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ARTIFICIAL INTELLIGENCE FOR RENEWABLE ENERGY IN NORTH AFRICA: INNOVATING SMART CITIES

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ABSTRACT

One of the most promising research areas for future smart cities is the field of smart energy. Critical issues related to optimisation, the establishment of adaptive smart grids, and advanced computational techniques enabled by artificial intelligence and machine learning warrant further exploration. Renewable energies (RE) are a major asset for global development in the face of climate change and resource scarcity. Artificial intelligence (AI) offers innovative approaches to organizing activities in response to these ever-changing needs. By integrating AI, we can improve the design, deployment and production of RE infrastructures, addressing multiple challenges and boosting the sector's growth and resilience. Our aim is to explore how AI can optimize renewable energy processes in North Africa, assess its impact on different energy sources, analyze labor productivity in the renewable energy sector and discuss its implications for the future development of smart cities.

1.0 Introduction

A thorough grasp of computers, economics, and social aspects is necessary to overcome the substantial obstacles involved in integrating advanced artificial intelligence (AI) into smart energy systems and grids [1]. An initial domain description and a well-founded research topic statement are necessary for this integration. In an effort to find answers for global development that go beyond the effects of the post-industrial era, academics, industry, and society are all involved in sustainable development initiatives. New procedures and improved literature addressing these developments have resulted from this.
Research on smart cities is interdisciplinary and centers on disruptive technologies and concepts of sustainable economic development, with a particular emphasis on energy management. The energy industry is changing its ways in terms of generation, distribution, storage, and sales to save costs, improve flexibility, and lessen environmental impacts, such as CO2 emissions.

The depletion of conventional fuels during the mid-1970s energy crisis made renewable energy (RE) and resource conservation more important. Concerns over pollution, global warming, and resource depletion grew during the 1980s. For continued environmental and public health protection, the emphasis has switched to renewable energy sources with minimal carbon emissions. By lowering reliance on imports and lowering greenhouse gas emissions dramatically, RE integration provides a self-replenishing substitute for fossil fuels. Nonetheless, it is still difficult to manage RE to satisfy the world's needs for clean energy [2].

Artificial Intelligence (AI) presents a noteworthy prospect for tackling modern-day societal requirements by offering quick prediction, adaptability, capacity for explanation, and symbolic reasoning [3]. AI is revolutionizing global development and the knowledge society by bringing new perspectives to conventional production elements and organizational functions. Energy management and optimization are getting better because to recent developments in neural networks, cognitive computing, and machine learning. Future-generation smart city services are promised by the merging of AI with 5G and sensor networks.

AI in energy systems enables optimization, customizes production and consumption, and necessitates examination of social and economic aspects beyond technological means. An AI-enabled Smart Energy Grid is supported by a number of AI techniques, such as machine learning, data mining, and structured data management. The market for renewable energy is expanding in North Africa. Economic analysis can draw attention to the need for additional funding and incentives. The relationship between renewable energy, sustainability, and economic development makes it imperative to examine social effect and efficiency considerations in smart city research. The utilization of AI's sophisticated machine learning and cognitive computing abilities is crucial in attaining unanticipated efficiencies in smart energy networks.

The purpose of this study is to investigate how AI may improve the efficacy of RE while also advancing sustainability and economic efficiency. The study presents AI-driven RE services as part of the special issue on future smart cities, with the goal of achieving major social impact and enhancing economic efficiency. To put it briefly, the paper examines research on RE, AI, and smart cities and informs a research model that uses AI to enable phased deployment of RE in North Africa. It examines the major variables influencing RE's development in North Africa and considers AI's potential to be a disruptive technology for smart energy infrastructure. The literature review, data presentation, research methodology and findings, conclusions, and recommendations for further study comprise the article's organizational framework.

2.0 Literature review

The energy industry is undergoing major changes that will affect its resilience and growth; renewable energy sources will be essential to the future of global development. Renewable energy sources have significant promise in the face of resource depletion, pollution, and climate change [4]**.** Major changes include variable energy output, improved data management, bidirectional energy flows, and an increased requirement for energy storage are being driven by the growing adoption of renewable energy technology. More sophisticated systems for the generation, transmission, and distribution of energy are required for this shift.

