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题目 THE SUSTAINABLE DEVELOPMENT PATH OF MOROCCO'S ENERGY INDUSTRY

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THE SUSTAINABLE DEVELOPMENT PATH OF MOROCCO'S ENERGY INDUSTRY

Abstract

The rapid economic expansion has resulted in heightened energy consumption and environmental damage, which is described as the dual security challenge associated with conventional energy. In this context, the new energy sector has started to develop. Countries around the world have commenced research and development in new energy to modify the economic development model, enhance the energy structure, tackle energy security challenges, and exploit ecological advantages from the conservation of fossil fuels and the reduction of pollution emissions. New energy has emerged as the focal point of international economic competition.

Morocco has unequivocally committed itself to transitioning its economy towards green initiatives by selecting the new energy industry for decarbonization, establishing it as a pathway for sustainable development within the country, which now functions as a vital criterion for access to international markets. With the objective of integrating energy efficiency among key players in energy-intensive sectors, this paper primarily aims to enhance the understanding of potential impacts of decarbonization strategies, utilizing solar energy integration opportunities as a method for forming a resource-efficient, sustainable, and low-carbon industrial framework in Morocco. Indeed, the paper focuses on the industrial textile sector, which is described as an energy-intensive industry. This sector represents the largest employer and holds considerable significance as the oldest industrial activity in Morocco. This research examines the effects on energy, economy, and environment, evaluating production, investment, and the constraints on CO2 emissions. Moreover, the energy industrial sector is recognized for its substantial dependence on fossil fuel imports, which drives up both energy factors and prices. Within this context, various geographical locations and factories were analyzed under six distinct climatic regional conditions, proposing the most efficient and sustainable configurations suited to each site and presenting models that illustrate the scopes and levels of energy and environmental benefits and investments that could incentivize stakeholders in the sector. Consequently, this work aspires to develop concepts that motivate local factories, support the national vision, and redefine industrial ecology. In this paper, a total installed power of 8. 88 MW is documented, resulting in an annual total of 8484. 65 tonnes of CO_2 emissions, with an average payback period ranging from 2. 6 years to 4. 5 years, accompanied by favorable economic indicators, including an LCOE of 0. 034 $/kWh and an NPC value of $181,863, underscoring the significant environmental advantages associated with adopting this strategic vision that can achieve sustainable development in Morocco. However, despite these positives, the sustainable development of Morocco's new energy sector is hindered by several challenges as outlined in this paper, such as limited technological innovation, reliance on imported renewable energy components, insufficient energy storage solutions, and difficulties with grid integration. The variability of solar and wind energy, in conjunction with aging infrastructure, poses risks to energy reliability, while financial constraints and regulatory inadequacies obstruct investment in clean energy initiatives. To address these challenges, Morocco must invest in research and development (R&D) to enhance domestic production of solar panels, wind turbines, and energy storage systems. Advancing smart grid technologies, expanding cross-border energy connections, and integrating digital solutions like AI-driven energy management will optimize electricity distribution. Furthermore, fostering public-private partnerships (PPPs), implementing green financing mechanisms, and promoting carbon pricing policies can accelerate investment. Ensuring environmental sustainability through effective land use, water-saving technologies, and circular economy practices is also essential. By confronting these challenges and implementing innovative policies, Morocco can achieve a resilient, self-sufficient, and sustainable energy transition.

Key words : energy , Sustainable Development , decarbonation , The New Energy Industry , textile industry .

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Chapter 1 : introduction

1.1 Background and significance of the topic :

1.1.1 Topic Background :

Energy serves as the fundamental basis for human existence and advancement. Every advancement in human society is intrinsically linked to energy. Nevertheless, traditional energy sources are confronted with significant challenges regarding both supply and usage security. Alternative energy and associated industries, predominantly wind energy, solar energy, and biomass energy, have emerged. This development is beneficial for ensuring national energy security, enhancing international competitiveness, decreasing external energy dependence, and generating a new impetus for traditional industries. It injects vitality into the energy sector; it is advantageous for safeguarding the ecological environment and fostering a “resource-saving and environmentally friendly” society. The promotion of new energy can substantially diminish environmental pollution and, in turn, reduce economic losses; it is conducive to optimizing and upgrading industrial structures, as well as adjusting the economic framework. The new energy industry possesses considerable technological content and broad market prospects, meeting industry requirements and representing a nascent sunrise sector.

Morocco's transition toward a sustainable energy industry constitutes a strategic response to its historical dependence on fossil fuel imports, increasing energy requirements, and the global imperative for climate change mitigation. Given its limited domestic fossil fuel resources, the nation has prioritized renewable energy development, aspiring to establish it as the foundation of its energy sector. The Moroccan government has set ambitious objectives, aiming for 52% renewable energy capacity by 2030, bolstered by significant projects such as the Noor Ouarzazate Solar Complex, which is one of the largest concentrated solar power facilities globally, and the Tarfaya Wind Farm, an essential asset in Africa’s wind energy development. In addition to bolstering its energy security and economic resilience, Morocco’s decarbonization initiatives align with its international obligations under the Paris Agreement, positioning it as a benchmark for sustainable energy transitions in developing countries. The country’s endeavor toward green hydrogen production further enhances its potential as a significant exporter of clean energy, particularly to European markets pursuing carbon neutrality. Beyond economic advantages, Morocco's transition to renewable energy promotes social and environmental enhancements, including rural electrification, job creation, air pollution mitigation, and resource conservation. However, the journey toward complete decarbonization continues to face challenges, including the necessity for improved energy storage solutions, grid modernization, and diversified financial mechanisms to attract long-term investments. To sustain progress, Morocco persistently implements progressive policies, regulatory frameworks, and public-private collaborations, ensuring its energy industry remains a catalyst for sustainable development, environmental stewardship, and economic innovation. As the nation increasingly integrates renewable technologies and energy-efficient practices, its transformation establishes a standard for emerging economies aspiring to a low-carbon, sustainable future.

1.1.2 significance of the topic :

1- theoretical significance :

Industrial development necessitates value norms, and distinct value dimensions will yield varied industrial development trajectories. In the developmental phase, the value requirements of industrial development differ. During the phase of economic and social transformation in which sustainable development is implemented, the advancement of the new energy industry should be grounded in the fundamental principle of sustainability, which aims to enhance the theoretical framework of industrial development and supply new energy. Furthermore, prior researchers have only undertaken theoretical examinations regarding the sustainable development of the new energy industry, lacking empirical validation, particularly in an industrial sector such as textiles, which is recognized for consuming a significant proportion of energy due to its heavy demand. This paper also aims to contribute to a more profound understanding of the potential impact of decarbonization plans, using the integration opportunities of solar energy as a measure for a frugal, sustainable, and low-carbon Moroccan industry. Additionally, it investigates the existing challenges in the sustainable development of the energy industry and the factors that hinder the sustainable advancement of the new energy industry in order to provide novel insights for sustainable development.

2- Practical significance :

Exploring Morocco's sustainable energy development has important real-world consequences for politics, economics, and environmental protection. The country's successful techniques for implementing renewable energy, developing regulatory frameworks, and building international alliances provide useful lessons for other countries transitioning to sustainable energy sources. From an economic standpoint, the analysis shows how renewable energy creates job possibilities, attracts foreign investment, and supports industrial expansion, thereby serving as a model for economic diversification. Morocco's method also improves energy security by reducing reliance on imported fossil fuels, with implications for other energy-dependent countries. Furthermore, the study contributes to climate change mitigation efforts by demonstrating how large-scale renewable initiatives cut carbon emissions while promoting sustainability goals. The country's involvement in regional energy cooperation and technology transfer provides direction for implementing new energy solutions. In summary, Morocco's energy transition serves as a model for developing countries, demonstrating practical techniques to creating a resilient, environmentally friendly, and commercially successful energy industry.

1.2 literature review :

The transition towards sustainable energy development has been extensively examined, particularly in developing countries seeking to reduce energy dependency and address climate change concerns. Morocco's energy transformation has attracted increasing academic interest due to its ambitious renewable energy initiatives, large-scale projects, and strategic investments. This literature review investigates pivotal research concerning Morocco's energy transition, focusing on its policy framework, renewable energy undertakings, economic and environmental impacts, and challenges to achieving sustainability.

1. Morocco's Energy Policy and Strategic Vision

Numerous studies highlight Morocco's national energy strategy, which aims for 52% of electricity generation from renewable sources by 2030 (Bennouna et al. , 2020). The Moroccan government has implemented long-term energy policies, such as the National Renewable Energy and Energy Efficiency Plan and the

Energy Strategy 2030, emphasizing sustainability, security, and affordability (El-Katiri, 2016). Researchers argue that Morocco's proactive approach, including the establishment of organizations like the Moroccan Agency for Sustainable Energy (MASEN), has been instrumental in advancing the transition (Amegroud, 2017).

2. Renewable Energy Projects and Technological Advancements

A considerable volume of research investigates Morocco's large-scale renewable energy projects, particularly the Noor Ouarzazate Solar Complex, one of the largest concentrated solar power (CSP) installations globally (Jamil and Ahmad, 2021). Studies indicate that Morocco is leveraging its solar and wind resources, with significant projects such as the Tarfaya Wind Farm and new photovoltaic installations diversifying the nation’s energy mix (García et al. , 2018). Scholars contend that Morocco's strategic location and natural resources render it well-positioned for renewable energy generation, although integration into the grid and storage challenges remain considerable obstacles (Cherkaoui and Rachidi, 2022).

3. Economic and Social Consequences of Morocco's Shift to Sustainable Energy

The economic implications of Morocco's transition to sustainable energy have been thoroughly investigated. Research suggests that investments in renewable energy have catalyzed economic growth, attracting foreign capital and creating job opportunities, particularly in rural areas (Mahia et al. , 2020). Nevertheless, certain scholars emphasize the significant upfront costs associated with renewable energy projects and the necessity for enhancing local production capabilities and workforce development (Attiaoui et al. , 2019). Despite these challenges, research concludes that Morocco’s public-private collaboration strategy has successfully secured financing for large-scale initiatives (Brand and Zingerle, 2019).

4. Environmental and Climate Change Aspects

Another essential area of research involves the effects of Morocco's energy transformation on climate change mitigation. Studies indicate that the country’s transition to renewable energy sources has considerably reduced carbon emissions, in line with its commitments under the Paris Agreement and Nationally Determined Contributions (NDCs) (Ouassfi et al. , 2021). Scholars also examine

Morocco’s strategies for water-efficient energy production, considering the water-intensive nature of CSP technology in arid regions (Zemouri et al. , 2022).

5. Obstacles and Future Outlook

Despite its progress, Morocco faces challenges in achieving a fully sustainable energy transition. Research identifies issues such as constraints in energy storage, variability in renewable energy generation, and reliance on imported technology (El-Bakkali and Tahri, 2021). Furthermore, researchers contend that for Morocco to emerge as an energy export hub, additional investments in grid infrastructure and regional energy collaboration are essential (Bennis and Ouka, 2023). Future investigations suggest that advancements in green hydrogen production could further strengthen Morocco's position within the global energy landscape (Tiba and Haddad, 2022).

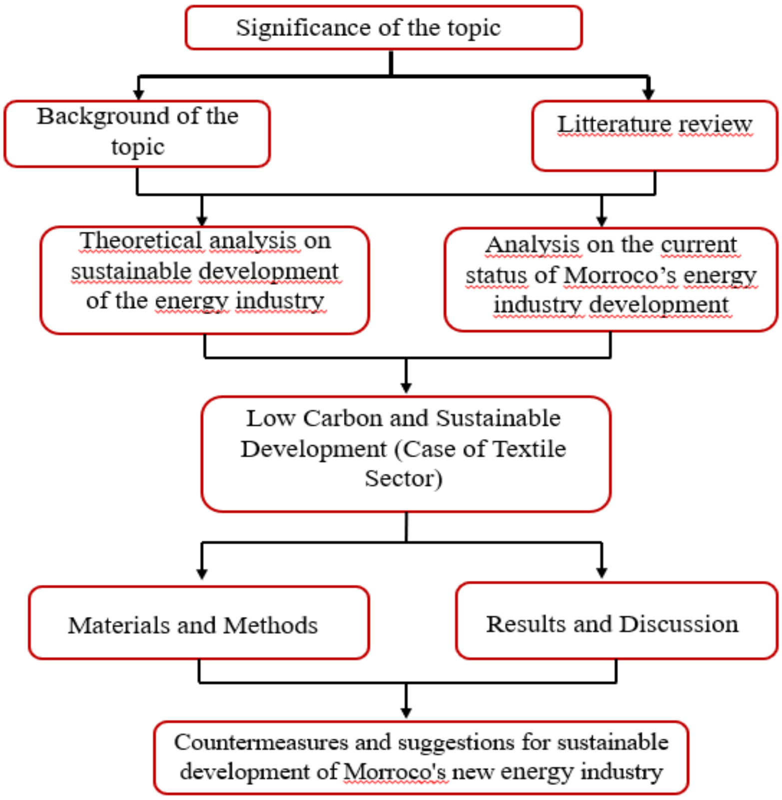
The available research substantiates that Morocco's transition to sustainable energy acts as a prominent model for developing nations, driven by strong policies, extensive renewable projects, and economic benefits. However, continuous research is necessary in domains such as energy storage, local production, and technological advancement to guarantee long-term feasibility. Morocco's experience provides significant insights for other countries striving to attain energy security, economic development, and environmental sustainability through investments in renewable energy.

1.3 Research content:

1.3.1 Research content :

This research investigates the sustainable growth of Morocco's energy sector, encompassing several key areas: Initially, it performs a review and analysis of existing studies on sustainability within the industry and energy sectors, identifies shortcomings in current research, and proposes innovative methodologies. Next, it delineates the concept of the energy industry and theoretically examines its sustainable development through relevant sustainability theories. Subsequently, the case of the textile sector in Morocco is analyzed as the primary employer and the most significant energy industrial activity in Morocco, serving as a strategy for the energy transition towards a sustainable, low-carbon energy industry and contributing to sustainable development. Finally, the research puts forth solutions to address the challenges encountered in the development of Morocco's energy industry.

1.4 Research Framework :



Chapter 2 : Theoretical Analysis of Sustainable Development of New Energy Industry

The concept of sustainable development has experienced substantial transformations, now incorporating environmental conservation, social equity, and economic growth. A pivotal element in this transformation has been the emerging energy sector, which has shifted from conventional fossil fuels to renewable sources. Technological advancements and international policy measures have accelerated the adoption of clean energy solutions, resulting in reduced carbon emissions and improved energy autonomy. This continuous transition highlights the sector's commitment to fostering a more environmentally responsible and sustainable future. This chapter focuses on conducting a theoretical analysis of the sustainable development of the new energy industry in Morocco in conjunction with pertinent theories.

2.1 Definition of concepts :

2.1.1 New Energy :

The Oxford Dictionary defines new energy, in contrast to conventional energy, as "energy utilized as fuel without depleting natural resources or damaging the environment. " The Natural Resources Defense Council (NRDC) characterizes it as "energy not extensively utilized and frequently environmentally advantageous," whereas the National Energy Administration describes it as "energy recently introduced or still undergoing research. " The "12th Five-Year Plan" specifically details new energy sources for this timeframe, including wind, biogas, solar photovoltaic and thermal applications, biomass power generation, nuclear energy, shale, geothermal energy, biomass gasification, biofuels, and ocean energy. New energy is often associated with renewable energy; however, although both are actively advocated as clean energy sources, there are notable differences between them. Primary energy is divided into renewable and non-renewable categories. Renewable energy, which naturally replenishes and is inexhaustible, includes hydropower, wind, solar, and biomass energy. New energy encompasses most renewable sources with the exception of hydropower, yet not all new energy qualifies as renewable. For example, nuclear energy cannot revert to its initial state after the release of energy through fission, fusion, or decay processes.

2.1.2 New Energy Industry :

The new energy sector, identified as a strategically emerging industry, includes various departments dedicated to the exploration and implementation of new energy sources for industrial purposes. The "Guide Catalog of Key Products and Services of Strategic Emerging Industries (2016 Edition)" from the National Development and Reform Commission categorizes this sector into six distinct segments: nuclear power technology, wind power, solar energy, smart grid, and other new energy industries. Conversely, the "Classification of Strategic Emerging Industries" by the National Bureau of Statistics divides this sector into nuclear power, wind power, solar energy, biomass energy, other new energy industries, smart grid, along with additional components. This article utilizes the classification method established by the National Bureau of Statistics for its analytical framework.

Nuclear energy, which generates power through fission, qualitative change, and decay of atomic nuclei, is classified as non-renewable but is esteemed for its clean, safe, efficient, and economical characteristics. Common nuclear fuels comprise uranium, lithium, plutonium, and thorium. The nuclear energy industry predominantly focuses on fuel processing, equipment manufacturing, and power generation.

Solar energy, which is harnessed from the sun’s internal nuclear fusion reactions, is abundant, clean, renewable, and extensively available. The methods for its utilization include photothermal, photovoltaic, and photobiological processes, with the most common applications being photothermal and photovoltaic. Solar water heaters serve as an illustration of photothermal usage, while photoelectric utilization encompasses both photothermal and photovoltaic power generation. Nonetheless, solar energy’s low density and its intermittent supply due to the Earth’s rotation present challenges, leading to lower utilization rates when compared to other forms of new energy. Current ground-based photovoltaic systems predominantly utilize crystalline silicon solar cells, with the production stages involving silicon materials, wafers, battery cells, components, and complete systems.

Wind energy, which is an indirect form of solar energy, originates from air movement resulting from surface heating caused by solar radiation. It possesses characteristics that are similar to those of solar energy. Human utilization of wind power can be traced back to ancient times, wherein it was employed for water lifting, irrigation, flour milling, and sailing. Progress in wind energy technology experienced setbacks due to the widespread use of steam engines and oil. It was not until the oil crisis that significant focus was directed towards wind energy development. Presently, wind power generation is regarded as the primary technique for capturing wind energy resources. The value chain of the wind power industry predominantly comprises wind turbine manufacturing and wind farm development. Wind turbine manufacturing can be subdivided into complete machine production and component fabrication. Wind farm development includes the assessment of resources, construction, and management of operational power stations.

Biomass energy, which is derived directly or indirectly from the process of photosynthesis in plants, encompasses sources such as crop residues, tree limbs, animal waste, energy crops, industrial and domestic wastewater, and municipal solid waste. As a renewable energy source and the only renewable carbon source available, it can be converted into gaseous or liquid fuels through several processes, including solidification, combustion, gasification, and liquefaction. Due to its diverse sources and applications, biomass energy entails a wide variety of equipment, including systems for power generation, hydrogen production units, biomass fuel manufacturing machinery, as well as degradation and conversion apparatus.

A smart grid is an automated transmission network that utilizes advanced technology, equipment, and techniques to oversee and manage every user and grid node. It guarantees a bidirectional flow of information and electricity among all points in the transmission and distribution process, ranging from power plants to end users. Smart grids are distinguished by their safety, reliability, cost-effectiveness, and efficiency, and have the capacity to accommodate various forms of power generation. The implementation of smart grids has facilitated the integration of diverse types of new energy power generation, serving as the fundamental basis and guarantee for the new energy power generation industry.

Other emerging energy sectors encompass the manufacturing of prime mover equipment for tidal, wave, and ocean current energy; specialized equipment for oil refining and chemical production; and the operation of tidal energy, biogas, and geothermal power generation facilities. These new energy industries are presently smaller in scale, featuring technologies that are still in development, presenting considerable potential for future growth.

2.2 Theoretical basis :

2.2.1 Basic theory of sustainable development :

The concept of sustainable development functions as a guiding framework for reconciling economic advancement, societal progress, and environmental preservation to ensure a prosperous future for humanity. This principle arose as a reaction to global challenges, including resource depletion, climate change, and social inequalities. The 1987 Brundtland Report significantly popularized this idea, highlighting the complex interrelations between human activities and natural ecosystems. Sustainable development stresses the imperative of adopting long-term strategies that promote economic stability, prudent environmental stewardship, and equitable social conditions.

