



Artificial Intelligence as a Catalyst for Sustainability and Energy Transition: Opportunities, Challenges, and Future Prospects for Emerging Economies, Case of Algeria

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Abstract:

This paper examines how artificial intelligence (AI) can promote sustainable development and an energy transition in emerging economies, with a focus on Algeria. Using a qualitative and analytical approach based on international reports from the IEA, World Bank, and OECD, the study demonstrates that AI can improve energy efficiency, governance, and renewable energy integration. However, challenges remain, such as limited infrastructure, skill shortages, and weak regulation. Ultimately, the paper concludes that adopting a national AI strategy and promoting international cooperation are essential for achieving a smart, sustainable energy future in Algeria.

Key Words: Artificial Intelligence, Energy Transition, Sustainable Development, Emerging Economies, Algeria.

JEL Classification: O33, Q55, Q43

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Introduction:

Over the past few decades, the planet has undergone an unprecedented technological transformation, driven by the rise of artificial intelligence (AI). At the same time, the international community is facing a climate and energy emergency that requires innovative, sustainable, and comprehensive responses. In this context, AI is gradually establishing itself as a strategic tool at the heart of energy transition and sustainable development policies. Far from being a simple technological innovation, it is becoming a cross-cutting lever capable of revolutionizing modes of production, consumption, and energy governance.

The energy transition is one of the major challenges of the 21st century. It involves gradually replacing fossil fuels, which are responsible for the majority of greenhouse gas emissions, with clean, renewable, and more efficient energies. This structural change is accompanied by profound economic, social, and institutional transformations, requiring systems capable of analysing enormous volumes of data, predicting consumption patterns, and optimizing decision-making processes. It is precisely in this field that artificial intelligence is realizing its full potential: intelligent management of electricity networks (smart grids), forecasting solar and



wind power production, predictive maintenance of infrastructure, optimization of energy flows, and reduction of gas emission

Artificial intelligence (AI), defined as the ability of computer systems to learn, reason and solve problems independently, is having a profound impact on production, consumption and governance. Integrating AI into the energy sector creates unprecedented opportunities to optimise consumption, improve network efficiency, reduce carbon emissions and anticipate resource requirements. From smart grid management and predictive infrastructure maintenance to solar and wind power forecasting, AI is accelerating the transition to a low-carbon economy.

According to a report by the International Energy Agency (IEA), (2024), implementing AI solutions in global energy systems could cut CO₂ emissions by up to 15% by 2035 while enhancing the resilience of electricity grids. Similarly, the ((OCDE), (2023) emphasises that AI enables more efficient resource allocation and fosters the development of an innovation-driven green economy. These developments are fully aligned with the United Nations' Sustainable Development Goals (SDGs), particularly SDGs 7 (affordable and clean energy), 9 (industry, innovation, and infrastructure), and 13 (climate action).

However, the contribution of AI to sustainable development is not limited to energy issues. Its scope extends to broader areas such as combating climate change, reducing inequalities, improving environmental governance and promoting a circular economy. AI facilitates the large-scale collection and analysis of environmental data, helps to anticipate climate risks and contributes to the development of more inclusive public policies based on scientific evidence. These contributions position AI at the heart of the 'smart sustainable development' paradigm.

This technological and energy transition is of strategic importance for emerging economies, particularly Algeria. Historically dependent on hydrocarbons, the Algerian economy is now seeking to diversify its energy sources and improve its energy efficiency. Adopting artificial intelligence-based solutions in areas such as solar production, electricity grid management and land-use planning represents a significant opportunity to accelerate the transition to a more resilient, competitive and sustainable model. However, implementing this change requires coherent public policies, investment in research and innovation, and a regulatory framework that promotes the ethical and responsible integration of AI.

The central issue of this study is as follows: ***How can artificial intelligence contribute to achieving sustainable development goals and accelerating the energy transition in emerging economies, particularly Algeria?***

This question gives rise to several sub-questions:

- What are the main applications of AI in sustainable energy policies?
- How can emerging economies overcome the technological and institutional constraints associated with adopting AI?
- What are the economic, environmental and social impacts of integrating AI into energy transition strategies?



Research hypotheses: In light of this issue, the following hypotheses can be formulated:

- H1: Artificial intelligence has a positive impact on energy performance and carbon emissions in emerging economies.
- H2: The impact of AI on the energy transition depends on a country's level of technological and institutional development.
- H3: Investments in digital infrastructure and AI training strengthen emerging countries' capacity to achieve a sustainable energy transition.
- H4: In Algeria, gradually integrating AI into energy planning optimises the use of renewable resources and diversifies the national economy.

Research objectives:

- To identify concrete applications of artificial intelligence in the fields of energy and sustainable development.
- Analyse the impact of AI on environmental performance and energy management.
- Highlight the challenges of adoption and propose integration strategies tailored to emerging economies.

