

TRANSITIONING TO RENEWABLE ENERGY: A PATHWAY FOR ACHIEVING NET-ZERO POWER GENERATION IN ALGERIA BY 2050

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RESUME :

La transition vers une économie neutre en carbone est une priorité mondiale cruciale pour atténuer les effets néfastes du changement climatique. Cette étude explore la voie de l'Algérie vers un système de production électrique à émissions nettes nulles d'ici 2050, en accord avec les engagements de l'Accord de Paris. Le modèle énergétique « bottom-up » Open Source Energy Modeling System (OSeMOSYS), accompagné de données spécifiques à l'Algérie, a été utilisé pour éclairer les décisions relatives au mix électrique optimal. L'étude évalue un scénario dans lequel les sources d'énergie renouvelable, notamment le solaire et l'éolien, constituent 100 % du mix électrique à l'horizon 2050, tout en éliminant progressivement les combustibles fossiles conventionnels. Atteindre cet objectif nécessite une accélération rapide du déploiement des technologies à des rythmes sans précédent. Cette transition sera appuyée par des avancées dans le stockage de l'énergie et la modernisation des réseaux électriques pour intégrer la production variable des énergies renouvelables. Cependant, atteindre cet objectif ambitieux nécessitera des investissements massifs et une innovation technologique continue.

Mots clés : Production d'électricité, Zéro émission nette, Énergies renouvelables, Stockage de l'énergie, Transition énergétique.

ABSTRACT:

The transition to a carbon-neutral economy is a critical global priority for mitigating the adverse effects of climate change. This study explores Algeria's pathway to achieving a Net-Zero power generation system by 2050, aligned with the Paris Agreement. A bottom-up Open Source Energy Modeling System (OSeMOSYS) and starter kit data for Algeria are used to inform the decision about the optimal electricity mix. The study evaluates a scenario where renewable energy sources, particularly solar and wind, constitute 100% of the power mix by 2050 while gradually phasing out conventional fossil fuels. Achieving this target necessitates a rapid acceleration in the deployment of technologies at unprecedented rates. This transition will be supported by advancements in energy storage and grid

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modernization to accommodate variable renewable generation. However, reaching this ambitious goal requires robust investment and technological innovation.

Key words: Power Generation, Net Zero, Renewable Energy, Energy Storage, Energy transition.

I INTRODUCTION

The commitment of countries to reduce their emissions to zero in the coming decades continues to grow. However, despite full compliance with the commitments made by governments to date, they are not high enough to reduce global energy-related carbon dioxide emissions to zero by 2050 and offer the world an opportunity to limit global temperature rise to 1.5°C.

Climate science shows that to effectively slow climate change, we must stop carbon emissions altogether, as reducing them is no longer sufficient. Achieving Net zero means balancing any remaining emissions by absorbing an equivalent amount from the atmosphere. To meet the Paris Agreement's global warming target of 1.5°C, developed countries need to reach net zero by around 2050, while developing countries must aim for 2060 or earlier. On a positive note, many countries have already set such targets. Numerous technologies already exist that can bring emissions down to zero, including renewable energy, hydrogen, and nuclear generation.

Many countries have committed to setting net zero targets within a timescale aligned with the Paris Agreement. While many countries struggle to reduce their carbon emissions, and some refuse altogether, Bhutan is gaining global recognition for its climate policies, despite being situated between two of the world's largest polluters China and India. Some countries that committed early even plan to achieve a carbon-negative economy by around 2035 to 2045.

Several nations in the MENA and North Africa regions have taken decisive actions to implement what we now call a climate-friendly economy, representing the first step toward transitioning to a net zero emissions economy. The United Arab Emirates and Oman have committed to achieve net zero by 2050, while Saudi Arabia and Bahrain have set a net zero target for 2060 [1]. Others in the region, including Egypt and Qatar, have updated their Nationally Determined Contributions (NDCs). A movement and growing awareness positively influence the Global South's outlook.

However, in economies based on natural resources and in sectors where technological advancements are limited, emissions are unlikely to be reduced to zero. As a result, the decarbonization process will take longer in these areas.

Algeria, with its vast reserves of fossil fuels, plays a critical role in the global energy landscape as a prominent member of the Organization of Petroleum Exporting Countries

(OPEC), boasting a Gross Domestic Product (GDP) of 186.995 billion \$ in 2022[2]. However, this resource-driven economic expansion has positioned Algeria as one of the leading contributors to carbon dioxide (CO₂) emissions in Africa, ranking third after South Africa and Egypt[3], with total emissions of 176,35 Mt CO₂[4]. The energy sector is responsible for 81.5% of the country's total greenhouse gas emissions, with CO₂ being the primary contributor, as indicated by the Ministry of Environment and Renewable Energies [5].

