The Shift towards Renewable Energies and Its Role in Sustainable Development in Algeria

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Abstract: - As part of the energy transition towards renewable energies, Algeria, like many other countries around the world, is seeking to use renewable energy sources to enhance its energy security by diversifying its energy mix and reducing its dependence on fossil fuels. This study aims to shed light on the potential of renewable energy in Algeria by presenting theoretical concepts about renewable energies. It will also highlight the current renewable energy projects in the country and identify future strategies and ambitious plans to encourage investments in this field. We conclude that despite many challenges, Algeria has made significant progress in its transition to renewable energy, which is characterized by a great diversity of sources. The country has already developed several solar and wind energy projects and launched initiatives to promote energy efficiency and conservation. With continued investment and policy support, Algeria has the potential to become a leader in renewable energy and achieve energy security while addressing the challenges of climate change.

Key-Words: - Energy transition, investment, green energy, renewable energy, Algeria, sustainable development, Investment, future strategies.

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1 Introduction

Renewable energy is a vital issue in the current era, where there is a growing interest in preserving the environment and minimizing the negative effects of excessive use of conventional energy.

Investing in clean energy is critical to achieving sustainable development and overcoming environmental and economic challenges.

The world is striving to triple renewable energy capacity by 2030, a goal that was reaffirmed at the COP28 climate change conference hosted by the UAE last year.

In light of the outcomes of the conference and international efforts to achieve the set climate targets, the year 2024 is expected to witness an increase in renewable energy investments, which will contribute to achieving a number of results, including:

Reducing carbon emissions: Renewable energy is an effective way to reduce greenhouse gas emissions and climate change. By using renewable energy sources such as solar, wind, and hydraulic power, you can reduce your reliance on fossil fuels and switch to a cleaner, greener energy system.

Diversity in energy sources: Investing in renewable energy promotes diversity in energy sources and reduces dependence on finite natural resources. Switching to renewable sources can strengthen the economy and minimize the negative effects of global energy price fluctuations.

Saves energy and improves energy efficiency: Renewable energy is resource-efficient, encouraging improved energy efficiency and minimizing waste. Investing in new and sustainable technologies can reduce reliance on traditional energy and provide more sources that are efficient.

Support innovation and job creation: Investing in renewable energy encourages technological development and innovation in the energy sector. This can lead to the creation of new jobs in the renewable energy and environmental technology industries, and boost the economy overall.

Improved public health: By adopting renewable energy sources, air and water pollution caused by the use of fossil fuels can be minimized. This

contributes to improved air and water quality, which benefits human health and reduces pollution-related illnesses.

The renewable energy industry is part of the energy market that focuses on harnessing natural resources that are constantly renewable, such as the sun and wind, and therefore will never run out, unlike other types of energy, including coal and crude oil.

According to the International Energy Agency (IEA), renewables are expected to account for 35 percent of global power generation by 2025. This growth trend is expected to continue, with renewable energy production and demand continuing to increase for the foreseeable future. Recent years have seen a wider influx of investments in renewable energy, driven by growing awareness of climate change and a collective effort to embrace greater environmental responsibility.

Despite rising global demand for electricity, which is expected to triple by 2050, renewable energy makes up only a small fraction of the total energy supply.

Why is investment in green energy on the rise?
Investment in green energy is increasing for several reasons:

The trend towards sustainability: There is growing concern about climate change and its harmful effects on the environment and economy. Many governments and organizations are striving to achieve environmental goals and reduce carbon emissions. Investing in green energy is an important part of these efforts.

Reduce costs: Green energy technology has evolved significantly, reducing the costs of producing electricity from sources such as solar and wind. This makes investing in the industry more economically attractive.

Economic sustainability: Investing in green energy is believed to contribute to the creation of new jobs and promote economic growth. It can have a positive impact on the economy by fostering innovation and developing sustainable industries.

Legislation and incentives: Many governments promote investment in green energy by offering financial incentives and supportive legislation such as enhanced carbon pricing and tax breaks.

Responding to market needs: Demand for electricity is increasing as a result of population growth and an expanding economy, and green energy is an attractive option to meet these needs in a clean and sustainable manner.

Advanced technologies: Advances in technology in areas such as energy storage and efficient electricity transmission are making green energy investment more attractive.

Pressure from consumers and investors: Increasing pressure from consumers and investors is putting pressure on businesses and organizations to transition to clean energy sources and invest in sustainable projects.

Therefore, this study aims to highlight the available opportunities and challenges facing Algeria towards moving forward in adopting renewable energies primarily in its energy mix to achieve sustainable development in light of the current situation that calls for the necessity of finding ways to get out of oil dependency and achieve economic diversification.

2 Renewable Energy, Sustainable Development and Development Goals

The United Nations Development Programme asserts that energy is pivotal for achieving sustainable development and alleviating poverty, as it influences social, economic, and environmental dimensions, encompassing livelihoods, water accessibility, agricultural productivity, health, population dynamics, education, and gender-related concerns. Significant enhancements in the quality and quantity of energy services, especially in poor nations, are essential for the attainment of the Millennium Development Goals, [1].