I. Theoretical and Conceptual Framework:

1. Key concepts: sustainable development, energy transition and artificial intelligence:

1.1 Sustainable development: It is based on the simultaneous integration of environmental, social and economic considerations into public and corporate decision-making processes (Brundtland, 1987) (Elkington, 2019)). The aim is to meet current needs without compromising the ability of future generations to do the same, which implies preserving resources, reducing greenhouse gas emissions, and promoting inclusive development. More recently, the concept has been broadened to include digital governance, emphasising the importance of using technologies (including AI) to support the SDGs while respecting social and ethical principles (Vinuesa, 2020) (UNESCO, 2022)

1.2 Energy transition: Energy transition refers to the shift from an energy system based mainly on fossil fuels to one based on low-carbon energy sources (renewables, efficiency, storage, alternative carriers such as green hydrogen). It encompasses the decarbonization of electricity production, the electrification of uses (transport, heating), and the implementation of flexible infrastructure (smart grids, distributed storage). Institutional reports ((IEA), 2023) ((IRENA), 2024) identify the transition as a complex techno-institutional process requiring innovation, massive investment, and regulatory reform.

1.3 Artificial intelligence (AI): AI is a set of methods, including supervised learning, unsupervised learning, deep learning, reinforcement learning, natural language processing, and computer vision, that enable computer systems to learn from data, make predictions, recommend actions, and automate complex processes (Russell S. &., 2022). In the energy sector, AI is employed for production/consumption forecasting, operational optimization (system control and



dispatching), predictive maintenance, demand response, and supporting public policy design decisions (Zhang X. L., 2023)

1.4 The interconnection of the three concepts: The intersection of AI, energy transition, and sustainable development is based on two complementary mechanisms: (i) AI as an efficiency tool for waste reduction and operational optimization, and (ii) AI as a catalyst for better governance through improved information, impact assessments, and prospective scenarios. However, the literature highlights a normative tension. While AI can contribute to sustainability, it also generates externalities, such as the energy footprint of data centers, technological dependence, and ethical risks, that must be anticipated ((IEA), 2025) (Agrawal, 2018).

1.5 The Links Between AI and the Green Economy:

a. AI as a Driver of Productive Efficiency: At the microeconomic level, AI improves the efficiency of industrial and energy processes by optimizing processes, performing predictive maintenance, and reducing losses. Empirical studies demonstrate substantial benefits, such as predictive maintenance reducing downtime and operation and maintenance (O&M) costs, and analytics optimizing the efficiency of solar and wind farms (McKinsey Global Institute, 2023) (Zhang X. L., 2023). These improvements translate into decreased average costs of renewable energy production, thereby improving the competitiveness of green technologies.

b. AI and new green business models: AI facilitates business models based on flexibility, energy services (e.g., Energy as a Service), aggregated demand management, and energy performance guarantees. These models internalize environmental benefits into commercial logic, accelerating private investment in clean technologies ((WEF), 2023).

c. Macroeconomic effects and positive externalities: At the macro level, adopting AI in the energy sector can increase overall productivity, support the diversification of commodity-dependent economies (e.g., hydrocarbon producers), and create budgetary flexibility through energy efficiency. The IMF and World Bank emphasize the importance of fiscal and incentive instruments to capture these gains and finance the transition ((IMF), 2024) (World Bank, 2022)

d. Risks and negative externalities: Digital conversion generates costs in the form of increased energy consumption by AI infrastructure (e.g., model training, data centers), dependence on technology providers, and risks of unequal access (e.g., algorithmic bias, digital divide). The literature calls for measuring the net benefit—emission savings enabled by AI minus additional emissions related to infrastructure—and for developing digital sustainability standards ((IEA), 2025) ((EEA), 2024).

e. Policies to Support the AI-Powered Green Economy: In order to transform technological potential into socioeconomic outcomes, governance must combine incentives for innovation (research and development, green financing), targeted industrial policies (AI-energy clusters), and training and social protection measures to support the transition of workers (l'Organisation Internationale du Travail, OIT,



2023) (OCDE, 2023). Finally, international coordination is crucial to avoid reproducing North-South asymmetries (standards, technology transfers).

2. Literature review:

The integration of artificial intelligence (AI) into energy and sustainable development policies has attracted growing interest over the past five years. On a theoretical level, several seminal works have laid the conceptual foundations for AI and its applications in complex economic systems. (Russell S. &, 2022) emphasize that machine learning and probabilistic reasoning technologies are the cornerstone of the digital transformation of energy systems. (Agrawal, A., Gans, J., & Goldfarb, A., 2018) demonstrate that the economic value of AI lies in its ability to predict and optimize decisions, making it a powerful lever for improving energy efficiency and planning for the green transition. These foundations have been further developed by (Brynjolfsson, 2017) who emphasize the link between digital innovation, productivity, and sustainability.