(1) The origin of "sustainable development":

The concept of "sustainable development" has gradually emerged over many years, arising from concerns regarding the environmental, economic, and social implications of swift industrialization and resource depletion. Its origins can be traced to the early environmental movements of the 20th century, especially during the 1960s and 1970s when scholars began raising alarms about the harmful impacts of human actions on the environment. A significant scientific report, The Limits to Growth (1972), commissioned by the Club of Rome, utilized computer simulations to project the long-term consequences of unchecked economic and population growth on finite natural resources. This study argued that, without considerable changes in global policies, economic expansion would lead to environmental degradation. These ideas gained momentum in the 1980s, culminating in the publication of the 1987 Brundtland Report, officially titled Our Common Future, by the World Commission on Environment and Development (WCED). This document presented the widely accepted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. " It emphasized the importance of merging economic growth, environmental protection, and social equity to guarantee long-term global stability. This definition represented a shift from earlier discussions that viewed environmental conservation and economic development as opposing goals, instead highlighting their interdependence. Following the Brundtland Report, sustainable development became a primary focus in global policymaking, resulting in significant international agreements such as the 1992 Rio Earth Summit and the subsequent endorsement of the United Nations' Sustainable Development Goals (SDGs) in 2015. Ongoing scientific inquiry continues to refine the concept, underlining the significance of climate action, biodiversity conservation, and circular economy principles to ensure that development remains sustainable in the context of contemporary global challenges. In the current era, sustainable development is widely recognized as an essential framework for addressing urgent issues such as climate change, resource depletion, and social inequality, shaping policies and strategies at both national and international levels.

(2) The connotation of sustainable development:

Sustainable development encompasses a comprehensive system of disciplines, integrating various fields such as economics, sociology, resource management, environmental studies, and political science. Each research area within this domain tends to highlight different facets of sustainability.

1 - Definition from an economic perspective:

In the field of economics, sustainable development is regarded as a framework for growth aimed at achieving long-term economic progress without depleting natural resources or inflicting environmental harm. This paradigm emphasizes the effective use of resources, encourages investment in renewable energy sources, and promotes policies that enhance social equity and economic stability. The objective is to establish a equilibrium among economic growth, environmental preservation, and social well-being, thereby guaranteeing that future generations will also possess access to economic opportunities.

2 - Definition from a sociological perspective:

From a sociological standpoint, sustainable development encompasses the promotion of social equity, inclusivity, and long-term welfare while ensuring that economic and environmental progress benefits all segments of society. It accentuates the importance of diminishing disparities in access to education, healthcare, and economic prospects while fostering cultural diversity and social unity. This viewpoint underscores the significance of social justice, human rights, and community engagement in decision-making processes. Sustainable development, from this perspective, aspires to cultivate resilient and adaptable communities wherein individuals can flourish without jeopardizing the welfare of future generations. By addressing challenges such as poverty, gender disparity, and social exclusion, this approach guarantees that advancement is both inclusive and enduring.

3 - Definition from the perspective of natural science:

From a natural science standpoint, sustainable development represents the quest for human advancement in alignment with Earth’s ecological systems. It prioritizes the safeguarding of biodiversity, the prudent management of natural resources, and the alleviation of environmental threats such as climate change and pollution. Grounded in scientific inquiry, this approach advocates for breakthroughs in renewable energy, conservation methods, and ecosystem restoration to ensure that the balance of nature is upheld. By adhering to the planet’s natural constraints, sustainable development strives to secure a flourishing environment for both current and future generations.

4 - Morocco’s Sustainable Development Concept:

Morocco has adopted the concept of sustainable development as a fundamental element of its national strategy, amalgamating economic growth with environmental preservation and social advancement. The nation’s dedication to sustainability gained traction in the early 21st century, notably with the initiation of the National Strategy for Sustainable Development (SNDD) in 2017, which seeks to guide Morocco towards a green economy. Scientific research underscores Morocco’s leadership in renewable energy, particularly through its ambitious solar and wind energy initiatives, such as the Noor Ouarzazate Solar Complex, one of the largest concentrated solar power plants globally. These projects are in alignment with international sustainability objectives by diminishing dependence on fossil fuels and reducing carbon emissions. Furthermore, Morocco has enacted policies to foster water conservation, address desertification, and support sustainable agriculture in response to the challenges posed by climate change. Socially, the country has centered its efforts on mitigating inequalities by enhancing access to education, healthcare, and economic opportunities, especially in rural regions. The incorporation of sustainability into Morocco’s policies reflects its long-term vision of attaining economic resilience while conserving its natural resources for future generations. By continuing investments in green technologies and sustainable practices, Morocco is positioning itself as a regional leader in sustainable development, serving as a model for other developing countries.

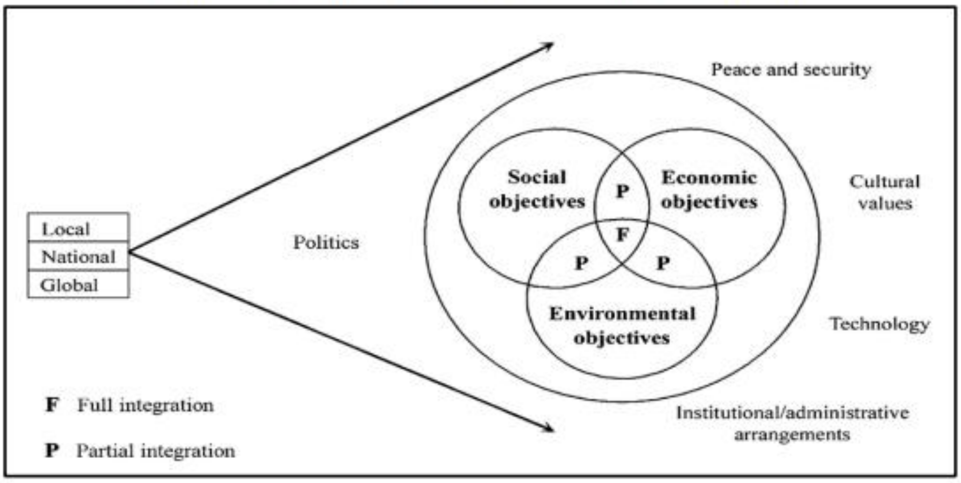
2.2.2 Theory of sustainable development of new energy industry :

The implication of reasonable improvement in relation to the new energy industry pertains to the transition toward energy sources that are benign to the ecosystem, economically viable, and socially equitable. This concept is linked to the necessity of reducing dependence on fossil fuels, mitigating climate change, and promoting long-term energy security. Empirical research emphasizes that sustainable improvement in the new energy sector entails the widespread adoption of renewable energy sources, such as solar, wind, hydro, and geothermal power, which exert lower environmental impacts when compared to conventional energy sources. Moreover, the sustainable advancement of the new energy industry encompasses not merely a shift to cleaner technologies but also the establishment of a circular economy where energy systems are efficient, resilient, and integrated with energy storage solutions. In this context, the industry focuses on technological innovation, such as advanced networking systems, energy storage, and smart grids, to ensure that renewable energy is reliable and adaptable. Furthermore, sustainable development in the new energy sector involves fostering economic growth through the creation of green jobs while ensuring that the transition benefits society as a whole by providing affordable, accessible, and clean energy for all. Ultimately, the significance of sustainable development in the new energy industry revolves around achieving a balance between environmental conservation, economic advancement, and social welfare, ensuring that future generations can meet their energy requirements without compromising the health of the planet.

Theoretical analysis of sustainable development of new energy industry:

The theoretical examination of sustainable development in the new energy sector evaluates the integration of environmental, economic, and social factors into the energy sector's transition towards sustainability. The new energy sector is fundamentally characterized by its reliance on renewable energy sources. From a theoretical perspective, the shift to sustainable energy systems is predicated upon several essential principles. Firstly, the principle of environmental sustainability asserts that energy production and consumption should not degrade natural ecosystems or contribute to long-term environmental harm. According to a study by the International Renewable Energy Agency (IRENA), "Renewable energy is key to decarbonizing the energy system and achieving global climate goals" (IRENA, 2020). This encompasses reducing greenhouse gas emissions, minimizing pollution, and promoting energy efficiency. The theoretical framework also highlights economic sustainability, emphasizing the need for renewable energy technologies to be economically viable. A report from the World Bank states, "Renewable energy technologies can create jobs, lower energy costs, and ensure long-term energy security, especially in developing countries" (World Bank, 2021). This includes decreasing production costs, increasing technological innovation, and ensuring that the energy sector remains competitive and resilient amidst fluctuating global energy markets. Furthermore, social sustainability in this context emphasizes the equitable distribution of energy access, ensuring that all populations, particularly marginalized communities, can benefit from clean and affordable energy sources. As affirmed by the United Nations Sustainable Development Goal 7, "Access to affordable, reliable, sustainable, and modern energy for all" is crucial for reducing poverty and fostering social development (UN, 2015). A critical component of the theoretical analysis also focuses on the concept of energy equity, which addresses the fair distribution of energy benefits and the potential adverse effects on vulnerable populations. Additionally, sustainable development in the new energy sector involves a shift towards a circular economy, where the entire lifecycle of energy systems, from production to disposal, is optimized for minimal waste and resource efficiency. According to the Ellen MacArthur Foundation, "A circular economy is one where we design energy systems to be restorative and regenerative by intention" (Ellen MacArthur Foundation, 2019). This involves advancing technologies for energy storage, smart grids, and decentralized energy systems, which enable more resilient, flexible, and efficient energy infrastructures. Ultimately, the theory of sustainable development in the new energy sector must account for intergenerational equity, ensuring that future generations inherit energy systems capable of meeting their needs without compromising environmental integrity. As stated by the World Commission on Environment and Development, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The theoretical exploration thus underscores a comprehensive, systems-based approach that integrates technological, economic, and social advancements to achieve a sustainable energy future, ultimately aiming to decouple economic growth from environmental degradation and build a more resilient, equitable, and sustainable energy landscape.

Figure 1: Scheme of sustainable development developed



Source: Lozano 2012.

Improvement is often delineated by three circles, representing the subjective objectives of environment, economy, and society, situated along the axes of time and the north-south dimension (Fig. 1). Figure 1 encapsulates the following findings:

- Economic, cultural, and environmental cycles are interdependent. Both private and public actors should never operate in isolation and independently, but should always consider the interplay of the three components of environment, society, and economy;

- Sustainable development encompasses more than merely protecting the environment. To fulfill our material and immaterial needs, we require a thriving economy and a conscientious society;

- Sustainable development necessitates a long-term structural transformation in our economic system and society, to reduce our consumption of resources and the environment to a level that is sustainable in the long run, while maintaining a productive economy;

- Global interdependencies must be acknowledged (North-South perspective). From an environmental standpoint, the lifestyle currently prevalent in industrialized nations cannot be replicated on a global scale. In the long run, however, sustainable development is also needed to enhance the quality of life for that significant portion of humanity that lives in extreme poverty (Touhami, 2022).

Summary

New energy is comparative with conventional energy, so its degree isn't fixed. As of now, it essentially incorporates wind energy, sunlight based energy, thermal power, biomass energy, and so forth, and the new energy industry is an assortment of divisions that create and apply new energy. In view of the exploration at home and abroad, joined with the improvement attributes of the new energy industry, this section leads a hypothetical examination of the maintainable advancement of the new energy industry from the three significant frameworks of "economy, nature, and society" and the three components of "force, quality, and reasonableness" to mirror the substance of the activity of the feasible improvement arrangement of the business, which is ceaseless, composed, and creating.

Chapter 3 : Analysis of the current status of Morocco's new energy industry development

Morocco's energy sector has transitioned from a significant reliance on imported petroleum products to a focus on sustainable, environmentally friendly energy sources. Since the mid-2000s, the country has made substantial progress in developing solar and wind energy, with renewable energy now accounting for approximately 37% of its energy capacity. The government's policies have emphasized energy diversification, efficiency, and local participation, establishing Morocco as a leader in renewable energy in Africa. Despite challenges such as energy storage and access, Morocco's advancements underscore its commitment to sustainable development and a green economy.

3.1 Analysis of the macro-environment for the development of new energy industry :

The large-scale climate for the advancement of the new energy industry is shaped by several key variables: mechanical, financial, political, and ecological. Mechanically, advancements in renewable energy technologies, such as solar, wind, and energy storage systems, are driving cost reductions and enhancing efficiency. Financially, global transitions towards green economies, supported by increasing investments in clean energy, are creating new market opportunities. Politically, international agreements, such as the Paris Agreement and national policies promoting sustainability and carbon reduction, are fostering positive regulatory frameworks. Ecologically, the growing urgency of addressing climate change and reducing fossil fuel emissions is prompting governments and organizations to prioritize renewable energy. However, challenges such as energy storage, grid integration, and funding for large-scale projects still persist, necessitating continued innovation and policy support to fully realize the potential of the new energy industry.

3.1.1 the Moroccan Government policies :

The Moroccan government has positioned itself at the forefront of integrating sustainable development into its energy policies, with a strong emphasis on renewable energy to ensure long-term energy security, economic growth, and environmental protection. Morocco's energy strategy is focused on diminishing its reliance on imported fossil fuels, which currently account for approximately 90% of the nation's energy requirements. As a result, Morocco has established ambitious objectives to increase the share of renewable energy in its energy mix, aiming for its installed capacity to derive from renewable sources by 2030, with particular emphasis on solar, wind, and hydroelectric power.

Key policies driving this transformation include the National Energy Strategy (2009), which laid the groundwork for the country's renewable energy revolution, and the Moroccan Solar Plan (2009), which stimulated the development of large-scale solar projects. The government has also prioritized wind energy, with projects being developed nationwide. Morocco's commitment to energy efficiency is likewise reflected in its policies, with initiatives aimed at reducing energy consumption in both industrial and residential sectors.

To attract private investment and ensure the economic viability of renewable energy projects, Morocco has implemented financial incentives such as tax exemptions, subsidies, and favorable power purchase agreements (PPAs). These incentives have created a conducive environment for foreign investments in the renewable energy sector. Furthermore, the government has fostered public-private partnerships (PPPs) to fund large-scale renewable projects, facilitating global collaboration and technological exchange.

Morocco's energy policies are also aligned with global sustainability frameworks. The nation's commitment to carbon neutrality by 2050 and its adherence to the Paris Agreement highlight its dedication to global environmental objectives. In recent years, the government has also focused on developing the necessary infrastructure, such as smart grids and energy storage systems, to support the integration of renewable energy into the national grid. Additionally, Morocco's policies aim to improve energy access in rural areas, addressing social equity alongside environmental sustainability.

Despite these achievements, challenges persist, particularly in ensuring energy access for all citizens, overcoming technical barriers associated with energy storage, and achieving the necessary grid integration for renewable sources. Nonetheless, Morocco's forward-looking policies have positioned it as a regional leader in the transition to renewable energy and as a model for other countries striving to balance energy security, economic growth, and environmental sustainability.

3.1.2 Infrastructure construction :

Morocco has made significant investments in infrastructure to support the expansion of its renewable energy sector, particularly in environmentally friendly energy domains such as solar, wind, and hydroelectric power. Key infrastructure projects include the development of large-scale renewable power plants, such as the Noor Ouarzazate Solar Complex, which ranks among the largest solar power plants globally, and the Tarfaya Wind Farm, which enhances Morocco's wind energy capacity. These projects require robust infrastructure, including transmission lines, energy storage systems, and grid integration technologies to ensure efficient energy delivery. The Moroccan government has also prioritized upgrading the national electricity grid to accommodate an increasing share of renewable energy, with a focus on establishing a more flexible and resilient infrastructure through smart grids. Furthermore, the country has expanded its energy storage capacity to address the intermittency of renewable sources, with projects such as the Ain Beni Mathar combined cycle power plant and the installation of large-scale battery storage systems. Morocco has also invested in regional interconnection infrastructure, such as the Morocco-Spain power interconnection, to enhance energy security and facilitate the export of surplus renewable energy to Europe. These infrastructure advancements are critical to Morocco's long-term energy strategy, ensuring that renewable power can be efficiently harnessed, stored, and distributed throughout the nation and beyond.

Morocco has achieved remarkable advancements in the development of its infrastructure for renewable energy. Presently, renewable sources constitute 37% of the nation's installed energy capacity, with the intention of raising this figure to 52% by the year 2030. The Noor Ouarzazate Solar Complex possesses a capacity of 580 MW and aspires to reach a solar capacity of 2,000 MW by 2020, positioning it as a significant catalyst for this transition. Morocco's installed wind capacity stands at 1,300 MW, with an objective of 2,000 MW by 2030. Wind energy continues to play an essential role. One of Africa's largest wind farms, the Tarfaya Wind Farm, contributes an additional 301 MW to the overall total. The nation’s total energy production is supplemented by hydropower, which further enhances the diversity of its renewable energy source mix. Morocco is allocating resources towards energy storage technologies to effectively manage the intermittent nature of renewable energy supply. An illustration of this is the Ain Beni Mathar Integrated Solar Combined Cycle (ISCC) plant, which integrates both solar and gas-fired power generation. The government is also endeavoring to enhance grid integration through initiatives such as the 1,400 MW electricity interconnection between Spain and Morocco, facilitating energy export to Europe. Furthermore, Morocco has committed to achieving carbon neutrality by the year 2050, underscoring its dedication to environmentally sustainable energy development.

3.1.3 International environment :

Technological advancements and governmental policies aimed at reducing carbon emissions and transitioning to sustainable energy systems are propelling the swift growth of the global market for new energy. Approximately 29. 5% of the world's electricity was produced by renewable sources in 2020, with wind and solar power assuming increasingly prominent roles as part of a more extensive transition toward clean energy. China, recognized as the largest investor in renewable energy, is at the forefront by establishing ambitious targets such as achieving carbon neutrality by 2060 and ensuring that 25% of energy is derived from non-fossil fuel sources by 2030. In a manner similar to the United States, the European Union's European Green Deal aspires to attain net-zero emissions by 2050 along with a 40% share of renewable energy by 2030. The goal of realizing 100 percent clean energy by 2035 is bolstered by considerable investments in clean energy technologies and grid modernization within the United States. The energy storage market is projected to expand from $8. 8 billion in 2020 to $26. 6 billion by 2027, while investments in renewable energy reached $305 billion globally in 2020, with a notable share directed toward solar and wind initiatives. Supportive policies, subsidies, and incentives that promote the development of clean energy infrastructure underpin these global efforts. This illustrates a worldwide commitment to combatting climate change and fostering sustainable development.

3.2 Analysis of the scale of new energy industry :

The aspiration of Morocco is to employ energy as a catalyst for attractiveness and development, with the objective of initiating a genuine competitiveness shock centered around pricing criteria and low-carbon production methods. This strategy will also strengthen the country's energy security (in terms of volumes and prices) and position it as a global contender in sustainability and renewable energies, supported by a robust emphasis on research and development and the industrialization of energy production equipment, as well as new innovative industries that facilitate the ambitious energy transition, such as the industrialization of novel and efficient technologies (solar water heater [30], photovoltaic panels, etc.).

Indeed, within the context of Morocco, electricity production presently represents the predominant component of the energy transformation sector due to the absence of refining activities. The electricity sector alone is accountable for 40% of Morocco's energy CO2 emissions, a percentage that can be attributed to the still-significant dependence on conventional thermal power plants (natural gas, coal, diesel, and fuel oil), which constituted 80% of the energy mix in 2018. The preceding decade has observed the emergence of natural gas, the increase of renewables, and a resurgence of coal since 2013. The decarbonization actions require both a reduction in emissions and an optimization in energy consumption, necessitating an analytical examination of this sector in numerical terms in Morocco. The national energy landscape is distinguished by considerable external dependency and a notable increase in energy demand. Up to 93% of energy is imported in the form of petroleum products, coal, and electricity. Only hydroelectric, wind, and solar energies are produced domestically. These statistics, along with the previously mentioned environmental condition of the sector, illustrate how the state is progressing towards encouraging investment in renewable energy, extending electricity access to nearly its entire population, and making fossil fuel subsidies a significant subject of political discourse.