The UNDP's energy for sustainable development initiatives facilitate the achievement of universal access to modern energy for the impoverished while enhancing the quality, security, and affordability of such energy sources. Access to sustainable sources of clean, dependable, and affordably priced energy is essential for human growth. This pertains not just to physical infrastructure but also to the affordability, reliability, and commercial feasibility of energy.

The UNDP assists developing nations in enhancing access to dependable and contemporary energy sources to alleviate poverty, enhance public health, stimulate economic growth, and mitigate climate change via a comprehensive development strategy. Investment in clean, efficient, economical, and reliable energy systems is essential for a thriving and environmentally sustainable future. Achieving energy security necessitates the diversification of energy sources, emphasizing consumer requirements, domestic energy supplies, energy efficiency, and regional interconnectivity. The UNDP collaborates with developing nations to

attain the specified results by offering robust policy guidance and concentrating on three principal areas of intervention : (i) enhancing policy and institutional frameworks aligned with low-emission, climate-resilient development, which constitutes the foundation of the strategy, [2].

(ii) (ii) Mobilizing and augmenting financing alternatives to facilitate market transformation, thereby stimulating public and private investment, which includes the establishment of enabling policies, regulatory frameworks, and the elimination of obstacles to energy efficiency, renewable energy, and sustainable urban transportation; and (iii) Formulating effective strategies to enhance energy service delivery through a blend of proven and innovative business models that are financially and institutionally sustainable.

The UNDP has advanced several renewable energy technologies by offering excellent policy advice and developing and implementing initiatives. Program funding comprises UNDP regular resources, the Global Environment Facility (GEF), the GEF Small Grants Programme, governmental contributions, corporate sector investments, and civil society partnerships. The UNDP is aiding nations in eliminating obstacles to energy efficiency, renewable energy, and sustainable transportation through its portfolio of energy and climate mitigation projects financed by the GEF, thereby enhancing access, quality, security, and affordability of clean energy worldwide. Additionally Access to contemporary renewable or nonrenewable energy services is strongly correlated with levels of development. The Johannesburg Plan of Implementation (JPI), formulated during the World Summit on Sustainable Development (WSSD) in 2002 [3], asserted that the connection between sufficient energy services, the attainment of the Millennium Development Goals (MDGs), and the provision of access to modern energy sources (such as electricity or natural gas) for the impoverished is essential for realizing the eight MDGs, [4], [5]. In 2010, about 20% of the global population, particularly in rural regions, lacked access to electricity, and 20% primarily utilized traditional biomass for cooking, which was sourced unsustainably. It is essential to provide these individuals access to electricity and contemporary cooking facilities.

Additional concrete indicators include per capita final energy consumption relative to income, electricity access disparities between rural and urban areas, and the number of individuals utilizing coal or traditional biomass for cooking. Energy access pertains to the necessity for models that may assess the sustainability of prospective energy system trajectories about the diminishing inequality between rural and urban areas (in terms of energy types and amounts utilized or infrastructural reliability) within nations or regions.

2.1 Social and Health Impacts of Renewable Energies

Energy is the basis of human development, and the various forms of energy - wood, water, oil, etc. - have helped to improve the lives of societies over time. According to [6], ‘Energy is life’ since it meets most of man's individual and collective needs. We need energy for food, heating, lighting, construction, industry, transport, communications, leisure, and so on. By guaranteeing equitable and fair access to energy resources for all societies, energy can contribute to economic development by improving living standards through its effects on health and education, [7]. The substitution of various renewable energy sources for fossil fuels is one of the technological changes in sustainable energy development strategies. Access to energy is a key factor in the analysis of well-being. Renewable energy improved access to food and water, created jobs, reduced health impacts, and enriched livelihoods, [8]. Therefore, the transition to a green economy, based on the consumption of renewable energy that improves the quality of life of all living beings and preserves them for the future, is absolutely necessary. According to the United Nations although renewable energies have received increasing attention in recent years, their effects on human development are not well documented in the existing literature. In this context, [9] shows that the effect of renewable energies on the social dimension of sustainable development could be significant. They point out that the use of renewable energies helps to maintain natural spaces and resources and to improve the quality of life and human needs [10], using a panel data method for six European countries, find on the one hand that renewable energies contribute positively to human development and, on the other, that the effect of fossil fuels is negative. Similarly, [11] points out that substituting renewable energies for fossil fuels offers significant public health benefits by preventing neurological damage, respiratory problems, cancer, and heart attacks. They also show that to improve public health, renewable energies would help to reduce water and air pollution by emitting fewer toxins.

In the case of African countries, [12] studied 15 countries and showed that access to clean and new

energy sources has a significant effect on the human development index (HDI).

It should be noted that the development and growth of renewable energies has been particularly marked in OECD countries. Thus, the contribution of renewable energies to meeting total energy demand. In this context, [13] studied the case OECD economies, and confirmed that renewable energies increase the prospects for health and well-being in these countries by reducing the effects of CO2 emissions, which will extend life expectancy and reduce health costs. Recently, [14] attempted to empirically examine the link between energy quality and human development for a few rural areas in different geographical zones. Their results show the existence of a positive link between, on the one hand, the use of locally produced clean energy resources combined with other clean fuels and the improvement of the human development index, on the other hand.