To increase conversion efficiency, it will be necessary to develop technology for energy production, integration, and flow control in isolated networks. Renewable energies can be used in remote places as an alternative to conventional fossil fuel power plants [5]**.** Their primary benefit is that they are not dependent on the erratic prices of fossil fuels. However, efficient techniques for energy production and storage during favourable conditions are necessary due to the unpredictability of renewable energy sources. Forecasting data accurately is crucial to

avoiding inefficiency and unreliability. The main issue is still intermittent power generation, which, if improperly handled, might result in a greater dependency on fossil fuel backup.
Because it depends on erratic weather patterns, the production of energy from renewable sources is by its very nature unreliable. As renewable energy sources proliferate, precise forecasting is essential to preserving supply and demand stability and balancing the electrical system. Producers may incur significant costs due to supply disruptions, and customer demand is unyielding [6]**.** The integration of artificial intelligence (AI) technologies and reliance on more predictable energy sources, such as coal and gas, are necessary to balance the fluctuating renewable energy supply. These costs should be factored into the total opportunity cost of using renewable energy.

While AI has been around since the 1950s, significant advancements in the field first appeared in the 1990s. Three components make up artificial intelligence (AI): learning (using data to improve knowledge and algorithms), recognition (using past experiences to identify situations), and action (carrying out autonomous tasks). Artificial intelligence (AI) is the ability of machines to function well in their surroundings, solve problems in the real world, and make predictions, recommendations, and judgments based on predetermined goals.

AI systems provide a thorough understanding of processes by having the ability to autonomously modify their behavior based on experience and data analysis [7]**.** AI becomes indispensable for decision-making as electrical systems become more sophisticated and involve larger data sets. Artificial Intelligence (AI) has the potential to completely transform the global energy system by assisting in the management of renewable energy sources such as solar and wind. For the grid to function flawlessly and for renewable energy flows to be managed effectively, probabilistic load forecasting is essential. The current energy system is changing to include renewable energy sources and uses sophisticated algorithms to more precisely regulate production, transmission, and consumption.

Large-scale data analysis from intelligent network components will be made possible by AI-driven systems, allowing for real-time decision-making for the best use of available resources [8]**.** These systems are expected to enhance energy efficiency, anticipate changes in energy production and demand, rectify imbalances, avert power outages, and economically optimize grid management [9]**.** But integrating AI also comes with dangers, including those pertaining to labor effects and system security.

AI promises to overcome traditional production constraints, driving economic growth and facilitating environmental and societal development. In the renewable energy sector, AI will transform technologies and job demand, necessitating investment in technical capital and lifelong learning. The industry for renewable energy is experiencing a serious labor shortage as a result of its rapid expansion and inadequate training initiatives. The need for specialized education and training to fill the employment gap in solar, wind, and other renewable technologies is pressing for both governments and industry. Inclusion and diversity promotion are also essential for innovation and supplying the world's energy demands. Resolving these shortages will encourage the sector's economic growth and sustainable energy transitions [10]**.** Developed nations have an advantage due to their skilled workforce.

3.0 Research Methodology, Empirical Investigation, and Principal Discoveries

Our study model is based on the extensive literature review that was provided in the preceding section. The main elements of our research approach are listed below, considering the multidisciplinary nature of our study and our main objective of combining sophisticated computer science with economics and smart city research:

- Understand the macroeconomic contribution to the smart grid and renewable energy discourse.
- Incorporate advanced artificial intelligence components into the research model, recognising AI as a key research area with significant implications for efficiency and performance in smart grids and renewable energy.
- Assessing the collective impact of macroeconomic factors and AI value propositions on resilient Smart Cities research

In the following three subsections, we acknowledge from the outset that the complexity of the phenomenon imposes several limitations on our work.

3.1 Research Model

The literature on the renewable energy (RE) sector and the role of artificial intelligence (AI) has raised concerns in these areas, which have been incorporated into the objectives of our research (Figure 1):

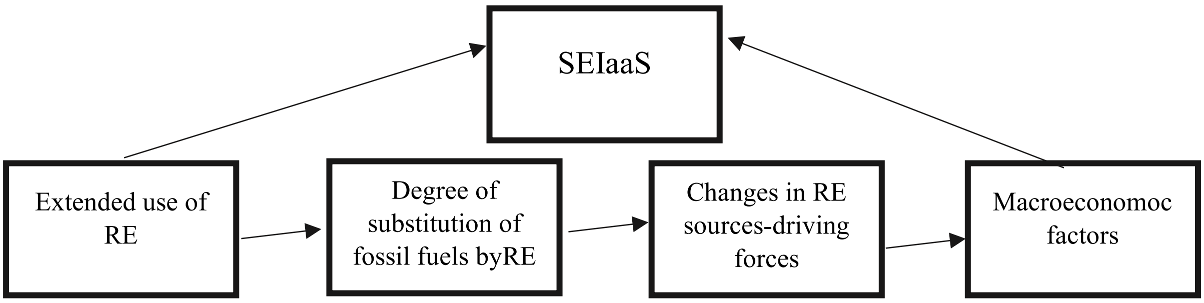

Figure 1: The research model

- The developments and macroeconomic factors indicating the integration of AI in the renewable energy (RE) sector in North Africa.
- The impact on energy management and the implications for future smart cities research resulting from the application of AI in RE (towards Smart Energy Infrastructure as a Service - SEIaaS) in the North African context.