Moroccan electricity generation serves as an example of traditional production. The National Grid is responsible for a substantial portion of the electricity generation.

3.2.1 Wind energy :

Morocco possesses considerable potential for wind energy, characterized by robust winds in the northern and coastal areas, estimated to amount to approximately 25,000 MW of wind energy annually (El Khchine et al. 2019). By the year 2021, Morocco achieved a total installed wind-power capacity of roughly 1,500 MW (Captain-tide tool for tidal range database. . .).

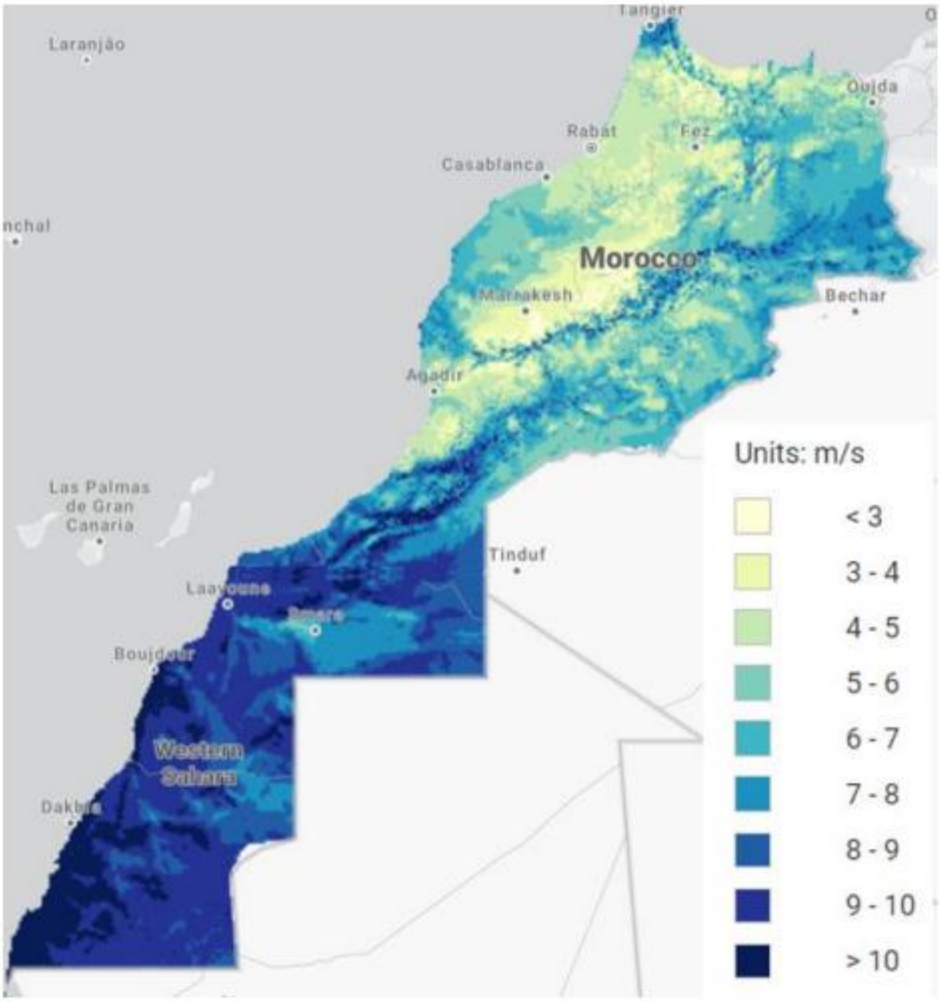


Fig. 2. Morocco's global wind energy speed (Re-explorer Geospatial...)

Source : ENERGY POLICY JOURNAL

The government has prioritized the installation of 10,000 MW of wind power capacity as part of its energy strategy by the year 2030 (Ministry of Energy. . . 2016). To fulfill these objectives, particularly considering Morocco's capability to generate up to 27% of its electricity from wind power (Moroccan Agency of

Sustainable Energy), action is essential. As of 2019, Morocco had 759 MW of installed wind power, rendering it the foremost nation in Africa concerning wind capacity. It has also secured one of the most advantageous sites for large-scale wind utilities in Africa (Fig. 3). The most promising sources of wind energy in Morocco are located along the Atlantic coast, where wind speeds can exceed 10 m/s. Specifically, when integrated with seawater desalination, the Atlantic region presents substantial opportunities for the advancement of wind energy projects (Fig. 2). Given the high demand for energy and clean water in Morocco, the integration of these resources may serve as an attractive solution.

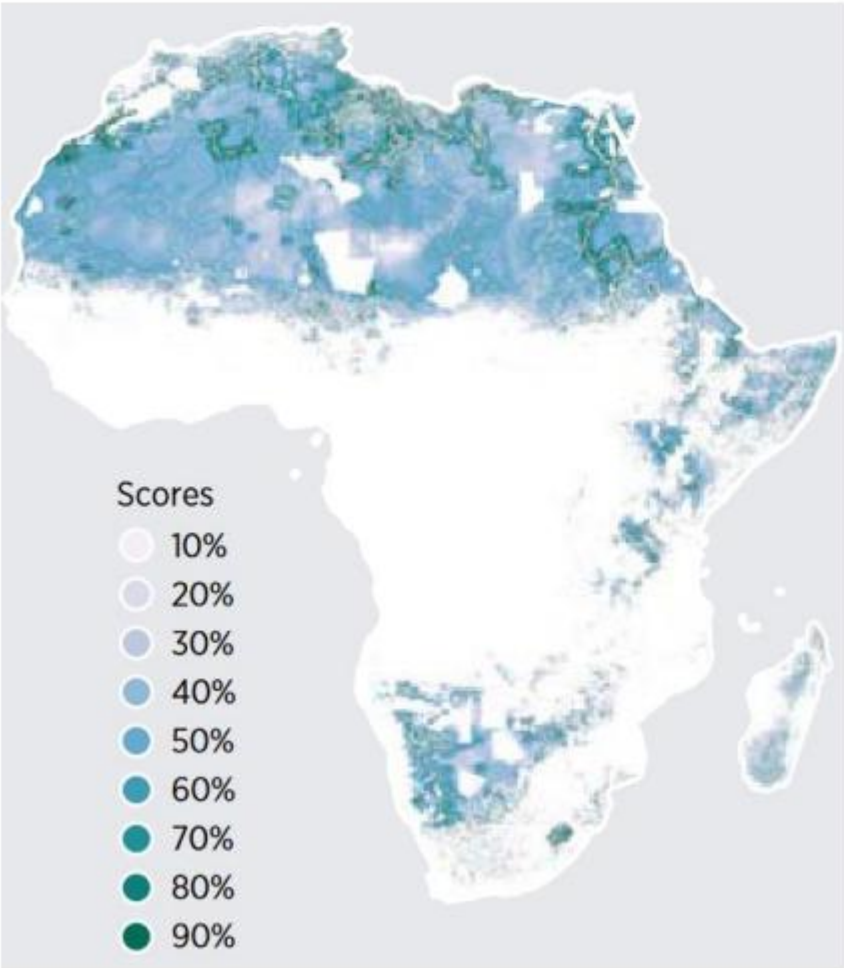


Fig. 3. Africa's most suitable areas for utility-scale wind (IRENA and AfDB 2022)

Source : ENERGY POLICY JOURNAL

Morocco has additionally experienced the establishment of various wind farms, among which are the Boujdour wind farm (300 MW), the Tiskrad wind farm (100 MW), and the Jbel Lahdid wind farm (270 MW) (ONEE). Furthermore, the country should explore the potential of harnessing its offshore wind energy, especially in the Safi region, where the potential of this resource is highest and the water depth is less than 50 m, thereby rendering it highly suitable for the implementation of offshore wind turbines (Fig. 4).

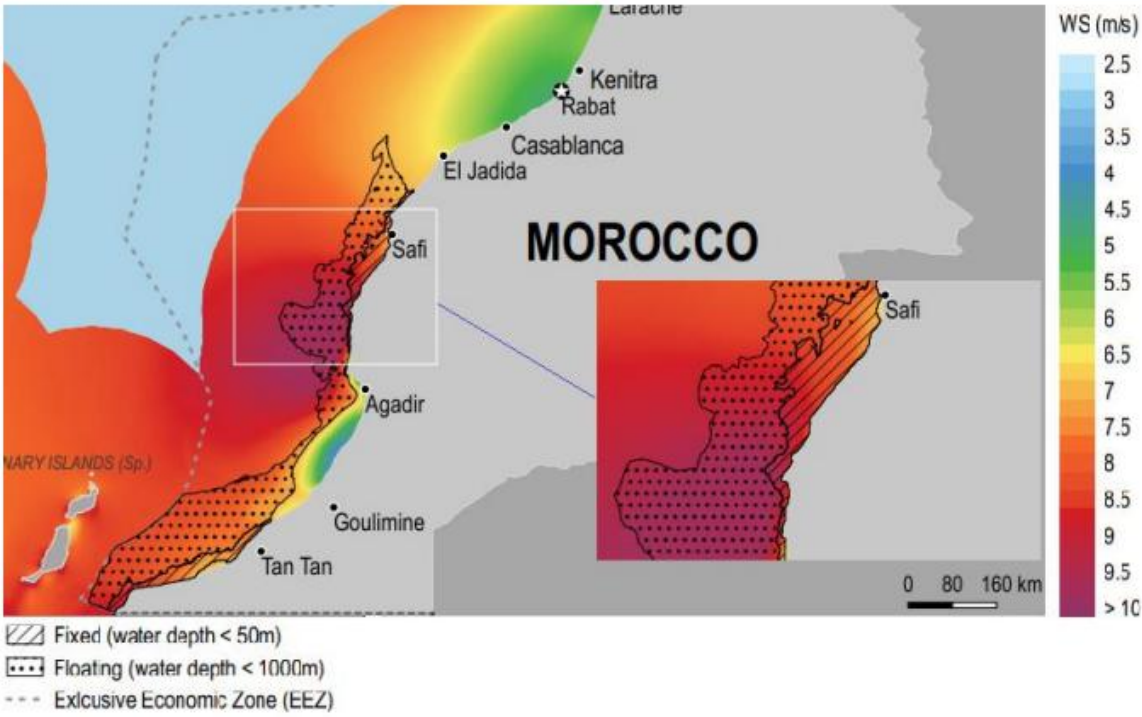


Fig. 4. Morocco's offshore wind suitable sites (Naimi et al. 2016)

Source : ENERGY POLICY JOURNAL

The hub heights of wind turbines utilized in Morocco typically ranged from 100 to 150 meters (Sierra and others, 2016). Nonetheless, there exist models of wind turbines that are available in various sizes and possess hub heights of a minimum of 220 meters (Ahmed et al. , 2019). The height of wind turbines is a crucial factor that may influence their efficiency (Smith et al. , 2016). Despite the successful completion of projects aimed at the development of wind energy in Morocco, several challenges persist. For instance, the substantial initial costs associated with the construction and maintenance of wind farms are notable hurdles. It is essential to enhance the efficiency of wind turbines by elevating the hub heights (Figures 5 and 6), in order to render wind power plants more economically viable, while simultaneously increasing the requirements in terms of technical expertise and investment. Furthermore, the geographical and environmental obstacles associated with establishing wind projects in Morocco, including the rugged terrain and insufficient access to transmission infrastructure, can impede the commercialization of wind power. Ongoing investment and advancement of wind energy in Morocco is vital for realizing this potential and contributing to the nation's sustainable development, particularly in the southern region where the wind potential is optimal, yet there remains a shortage of projects (Figure 7).

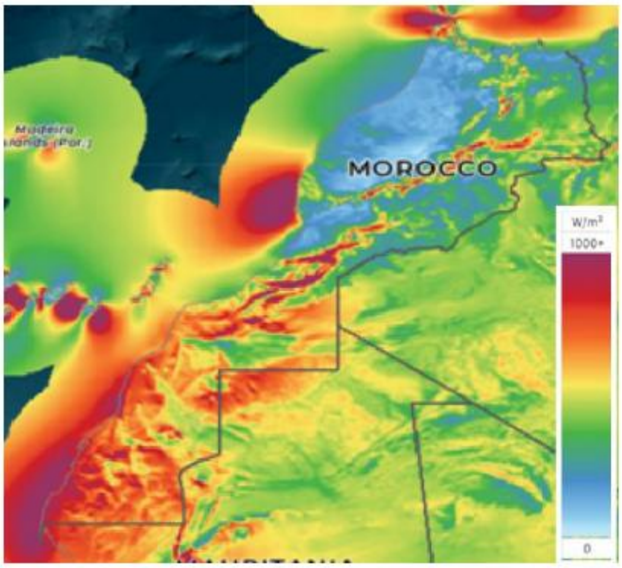


Fig. 5. Morocco's offshore wind energy potential at 100 m (Global Wind Atlas...)

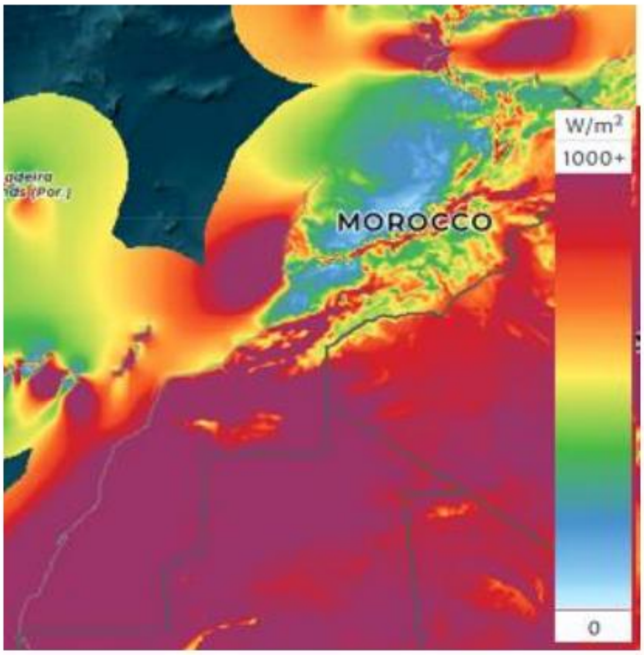


Fig. 6. Morocco's offshore wind energy potential at 200 m (Global Wind Atlas...)

Fig. 7. Morocco's wind energy plants location (MASEN 2020)

Source : ENERGY POLICY JOURNAL

3.2.2 Solar energy :

Morocco's solar energy potential is undoubtedly its most significant asset, a benefit stemming from its high solar radiation levels, which range from 6 to 7 kWh/m2 on average per day and encompass approximately 85% of its territory, surrounded by dunes (Integrated Solar Energy. . .). Motivated by this considerable solar potential, the government of Morocco plans to invest in solar energy projects. In 2009, Morocco initiated the National Solar Plan to elevate the contribution of solar energy to 14% of its electricity mix by 2020 and 52% by 2030 (Integrated Solar Energy. . .). The strategy to accomplish these objectives includes the development of crucial large-scale solar projects, such as the Noor Solar Power Complex, which is the largest concentrated solar power plant in the world. This complex is situated in the Ouarzazate region, in central Morocco, where the climatic conditions are optimally favorable (Figs. 8 and 9). As of 2021, Morocco had achieved a total installed solar capacity of approximately 850 MW, according to the National Office of Electricity and Drinking Water (ONEE) (Captain-tide tool for tidal range database. . .). Following the success of the Noor

Solar Power Plant, the Nour 1 Solar Power Station (160 MW), Nour 2 Solar Power Station (200 MW), and Nour 3 Solar Power Station (150 MW) (Hanger et al. 2016) significantly contribute to the kingdom's energy mix, along with other notable projects of a similar type, such as the Noor Tafilalt solar photovoltaic project (120 MW), which consists of three solar power plants located in the regions of Zagora, Erfoud, and Missour according to ONEE 2021a.

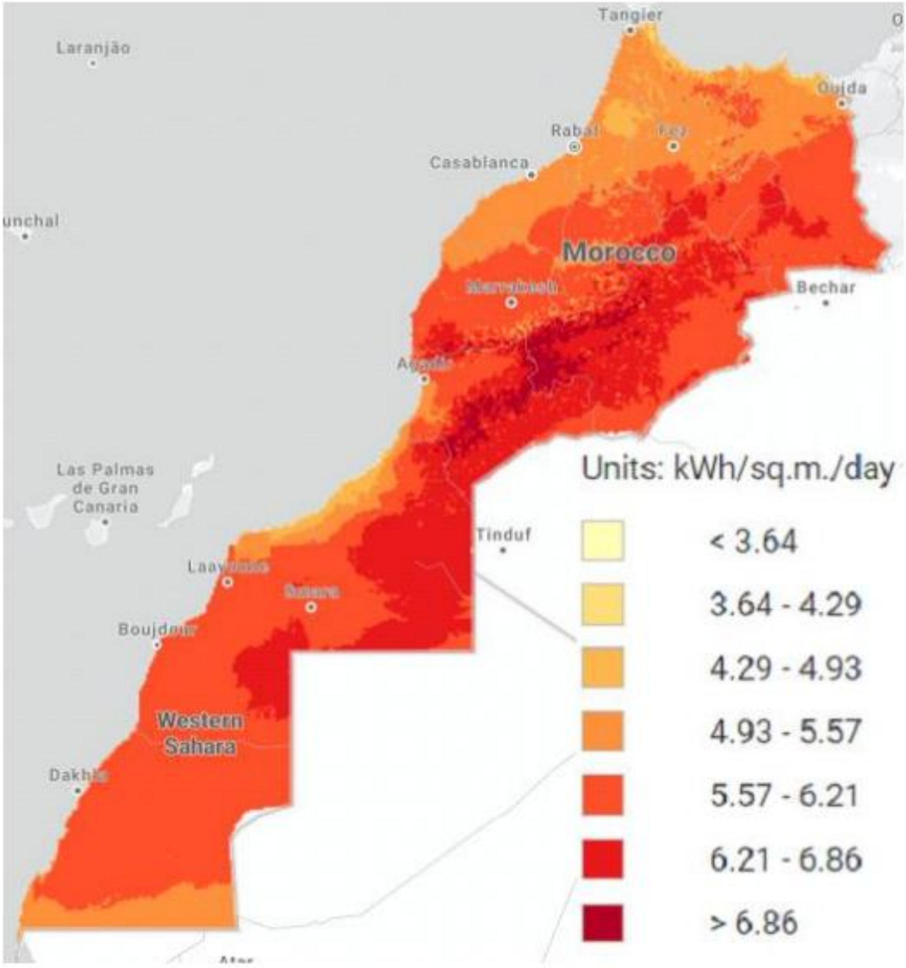


Fig. 8. Moroccan solar energy potential (Re-explorer Geospatial...)

Source : ENERGY POLICY JOURNAL

3.2.3 Hydroelectric power :

Hydroelectric power is a clean and renewable source of electricity playing a significant role in the energy mix of Morocco. The Mohammed VI dam on the Oum Er-Rbia river, which has an installed capacity of 365 MW and is the kingdom's hydroelectric dam, is in operation. Dam (300 megawatts), Al Wahda dam (135 megawatts), Sidi Moktar dam (120 megawatts), and a number of additional information (Ministry of Energy, Mines, and Sustainabl Development, 2021). These dams located throughout the country, however, are now impacted by the potential droughts roaming over it in the

in recent times (Fig. 10). However, this did not prevent the kingdom from altering its strategy; instead, it implemented some new hydroelectric dams and expanded the existing ones. Thanks to this strategy, as of 2021, Morocco achieved a total installed hydroelectric capacity of around 2000 MW (ONEE 2021b), with additional goals set for new projects like Abdelmoumen. STEP, the 2nd Energy Transfer Station by Pumping (STEP) in the kingdom, in the region of Agadir, which has a capacity of 350 MW and a total cost of about 3.8 billion dirhams.

