporary approaches adopted by economic institutions to achieve sustainability and enhance their competitiveness in light of the requirements of sustainable development. This concept is based on the adoption of preventive measures aimed at improving the efficiency of production processes through the optimal use of natural resources, energy, and raw materials, while minimizing waste generation and pollutant emissions at their source rather than addressing their consequences after they occur.

The cleaner production strategy contributes to the economic sustainability of institutions by reducing production costs, minimizing waste, and improving productivity, which ultimately leads to increased profitability and enhanced market competitiveness. It also supports environmental sustainability by reducing pollution, rationalizing resource consumption, and preserving ecological balance. At the social level, it contributes to improving working conditions, protecting the health of employees and society, and strengthening corporate social responsibility.

In light of the growing environmental and economic challenges, the cleaner production strategy has become an essential option for institutions seeking sustainable growth, as it enables them to reconcile economic objectives with environmental protection requirements and social welfare goals. Therefore, adopting this strategy represents an effective pathway to ensuring the sustainability of economic institutions and enhancing their contribution to achieving sustainable development goals in the long term.

Keywords: Sustainable Development, Cleaner Production, Sustainability of Economic Institutions, Corporate Social Responsibility, Clean Technology.

Introduction

Cleaner production is one of the modern concepts that emerged alongside the concept of sustainable development. It aims to integrate environmental considerations into the production process throughout the entire life cycle of a product. Consequently, economic institutions have found themselves compelled to assume responsibility for environmental pollution and the damages resulting from their various activities. Furthermore, the pressures exerted by different



stakeholders seeking a pollution-free environment and a more rational use of energy and environmental resources have encouraged economic institutions to recognize the importance of incorporating cleaner production technologies into their strategies. This integration facilitates the management of environmental issues within the framework of environmental regulations and contributes to mitigating environmental problems.

To provide a deeper understanding of this strategy, this study seeks to examine the concept of cleaner production, its key characteristics, and the differences between cleaner production and conventional production systems.

Based on these considerations, the following main research question is posed:

How does the cleaner production strategy contribute to improving the performance and efficiency of economic institutions in accordance with the principles of sustainable development?

Research Objectives

This study aims to achieve several objectives, including:

Identifying the main concepts related to sustainable development, along with its various dimensions and indicators;

Examining the current state of sustainable development and the efforts undertaken to achieve it within a sustainable environment;

Clarifying the role of the cleaner production strategy in economic institutions in achieving sustainable development across its various dimensions;

Raising awareness among managers and decision-makers regarding the importance of integrating environmental standards into the activities of economic institutions;

Analyzing and highlighting the benefits achieved by economic institutions through the implementation of the cleaner production strategy.

Research Methodology

The researcher adopted a set of methodological approaches appropriate to the objectives of the study. The descriptive and analytical methods were employed to provide a comprehensive understanding of the theoretical concepts addressed in the research. In addition, the inductive method was used to examine the role played by the cleaner production strategy in enhancing the performance and efficiency of economic institutions in line with the principles of sustainable development.

The study is organized into three main sections:

Section One: The Fundamental Pillars of Sustainable Development;

Section Two: The Concept and Nature of Cleaner Production;

Section Three: Cleaner Production Strategy Practices and Their Role in Supporting the Dimensions of Sustainable Development.

Section One: The Fundamental Pillars of Sustainable Development

The term sustainable development has gained significant prominence on the international stage among the many concepts and terminologies associated with development. Its usage has



become widespread to the extent that it is now an integral component of development definitions. Increasing attention has been directed primarily toward improving quality of life and preserving the environment. In other words, the environmental, economic, social, and technological dimensions have been incorporated into the concept of development, leading to the expansion of sustainable development concepts and the diversification of its definitions.

First: The Concept of Sustainable Development

Sustainable development was defined in the report issued by the World Commission on Environment and Development as: “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.”¹

Sustainable development is also defined as “the continuous pursuit of improving the quality of human life while taking into account the capacity and potential of the ecosystem, which constitutes the foundation that sustains life.”²

Furthermore, Edouard Barbier defined it as: “an activity that seeks to maximize social welfare while ensuring the preservation and conservation of available natural resources, with the least possible damage and harm to the environment.”³

The Director of the United States Environmental Protection Agency defined it as: “a process that recognizes the necessity of achieving economic growth compatible with environmental capacities, based on the premise that economic development and environmental protection are complementary rather than contradictory processes.”⁴

From the foregoing definitions, it is evident that sustainable development seeks to ensure economic well-being for both present and future generations while preserving and protecting the environment. It aims to achieve economic development and an adequate standard of living without undermining the environment’s ability to satisfy the needs of current and future consumers. Moreover, it strives to establish a balance among the environmental, economic, and social systems that constitute the development process through environmental protection and the conservation of natural resources, particularly non-renewable resources, for the longest possible period, thereby safeguarding the rights of future generations.

¹ World Commission on Environment and Development, *Our Common Future*, United Nations Environment Programme (UNEP), 1987.

² Jean-Paul Maréchal & Béatrice Quenault, *Le Développement Durable: Une Perspective pour le XXI^e Siècle*, Presses Universitaires de Rennes, Rennes, 2005, p. 63.

³ Gabriel Wackermann, *Le Développement Durable*, Ellipses Editions, France, 2008, p. 31.

⁴ Adnan Dawood Mohammed Al-Adhari, *Foreign Direct Investment, Development and Sustainable Development in Some Islamic Countries*, Dar Ghaidaa for Publishing and Distribution, Amman, Jordan, 2016, p. 34.



Second: The Objectives of Sustainable Development

The objectives of sustainable development, which have become an integral part of international legislation and constitute a core component of international environmental policy, may be summarized as follows:¹

Eradicating poverty in all its forms everywhere;

Ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture;

Ensuring healthy lives and promoting well-being for all at all ages;

Ensuring inclusive, equitable, and quality education and promoting lifelong learning opportunities for all;

Achieving gender equality and empowering women;

Ensuring the availability and sustainable management of water and sanitation services for all;

Ensuring access for all to affordable, reliable, sustainable, and modern energy services;

Promoting sustained, inclusive economic growth, full and productive employment, and decent work for all;

Building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation;

Making cities and human settlements inclusive, safe, resilient, and sustainable;

Conserving and sustainably using oceans, seas, and marine resources for sustainable development;

Protecting, restoring, and promoting the sustainable use of terrestrial ecosystems; sustainably managing forests; combating desertification; halting and reversing land degradation; and halting biodiversity loss;

Promoting peaceful and inclusive societies for sustainable development, providing access to justice for all, and building effective, accountable, and inclusive institutions at all levels;