The urgency for a transition to renewable energy in Algeria is highlighted by its electricity production statistics: in 2022, the country generated 90.6 TWh of electricity with an installed capacity of the national generation park 25.4 GW[6], 98 % was generated by natural gas, while renewable sources contributed a mere 1%.

Given Algeria's considerable potential in renewable resources such as solar, wind, hydro, biomass, and geothermal[7], it is essential to undertake a strategic transition to sustainable energy practices. This shift is crucial for achieving net zero emissions.

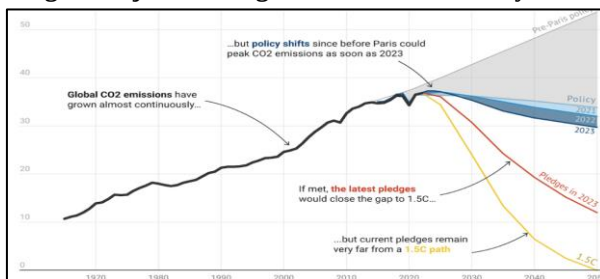
This creates a critical challenge in terms of aligning with global climate objectives, which emphasize the reduction of greenhouse gas emissions and the transition to cleaner energy sources. This study will examine the feasibility of accelerating Algeria's pathway to a Net Zero Emissions by 2050 scenario, focusing on how the country can achieve significant reductions in emissions within the power sector, The main objective of this study is to explore potential pathway and perform a quantitative analysis of the future power generation sector in Algeria.

This paper is structured as follows: the second section addresses the urgent need for climate action in light of rising CO₂ emissions and explores pathways to achieving Net Zero by 2050. The third section highlights Algeria's current electricity production, emphasizing its reliance on natural gas while showcasing its significant renewable energy potential. The fourth section outlines the methods and tools used in this study. Section five presents and discusses the results of our study. Finally, the sixth section provides the conclusion.

II CLIMATE CHANGE AND NET ZERO

Global CO₂ emissions are rising steadily, driven by economic growth and industrialisation. The figure shows the possible consequences of policy changes since the Paris Agreement, suggesting that emissions could peak by 2023 as a result of recent commitments. Different scenarios are presented, such as a pre-Paris policy baseline, projected emissions under the new provisions, and pledges announced for 2023, all confronted with a trajectory of zero emissions by 2050 to limit global temperature rise to 1.5°C. While the fulfilment of the latest pledges can significantly narrow the gap towards this goal, current commitments remain insufficient, highlighting the urgent need for more aggressive climate action to ensure a sustainable future.

Fig.1. Projections of global CO₂ emissions by 2050.



Source : [8]

In line with the Paris Agreement's goal of keeping the rise in the average global temperature to 1.5°C over pre-industrial levels, the energy sector can embrace the Zero Net Emissions by 2050 (NZE) scenario. The IPCC's attempts to promote carbon neutrality through its reports and make it a guiding principle in international climate negotiations, particularly through the Paris Agreement, have been bolstered by scientific study, which is where the idea of carbon neutrality originated.

In 2009, A new study in the Proceedings of the National Academy of Sciences, led by Susan Solomon, concludes that climate change effects from increased carbon dioxide (CO₂) levels are largely irreversible for over a millennium. Even if CO₂ emissions stop after rising to 450-600 ppm, regions may face prolonged decreases in rainfall and rising sea levels, impacting agriculture and ecosystems. The study underscores the lasting impacts of CO₂ on global temperatures and highlights the challenges of geoengineering solutions[9]. The article "Warming caused by cumulative carbon emissions towards the trillionth tonne" by Allen et al.[10] demonstrates that the relationship between cumulative carbon dioxide emissions and global warming is significant. The authors argue that the warming effect of carbon emissions is largely determined by the total amount of carbon emitted rather than the rate or timing of emissions. They emphasize that reaching cumulative emissions of one trillion tonnes of carbon (approximately 3.67 trillion tonnes of CO₂) is likely to result in a substantial increase in global temperatures, with a probable peak warming of around 2 degrees Celsius above pre-industrial levels. This underscores the importance of focusing on cumulative emissions in climate policy to effectively manage and mitigate global warming.

In 2012, Matthews et al. [11] focused on cumulative carbon emissions provides a clearer and more effective framework for climate policy aimed at stabilizing global temperatures. The authors argue that the total amount of carbon dioxide emitted over time is a key determinant of long-term warming, rather than just the rate of emissions. They emphasize that establishing limits on cumulative emissions can help policymakers set more concrete and scientifically grounded targets for reducing greenhouse gases, thereby enabling better management of climate change risks and promoting effective climate stabilization efforts. This approach

aims to clarify the relationship between emissions, carbon budgets, and temperature outcomes, ultimately guiding international climate agreements and national policies.