In the literature consulted on the 'green' energy transition, the study of the impact of the development of renewable energies on socio-economic well-being in the countries of North Africa is motivated by at least two reasons. Firstly, this literature shows that the world leaders in renewable energies are also in the South and not just in the North because countries in transition are forced, more quickly than developed countries, to increase and diversify their energy mix.

Secondly, the use of fossil fuels, which are the main cause of air pollution and climate change, represents a major challenge for achieving sustainability objectives, particularly in the new 2030 Agenda for Sustainable Development. As such, renewable energies can be used to mitigate the negative effects of environmental degradation on sustainable development in terms of economic and human development. Thus, as already emphasized, renewable energies are a means of achieving certain sustainable development objectives. Consequently, any effort to achieve them will lead to an increase in demand for renewable energy sources, [15], [16]

2.2 Economic Impact of Renewable Energies

The integration of natural resources into economic theory is not a new approach. Indeed, their integration into theories of growth and development is one of the most hotly debated topics. Basic growth models, such as [17], do not attempt to clarify the source of technological progress; on the contrary, they assume it to be exogenous and do not include natural capital or energy in the production function.

The aim of sustainable development is to move away from the traditional economic approach, which considers only the quantitative aspect of growth as the basis for analysis. It is also absolutely essential to take into account the qualitative considerations of development and to conceive of it in a much more plural and global way. Because what makes people happy is no longer an increase in the volume of production, but rather economic development that enables them to live in harmony with their environment, by promoting the fulfillment of all their capacities[. In addition, biophysical economic models are based entirely on energy and consider it to be the sole primary production factor. They assume that the energy available in each period is exogenous, [18], [19], [20]. Compared to conventional economists, ecological economists believe that the economic sphere is not separate from the natural world, from which it draws necessary resources and into which it disposes of waste. They also believe that the two spheres are interdependent and integrated.

Man's relationship with his environment has been turned upside down, as he now has to take responsibility for his actions affecting the environment and its future. This can be seen as 'the second ecological revolution of the contemporary world. This ecological revolution has the merit of giving birth to the principle of responsibility, which has become the watchword of political decision-makers. This refers to the simple reality that man is the only actor with the means to alter and definitively destroy his environment, [21]. As a result, now more than ever, economic and social players are being encouraged to think ahead. To be far-sighted and perceptive about the principles for controlling their behavior.

In support of this assertion], among others, argue that energy is a vital factor of production. Fossil fuels, such as oil, natural gas, and coal, are mainly used as energy, [22]. These conventional energy sources are considered among the drivers of economic growth. However, due to growing concerns about the risk of conventional energy sources, energy price shocks, greenhouse gas emissions, and other environmental issues, renewable energy has been suggested as a key solution [23], Capable of providing energy without greenhouse gases and atmospheric pollutants, emitting zero or minimal amounts of these gases, [24]. In recent years, the consumption of renewable energy sources has significantly increased worldwide. According to [25], renewable energies are the world's fastest-growing energy source, their global consumption has increased significantly over

the last two decades. Consumption levels nearly reached 90.23 exajoules in 2023. Despite its rapid growth, the annual renewable energy use must increase at an average rate of about 13% during 2023-2030, twice as much as the average over the past 5 years.

Furthermore, the renewable energy sector is an important source of green jobs. In fact, sectors such as solar, wind, geothermal, biomass, and wood energy are key drivers of decent employment. Just within the renewable energy supply chain, numerous activities are being created.

The issue of renewable energy has garnered the attention of researchers, business leaders, and policymakers as a substantial component of global energy consumption, [26]

Researchers in the field of economics focus mainly on analyzing the economic benefits of renewable energy consumption. In this context, it is possible to classify previous literature on the link between renewable energy and economic growth under two main lines of research. The first is a review of previous work on the causal relationships between renewable energy, non-renewable energy, and economic growth.

The literature on this topic could also be divided into four hypotheses, namely: the growth, conservation, feedback, and neutrality hypotheses. If we look at the results of existing empirical work, we see that there is no consensus in relation to the directions of different causalities. According to [27] this can be explained by the nature of the variables chosen, the different data sets used, and also by the methodological approaches adopted.

Although theoretical debates often refer to energy as a major factor in economic growth, its impact on the environment must also be considered, [28]. Indeed, after a century of exceptional growth characterized by a genuine improvement in people's living conditions and an expansion of the various forms of fossil energy, the environmental balance sheet is now becoming overwhelming. The damage inflicted on the environment, seen as a problem of resource allocation, has led economists to seek appropriate responses. Consequently, the second line of research focuses on the relationship between renewable and non-renewable energies, CO2 emissions, and economic growth. As our study falls within this same framework, we present the results of some of this work. For example, in the case of India, [29] empirically examined the nature of the links between renewable energy, GDP, and CO2 emissions and found that an increase in the level of renewable energy use promotes economic growth and mitigates carbon emissions. [30] by applying Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM) on 85 developed and developing economies for the period 1991-2012, showed that renewable energy use positively affects economic growth and reduces carbon emissions. For [31], studying the case of nineteen developed and developing economies, confirmed that an increase in the demand for renewable energy leads to an increase in the levels of economic activity, but does not lead to a reduction in CO2 emissions.