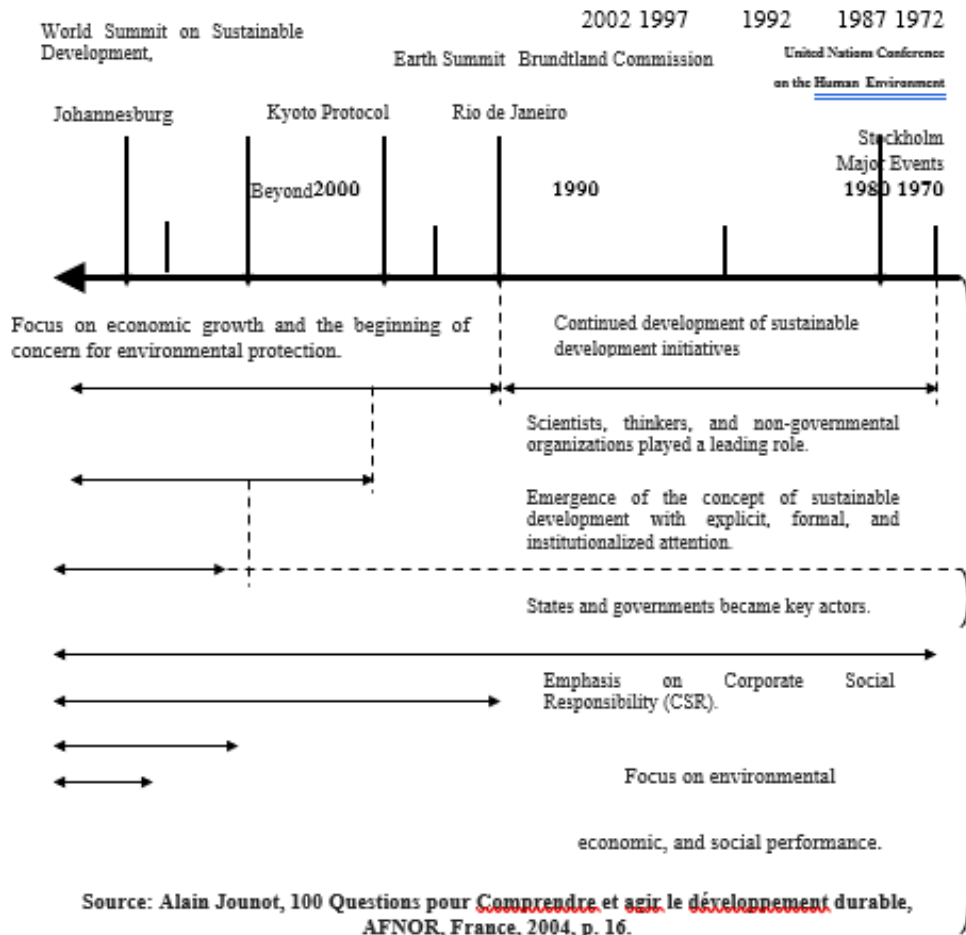
Strengthening the means of implementation and revitalizing the global partnership for sustainable development.

Third: The Evolution of the Role of Stakeholders in Achieving Sustainable Development

The historical evolution of sustainable development and its concepts would not have been possible without the presence of key stakeholders who contributed to shaping these concepts, defining their dimensions, and achieving many of their objectives. These stakeholders can be grouped into four main categories: scientists and thinkers, non-governmental organizations (NGOs), states and governments, institutions, and individuals.

Figure No. 01: Evolution of the Role of Stakeholders in Achieving Sustainable Development

¹ Aicha Salma Kihli & Amal Rahman, *Environmental Protection in Economic Thought between Theory and Implementation Initiatives*, Al-Rimal Printing House, El Oued, Algeria, 2020, pp. 57–58.



AFNOR, France, 2004, p. 16.

The previous figure illustrates how these stakeholders contributed to both the conceptual and practical evolution of sustainable development. Initially, the attention of most states and governments was focused on achieving economic growth that would significantly improve national economies, whether in developed or developing countries. However, voices from economic thinkers, environmental scientists, and certain non-governmental organizations emerged, calling for greater attention to environmental concerns alongside economic development. This was a response to the severe environmental degradation that had begun to manifest itself clearly and extensively.

As a result of the continuous pressure exerted by thinkers and NGOs, and their strong advocacy for environmental and social issues, numerous local seminars and international summits were organized. These efforts culminated in the publication of the Brundtland Commission's report, *Our Common Future*, in 1987. This report played a major role in shifting concern for environmental and social issues from thinkers and NGOs to states and governments in an



explicit manner. It warned countries and political actors of the dangers of pursuing development paths that were environmentally destructive and resource-depleting.

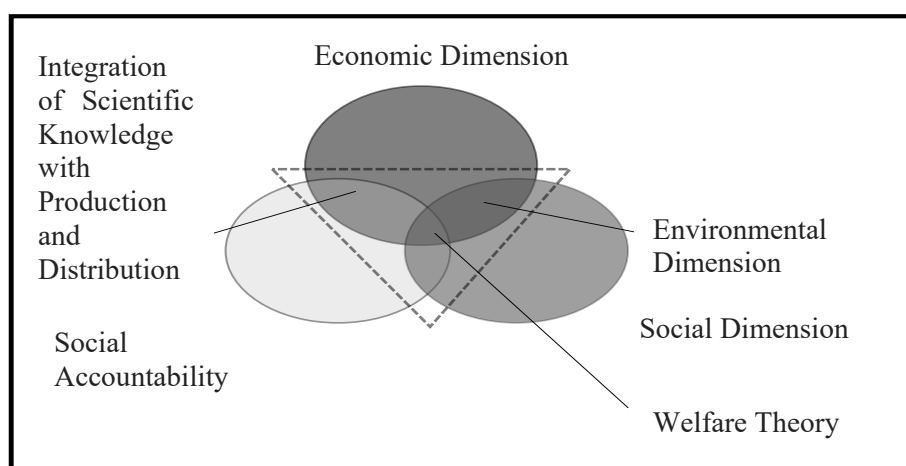
Consequently, most states and governments became active participants in achieving sustainable development, both because they became aware of the risks associated with previous development models and because of the pressure exerted by non-governmental organizations, such as Green movements, environmental protection organizations, and human rights organizations.

Subsequently, attention shifted to institutions as a result of governmental pressure, particularly following the signing of the Kyoto Protocol in 1997. Many major countries committed themselves to reducing pollution levels resulting from various economic activities. In turn, governments required most of their institutions to contribute to achieving these objectives. As a result, institutions became active and effective stakeholders in promoting economic, social, and environmental sustainability through their commitment to corporate social responsibility. Furthermore, institutions contributed to raising consumer awareness about the importance of sustainable development and simplifying its concepts for the general public through sustainable marketing practices and green advertising campaigns. Consequently, awareness of the importance of sustainable development increased among various segments of society.¹

Fourth: The Main Dimensions of Sustainable Development

Most studies and research confirm that sustainable development has three interrelated, overlapping, and integrated dimensions within an interactive framework. These dimensions are the economic, social, and environmental dimensions. The following figure illustrates the overlap among these dimensions, where their intersection results in sustainable development.

Figure No. 02: The Interconnection of the Dimensions of Sustainable Development



¹ Chehhat Amina, Environmental Strategies in Economic Institutions as an Option for Achieving the Dimensions of Sustainable Development – An Applied Study, Ph.D. Thesis in Economic Sciences, Specialization: Environmental Economics and Sustainable Development, Faculty of Economic, Commercial and Management Sciences, Abbas Laghrour University of Khenchela, 2022/2023, pp. 11–12.



Source: Mustafa Youssef Kafi, Transport Economics and the Environment within the Framework of Sustainable Development, Alpha Documentation, Constantine, Algeria, 2017, p. 134.

From the previous figure, it can be observed that sustainable development is achieved through the availability of the three dimensions simultaneously, that is, within the area of intersection. The intersection of the economic and social dimensions leads to the realization of welfare under the principles of accountability and social justice. The intersection of the economic and environmental dimensions seeks to identify knowledge-based methods and approaches that ensure sound production and distribution processes. Meanwhile, the intersection of the social and environmental dimensions reflects the extent to which environmental awareness and culture are promoted.

It should be noted that these dimensions are interconnected, overlapping, and complementary. They should not be treated separately, nor should priority be given to one dimension over another, as all of them collectively embody the principles and approaches of sustainable development.

