

Security and Energy Transition in Algeria

الأمن والتحول الطاقوي في الجزائر

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Abstract:

Reconciling energy security and energy transition constitutes a complex strategic challenge for Algeria, given its continued reliance on hydrocarbons and the steady increase in domestic energy demand. This study examines the legal and institutional framework required to achieve an effective balance between these objectives, despite the apparent tension between sustainability requirements and supply security.

It highlights key financial, regulatory, and socio-political constraints, while assessing the effectiveness of the legal framework governing renewable energy. The paper concludes that a gradual and pragmatic legal approach, grounded in the “principle of reality,” is necessary through adaptive legislation, strengthened governance, and diversified financing mechanisms to ensure sustainable energy security.

Keywords: Energy security; Energy transition; fossil fuels; sustainable.

ملخص:

يمثل التوفيق بين أمن الطاقة والتحول الطاقوي تحديًا استراتيجيًا معقدًا للجزائر في ظل اعتمادها المستمر على المحروقات وتزايد الطلب الداخلي على الطاقة. وتهدف هذه الدراسة إلى تحليل الإطار القانوني والمؤسسي الكفيل بتحقيق توازن فعال بين هذين الهدفين، رغم ما قد يبدو من تعارض بين متطلبات الاستدامة وضمان استمرارية الإمدادات.

وتبرز هذه الدراسة أهم القيود، خاصة المالية والتنظيمية والاجتماعية، مع تقييم مدى فعالية الإطار القانوني المنظم لقطاع الطاقات المتجددة. وتخلص إلى ضرورة اعتماد مقاربة قانونية تدريجية قائمة على مبدأ الواقعية، من خلال تطوير التشريعات وتعزيز الحوكمة وتعبئة آليات التمويل، بما يضمن تحقيق استدامة أمن طاقوي.

الكلمات المفتاحية: الأمن الطاقوي؛ التحول الطاقوي؛ المحروقات؛ استدامة.

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Introduction:

Algeria, as a major hydrocarbon-producing country, faces a critical and multifaceted challenge in reconciling energy security with the imperatives of energy transition. Rather than conceptualizing these two dimensions as contradictory or mutually exclusive, they should be approached as inherently complementary, constituting two interdependent pillars of a unified energy system aimed at ensuring both sustainability and security.

The core of this investigation lies in defining a viable pathway to harmonize these two processes within specific temporal horizons: the mid-term (2035) and the long-term (2050). Specifically, it addresses a critical question: How can Algeria navigate its energy transition without compromising national energy security beyond 2030?

Clearly, divorcing the two processes could create instability and discontinuity of energy provision, a vital component not only of productive activities but also of social consumption and transportation needs. In fact, the failure to integrate energy transition with energy security could seriously threaten national security altogether. Therefore, energy policies have to be based on what might be called “a principle of reality,” ensuring that decisions taken are in line with the realities and priorities of the nation.

On the other hand, this combination generates a very complicated dynamic of energy transition process, fraught as it is with important technical difficulties and costs as well as potential errors of strategy. Each country faces this process of transition in different ways, according to its political framework, social preferences, energy resources, and capacity to innovate and develop technologies.

In such a way, energy security and energy transition can be perceived as two complementary sides of one coin which require simultaneous implementation. In order to attain this double aim, there is no choice but to develop a series of strategies according to certain specific conditions of each individual state. Indeed, every country pursues its own particular path in response to its political, economic, social and technological peculiarities. However, in general, the purpose here consists in finding a proper balance between the provision of a stable energy base in the current period and the creation of a sustainable energy supply for future periods.

Regarding the case of Algeria, this investigation aims at shedding light on the issues of making reasonable public policy decisions based on a profound consideration of the structural characteristics of the state under study in terms of both the available resources and the necessary capabilities to realize the potential opportunities.

Therefore, the following research question arises here: **What are the main challenges faced by Algeria in pursuing a realistic and efficient strategy of the long-term energy transition taking into account the growth of the domestic energy demand and changing geopolitical conditions of the international energy market?**

These problems will be analyzed in this study by identifying the factors that hindered the implementation of the renewable energy program that was launched in 2011, as well as the changes that should be introduced in terms of strategy and operations. In this way, this study will seek to avoid voluntarism, which includes calls for abandoning the use of carbon energy systems altogether in favor of more sustainable sources. These views do not seem to correspond with the economic conditions prevailing in Algeria, including its constrained macroeconomic framework, as well as changing dynamics of global power in relation to controlling and harnessing energy sources.

This paper is structured in two main parts. The first part is devoted to clarifying the conceptual foundations of energy security and energy transition. The second part focuses on

deriving initial lessons from the challenging and, at times, obstructed implementation of Algeria's renewable energy program.