On a technical level, recent literature highlights the contribution of AI to the management and optimization of smart grids. The work of Zhang, Li, and Wang (Zhang Y. L., 2023) shows that deep learning algorithms improve demand forecasting and reduce energy losses. Tsiropoulos and Jäger (Tsiropoulos, 2024) confirm this trend by emphasizing that machine learning-based systems enable better integration of renewable energies and increased stability of electrical networks. These results are consistent with the observations of López and García (López, 2020) who showed that AI plays a decisive role in reducing the energy consumption of industrial and domestic systems through the optimization of flexibility and predictive maintenance.

Empirical studies on renewable energy production also demonstrate the potential of AI in resource planning and management. According to reports by the International Renewable Energy Agency (IRENA), (2024) and the International Energy Agency (IEA, 2023), neural networks and hybrid AI models have increased the accuracy of solar and wind forecasts, facilitating their integration into national grids. (McKinsey Global Institute, 2023) notes, for example, that the use of AI in energy storage and distribution management could reduce operating costs by up to 15% by 2030. These technological advances extend to smart buildings, where AI optimizes energy consumption through predictive control systems and home automation platforms, as demonstrated by studies by Zhou, Chen, and Han (Zhou, 2024) and case studies by the World Economic Forum (WEF, 2023).

At the macroeconomic level, several international institutions, such as the International Monetary Fund (IMF, 2024), the World Bank (2024), and the International Labor Organization (ILO, 2023), have highlighted the positive effects of AI on the productivity and competitiveness of emerging economies. These analyses highlight that adopting AI not only promotes decarbonization, but also creates skilled jobs in green sectors, while requiring adjustments to employment and training policies. In North Africa, Benali (2022) and Khelifi (2022) observed that digital skills gaps are hindering the integration of AI into energy systems, hence the



need for targeted reskilling programs for engineers and technicians in the sector (Benali N. , 2022; Khelifi, 2022)

In the MENA region, recent research confirms the strategic importance of AI in the energy transition. Case studies conducted in Morocco, Egypt, the United Arab Emirates, and Algeria (Benali N. , 2022; Mokrani, 2023; Khelifi, 2022) highlight promising projects in the fields of solar and green hydrogen. Reports from the African Development Bank ((AfDB), 2024) and the United Nations Development Program (((UNDP) P. d., 2025) show that these initiatives could reduce dependence on hydrocarbons and improve energy resilience. In Algeria, several dissertations and theses (Benali, 2022; Mokrani, 2023) emphasize that AI applied to energy resource management could enhance the effectiveness of public policies and accelerate economic diversification. Recent Arab contributions (2022, محمد الأمين, الحاج, بن عبد الله, 2023, الهاشمي, عبد الرزاق, 2023, الله, سمير, 2023) also analyze the prospects for AI in transforming the Arab energy model, with an emphasis on digital sovereignty and local governance.

Finally, the literature identifies several gaps that require further investigation. First, most studies focus on developed countries, leaving a deficit of empirical research on the real impact of AI in emerging economies. Second, few analyses assess the net carbon benefit of large-scale AI solutions, taking into account the energy costs of digital infrastructure. In addition, the scarcity of reliable local data sets is a major obstacle to predictive modeling in Southern countries. Several authors (Tsiropoulos & Jäger, 2024; McKinsey, 2023) are therefore calling for interdisciplinary approaches combining engineering, economics, and governance to ensure a fair and sustainable energy transition supported by artificial intelligence.

3. Global challenges of the energy transition in the digital age:

The energy transition is now a major strategic issue in global governance. It refers to the shift from an economic model based on fossil fuels to a system based on renewable, cleaner, and more sustainable sources. In the digital age, this transformation is accelerating under the influence of cutting-edge technologies, including artificial intelligence (AI), the Internet of Things (IoT), big data, and blockchain. These innovations are no longer limited to improving energy performance, but are profoundly redefining the ways in which energy is produced, distributed, and consumed on a global scale.

Economically, the digital age is enabling the optimization of energy demand management through smart systems. For example, smart grids use AI and predictive algorithms to balance supply and demand in real time, reducing waste and costs. The World Bank (World Bank, 2023) points out that countries investing in the digitization of their energy infrastructure achieve an average of 25-30% more energy savings than traditional models. This opens up considerable opportunities for emerging economies seeking to balance growth and sustainability.