Fig. 9. Morocco's solar energy plants location (MASEN 2020)

Fig. 10. Hydro power projects Map in Morocco (MASEN 2020)

Source : ENERGY POLICY JOURNAL

3.3 The current state of renewable energy financing in Morocco :

Morocco has achieved notable advancements in recent years, facilitated by various funding sources, including the MASEN (Moroccan Agency for Sustainable Energy), which has obtained $4. 3 billion in financing for its Noor Midelt solar power complex through the support provided by a consortium of export credit agencies and international banks (MASEN, 2018). The African Development Bank (AfDB) has also extended numerous loans to bolster the development of renewable energy initiatives in Morocco, comprising a $120 million loan sanctioned in December 2020 and a $300 million loan sanctioned in October 2018 (African Development Bank. . . 2018).

The World Bank has similarly rendered assistance for renewable energy projects in Morocco, having approved a $500 million loan in January 2019 in addition to a $50 million grant from the Clean Technology Fund (CTF) in January 2020 (CTF grants. . . 2020).

The European Investment Bank (EIB) has authorized several loans to facilitate renewable energy initiatives in Morocco, comprising a $170 million loan approved in July 2019 and a $242 million loan sanctioned in January 2021 (EIB 2021).

The International Finance Corporation (IFC), which is part of the World Bank Group, has granted two loans to promote the development of renewable energy projects in Morocco, including a $70 million loan for a 200 MW wind farm approved in October 2019 and a $100 million loan for a 300 MW solar power plant sanctioned in January 2021 (IFC 2016).

The International Renewable Energy Agency (IRENA) has likewise offered technical assistance and funding to aid the development of renewable energy projects in Morocco, including the establishment of a 100 MW solar power plant (IRENA 2021). In summary, these financial sources have greatly contributed to the advancement of renewable energy initiatives within Morocco, facilitating substantial progress toward the nation’s objective of expanding the share of renewable energy within its energy mix.

3.4 Analysis of the social and ecological benefits of the new energy industry :

In accordance with Morocco's energy transition strategy and sustainable development goals, the nation's emerging energy sector has generated significant social and environmental advantages. Socially, the advancement of renewable energy infrastructure has led to the establishment of thousands of jobs in construction, maintenance, and technological innovation. Major initiatives such as the Noor Ouarzazate Solar Complex and the Tarfaya Wind Farm have enhanced local livelihoods and fostered economic inclusion, particularly in rural areas, by creating both direct and indirect employment opportunities. Furthermore, Morocco’s investment in renewable energy has bolstered energy security, decreasing dependence on imported fossil fuels, which constituted over 90% of the nation’s energy supply prior to the transition. By augmenting domestic energy production, Morocco has stabilized electricity prices and broadened energy accessibility, especially in remote regions where decentralized solar and wind systems now offer sustainable electricity solutions.

The transition towards renewable energy has markedly diminished environmental degradation and greenhouse gas (GHG) emissions from an ecological standpoint. Morocco's ambitious renewable energy objectives are anticipated to reduce CO_2 emissions by 20 million tons per year by 2030, contributing to global climate change mitigation efforts. The implementation of clean energy sources has additionally assisted in lessening air pollution associated with fossil fuel combustion, thereby improving public health by reducing respiratory ailments related to air pollutants. Moreover, the conservation of natural resources such as water has been a notable environmental benefit. Unlike traditional thermal power plants, which utilize substantial quantities of water for cooling, solar and wind energy necessitate minimal water consumption, which is particularly vital in Morocco’s arid climate. By promoting environmentally sustainable land-use practices and minimizing the environmental impact of energy production, the adoption of renewable energy sources has also played a role in land preservation. Overall, Morocco's transition to new energy has significantly influenced the country's social and environmental welfare, positioning the nation as a model of sustainable development in Africa and the MENA region. With sustained investment, technological advancement, and robust policy support, Morocco’s new energy sector is poised to further amplify its beneficial effects on society and the environment, thereby supporting long-term economic resilience and ecological conservation.

Summary :

Morocco’s new energy sector represents a paradigm of effective transition, propelled by robust government policies, strategic infrastructure development, and international collaboration. The sector has become increasingly resilient due to investments in grid modernization, energy storage, and financial mechanisms, which have attracted international partnerships with entities such as IRENA and the World Bank. The extent of Morocco’s renewable energy sector has rapidly increased, surpassing 4 GW of installed capacity, although challenges persist regarding storage and grid stability. Green bonds, concessional loans, and Power Purchase Agreements (PPAs) have been utilized to secure financing for renewable energy, but further innovation is required for sustained investment. In addition to enhancing energy security, the sector creates employment opportunities, improves energy access, and provides environmental advantages, significantly decreasing emissions and resource consumption. With ongoing investment and innovation, Morocco is poised to reinforce its leadership in the global clean energy transition, ensuring long-term economic, social, and ecological sustainability.

Chapter 4 : Materials and Methods

4.1. Data and Hypothesis :

4.1.1 Moroccan Textile Factories: Industrial Company :

In the context of this study, a survey has been initiated regarding the textile sector in Morocco. Concentrating on the specifics (energy demands, consumption, production, etc.) of certain production units, dispatches were conducted to various geographical locations in order to create a representative sample based on the climatic and economic conditions of the chosen regions, thus ensuring a significant diversification of the results and a thorough analysis of the national textile sector, which is characterized as energy-intensive. As previously stated in this study, an energy diagnostic has been performed on several textile companies situated in different geographic areas of Morocco—namely Casablanca, Meknes, Fez (detailed case), Settat, Sale, Marrakech, Tangier, and Agadir—that have implemented Photovoltaic energy as a clean technology to decrease the energy expenses of factories and assist them in moving towards carbon neutrality while aligning with the kingdom's current strategic vision.

(a) Detailed case: Fez

In the city of Fez, three typical cases of the textile industry have been examined as detailed and representative instances. The leading region of Sais (Meknes-Fez) possesses a favorable geographic and economic position. Considering the advantageous climatic conditions in the majority of Moroccan regions, the area of Fez-Meknes boasts considerable resource diversification and hosts significant national industrial activities. Figures 3–5 illustrate the electrical profile of three textile factories located in the principal selected regions.

(b) Different zone case and company

A total of twenty-seven small and medium enterprises in the Moroccan textile sector were visited, with eight of them located in Casablanca. As the industrial leader in Morocco, Casablanca accommodates nearly two-thirds (63%) of the national companies, with 10% engaged in industrial activities. Table 1 summarizes the results pertaining to the energy diagnostic loads of the surveyed industrial park for the year 2019, which reflects the normal operational circumstances prior to the pandemic situation.

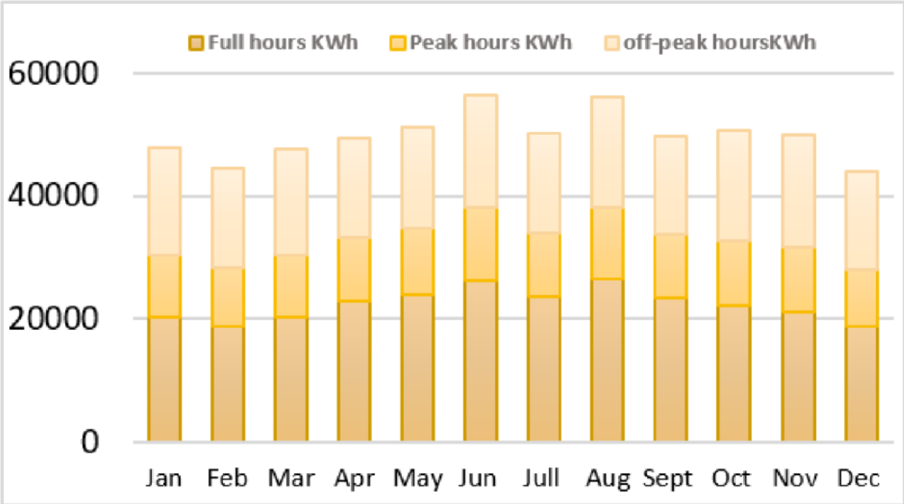


Figure 11 Monthly electrical load of the factory 1—Fez 2021.

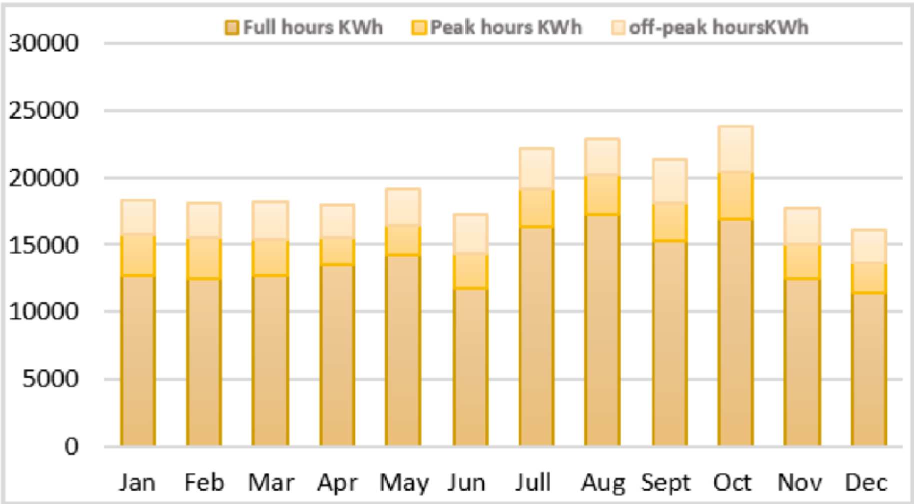


Figure 12. Monthly electrical load of the factory 2—Fez 2021.

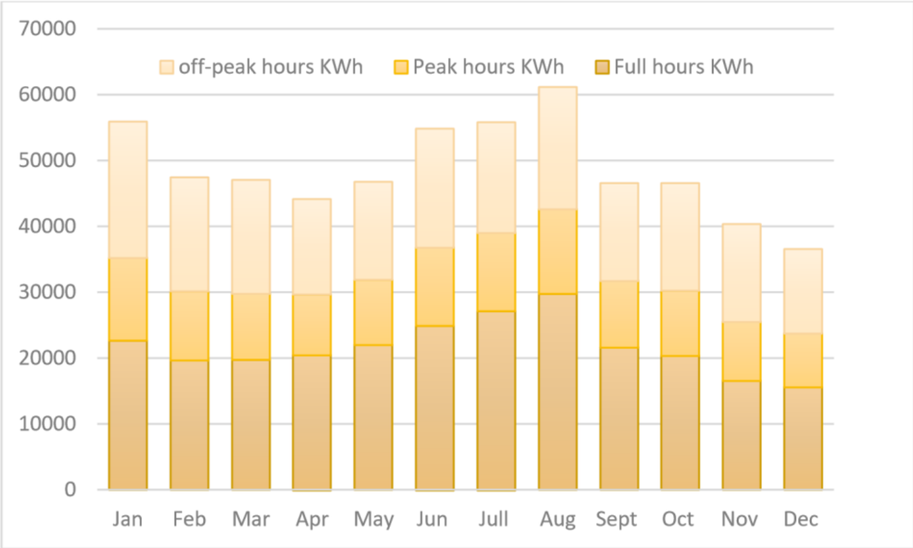


Figure 13. Monthly electrical load of the factory 3—Fez 2021.

Table 1. Survey summary on electric loads.

City	Companies	Total Energy Consumption (kWh/Year)	Daily Electric Profile (kWh/Day)
Casablanca	Company 1	1,813,766	5650
	Company 2	775,823	2424
	Company 3	274,925	864
	Company 4	4,389,956	12,724
	Company 5	215,960	674
	Company 6	67,211	210
	Company 7	102,125	318
	Company 8	113,098	353
Tangier	Company 1	2,305,000	7092
	Company 2	1,146,840	3583
	Company 3	1,649,550	5138
	Company 4	696,985	2178
	Company 5	946,163	2956
	Company 6	8451	27
	Company 7	231,187	720
Meknes	Company 1	45,372	142
	Company 2	289,364	904

	Company 3	95,539	298
Sale	Company 1	338,125	1056
	Company 2	462,075	1439
	Company 3	771,648	2403
Marrakech	Company 1	14,883,639	46,511
Agadir	Company 1	11,115,636 1,524,782	34,736 4750
	Company 2		
	Company 3	5,256,697	16,427
Settat	Company 1	30,264,554 3,990,382	94,282
	Company 2		12,431

4.2 Proposed Model: Theoretical Model; Methodology Follow :

Table 2. The selected sites.

City	Latitude	Longitude	Altitude
Casablanca	33° 35^{0}17” N	7° 36^{0}40” W	27 m
Meknes	33° 53^{0}36” N	5° 32^{0}50” W	531 m
Fez	34° 01^{0}59” N	5° 00^{0}01” W	406 m
Setat	33° 00^{0}03” N	7° 36^{0}59” W	365 m
Sale	34° 01^{0}46” N	6° 50^{0}09” W	11 m
Marrakech	31° 38^{0}02” N	7° 59^{0}59” W	457 m
Tangier	35° 46^{0}02” N	5° 47^{0}59” W	20 m

The methodology employed in this paper was formulated as both a technical and policy-oriented approach aimed at facilitating the identification of the hybrid technology that should be prioritized. The ultimate decision is informed by the mitigation potential under various conditions, considering the most critical criteria such as technical parameters, financial and economic feasibility, and sustainability considerations. Furthermore, the identification of variables that may obstruct the integration of renewable energies within the industry was conducted, proposing photovoltaics as a solution warranting increased attention for a smooth energy transition.

The methodology is structured into five steps (Figure 14) to evaluate and address the key problematic issues. There are three primary aspects to consider when analyzing the results. First, the methodology has been designed as a rapid measurement technical process utilizing a combination of data sources, contingent upon their availability in Morocco, with the quantification of energy, climate, and environmental inputs in the textile sub-sector. Nonetheless, the approach can be modified and implemented in any other industrial sub-sector. The study primarily utilized official national data and industrial sources, territorial investigations, and information.

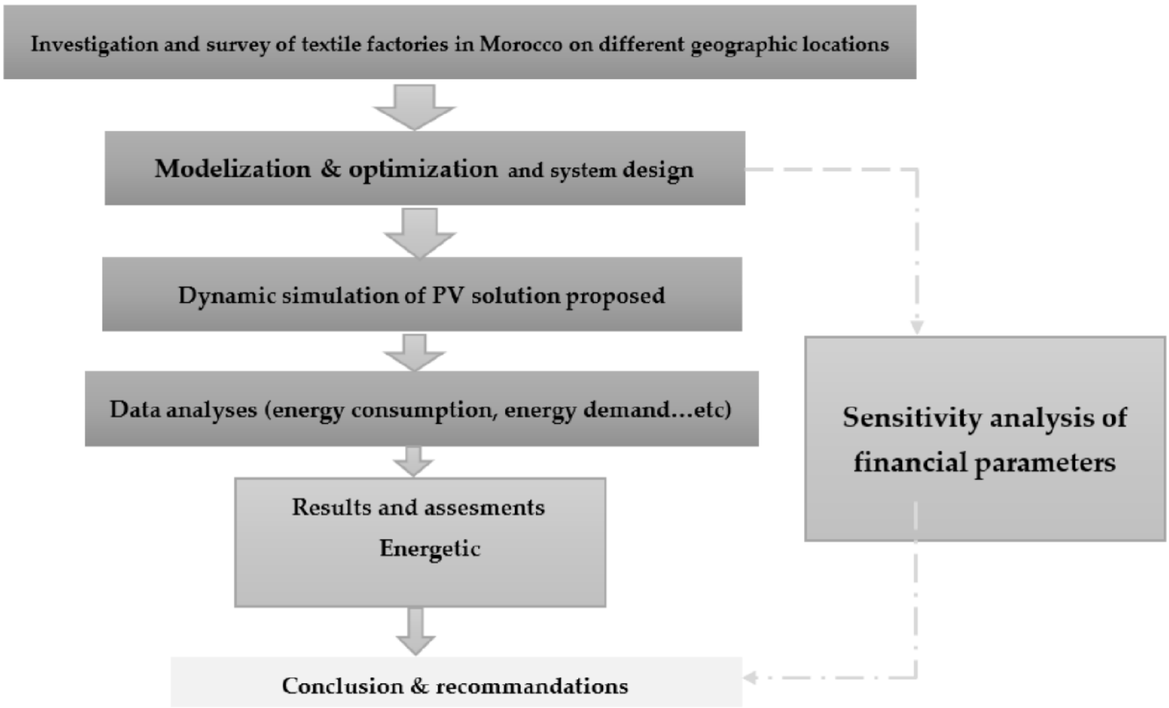


Figure 14 . Analytical framework methodology.

In this paper, seven distinct locations were examined, presenting photovoltaic technology as a remedial measure to decrease the energy expenditure and the environmental repercussions of fossil fuels. Various factories in each location were analyzed. For Fes city, three cases were thoroughly presented with more detailed analysis as a representative case of this study. The remaining cases in several Moroccan locations were outlined in a summarised analysis.

4.2.1. Proposed System Analysis :

During the previous decade, renewable energy systems have experienced substantial advancements. However, the integration of renewable solutions infrequently varies by country, and even within the same country, it differs from one region to another. In this study, the implementation of photovoltaics connected to the grid was identified as the most appropriate method to mitigate the energy expenses of textile factories and to decrease their carbon emissions.

Nonetheless, as previously noted, hybrid systems that amalgamate multiple sources, such as renewable energy systems and the national distribution network or conventional sources, can be advocated for future initiatives. The primary challenge associated with these systems is ensuring adaptable energy management. Indeed, the execution of the energy management strategy must align demand with supply. These systems must assure financial viability and environmental sustainability, which facilitate energy efficiency and lower electricity costs. Consequently, it is essential to limit the systematic reliance on the national electricity grid, which predominantly utilizes non-renewable sources, thereby promoting the sustainable and social advancement of communities in rural areas. In fact, several studies have examined the techno-economic viability of solar photovoltaic systems for offshore energy or those connected to the grid. Isolated systems with batteries are frequently utilized for remote locations and agricultural practices, although their large-scale integration remains constrained. However, grid-connected systems are designed to deliver clean electricity to the power grid. These final configurations find multiple applications for private customers linked to the grid, distribution centers, and particularly within the territorial and industrial sectors. Various solutions can be proposed through hybridization with diesel engines, combined heat and power (CHP) systems, biogas, and wind energy.

Utilizing Hybrid Multiple Energy Resource Optimization (HOMER) software, the applied loads correspond to the annual energy consumption of the textile factories, considering usage during peak hours, while the climatic data for the various regions are collected and analyzed through triangulation. The grid-connected system proved to be the most dependable option for the industrial sector in Morocco. The network connection can facilitate storage. Consequently, batteries are incorporated into the selected configuration and may be excluded in the optimal solution. The overall configuration of the proposed system is illustrated in Figure 15.

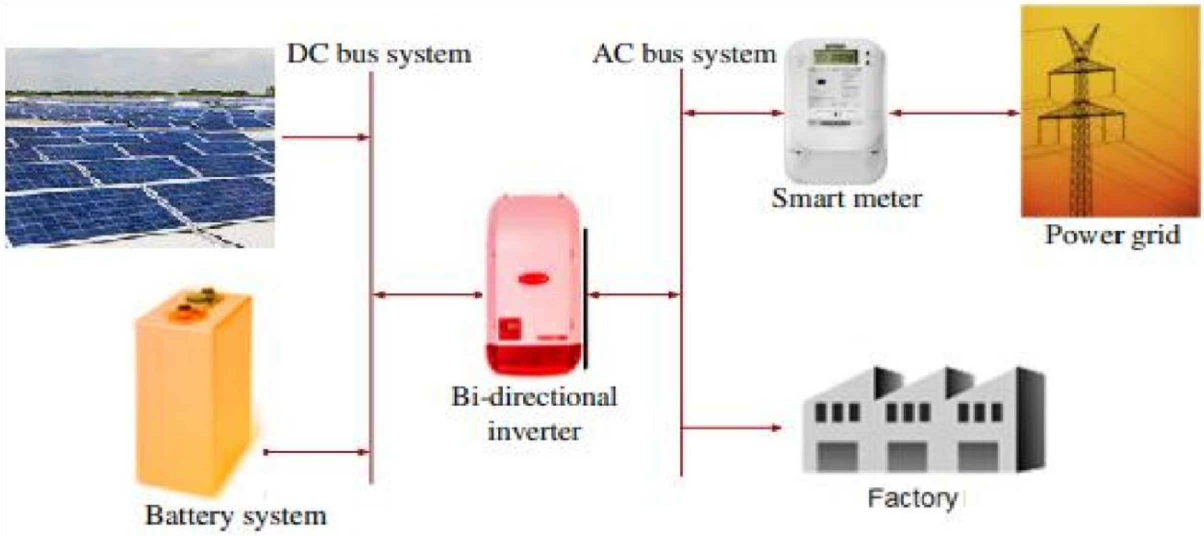


Figure 15 . PV on-grid system with storage.

