

Clean Technologies and Their Role in Promoting Sustainable Industrial Development in Algeria

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Abstract: Algeria faces numerous challenges and issues related to greenhouse gas emissions that contribute to climate change, primarily due to the reliance on fossil fuels and the pressing need to modernize its industrial sector in a more sustainable and environmentally friendly manner. The Algerian state fully recognizes the importance of integrating advanced technologies and innovative clean approaches, such as shifting towards the use of renewable energy as a viable and eco-friendly alternative to depletable sources. This strategic shift has become a necessity to safeguard the rights of future generations—both in terms of ensuring access to diverse energy sources and preserving a livable, less-polluted environment. In this context, the Algerian government has introduced new measures aimed at improving energy efficiency and promoting innovative industrial practices within its national development strategy. These efforts are intended to achieve sustainable growth while aligning with global environmental objectives.

Keywords: Clean Technologies; renewable energies; sustainable industry;..

Jel Classification Codes: Q25, Q28, Q2.

INTRODUCTION

In recent years, clean technologies have garnered widespread attention as the most effective solution to the increasingly pressing environmental challenges. These technologies are considered a key instrument for achieving sustainable industrial development, as they aim to improve production and productivity while minimizing, or even eliminating, the negative impacts on the environment. Traditional industries that rely heavily on fossil fuels are among the main sources of industrial pollution, necessitating the exploration of innovative technological solutions.

As a result, the world is currently undergoing a fundamental transformation in its energy systems. Renewable energy sources have gained increasing importance and now occupy a central role in the energy policies and strategies of many countries—both importers and producers of fossil fuels alike. However, transitioning toward renewable energy remains a major challenge for fossil fuel-exporting countries, whose economies depend largely on revenues generated from these conventional sources, often constituting the primary source of public funding.

In this context, Algeria has prioritized the integration of clean technologies into its industrial development plans as part of its commitment to achieving the United Nations Sustainable Development Goals (SDGs). This study aims to shed light on Algeria's efforts to utilize clean technologies—particularly renewable energy—as a means to support the industrial sector, especially traditional industries, by progressively transforming them into environmentally friendly and green industries.

✓ The Problem Statement

Similar to many developing countries, Algeria is experiencing significant challenges related to environmental degradation, primarily due to its heavy reliance on fossil fuel sources and the resulting atmospheric emissions. Amidst global transitions toward a green economy based on renewable energy and innovative clean technologies, a critical research question emerges:

To what extent do clean technologies—particularly renewable energy sources—contribute to supporting the path of sustainable industrial development in Algeria, and how capable is the state of effectively integrating them into its economic and industrial strategies?

✓ **Research Hypotheses**

Based on the previously stated research problem, this study is built upon the following hypotheses:

1. Clean technologies, particularly renewable energy sources, can effectively contribute to achieving sustainable industrial development in Algeria by reducing dependence on fossil fuels and minimizing industrial environmental pollution.
2. The adoption of clear national strategies by the Algerian state in the field of clean energy can gradually transform the traditional industrial structure toward green production models.
3. Limited financial resources, along with constraints in technology transfer and technical know-how, represent major obstacles to the widespread integration of clean technologies within Algeria's industrial sector.

✓ **Study Methodology**

This study adopts a dual methodological approach combining both descriptive and analytical methods. The **descriptive method** is employed to explore the relationship between clean technologies—particularly renewable energy—and the industrial sector, as well as to outline the main drivers behind Algeria's growing commitment to energy transition within the context of sustainable development. In parallel, the **analytical method** is used to assess the potential impact of integrating clean energy solutions on the various dimensions of sustainable industrial development in Algeria, with a particular focus on reducing environmental degradation, improving energy efficiency, and fostering green industrial transformation

✓ **Study Objectives:**

- To analyze the general concept of clean technology, highlighting its main characteristics and areas of application, particularly within the industrial sector.
- To identify the contribution of renewable energy as one of the most important tools of clean technology in supporting industrial growth while preserving the environment.
- To evaluate the national policies and strategies adopted by Algeria to integrate clean technologies into its industrial development plans.

1. The Concept and Importance of Clean Technology

Clean technology refers to a set of methods and techniques applied within industrial contexts with the primary aim of minimizing negative environmental impacts on key natural elements such as air, water, and soil. This is achieved through the rational and efficient use of natural resources, contributing significantly to the reduction of greenhouse gas emissions. Prominent among these techniques is the use of various forms of renewable energy sources, including solar, wind, and hydroelectric power. Clean technologies also encompass waste treatment and recycling processes, in addition to energy conservation strategies.