From an environmental perspective, digitization offers new tools for monitoring and reducing carbon emissions. Artificial intelligence can be used to map and predict climate impacts, optimize energy flows in smart cities, and promote energy efficiency in the transportation and industrial sectors. The United Nations



Environment Programme UNEP ((UNEP), 2022) report highlights those digital technologies could reduce global greenhouse gas emissions by 15% by 2030, provided that energy data is governed in an ethical and inclusive manner.

However, this transformation raises major geopolitical and social issues. Northern countries, with their greater investment and innovation capacities, still dominate the production and control of digital technologies, thereby widening the global energy and technology divide. The International Energy Agency IEA ((IEA), 2024) warns of an “energy dualization” in which developed nations would reap the benefits of digitization, while countries in the South would remain dependent on traditional and polluting energy systems.

In addition, cybersecurity and data sovereignty challenges are becoming central issues. Smart energy infrastructures are now vulnerable to cyberattacks, jeopardizing national security and service continuity. According to the Global Cybersecurity Outlook report ((WEF), 2024) , more than 40% of cybersecurity incidents reported in 2023 involved energy management networks. These threats require the establishment of robust digital governance and an international regulatory framework for the protection of energy data.

Finally, from a societal and ethical perspective, the digital energy transition must be accompanied by reflection on jobs, skills, and climate justice. AI technologies are profoundly changing the labor market in the energy sector, promoting the development of skills in data analysis and smart maintenance professions. However, the OECD ((OECD), 2023) reiterates the need to ensure a just transition in order to avoid the exclusion of workers from traditional energy sectors.

The digital age is transforming the energy transition into a true systemic revolution, combining innovation, sustainability, and global governance. The success of this transition will depend on the ability of countries to cooperate, share green technologies, and implement integrated public policies that combine artificial intelligence, energy equity, and sustainable development.

II. Artificial intelligence as a lever for energy transition:

1. Applications of AI in renewable energy production (solar, wind, hydro) :

Solar production forecasting. Solar irradiation varies greatly depending on short-term (clouds, dust, humidity), seasonal, or geographical weather conditions. AI models such as convolutional neural networks (CNN), hybrid CNN-LSTM models, or Transformers are used to accurately predict solar production on an hourly, daily, and seasonal basis. For example, LTPNet (Te Li, 2024) combines deep learning and an environmental decision support system to achieve significant error reductions: ~30% in MAE, ~20% in MAPE, etc .

1.1 Wind optimization: AI can be used to optimize turbine placement (wind farm layout), blade management based on wind conditions, and predictive maintenance to anticipate wear, corrosion, or damage due to turbulence. In China, AI-driven predictive systems are used to manage maintenance shutdowns to maximize net production. Studies also show the importance of coupling with high-resolution meteorological data to improve model reliability ((IEA), 2023)



1.2 Hydroelectric and multi-vector systems: Although hydroelectricity is more stable than solar/wind power, it is subject to variations in flow, precipitation, and evaporation. AI is used to model these fluctuations, plan water releases, anticipate peak periods or shortages, and coordinate with other renewables and storage. An example: the study Digital Twins based Day-ahead Integrated Energy System Scheduling under Load and Renewable Energy Uncertainties (You, 2021) shows that a digital twin applied to an integrated energy system can reduce operational costs by ~63.5% compared to conventional planning methods.

1.3 Storage & flexibility: Integrating renewables requires storage capacities (batteries, pumped storage, hydrogen, etc.) and AI algorithms to decide when to charge/discharge, optimize losses, and balance cost vs. yield. These technologies combined with AI improve the overall efficiency of multi-vector systems.

2. Optimizing consumption and distribution via smart grids:

2.1 Predictive demand management: AI can predict peaks in demand by combining historical data, weather, special events, and residential and commercial usage. These predictions help operators adjust production or encourage users to modify their consumption (dynamic pricing, demand response). Several European countries have seen reductions of 8-12% in peak demand thanks to demand response programs supported by AI systems and smart meters (European Commission, 2023)

2.2 Distributed infrastructure & edge intelligence: Recent literature (Molokomme, , Onumanyi, , & Abu-Mahfouz, 2022) studies edge computing for smart grids, i.e., moving part of the computing and decision-making from the cloud to local devices (sensors, micro-stations). This reduces latency and bandwidth, increases resilience, and can decrease the energy consumption associated with data transfer .

2.3 Anomaly Detection and Predictive Maintenance: Rapid detection of faults or anomalies (lines, transformers, overloads) is a critical aspect of distribution. AI enables continuous monitoring via sensors and machine learning (ML)/deep learning to detect anomalies before they cause major failures. In West Africa, pilot studies have shown that such detection can reduce service interruptions by 20-30% in rural areas.