In 2013, The IPCC's Fifth Assessment Report emphasizes that to limit global temperature change, it is essential to control the cumulative CO₂ emissions in the atmosphere. It states that achieving this goal requires that net anthropogenic CO₂ emissions ultimately reach zero. This means that, in order to halt global warming, all human-induced contributions of CO₂ to the atmosphere must be eliminated, thereby stabilizing the climate and preventing further temperature increases. The report underscores the importance of setting effective policies and strategies to reduce emissions and transition towards carbon neutrality to mitigate the impacts of climate change.

In 2015, Article 4.1 of the Paris Agreement emphasizes the commitment of participating countries to achieve global peaking of greenhouse gas emissions as soon as possible. The goal is to establish a balance between anthropogenic emissions produced by various sources and the removals of greenhouse gases by natural sinks during the second half of the century. This balance is crucial for limiting global warming and achieving climate stability. The article underscores the need for urgent action and coordinated efforts to reduce emissions, enhance carbon sinks, and promote sustainable practices to combat climate change effectively.

In 2018, IPCC Special Report on Global Warming of 1.5 Degrees Celsius concludes that limiting the global temperature rise to approximately 1.5 degrees Celsius and mitigating the most severe impacts of climate change necessitates achieving net-zero carbon dioxide (CO₂) emissions by mid-century. Additionally, the report emphasizes the importance of making significant reductions in non-CO₂ greenhouse gas emissions. This comprehensive approach is critical for reducing the risks and impacts associated with climate change, highlighting the urgency of adopting robust climate policies and strategies to facilitate a sustainable and resilient future.

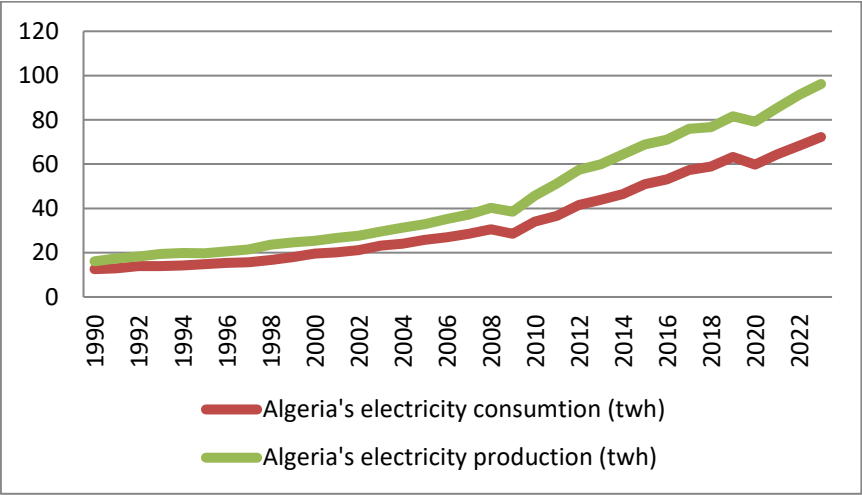
In 2023, the first-ever global stocktake is scheduled to conclude at the UN Climate Change Conference (COP28). This stocktake represents a critical evaluation of progress made by countries in achieving their climate commitments under the Paris Agreement. It aims to assess collective efforts towards limiting global warming and to identify gaps and challenges that need to be addressed. The outcomes of this stocktake will play a vital role in shaping future climate policies, enhancing accountability, and fostering international cooperation to accelerate actions necessary for mitigating climate change and achieving long-term sustainability goals.

III RENEWABLE ENERGY POTENTIAL

In 2022, Algeria's electricity production reached 90.6 TWh with an installed capacity of the national generation park 25.4 GW, compared to 24.6 GW in 2021, representing an annual growth rate of 3.1%.