We propose the following hypotheses in an effort to fulfill our primary study goal and determine the consequences of our findings for North African energy management:

- Hypothesis 1: The amount of renewable energy (RE) used and the effectiveness of RE transformation processes along the energy chain, from gross domestic consumption to final energy consumption, have been impacted by changes in gross domestic consumption patterns.
- Hypothesis 2: Because of a number of variables affecting their accessibility and advancement in technology, the makeup of renewable energy sources (such as solar, wind, biomass, etc.) has changed throughout time.
- Hypothesis 3: The macroeconomic variables influencing labor productivity and other changes in the renewable energy sector are different from those affecting the economy overall. There is a correlation between North Africa's investment levels and worker productivity in the renewable energy industry, which affects both sector-specific growth and the region's overall economic performance.

We have used data from international organizations to address the research issues and validate our hypotheses, concentrating on the following indicators specific to North African nations:

- Indicators of Energy Balance: We have employed energy balancing metrics for the countries of North Africa, which are expressed in Mtoe (million tonnes of oil equivalent) and comprise gross onshore consumption, transformation input, transformation output, and final energy consumption. All energy sources, including natural gas, oil and its products, solid fossil fuels, nuclear energy, renewable energy, and biofuels, are included in this set of indicators for measuring energy consumption. Types of renewable energy include geothermal, wind, solar, hydro, biofuels, and renewable trash.
- Economic and Labor Indicators: Measures like GDP per capita, gross value added, total employment, and labor productivity are all examined at the national level and are derived from the Arab Maghreb Union (UMA) and are based on official information from the UMA.
- Renewable Energy Investment: The United Nations Environment Programme Centre is the source of information on renewable energy (RE) investment in North African nations.

Our computations have been based on official statistics:

- In the energy and renewable energy industries, the effectiveness of transformation processes is assessed by comparing the output to input ratio at the time of transformation.
- The ratio of gross value added—a measure of the industry's economic activity—to total employment is used to calculate labor productivity in the renewable energy sector.

3.2 Artificial Intelligence as a Driving Force for Renewable Energy Deployment. North Africa in a Global Context

The development of AI as a new powerful technology and strategy has a profound impact on the field of Smart Energy. The wide range of AI application domains in Smart Energy includes, but is not limited to, the following

- Complex consumer profiling and understanding
- Cutting-edge modeling of consumption patterns and monitoring of demand
- Use of computational neural networks for machine learning techniques in energy optimisation and management
- Using evolutionary algorithms to optimise smart grids
- Progress towards advanced smart grids and dynamic restructuring of cloud energy services
- Integration with IoT and 5G networks
- Development of models and recommendation systems for energy and renewable energy systems
- Establishing interoperability and standardisation across distributed energy networks

In the energy industry, North Africa is becoming a global leader, especially in renewable energy. Given its critical role in improving energy security, protecting the environment, and diversifying energy sources, promoting renewable energy is one of North Africa's main energy policy goals. A thorough legislative framework for controlling energy use and encouraging the use of renewable energy sources is offered by the Renewable Energy Directive (9). It

establishes challenging goals: by 2018, 10% of energy used for transportation will come from renewable sources, and 20% of gross final energy consumption will come from renewable sources. It acknowledges the significance of fostering economic growth through innovation and sustainable energy regulations.
The North African area embraced an inclusive, sustainable, and intelligent growth strategy in 2010. But how it is implemented differs from nation to nation. The implementation of the policy has been difficult in Libya and Mauritania because of political unrest and economic difficulties. Morocco, Tunisia, and, to a lesser extent, Algeria have advanced more, particularly in sectors like innovation promotion and renewable energy. [11]. These three priorities are interlinked, as the strategy aligns investment objectives in research and development, employment, education and poverty reduction with climate and energy objectives. The objective of promoting a more efficient and greener economy is supported by three specific targets: to reduce greenhouse gas emissions by 20% compared to 2000 levels, to increase the share of energy from renewable sources in final energy consumption to 10% by 2018, and to improve energy efficiency by 10% by 2018.

In 2018, a new directive came into force, setting a new target for renewable energy of at least 32% of energy consumption by 2030. This directive includes a provision for upward revision in the event of significant cost reductions in renewable energy production. This new target aims to stimulate investment in and development of clean and flexible technologies related to renewable energy.