Second Axis: The Cleaner Production Strategy in Economic Institutions

Cleaner production is considered one of the modern concepts that emerged alongside the concept of sustainable development. It aims to integrate environmental considerations into the production process throughout the entire life cycle of a product. To provide a deeper understanding of this strategy, this section examines the concept of cleaner production, its main characteristics, and the differences between cleaner production and conventional production.

First: Definition of Cleaner Production

The International Organization for Standardization (ISO) defines cleaner production as: “the use of processes, services, and goods that reduce, prevent, or control pollution, such as treatment, recycling, process modification, and waste control methods.”¹

It is also defined as: “production whose environmental performance exceeds that of an industry, industrial sector, or industrial process in terms of resource consumption and waste generation.”²

Regarding services, the primary objective of applying this approach is to incorporate environmental considerations into the design and delivery of services.³

Based on the above definitions, cleaner production can be described as the continuous improvement of production processes for goods and services with the aim of reducing the consumption of natural resources and preventing water, air, and soil pollution at the source.

¹ Hikmat Rashid Sultan & Hinar Ibrahim Amin Bamarni, Production and Operations Management: Contemporary and Integrated Manufacturing Systems (CIMS), Dar Al-Akademiyoon for Publishing and Distribution, Amman, Jordan, 2021, p. 310.

² Metlef Hadda, “Cleaner Production Technology: The Future Strategy for Environmental Preservation,” Industrial Economics Journal, El Hadj Lakhdar University, Batna 1, No. 07, 2014, p. 184.

³ Zayan Sayeh, Acquiring Cleaner Production Technology in Petroleum Sector for All Companies, The 7th International Conference for Environmental and Petroleum Issues, 27–29 March 2004, Cairo, Egypt, p. 04.



This approach seeks to minimize the risks faced by humans, the environment, and all living organisms on Earth.

This definition highlights several key aspects of cleaner production that should be considered during the production process: ¹

1. Inputs:

These include raw materials, energy, design, and all other elements necessary for production processes. Cleaner production can be applied through the selection of renewable and recyclable raw materials, the use of renewable energy sources, the avoidance of non-renewable materials and energy resources, and the design of environmentally friendly products while eliminating toxic substances and hazardous waste.

2. Processes:

These refer to production operations. Cleaner production is reflected in the use of clean technologies, which generally provide the same products as conventional technologies but with less environmental pollution and greater efficiency in the use of raw materials and energy.

3. Products:

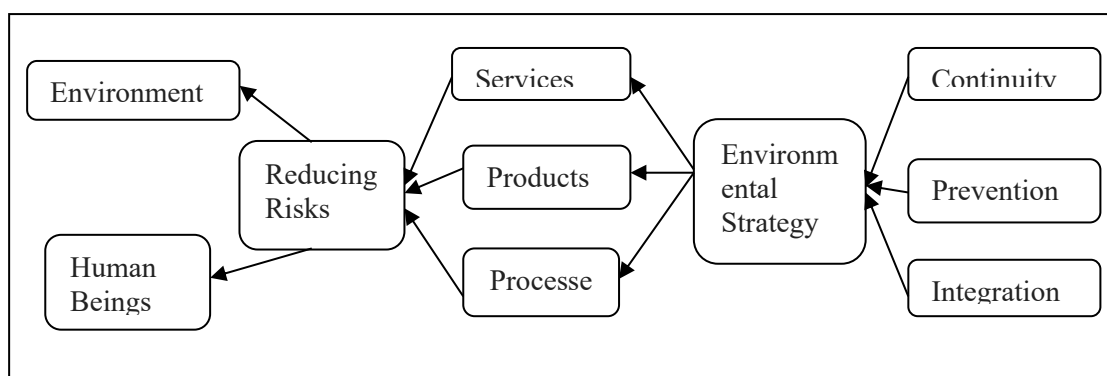
Production processes with minimal environmental impact create clean products that can be recycled and reused, resulting in reduced resource waste and lower levels of waste generation.

4. Services:

These involve integrating environmental concerns into the design and delivery of services.

The following figure illustrates the concept of cleaner production as presented by the United Nations Environment Programme (UNEP):

Figure No. 03: Cleaner Production According to the United Nations Environment Programme Concept



Source: Bouhabila Ilham, “The Role of Cleaner Production Technology in Protecting the Environment from Pollution: A Case Study of the Algerian-Qatari Steel Company (AQS),” *North African Economies Journal*, Hassiba Ben Bouali University, Chlef, Vol. 16, No. 22, 2020, p. 369.

¹ Bouhabila Ilham, “The Role of Cleaner Production Technology in Protecting the Environment from Pollution: A Case Study of the Algerian-Qatari Steel Company (AQS),” *North African Economies Journal*, Hassiba Ben Bouali University, Chlef, Vol. 16, No. 22, 2020, pp. 368–369.



From the figure, it is clear that the Cleaner Production Strategy in production processes includes the conservation of raw materials and energy, the elimination of toxic substances, and the reduction of the quantity and toxicity of emissions and waste before they leave the production process. As for products, it focuses on reducing harmful impacts throughout the product life cycle, which begins with the extraction of the raw materials required for its production and continues until its safe disposal.

Secondly: Steps for the Successful Implementation of the Cleaner Production Strategy

The Cleaner Production Strategy involves a set of necessary steps to achieve its objectives, as follows: ¹

1. Defining Objectives:

This involves identifying an approach that minimizes pollutants at their source, promotes efficient use of energy and raw materials, and encourages the recycling and reuse of waste.

2. Identifying Available Alternatives:

This step consists of determining the various available methods, examining their technological characteristics, and assessing the feasibility of implementing each one. Only those methods that prove technologically and practically feasible are subjected to an economic feasibility study.

3. Calculating the Direct Cost of Each Method:

This includes fixed costs such as new factory designs and the purchase and installation of machinery and equipment, in addition to operating costs such as worker retraining and rehabilitation, start-up expenses, and the associated financial commitments.

4. Calculating the Financial Return of Each Method:

The expected return includes savings in treatment costs, waste transportation costs, water and energy consumption, raw material usage, and insurance expenses for both the factory and workers. Additional returns may result from increased production due to improved working conditions, higher productivity, and enhanced product characteristics.

Financial Return = Increased Income Resulting from Improved Production Conditions and Higher Productivity + Savings in Treatment Costs, Waste Transportation, and Other Related Expenses

5. Comparing Costs and Direct Economic Returns:

This method is considered the best tool for evaluating the economic benefits of environmental protection measures (Cleaner Production) through the comparison of alternatives and supporting decision-making. Three possible outcomes may result from evaluating each method:

Return > Cost: The method is economically efficient.

Return = Cost: The method is economically neutral.

Return < Cost: The method is not economically efficient, but it may be justified from social and environmental perspectives.

6. Selecting the Optimal Method:

This refers to the method that is technologically feasible and economically productive. Generally, preference is given to the method that maximizes the difference between economic

¹ Cheraf Brahimi, Previously Cited Reference, pp. 153–154.



return and cost. However, social and environmental considerations, as well as external benefits that cannot be measured monetarily, often influence the selection process. Consequently, a method with neutral economic efficiency may be preferred over a more economically efficient one if it generates greater social and environmental benefits. In some cases, a method may even be selected despite its lack of economic efficiency because of the external benefits, social gains, and environmental protection it provides.