3 Global Renewable Energy Investment and Capacity

3.1 Global Investments in Renewable Energies

Global new investment in renewable energy, excluding hydroelectricity, totaled $214.4bn in 2013, down 14 percent from the previous year.

Hydroelectricity amounted to USD 214.4 billion in 2013, down 14 percent from the previous year and down 23 percent from 2011. Taking into account investments excluding hydroelectricity, total new investments in renewable energies totaled $249.9 billion in 2013, which is included in the renewable energy sector.

For the second consecutive year, investments declined after several years of growth, partly due to uncertainty about incentive policies in Europe and the United States, and partly due to incentive policies in Europe and the US, and partly due to a sharp drop in the cost of the technology used

However, there is considerable optimism that investments will increase, with Bloomberg New Energy Finance indicating that investment in wind and solar could reach $500bn, surpassing investments in fossil fuels and nuclear by around five times by 2035 (Figure 1).

Fig. 1: Global investments in renewable energies, [32]

With the technological advances and commercial acceptance of renewable energy and new energy industries, as shown in Figure 1, the cumulative use of renewable energy is increasing at a steady pace.

3.2 The Global Renewable Capacity

The following Figure 2 shows the global capacity of renewable energies.

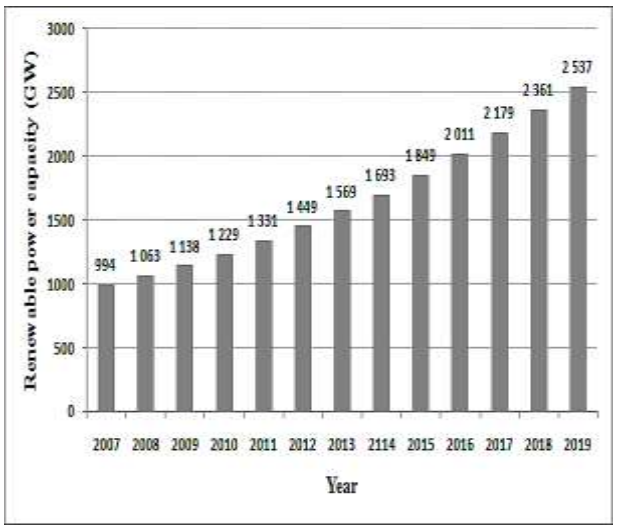

Fig 2: The global capacity of renewable energies, [33]

The global renewable capacity increased from 2179 GW to 2361 GW between 2017 and 2018, marking a growth of 8.4%. In 2019, renewable power capacity grew by an additional 7.5% (176 GW) compared to 2018. On average, the global renewable power capacity has been increasing by 8.1% annually from 2007 to 2019.

In 2017, the solar photovoltaic (PV) and wind power capacities experienced significant growth rates of 32% and 10%, respectively. This expansion is largely due to the continuously decreasing costs and increasing maturity of these technologies. Between 2010 and 2017, the levelized cost of energy (LCOE) from PV decreased by 73%, while that of onshore wind energy dropped by almost 25%. The current costs of renewable energy sources (RES) have become nearly competitive with traditional fossil fuel technologies, and in some regions, they are even more economical, especially when considering externalities such as health impacts.

Recognizing the global trend towards renewable energy, Algeria is also advancing its renewable energy-based applications to meet its greenhouse gas (GHG) reduction targets.

The Algerian government's action plan for energy transition aims to reconcile energy needs with environmental protection. Central to this effort is the move towards a green economy, highlighted in the five-year plan (2015-2019), which positions green growth as essential for development and technological progress. This plan includes a comprehensive strategy for financing renewable energy projects and implementing a national energy conservation plan, initially launched for 2006-2010.

4 Algeria's Energy Transition towards Renewable Energies to Support Sustainable Development

Through the Ministry of Energy Transition and Renewable Energy, Algeria has committed to a new national energy model by 2030. This model involves managing energy supply and demand across various sectors, including housing, industry, transportation, and agriculture, while setting quantifiable objectives for future energy choices. The transition law will focus on mitigating climate change, meeting domestic energy demands, ensuring energy independence, and reducing greenhouse gas emissions by 7 to 22%.

The key challenge is Algeria's dependence on hydrocarbons, a non-renewable resource unable to meet the rising energy demand sustainably. To address this, Algeria's energy transition plan integrates an ecological transition approach, aiming for a more sustainable energy system that provides clean energy for future generations. All economic sectors, particularly industry and agriculture, are expected to transition from fossil fuels to renewable energy and enhance production and consumption systems.