Section I: Revisiting the concept of energy security towards energy transition

When we analyze the various national energy models, the first common observation we can make is that nowhere in the world are they based on a sudden break between the production and use of conventional energies (fossil fuels, nuclear, etc.) and those of renewable energies.

A) Revisiting the concept of energy security in Algeria

An analysis of various national energy models reveals a consistent pattern: no country globally has transitioned its energy system through an abrupt shift from conventional sources (fossil fuels, nuclear, etc.) to renewable energies. This holds true for Algeria as well, despite some advocating for an immediate break from the current model and a rapid adoption of potentially immature renewable technologies.

An analysis of various national energy models worldwide consistently demonstrates that the transition from conventional energy sources (fossil fuels, nuclear) to renewable energies is not characterized by an abrupt break. Instead, it unfolds as a gradual and complex process influenced by a multitude of factors, including existing infrastructure lock-in, economic considerations, technological maturity, policy frameworks, and societal acceptance. This evolutionary pattern is evident across historical energy transitions, such as the shift from wood to coal and then to oil¹. These transitions typically span decades, involving parallel development and integration of new technologies rather than a sudden replacement of the old.

This observation holds true for Algeria. While the nation possesses significant renewable energy potential, particularly solar, its energy system is deeply entrenched in hydrocarbon production and export, which constitutes a significant portion of its economy². Despite a growing recognition of the need for diversification and sustainability, and the advocacy from some circles for an immediate abandonment of fossil fuels in favor of nascent renewable technologies, a sudden shift is not reflective of global energy transition trends. The inherent challenges associated with rapidly deploying immature technologies at scale, ensuring grid stability and reliability, and managing the socio-economic impacts of abruptly phasing out a dominant industry necessitate a more measured approach³.

Indeed, the primary driver shaping national energy models, even amidst growing rhetoric favoring "clean" or renewable energy sources with reduced carbon footprints, is often the fundamental imperative of energy security. This paradigm prioritizes the uninterrupted availability of energy resources at affordable prices to ensure the functioning of the economy and the well-being of citizens⁴. For many nations, particularly those heavily reliant on existing energy infrastructure and resource endowments, energy security remains the bedrock upon which any transition towards cleaner sources must be built. Disrupting established energy systems without a secure and reliable alternative can lead to economic instability and social unrest.

Reinforcing this perspective is the World Energy Council (WEC), of which Algeria is an active participant. The WEC's widely recognized energy trilemma framework explicitly acknowledges the interconnectedness of three crucial dimensions in energy policymaking: energy security, energy equity, and environmental sustainability⁵. Energy security, in this context, encompasses the reliable and resilient supply of energy, the management of current and future energy sources, and the robustness of energy infrastructure against disruptions. Energy equity addresses the accessibility and affordability of energy services across the population. Environmental sustainability focuses on mitigating the environmental and climate impacts of energy production and consumption.

The WEC's trilemma highlights that achieving a sustainable energy future requires a balanced approach that considers all three pillars. Nations like Algeria, with significant existing investments in fossil fuel infrastructure and a reliance on hydrocarbon exports for revenue, must navigate this trilemma carefully. While the long-term goals may align with environmental sustainability through increased adoption of renewables, the immediate priority often lies in maintaining energy security and ensuring equitable access to energy for their population, leveraging their existing resources while strategically integrating cleaner alternatives⁶. The pace and pathway of Algeria's energy transition will likely be heavily influenced by its commitment to this balance within the framework of the energy trilemma.

In fact, national energy models, beyond the stated policy of preferring the use of "clean" or renewable energies with a low carbon footprint, are embedded in the paradigm of energy security, which must be ensured first. Along the same lines, the World Energy Council, of which Algeria is an active member, has defined its energy trilemma around three pillars: energy security, energy equity, and environmental sustainability

We can add that this institution, in its prospective study on two global scenarios to 2050, notes that all the results of these scenarios maintain the preponderance of fossil fuels in the energy mix (59% and 77%) compared to renewable energies (20% and 30%), with gas as the dominant source⁷

On the other hand, a retrospective analysis of the evolution of national energy systems over the last five decades clearly shows that major developed countries have prioritized their energy security, sometimes putting environmental concerns second in trade-off situations.

B) Revisiting the concept of energy security in some developed countries

The 1973 oil shock, triggered by Middle Eastern geopolitics, brought about the harsh reality of the vulnerability of industrialized economies to disruptions in their energy supply, particularly the high degree of dependence on foreign oil. The turning point spelt an inherent shift in the energy policy of the majority of industrialized countries, given high and enduring priority to energy security. The immediate response was the creation of the International Energy Agency (IEA) in 1974, a collective initiative of major oil-consumers to harmonize energy policies and ensure oil supply security in the event of future crises.