Thirdly: Requirements for Implementing the Cleaner Production Strategy

Cleaner Production techniques are implemented by identifying options that provide the economic institution with relative advantages from technical, economic, and environmental perspectives. Based on these options, the institution establishes its priorities as follows: ¹

First Priority:

Reducing costs and improving efficiency. These priorities include clear development measures that are low-cost, easy to implement, and achievable within a short-term period not exceeding one year.

Second Priority:

Related to factors that have actual or potential polluting effects and that provide benefits to the institution through investments implemented over a medium-term period ranging from one to three years.

Third Priority:

Related to factors that do not have immediate negative impacts but are expected to generate long-term benefits extending beyond three years.

The implementation of the Cleaner Production Strategy within an institution requires the simultaneous presence of two fundamental conditions. The absence of either condition leads to concepts that differ from Cleaner Production, namely: ²

Improving economic performance and reducing production costs or differentiating the product; Improving environmental performance by reducing negative environmental impacts.

Focusing solely on economic performance by seeking lower costs, maximizing profits, or making the product more distinctive results in either the development of production technology or industrial development, due to the absence of environmental considerations. In both cases, the outcome cannot be considered Cleaner Production. Therefore, it can be stated that the successful implementation of the Cleaner Production Strategy requires the integration of these two principles throughout all institutional operations and at all organizational levels. ³

¹ Hisham Omar Hammoudi et al., Environmental Accounting in Support of Adopting Cleaner Production as an Approach within Green Technology Economics, Second Scientific Conference of Cihan University, Erbil, College of Administrative and Financial Sciences, 27–28 June 2018, p. 414.

² Salah Mohamed El-Haggag & Dalia Abdel Hamid Saqr, Environmental and Technological Management System: Methodologies, Techniques, and Sustainability, 1st ed., Arab Thought House, Cairo, Egypt, 2006, p. 113.

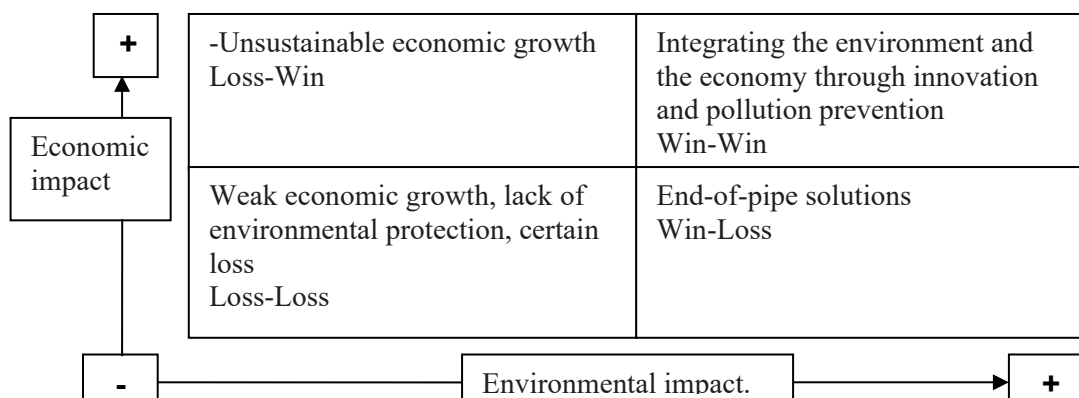
³ Bouhabila Ilham, The Role of the Cleaner Production Strategy in Improving Competitiveness in Industrial Enterprises, PhD Thesis (LMD) in Management Sciences, Faculty of Economic, Commercial and Management Sciences, Ferhat Abbas University Setif 1, 2019/2020, p. 48.



The following figure illustrates the integration of the two aforementioned conditions in order to achieve Cleaner Production:

Figure No. 04: Integration of the Cleaner Production Strategy

The previous figure illustrates the Cleaner Production Strategy, which is divided into three groups as follows:¹



Source Reduction: This refers to reducing waste generation at its source rather than producing waste and attempting to reduce it at later stages. This can be achieved through the following measures:

The diagram illustrates the concept of integrating cleaner production economically and environmentally. If there is high economic growth without concern for environmental protection, the organization will suffer losses due to the inefficient use of resources, in addition to the burdens it will bear as compensation for environmental damage. If attention is paid to the environmental dimension at the expense of the economic dimension, this will result in a certain loss because the economic aspect is considered a guarantee for the continuation of any economic activity. However, if there is high economic growth and a positive environmental impact, meaning environmental protection,

This yields a twofold economic benefit resulting from the efficient use of resources: lower costs and, conversely, reduced depletion of environmental resources and lower pollution levels. The link between the environment—and its resources—and the economy is forged through the innovation of highly efficient production methods—efficient in both economic and environmental terms—thereby leading us to the concept of "cleaner production."

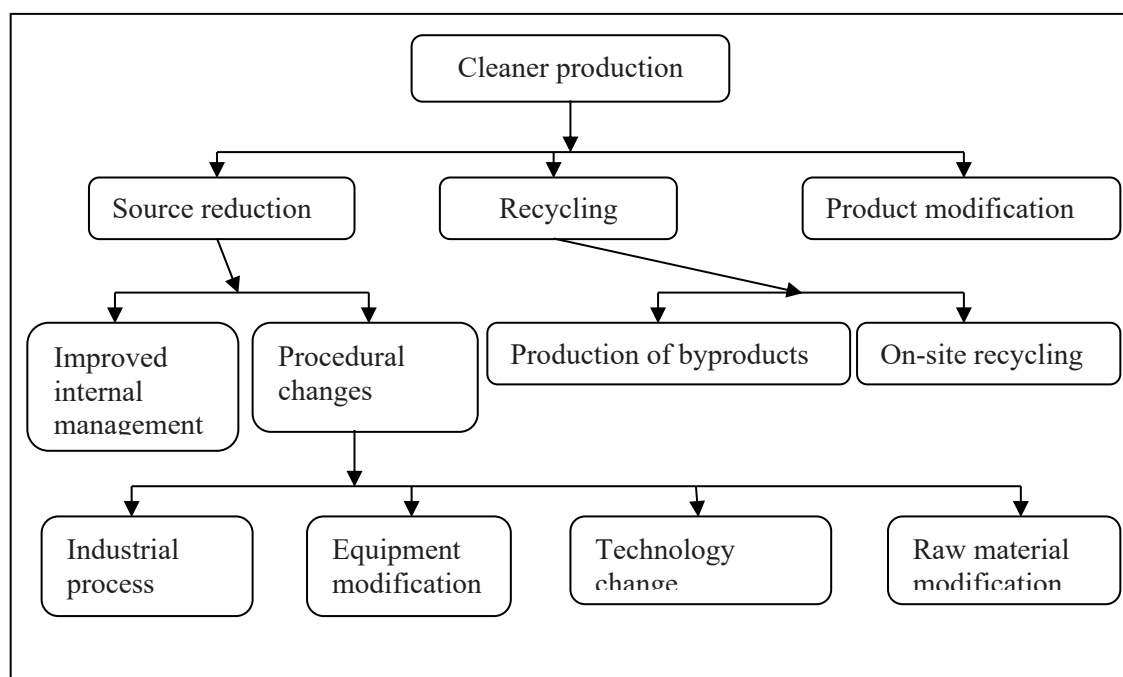
The win-win principle is based on the premise that preventing and controlling pollution at the source yields tangible financial gains for the enterprise—such as reduced pollution-related costs and lower fines—while also delivering intangible benefits, such as an enhanced corporate reputation.