4.1 Policies Supporting the Work of the National Renewable Energy Programme

A-Research and development, [34]**:** Algeria has chosen the scientific research approach to develop the renewable energies program to make it a real catalyst for the development of the national industry that values different capacities (human, material, scientific, ...). Scientific research is essential to acquire technologies, develop knowledge, and improve energy efficiency. In this context, in addition to research centers attached to institutions such as :

- The Centre for Research and Development of Electric and Gas Energies (CREDEG), a branch of Sonelgaz, other Organisations such as the National Agency for the Promotion and Rational Use of Energy (APRUA), and companies specialized in the development of renewable energies (NEAL) are

collaborating in the development of renewable energies: New Energy Algeria): these collaborate with scientific research centers, notably:

The Centre for the Development of Renewable Energies (CDER), established in March 1988 in Bouzriah, is a center in charge of preparing and implementing scientific and technological research and development programs and developing energy systems for the exploitation of solar, wind, geothermal, biomass and hydrogen energies.

-The Solar Equipment Development Unit (UDES) - Established on 9 January 1988 in Boussemail, Tipaza, is in charge of the development of solar equipment, in particular technical, economic, and engineering studies, limited prototypes and pilot production related to solar equipment with thermal or photovoltaic effect for domestic, industrial and agricultural use as well as thermal, mechanical and other electrical equipment and systems involved in the development of solar equipment and in the use of solar energy.

USTD - Established in 1988 under the Ministry of Higher Education and Scientific Research, its mission is to carry out scientific research, technological innovation, evaluation, and post-graduate training in the fields of science, materials technologies, and semiconductor devices for applications in various fields and contributes, in cooperation with Algerian universities, to the development of knowledge and its transformation into technological skills and products necessary for economic and social recovery (1999).

-The Applied Research Unit in Renewable Energy - URAER was established in 1999 in Ghardaia, affiliated with the Renewable Energy Development Centre, with the mission of cooperating with universities and other research centers through research and training in the field of renewable energies.

-URERMS (Unit for Applied Research in the Beauty of Renewable Energy in Desert Areas) was established in Adrar in 1988 and is a scientific institution under the Ministry of Higher Education and Scientific Research, whose main activity is to carry out research and experimental activities for the promotion and development of renewable energies in desert areas and the restructuring of research institutions.

-The Algerian Institute for Renewable Energies (IARE) - which plays a key role in the State's training efforts and qualitatively ensures the development of renewable energies, including training in the fields of engineering, safety and security, energy auditing, and project management

4.2 Legal framework, Incentives and Taxation Measures

A. Legal framework : The development of renewable energies in Algeria is governed by a set of legal texts as follows, [35].

Law No. 99-09 of 28 July 1999 on energy control.

Law No. 02 01 dated 5 February 2002 on electricity and the public distribution of natural gas through pipelines, and -Law 04 No. 09 dated 14 August 2004 on the promotion of renewable energies within the framework of sustainable development.

Law No. 04-09 of 14 August 2004 on the promotion of renewable energies within the framework of sustainable development. This law provides for the formulation of a national program for the promotion of renewable energies, the encouragement and promotion of the development of renewable energies, and the establishment of a national observatory for renewable energies for their promotion and development.

The Supplementary Finance Law 2009: includes the establishment of a fund for renewable energies, which is financed by a 0.5% petroleum levy.

B/ Incentive and taxation measures:

Project holders in the field of renewable energies can benefit from the advantages granted by Ordinance 01-03 of 20 August 2001 on investment development.

Financial, fiscal, and customs privileges can be granted to activities and projects that contribute to improving energy efficiency and promoting renewable energies. Projects benefit from the concessions provided for in the legislation and regulations on investment promotion, as well as in favor of priority works according to Law 09-99.

B.Other incentive measures

Algeria's political will to implement the renewable energy development program will be expressed through the provision of subsidies to cover the costs resulting from the electricity tariff system to investors in this field.

The creation of a national energy control fund to finance these projects and the granting of interest-free loans and guarantees by banks and financial institutions in accordance with Law 09-99

C. Algeria's renewable energy capacity

Algeria's renewable energy capacity has grown significantly over the past 12 years as investments in the sector have increased, but fossil fuels still completely dominate the end-consumption sectors.

Total installed renewable energy capacity in Algeria at the end of last year was up 137 percent compared to levels in the early 2000s, according to data from German research firm Statista, but is still below the 2018 peak over the 2011-2022 timeframe.

The following graph shows the changes in renewable energy in Algeria from 2011 to 2022; Figure 3 illustrates this.

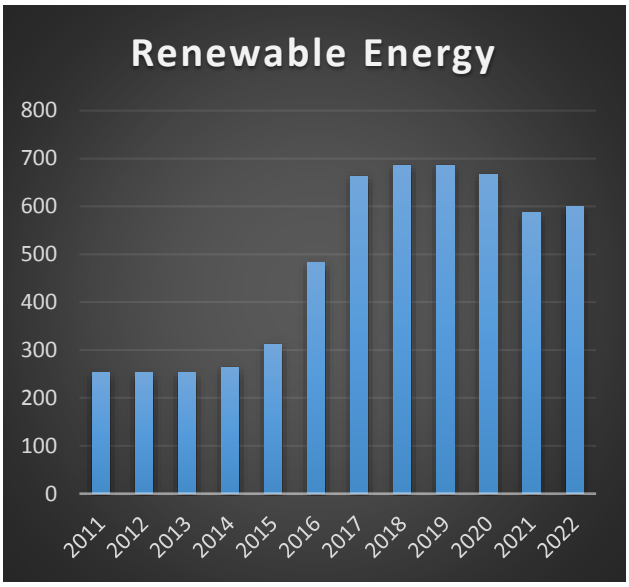

Fig. 3 : Algeria's renewable energy capacity, [36]

In the following lines, the Energy Research Unit reviews Algeria's renewable energy capacity figures from 2011 to 2022, based on Statista data.