2.4 Optimizing transmission and distribution (T&D) losses is also important: Losses in the network due to heat, resistance, leaks, and power theft represent a significant cost. AI can model these flows, identify the most inefficient segments of the network, and propose targeted repairs. In the study "A Comparative Study of AI Methods on Renewable Energy Prediction for Smart Grids": Case of Turkey (Karaaslan, Demir, & Yildirim, 2024) the authors demonstrate that combining forecasting models enhances the grid's capacity to predict overloads and plan interventions, thereby reducing overall losses .

3. AI and energy efficiency in industry and transportation:

3.1 Heavy industry/energy processes: In sectors such as steel, chemicals, cement, and metallurgy, AI is used to optimize thermal processes, reduce fuel consumption, optimize combustion, control emissions, and minimize waste. For example, AI



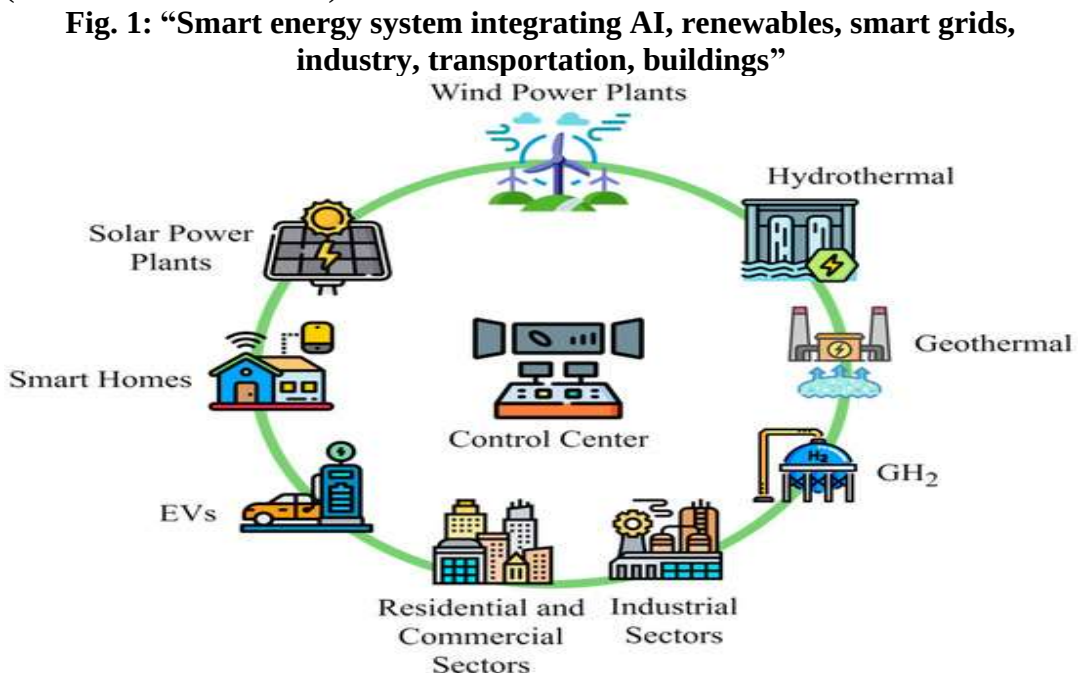
platforms can be used to regulate furnace, boiler, or injection parameters to reduce energy costs and pollution.

3.2 Smart buildings/cities: AI + IoT sensors + building management systems (BMS) can regulate heating, ventilation, air conditioning, and lighting based on occupancy, weather, and electricity rates. Cities in Europe (Germany, Scandinavia) report 20-30% reductions in building energy consumption after installing these smart systems.

3.3 Smart transportation: AI is used in: planning fuel-efficient routes, traffic management systems, transportation electrification (smart electric vehicles), optimizing charging infrastructure, logistics (optimizing routes and loads). In China, AI platforms optimize bus fleet schedules and routes, significantly reducing urban emissions.

3.4 Industry-transport coupling: The symbiosis between energy industries and transport (electrification, optimized energy use, competitive clean energy supply) is facilitated by AI, enabling a faster transition to low-emission systems.

Fig. 1 illustrates a smart energy ecosystem in which AI (and big data) serve as a “command center” connecting: Renewable production (solar, wind, hydro), Smart homes and buildings (consumption management, IoT), Industrial & commercial sector, Electric transportation/electric vehicles, Energy management/control centers (EMS/Command Centers).



Source: “Energy Intelligence: A Systematic Review of Artificial Intelligence for Energy Management”, MDPI, 2023)



4. The socio-economic and environmental impacts of artificial intelligence in the sustainable energy transition:

4.1 Economic and productive impacts of artificial intelligence in the energy sector: The introduction of artificial intelligence (AI) in the energy sector represents a major economic turning point. By automating the management of energy production, distribution, and consumption, AI is promoting the emergence of new economic models based on efficiency and sustainability. According to McKinsey Global Institute (2023), the application of AI in the global energy industry could generate up to \$380 billion in added value by 2030, mainly through process optimization and reduced operating costs (McKinsey Global Institute, 2023).