Fourth: Objectives of Implementing the Cleaner Production Strategy in Economic Enterprises



The concept of implementing a cleaner production strategy aims to achieve financial, technical, and economic savings, as well as environmental improvements, at an optimal cost. This activity encompasses controlling waste volume, waste segregation and recycling, recovering raw materials and energy, and modifying operational methods and industrial processes. It is an endeavor that enables the realization of various strategic objectives with environmental dimensions—most notably the advancement of manufacturing methods through improvements across the product life cycle. This cycle spans raw material extraction, manufacturing, storage, product usage, and environmentally safe disposal. The role of cleaner production technology within the product life cycle is illustrated in the following diagram:

Figure 05: Cleaner Production Strategy



The previous figure illustrates the cleaner production strategy, which is divided into three groups as follows:¹

1. Product Modification: This involves adapting the product to meet market and environmental requirements without compromising its quality. For example, toilet paper can be left in its natural gray color instead of being bleached with chemicals. This reduces the use of bleaching agents, leading to environmental improvements, lower raw material consumption, and a reduction in product cost.

2. Recycling: Recycling is divided into two levels. The first level involves recycling within the facility. For instance, if defects are found in plastic containers during production, they can be returned to the production line in specific proportions so as not to affect the properties and quality of the final product, regardless of its type. Since these materials have not yet been used or contaminated and remain within the production process, they can be safely recycled.

¹ Dalia Abdel Hamid Saqr and Salah Mahmoud Al-Hajjar, op. cit., pp. 110–111.



The second level involves recycling outside the facility. In this case, the containers have already been used by consumers and discarded as household solid waste. Since they may be contaminated with other substances, recycled materials are generally used to manufacture products that do not come into contact with food, such as garbage bags, clothing hangers, and electrical conduits.

3- Source reduction: This refers to minimizing waste generation at the outset rather than producing waste and attempting to reduce it at later stages through the following measures:

A. Improving Internal Management of the Facility Examples include repairing presses or valves that continuously leak water, sorting and separating solid waste for sale or recycling, and carefully transporting chemical and fuel containers to prevent spills.

B. Modifying Industrial Procedures and Processes Such as:

Replacing hazardous raw materials with less hazardous alternatives. For example, substituting sulfur dyes (sodium sulfide) used in textile dyeing with glucose can result in economic savings and environmental improvements.

Replacing existing technology with technologies that consume less energy and fewer raw materials. For example, the cement industry has shifted from wet-process technology, which was commonly used in the past, to dry-process technology, which is currently employed in many production lines, especially modern ones. The wet process consumes significantly more energy than the dry process.

Modifying existing equipment to achieve savings in raw materials, water, and energy. For instance, converting washing operations to a counter-current washing system can reduce water consumption by half or even more.

Fifth: The Difference Between Cleaner Production and End-of-Pipe Treatment

The cleaner production approach differs from conventional end-of-pipe treatment methods. The following table highlights the differences between end-of-pipe treatment and the cleaner production strategy.

Table No. 01: Comparison Between Cleaner Production and End-of-Pipe Treatment Approaches

Cleaner Production Approach	End-of-Pipe Treatment Methods	Criterion
Prevention and reduction of waste generation (Proactive)	Treatment of waste after it is generated (Reactive)	Methodology
Integrated	Partial	Scope
Industrial modernization	Traditional	Approach
Cost savings	Additional cost	Economic Dimension



Source: Document entitled “The National Cleaner Production Strategy for Egyptian Industry”, p. 03, available at: <http://www.ecaa.gov.eg/portals/0/ecaaReports/N-Policy/cleaner-production.pdf>, accessed on 30/03/2022 at 11:55.

It should be noted that the methodology adopted in cleaner production, which focuses on minimizing waste generation, does not eliminate the role of end-of-pipe treatment as a means of reducing the environmental impacts of industrial facilities. A certain amount of waste generation is unavoidable and cannot be completely eliminated. Therefore, efforts should be directed toward minimizing such waste and reducing its harmful effects on both the environment and human health.

End-of-pipe solutions refer to the separation of pollutants and hazardous substances and their final treatment or disposal through scientifically approved methods. This approach is widely adopted in many countries around the world. However, Cleaner Production (CP) technology is considered a superior alternative for the following reasons: ¹

End-of-pipe solutions often add new costs to production expenses, leading to an increase in the overall cost of the product and, consequently, its final selling price, since the final price reflects the average production cost plus the profit margin.

This technique can mainly be applied to polluting technologies that have gradually become obsolete with the emergence of newer and cleaner technologies.

Waste generated under end-of-pipe solutions is often difficult to dispose of permanently, especially when it cannot be reused or recycled.

In addition, end-of-pipe treatment methods require specialized personnel for waste management and treatment, which increases administrative costs. In contrast, the adoption of Cleaner Production technology contributes to reducing the production cost per unit through the use of fewer and less expensive raw materials, lower energy consumption, and the recovery and reuse of waste through recycling. Therefore, Cleaner Production technology is considered more beneficial from both economic and environmental perspectives.

Third Axis: Cleaner Production Strategy Practices and Their Role in Supporting the Dimensions of Sustainable Development

Cleaner Production is considered one of the strategic approaches that enable economic organizations to compete at the local, regional, and global levels. Through the adoption of this strategy, organizations can achieve numerous benefits, including environmental protection, economic returns through savings in raw materials, energy, and water consumption, as well as improving the image of the product. All these benefits contribute to reinforcing and promoting the principles of sustainable development.

¹ Adeeb Saker, The Investment in Technology of Cleaner Production in the Syrian Industry, Tishreen University Journal for Research and Scientific Studies – Economic and Legal Sciences Series, Vol. 39, No. 06, 2017, p. 66.



First: Cleaner Production Strategy Practices

Cleaner Production is based on a set of practices or options adopted by organizations in its implementation. The literature in this field indicates that Cleaner Production practices include the following: ¹

1. Good Operational Practices

Also referred to as good management measures, these are procedural and administrative actions that organizations can implement to reduce emissions and pollutants, improve efficiency, and lower costs. These practices can be applied across all organizational departments and include: Management and employee practices, including employee training, incentives, rewards, and other programs that encourage the reduction of emissions and pollutants.

Material handling and storage practices, including procedures for handling incoming materials and maintaining suitable storage conditions to minimize material deterioration, leakage, and their negative environmental impacts.

Practices aimed at reducing pollutants and emissions resulting from the aging of machinery and equipment.

Waste segregation practices, which reduce the volume of hazardous waste by preventing the mixing of hazardous and non-hazardous waste.

Cost accounting practices, including accounting for costs associated with waste treatment and disposal.

2. Changes in Raw Materials

Changes in raw materials contribute to Cleaner Production by reducing or eliminating hazardous and toxic substances used in production processes, thereby minimizing waste generation and pollutant emissions. These changes are achieved through the purification of materials and their substitution with safer alternatives.

3. Technological Changes

These are technological modifications aimed at introducing changes in facilities and equipment to reduce waste generation and pollutant emissions. Such changes may range from simple, low-cost modifications to complete process replacements requiring substantial capital investment.

These changes include:

Modifications to production processes;

Adjustments to equipment, facilities, and internal design layouts;

Changes in operational parameters such as flow rates, temperatures, and working conditions.