Renewable energy capacity in Algeria fluctuated between high and low during the period from 2011 to 2022, reaching its highest rate during 2018 and 2019, then declining during 2020 and 2021, before rising again last year.

The data shows that Algeria's renewable energy capacity stabilized from 2011 to 2013 at 253 MW.

In 2014, installed renewable energy capacity rose to 264 MW, continued to rise the following year to 312 MW, and then saw a significant increase to 482 MW in 2016.

Algeria's renewable energy capacity jumped to 663 MW in 2017, continued to grow, and reached its highest level of 686 MW in 2018, then stabilized the following year at the same capacity.

In the year of the coronavirus crisis, Algeria's installed renewable energy capacity declined to 667 MW, then continued to decline in 2021 to 587 MW.

Last year, Algeria's renewable energy capacity rebounded to 599 MW but is still below the record level recorded in 2018 and 2019.

Algeria is among the 192 countries that have signed the Kyoto Protocol and one of 114 nations that have ratified the Copenhagen Accord. The country has established bilateral cooperation agreements with various countries, including the USA, France, Germany, and Spain in the north, Brazil in the south, and China in the east. These partnerships provide opportunities for investment growth, technology transfer, the strengthening of interconnections, and the creation of the Maghreb electricity market.

Containing renewable energies in the national energy mix is in fact a major challenge in order to preserve fossil resources, diversify the branches of electricity production, and contribute to sustainable development, as the energy policy (2011/2030) is largely based on renewable energies, especially those related to solar energies and solar energy. Wind and introduction of biomass branches by optimizing waste recovery as well as thermal, geothermal, and solar thermal energy.

The amount of energy expected to be achieved under the program extending from the year 2015 to 2030 is estimated at 22,000 megawatts, of which 4,500 megawatts will be achieved by the year 2020. This program is distributed as follows Table 1.

Table 1. Renewable energy targets in Algeria, [37]

Renewable	First Stage	Second Stage	Total
Photovoltaic	3000	10,575	13,575
Wind energy	1010	4000	5010
CSP	-	2000	2000
Cogeneration	150	250	400
Biomass	360	640	1000
Geothermal	05	10	15
Total (MW)	4525	17,475	22,000

The completion of this program will allow reaching, by the year 2030, a share of renewable energies estimated at 27% of the national share of electricity production, noting that producing 22,000 megawatts of renewable energies allows saving 300 billion cubic meters of natural gas.

Solar energy represents the most effective alternative due to its importance as it is enormous energy that can be exploited anywhere and constitutes a free, inexhaustible source of fuel. It is also considered clean energy, does not produce any type of environmental pollution, and can be used in many fields of agricultural activity, heating and cooling. Water, water desalination, sewage treatment, and electricity generation as well.

Solar energy in Algeria has witnessed development over the past years, and it is expected that this industry will continue to grow at relatively high rates in the future. It is also expected that solar energy will contribute to the generation of total electricity. However, the most important obstacles standing in the way of achieving these expectations are the high costs of its exploitation, which exceed the electricity generation costs is another technology (Table 2).

Table 2. The costs of generating electricity from various energy sources, [38]

Electricity generation costs ($/MWh)	Electrical power source
70-325 dollars / MWh	Photovoltaic cells
35-45 dollars/MWh	Natural gas
40-45 dollars /MWh	Coal

The table displays the costs of generating electricity from various energy sources during the year 2030, where we note

Photovoltaic cells: The varying costs of generating electricity using photovoltaic cells appear, with the range ranging from $70 to $325/MWh. The difference in cost can be due to factors such as the efficiency of the photovoltaic cells and the location of the project.

Natural gas: The cost of generating electricity using natural gas appears to be the cheapest among all the energy sources mentioned in the table, as the cost ranges between $35 and $45/MWh.

Coal: The cost of generating electricity using coal ranges between $40 and $45/MWh, which is slightly less than the cost of generating electricity using natural gas.

This information can be used to make decisions regarding electricity generation and determine the most effective and cost-effective source.

Based on experts' warning of the depletion of Algerian oil reserves within 50 years, the government sought to search for alternative ways to exploit energy beyond the era of oil. It revealed an ambitious plan to produce (10%) of electricity from renewable resources by 2020, as it has enormous potential. Renewable energies, especially solar energy, due to its vast area on the one hand and its geographical location on the other hand, as it is considered one of the richest solar fields in the world due to the amount of energy supplied per square meter, estimated at (kilowatts/hour/m) over most parts of the national territory and sometimes reaching up to (7 kilowatt-hours/m2), which allows annual radiation exceeding (3000 kilowatt-hours/m2) over an area estimated at 2,381,745 km.