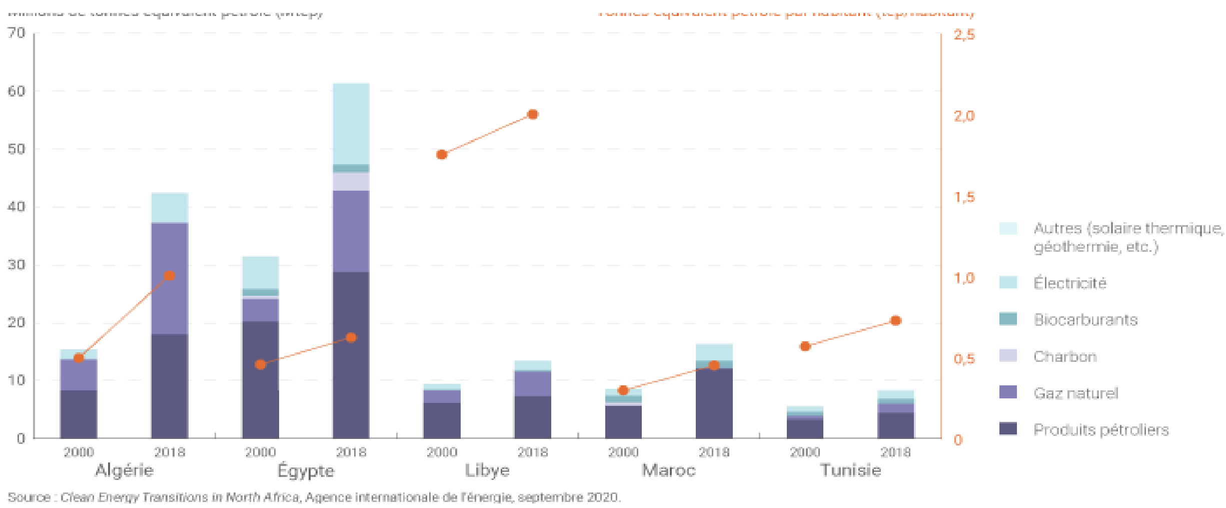

Figure 2: Final Energy Consumption of North African Countries (12)

The progress made by North African countries in renewable energy is measured by the share of renewable energy in gross domestic consumption, an indicator considered by the authorities to measure the region's sustainable development goals. As shown in Figure 2, several countries have exceeded the 2020 target (Egypt, Algeria). There are also countries that are far from the agreed national level for 2020 (Libya, Morocco, Tunisia).

Analysing the relationship between the share of renewable energy and real GDP per capita, we find that there is no direct correlation, as might be expected. There are countries with a high level of development, reflected in a high level of GDP per capita, that have a low share of renewable energy in gross domestic consumption and that have not met their renewable energy targets: Libya and Morocco (bottom right-hand corner, Figure 3).