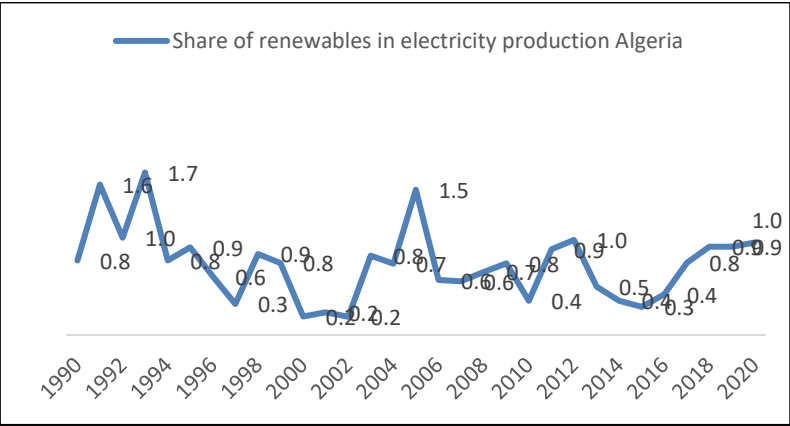
Algeria intends to incorporate a significant amount of renewable energy into its power network in order to address rising consumption levels. However, this may be a long road, in 2022 98% of electricity supply was generated by natural gas, 42.9% of electricity generation is provided by gas turbine, 52% generated from combined-cycle power plants and 4.8% by steam turbine [12], while the share of renewables was 1%. According to the figures 3 and 4, renewables play a marginal role in the energy mix. Indeed, solar power contributed by 84% of the total electricity generated from renewables, hydropower by 15% and wind power at just 1%.

Fig.2. Algeria’s electricity production and consumption (Twh) (1990-2023).



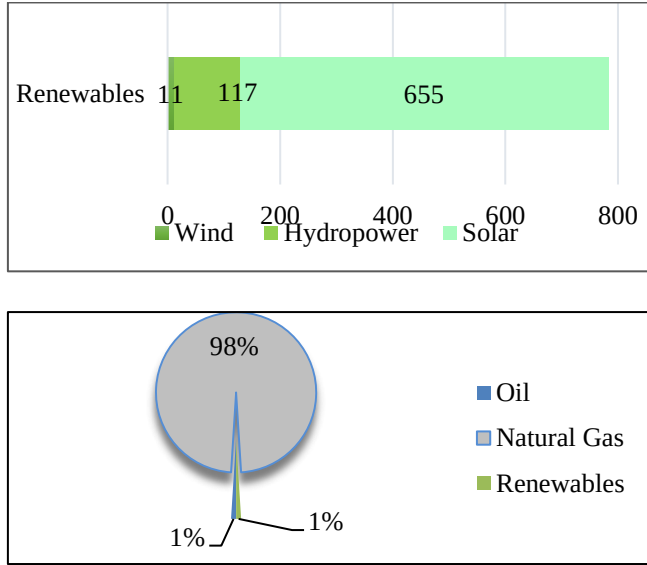
Source : [13]

Fig.3. Share of renewables in electricity production Algeria (1990-2020).



Source : [14]

Fig.4. Algeria's electricity generation Mix by 2018 (GWh).



Source : [15]

In 2014, Algeria installed its first wind turbine farm in Kabertene Adrar, located in the southern region of the country, with a total generation capacity of 10 MW[16]. The southwestern region of the country experiences a high average wind speed, with annual mean wind speeds exceeding 5 m/s. Merzouk.N and Merzouk.M [17] found that wind turbines with capacities of 600 and 800 kW could provide sufficient power density for small-scale applications.

Table.1. Algeria's WIND potential Twh/Year

All areas with wind turbine CF greater than 20%	30,155
All areas with wind turbine CF greater than 30%	2535,9
All areas with wind turbine CF greater than 40%	153,4

Source: [18]

Algeria possesses one of the highest solar energy potential. The World Energy Council has agreed that Sahara area climate is favorable for the growth of solar energy , beeing the highest average solar irradiation and temperature, by receiving around 3,500 hours of sunlight[19]. The table 2 presents a detailed breakdown of Algeria's solar potential.

Table.2. Algeria’s solar potential.

Areas	Coastal area	High plains	Sahara
Surface (%)	4	10	86
Area(km ²)	95.27	238.174	2.048297
Mean daily sunshine(h/year)	2650	3000	3500
Received average energy KWh/m ² /year	1700	1900	2650
Solar daily energy density (KWh/m ²)	4.66	5.21	7.26
Potential daily energy (TWh)	443.96	1240.89	14,870.63

Source: [20]

Algeria exhibits significant potential for hydropower generation due to the presence of numerous potential dam sites, it has 103 identified potential dam sites, and the estimated annual average rainfall is approximately 65 billion cubic meters. The majority of hydropower plants are situated in the northern regions of the country, it operates 13 hydropower plants with a total annual generation capacity of 389.4 GWh, positioning hydropower as the fourth largest component of the nation’s energy mix, following natural gas, oil, and solar energy[21].Despite the significant potential for renewable energy in Algeria, it remains marginal, with fossil fuels continuing to be the country's primary energy source. The goal of the massive renewable energy development program is to install a capacity of 15,000 MW by 2035, including 4,000 MW by 2024, the implementation of this program will increase the share of renewable energy, primarily solar, in the electricity mix by 2030[22].