4.2.2. Mathematical Model :

PV systems represent one of the most appropriate renewable energy sources of the next generation. Batteries may provide a superior solution for stand-alone systems to address the discrepancy between the system's power generation and the demand for electrical load. Particularly for hybrid systems that are connected to the grid, electrical storage may be considered optional, as illustrated in the optimization presented in the current study.

The Photovoltaic energy can be expressed as follows:

$$P_{pv} = P_{stc} \cdot Y_r \cdot \frac{G_{pv}}{G_{stc}} \qquad (1)$$

Under standard test conditions (STC), Ppv denotes the power generated, Yr signifies the rated capacity factor; Gpv represents the incident solar radiation per unit area of the PV collector surface (W/m2), and Gstc indicates the incident radiation at STC (kW/m2). The efficiency/yield of the PV module is assessed under standard test conditions, illustrating the transformation of the received radiation into electrical energy at its maximum power point, determined by the following calculation:

$$\eta_{pv} = \frac{P_{pv}}{A_{pv}\, Irr_{STC}} \tag{2}$$

where, Apv represents the surface area of a solar photovoltaic panel (m^2) and IrrSTC denotes the irradiance under Standard Test Conditions (STC).

The battery state of charge (Bc) at a particular time of load is expressed by Equation (3):

$$B_c = B_c(t=0) + \eta_c \sum_{0}^{t} B_{cb}(k) + \eta_d \sum_{0}^{t} B_{db}(k)s \tag{3}$$

where Bc (t = 0) is the battery initial state of charge, Bcb is the battery electrical power charged, and the power discharge is expressed as Bdb, ηc and ηd are the charging and discharging efficiencies.

The inverter is a critical element in the system. Connected between the DC and

AC busses, the inverter converts the DC power output generated to the AC load, with a supposed constant inverter efficiency (ηInv) of 98%. The AC power output is calculated as follows:

$$Pout = \eta_{Inv}\, Ppv \tag{4}$$

The performance ratio constitutes an essential parameter, which is contingent upon the system's final yield Yf as indicated in Equation (5) and the reference yield Yr articulated in Equation (6).

$$Y_f = \frac{E_{net}}{P_o} \tag{5}$$

Po refers to the power of the Installed PV system, measured in kW, while Enet denotes the net energy output, represented in kWh.

$$Y_r = \frac{H_i}{G_r} \quad (6)$$

The PV reference irradiation at the examined location is articulated as Gr in kW/m2, while the Total plane irradiance Hi is articulated in kWh/m2.

To assess the performance of the PV system, a significant variable must be computed. This is denoted as a ratio in Equation (7).

$$PR\ \% = \frac{Y_f}{Y_r} 100 \quad (7)$$

4.3 Economic Analysis Model :

The metrical economics employed in the study conducted comprise the net present cost (NPC) and the simple payback period (SPBP). Consequently, the cost of electricity (COE) and the capital cost associated with the selected system are critical for conducting a sensitivity analysis on the NPC. The uncertainty regarding the CEO is also assessed, taking into account the variations in financial indexes (inflation, discount rate). The NPC and the COE serve as two highly significant indicators; the classification of potential configurations is accomplished through a comparison of the NPC. As such, the most favorable configuration is characterized by the minimum NPC. This Financial Index encompasses the investment (setup costs, maintenance costs, replacement cost) as well as the system revenues generated throughout the duration of the project's life cycle. The negative values of the NPC and the COE indicate that the income derived from electricity injection into the grid outweighs the total costs and the expenses related to electricity purchases.

a) Net present cost (NPC)

Over a period of 25 years, which signifies the comprehensive project lifetime, NPC is an evaluation derived from the costs incurred by the HRES diminished by the revenues reported by the system. NPC encompasses the capital/investment, replacement, operation, and maintenance costs. NPC is a significant economic factor for renewable systems. This parameter must be computed for each individual system component as well as for the system collectively, as delineated in Equation (8).

$$NPC = \sum_{0}^{25} \frac{AA_{TC}}{(1 + i_r)^n} + I_{cc} \tag{8}$$

AATC represents the adjusted annual total costs, ir denotes the discount rate, n signifies the project lifetime, and Icc stands for the initial capital cost.

(b) Simple payback period

The simple payback period (SPBP) is utilized to ascertain the duration required to reach the break-even point and recuperate the funds invested in a project. In practical terms, a SPBP of 5 years is generally considered acceptable for renewable solutions. The SPBP can be computed as follows:

$$SPBP = \frac{I_{cc}}{\text{Annual saving}} \tag{9}$$

(c) Cost of Energy (COE)

Based on the production of electrical energy from the PV system, the required average cost per kWh signifies the levelized cost of energy (COE). This is the ratio that divides the annualized cost of electricity production (the total annualized cost less the cost of serving the thermal load) by the total electric load served. The calculation formula for COE is depicted in Equation (10).

$$COE = \frac{C_{ann,tot}}{E_{served}} \tag{10}$$

where Cann,tot represents the system's total annualized costs, and Eserved denotes the served total electric load expressed in kWh/year.

4.4. Environmental Assessment and Sustainability Management :

In the current section, an environmental evaluation of the proposed system is conducted utilizing the ABC Carbon method and the HOMER platform under the climatic conditions of Morocco. The ABC Method serves to compute fundamental metrics: Total annual GHG emissions and the equivalent costs. The objective is to compare the chosen configuration with various optimized systems. The environmental assessment denotes the annual CO2 emissions and is calculated by multiplying the electrical demand by the emission factors; accordingly, the result encompasses a margin of uncertainty based on the collected data and the emission factor utilized. The emission factors for electricity, using the factor from Morocco's Environment and Energy Management Agency (ADEME), are approximately 0. 682 kg CO2/kWh.

From a broader perspective, the total GHG emissions mitigated by solar systems (EMAV. Grid) is formulated with the assumption that every 1 kWh produced by PV systems is equivalent to 1 kWh sourced from the Moroccan electricity grid. The CO2 emissions mitigated are articulated in Equation (11). The emission factor for the on-grid system was approximated under local evaluation at 50 g CO2/kWh for PV systems.

$$EM_{AV.Grid} = \frac{E_{Pv}\left(F_{grid} - F_{PV}\right)}{10^6} \tag{11}$$

where FPV denotes the emission factor associated with photovoltaic technologies.

In the current section, the evaluation of sustainability is conducted in conjunction with the quantification of greenhouse gases (GHG). It is established that increasing the proportion of renewable energy sources within the system diminishes GHG emissions. It is essential to compute the total renewable energy production. To determine the renewable fraction (RF), the subsequent equation is employed:

$$FR = 1 - \frac{E_{nnR}}{E_{serv}} \tag{12}$$

EnnR and Eserv signify nonrenewable electricity and energy supplied, respectively, expressed in kWh/year.

Chapter 5 : Results and Discussion

The National Renewable Energy Laboratory in the United States created HOMER, an optimization tool for RE hybrid systems. The ideal model was created after thousands of simulations based on the variability of essential technical and economic inputs (radius, price changes, energy fraction, system cost, etc.).The proposed systems are prioritized and ranked based on their lowest COE and NCP values. However, the various designs are compared based on cost, electricity generation, size, and renewable energy share. The performance and sensitivity data are detailed to determine the most optimal configuration for the three plants in the Fes region, which will be carried out and generalized to all national facilities. The potential energy savings percentage in the great majority of textile firms can range from 15 to 70%, which justifies the deployment of these systems due to their economic and environmental benefits. After the simulation process, many configurations were tested. In this study, three photovoltaic scenarios are examined among different configured energy systems; however, we omit PV/biogas hybridization from our ideas for the textile sector due to technical and economic constraints.

5.1. Detailed Case: Fez Region

a) Scenario 1: grid-only system

The typical option for ensuring energy to textile businesses is to connect to the grid solely, as is the case in Morocco and numerous other countries. Figure 16 depicts the monthly energy consumption profile for three factories located in three separate areas (industrial districts).

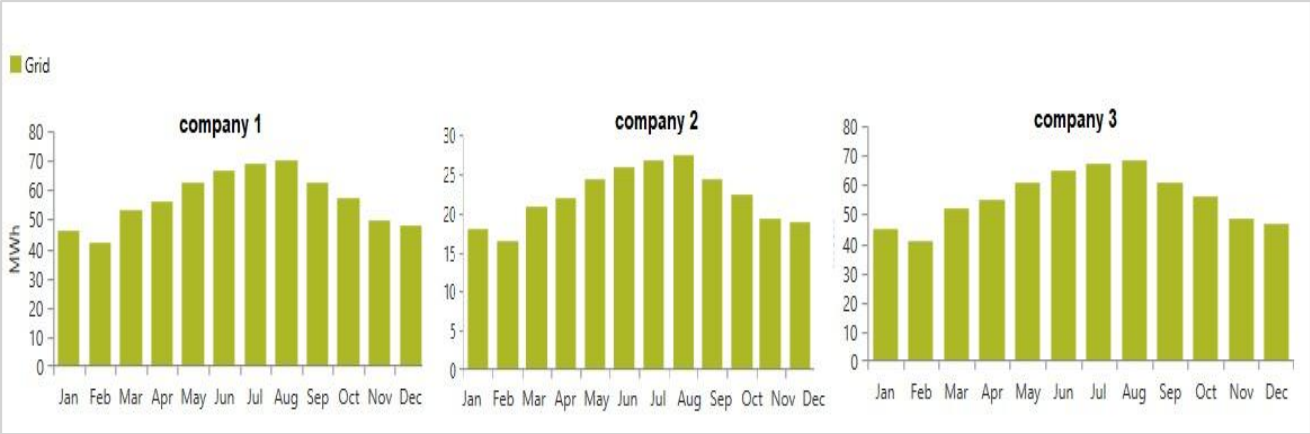


Figure 16 . Monthly electric load for the three companies (Fez region), 2021.

The consumption profile is the same for all three factories; consumption rises in the summer and falls in the winter. The highest consumption was reported in August, with values of 70, 27 and 68 MWh for firms 1, 2, and 3. The minimum for the three scenarios is shown in February as 18, 48, and 45 MWh in the same sequence. The rise in consumption during the summer can be attributed to the demand for air conditioning in the workplace. It is also caused by a decrease in machine efficiency as a result of excessive heat.

The discrepancy in findings between plants is explained by their size, with the most widespread plant exhibiting the highest consumption. However, the current investigation highlights the limitations of this traditional technique. Even if the initial cost is small, the network architecture results in the highest COE (Table 3). Furthermore, as shown in Table 3, CO2 emissions are critical for all three factories.

Table 3. On-grid system for the lead companies (Fez Region).

Architecture	Electric Load	GridNPC	COE	Initial Operating Costs Capital	Energy Purchased	CO_2
Hybrid On-Grid	(kWh/Day)	(kW) ($)	($)	($) ($)	(kWh)	kg/Year
Company 1	1868	999,999 871,394	0.1	68,166 0	681,663	430,811
Company 2	728	999,999 339,709	0.1	26,574 0	265,743	167,949

Company 3	1822	999,999 850,292	0.1	66,516 0	665,156	420,378

(b) Scenario 2: PV grid-connected system

The usage of grid-connected solar systems on industrial site rooftops has begun to grow in a number of nations and manufacturing divisions. The ongoing drop in PV prices, as well as the implementation of legislation and synergies that encourage the use of renewable energies, have encouraged industrial ecology and SMEs to invest in these long-term solutions.

Three of these industrial businesses, which operate in diverse regions, were chosen for a technical and economic assessment. Each of these PVs was evaluated based on roof surface availability and the results of carbon balances (ABC) generated as part of the "Tatwir" national program.

The systems measurements analysis seeks to evaluate the performance of grid-connected PV systems, which are used to determine the major metrics such as annual energy production. Table 4 shows the PV systems proposed for the three factories in the Fez region, as well as the installed capacity and system production.

Table 4. PV systems capacities and productions (for the three factories).

Company	Energy Production PV Installed (Kw) (kWh/Year)	
Company 1	250	425,033
Company 2	165	280,522
Company 3	250	425,669

Figure 17 illustrates that the system may generate up to 425,033 kWh of electricity per year for company 1, with a photovoltaic generator accounting for 50.5% of it. 49.5% of balanced electricity is acquired from the grid to be available when needed. Consider 83.2% of total electricity consumption utilized to ensure the AC load, compared to 16.8% sold to the grid.

As a result, most energy purchases occur during peak hours, when prices are at their highest. The usage of batteries can overcome this limitation, but it will incur more expenditures while increasing the COE and inverter capacity. The COE for the PV-grid-only system is 0.054 USD per kWh. However, the NPC for this system is $572,940. Furthermore, Table 5 shows the cost breakdown of project components over time. Thus, according to our comparison tests, the proposed system emits the least amount of greenhouse gases, with 263,475 kg CO2 per year.

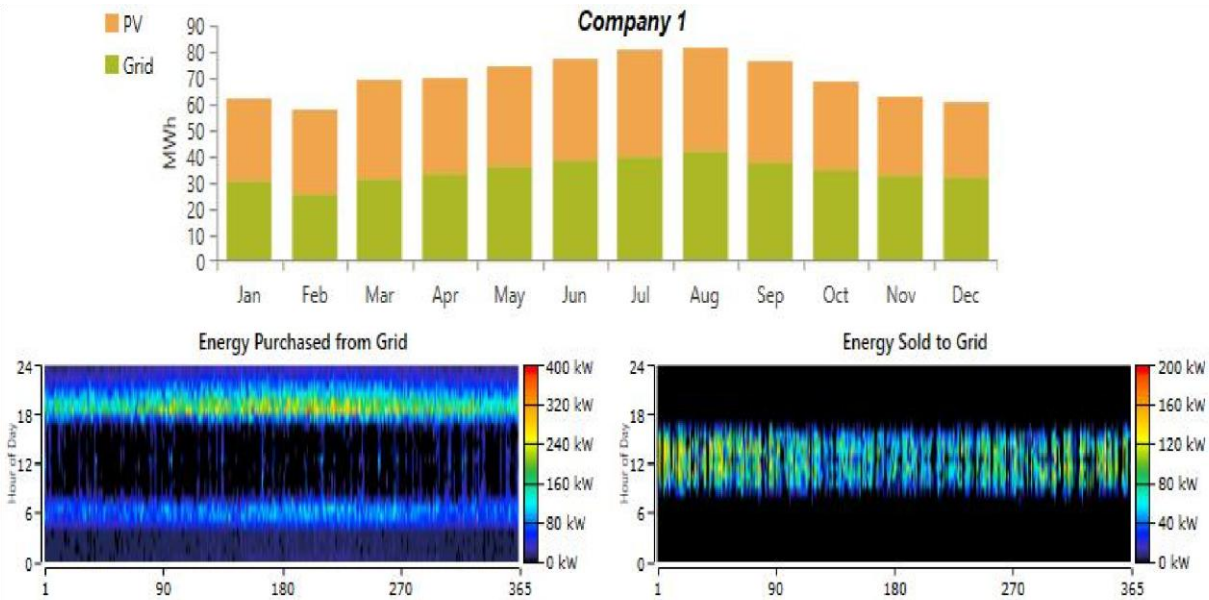


Figure 17 . Company 1 system production, 2021.

Table 5. The cost summary of the project in the lifetime

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)

Generic/flat plate PV	75,000.00	0	31,958.39	0	0	106,958.39
Grid	4500.00	0	445,014.95	0	0	449,514.95
System Converter	12,292.50	5129.23	0	0	954.71	16,467.02
System	91,792.50	5129.23	476,973.34	0	954.71	572,940.36

Accordingly, energy acquisitions occur during peak hours, wherein the prices reach their maximum levels. The implementation of batteries can alleviate this limitation; however, it will incur additional costs and elevate both the COE and the inverter's capacity. The COE for the PV-grid only system is $0. 054 for 1 kWh. Nevertheless, the NPC of the grid for this system is $572,940. Furthermore, Table 5 illustrates the cost summary of components throughout the project's lifetime. Thus, in accordance with our comparative studies, the proposed system exhibits the least resistance in greenhouse gas emissions, with 263,475 kg CO_2/year.

For Company 2, an optimized system featuring a PV array with a capacity of 165 kWp has been established for this organization. The PV array has been connected to the grid through an inverter rated at 135 kW. Over the course of 4382 hours, this PV-installed capacity can generate an annual output of 280,522 kWh, demonstrating a substantial renewable fraction of 65. 2% (Figure 18 a,b).

The electricity produced is utilized in the following manner: 63. 9% (265,720 kWh/year) is consumed by the end-users, 36. 1% (149,875 kWh/year) is sold back to the grid, and 5% has been accounted for as transmission losses. Consequently, Figure 19 illustrates the net energy purchased monthly by the installed model. As noted, the system proves to be more lucrative during the warmer month, with a total net energy acquisition of 76 kWh. Therefore, the total initial investment for the model is established at USD $49,500. The system's lifespan is considered as 25 years, with an average efficiency of 90%.

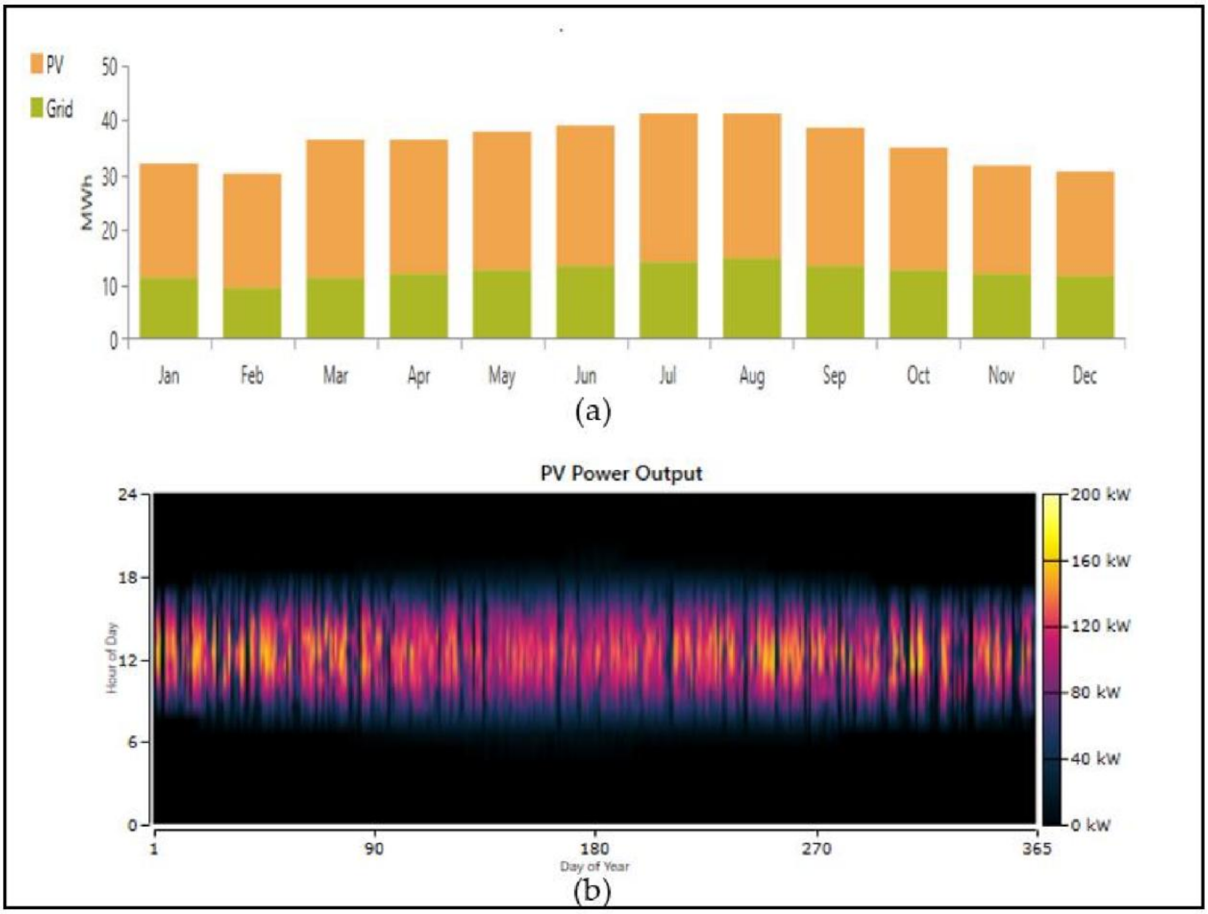


Figure 18 . Company 2 production profiles. (**a**) monthly PV production, (**b**) the PV hourly production.