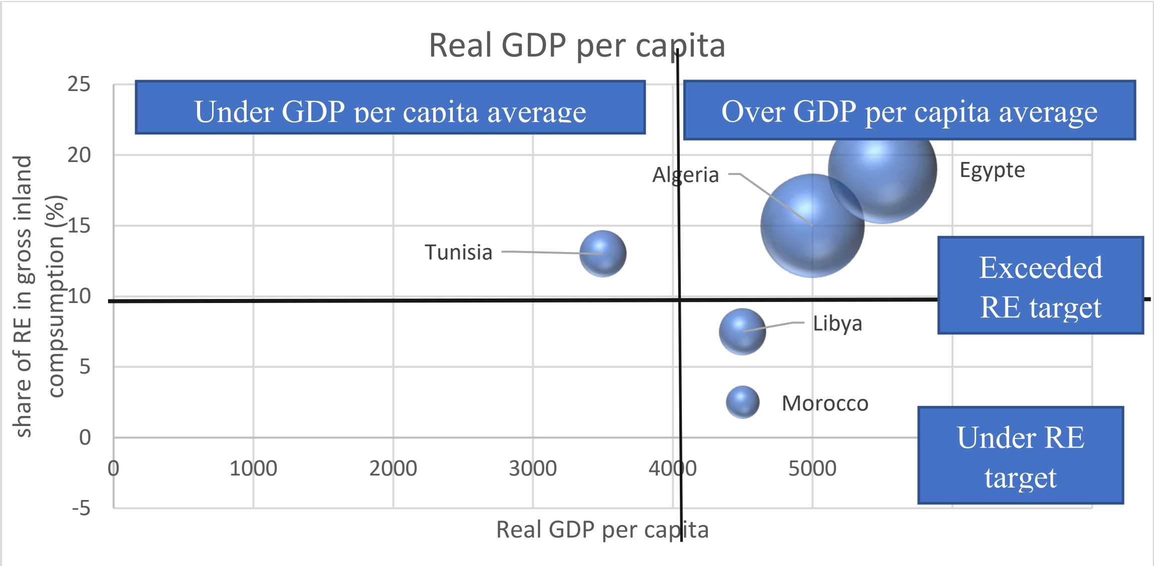

Figure 3: Share of RE sector and GDP per capita

This aspect highlights the delay in considering the importance of the renewable energy sector for the country's development**. Countries such as Morocco and Libya were challenged by the target of doubling the share of renewable energy.** They are currently below the agreed level, but have the potential to reach it if they continue their efforts. African countries have the capacity to invest in the technologies that are the main drivers of renewable energy deployment. In addition, modern technologies imply an increase in the overall efficiency of economic activity due to the growing degree of automation and integration of AI.

3.3 Efficiency Gains in the Renewable Energy Sector in North Africa - A Macroeconomic Approach

The growth of the renewable energy (RE) industry in North Africa was examined, with an emphasis on determining the macroeconomic variables that support and demonstrate the incorporation of AI in this industry.

In the energy balance, Gross Inland Consumption—which refers to both supply and production—is the most significant indicator. It includes energy consumption by the energy industry itself, distribution and transformation losses, and end consumers' ultimate energy consumption. It is a representation of the entire quantity of energy needed to meet domestic consumption needs. Gross inland consumption fell and reached 90% before 2018. Nonetheless, the consumption of renewable energy grew steadily, satisfying North Africa's needs. In addition, the share of renewable energy in gross inland consumption rose by 180% in 2018.

Over the past ten years, there has been a shift in the Gross Inland Consumption structure by kind of energy at the North African level. By 2018, the only energy industry that has grown in terms of Gross Domestic Product (GDP) and volume (MtOe) is renewable energy. The percentage of renewable energy in gross inland consumption has increased, which indicates how much renewable energy has replaced traditional fossil or nuclear fuels.

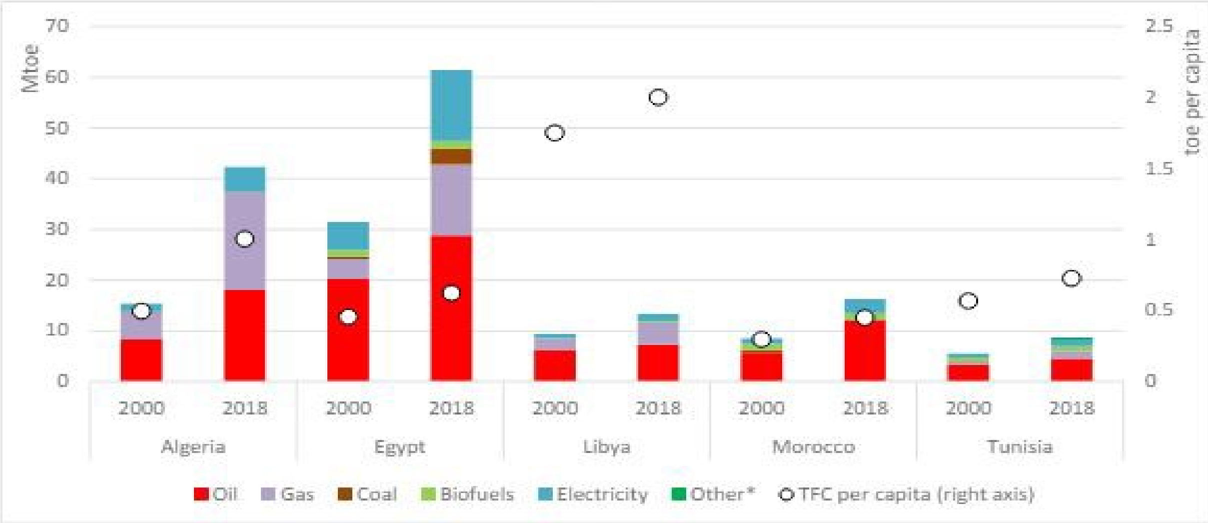

Figure 4: Total final consumption by fuel and per capita, 2000 and 2018

Source: IEA (2020), World Energy Balances 2020.

***Other includes solar thermal, geothermal, commercial heat, etc. Notes: Mtoe = million tonnes of oil equivalent; toe = tonnes of oil equivalent; TFC = total final consumption.**

Figure 4 illustrates how oil dominates the energy composition of North Africa, contributing between 45% and 85% of total consumption. But the transportation industry isn't the only one using oil; in Morocco, for instance, the residential sector accounts for a fifth of usage, with LPG being used for cooking. In Algeria and Morocco, where 1.5% of the population uses traditional biomass as their main cooking fuel, cooking traditions persist despite efforts to switch to cleaner energy sources. This dynamic presents a gender perspective since women and girls bear the brunt of the responsibility for gathering wood and using it for cooking, and they are also disproportionately exposed to the harmful health effects of traditional biomass use.