Since then, the pursuit of energy security by developed countries has increased and taken different shapes of strategic measures, characteristically involving efforts to take greater control of their energy supply chains and maximize the utilization of domestic sources wherever possible. Such priority can be observed across different dimensions:

1. Diversification of Energy Portfolios:

Industrialized countries have been actively seeking to end their dependence on a single energy source and highly unstable foreign markets by diversifying the energy base. This strategy involves:

Investing in Renewable Energy Technologies: Driven by both energy security and environmental concerns, nations like Germany⁸ and Denmark⁹ have made significant investments in wind, solar, and other renewable energy sources to enhance energy independence and reduce reliance on fossil fuel imports.

Promoting Nuclear Power: Countries such as France have historically relied heavily on nuclear energy to ensure a stable and domestic electricity supply, albeit with ongoing debates regarding safety and waste management¹⁰.

Developing Indigenous Fossil Fuel Resources: Nations with domestic coal, natural gas, or unconventional hydrocarbon reserves (e.g., the United States with shale gas) have often prioritized their development to bolster energy security and reduce import dependency¹¹.

2. Securing and Controlling External Supplies of Energy:

Industrialized countries have used numerous mechanisms to offer secure access to international energy supplies:

Creation of Strategic Petroleum Reserves: The IEA mandates member countries to maintain emergency oil stocks equivalent to a minimum of 90 days of net imports. These reserves constitute a significant security measure against supply disruptions.

Fostering Strong Diplomatic and Commercial Relations: To acquire long-term supply contracts and favorable trade terms, building solid relations with large energy-producing nations is paramount¹².

Overseas Energy Infrastructure Investment: Companies from advanced nations have long invested in foreign nations' oil and gas exploration, production, and transportation infrastructure in order to access the resource and some level of control over supply chains.

Military and Geopolitical Strategies: Energy security concerns have appeared in the foreign policy and military strategic deployments of some advanced nations, historically and presently, to secure vital energy corridors and ensure access to basic resources.

3. Valorizing National Hydrocarbon Resources:

Developed countries with domestic oil and gas reserves have often prioritized their exploitation for energy security reasons:

Technological Innovation: Investments in advanced extraction technologies, such as hydraulic fracturing (fracking) in the United States, have unlocked previously inaccessible hydrocarbon resources, significantly boosting domestic production and reducing import dependence¹³.

Policy Support and Incentives: Governments have, in most instances, enacted policies and provided economic incentives to encourage the exploration and production of native oil and gas reserves.

Strategic Resource Management: Some nations have adopted approaches to managing the rate of domestic resource production to achieve long-term energy security and economic rewards.

The United States first. President Barack Obama had made the foreground of his initial presidential campaign to advance green energy. In practice, he pursued a very different energy policy from that which he campaigned on. This policy, taken to scale by President Trump, was characterized by the large-scale production of shale gas and shale oil. This allowed the United States not only to be energy independent for the first time in history but also a natural gas exporter and even a coal exporter.

France, which hosted the Climate Change Summit in December 2015, is on the same strategic path but with different conditions. Parallel to the discourse on its formal choice of energy mix, its nuclear power option has been strategically consolidated in the long term, chosen as the foundation of its energy security. Thus, the French energy transition law maintains the capping of its nuclear power capacity at its current level of 63.2 gigawatts (GW) until 2050¹⁴. It has recently consolidated this strategic nuclear choice through the project to build an EPR (European Pressurized Reactor) and a nuclear-powered aircraft carrier by 2030, and has just commissioned a giant container ship powered by LNG. Finally, it's worth remembering that it has a global oil group: TOTAL.¹⁵

Germany, after abandoning the use of nuclear power following the Fukushima accident and strong pressure from the Green political parties, had to fall back, despite everything, on electricity generation from coal. The intermittency of electricity production from a wind farm, however massive, cannot ensure its energy security. It took advantage of the windfall provided by the low-

cost availability of American coal, which was replaced there by shale gas, to fuel its power plants. Furthermore, it strengthened its natural gas supply from Russia through the construction of the Nord Stream 2 gas pipeline across the Baltic Sea ¹⁶. This is contested by the United States and even the European Union (EU) from a geopolitical standpoint.

Applied today in Algeria, this concept of energy security first implies covering the national electricity demand, produced entirely from natural gas-fired power plants. This necessitates a continuous supply of natural gas until 2030 and beyond to cover not only this demand but also the steadily increasing demand from residential areas and industries for gas. This concept also implies covering the country's fuel needs.