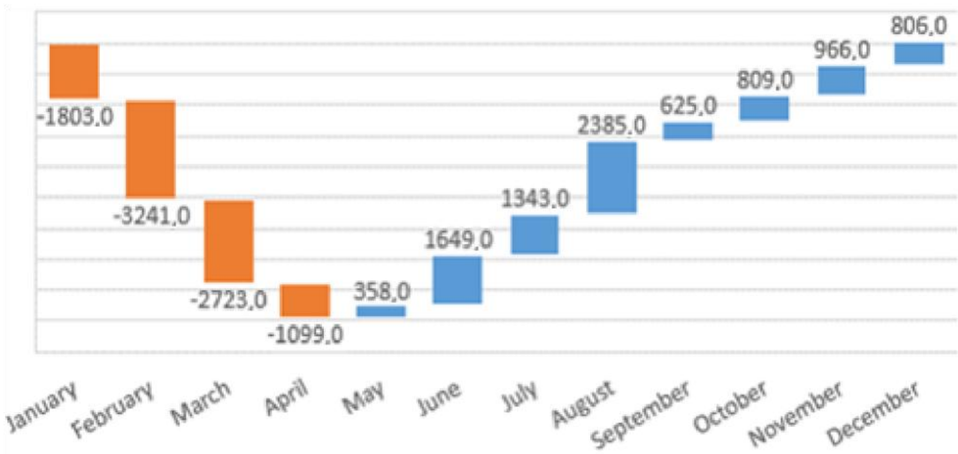


Figure 19 . Annual production purchases profile.

The simulation results demonstrate appealing economic parameters, featuring an LCOE of 0. 034 \$/kWh and a NPC parameter of \$181,863. As illustrated in Figure 20, the total NPC can be validated by the substantial capital investment in PV and the O&M costs associated with the grid connection. Overall, the proposed model represents a user-friendly and optimal solution, yielding the lowest carbon emissions of 94,769 CO2 kg/year.

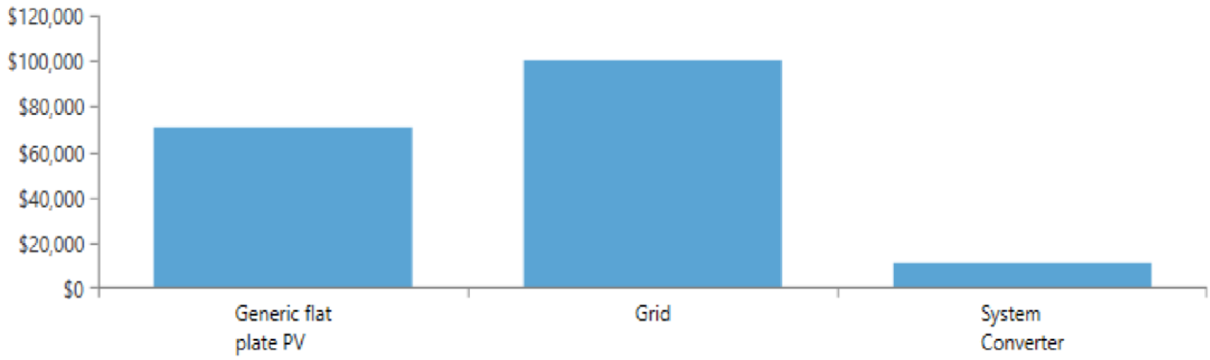


Figure 20 . Summary on investment costs.

Moreover, to illustrate the impact of climatic variations and solar radiation, we have reached a consensus to install the identical photovoltaic capacity (250 kW) for sites 1 (company 1) and (company 3), considering that their energy requirements are comparable and nearly the same (1868; 1. 822 kWh, respectively). The distance that separates the two sites is 26 km. The monthly production profile of the proposed system is depicted in Figure 21, and the renewable penetration is approximately 49. 9%. In contrast, the volume of carbon generated amounts to 255. 670 kg/year.

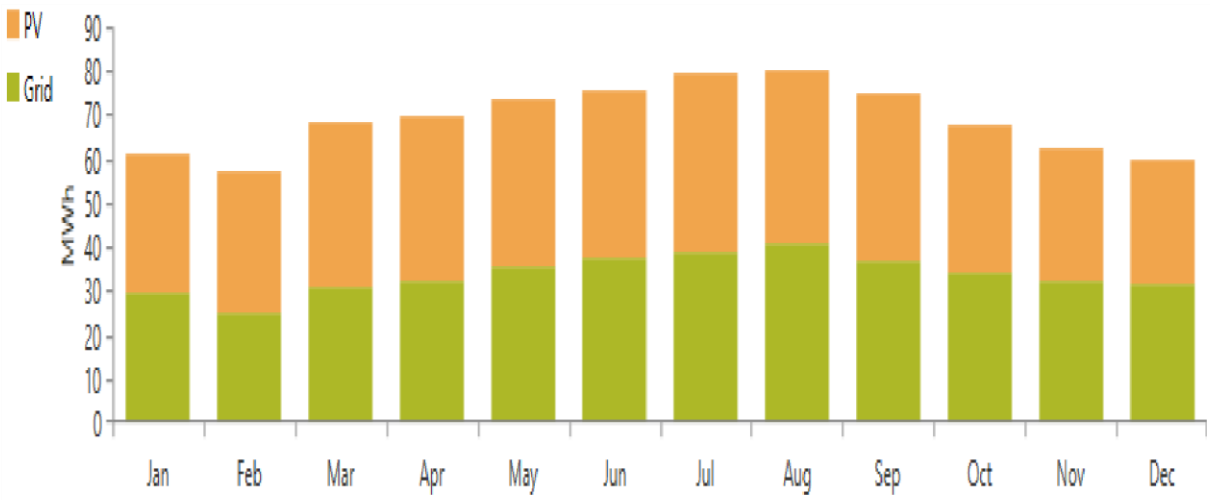


Figure 21 . Monthly renewable production for company 3.

The LCOE produced by the system installation is $0. 05 in contrast to $0. 03 for site 2, even with the climatic conditions and maximum output of site 3. This can be attributed to the electricity purchase price, which is comparatively low in Morocco, and similarly, the volume sold is injected during peak hours. In this scenario, 82% (665. 030 kWh/year) of the produced energy is utilized by the users, while 17. 7% (142. 684 kWh/year) is returned to the grid. Correspondingly, Figures 15 and 16 illustrate the profile of energy exchanges with the network and an overview of the system's cash flow. Overall, the thorough evaluation of the results indicates that PV grid systems are more effective, advantageous, and environmentally friendly when compared to the conventional system (only-grid) that is predominantly used. Moreover, it has been noted that decreasing the initial installation expenses (which encompass the capital cost of PV, connection fees, and other related costs) can significantly lower the cost of electricity (COE).

Additionally, it has been recognized that radiation is a crucial factor in the economic feasibility of this system.

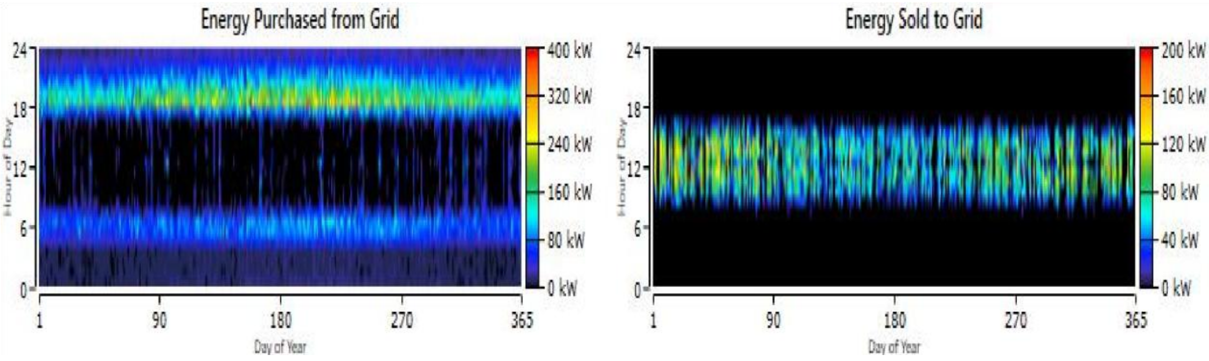


Figure 22 . Energy exchange with the grid for company 3.

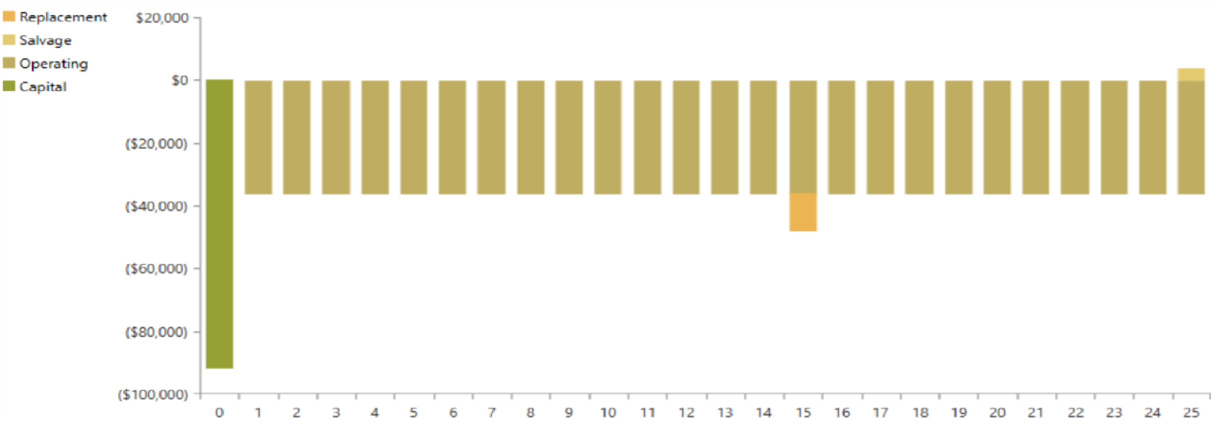


Figure 23 . Summary of the system's cash flow.

5.2. Optimal Decisions for Other Zone Company :

The ideal sizing method implemented for the representative case study of Fez is applied to the different industrial locations examined, considering the technology and the type/number of inverters as well as the angle of the photovoltaic modules. The primary aim is to compare the performance metrics derived from the earlier three main sites in Fez city with those documented under diverse climatic conditions and geographical settings, and additionally to provide a comprehensive study of the majority of textile industrial sites in Morocco. For each site, we provided various scenarios analyzing different factory sizes and demands to address all climatic and functional influencing factors. A summary is included in Table 6.

A power capacity of 8. 88 MW constitutes the total energy installed across seven cities in Morocco, represented by 27 various textile factories that currently exist. This research focuses on the new Moroccan strategic vision aimed at the decarbonization of the industrial sector, where an annual total of 8484. 65 tonnes of CO2 can be mitigated. Furthermore, the energy outcomes indicate that the arid regions typically possess sufficient solar radiation, enabling an efficient performance factor for photovoltaic power plants, thereby increasing the renewable energy fraction. This situation elucidates the appealing levelized costs of electricity (LCOEs) for these specific regions. The payback period is considered reasonable and optimal across all examined sites, not exceeding a threshold of 4 years, with an average duration of 2. 6 years, and extending to 4. 5 years in certain cases. This metric is influenced by multiple parameters, as outlined in Table 6. It is contingent on the size of the site, the initial capital investment, and the solar fraction (renewable), which depends on the climatic conditions specific to the site as well as the operating expenditures. The monthly distribution of photovoltaic production is consistent across all plants (for example, Casa). This uniformity is replicated across all of the plants. It is attributed to the identical climatic conditions inherent to the geographical region in which they are situated. The variation in power output is related to plant size and the specific installation proposed; however, all plants exhibit a similar performance pattern (peak and decline).

Table 6. Summary results for different factories.

Cities and Main COMPANIES		Pv (kW)	Converter (kW)	Production (kW/Year)	COE ($)	NPC ($)	Simple Payback (Year)	Operating Cost ($)	Initial Cost ($)	RF %	Saved CO_2 (kg/Year)
Casablanca	1	554	750	938,907	0.069	1.91 M	2.88	132,541	215,625	39.9	469,232
	2	300	246	508,739	0.057	761,546	2.93	51,028	109,235	46.7	211,753
	3	120	97.7	203,496	0.053	264,823	3.18	17,089	46,365	50	78,000
	4	604	507	1,024,262	0.084	5.01M	2.39	374,756	216,105	21	606,241
	5	75	62	127,185	0.062	221,564	3.14	14,931	30,695	43.6	56,821
	6	40	32.5	67,832	0.043	60,573	2.17	3295	3295	59.1	20,372
	7	50	40.4	84,790	0.05	96,304	3.75	5819	21,932	53.7	43,755
	8	65	53	110,227	0.043	100,185	3.74	5711	27,178	58.2	34,009
Tanger	1	650	514	1,068,053	0.069	2.44 M	2.67	172,929	231,988	36.8	539,373
	2	320	262	525,811	0.07	1.24 M	3.01	88,228	116,203	36.1	268,872
	3	520	426	854,443	0.066	1.74 M	2.75	120,578	186,078	39.7	409,229
	4	350	282	575,106	0.049	642,671	2.84	40,385	126,416	53.2	200,435
	5	350	285	575,100	0.06	955,512	2.91	64,845	126,845	44.3	250,038
	6	65	52.6	106,514	0.035	70,613	3.02	3400	27,154	64.4	26,994
	7	75	60	123,237	0.066	244,172	3.16	16,707	30,954	40.5	58,046
Meknes	1	45	37	76,477	0.024	31,455	4.63	26,200	20,214	72	15,060
	2	45	39	76,470	0.084	356,677	4.75	26,310	20,346	22	45,112
	3	50	40	84,974	0.047	88,269	4.67	5189	21,934	55.6	28,211
Salé	1	120	98	206,210	0.06	340,123	2.95	22,977	46,398	44.6	90,502
	2	150	124	257,762	0.063	473,073	2.82	32,551	56,959	42.1	119,551
	3	175	144	300,722	0.075	863,102	2.35	62,385	65,618	31.6	165,125
Marrakech	1	920	787	1,556,028	0.093	20.3 M	2.37	1.56 M	327,736	8.7	1,476,360
Agadir	1	650	553	1,195,707	0.093	15.1 M	2.18	1.16 M	232,704	10	716,795
	2	460	379	846193	0.063	1.53 M	2.46	106,910	165,210	42.1	369,420
	3	560	474	1,030,148	0.087	6.7 M	2.09	508,371	200,960	16.3	615,858
Settat	1	920	751	1,549,333	0.096	42.6 M	2.37	3.30 M	325,559	5%	927,136
	2	650	536	1,094,637	0.082	4.81 M	2.41	358,412	231,683	22.8	642,354

5.3. Sensitivity Analysis :

To enhance the understanding of the feasibility of PV grid systems, this section seeks to examine the dynamics of performance and financial model outcomes. Therefore, sensitivity analysis is conducted to assess the viability of the third system proposed to meet an average daily requirement of 1868 kWh.

The sensitivity analysis entails assigning multiple values to one or more input variables to explore the correlation between the input variables and the resulting metrics. In the simulations developed and sensitivity analysis conducted, several parameters were subjected to dynamic variability, with radiation ranging from [4: 4. 5: 5: 5. 5] kWh/m2/day, to verify the system's viability across varying locations in Morocco. As illustrated in Figure 24 , solar variation has a significant impact on financial results.The sensitivity analysis undertaken considers the variability of economic variables (inflation, discount rate). For example, with a fixed inflation rate of 5%, an increase in the discount rate from 8% to 12% will raise the COE from 0. 053 to 0. 055 $/kWh. Consequently, the NPC decreases from 689,664 to $543,837.

Inflation further influences the COE and NPC. As depicted in Figure 25 , transitioning from an inflation rate of 0% to 10% will reduce the COE by 0. 06 $/kWh while increasing the NPC from $572,940 to $1,670,000. It is important to note that these economic parameters also affect the technical performance and capacity of the components.

Otherwise, the present study conducted an examination of the system design's flexibility, as depicted in Figure 26. Therefore, expanding the capacity of installed photovoltaic (PV) plants can guarantee a low Levelized Cost of Energy (LCOE) and a high renewable fraction; however, it will incur financial expenses due to the augmented inverter capacity. Accordingly, it can be concluded that PV/grid systems are both flexible and efficient, and they can be implemented in the industrial textile sector, achieving a low COE of $0. 02 per kWh.

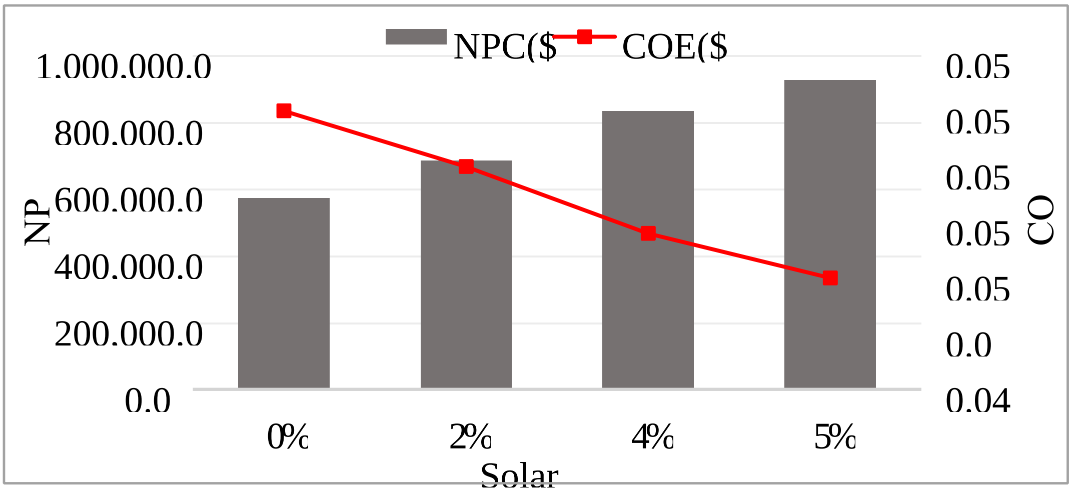


Figure 24 . Solar radiation effects on COE and NPC.