1.1. Definition of Clean Technology

In light of the ongoing global technological advancements that have transformed nearly every aspect of human life—both at home and across all economic sectors—the term *clean technology* (often referred to as *cleantech*) has been defined in a variety of ways.

The expression *clean technology* is a compound term formed from the words *clean* and *technology*. The word *clean* in this context refers to the environmental impact, which should be characterized by minimal pollution or active efforts to reduce contaminants. *Technology*, meanwhile, refers to the tools and methods that enable the creation of a cleaner, more sustainable environment (Shakeel, 2021). It is also commonly referred to as green technology, with a central focus on renewable energies and all environmentally responsible activities, including green and sustainable building practices (Shahata, 2022, p. 4). This concept refers to the production

processes and operational methods applied across various sectors—particularly in industry—with the aim of reducing and limiting environmental degradation and pollution. This is achieved through a range of technologies and measures designed to enhance energy efficiency, promote the rational and balanced use of natural resources, and support the transition to renewable energy sources as a means of protecting the environment from the harmful effects associated with fossil fuel consumption (Chinoun, 2021, p. 42).

Clean or green technology is also defined as a collection of methods, systems, or programs designed to minimize the consumption of natural resources to the greatest extent possible. The goal is to avoid the depletion of non-renewable resources—when applicable—and to reduce financial burdens related to extraction, while also significantly reducing carbon emissions. These outcomes are always pursued in parallel with efforts to enhance economic efficiency and protect the environment simultaneously.

This type of technology encompasses a wide range of strategies and applications, including the use of renewable energy sources, the recycling of industrial waste, particularly solid waste, and the implementation of circular economy technologies.

Clean Edge, a research firm specializing in clean technology, describes cleantech as a diverse and expansive set of products, services, processes, and activities that utilize renewable resources and energy sources, while significantly reducing the consumption of natural resources. Moreover, it aims to minimize—if not eliminate—harmful gas emissions and waste.

According to the company, clean technologies not only possess strong competitive potential, but also have the capacity to outperform conventional energy sources (Clean Edge)

Innovations in clean technology refer to the continuous improvements and advancements integrated into industrial processes, with the primary goal of reducing the amount of pollutants and waste generated during manufacturing stages. These innovations play a crucial role in enhancing environmental efficiency and promoting sustainability (Korichi, 2018, p. 48).

Investments in clean technology—particularly in renewable energy sources—have witnessed significant global growth in recent years. According to recent data, electricity generation from renewable sources such as solar and wind energy accounted for approximately 30% of total global electricity production in 2022, marking a substantial leap forward and reflecting increasing global interest in clean energy (CNN Arabic, 2024).

This shift has been strongly influenced by fluctuating oil prices driven by recurring crises and shifting geopolitical policies. The volatility of fossil fuel markets—whether due to sudden surges or drops in prices—has led many countries to reconsider their energy strategies. As a result, there is now a more serious and committed push toward investing in renewable energy and transforming existing energy systems into sustainable, long-term models.

Even oil-producing and exporting countries like Algeria, whose economy is heavily dependent on oil revenues, have begun to pivot toward renewable energy investment as part of a broader strategic shift.

2.1. Characteristics of Clean Technology

Clean technology is distinguished by a set of attributes that make it a strategic and optimal solution in the global pursuit of full sustainability across human activities, while simultaneously preserving the planet as a viable habitat. Key characteristics of clean technology include:

- **Resource Efficiency:**

Clean technology contributes to the reduction of raw material and natural resource consumption, while promoting energy conservation—particularly in industrial sectors that rely heavily on fossil fuels.

- **Reduction of Pollution and Harmful Emissions:**

One of the core objectives of clean technology is to minimize or eliminate industrial waste and harmful gas emissions that contribute to environmental degradation, air pollution, and global warming. Compared to conventional technologies, clean tech offers significantly lower pollution levels (source 3).

- **Sustainable Energy Use:**

Clean technologies are fundamentally built on renewable, environmentally friendly energy sources, such as solar power, wind energy, and hydroelectric power. As such, clean tech embodies the principle that economic development and environmental protection must go hand in hand—a concept now considered essential in energy and sustainability planning (Shakeel, 2021, p. X).

- **Recycling and Reuse:**

Clean technology also fosters innovative solutions for recycling, particularly solid waste, thereby serving a dual purpose: reducing environmental harm and repurposing waste into usable resources.