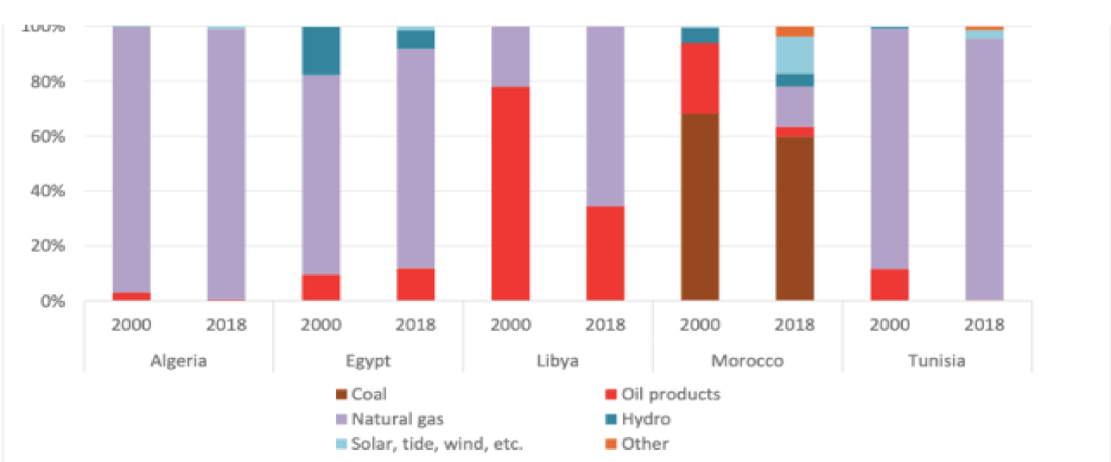

Figure 5: Electricity generation mix in North Africa, 2000 and 2018

Source: IEA (2020), World Energy Balances 2020.

In most of the countries in the region, electricity is negligible; however, in Egypt, it constitutes one-fifth of end-use consumption, as Figure 5 illustrates. This stands in stark contrast to the global average of 18.9% of total energy use and offers a substantial window of opportunity for nations aiming to achieve a more sustainable and secure energy future. In nations without an abundance of fossil fuel resources, like Morocco and Tunisia, this potential is especially apparent. A variety of alternatives to subsidized oil are available in these nations, providing substantial advantages in the shift to greener and more sustainable energy sources.

Beyond substituting more polluting fuels and extending the areas in which electricity can be used, there is room for improvement in the process of generating energy. A significant reliance on fossil fuels characterizes the energy generating mix of North Africa. Renewables make up only 4.6% of the entire power mix despite an abundance of renewable resources, far less than the global average of 25%. Given that North Africa boasts some of the world's highest sun irradiation and strong wind potential in coastal locations, this imbalance is out of proportion to the region's available resources (Global sun and Wind Atlas, 2020). North Africa has a tonne of potential to use more renewable energy, which may help Morocco and Tunisia become less reliant on imported fuels and give Algeria more resources for export. Every one of the five nations has established long-term goals for growing the capacity of renewable energy sources. By 2030, Algeria wants to reach 22 gigawatts (GW), Morocco 10 GW, Libya 4.6 GW, Tunisia 2.8 GW, and Egypt 54 GW by 2035.

In conclusion, between 2000 and 2018, the proportion of renewable energy (RE) in gross inland consumption and final energy consumption grew. As a relatively new business, renewable energy (RE) depends far more on artificial intelligence-related advanced technologies and technological breakthroughs than fossil energy, which also contains technological innovations but is mostly dependent on conventional processes like blast furnaces and coke ovens. The primary driver of the RE sector's growth is the increased application of AI.

The growth in Transformation Output outpaces the growth in Transformation Input in the Renewable Energy (RE) industry. The gross production of derived products is represented by the transformation output, which is the outcome of the energy product transformation process. These products could go through multiple cycles of change in the energy balance. Some items are only available as transformation output, including motor gasoline and electricity.

The structure of production of renewable energy (RE) and the elasticity of substitution between input factors (nature, labor, and technology) determine resource productivity in the RE sector, which is a measure of the incorporation of AI in processes and employment. Specifically, labor productivity is a crucial metric for evaluating advancement across all economic domains. High labor productivity and labor intensity are associated with sectors that have high gross value added (GVA) per person employed. Comparing the developing RE industry to other traditional energy sectors and even to economic activities in the economy at large, labor intensity is typically higher.