The energy available daily over a cross-sectional area of (1 m²) reaches (5 kilowatt-hours) over most parts of the national territory, i.e. about (1700 kilowatt-hours/m²) per year in the north of the country and (2263 kilowatt-hours/m²) per year in the south. The country.

The Algerian government seeks to expand the use of solar energy in several areas, by implementing huge programs and projects to generate solar energy, including solar power plants that use solar concentrating technology and large solar power plants that use effective solar cell panels. It works to encourage the use of Solar energy in buildings, and industrial and commercial areas, by providing facilities to finance projects and encouraging investments in this field.

The ambitious Algerian solar energy program will allow, within twenty years, the production of electricity from renewable energies with the same quantities of electricity currently produced from natural gas. It is divided into three stages:

(2011-2014): A first pilot phase extending over three years related to sponsorship and framing of the program.

(2014-2020): The second phase: Improving management in the field of research and development.

(2020-2030): The final stage concerns the economic applications of research and the initiation of development projects.

The bulk of Algeria's total renewable energy production comes from solar photovoltaic (PV) plants, with most of them connected to the grid.

Solar PV accounts for 92 percent of Algeria's renewable energy, excluding hydropower, and 84 percent of all solar PV is connected to the grid.

Solar thermal accounts for 6 percent and wind accounts for 2 percent of the country's renewable energy sources, excluding hydroelectricity.

Algeria has succeeded in equipping about 840 schools with solar systems by the end of December 2021. This is illustrated by the curve in Figure 4.

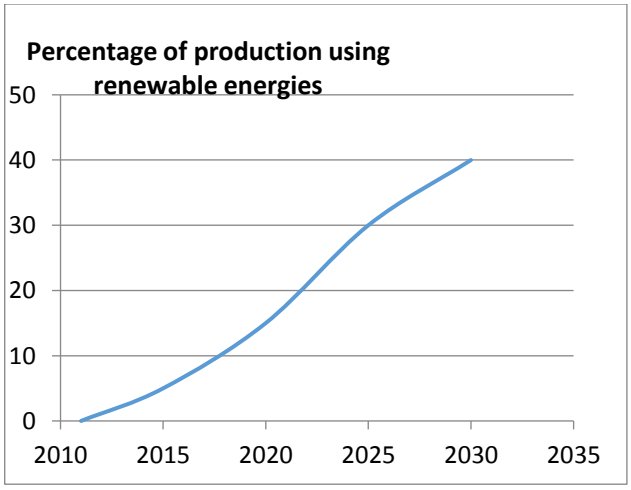

Fig. 4: Percentage of products using renewable energies, [39]

Figure 4 shows that the use of renewable energies is continuously improved over different years. In 2011, no renewable energy was produced, but in 2015 the percentage of renewable production increased to 5%. In 2020, the percentage of

renewable production increased to 15% and is expected to reach 30% in 2025 and 40% in 2030.

This improvement in the use of renewable energies can be explained by increased awareness of the environmental impact of the extensive use of fossil energies and the movement of countries to preserve the environment, adopt renewable energy sources, and improve the technology of their use to make them more effective and economical. The renewable energy program is defined by the following stages:

2013 Installation of a total capacity estimated at (110 megawatts): 30 megawatts of the Hassi R'Mel hybrid power station.

By 2015, a total capacity of 650 megawatts will be installed.

By 2020, it is expected to install a total capacity of approximately (2,600 megawatts) for the local market and the possibility of exporting approximately 2,000 megawatts.

By 2030, it is expected to install a total capacity of approximately (12,000 megawatts) for the local market and the possibility of exporting approximately (10,000 megawatts).

The Algerian Ministry of Energy and Mining expects that about 40% of the electrical energy produced by the project for local consumption will be from renewable energy sources by 2030 (37% solar energy and 3% wind energy)

It is considered a huge program and a huge challenge, and the government must accompany customers and help them implement it on the ground. Recent forecasts in this field highlight the goal of reaching (30%) by the year 2025, which represents the share of renewable energies in the country's energy plan, and in the medium term, that is, on the horizon. 2015 Reaching 5% of the share of renewable energy in the nation's energy plan. As for the prospects of this program, the possibility of exporting these energies if Algeria achieves control over technology and if Europe is ready to open its market.

Wind energy: Algeria has fields suitable for establishing wind farms to produce electrical energy, especially in the southern regions where the average wind speed exceeds 6 m s, such as the Adrar, Timimoun, and Ain Salah regions. The importance of using wind energy lies in its being economical (5 to 6 dinars per kilowatt per year). hour), which makes it less compared to solar energy, and it also has simple and uncomplicated technology compared to other energy sources. What distinguishes Algeria is the appropriate geographical location to exploit this energy, as the winds that blow over Algeria carry with them a lot of humid marine air, large quantities of special continental air, and some desert and local air (Table 3).