A final historical reminder about this concept of energy security, which in some respects has a certain geopolitical aspect. Thus, hydrocarbon exporting countries organized within OPEC, including Algeria, condition the energy security of consuming countries on the level of revenues from the market valuation of hydrocarbons. They emphasize that the stability and security of investments in the hydrocarbon industry can only result from a fair price, the sole guarantee of the availability of fossil fuels for the global market, and therefore of global energy security. To such an extent that OPEC decreed the "oil embargo" in 1973, which quadrupled the price of a barrel.

As for the concept of energy transition, it emerged more recently. It originated in Germany under the pressure, notably, of the increasingly powerful "Green" political parties, which ultimately imposed support for the emergence of renewable energies and the long-term dismantling of nuclear power (8 of its 17 nuclear power plants were closed in 2013, after Fukushima, with a prospect of total closure of the fleet by the end of 2022).¹⁷

There too, the understanding of this concept can differ between countries potentially emitting renewable energies and countries buying these energies, which may develop a propensity to make the emitting countries bear the burden of investments without guaranteeing a price ensuring a reasonable return on investment. This is the whole complexity and difficulty of the approach initiated by the DESERTEC project, whose limitations I had anticipated at the time. Since then, this institution, now a Think tank based in Dubai, has fallen back on the project of massive hydrogen production and export from the MENA region countries to Europe. This change of strategy is, moreover, as problematic as the previous one for the countries of this region.

However, two important elements are common to both concepts and contribute to their convergence in an optimal energy mix: environmental protection and energy efficiency. As a contribution to the open debate on our own energy challenges, let's take these two common and convergent elements as a foundation to give a more serene and less polemical tone to the discussion.¹⁸

On the point related to the issue of energy efficiency, the country is lagging behind to some extent: its energy, industrial, and social systems are energy-intensive compared to the rest of the world. We cannot discuss the necessity of energy transition while maintaining the current level of energy waste. Therefore, the scope of reforms in this area is very broad: readjustment of the energy consumption model through tariff policies that reduce waste and cross-border smuggling, particularly concerning fuels; integration of energy efficiency into industrial processes and housing programs.

On the issue of vigilance in environmental protection, there is a consensus to put in place regulations and all industrial safety measures before, during, and after the extraction of conventional and, even more so, unconventional hydrocarbon resources. This being agreed, I observe that the secure long-term (2050) recourse to unconventional hydrocarbons is not excluded by any country with significant resources, if we refer to the communication of Ms. Marie-José Nadeau, Honorary Chair of the World Energy Council (WEC). She indeed notes that by this

horizon, "the contribution of natural gas increases in all scenarios," including through the exploitation of "unconventional gas in North America, Argentina, and Australia."¹⁹

In Algeria too, we will eventually need, and beyond 2035 for that matter, all our energy sources, including unconventional gas, to cover our increasing national energy demand and partially finance our economic and social development, including the development of renewable energies.

In conclusion to this part, the energy transition involves nuclear power and coal in Europe, and shale oil and gas in the United States, Argentina, and Australia. Why then, in Algeria, should the energy transition bypass the available conventional and unconventional fossil fuels, at the risk of disrupting its energy security? An energy transition that should also rely on the country's most abundant and available resource: solar energy.

Section II: Renewable energies in algeria

Algeria's path toward renewable energy has had difficulties during its startup phase because of its ambitious goals; however, Algeria has run into challenges trying to meet those goals. Even with its vast amount of solar energy, the pace of renewable energy development has been slower than anticipated due to a number of factors including bureaucracy, lack of required infrastructure, and predominance of the hydrocarbon industry. But the realization of the need for a pragmatic, realistic approach to maximize Algeria's renewable energy potential is fast becoming apparent. To take advantage of its resources, Algeria needs to reevaluate the initial solar vision, concentrate on realistically attainable objectives, entice more investment interest from the private sectors, and simplify the regulatory and legal characteristics of its current marketplace to create a more beneficial environment for solar and other renewable energy technology businesses to invest in Algeria and develop its renewable energy infrastructure. A realistic and adaptable plan of attack is essential if Algeria is going to effectively utilize its natural resources for a sustainable energy future.

A) A difficult start and a vision to be reassessed with a pragmatic approach

Algeria's pursuit of renewable energy integration has been marked by a slow and challenging start, requiring a fundamental shift toward a more pragmatic strategy. Despite establishing an early legislative framework—starting with decrees in the 1980s and formalized by laws on Energy Control and laws on RE Promotion—the country's initial 2011 program struggled with weak implementation and overly ambitious, unachievable targets (e.g., 22,000 MWp by 2030). Subsequent delays, coupled with financial constraints and technological hesitation, compelled the public authorities to reassess their vision. The revised 2020 plan, focusing exclusively on a more manageable 15,000 MWp of solar photovoltaic capacity by 2035, signals a pragmatic prioritization. This approach leverages the significant cost reductions in PV technology and Algeria's abundant solar resources, marking a decisive shift towards achievable grid integration and sustainable development within a volatile global energy and financial context.