- **Sustainable Innovation and Development:**

A core function of clean technology is the continuous search for eco-friendly, long-term solutions through innovation. This includes the development of new tools, techniques, and products that may require tailored market entry strategies and accompanying regulatory and infrastructure frameworks

- **Compliance with National Strategies and Regulations:**

Clean technologies are shaped and supported by government strategies and regulations, including incentives and laws that enable market entry and competitiveness as a distinct form of industrial production (Shakeel, 2021, p. XII).

3.1. The Importance of Clean Technology

Today, technology has become a central approach to balancing industrial development with sustainable development goals. It is increasingly seen as the leading solution for achieving profitable production and productivity, while maintaining ecological balance and minimizing the negative effects of human activity.

The importance of clean technology lies in the following:

- **Preservation of Natural Resources:**

Through minimizing and rationalizing the consumption of natural resources—including non-renewable energy sources that are heavily exploited by industrialized nations—clean technology helps safeguard current generations while ensuring future resource availability, in line with sustainable development objectives.

- **Reduction of Harmful Gas Emissions:**

Integrating clean technologies into industrial processes contributes significantly to the reduction of greenhouse gas emissions.

- **Improvement of Air Quality:**

By limiting the release of harmful gases, clean technology helps preserve clean air, thereby supporting public health and providing a safer, healthier environment.

- **Enhancement of Water Quality:**

Through the recycling of solid and liquid waste, clean technologies help protect water resources by preventing the disposal of pollutants into clean water streams.

4.1. Benefits of Clean Technology

The use of clean technology has a broad range of positive environmental, economic, and social impacts. These benefits include:

- **Environmental Impact**

The application of clean technologies plays a critical role in reducing the negative effects of traditional energy use and short-sighted industrial practices that historically prioritized profit over environmental concerns.

Algeria, in particular, is expected to face increasing environmental challenges, including drinking water shortages and threats to food security, as rainfall has become increasingly irregular in recent years. This instability is largely attributed to climate change caused by pollution, highlighting the urgent need for sustainable practices.

Investments in renewable energy technologies and sustainable agriculture could significantly reduce Algeria's environmental footprint by minimizing reliance on fossil fuels and protecting its natural resources for future generations.

• Economic Growth and Development

The integration of clean technologies and innovation into Algeria's industrial sector is expected to stimulate economic growth.

By upgrading production systems to reduce environmental impact and promote efficient resource use, these technologies can increase productivity, reduce production costs, and enhance the competitiveness of Algerian products in local and global markets.

Furthermore, transitioning to clean energy could create new industries and job opportunities, which in turn would help reduce unemployment and contribute to overall economic development and improved living standards.

• Social Benefits

The transition to clean technology also promises significant social benefits, especially in public health—one of the key indicators of sustainable development. By reducing dependence on fossil fuels and cutting harmful emissions, Algeria can improve air quality, which would lead to a decline in pollution-related diseases, particularly respiratory illnesses such as asthma, which have been on the rise in recent years due to industrial pollution and the proximity of polluting factories to urban areas.

Adopting clean energy technologies may also help reduce the burden of non-communicable diseases, by promoting healthier, cleaner living environments.

2. The Role of Clean Technology in Sustainable Industrial Development

Investing in clean technology can significantly improve industrial efficiency, especially with the continuous advancements in modern technologies. These investments in technology can also serve as a broad entry point to achieve the goals of sustainable industry, such as maximizing profits, minimizing waste, especially in energy, while keeping the environment clean and contributing to reducing harmful emissions. Although Algeria possesses significant potential in renewable energy, particularly in solar energy—since most of the investments in renewable energy in Algeria are in the solar energy sector—there are several challenges facing these stations and investments in renewable energy. These include a lack of funding in some areas, weak technology transfer, and the absence of foreign investments and partnerships in others, as well as the lack of storage solutions.

According to recent studies, most of the energy obtained from investments in clean energy comes from smaller-scale projects rather than large national projects. Therefore, small-scale projects, which could be private rather than public, are the primary drivers of investments in renewable energy.

3. Applications of Clean Technology

Clean technology applications play a vital role in promoting sustainable industrial development in Algeria. The government's commitment to reducing carbon and greenhouse gas emissions, as well as its efforts to enhance energy efficiency and rationalize the use of fossil fuels (such as oil and gas), are reflected in several national initiatives that have introduced clean technologies into various energy-intensive sectors.