In emerging economies, these economic gains are essential to offset budget constraints and modernize aging energy infrastructure. In Algeria, for example, AI technologies can support economic diversification by promoting the integration of innovative sectors related to renewable energy and digital energy management (Benali & Kermiche, 2022).

AI also improves the prediction of energy prices and demand, which is crucial for macroeconomic stability. Machine learning models facilitate the simulation of exogenous shocks, such as oil price fluctuations or supply crises ((IMF), 2024). These quantitative approaches enable policymakers to develop more resilient and adaptive energy policies that are aligned with sustainable development goals (World Bank, 2025)

4.2 Impacts on employment and labor market transformation: While AI increases productivity in the energy sector, it also transforms the structure of the labor market. According to the International Labor Organization ((ILO), 2023), the digitization of the energy sector could eliminate about 5% of traditional jobs in the extractive industries, but at the same time create up to 12 million green jobs in smart management technologies, smart grid maintenance, and energy algorithm design.

In emerging economies, the success of this transition depends on training human resources and creating an inclusive technological ecosystem. Sultan's work shows that leveraging digital human capital is essential for AI to be a driver of inclusive growth (Sultan, 2022). In Algeria, higher education programs are beginning to introduce courses focused on artificial intelligence applied to energy and the environment, particularly through partnerships between universities and technology companies (Mokrani, 2023).

4.3 Environmental impacts and sustainability: In environmental terms, AI contributes to a significant reduction in greenhouse gas emissions through better management of energy production. The International Renewable Energy Agency (IRENA, 2024) estimates that integrating predictive algorithms into electricity grid management could reduce global CO₂ emissions by nearly 2.8 gigatons per year by 2030. At the same time, studies such as that by Zhang et al. show that AI optimizes the use of natural resources by improving the accuracy of preventive maintenance of energy infrastructure, thereby limiting waste and industrial pollution (Zhang,, Li, & Wang, 2023). In addition, AI technologies contribute to the sustainable management



of water, biomass, and urban heat, promoting convergence between the energy transition and the ecological transition ((OECD), 2023).

In the Global South, these positive environmental effects are still limited by inequalities in access to data and digital infrastructure (UNDP, 2025) . However, initiatives such as the African Smart Grid Initiative (2024) demonstrate a growing effort to integrate AI into regional energy sustainability policies.

III. Issues, challenges, and prospects for integrating artificial intelligence into the energy transition of emerging economies—the case of Algeria:

The integration of artificial intelligence (AI) into the energy policy of emerging economies, particularly in Algeria, represents a strategic shift towards the modernization of energy systems and the transition to a more sustainable model. However, this process continues to face several structural, institutional, economic, and environmental constraints. These challenges, if properly understood and overcome, can transform AI into a real driver of efficiency, governance, and innovation in the energy sector.

1. Strategic challenges and opportunities for AI in the energy transition:

The integration of artificial intelligence (AI) into the energy transition represents a major opportunity for emerging economies, particularly in North Africa. AI offers unprecedented capabilities for optimizing energy systems through predictive modeling, smart grid management, and reduction of operational losses ((IEA), 2023) In the Algerian context, these technologies would make it possible to modernize electricity production and distribution, while promoting diversification of the energy mix, which is dominated by hydrocarbons (more than 90%) (Ministry of Energy and Mines, 2024).

From an economic perspective, AI can stimulate green growth by promoting investment in clean technologies, energy start-ups, and public-private partnerships. According to the World Bank, potential gains in energy efficiency could reduce demand by 10 to 15% in emerging countries by 2030 (World Bank, 2024).

Technologically, AI systems make it possible to better anticipate the intermittent production of solar and wind energy, thereby contributing to grid stability and reducing waste (PricewaterhouseCoopers (PwC), 2023)

Socially, the integration of AI can contribute to greater energy equity by extending access to electricity in rural areas via smart microgrids. However, this benefit remains contingent on national policies for training and digital inclusion ((UNDP) U. N., 2024) .

2. Technical and technological challenges: infrastructure, connectivity, and data access:

One of the main obstacles to the adoption of AI in the energy transition of emerging economies is the weakness of digital and energy infrastructure. AI relies on the massive availability of reliable data, high-performance IoT sensors, and high-speed connectivity ((OECD), 2023).



However, in Algeria, regional disparities in internet coverage and the lack of an integrated energy database are hindering the implementation of large-scale AI solutions (Benhamou & Guemache, 2022).