1. The Legislative Framework for Renewable Energies in Algeria

Algeria has attached great importance to the subject of renewable energy by ratifying a legislative framework that incentivizes investment in this energy. This part of the study addresses the most important laws issued at the national level in the field of supporting and disseminating the use of renewable energy in various applications.

Algeria's energy diversification policy was translated through the provision of the necessary legal mechanisms to promote renewable energies within the context of a series of reforms that began with the start of the first decade of the second millennium.

The first signs of Algerian interest in renewable energies began in 1983 when an agreement was concluded with Belgium. On February 19, 1983, the two countries reached an agreement in the field of renewable energy development, aiming to encourage scientific, technological, and industrial

cooperation related to the execution of projects connected to the development of new and renewable energies.

This included, in particular, studying and executing pilot projects for electricity generation and supplying rural areas with energy according to their needs (pumping, water desalination, water heating, drying and exporting agricultural products) and developing the manufacturing industry of power generation equipment for the exploitation of new and renewable energy sources.²⁰

As for the laws, the starting point was the old Environmental Law 83-03 of February 5, 1983. However, it did not specifically address renewable energies but rather sufficed with conserving and valuing natural resources. Therefore, in this requirement (section), I will address the laws related to this specific field.

Key Legislation Concerning Renewable Energy in Algerian Law:

1.1. Law 98-11:²¹

Law 98-11 of August 22, 1998, comprising the Guiding Law and the Five-Year Program on Scientific Research and Technological Development (1998–2002). Among its objectives was to ensure the promotion of scientific research and technological development, and the economic and social development of the country. This law also focused on the development of natural resources, the environment, and ecological diversity.

This law also stipulated the necessity of integrating scientific research and technological development programs in the field of renewable energies and creating high-quality projects with a direct impact on the country's social and economic reality, in addition to the rational use of our renewable energy assets and establishing specific regulations for them.

1.2. Law 99-09: Relating to Energy Control:²²

This law aims to define the conditions, means of framing, and implementation of the national policy for energy control (or energy management). This control includes all applied measures and activities intended to rationalize the use of renewable energy sources, limit the impact of the energy system on the environment by reducing greenhouse gas and vehicle emissions in cities, and strive for the development and promotion of exploitable renewable energy sources.

This law explicitly addresses renewable energy sources in Article 4, where it defines the development of these energy sources: "The development of renewable energy sources is the introduction and promotion of sectors for converting exploitable renewable energy sources, particularly solar, geothermal, hydropower, and wind energy." Through this article, we find that the legislator did not only define these energy sources themselves but also mentioned that their development is achieved by promoting and exploiting them.

From the foregoing, we find that this law gave importance to renewable energy sources and called for their development and promotion through their financing and integration into the national economic sector. Furthermore, the national program for energy control falls within the scope of encouraging the exploitation of renewable energy.

1.3. Law 01-20: Relating to National Planning and Sustainable Development:²³

The provisions of this law define the guidelines and tools related to national planning that are intended to ensure the development of the national space and the creation of coherent and sustainable development, in accordance with the foundations set by this law. Among these foundations is the adoption of policies that help achieve sustainable territorial planning.

The law addresses the objectives of this plan in Article 33, which specifies the rational exploitation of energy resources and the development of renewable energy sources. It also aids in

combating environmental pollution and the effects of global warming resulting from the exploitation of fossil energy.

Furthermore, it links energy and the economy and sets the conditions that the State and regional authorities must adhere to for managing energy control activities, as well as the production and use of renewable energy sources

1.4. Law No. 04-09: Relating to the Promotion of Renewable Energy:²⁴

This law explicitly defined renewable energy sources in Article 3 as:

"Forms of electrical, kinetic, thermal, or gaseous energy obtained from the conversion of solar radiation, wind power, geothermal heat, organic waste, hydraulic energy (hydropower), and biomass utilization techniques."

Through this definition, we find that the legislator addressed the sources from which renewable energy is derived: solar energy, wind energy, geothermal heat, hydraulic energy, organic waste, and biomass. This definition is the same as the one contained in Law 02-01 concerning Electricity and Gas Distribution via Pipelines.

Furthermore, this law addressed the National Program for the Promotion of Renewable Energy. This program is considered the set of activities that work to promote renewable energy. This program is a five-year plan that falls within the scope of future schemes specific to National Planning and Sustainable Development.

1.5. Executive Decree No. 17-98 of February 26, 2017

Defining the Procedures for Tendering for the Production of Renewable Energy or Cogeneration of Power and their Integration into the National Electricity Supply System, as Amended and Supplemented by Executive Decree No. 17-204.