In order to compare the labor productivity of the national economies of the North African countries, we have computed and analyzed the labor productivity within the renewable energy sector. Our findings (Figure 6) support the theory that the renewable energy sector depends on trained labor and contemporary technologies since labor productivity there is higher than in the general economy. Furthermore, labor productivity in the renewable energy sector is higher in nations with a comparatively lower share of renewable energy in gross domestic consumption (Figure 3, bottom right).

In industries like renewable energy, innovation is essential to the quick adoption of renewable energy solutions. A more inventive industry can more effectively maximize its current resources. Innovation in this field has been the driving force behind the integration of artificial intelligence into renewable energy systems (Table 1). Innovation is progressively leveraging intelligence to enhance the utilization of current technology in today's knowledge-based society.

Investment in renewable energy is essential not only to implement new innovations, but also to strengthen the technological infrastructure of a burgeoning sector.

Table 1 : The Key points of integrating AI into RE

Public and private sector investment support.
Requires investment in innovative technologies that create skilled jobs.
Importance of reducing import dependency and promoting sustainable domestic markets.
Positive macroeconomic indicators in North Africa thanks to accelerated integration of AI in renewable energies.
Over 90% of investment in renewable energies comes from the private sector, despite initial public sector support.
Significant economic benefits: reduced pollution, improved human health, etc.

A few nations seem to be able to reach the target for renewable energy (RE) given their geological advantages. For others, on the other hand, particularly those who live in areas with favorable winds, sunshine, or rainfall, energy production may momentarily surpass demand (days or months). But for the foreseeable future, this will continue to be a major problem for many other nations.

3.4 Artificial Intelligence: A Challenge as a Disruptive Innovation - Towards Intelligent Energy Infrastructure Services in the Renewable Energy Sector

Disruptive innovations are characterized in the renewable energy (RE) industry, as in other industries, by smaller targeted market segments, lower marginal gross revenues, and services that might not seem as appealing at first as solutions that follow the usual performance trajectory. Nonetheless, RE markets are still dominated by traditional energy technology. But if these new AI-infused technologies get more efficient and perform better at first, their rate of spread should quicken and eventually make them dominate the RE space, as has been seen in a number of other industries.

The most important factor in determining a technology's success in the rivalry between established and new technologies in the real estate sector is when the technology enters the market. As latecomers, this disadvantages new technologies in the RE industry. Better alignment with client preferences, price points, and performance rates over time, however, can eventually outweigh this drawback.Innovation in technology, especially disruptive innovation, has the power to completely change the renewable energy (RE) industry by boosting productivity and altering how people generate and use energy in society. Driven by environmental imperatives, concerns about resource depletion, and variable prices for oil and other commodities, producers in the RE business stand to benefit from these developments. For nations looking to lessen their reliance on imports and traditional fuels, these developments are essential. Furthermore, rivalry between technologies—for example, solar versus coal or wind versus natural gas—is driving innovation and improving standards in the industry.
Applications of artificial intelligence (AI) are disruptive technology for the real estate industry. Artificial Intelligence (AI) comprises machine learning methods, robots, algorithms, and automated decision-making systems. It presents noteworthy advantages for both the economy and society. It is employed in a number of industries, such as renewable energy, to encourage

environmental responsibility and sustainability. North Africa has already started to investigate and use this new frontier in the RE sector, and AI systems are essential to bringing it to the next level. Without the employment of numerous AI applications in the renewable energy sector, the above-discussed considerable growth in energy from renewable sources would not have been conceivable.

- Collect and analyse vast amounts of data from smart devices.
- Accurately predict renewable resource conditions to manage intermittency.
- Identifying demand patterns through analysis of grid data or input from human operators.
- Implement smart grids capable of making highly autonomous decisions.
- Promptly switching between renewable and fossil fuel sources in response to renewable variability and demand peaks.
- Deploy intelligent storage systems that can adapt to changes in demand in real time.
- Timely identification and management of supply and demand peaks.
- Proactively addressing production failures, storage system issues and energy infrastructure disruptions.

With an emphasis on cost savings and flexibility in response to change, the energy management strategy seeks to increase energy reliability and spot chances for increased efficiency through the use of technology. Infrastructure will be progressively consolidated and/or made available as a service in order to go in this direction.
The energy sector, and specifically the renewable energy (RE) industry, is going through a major transition, much like other industries, from a traditional product-based business model to a service-based one. With a high degree of flexibility and control, the "as a service" approach gives businesses the ability to use applications without having to worry about setting up, configuring, or maintaining the hardware that the apps run on. Storage, networking, computation, and database administration are all offered as standardized network services by Infrastructure as a Service (IaaS).
Since the success of an innovation depends on the efforts of other enterprises in the ecosystem, technological interdependence can have an impact on how well businesses adopt new generations of technology. Innovations don't happen in a vacuum; their influence is shaped by their size as well as where they are in the ecosystem in relation to focal enterprises. In order to address external difficulties, other actors must innovate as well, integrating local businesses into a network of interconnected innovation.
Within this network of interdependencies, the provision of smart energy infrastructure as a service (SEIaaS) is starting to gain traction as a fresh and practical approach to managing renewable energy, especially as infrastructure starts incorporating new technologies and artificial intelligence in response to the industry's rapid transformation. Infrastructure for renewable energy comprises energy generation, storage, transmission, and distribution systems.