3.1. Renewable Energy Technologies

Renewable energy is at the forefront of clean technology applications in Algeria. These include investments in solar, wind, and hydroelectric energy, which are now considered essential to meeting the country's electricity and energy demands while avoiding the emissions associated with conventional fossil fuels.

In the field of solar energy, Algeria has begun constructing several solar power plants aimed at expanding its production capacity from solar sources. The national goal is to generate 13.5GW of the country's electricity from solar power by 2030 (ADBG, 2020).

One notable example is the hybrid power station in Hassi R'mel, which combines solar energy with natural gas. This represents an innovative approach to diversifying the energy mix and promoting sustainability in the energy sector.

In addition, the "Solar 1000" project—launched in 2021 by the Algerian government—seeks to dramatically increase electricity production from clean, solar-based sources and reduce reliance on depletable conventional power generation (Laouadi, 2025, p. 4). It is one of the country's largest renewable energy initiatives to date.

Recent partnerships—such as the collaboration between IBM and the United Nations Development Programme (UNDP)—demonstrate a clear commitment to advancing energy solutions in Algeria. By leveraging advanced technologies such as artificial intelligence, these initiatives aim to provide policymakers and the public with effective tools to analyze and address energy-related challenges. The focus on renewable energy, particularly the development of solar energy projects, highlights Algeria's goal to expand its sustainable energy capacity, with ambitious plans for significant growth in solar panel installations in the coming years.

3.2. Energy Efficiency and Rational Use:

In addition to its focus on renewable energy, Algeria is also prioritizing energy conservation and efficiency as two core pillars of its clean technology strategy.

The National Energy Efficiency Program aims to improve energy efficiency by 10% annually across various energy-intensive sectors, particularly transportation and industry (Achab, 2021).

The Algerian government has also launched incentive programs promoting "more sustainable buildings", encouraging citizens to adopt energy-efficient practices and technologies. These efforts are expected to reduce overall energy consumption and thereby help to lower associated emissions.

3.3. Industrial Applications:

Algeria's industrial sector is actively adopting clean technologies to foster sustainability in production. For instance, partnerships between major companies like Sonatrach and ENI have resulted in the establishment of solar power stations that not only generate clean energy but also meet the electricity needs of remote oil and gas production sites (ENI, 2022).

3.4. Technological Innovations:

Algeria's commitment to clean tech innovation is evident in its diverse programs and initiatives. The government's National Renewable Energy Development Program emphasizes the intensive development of solar resources, particularly in the High Plateaus and the Saharan region, reflecting a strategic approach to harness natural resources for sustainable development.

Also, the country is moving toward adopting emerging technologies such as blue and green hydrogen to gradually replace natural gas consumption, aligning itself with global environmental goals.

3.5. Enterprise Resource Planning (ERP) Systems – Emerging Technologies:

Enterprise Resource Planning (ERP) systems are integrated information systems designed to unify and manage all core business operations within an organization. These operations include finance, sales, human resources, procurement, production, inventory, and distribution. ERP platforms provide a centralized data

environment that allows employees across all departments to access the same information in real time, thereby enhancing operational efficiency and supporting informed decision-making (Rawat, 2023)

These systems offer a variety of benefits (Hernandez, 2023):

a. **Operational Efficiency:**

By integrating diverse functions into a single platform, ERP systems eliminate redundancy and streamline workflows.

b. **Resource Management:**

ERP helps companies to allocate human, material, and financial resources more effectively, thereby improving productivity.

c. **Informed Decision-Making:**

Integrated systems offer comprehensive insights into ongoing operations, enabling faster and more accurate decisions.

d. **Regulatory Compliance:**

ERP systems help ensure that operations are aligned with local and international regulations and standards.

e. **Time Savings:**

These systems reduce the time employees spend retrieving or entering data manually, which translates into faster, more efficient operations.

A successful case study highlights the use of ERP systems in the manufacturing and distribution sectors, where such systems help streamline operations by integrating various supply chain activities, reducing waste, and enhancing product quality. These integrations are particularly critical as companies seek to meet rising consumer demands and comply with regulatory requirements.

In Algeria, several companies in manufacturing and distribution have begun implementing ERP systems to optimize business operations. These systems are used to unify management, organize supply chains, reduce waste, and enhance product quality, ultimately boosting their competitiveness in both domestic and international markets.

4. Challenges and Barriers

Algeria faces numerous challenges and barriers in its efforts to promote sustainable industrial development through clean technology. These obstacles stem from financial, technical, and political sectors, which collectively hinder the effective implementation of climate-related initiatives.