1.6. Executive Decree No. 13-218 of June 18, 2013

Specifying the Conditions for Granting Remuneration for the Costs of Diversifying Electricity Production. Amended by Executive Decree No. 17-167.

This decree is a critical regulatory tool used to:

Incentivize Diversification: Provide financial compensation or rewards to producers to cover the additional costs associated with generating electricity from diverse and often cleaner sources, particularly renewable energy.

Regulate Financial Mechanisms: Define the precise conditions and mechanism by which these costs are calculated and the remuneration is granted, thereby regulating the financial relationship between the State/Regulator and energy producers.

Support Policy Implementation: Serve as an implementing text for broader energy laws (like those mentioned previously) aimed at promoting renewable energy and ensuring a stable and diverse national electricity supply.

2. Algeria's Renewable Energy Program: Challenges of a Delayed Start and the Shift Towards Pragmatism (2011–2035)

The first governmental renewable energy program launched in 2011 had only week implementation and therefore, of course, very weak results. That program targeted to produce 22,000 MWp of solar electricity by 2030, 10,000 of which targeted to be exported to Europe. Public authorities, after long hesitation to be made between two technological options: concentrating solar power (CSP) and photovoltaics, have opted for the latter. This early restraint proved useful as

Algeria did not commit to an expensive and yet immature CSP technology and benefited from the huge diminution in the cost of photovoltaic technology.²⁵

Based on these new, less expensive technological foundations, the Ministry of Energy, which had planned in 2017 to launch a tender for the construction of photovoltaic power plants with a capacity of 4050 MW, in three tranches of 1050 MW, postponed the operation due to the difficulty and complexity of implementation. The public authorities, who had integrated the obligation of industrial integration into the program, hesitated between entrusting this program to the Sonatrach-Sonelgaz association in partnership with major industrial groups in renewable energies or awarding it to local private companies without sufficient experience in managing large projects.²⁶

In fact, the successive postponements are certainly due to disagreements on the direction and on the choice of companies to involve, but also to a weak propensity of foreign partners to favor the emergence of a local industry for equipment and spare parts intended for the photovoltaic sector. Moreover, in the current situation of strong financial and budgetary constraints, the issue of financing this program proves more complex and, to my knowledge, has not yet been resolved. In this regard, the public authorities, even if they might be tempted to do so, will have difficulties financing this program through budgetary means. They could prioritize the mobilization of private financial resources combined with bank loans based on the project financing formula. Recourse to potential funds released by the international community and their financial institutions to combat climate change, in particular, could also support these projects.

The announcement of Algeria's revised renewable energy program in 2020, aiming for 15,000 MWp of solar photovoltaic capacity by 2035, must be understood within the complex and volatile global energy context of the time. The COVID-19 pandemic had a profound and multifaceted impact on the energy sector, most notably triggering a significant downturn in global oil demand and consequently a worsening oil crisis. For oil-exporting nations like Algeria, heavily reliant on hydrocarbon revenues, this crisis created substantial economic pressures and increased uncertainty regarding future income streams²⁷. This economic vulnerability likely contributed to the adoption of a "less ambitious" renewable energy development program compared to potentially more expansive pre-pandemic plans.

The decision to focus exclusively on solar photovoltaics (PV) for this new program suggests a strategic prioritization based on several factors. Solar PV technology has witnessed significant cost reductions and efficiency improvements over the past decade, making it increasingly competitive with traditional energy sources in many regions²⁸. Furthermore, Algeria possesses significant solar resources, making PV a logical choice for leveraging domestic renewable energy potential²⁹. The relative modularity and shorter deployment times of solar PV projects compared to other renewable technologies (like large-scale wind or concentrated solar power) might also have been a consideration in a context demanding quicker returns and manageable investment scales.

The stated objective of connecting the 15,000 MWp of solar power plants to the national electricity grid underscores the intention to integrate this renewable capacity directly into the existing energy infrastructure. This grid integration is a crucial aspect of ensuring the reliability and stability of the power system as the share of variable renewable energy increases³⁰.

Effective grid management, including investments in grid modernization, energy storage solutions, and demand-side management, will be essential for successfully absorbing this large-scale solar generation.

The announcement of a first tranche of 1,000 MW to be implemented in 2021 signals a phased approach to achieving the 2035 target. This step-by-step implementation allows for learning, adaptation, and potentially adjustments to the program based on technological advancements, economic conditions, and grid integration experiences. The endorsement of this first phase by the

Minister responsible for Renewable Energies and Energy Transition indicates the government's willingness, at least in the short term, to this medium-term renewable energy development policy.