IV METHODS AND TOOLS

A. Methods and Tools

OSeMOSYS is a linear optimization bottom-up model for long-term energy modelling, specifically designed as a tool to inform local, national or multi-regional energy strategies and support capacity-building activities. It was developed in collaboration with a range of institutions, including the International Atomic Energy Agency (IAEA), the United Nations Industrial Development Organisation (UNIDO), KTH Royal Institute of Technology,

Stanford University, University College London (UCL), University of Cape Town (UCT), Paul Scherrer Institute (PSI), Stockholm Environment Institute (SEI), and North Carolina State University[23]. An overview of OSeMOSYS and its functionalities is presented in [24].

The objective of the OSeMOSYS solver is to find the optimal combination of technologies able to meet the energy (energy services or demand(s)) at the lowest Net Present Value (NPV) possible of the energy system, taking into considerations the constraints (i.e. capacity, activity, emissions, operational life) set by the user.

In our research, we first initiated the modeling process by downloading relevant data files from Zenodo repositories [25]. To facilitate data management and model execution, we acquired and utilized clicSAND, an open-source graphical user interface designed for the OSeMOSYS framework [26]. We prepared the data using Excel spreadsheets, which were then inputted into clicSAND. Next, we selected the GLPK (GNU Linear Programming Kit) as the open-source solver to execute our model[27]. After setting up the model parameters in clicSAND, we employed the OSeMOSYS Cloud [28] to run the model. This platform provides an online solver service, enabling efficient computation through cloud-based resources. The process consists of five key steps: first, we download the model code (OSeMOSYS model v3.txt) and the associated data file; next, we set up a server environment to run the model. The third step involves preprocessing the data to ensure it meets the model's requirements, followed by generating the necessary matrix. Finally, the model is solved using the selected solver, and the results are either visualized directly in the OSeMOSYS Cloud or exported to Excel via the clicSAND interface. Additionally, we exported the results into an Access database for further analysis, which we visualized using an Excel template.

B. *Study boundaries and scenario description*

The OSeMOSYS model for Algeria (OSeMOSYS-DZ) is structured to optimize the country's energy system through a series of defined temporal, spatial and technical boundaries.

The OSeMOSYS-DZ model for Algeria operates within a mid-term timeframe, spanning from 2020 to 2070. Historical data from 2015 to 2019 provides the foundational context for the analysis (Year: 2015-2070). To capture the temporal dynamics of energy demand throughout the year, The year is divided into four seasons: Winter, Spring, Summer, and Fall. Each season is further split into 24 time slices, representing different periods of the day such as morning, afternoon, evening, and night, or even hourly divisions. This results in a total of 96 time slices (S101, S102, ..., S424) (4 seasons $\times$ 24 time slices). This approach allows for a detailed and nuanced understanding of energy demand and supply variations across different timescales.

In the OSeMOSYS-DZ model, the spatial boundaries are defined by a single region RE1 encompassing the entire country. The model operates using US Dollars (USD \$) as its currency.

The model analysis focuses on the following technologies: Concentrated Solar Power (CSP) with storage, onshore and offshore wind power, Solar PV systems (both distributed and utility-scale), and biomass. Technologies such as solar thermal, hydrogen, and wave energy are excluded due to their high cost implications.

We incorporated storage systems, onshore wind power, CSP, and utility-scale PV systems with two hours of storage. Transmission technologies are limited to a local interconnected transmission system, facilitating the movement of electricity within the country. Distribution technologies are not included in this research study. The table in appendix A presents technologies used.

The scenario Net-Zero in this study was created using the Algeria Data Starter Kit [29], it anticipates a significant transition towards a climate-neutral energy system by 2050, with reduced reliance on fossil fuels and substantial investments in renewable technologies. The scenario forecasts a gradual decline to zero in domestic production and imports of fossil fuels and biomass starting in 2021. No investments are planned for nuclear power. Instead, there will be significant investments in CSP, onshore and offshore wind, and Solar PV systems (both distributed and utility-scale), alongside investments in storage technologies to manage the variability of renewable energy sources.

In terms of demand and supply, the Net Zero 2050 scenario, electricity demand is projected to nearly double by 2070, rising from 183.1 PJ in 2018 to 306.32 PJ, driven by population growth, higher income levels, increased use of electrical devices in homes and commercial buildings, and electrically driven industrial processes[30]. Gradual constraints will be applied to fuel-switching and energy efficiency improvements on the demand side.