4. Changes in Product Design

These are modifications made to product characteristics with the objective of reducing waste generation during the product's use or at the end of its life cycle. Such changes may involve redesigning the product and its technical composition to minimize environmental impacts throughout the product's life cycle. These changes include:

¹ Mohamed Fellag & Fatima Zahra El-Akkazi, The Impact of Cleaner Production Technology on the Competitive Performance of Industrial Organizations: A Case Study of the Cement and Derivatives Company of Chlef, Journal of Economic Studies, Vol. 21, No. 01, 2021, pp. 544–545.



Changes in quality specifications;

Changes in product composition;

Changes in product reliability;

Product substitution.

5. Reduction, Reuse, and Recycling

These terms refer to preventing waste generation at its source, beginning with reducing the use of raw materials and energy, reusing generated waste, and recycling it into useful materials through a series of treatment processes. In other words, they involve the repeated use of a product by altering its original purpose.

Second: The Role of the Cleaner Production Strategy in Supporting the Dimensions of Sustainable Development

The adoption of a cleaner production strategy contributes to achieving sustainable industrial development, as it relies on economic and environmental mechanisms that support the production of competitive products by integrating economic and environmental considerations. The economic and environmental significance of implementing a cleaner production strategy is reflected in reducing production costs, lowering waste disposal expenses, decreasing the quantity and toxicity of pollutants, and consequently minimizing risks and adverse impacts. This positively affects the environment and reinforces the principles advocated by sustainable development.

1. The Economic Dimension of the Cleaner Production Strategy

Organizations that implement a cleaner production strategy can achieve sustainable development through the following: ¹

A. Preservation of the Natural Resource Base:

By directing organizations toward recycling and reusing recyclable materials, the dependence on virgin raw materials as production inputs can be significantly reduced. Moreover, obtaining raw materials through recycling processes is generally less costly than acquiring them from primary markets.

B. Resource Efficiency:

The operational mechanisms of the cleaner production strategy help industrial enterprises achieve efficient resource utilization through effective waste management policies. In addition, reliance on renewable energy reduces pollution treatment costs and decreases pollution-related taxes.

C. Improving the Organization's Image:

This is achieved through the organization's environmental orientation and its commitment to environmental protection by adopting strategic policies that incorporate environmental considerations.

¹ Razika Rahmoun & Wahiba Qaham, Cleaner Production as a Strategy to Support the Dimensions of Sustainable Development (Practical Examples of Cleaner Production Activities in Egypt), International Economy and Globalization Journal, University of Djelfa, Vol. 1, No. 1, 2018, p. 110.



D. Gaining a Competitive Advantage:

By adopting an environmental management system, organizations can obtain a competitive edge, which can only be achieved through reducing waste and emissions generated by industrial activities.

E. Achieving Additional Profits:

This can be realized through reducing pollution-related costs and lowering water acquisition expenses.

2. The Environmental Dimension of the Cleaner Production Strategy

This dimension is reflected in the following:

Irrational management of natural resources is considered one of the most significant environmental impacts resulting from industrial activities. By implementing cleaner production mechanisms, such as effective industrial waste management, these impacts can be mitigated. Reducing industrial waste, recycling it, and reusing it contribute to the protection of agricultural lands, particularly those located near waste disposal sites, as well as the protection of fisheries and biodiversity.

Protecting water resources, including both groundwater and surface water bodies. Industrial pollutants, especially liquid waste, contaminate rivers, valleys, and coastal waters through improper disposal practices. Therefore, the treatment of industrial wastewater significantly reduces its impact on biological life.¹

Rationalizing production inputs within industrial enterprises, such as water, energy, and raw materials, contributes to conserving these resources, particularly because many of them are non-renewable.

Reducing industrial pollution, which is considered one of the most dangerous forms of pollution due to its severe environmental consequences. This can be achieved by monitoring pollution sources throughout the entire production process, from the entry of raw materials to manufacturing and the final sale of products.

3. The Social Dimension of the Cleaner Production Strategy

This dimension can be summarized as follows:

The integration of cleaner production methods and mechanisms within industrial enterprises contributes to the creation of additional employment opportunities through activities related to internal and external recycling and waste recovery processes resulting from manufacturing operations.

Controlling leakages and emissions generated by industrial processes within the enterprise helps reduce negative impacts on workers' health and safety, while also enhancing their productivity.

¹ Hanan Tartar & Ali Al-Yazid, The Role of the Cleaner Production Strategy in Environmental Protection for Achieving Sustainable Development, Al-Nibras Journal for Legal Studies, Larbi Tebessi University, Tebessa, Vol. 6, No. 2, December 2021, p. 138.



The implementation of a cleaner production strategy contributes to reducing industrial waste in all its forms, whether liquid, solid, or airborne emissions.¹

Social issues generally encompass occupational health and safety, employee well-being, the activities undertaken by the organization, workers' rights, human rights, workforce diversity, and inclusion. Social disclosure often focuses on internal aspects, including reporting data related to employees, health and safety performance, and employee surveys, rather than broader issues concerning local communities and society as a whole.

Third: The Cleaner Production Strategy as a Tool for Enhancing Environmental Performance

The primary objective of cleaner production is to demonstrate the possibility of achieving financial savings and environmental improvements at relatively low cost. This includes reducing pollution through improved internal management (housekeeping), minimizing waste generation, separating waste for recycling, and recovering raw materials, chemicals, and energy. Cleaner production technologies can be explained by focusing on clean technologies and clean-up technologies as follows:²

1. Clean Technology

Clean technology aims to reduce pollutants from the very beginning of the production process through technological development, the careful selection of raw materials and energy sources, and the adoption of low-cost innovations that minimize waste generation and consequently eliminate the need for future treatment. Therefore, the concept of clean technology involves introducing technological changes that improve the environmental performance of products and operational processes before, during, and after manufacturing stages.

The concept of clean technology is based on the principle of eco-efficiency, which refers to the ability of enterprises to produce goods and services at competitive prices and high quality, satisfying human needs and enhancing quality of life while simultaneously reducing the negative impacts associated with production processes. It also promotes the efficient use of resources and cost reduction. The adoption of clean technology results in numerous positive effects, including:

2. Clean-Up / Environmentally Sound Technology

Clean-up technology refers to technologies designed to protect the environment by reducing pollution levels and promoting the more sustainable use of available resources. Such technologies facilitate the recycling of various wastes and products and manage them in a manner that is more environmentally acceptable than alternative technologies. This type of technology is employed when resources are not utilized efficiently, leading to waste generation and inefficiencies associated with daily operational processes.

It also aims to reduce environmental damage through the modification or addition of pollution-control measures at the end of the production process. These measures are commonly known

¹ Fatah Ghallab et al., Sustainability of Economic Enterprise Products from the Perspective of Cleaner Production Technology, *Journal of Economics and Finance*, Hassiba Ben Bouali University of Chlef, Vol. 5, No. 1, 2019, p. 187.

² Fateh Mjahdi and Cherah Brahimi, op. cit., pp. 80–81.

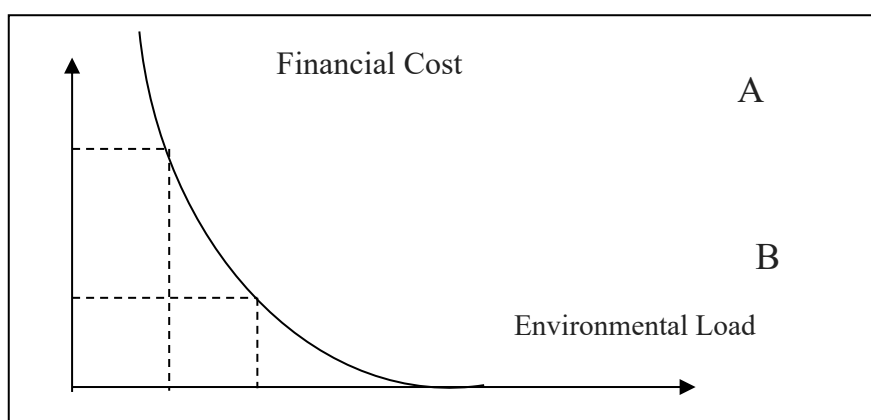


as End-of-Pipe Technologies, which represent a set of reactive actions taken in response to existing environmental damage. They focus on removing harmful substances generated by emissions and liquid wastes, treating them, or disposing of them safely and appropriately.