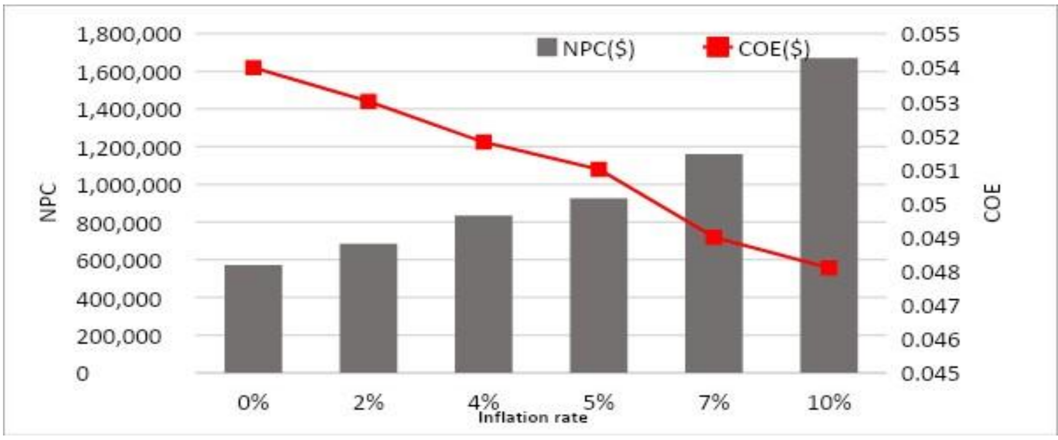


Figure 25 . Inflation effects on COE and NPC.

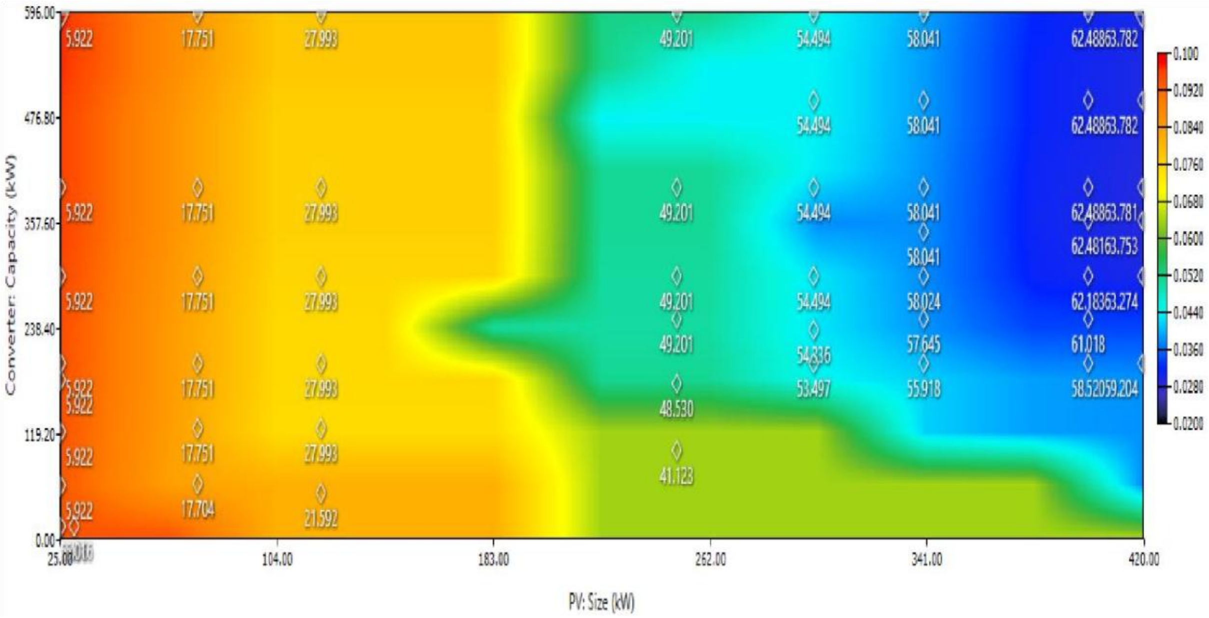


Figure 26 . Effects of design parameters on COE and Renewable Fraction.

As previously calculated, the daily load of the chosen company is deemed to be 1868 kWh/day. To more effectively account for the dynamic characteristics of the loads and by generalizing the suggested solution for the other companies examined, the energy demands are varied from 850 kWh/day to 2500 kWh/day. The performance of the total NPC and COE has been evaluated correspondingly. As illustrated in Figure 27, the COE and NPC of the proposed model rose with increasing loads and declined for lower energy requirements.

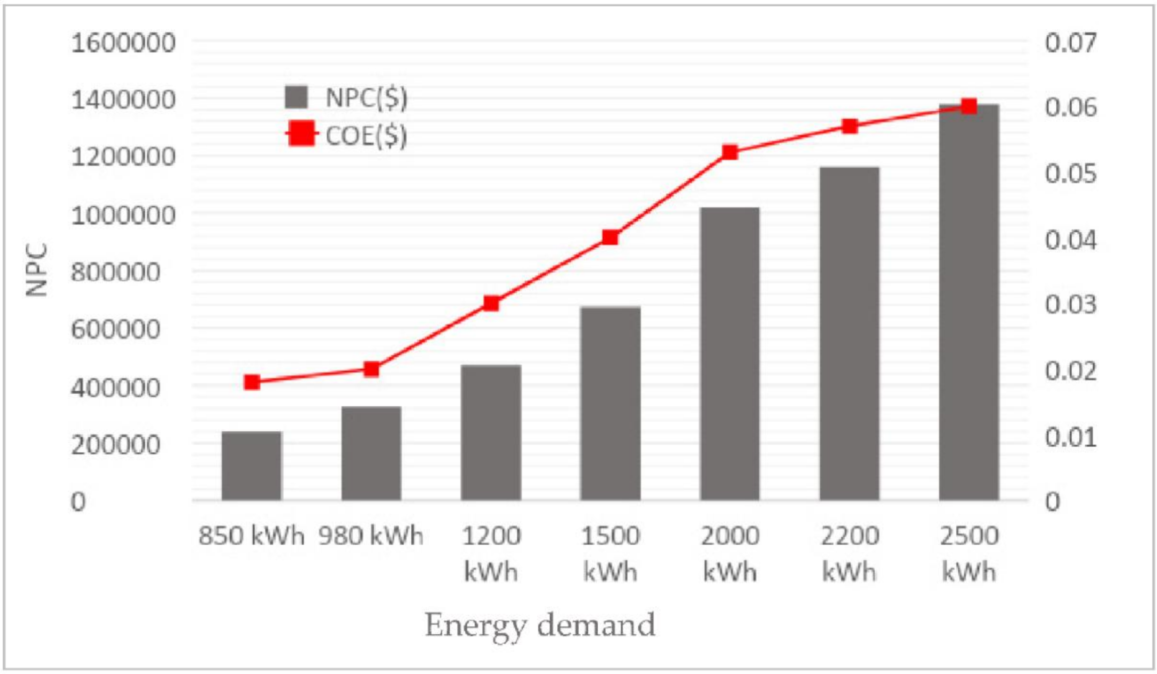


Figure 27. Effects of variability of loads on COE and NPC.

Summary :

The advanced decarbonization of the electricity sector and the deployment of renewable energies create a favorable environment for industrial activities. Achieving a deep decarbonization of the electricity mix by 2040 and 2050 with reductions of 70% and 80%, respectively, is an essential and entirely feasible first step. However, a substantial reduction in industrial emissions necessitates measures that extend beyond the greening of the electricity mix and encompasses a variety of initiatives, including energy efficiency, low-carbon electricity, heightened electrification of applications, energy substitution, source material reduction, material reuse and recycling, as well as the digitization of industrial technologies and practices (such as automation and digitization of processes, the Internet of Things, and machine-to-machine communication, among others). The rapid and ongoing decline in the costs associated with renewable energy and storage substantiates the path being pursued by Morocco. This trajectory facilitates the adoption of highly ambitious decarbonization strategies that focus on the production of green electricity and hydrogen. A renewable energy contribution of 70% by 2040 and 80% by 2050 within the electricity mix in terms of energy and capacity is attainable given the existing technologies and cost projections. Exceeding these percentages could incur significant additional expenses; however, advancements in technology anticipated over the coming decades may enable countries to successfully realize their decarbonization and energy transition objectives.

Chapter 6 : Suggestions for sustainable development of new energy industry

6.1 Analysis of bottlenecks restricting the sustainable development of Morroco's new energy industry :

The sustainable development of Morocco's new energy sector encounters several obstacles that impede its advancement, despite the nation's firm commitment to renewable energy. One significant challenge is the limited energy storage capacity, which constrains the effective utilization of solar and wind energy due to their intermittent nature. Moreover, the substantial initial investment costs associated with renewable energy infrastructure present financial restrictions, particularly regarding private sector engagement. Insufficient grid infrastructure further hinders large-scale integration of renewable energy into the national grid, resulting in inefficiencies in energy distribution. Policy and regulatory impediments, including bureaucratic delays and inadequate incentives for renewable energy adoption, also decelerate the transition process. In addition, technological dependence on foreign expertise and equipment elevates costs and diminishes local innovation. Addressing these obstacles through enhanced energy storage solutions, improved grid modernization, financial incentives, and local capacity building will be vital for ensuring Morocco's successful transition to a sustainable energy future.

6.1.1 Lack of core technologies and insufficient innovation capabilities :

The development of Morocco's new energy sector encounters significant obstacles due to the absence of fundamental technologies and inadequate innovation capabilities, which impede its potential to compete in the international renewable energy market. While the nation has made considerable strides in the adoption of solar and wind energy, a substantial portion of the technology utilized in large-scale initiatives, such as the Noor Ouarzazate Solar Complex, is sourced from foreign manufacturers. This dependency on external expertise and resources constrains Morocco's capacity to cultivate a self-sufficient energy sector and diminishes the economic advantages that could stem from local manufacturing and technological progress. The lack of a robust domestic research and development ecosystem further intensifies this dilemma, as Moroccan institutions and companies frequently lack the requisite infrastructure and funding to cultivate cutting-edge innovations in energy storage, grid integration, and smart energy systems.

Moreover, the inadequate collaboration among universities, research centers, and industry stakeholders hinders the development of indigenous technological solutions. Numerous Moroccan universities engage in energy-related research; however, the results are seldom translated into commercially feasible technologies owing to restricted funding, a scarcity of skilled researchers, and an underdeveloped technology transfer ecosystem. Furthermore, the limited number of patents and scientific publications pertaining to renewable energy in Morocco signifies a deficiency in innovation when compared to leading countries in the sector. The nation also grapples with a shortfall of venture capital and industrial policies that promote startups and local enterprises in developing and commercializing novel energy technologies.

Additionally, a critical challenge is the reliance on foreign technology providers, particularly from Europe and China, which frequently constrains Morocco’s ability to customize and tailor energy solutions to meet its specific environmental and economic requirements. This dependence also renders the country susceptible to geopolitical and economic fluctuations, which may influence technology transfer agreements and investment inflows. Absent a solid local foundation in advanced energy technologies such as next-generation solar panels, energy storage solutions, and hydrogen production, Morocco risks becoming a passive consumer rather than an active innovator in the global energy transition. To surmount these challenges, Morocco must commit to investing in domestic RandD programs, fostering public-private partnerships, and enacting policies that encourage technological innovation, thereby ensuring a sustainable and competitive future for its new energy sector.

6.1.2 the situation of new energy consumption :

Despite the advancements in power generation, patterns of energy consumption and challenges persist. Morocco has encountered increasing energy demand resulting from rapid urbanization, industrial expansion, and population growth. However, as the country continues to depend on imported fossil fuels, particularly coal and natural gas, it confronts challenges in realizing a completely sustainable energy transition. While renewable energy capacity is growing, the integration of these sources into the national grid presents challenges due to their intermittent nature. Energy storage solutions, such as battery storage and pumped hydro storage, remain underdeveloped, constraining Morocco's ability to stabilize energy supply during times of low solar and wind output. Furthermore, modernization of the transmission and distribution infrastructure is necessary to efficiently accommodate the increasing share of renewable energy.

In terms of consumption, Morocco has undertaken efforts to promote energy efficiency and sustainability through initiatives such as the National Energy Efficiency Strategy, which seeks to diminish energy consumption in sectors including transportation, industry, and buildings. Additionally, the country is investigating opportunities for green hydrogen production, utilizing its extensive solar and wind resources to potentially become a future exporter of clean energy to Europe and other regions. However, the substantial costs associated with renewable energy infrastructure, the scarcity of local technological expertise, and policy and regulatory challenges continue to present significant obstacles to achieving a fully renewable-powered energy system. To ensure a sustainable energy future, Morocco must persist in investing in grid modernization, enhancing energy storage capabilities, and nurturing domestic innovation in the renewable energy sector.

Year	Total Electricity Production (TWh)	Renewable Energy Production (TWh)	Share of Renewables (%)	Breakdown of Renewable Sources (TWh)
2015	31.22	4.81	15.4%	Hydro: 2.28, Wind: 2.52, Solar: 0.01
2019	41.65	7.93	19.0%	Hydro: 1.65, Wind: 4.70, Solar: 1.58
2020	40.06	7.40	18.5%	Hydro: 1.29, Wind: 4.59, Solar: 1.52

Table 7 . Morocco's renewable energy power generation and consumption between 2015 and 2020

Between 2015 and 2020, Morocco's renewable energy sector witnessed substantial growth, propelled by strategic investments in solar and wind energy. The total production of renewable energy increased from 4. 81 TWh in 2015 to 7. 93 TWh in 2019, representing a 65% escalation within just four years. This growth was predominantly attributed to the development of large-scale renewable energy initiatives, such as the Noor Ouarzazate Solar Complex and various wind farms throughout the nation. Wind energy generation ascended from 2. 52 TWh in 2015 to 4. 70 TWh in 2019, illustrating Morocco's strong commitment to exploiting its wind capabilities. Moreover, solar energy experienced a striking enhancement, rising from a mere 0. 01 TWh in 2015 to 1. 52 TWh in 2020, as Morocco continued to augment its photovoltaic and concentrated solar power (CSP) capacities.

Nevertheless, hydropower production diminished from 2. 28 TWh in 2015 to 1. 29 TWh in 2020, chiefly due to variable rainfall patterns and water shortages, which impacted the operational efficiency of hydroelectric facilities. The COVID-19 pandemic in 2020 caused a temporary reduction in overall electricity demand, leading to a slight decrease in renewable energy output in comparison to 2019. Despite this minor hindrance, Morocco sustained a significant portion of renewables in its electricity mix, with renewable energy constituting 18. 5% of total electricity production in 2020, as opposed to 15. 4% in 2015.

6.1.3 Ecological issues in the development of new energy industries :

The development of new energy industries in Morocco, although crucial for decreasing reliance on fossil fuels and alleviating climate change, presents numerous ecological challenges that must be resolved to ensure sustainable growth. Large-scale solar and wind power initiatives necessitate considerable land use, which can result in habitat loss, biodiversity disruption, and alterations in local ecosystems. For example, the establishment of solar farms, such as the Noor Ouarzazate Solar Complex, requires the clearance of extensive land areas, potentially impacting native flora and fauna. Likewise, wind farms, particularly in areas like Tarfaya and Tangier, can influence bird and bat populations due to collision hazards with turbine blades and modifications in migration patterns.

Another significant ecological concern is the water consumption in concentrated solar power (CSP) facilities. CSP technology, which is extensively utilized in Morocco, demands substantial quantities of water for cooling and cleaning solar mirrors, imposing stress on water resources in already arid regions. Given Morocco's limited freshwater resources and recurrent droughts, the proliferation of CSP plants could worsen water scarcity if not managed effectively through water recycling or dry-cooling technologies.

Furthermore, the production and disposal of renewable energy infrastructure raise environmental issues. The fabrication of solar panels and wind turbines entails the extraction of rare earth metals, which can cause soil and water contamination if not sourced responsibly. Additionally, the eventual decommissioning of renewable energy infrastructure presents waste management challenges, as recycling technologies for solar panels and wind turbine blades remain poorly developed on a global scale.

To tackle these ecological challenges, Morocco must enforce sustainable land-use planning, establish wildlife protection measures, and invest in water-efficient technologies. Moreover, the implementation of circular economy principles, such as recycling and repurposing energy components, can aid in minimizing the environmental footprint of the new energy sector. By embedding ecological considerations into its renewable energy policies, Morocco can harmonize clean energy expansion with environmental conservation, thereby ensuring a genuinely sustainable energy transition.

6.2 Strategies and suggestions for the sustainable development of Morocco's new energy industry :

1. Strengthening Technological Innovation and Local Manufacturing

One of the primary challenges in Morocco's new energy sector is its reliance on foreign technology for solar panels, wind turbines, and energy storage solutions. To promote sustainability, Morocco ought to concentrate on developing local manufacturing capabilities in renewable energy technologies. Investing in research and development (R&D) can cultivate domestic expertise, diminish reliance on imports, and create a knowledge-based economy. Encouraging public-private partnerships (PPPs) with global technology leaders can assist in facilitating technology transfer, ensuring that Morocco can develop and maintain its own energy infrastructure effectively.

Furthermore, Morocco must augment its innovation capabilities in energy storage solutions, such as advanced lithium-ion batteries, hydrogen storage, and pumped hydro storage systems. Given that renewable energy sources like solar and wind are intermittent, effective storage technologies will be vital in ensuring grid stability and energy security. Investment in smart grid technologies and artificial intelligence (AI)-based energy management systems can also optimize energy distribution and reduce transmission losses.

2. Expanding Renewable Energy Infrastructure and Grid Modernization

To sustain the swift growth of renewable energy, Morocco must expand and modernize its energy grid. The integration of large-scale solar and wind projects necessitates a more flexible and resilient power grid capable of managing fluctuations in supply and demand. Upgrading transmission and distribution networks, implementing smart grid technologies, and bolstering cross-border energy interconnections with Europe and North Africa will enhance the efficiency and reliability of renewable energy distribution.

Moreover, Morocco should concentrate on decentralized energy generation, promoting distributed solar photovoltaic (PV) systems for households, industries, and commercial buildings. Encouraging microgrids and off-grid solutions for rural areas will increase energy access while alleviating the pressure on the national grid. Developing a regulatory framework for energy prosumers (individuals and businesses that both produce and consume electricity) will incentivize self-sufficient energy solutions and enhance energy resilience.

3. Enhancing Financial Incentives and Green Investment

The expansion of Morocco's new energy industry necessitates substantial financial resources, thereby making investment in renewable energy financing mechanisms essential. The government should persist in providing tax incentives, subsidies, and low-interest loans for renewable energy projects, thereby encouraging private sector participation. Additionally, Morocco can take advantage of international climate funds, such as the Green Climate Fund (GCF) and the World Bank's renewable energy programs, to support large-scale projects.

To attract increased private investment, Morocco should establish a green bond market, enabling investors to finance sustainable energy projects through dedicated financial instruments. Moreover, carbon pricing mechanisms and renewable energy credit systems can be introduced to render fossil fuels less appealing while encouraging investment in clean energy solutions. Public-private partnerships (PPPs) and foreign direct investment (FDI) in renewable energy should be actively promoted through transparent policies and investor-friendly regulations.

4. Addressing Environmental and Social Sustainability

While renewable energy projects possess considerable advantages, they must be executed in an environmentally and socially responsible manner. The establishment of large-scale solar and wind farms may disrupt ecosystems, resulting in biodiversity loss and conflicts over land use. Consequently, Morocco should conduct environmental impact assessments (EIAs) for all energy initiatives, ensuring minimal ecological disturbance. The advancement of floating solar farms on reservoirs and the integration of agro-photovoltaic systems (which combine solar panels with agricultural land) can assist in reconciling energy production with land preservation.

Water consumption presents another significant concern, particularly for concentrated solar power (CSP) plants that necessitate substantial quantities of water for cooling purposes. Morocco should allocate resources towards dry-cooling technologies and investigate the utilization of desalinated water to mitigate the effects on local water supplies. Furthermore, policies ought to promote the recycling and disposal of solar panels and wind turbine components, ensuring that waste generated from renewable energy infrastructure does not pose future environmental risks.