Constraints also relate to computing capacity and data storage, which are often dependent on foreign platforms, posing a problem of digital sovereignty. In addition, the scarcity of local expertise in data science and cybersecurity limits the creation of a sustainable energy innovation ecosystem (World Economic Forum (WEF), 2024).

3. Institutional, economic, and governance challenges:

Institutional challenges primarily concern the fragmentation of public policies between the ministries of energy, digital technology, and higher education, which makes cross-sector coordination difficult (Cherif, & Mekhloufi, 2023).

Economically, the lack of green financing remains a major obstacle: the investments needed for energy digitalization exceed 3% of GDP in most emerging countries, a threshold that is rarely reached (International Monetary Fund (IMF), 2023).

Furthermore, the issue of energy data sovereignty has become strategic. Dependence on foreign technology platforms (such as Google Cloud or Amazon Web Services) for the processing of critical data poses security and confidentiality risks ((UNCTAD), 2024).

Finally, AI governance in the energy sector requires a clear regulatory framework on the use of algorithms, transparency of automated decisions, and accountability in the event of energy forecasting errors (European Commission., 2023)

4. Social and environmental risks associated with technology:

Although AI is seen as a driver of energy efficiency, its widespread use also generates a growing digital carbon footprint. Data centers and deep learning models consume significant amounts of energy, which could undermine climate goals if electricity production remains dominated by gas (IEA, 2024).

On the social front, the automation of energy systems could create tensions in the labor market, particularly for technicians who are not trained in digital maintenance (International Labour Organization (ILO), 2023).

A retraining and continuing education strategy is therefore essential to ensure that the energy transition is socially inclusive.

5. Strategic Outlook and Recommendations for a Smart Energy Transition in Emerging Economies: The Case of Algeria:

5.1. Long-Term Development Outlook: Integrating artificial intelligence (AI) into the energy transition creates significant opportunities for emerging economies, especially regarding energy efficiency, technological autonomy, and environmental sustainability. If Algeria succeeds in aligning its industrial, digital, and energy policies, it could become a major regional player in the field of smart energy technologies by 2035.

Developing an AI-based energy innovation ecosystem would promote the creation of skilled jobs and economic diversification beyond hydrocarbons. This requires establishing specialized technology hubs (EnergyTech and Green AI Hubs), strengthening applied research capacities, and promoting partnerships between universities, startups, and public companies, such as Sonelgaz and Sonatrach.



In addition, digitizing energy infrastructure would enable better demand forecasting, optimized storage, and reduced network losses through machine learning and predictive maintenance. These innovations would help strengthen the country's energy resilience in the face of external shocks (oil prices, geopolitical tensions, fluctuations in global demand).

5.2. Policy and institutional recommendations: To take advantage of the possibilities presented by AI in the energy transition, several recommendations are necessary.

a. Develop a national strategy for integrating AI into energy Algeria must adopt a specific roadmap aligned with the 2035 National Energy Transition Strategy, defining priorities for research, investment, and training. This strategy should include the creation of an AI and Energy Sustainability Observatory to monitor progress and coordinate initiatives between the Ministries of Energy, Environment, and Knowledge Economy.

b. Strengthen regulatory and ethical frameworks It is crucial to establish a legislative framework governing the collection and sharing of energy data, while ensuring the protection of national digital sovereignty. This framework must promote transparency and trust in AI technologies applied to energy, in accordance with the principles of the African Charter on Artificial Intelligence (African Union (AU), 2023).

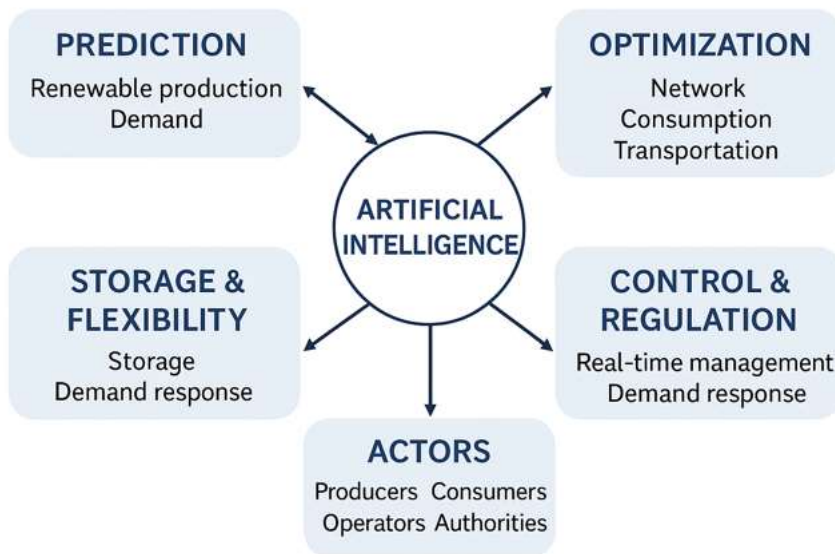
c. Stimulating Public and Private Investments in GreenTech: The State should encourage investments in energy R&D through tax incentives, public-private partnerships, and green financing mechanisms (such as green bonds). National financial institutions could play a leading role by supporting local startups working on AI-based energy technologies.

d. Promoting Training and International Cooperation: The success of the smart energy transition largely depends on the development of human skills. It is recommended to establish joint academic programs between Algerian universities and foreign institutions (for example: Stanford University, Imperial College, Polytechnique Montréal) to strengthen expertise in AI technologies applied to energy.