V RESULTS AND DISCUSSIONS

The Net Zero scenario stipulates the need for rapid adoption of renewable energies in response to the 2050 decarbonisation target. This transition implies a significant and important change in the energy mix, a deep reflection is needed to find the most optimal mix. This section presents and contrasts the results obtained under the Net Zero scenarios, with a particular focus on electricity generation by technology. The most important result of this research is that the transition to net-zero emissions by 2050 will be marked by a substantial increase in renewable energy sources, particularly wind and solar.

The transition from fossil fuels toward renewables dramatically accelerates. Regarding the extent of expansion in renewables over the next decades, the Figure 7 presents projected

power generation from various energy sources and the progression of the electricity mix in Algeria for the years 2030, 2050, and 2070.

In 2030, Algeria's electricity generation mix is dominated by CSP with Storage, contributing 521.22 PJ, underscoring its critical role in the nation's path toward net-zero emissions. This technology addresses the intermittency of solar power, enabling a more reliable and flexible energy supply, which is essential for achieving a stable renewable system and accelerating the energy transition.

Wind energy also plays a significant role in this electricity mix, with Onshore Wind with Storage generating 111.19 PJ and Onshore Wind without Storage contributing by 66.71 PJ. Although their combined generation is less than that of CSP with Storage, these technologies demonstrate the growing diversification of Algeria's renewable energy sources. Offshore Wind adds 44.48 PJ, further emphasizing wind power's contribution to the transition. Utility-scale Solar PV, both with and without storage, each contribute 66.71 PJ, reflecting the importance of solar power in the electricity generation mix. Additionally, Distributed Solar PV with Storage, generating 29.18 PJ, Although biomass (34.59 PJ), coal (12.94 PJ), and natural gas (77.8 PJ) remain part of the energy mix, their contributions are diminishing. This shift highlights Algeria's focus on accelerating the transition to a cleaner and more sustainable electricity generation mix to meet its net-zero goals by mid-century.

The results in terms of electricity production in 2050 reveal a multi-faceted energy portfolio characterised by substantial dependence on concentrated solar power (CSP) technology. The phase-out of natural gas for power generation is deemed essential, with natural gas units projected to be progressively phased out, ultimately achieving a target of 0 PJ of power generated from natural gas by 2050. On the other hand, CSP with storage (PWRCSPO02) emerges as the predominant technology with a contribution of around 46% of total projected energy production. This result underlines the essential role that CSP should play in reinforcing the stability and reliability of Algeria's energy supply, especially in a rapidly changing and dynamic context. According to the fig., onshore wind with storage (PWRWIND001S) contributes by 18% in the electricity mix, whereas onshore wind without storage (PWRWIND001) makes up 11%. The combined output of various onshore wind technologies emphasizes their importance in the context of renewable energy and highlights how crucial a role they play in easing the transition to a sustainable energy future. The scenario projection demonstrate that the utility-scale PV with 2-hour storage (PWRSOL001S) contributes by 10%, which reflect the importance of solar energy in the national energy strategy. On the other hand, utility-scale solar PV (PWRSOL001) and distributed solar PV with storage (PWRSOL002) contribute by 6% and 1%, respectively, these results indicate the supportive roles of utility scale solar PV and distributed solar PV within the broader renewable energy landscape. The contribution from CSP without Storage (PWRCSPO01) remains minimal, at 1%, reinforcing the necessity to develop for energy storage solutions to enhance the overall efficacy of solar energy deployment. Significance of CSP Technology: Its potential as a cornerstone of Algeria's renewable energy landscape is

shown by the significant expected generation from CSP with storage (951.41 PJ). Because CSP can store thermal energy for use during non-sunlight hours, it can address the intermittency issues with solar energy and offer a stable and dependable energy source.

In 2070, Algeria's electricity generation mix undergoes a significant shift, with CSP without Storage rising dramatically to 703.53 PJ, surpassing CSP with Storage, which drops considerably to 49.76 PJ. This transition likely reflects advancements in CSP technology or an evolution in energy storage strategies, signaling a strategic pivot in the use of concentrated solar power.

Onshore wind with storage continues to be a major contributor, generating 442.74 PJ, while onshore wind without storage grows to 265.65 PJ, emphasizing the sustained significance of wind energy in Algeria's net-zero transition. The increase in offshore wind, reaching 177.1 PJ, further diversifies the wind energy sector and strengthens its role in the overall electricity generation mix.