On the societal aspect, Morocco should prioritize job creation and skills development within the renewable energy sector. The establishment of technical training programs and university research centers centered on renewable energy will serve to equip the workforce with the requisite skills to bolster industry expansion. Ensuring that local communities derive benefits from renewable energy projects through community-based energy models and profit-sharing mechanisms will promote social acceptance and engagement in the transition towards clean energy.

5. Promoting Green Hydrogen as a Future Energy Solution

Given Morocco’s abundant solar and wind resources, green hydrogen offers a promising pathway for sustainable energy advancement. Morocco is positioned to potentially become a global center for green hydrogen production, providing clean fuel for transportation, industrial uses, and export markets. Investments in electrolysis technology, which transforms renewable electricity into hydrogen, should be prioritized. Establishing strategic alliances with Europe can facilitate Morocco's emergence as a significant supplier of green hydrogen in the international energy market.

Summary :

This chapter discusses and analyzes the bottlenecks that are constraining the sustainable development of Morocco's new energy industry and provides strategies and suggestions for the sustainable development of Morocco's new energy sector, which requires technological innovation, infrastructure expansion, financial incentives, environmental sustainability, and workforce development. To reduce dependence on foreign technology, Morocco must dedicate resources to research and development (R&D), promote local production of renewable energy components, and enhance energy storage solutions, such as batteries and green hydrogen. The modernization of the national grid with intelligent technologies and the enhancement of cross-border energy interconnections will strengthen energy reliability. Moreover, public-private partnerships (PPPs), green financing initiatives, and carbon pricing frameworks can encourage investment in the sector. Ensuring environmental protection through sustainable land management and water-efficient technologies will mitigate ecological impacts. Ultimately, training programs in renewable energy engineering will aid in cultivating a skilled workforce capable of driving future innovations. Through the implementation of these strategies, Morocco can achieve a sustainable, resilient, and energy-independent future.

Research Conclusions :

The advancement of the new energy sector is closely associated with the adjustment of the economic structure, the safeguarding of the ecological environment, and the welfare of the nation and its citizens. Consequently, attaining sustainable development and decarbonization is an unavoidable choice. This paper examines this matter, and the principal conclusions are as follows:

Firstly, through the analysis of the current state of the new energy sector, we have identified that, despite the domestic new energy industry having commenced development later than others, the government's support has facilitated rapid growth in the sector. As a result, the scale of the industry has enlarged and the benefits derived from the industry have improved; however, the macroeconomic environment for industrial advancement is mixed. Development, enhanced policy support, and steady progress in infrastructure construction serve as motivators for industrial growth, yet these efforts are influenced by the European debt crisis and overcapacity, which have led to a gradual weakening of the market in developed nations, the prevalence of trade protectionism, and the escalation of trade tensions. This situation presents a challenge to industrial progress.

Secondly, this paper also emphasizes the significance of decarbonization within the new energy industry sector and positions it as a pathway to attain sustainable development (using textiles as a case study). The textile industry sector in Morocco has been selected as a case study. It is reasonable to assert that the findings possess validity and applicability to other sectors where challenges to deep decarbonization and emissions reduction are typically elevated. The objective is to illuminate the positive impact concerning the fulfillment of electricity requirements and the decrease of greenhouse gas emissions. It presents a low-carbon industry that is capable of integration into the international market. Furthermore, this work aligns with the strategic direction of present-day Morocco in order to inspire academics, manufacturers, and SMEs to adopt photovoltaic (PV) grid-connected plants and hybrid systems within their strategic, energy, and environmental policies.

A techno-economic feasibility analysis of grid-connected PV for the industrial textile sector across eight different Moroccan locations was conducted. The primary variables, namely NPC, COE, and emissions, were meticulously assessed as fundamental parameters to emphasize the viability of the proposed systems. The results quantify the importance of system integration in the industrial sector, which can exceed 600 kg/year for a medium-sized plant and can surpass 400 kg/year. The proliferation of this usage across all factories in the kingdom is expected to yield significant figures in the reduction of harmful emissions. The avoided emissions in the studied plants in Casablanca surpassed 1500 kg/year and exceeded 1483. 16 tons/year when considering the total plants addressed in this paper. Moreover, the integration of these systems is likely to be effective throughout all industrial locations in Morocco due to the country's favorable climate, particularly benefiting central and semi-arid regions because of their high photovoltaic potential and radiation.

In this regard, Morocco has already taken the initiative in the Subsidies Directive for such decarbonization projects within the industrial sector to encourage participation in the low-carbon national vision. Despite these advancements, there remains considerable work to be accomplished regarding the initiation of additional support and investment programs for the industry, which is currently disheartened following the repercussions of the COVID-19 pandemic. Nevertheless, the crucial element that will enhance the plan is the awareness among stakeholders in this sector of the importance of decarbonization and the substantial energy and economic benefits it can yield and contributing to achieving suistanable development .

Finally, the sustainable development of Morocco’s new energy industry necessitates a multi-dimensional strategy that encompasses technological innovation, infrastructure expansion, financial incentives, environmental sustainability, and workforce development. To mitigate dependence on foreign technology, Morocco must allocate resources toward research and development , encourage local manufacturing of renewable energy components, and improve energy storage solutions such as batteries and green hydrogen. Upgrading the national grid with smart technologies and enhancing cross-border energy interconnections will augment energy reliability. Furthermore, public-private partnerships (PPPs), green financing mechanisms, and carbon pricing policies can draw investment into the sector. Ensuring environmental protection through sustainable land use and water-efficient technologies will reduce ecological impacts. Training programs in renewable energy engineering will assist in cultivating a skilled workforce to drive future innovations. By enacting these strategies, Morocco can attain a sustainable, resilient, and energy-independent future.

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References

1. Munasinghe, M. The sustainomics trans-disciplinary meta-framework for making development more sustainable: Applications to energy issues. *Int. J. Sustain. Dev.* **2002**, *5*, 125–182. [CrossRef]
2. Mana, A.A.; Allouhi, A.; Ouazzani, K.; Jamil, A. Feasibility of agriculture biomass power generation in Morocco: Techno-economic analysis. *J. Clean. Prod.* **2021**, *295*, 126293. [CrossRef]
3. Harbouze, R.; Pellissier, J.-P.; Rolland, J.-P.; Khechimi, W. Rapport de synthèse sur l'agriculture au Maroc. Ph.D. Thesis, CIHEAMIAMM, Montpellier, France, 2019; p. 104. Available online: https://hal.archives-ouvertes.fr/hal-02137637 (accessed on 8 June 2021).
4. Mana, A.A.; Allouhi, A.; Ouazzani, K.; Jamil, A. Toward a Sustainable Agriculture in Morocco Based on Standalone PV Pumping Systems: A Comprehensive Approach. In *Advanced Technologies for Solar Photovoltaics Energy Systems*; Springer: Cham, Switzerland, 2021; pp. 399–433.
5. IEA. *Energy Policies beyond IEA Countries. Morocco 2019*; International Energy Agency IEA: Paris, France, 2019.
6. IEA. *Energy Policies beyond IEA Countries, Report 2021*; Royal Institut for Stategical Studies: Rabat, Morocco, 2021.
7. Textiles Sector Growing in Morocco|Morocco 2015|Oxford Business Group. Available online: https://oxfordbusinessgroup.com/analysis/textiles-sector-growing-morocco (accessed on 8 June 2021).
8. Khude, P. A review on energy management in textile industry. *Innov. Ener. Res.* **2017**, *6*, 1463–2576. [CrossRef]
9. Ghaffar, A.; Pumijumnong, N.; Cui, S. Decarbonization action plans using hybrid modeling for a low-carbon society: The case of Bangkok Metropolitan Area. *J. Clean. Prod.* **2017**, *168*, 940–951.
10. Ali, G.; Abbas, S.; Pan, Y.; Chen, Z.; Hussain, J.; Sajjad, M.; Ashraf, A. Urban environment dynamics and low carbon society: Multi-criteria decision analysis modeling for policy makers. *Sustain. Cities Soc.* **2019**, *51*, 101763. [CrossRef]

11. Lallana, F.; Bravo, G.; Le Treut, G.; Lefèvre, J.; Nadal, G.; Di Sbroiavacca, N. Exploring deep decarbonization pathways for Argentina. *Energy Strategy Rev.* **2021**, *36*, 100670. [CrossRef]
12. Domínguez, R.; Vitali, S.; Carrión, M.; Moriggia, V. Analysing decarbonizing strategies in the European power system applying stochastic dominance constraints. *Energy Econ.* **2021**, *101*, 105438. [CrossRef]
13. Le Treut, G.; Lefevre, J.; Lallana, F.; Bravo, G. The multi-level economic impacts of deep decarbonization strategies for the energy system. *Energy Policy* **2021**, *156*, 112423. [CrossRef]
14. Wen, J.; Tao, M. Research on clean energy development strategy of China Three Gorges Corporation based on SWOT framework. *Sustain. Energy Technol. Assess.* **2021**, *47*, 101335.
15. Åsa, L.; Rootzen, J. Brick by brick: Governing industry decarbonization in the face of uncertainty and risk. *Environ. Innov. Soc. Transit.* **2021**, *40*, 189–202.
16. Singh, P.K.; Chudasama, H. Conceptualizing and achieving industrial system transition for a dematerialized and decarbonized world. *Glob. Environ. Chang.* **2021**, *70*, 102349. [CrossRef]
17. Ernst, W.; Boyd, G. Bottom-up estimates of deep decarbonization of US manufacturing in 2050. *J. Clean. Prod.* **2022**, *330*, 129758.
18. Griffiths, S.; Sovacool, B.K.; Kim, J.; Bazilian, M.; Uratani, J.M. Industrial decarbonization via hydrogen: A critical and systematic review of developments, socio-technical systems and policy options. *Energy Res. Soc. Sci.* **2021**, *80*, 102208. [CrossRef]
19. Rajabloo, T.; De Ceuninck, W.; Van Wortswinkel, L.; Rezakazemi, M.; Aminabhavi, T. Environmental management of industrial decarbonization with focus on chemical sectors: A review. *J. Environ. Manag.* **2022**, *302*, 114055. [CrossRef] [PubMed]
20. Baik, E.; Siala, K.; Hamacher, T.; Benson, S.M. California's approach to decarbonizing the electricity sector and the role of dispatchable, low-carbon technologies. *Int. J. Greenh. Gas Control.* **2022**, *113*, 103527. [CrossRef]
21. Bonilla, J.; Blanco, J.; Zarza, E.; Alarcón-Padilla, D.C. Feasibility and practical limits of full decarbonization of the electricity market

with renewable energy: Application to the Spanish power sector. *Energy* **2022**, *239*, 122437. [CrossRef]
22. Luo, S.; Hu, W.; Liu, W.; Xu, X.; Huang, Q.; Chen, Z.; Lund, H. Transition pathways towards a deep decarbonization energy system—A case study in Sichuan, China. *Appl. Energy* **2021**, *302*, 117507. [CrossRef]
23. Samantha, L.; Clarke, A.; Tozer, L. Technical pathways to deep decarbonization in cities: Eight best practice case studies of transformational climate mitigation. *Energy Res. Soc. Sci.* **2022**, *86*, 102422.
24. GIZ; PNUD. Plan Climat National A L'horizon 2030, Ministre de l'Energie, des Mines et du Développement Durable, Chargé du Développement Durable; PNUD: New York, NY, USA, 2020.
25. (PDF) Egm ev-Maroc fr|houda Ammor—Academia.edu. Available online: https://www.academia.edu/36004095/Egm_ev_ maroc_fr (accessed on 8 June 2021).
26. Berraho, A.; Birouk, A.; Menioui, M. Biodiversité et Equilibres Ecologiques. 2006, Volume GT8-4, pp. 119–185. Available online:

http://docplayer.fr/38619597-Biodiversite-et-equilibres-ecologiques.html (accessed on 8 June 2021).

27. GIZ. Recueil Annuel Des Instruments D'appui À L'entreprenariat; GIZ: Bonn, Germany, 2020.
28. AMITH, Portail Officiel de l'Association Marocaine des Industries du Textile et de l'Habillement. Available online: http: //www.amith.ma/portail/PageFR.aspx?id=64 (accessed on 8 June 2021).
29. Moudine, C.; El Khattab, Y. La Délocalisation au Maroc: Etat des Leix et Perspectives de Développement; MPRA: Munich, Germany, 2010.
30. Gargab, F.Z.; Allouhi, A.; Kousksou, T.; El-Houari, H.; Jamil, A.; Benbassou, A. A New Project for a Much More Diverse Moroccan Strategic Version: The Generalization of Solar Water Heater. *Inventions* **2021**, *6*, 2. [CrossRef]
31. Morocco—Countries & Regions—IEA. Available online: https://www.iea.org/countries/morocco (accessed on 6 September 2021).
32. Conti, J.; Holtberg, P.; Diefenderfer, J.; LaRose, A.; Turnure, J.T.; Westfall, L. *International Energy Outlook 2016 with Projections to 2040*; USDOE Energy Information Administration (EIA): Washington, DC, USA, 2016.
33. La Recette Marocaine du Développement Durable. Available online: https://www.latribune.fr/economie/international/larecette-marocaine-du-developpement-durable-615152.html (accessed on 8 June 2021).

34. Oualkacha, L.; Stour, L.; Agoumi, A.; Kettab, A. Climate change impacts in the Maghreb region: Status and prospects of the water resources. *Water Land Secur. Drylands* **2017**, 17–25. [CrossRef]
35. Moore, S. Evaluating the energy security of electricity interdependence: Perspectives from Morocco. *Energy Res. Soc. Sci.* **2017**, *24*, 21–29. [CrossRef]
36. L'Agence Marocaine pour L'énergie Durable (Moroccan Agency for Sustainable Energy—Masen). Available online: https://www.masen.ma/10-04-2022 (accessed on 8 June 2021).
37. Bahadori, A.; Nwaoha, C. A review on solar energy utilisation in Australia, Renew. *Sustain. Energy Rev.* **2013**, *18*, 1–5. [CrossRef]
38. Mills, D. Advances in solar thermal electricity technology. *Sol. Energy* **2004**, *76*, 19–31. [CrossRef]
39. Ghenai, C.; Bettayeb, M. Design and optimization of grid-tied and off-grid solar PV systems for super-efficient electrical appliances. *Energy Effic.* **2020**, *13*, 291–305. [CrossRef]
40. Xu, L.; Wang, Y.; Solangi, Y.A.; Zameer, H.; Shah, S.A.A. Off-grid solar PV power generation system in Sindh, Pakistan: A techno-economic feasibility analysis. *Processes* **2019**, *7*, 308. [CrossRef]
41. Golroodbari, S.Z.; Van Sark, W. Simulation of performance differences between offshore and land-based photovoltaic systems. *Prog. Photovolt. Res. Appl.* **2020**, *28*, 873–886. [CrossRef]
42. Obeng, M.; Gyamfi, S.; Derkyi, N.S.; Kabo-bah, A.T.; Peprah, F. Technical and economic feasibility of a 50 MW grid-connected solar PV at UENR Nsoatre Campus. *J. Clean. Prod.* **2020**, *247*, 119159. [CrossRef]
43. Kornelakis, A.; Koutroulis, E. Methodology for the design optimisation and the economic analysis of grid-connected photovoltaic systems, IET Renew. *Power Gener.* **2009**, *3*, 476–492. [CrossRef]
44. Aziz, A.S.; Tajuddin, M.F.N.; Adzman, M.R.; Mohammed, M.F.; Ramli, M.A.M. Feasibility analysis of grid-connected and islanded operation of a solar PV microgrid system: A case study of Iraq. *Energy* **2020**, *191*, 116591. [CrossRef]
45. Jin, C.; Jiang, W. Design of a digital controlled solar water pump drive system for a nano-filtration system. In Proceedings of the 2011 IEEE Ninth International Conference on Power Electronics and Drive Systems, Singapore, 5–8 December 2011; pp. 982–986.

46. Kolhe, M.; Joshi, J.C.; Kothari, D.P. Performance analysis of a directly coupled photovoltaic water-pumping system. *IEEE Trans. Energy Convers.* **2004**, *19*, 613–618. [CrossRef]
47. Elgendy, M.A.; Zahawi, B.; Atkinson, D.J. Comparison of directly connected and constant voltage controlled photovoltaic pumping systems, IEEE Trans. *Sustain. Energy* **2010**, *1*, 184–192.
48. Reges, J.P.; Braga, E.J.; Mazza, L.C.D.S.; De Alexandria, A.R. Inserting photovoltaic solar energy to an automated irrigation system. *Int. J. Comput. Appl.* **2016**, *975*, 8887. [CrossRef]
49. Cardoen, D.; Joshi, P.; Diels, L.; Sarma, P.M.; Pant, D. Agriculture biomass in India: Part 1. *Estimation and characterization, Resour. Conserv. Recycl.* **2015**, *102*, 39–48. [CrossRef]
50. Ashraf, M.A.; Liu, Z.; Alizadeh, A.; Nojavan, S.; Jermsittiparsert, K.; Zhang, D. Designing an optimized configuration for a hybrid PV/Diesel/Battery Energy System based on metaheuristics: A case study on Gobi Desert. *J. Clean. Prod.* **2020**, *270*, 122467. [CrossRef]
51. Makhdoomi, S.; Askarzadeh, A. Optimizing operation of a photovoltaic/diesel generator hybrid energy system with pumped hydro storage by a modified crow search algorithm. *J. Energy Storage* **2020**, *27*, 101040. [CrossRef]
52. Kahwash, F.; Maheri, A.; Mahkamov, K. Integration and optimisation of high-penetration Hybrid Renewable Energy Systems for fulfilling electrical and thermal demand for off-grid communities. *Energy Convers. Manag.* **2021**, *236*, 114035. [CrossRef]
53. Vendoti, S.; Muralidhar, M.; Kiranmayi, R. Techno-economic analysis of off-grid solar/wind/biogas/biomass/fuel cell/battery system for electrification in a cluster of villages by HOMER software. *Environ. Dev. Sustain.* **2021**, *23*, 351–372. [CrossRef]
54. Jumare, I.A.; Bhandari, R.; Zerga, A. Assessment of a decentralized grid-connected photovoltaic (PV)/wind/biogas hybrid power system in northern Nigeria. *Energy. Sustain. Soc.* **2020**, *10*, 1–25. [CrossRef]
55. Humada, A.M.; Hojabri, M.; Hamada, H.M.; Samsuri, F.B.; Ahmed, M.N. Performance evaluation of two PV technologies (c-Si and CIS) for building integrated photovoltaic based on tropical climate condition: A case study in Malaysia. *Energy Build.* **2016**, *119*, 233–241. [CrossRef]
56. Salisu, S.; Mustafa, M.W.; Olatomiwa, L.; Mohammed, O.O. Assessment of technical and economic feasibility for a hybrid PV-wind-

diesel-battery energy system in a remote community of north central Nigeria. *Alex. Eng. J.* **2019**, *58*, 1103–1118. [CrossRef]
57. Elmer, T. A Novel SOFC tri-Generation System for Building Applications; Springer: Berlin/Heidelberg, Germany, 2016.
58. Demiroren, A.; Yilmaz, U. Analysis of change in electric energy cost with using renewable energy sources in Gökceada, Turkey: An island example, Renew. *Sustain. Energy Rev.* **2010**, *14*, 323–333. [CrossRef]
59. Timmerberg, S.; Sanna, A.; Kaltschmitt, M.; Finkbeiner, M. Renewable electricity targets in selected MENA countries–Assessment of available resources, generation costs and GHG emissions. *Energy Rep.* **2019**, *5*, 1470–1487. [CrossRef]
60. Allouhi, A.; Saadani, R.; Buker, M.S.; Kousksou, T.; Jamil, A.; Rahmoune, M. Nationa. *Sol. Energy* **2019**, *178*, 25–36. [CrossRef]