3. Clean Technology and Clean-Up Technology from an Economic Perspective

Both Clift and Longley provided a simple distinction between clean technology and clean-up technology by assuming that harmful environmental impacts and resource depletion can be expressed through the concept of Environmental Load. Reducing this environmental load requires the enterprise to incur financial costs, calculated on the basis of the total cost of reducing the environmental burden throughout all stages of the product life cycle. The inverse relationship between environmental load and financial cost can be illustrated by the following figure:

Figure No. 06: Relationship between Environmental Load and Financial Cost in the Case of Clean-Up Technology



Source: Fateh Mjahdi and Cheraf Brahimi, Cleaner Production Program as a Mechanism for Enhancing the Effectiveness of Environmental Management Practices and Supporting Environmental Performance in Enterprises, Algerian Journal of Enterprise Performance, University of Ouargla, Issue No. 01, 2012, p. 82.

With the adoption of clean-up technology, the enterprise moves upward along the curve from point B to point A, indicating an increase in financial costs accompanied by a decrease in environmental load. In Figure (03-09), Curve 1 represents clean-up technology, whereas Curve 2 represents clean technology. If an industrial enterprise operates at point C while using clean-up technology on Curve 1, shifting to clean technology by moving from Curve 1 to Curve 2 may result in three possible outcomes:¹

A reduction in environmental load without any increase in costs, represented by point D. This constitutes a form of efficiency.

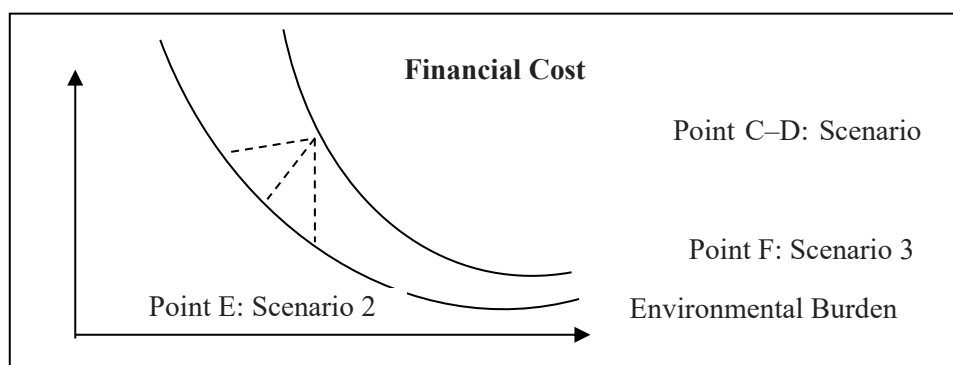
A constant environmental load accompanied by lower costs, represented by point E, which also reflects a form of efficiency.

¹ Fateh Mjahdi and Cheraf Brahimi, op. cit., p. 82.



A simultaneous reduction in both environmental load and costs, represented by point F, indicating greater benefits for the enterprise in all cases where clean technology is applied compared to clean-up technology.

Figure No. 07: Clean Technology and End-of-Pipe Technology and Their Relationship to Financial Cost



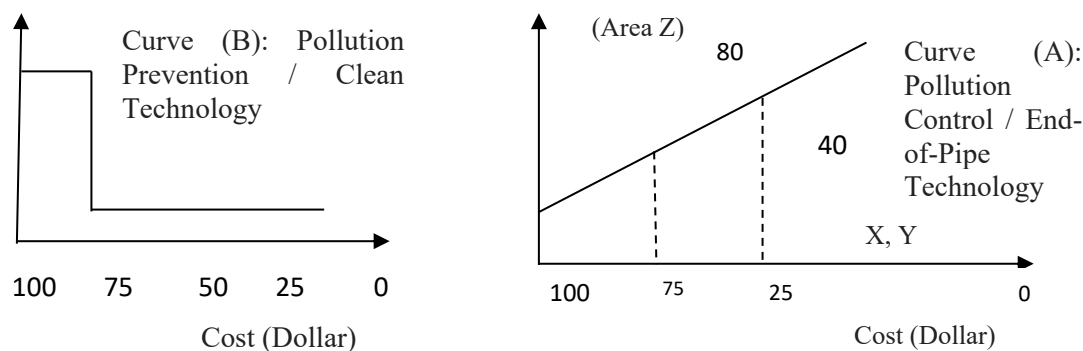
Source: Fateh Mjahdi and Cheraf Brahimi, Cleaner Production Program as a Mechanism for Enhancing the Effectiveness of Environmental Management Practices and Supporting Environmental Performance in Enterprises, Journal of Algerian Enterprise Performance, University of Ouargla, No. 01, 2012, p. 82.

Goodstein proposed another distinction between pollution prevention technology at the source (clean technology) and pollution control technology at the end of the production process (end-of-pipe technology) through an example illustrating how a firm chooses between the two types of technology when attempting to reduce pollutant emissions in response to environmental regulations and standards. According to Figure No. 08 below, curves (A) and (B) represent the relationship between the marginal cost of emission reduction and the level of emissions. It can be observed that the values representing emissions decrease progressively from 100 to zero, where 100 denotes the maximum level of emissions when the firm adopts no pollution prevention or control measures. The level of emissions gradually declines as the firm implements environmental innovations and incurs their associated costs, eventually reaching zero when emissions are completely eliminated.¹

Accordingly, the marginal cost curve of reducing pollutant emissions slopes upward, as illustrated by curve (A), indicating that costs increase progressively as environmental standards become more stringent and emissions are reduced from 100 parts per million to zero. In contrast, when the firm adopts pollution prevention technology, the marginal cost curve takes the form shown in curve (B). This indicates that the firm initially incurs an upfront cost to introduce changes in its production processes, represented by area Z beneath the marginal cost curve. As a result, emissions ultimately decline to zero.

Figure No. 08: Firm Choice Between Pollution Prevention and Pollution Control Based on the Marginal Cost of Emissions

¹Fateh Mjahdi and Cheraf Brahimi, op. cit., p. 82.



Emissions (parts per million)

Emissions (parts per million)

Source: Fateh Mjahdi and Cheraf Brahimi, Cleaner Production Program as a Mechanism for Enhancing the Effectiveness of Environmental Management Practices and Supporting Environmental Performance in Enterprises, Journal of Algerian Enterprise Performance, University of Ouargla, No. 01, 2012, p. 83.