In the renewable energy industry, software-enabled infrastructure as a service (SEIaaS) refers to the providing of energy infrastructure, such as servers, storage, networks, and related software, to end users as a service instead of needing implementation. This strategy makes it unnecessary for organizations to make long-term commitments and enables them to access resources as needed. Customers can install their own software on the infrastructure as needed, but providers are in charge of providing housing, management, and upkeep for it. The main advantages of SEIaaS for the RE sector (Figure 6) are lower costs (because no infrastructure is purchased, both initial and maintenance costs are minimized), more flexibility (due to pay-asyou-go billing and quick adjustments to changes in the economy), and improved storage capabilities (which allow for automation on demand and flexible usage).

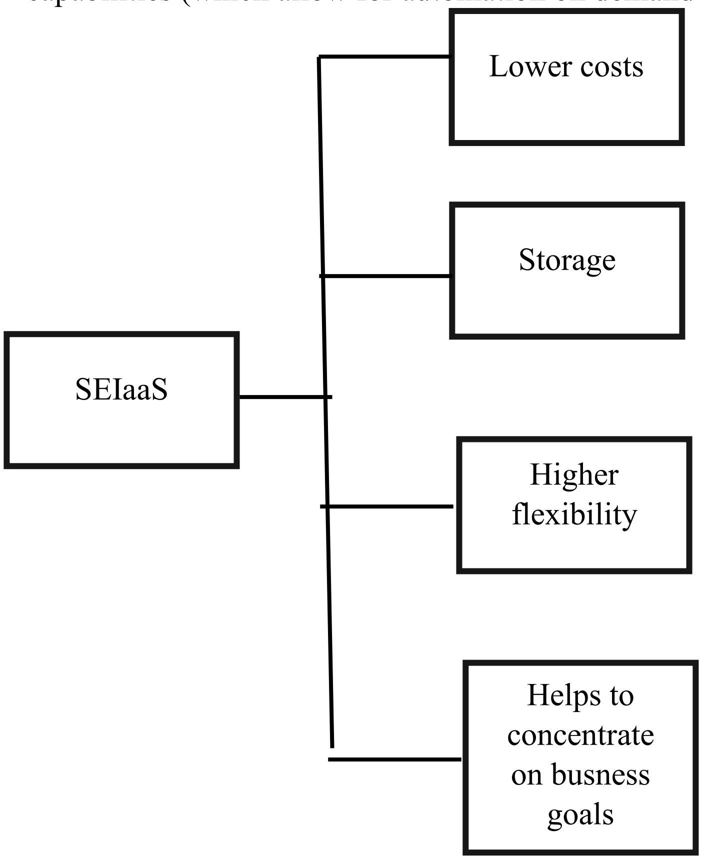

Figure 6: Benefits of SEIaaS in RE sector

SEIaaS can be made available through contracts or on a pay-per-use basis. End users usually place the greatest importance on the pricing flexibility provided, considering it to be very beneficial to pay for just the resources needed to run the application. When paired with the many other advantages of SEIaaS, this pricing flexibility presents this infrastructure delivery model as a management approach for assiduously bringing disruptive innovation into the real estate industry.

4.0 Conclusion

Adoption of renewable energy (RE), which provides sustainable solutions in the face of resource depletion and environmental concerns, is essential for addressing climate change on a worldwide scale. Artificial intelligence (AI) is redefining energy management in a market that is always changing by increasing efficiency and accessibility in this industry. Predictive analytics, reduced storage costs, improved network connectivity, and system stabilization are some of the ways AI reduces the variability of RE. Together, they are revolutionizing energy practices and improving sustainability both locally and worldwide. North Africa is a leader in RE thanks to its strict environmental regulations and widespread use of AI. Maintaining leadership in this changing energy economy requires ongoing AI development.

In future research on smart cities, integrating AI to improve RE efficiency will require addressing several important considerations, including:

- Integrating AI for renewable energy at both micro and macro levels, encompassing applications in smart homes as well as integrated platforms for optimizing smart energy networks.
- Developing an AI-driven big data ecosystem for energy to provide flexible and integrated services and applications.

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