4.1.Financial Constraints:

One of the main barriers facing Algeria is financial constraints. The country's national budget is somewhat limited, particularly due to the volatility of oil revenues. Algeria's economy is heavily reliant on oil revenues, which restricts the government's financial capacity to acquire clean technologies and invest in new innovations in this field. This also complicates the implementation of necessary climate actions to reduce emissions.

Although there are substantial financing opportunities from the European Union, aimed at renewable energy projects, effective utilization of these resources remains a challenge. Therefore, Algeria must create an investment-friendly climate to attract such investments from EU countries.

4.2.Technical Capabilities:

Technical capabilities, including advanced skills and the ability to quickly adopt new technologies, represent another major barrier for Algeria. A noticeable gap exists in the specialized skills required to develop new, innovative technologies related to renewable energy and climate adaptation. Despite improvements in

continuous training and vocational education, there is still a mismatch between the workforce's skills and the needs of the market. This has contributed to rising unemployment rates, meaning the available workforce in Algeria is not adequately qualified for clean technology.

This shortage of technical skills complicates the execution of clean technology projects, as companies often struggle to find qualified employees who can operate and maintain advanced systems.

Political factors also hinder consistent policy implementation in Algeria. Fragmented efforts and divergent interests between government bodies lead to inconsistent regulations and policies regarding clean technology and climate initiatives.

As well, the slow pace of bureaucratic processes further complicates these issues, creating an environment that may delay or suspend potential investments and initiatives.

The government's commitment to urbanization and sustainable development must align with a unified political approach to overcome these barriers and achieve effective policy coordination.

5. Future Prospects

The future of clean technology in Algeria is poised for significant transformation, driven by a range of political initiatives and developments in renewable energy technologies. According to the 2025 petrochemical industry outlook, sustainability and innovation are at the forefront of industry trends, with a strong focus on biofuel technology, advanced materials, and hydrogen removal processes aimed at improving efficiency and reducing environmental impacts.

5.1. Renewable Energy Development

Algeria's commitment to renewable energy is reflected in its recent projects and strategic initiatives, which remain central to its development plans through 2030. It is expected that wind energy production will reach approximately 5 GW by 2030, while solar energy will contribute 13.6 GW by the same year, supported by tenders for large-scale solar power plants launched by Sonelgaz (the National Electricity and Gas Company) (Laouadi, 2025, pp. 4-5).

5.2. National Energy Strategy

The National Energy Efficiency and Conservation Program, alongside the National Renewable Energy Development Program, highlights a comprehensive approach to energy management. These initiatives aim to achieve 30% of electricity generation from renewable energy sources by 2030, and target the production and export of between 30 to 40 terawatt-hours of green and blue hydrogen energy to European countries by 2040 (Chabouni, 2024, p. 301)

5.3. Economic Transformation:

Efforts to improve Algeria's economic landscape through clean technology are essential for sustainable development. The World Bank has highlighted the importance of continuing institutional and economic reforms, which include enhancing the competitive business environment and increasing investment in human capital.

5.4. Role of Foreign Investments:

Success stories in sectors like telecommunications, such as Orange Algeria's investment, demonstrate how foreign investments can positively contribute to the local economy while adapting to the unique challenges of the Algerian market. It is expected that upcoming political changes regarding property rights, taxes, and business regulations will enhance the investment climate, making Algeria a more attractive destination for sustainable investments.

Conclusion:

In conclusion, several key findings can be summarized from the study, including:

- Clean technology plays a critical role in improving both environmental and industrial performance, as it helps in reducing harmful emissions and enhances the efficiency of resource usage.

- Despite the challenges faced by Algeria, such as its heavy dependence on oil and gas, there are significant opportunities to leverage technological innovations to guide the economy towards sustainable industrial development.
- These technologies contribute to improving the competitiveness of Algerian industries in global markets, which strengthens the country's move towards economic diversification.

Recommendations

The following recommendations can be made:

- Algeria should focus on strengthening research and development in the field of clean technology and encourage investment in green industries that contribute to wider environmental protection.
- Government policies should support local companies adopting clean technologies, through tax incentives, favorable regulations, and new systems that promote clean tech.
- It is crucial to enhance collaboration with global institutions specialized in this field, increase joint investments, expand training programs in advanced technologies, and facilitate financing to contribute to the development of local skills and the acquisition of foreign expertise in clean technology.
- Raising awareness among the public about the importance of transitioning to sustainable industries is essential to ensure the long-term success of clean technologies.

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