The choice between pollution prevention technology and pollution control technology depends on the cost of emission reduction. If a firm seeks to reduce emissions to 75 parts per million (ppm), it will opt for pollution control technology at the end of the production process, since area X under the marginal cost curve in graph (A) is smaller than area Z in graph (B). However, if the firm aims to reduce emissions to 25 ppm, pollution prevention technology, which achieves superior environmental performance in the long term, becomes the less costly option compared with pollution control technology.¹

The previous example represents a simplification of practical reality. In practice, firms may have limited incentives to invest in pollution prevention technology as long as the cost of complying with environmental regulations remains low. This is because the initial investment cost of such technology is relatively high; however, these costs decline significantly over time due to the positive effects of economies of scale and learning. Pollution prevention technology is generally implemented in the long term because it requires the development and adoption of new environmental innovations. In contrast, end-of-pipe pollution control technology is more commonly applied in the short term because it is easier to acquire and involves lower associated costs, as it can be integrated into existing technologies without requiring substantial changes to production processes or organizational structures.²

Fourth: Integration of the Cleaner Production Strategy with Corporate Strategies

Cleaner production follows a strategic approach that is applied to processes and products in order to conserve raw materials, water, and energy, while eliminating or reducing toxic raw materials and minimizing toxic, excessive, or unnecessary waste streams. With regard to

¹Fateh Mjahedi and Cheraf Brahimi, previously cited reference, p. 83.

² Fateh Mjahedi and Cheraf Brahimi, previously cited reference, p. 83.



products, the strategic objective is to reduce environmental impacts throughout the product life cycle, beginning with the extraction of raw materials and ending with disposal as waste. The relationship between cleaner production and corporate strategies is multifaceted and may be summarized as follows:¹

1. From End-of-Pipe Treatment to Cleaner Production

End-of-pipe treatment transfers pollutants from one medium to another, such as converting gaseous emissions into liquid waste or transforming wastewater into solid waste. Despite the growing trend toward cleaner production, many organizations still regard this critical stage as a series of fundamental constraints because their priorities remain more closely linked to traditional concepts of competitiveness and sales performance than to reducing environmental impacts and waste flows. Consequently, firms often resort to end-of-pipe treatment rather than examining opportunities for intervention at each stage of the production process to prevent and reduce pollution at its source. Such an approach requires additional effort and coordination. In contrast, cleaner production offers a range of benefits when compared with end-of-pipe pollution treatment, making it the preferred option for many organizations. Nevertheless, it should be noted that end-of-pipe treatment, as a corrective measure, remains a complementary process.

2. Cleaner Production as an Integrated Strategic Management Approach

Cleaner production represents the adoption of a comprehensive management strategy that goes beyond isolated objectives that may arise on specific occasions. It promotes a policy that considers the entire production process as a whole. Therefore, cleaner production constitutes an integrated strategy, unlike many conventional strategies that focus only on end-of-pipe treatment measures. Such approaches often address specific impacts without tackling their root causes and consequently fail to prevent many of the problems that may emerge during the production process.

3. Cleaner Production as a Source of Opportunities

Cleaner production seeks to identify the most effective solutions for production processes within an organization. It encourages adaptation to emerging trends aimed at enhancing production efficiency and facilitating organizational growth and competitiveness through improvements in operating conditions. Furthermore, cleaner production contributes to the advancement of programs, the provision of analyses, the identification of opportunities, and the development of adequate operational methods suited to prevailing working conditions.

4. Cleaner Production as an Adaptive Strategy

Cleaner production is considered a strategy fully integrated into the production process as a whole. It responds automatically to potential changes generated by production activities, such as increased output or higher consumption of certain materials. This approach may be applied

¹ Wehiba Qeham, Environmental Management Tools as a Mechanism for Achieving Cleaner Production, PhD Thesis (LMD) in Economic Sciences, Specialization: Environmental Economics, Faculty of Economic, Commercial and Management Sciences, Badji Mokhtar University, Annaba, 2013/2014, pp. 155–157.



to a specific process, to all organizational processes, or to different stages of production. Its implementation can begin progressively according to organizational needs and responsibilities.

5. Cleaner Production and Economic Profitability

By managing waste streams through the adoption of appropriate measures, cleaner production contributes to reducing the consumption of water, energy, and raw materials. At the same time, the search for optimal production solutions, as promoted by cleaner production, can lead to increased labor productivity. This may be achieved through time savings that can be reinvested in the same production process or through the adoption of cleaner technologies that enable higher production levels within the same timeframe.

6. Cleaner Production and Environmental Benefits

Cleaner production represents the most appropriate and environmentally favorable option, as it seeks to prevent pollution at its source while promoting the optimal use of resources such as water, energy, and raw materials.

7. Cleaner Production as a Comprehensive Operational Policy

Cleaner production is a strategy embraced by all members of an organization, from technical workers and machine operators to senior managers. It contributes to improving organizational structures and enhancing technical development. The successful implementation of cleaner production relies on extensive awareness-raising efforts that translate into better environmental and production practices, thereby fostering responsible business conduct and maximizing the benefits generated by the workforce as a whole.

8. Cleaner Production and Corporate Reputation

Any strategy that incorporates environmental standards contributes positively to an organization's reputation. Cleaner production addresses waste stream management, which is considered one of the most important environmental protection requirements for organizations. While many experts argue that prevention is preferable to corrective action in both environmental and economic contexts, pollution prevention remains the most effective approach for strengthening and maintaining a positive corporate reputation.

Conclusion

When defining the development policy of any country, it is essential first to identify the strategic frameworks that align with the characteristics of the economy targeted for development. Over the decades, it has become evident that traditional development strategies are no longer effective, primarily because they prioritize the provision of economic and social welfare for current generations while neglecting the rights of future generations to natural resources and disregarding the environmental consequences resulting from the exploitation of those resources. Consequently, the natural environment has become increasingly vulnerable due to resource depletion and unsustainable human activities.

On the other hand, in order to protect the environment and contribute to the achievement of sustainable development, institutions should adopt policies and approaches that preserve environmental resources and support sustainable development goals. This can be achieved through the integration of the Cleaner Production Strategy into their policies. In fact, cleaner production represents one of the most significant achievements of contemporary environmental



thinking over the past two decades. This strategy extends from substantially reducing the consumption of environmental resources to avoiding, whenever possible, the use of hazardous materials characterized by high toxicity or environmental harm. It is considered one of the key mechanisms that enhance the effectiveness of environmental management systems at all stages, as it is a preventive strategy that shifts the focus from end-of-pipe treatment technologies toward developing solutions and innovations aimed at preventing or minimizing environmental impacts throughout every stage of the production process.

Study Findings

Based on the foregoing discussion, the study has reached the following findings, which provide answers to the questions associated with the main research problem:

The concept of sustainable development is of great importance, as reflected in its economic dimension, which seeks to reduce the consumption of conventional energy sources; its social dimension, which aims to achieve economic well-being, maintain population growth stability, and provide essential social services such as healthcare and housing; and its environmental dimension, which focuses on protecting ecosystems and natural resources from depletion.

There is a close relationship between energy and the achievement of sustainable development requirements, which necessitates greater attention to environmental protection. In this regard, the Cleaner Production Strategy constitutes an important tool, as it is a non-polluting approach that contributes to environmental preservation.

The renewable energy strategy represents an ambitious and purposeful program aimed at achieving comprehensive sustainable development at the national level, particularly by reducing the isolation of remote areas. However, its expected benefits are likely to become evident only in the medium and long term.

The Cleaner Production Strategy promotes the rational use of production inputs within industrial enterprises, including water, energy, and raw materials. Preserving these resources is particularly important because many of them are non-renewable.

The Cleaner Production Strategy contributes to reducing industrial pollution, which is considered one of the most dangerous forms of pollution due to its severe environmental impacts. This is achieved by monitoring and addressing pollution sources throughout the entire production cycle, from the entry of raw materials into the production process to manufacturing and the final distribution of products for sale.