B) Towards an operational consensus on an energy mix to be built around natural resources and energy sobriety

It now appears clear that a solid and broad consensus is emerging around both the content of the energy transition in Algeria and the steps to be taken by 2035. Three elements seem to structure this consensus:

1. The effective rationalization of energy consumption in the mobility, residential, and productive activities sectors

The effective rationalization of energy consumption across the mobility, residential, and productive activities (goods and services) sectors is a crucial pillar for achieving energy security, economic efficiency, and environmental sustainability. It involves implementing strategies and policies that aim to reduce energy waste, improve energy efficiency, and shift towards less energy-intensive practices within each of these vital areas.

1.1. Mobility Sector:

The mobility sector-comprising transport of people and goods-is a major energy consumer, and nearly all that energy presently comes from fossil fuels. Rationalizing energy use in this sector will call for an integrated approach:

Improvement in vehicle efficiency: This would encompass advancements in engine technology, in the form of hybrids and electric vehicles, lightweight materials, improved aerodynamics, and better tire efficiency. These kinds of innovations would be supported by government regulations, such as fuel economy standards and emissions targets.

Promoting Public Transportation: Investing in and improving the accessibility, affordability, and convenience of public transportation systems (buses, trains, trams, subways) can significantly reduce the number of private vehicles on the road, leading to lower overall energy consumption and emissions³¹.

Promoting Active Mobility: Designing infrastructure promoting and facilitating walking and cycling (such as pedestrian paths, cycle lanes, bike-sharing systems) not only saves energy but also has health and environmental advantages.³²

Maximizing Freight Transport and Logistics: Implementing more smart logistics policies, for instance, route planning, load consolidation, intermodal freight shipping (simultaneous use of different modes such as truck and rail), and employing more efficient freight trucks can help achieve great energy savings for goods transport³³.

Facilitating the Shift to Electric Mobility: Encouraging the use of electric vehicles (EVs) through subsidies, tax relief, and the establishment of charging facilities is vital to decarbonizing the transport sector, particularly if the grid supply becomes more dominated by renewables

Encouraging Eco-Friendly Aviation and Sea Transport: Research and development of novel alternative fuels (such as biofuels, hydrogen), engine efficiency, and best-in-class operating practices are vital to lowering the carbon intensity of aviation and shipping.

1.2. Residential Sector:

The demand for energy in the household sector is mostly caused by heating, cooling, lighting, and household appliance usage. Rationalization measures target:

Improving Building Energy Efficiency: Implementing stricter building codes that mandate better insulation, energy-efficient windows and doors, and passive solar design principles can significantly reduce the energy needed for heating and cooling. Retrofitting existing buildings with these measures is also crucial.

Promoting Energy-Efficient Appliances: Encouraging the use of energy-efficient appliances (e.g., refrigerators, washing machines, air conditioners) through labeling schemes, minimum energy performance standards, and consumer awareness campaigns can lead to substantial energy savings over their lifespan³⁴.

Encouraging Efficient Lighting: Transitioning to energy-efficient lighting technologies like LED bulbs significantly reduces electricity consumption for illumination³⁵.

Smart Home Technologies: Implementing smart thermostats, lighting controls, and energy management systems can optimize energy use based on occupancy and real-time conditions³⁶.

Promoting Behavioral Changes: Educating consumers about energy-saving habits, such as turning off lights when leaving a room, unplugging electronics not in use, and adjusting thermostat settings, can contribute to significant reductions in energy consumption³⁷.

Supporting Renewable Energy Integration: Encouraging the adoption of rooftop solar photovoltaic systems and solar water heaters can reduce reliance on grid electricity and fossil fuels for residential energy needs.

1.3. Productive Activities (Goods and Services) Sector:

This sector encompasses industrial processes, commercial buildings, agriculture, and other economic activities. Rationalizing energy consumption here involves:

Improving Industrial Energy Efficiency: Implementing energy management systems, adopting best available technologies, optimizing industrial processes, and recovering waste heat can lead to significant energy savings in manufacturing and other industries.

Enhancing Energy Efficiency in Commercial Buildings: Similar to the residential sector, improving insulation, using energy-efficient HVAC (heating, ventilation, and air conditioning) systems and lighting, and implementing building automation systems can reduce energy consumption in offices, retail spaces, and other commercial buildings³⁸.

Promoting Sustainable Agriculture: Adopting energy-efficient farming practices, using renewable energy sources for irrigation and machinery, and optimizing fertilizer use can reduce the energy intensity of the agricultural sector³⁹.

Encouraging the Circular Economy: Shifting towards a circular economy model that emphasizes reuse, repair, and recycling can reduce the energy needed for raw material extraction and manufacturing⁴⁰.

Investing in Research and Development: Supporting innovation in energy-efficient technologies and processes across all sub-sectors of productive activities is crucial for long-term energy rationalization.

Implementing Carbon Pricing Mechanisms: Carbon taxes or cap-and-trade systems can incentivize businesses to reduce their energy consumption and greenhouse gas emissions⁴¹.