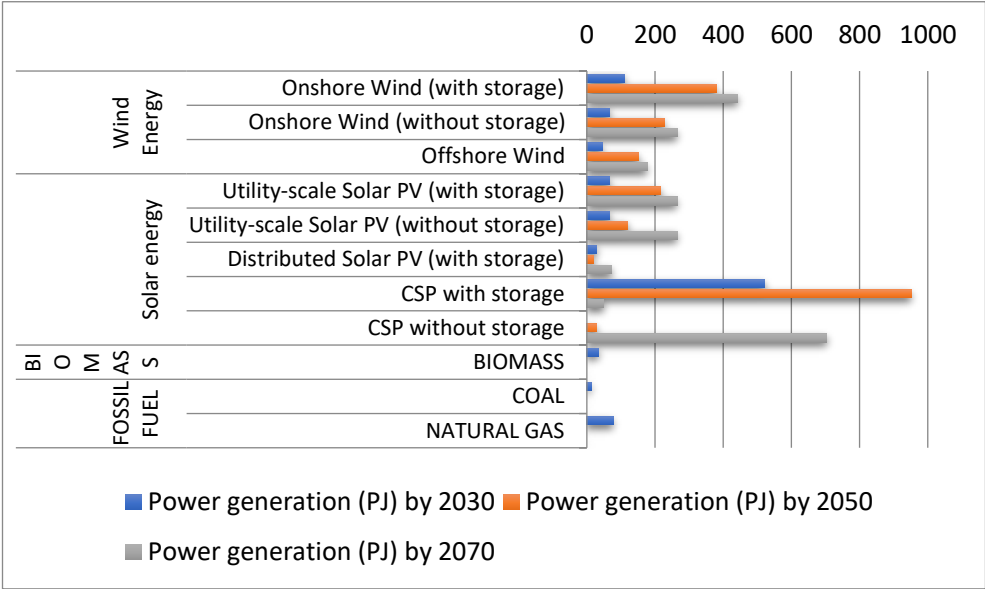
Utility-scale Solar PV with Storage and Utility-scale Solar PV without Storage converge, generating 265.60 PJ and 265.64 PJ respectively.

This near-equal contribution highlights a balanced solar strategy, where both storage-equipped and conventional PV systems are essential for maintaining grid stability and meeting electricity demand efficiently.

In contrast, Distributed Solar PV with Storage experiences a significant decline in the electricity mix, decreasing to 72.41 PJ by 2070.

Fossil fuels have been completely removed from the electricity generation mix, indicating the total decarbonization of Algeria's power sector by 2070, following a transition to 100% renewable energy that commenced in 2050.

Fig. 7 Evolution of Power Generation by Technology in Algeria's Net Zero Scenario: 2030, 2050, and 2070 (PJ)



Source : Authors

VI CONCLUSION

The objective of this study was to explore the feasibility of achieving net-zero emissions in Algeria's power sector by 2050, focusing on the necessary shifts in its electricity generation mix. The findings reveal that this transformation is not only feasible but essential for aligning with global climate goals, specifically the 1.5°C target set by the Paris Agreement.

Achieving net-zero emissions in Algeria by 2050 will require a substantial and rapid deployment of renewable energy technologies, with concentrated solar power (CSP) with storage playing a pivotal role. By mid-century, CSP with storage is projected to contribute 46% of the country's electricity generation, underscoring its importance in providing a consistent and flexible energy source. Onshore wind with storage emerges as another significant contributor, generating 18% of the electricity supply, while solar photovoltaic (PV) systems, both utility-scale and distributed, offer vital supplementary energy.

The study also projects a complete phase-out of fossil fuels, including natural gas, By 2050, an **ambitious** but necessary step to decarbonize the power sector will be taken. This shift away from fossil fuels aligns with the broader global transition toward renewable energy.

However, this transformation extends beyond technological deployment. It requires a comprehensive policy framework that supports innovation in energy storage, grid

management, and renewable energy deployment. Moreover, international cooperation is crucial, to facilitate access to advanced technologies and build the infrastructure needed for this large scale transition.

In conclusion, the scenario projections are consistent with a net zero scenario, which is in accordance with global climate targets and would see a sharp convergence of the energy balance towards renewable sources, with a minimum amount of fossil fuels starting in 2020s and a complete elimination of them by roughly 2050. The contrasting prospects of stabilization in the initial phase and the eventual phase-out of fossil fuels, combined with the necessary and significant increase in renewable energies, are two key aspects in evaluating the projections of the Net Zero scenario. Considering these findings, the challenge lies in rapidly expanding the deployment of existing technologies at highly ambitious levels, without undermining the scenario's feasibility.

Algeria's pathway to net-zero emissions by 2050 is both possible and advantageous, offering long-term benefits such as emissions reductions, enhanced energy security, and a sustainable future. However, realizing this vision will demand coordinated efforts across technology, policy, and societal engagement to address the challenges ahead and secure a resilient, renewable-based energy system for the country.