Moreover, Algeria would benefit from greater integration into regional and international cooperation networks, such as the United Nations Sustainable Development Programme (UNDP) and the Smart Africa Initiative, in order to pool resources and share knowledge.



Fig.2 Integration of Artificial Intelligence in the Energy Transition of Emerging Economies



Source: International Energy Agency (IEA, 2024), *AI and the Future of Energy Systems: Opportunities and Challenges for Emerging Economies*, Paris: IEA Publications.

5.3 Forward-Looking Vision and Sustainability: The future of the energy transition in the age of artificial intelligence relies on an integrated approach in which technological innovation serves economic, social, and environmental sustainability. Current foresight models suggest that AI could enable a reduction of nearly 10% in global CO₂ emissions by 2030, mainly through the optimization of energy networks and the intelligent management of resources (World Bank , 2023) These projections depend on governments' ability to invest in green digital infrastructures and to promote inclusive governance of energy data.

The OECD emphasizes the crucial role of public policies in creating a sustainable innovation ecosystem, where AI technologies support local renewable energy production and encourage citizen participation in the energy transition ((OECD),, 2024). Similarly, the World Bank highlights the importance of integrating AI into national sustainable development strategies to improve energy efficiency and reduce dependence on fossil resources.

From an environmental perspective, several studies (Zhang, Li, & Wang, 2022; Wang & Li, 2023) show that AI solutions based on machine learning and neural networks enhance the accuracy of energy forecasting and help adapt renewable energy production to real market needs. These advances pave the way for a more flexible and resilient energy mix, particularly in emerging economies where energy demand is rapidly increasing.

In terms of social sustainability, AI fosters the creation of skilled jobs in technological and energy sectors while posing challenges related to training and



professional retraining (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2023) Therefore, national policies should focus on digital capacity-building programs to ensure a just and inclusive transition.

Finally, from a long-term perspective, the (European Commission. , 2024) and the (United Nations Development Programme (UNDP)., 2024) underline the need for a global cooperation framework on the ethical and environmental standards of AI, in order to ensure global and equitable sustainability

Conclusion:

The integration of artificial intelligence (AI) into the energy transition now represents a strategic turning point for the achievement of sustainable development goals, particularly in emerging economies such as Algeria. Recent technological advances confirm that AI is a lever for systemic transformation capable of optimizing energy production, distribution, and consumption while promoting the reduction of greenhouse gas emissions and the diversification of energy sources.

The analysis conducted in this study has shown that AI is not limited to a simple automation tool, but acts as a vector for smart energy governance, facilitating data-driven decision-making, demand forecasting, and real-time resource management. In the Algerian context, this dynamic is part of a political commitment to reduce dependence on hydrocarbons, promote renewable energies (solar, wind), and accelerate the digitization of the energy sector. However, the success of this transformation requires the removal of several structural constraints, including the lack of digital infrastructure, the shortage of specialists in AI and data science, and a regulatory framework that is still in its infancy.

At the institutional level, energy transition governance must be based on multisectoral coordination mechanisms between public actors, energy companies, and research centers to ensure the coherent integration of AI technologies into national energy policies. The development of international partnerships, particularly with the European Union, the World Bank, and African institutions, can also offer opportunities for financing and skills transfer to support this technological change. Furthermore, the social dimension of the smart energy transition must not be overlooked. AI must be used to promote a fair and inclusive transition, ensuring equitable access to clean energy, the creation of skilled jobs, and the reduction of regional inequalities. In this sense, investment in training, applied research, and local innovation is an essential pillar for making AI a catalyst for sustainable development. Looking ahead, the successful integration of AI into Algeria's energy transition depends on a long-term strategic vision centered on three priorities:

- (1) strengthening digital and energy governance,
- (2) building a resilient and interconnected national technology ecosystem,
- (3) and promoting a culture of sustainability based on responsible innovation.

Thus, if designed in an inclusive and ethical manner, artificial intelligence can become a central pillar of energy sovereignty and environmental sustainability in Algeria and, more broadly, in emerging economies facing the challenges of the 21st century.



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