Table 3. The average wind speed in different regions in Algeria, [40]

Average wind speed (m/s)	Entities
From 1 to 4	North
exceed 4	South
exceed 6	Southeast (Adrar)

Table 3 shows the average wind speed in different regions in Algeria in meters/second. The average wind speed in the northern regions ranges from 1 to 4 meters/second, and this indicates that these regions are not very suitable for generating energy from wind.

In the southern regions of Algeria, the average wind speed exceeds 4 meters/second, and this makes these areas more suitable for generating energy from wind.

In the southeastern region of Adrar, the average wind speed exceeds 6 m/s, making this region among the best areas in Algeria for generating wind energy.

Algeria is working on developing wind energy and has implemented several small and medium-sized wind energy projects over recent years, including the wind energy generation project in the municipality of Ain Hajar in the state of Tizi Ouzou. The Algerian government is working to encourage more investments in this sector by providing support. Financing, technical and regulatory financing for investors, and the development of wind areas suitable for wind energy generation.

The Algerian government expects wind energy to play an important role in achieving its renewable energy strategy. The government aims to increase the share of renewable energy in electricity production by 27 percent by 2027, and by 2030, it aims to generate 22 thousand megawatts of renewable energy, including Wind energy.

In addition, the Algerian government expects wind energy to account for about 10% of the country's total electricity production by 2030.

Hydropower: Wind energy in Algeria is expected to enjoy greater interest and development in the future, as it can play an important role in providing clean and sustainable electricity to Algeria.

Although Algeria possesses enormous water resources, it is characterized by the scarcity of surface water. The overall financial potential in Algeria is estimated at less than 20 billion m3, of which only 75% is renewable, while the non-renewable financial resources are estimated at 12.4

billion m3, which includes water resources in the northern Sahara. The total amount of rain that falls on the Algerian region is estimated at 65 billion annually and is concentrated in specific areas, but it is exposed to evaporation due to heat, in addition to its rapid flow towards the sea and towards geographical water fields.

The irrigation capacity of the electrical production farm increased by 5% or about 286 gigawatts. This capacity is due to the insufficient number of irrigation sites and the lack of exploitation of the existing irrigation sites. In this context, the hydroelectric station in Jijel Province was rehabilitated with a capacity of 100 megawatts. As for geothermal energy, in Algeria. The Jurassic limestone in northern Algeria represents an important reserve of geothermal heat and leads to the presence of more than 200 hot mineral water sources located mainly in the northeastern and northwestern regions of the country. These springs are found at a temperature that often exceeds 40 degrees Celsius, and the hottest hot spring is The source of Al-Maskhoutin, 96, these natural springs generally leak from reservoirs located in the ground, alone flowing more than 2 meters of hot water, which is only a small part of what the reservoirs contain.

The continental formation also forms a large reservoir of geothermal heat that extends over thousands of square kilometers. This reservoir is called the “Alba” layer, as the temperature of the water in this layer reaches 57 degrees Celsius. If the flow resulting from the exploitation of the Alpine layer and the total flow of hot mineral water springs are combined, this represents the capacity level is more than 700 megawatts.

The Algerian government supports the development of hydropower projects and seeks to increase the proportion of renewable energy in the electrical energy mix. In 2020, Algeria launched a hydropower development plan aiming to generate 4,500 megawatts of hydropower by 2030. Figure 5 shows what has been started before.

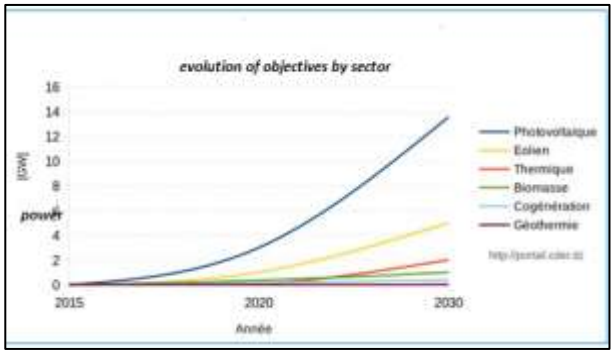

Fig. 5: Algerian renewable energy program, [41]

In addition, in the period 2030-2050, Algeria aims to set quantifiable objectives for energy transition to combat climate change and ensure energy security. However, significant challenges remain, including the need for greater efforts to combat desertification, drought, and erosion. The forest fires in 2021 highlight the ongoing struggle with environmental degradation.

5 Conclusion

Algeria's renewable energy potential plays a crucial role in the country's sustainable development. By harnessing diverse energy sources such as solar, wind, hydro, and geothermal, Algeria aims to reduce its dependence on fossil fuels, minimize greenhouse gas emissions, and promote environmental sustainability. These efforts contribute to the global fight against climate change and support the country's economic growth by creating jobs, attracting investments and fostering innovation in green technologies. The strategic development of renewable energy is in line with Algeria's commitment to the goals of sustainable development and a resilient economy, ensuring a cleaner, more resilient, and sustainable future for its citizens. Algeria's energy transition towards a green economy presents significant challenges and opportunities. Overcoming technical and technological barriers, financial constraints, and the need for adequate infrastructure are critical challenges

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used Deelp (Translate) and Grammerly (Grammar Checker) in order to approve reliability and clarity language of manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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