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VIII APEENDICES

Appendix. A. Technology Codes and Descriptions in Algeria's Energy Sector

<i>Code technology</i>	<i>Description</i>
IMPOIL	Crude Oil Imports
MINOIL	Crude Oil Extraction
IMPBIO	Biomass Imports
MINBIO	Biomass Extraction
IMPCOA	Coal Imports
MINCOA	Coal Extraction
IMPLFO	Light Fuel Oil Imports
IMPHFO	Heavy Fuel Oil Imports
UPSREF001	Crude Oil Refinery Option 1
UPSREF002	Crude Oil Refinery Option 2

Transitioning to Renewable Energy : A Pathway for Achieving Net -Zero Power Generation in Algeria by 2050

IMPNGS	Natural Gas Imports
MINNGS	Natural Gas Extraction
MINSOL	Solar Potential
MINWND	Wind Potential
IMPURN	Uranium Imports
MINURN	Uranium Extraction
MINGEO	Geothermal Potential
MINHYD	Hydro Potential
PWRBIO001	Biomass Power Plant
PWRCOA001	Coal Power Plant
TEC021	No longer used
PWRGEO	Geothermal Power Plant
PWROHC001	Light Fuel Oil Power Plant
PWROHC002	Oil Fired Gas Turbine (SCGT)
PWRNGS001	Gas Power Plant (CCGT)
PWRNGS002	Gas Power Plant (SCGT)
PWRSOL001	Solar PV (Utility)
PWRCSP001	CSP without Storage
PWRCSP002	CSP with Storage
PWRHYD001	Large Hydropower Plant (Dam) (>100MW)
PWRHYD002	Medium Hydropower Plant (10-100MW)
PWRHYD003	Small Hydropower Plant (<10MW)
PWRWND001	Onshore Wind
PWRWND002	Offshore Wind
PWRNUC	Nuclear Power Plant
PWRSOL001S	Utility-scale PV with 2 hour storage
PWRWND001S	Onshore Wind power plant with storage
PWRTRNIMP	Electricity Imports
BACKSTOP001	Backstop Technology for ELC001
PWRTRN	Electricity Transmission
PWRDIST	Electricity Distribution
PWROHC003	Light Fuel Oil Standalone Generator (1kW)
PWRSOL002	Solar PV (Distributed with Storage)
PWRHYD004	Off-grid Hydropower

PWRTRNEXP	Electricity Exports
BACKSTOP002	Backstop for ELC003
DEMTRAIEVC	EV Charger
DEMTRAMCYELC	Electric Motorcycle
DEMTRACARELC	Electric Car
DEMTRABUSELC	Electric Bus + Rail
DEMTRAMCYGSL	Gasoline Motorcycle
DEMTRACARGSL	Gasoline Car
DEMTRABUSGSL	Gasoline Bus + Rail
DEMINDEL	Industry Standard Efficiency Appliances
INDENEFFGD	Industry Good Efficiency
INDENEFFDP	Industry Deep Efficiency
DEMINDHEEH	Industry Electric Heating High
DEMINDHEEL	Industry Electric Heating Low
DEMINDHENG	Industry Natural Gas Heating
DEMINDHEOIL	Industry Oil Heating
DEMINDHEBIO	Industry Biomass Heating
DEMRESEL	Residential Standard Efficiency Appliances
RESENEFFGD	Residential Good Efficiency
RESENEFFDP	Residential Deep Efficiency
DEMRESCKNELC	Residential Electric Stove
DEMRESCKNOIL	Residential Oil Stove
DEMRESCKNBIO	Residential Biomass Stove
DEMRESHEBIO	Residential Biomass Heating
DEMRESHEOIL	Residential Oil Heating
DEMRESHEEL	Residential Electric Heating Low
DEMCOMEELC	Commercial Standard Efficiency Appliances
COMENEFFGD	Commercial Good Efficiency
COMENEFFDP	Commercial Deep Efficiency
DEMCOMHEOIL	Commercial Oil Heating
DEMCOMHEBIO	Commercial Biomass Heating
DEMCOMHEEL	Commercial Electric Heating Low
BSTOPMCY	Backstop for TRACMCY
BSTOPCAR	Backstop for TRACAR
BSTOPBUS	Backstop for TRABUS

Transitioning to Renewable Energy : A Pathway for Achieving Net -Zero Power Generation in Algeria by 2050

BSTOPINDEL	Backstop for INDEL
BSTOPINHEH	Backstop for INDHEH
BSTOPINDHEL	Backstop for INDHEL
BSTOPRESEL	Backstop for RESEL
BSTOPRESCKN	Backstop for RESCKN
BSTOPRESHEL	Backstop for RESHEL
BSTOPCOMEL	Backstop for COMEL
BSTOPCOMHEL	Backstop for COMHEL
TEC087 – TEC198	Additional Technology

Source : [26]