2. The unavoidable expansion of hydrocarbon reserves, particularly gas reserves;

While the argument for an "unavoidable expansion of hydrocarbon reserves, particularly gas reserves," holds some weight due to persistent energy demand, the role of natural gas as a transition fuel, energy security concerns, and existing infrastructure, it is not without significant challenges

and strong counterarguments. The urgency of climate change necessitates a rapid and decisive shift towards renewable energy sources and energy efficiency measures.

The expansion of hydrocarbon reserves, if it occurs, should ideally be viewed as a transitional strategy with a clear trajectory towards phasing out fossil fuels. This transition must be managed carefully to avoid locking in long-term dependence on hydrocarbons and to mitigate potential environmental and economic risks. Governments and industries must prioritize investments in renewable energy, grid modernization, energy storage, and demand-side management to ensure a sustainable and secure energy future that minimizes the unavoidable expansion of hydrocarbon reserves.

3. The more rapid development of renewable energies, mainly through photovoltaic solar electricity technology in decentralized systems.

The more rapid development of renewable energies, particularly through photovoltaic solar electricity technology in decentralized systems, holds immense promise for a sustainable and resilient energy future. By leveraging the decreasing costs, technological advancements, and modularity of solar PV, coupled with the benefits of decentralized energy generation, nations can enhance energy security, mitigate climate change, and empower communities. Addressing the associated challenges through strategic planning, supportive policies, and continued innovation will be crucial for realizing the full potential of this transformative energy paradigm.

Some aspects of the approach remain open, still maturing and/or under discussion in our country. The first concerns the use of unconventional hydrocarbons, of which Algeria holds the third largest global resources (19,800 billion m³). We saw earlier that the debate is settled in countries with significant potential, while concerns still persist in our country. These concerns will need to be addressed, when the time comes, through national consultation.⁴²

The second aspect concerns the immediate or non-immediate introduction of new emerging hydrogen technologies as a transport vector and energy source, without forgetting CSP. This introduction seems premature to me. However, for this latter technology, which is in an emerging industrialization phase in advanced countries, national scientific and industrial monitoring should be consolidated now by our research system and our major energy groups.⁴³

It seems to me that the public authorities, through the voice of the Prime Minister in his message published in the recent report of the Commission for Renewable Energies and Energy Efficiency (CEREFE), validate the three components of the energy mix mentioned above, including the expansion of our hydrocarbon reserves.⁴⁴ He indicates indeed that "any action allowing for increased optimization of internal energy consumption would be encouraged in the same way as actions that can contribute to extending the lifespan of our hydrocarbon reserves, by diversifying alternative energy production methods, particularly those based on renewable resources." He even specifies that "the volumes of gas and oil saved could, in this case, open up new prospects through an effective expansion of local petrochemical activities."⁴⁵

Conclusion

In conclusion, the transition towards a sustainable energy future in Algeria represents not only a mere technical change but a multidimensional phenomenon that needs to be understood in terms of Energy Security. It was shown throughout the paper that the current state of affairs on the international energy stage shows that the "abrupt break" away from conventional resources is far from being realistic. The Algerian energy sector provides for the country's economic sustainability due to the provision of the necessary funding for further transformations of the country's energy policy.

The findings of the paper include the following:

The Trilemma as the Key to Success: An efficient energy policy in Algeria should necessarily take into account the three components of the World Energy Council's trilemma – Energy Security (valorization of gas), Energy Equity (provision of affordable access), and Environmental Sustainability (phased integration of renewables).

Legislatively Advanced but Pragmatically Behind: Although Algeria already has a well-developed and early legislation (beginning from the 1980s), the main difficulty is to transform "legal intention" into operational reality. The adjustment of initially ambitious plans (2011) in favor of more realistic goals (2020, 15,000 MWp by 2035) reflects this necessity.

The Two-track Approach to Rationalization: The process depends on both the Energy Efficiency strategy and renewable energy production. Energy waste reduction in residential, transportation, and industrial areas represents the fastest and most cost-efficient way to maximize the operational life span of the nation's fossil fuels.

Technological Vigilance: The ultimate integration of nonconventional sources of energy and novel technologies such as Green Hydrogen must be conducted under the principle of technological vigilance. This means that any new technology must achieve industrial maturity and economic feasibility before integration to avoid compromising national energy sovereignty.

Ultimately the energy transition process must be evolutionary rather than revolutionary. It needs to be developed through a "Convergent Mix," in which natural gas plays the role of the necessary intermediate stage towards a solar-dominated future. The process requires minimizing regulatory barriers, attracting private investors, and cultivating energy sobriety. This approach will help Algeria leverage its abundant natural resources to establish an energy model for the mid-21st century.

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