

Reality and strategies for developing renewable energy in Algeria

واقع و استراتيجيات تطوير الطاقات المتجددة في الجزائر

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Abstract: Renewable energy is a way to promote the economy of the country and achieve sustainable growth as an environmentally friendly energy. It derives its source from the sun, wind, etc. Because fossil energy sources such as petroleum have the negative effects mainly in the depletion of such wealth and its susceptibility to extinction, it has become necessary to move towards new and alternative energies of fossil energies. Algeria has enormous potential in this area, especially those related to wind energy and solar, which encouraged it to adopt clear policies and strategies aimed primarily at achieving economic and social gains on the one hand.

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1. Introduction

Energy is important basic sources for achieving economic and social development, but excessive use of energy leads to problems of environment like global warming and climate change, which led to an attempt to adopt an effective system to preserve the environment on the one hand and achieve sustainable development on the other hand and change traditional non-renewable energy sources with other renewable sources, which is what Algeria sought to achieve by developing strategies to develop renewable energies.

The problem of the study:

What is the nature of the strategies adopted by Algeria in order to develop renewable energies?

2. The theoretical approach to renewable energies

Energy is a pivotal driver of economic growth, powering diverse transformation industries and production facilities. Experts emphasize that renewable energies, specifically, represent environmentally sound and sustainable power sources. Consequently, it's crucial to examine key concepts associated with them, starting with their definition and origins, and extending to global investment patterns in these innovative energy options.

2.1. The concept and advantages of using renewable energies

Different definitions of renewable energy exist, with some focusing on natural resources and others on generation methods. Generally, we can define it as follows:

- Renewable energy is an inexhaustible power source derived from replenishing natural resources, distinct from fossil fuels. It can also be harnessed from tidal forces, geothermal heat, and agricultural biomass. (Khababa, Khababa, & Kaarar, 2013, p. 43)
- These are considered enduring, inexhaustible resources, encompassing finite sources within nature alongside infinite sources characterized by continuous replenishment. (Cherif, 2008)
- The IPCC defines renewable energies as those originating from biological, geophysical, or solar sources and naturally replenished. (Keddi, Oussrir, & hamou, 2010, p. 133)
- The United Nations Environment Program (UNEP) defines renewable energy as energy derived from a limited natural source with a fixed supply. (www.uneb.org.)

2.2. Renewable energy sources

Among its most important sources, which are considered inexhaustible, available and permanent, we find:

2.2.1 Solar energy: It is a heat source that is converted into electricity, generating electrical energy. (moukadam & belakhdar, 2007, p. 37)

A recent innovation in solar energy utilization is "solar cooling," a method using solar power for cooling applications. This technology involves capturing solar energy via specialized panels, converting it into electricity for use in cooling or heating systems, and various other applications. (bekhiti & merrah, 2019, p. 5)

2.2.2. Water energy (water energy): There are many sources of energy from water, as it can be generated from the following sources: (bekhiti & merrah, 2019, pp. 5-6)

- The energy resulting from the difference in water temperature between the upper and lower layers.
- Tidal energy.

- From the waves of the seas.
- hydroelectric energy (from waterfalls).

2.2.3. Wind energy: It is an energy that converts kinetic energy into electrical energy using wind mills, and its use is not limited to generating energy only, but also for pumping water, irrigation and heating. Wind turbines can be built quickly, but wind is a volatile energy source.

2.2.4. Hydrogen energy: It is a secondary source where another energy source is required to generate hydrogen. (omar, 2006/2007, p. 28)

2.2.5. Biomass energy: It is energy generated from organic and animal waste, plant and agricultural waste, as well as industrial, commercial and household products. (elkhayat, 2006, p. 6)

2.3. The global status of renewable energies

A notable global shift, particularly among developed nations, towards renewable energy is underway, driven by environmental stewardship and the pursuit of genuine sustainable development. This necessitates examining these countries' investment strategies in renewable energies and assessing their contribution to the overall global energy supply.

Table 01. global renewable energy production

Unit: Terawatt/ho

Years	2011	2012	2013	2014	2015	2016
Solar	65.7	101.5	138.6	197.3	256.0	328.4
Wind	440.7	530.5	635.5	705.9	831.3	962.1
Hydroelectric	3492.6	3641.4	3787.9	3888.8	3878.7	4015.5
Geothermal and Biomass	398.7	432.1	466.2	505.6	546.5	554.7

Years	2017	2018	2019	2020	2021	2022	2023
Solar	445.3	574.7	705.5	854.9	1051.6	1321.9	1641.6
Wind	1141.9	1270.5	1421.4	1594.7	1859.6	2108.0	2325.3
Hydroelectric	4068.2	4188.2	4243.1	4359.4	4288.8	4323.4	4240.2
Geothermal and Biomass	586.1	633.4	665.0	702.9	756.2	776.8	781.5

Source: Prepared by researchers based on BP Statistical Review of World Energy 2024/ 73 edition

We note from the table above that hydroelectricity leads renewable energies in terms of production, as its production in 2011 amounted to about 3492.6 terawatt hours and is constantly increasing with a slight decrease in 2023 to reach 4240.2 terawatt hours, followed by wind energy, which is considered to be constantly increasing until it reached 2325.3 terawatt hours in 2023, followed by solar energy, which also witnessed a continuous increase until it reached 1641.6 terawatt hours in 2023, and finally we find geothermal energy and biomass, which in turn witnessed a continuous increase until it reached 781.5 terawatt hours in 2023.

In conclusion, we note that the production of renewable energies in the world is constantly increasing, and this is due to the major role that these energies play in preserving the environment, saving energy, depleting it, and other positive characteristics that distinguish these energies.

Table 02. the development of renewable energy consumption in the world.**Unit: Exajoule**

Years	2011	2012	2013	2014	2015	2016
Solar	0.65	1.00	1.36	1.92	2.48	3.16
Wind	4.38	5.24	6.24	6.88	8.06	9.27
Hydroelectric	34.69	35.94	37.16	37.93	37.60	38.70
Geothermal and Biomass	4.45	4.83	5.21	5.65	6.11	6.19

Years	2017	2018	2019	2020	2021	2022	2023
Solar	4.27	5.47	6.69	8.08	9.91	12.41	15.35
Wind	10.94	12.10	13.49	15.08	17.52	19.78	21.75
Hydroelectric	38.98	39.89	40.27	41.22	40.40	40.58	39.65
Geothermal and Biomass	6.54	7.07	7.43	7.85	8.46	8.69	8.74

Source: Prepared by researchers based on BP Statistical Review of World Energy 2024/ 73 edition

We note from the table above that hydroelectricity leads renewable energy in terms of consumption, as its consumption in 2011 amounted to about 34.69 exajoules and is constantly increasing with a slight decrease in 2023 to reach 39.65 terawatt hours, followed by wind energy, which is considered to be continuously increasing until it reached 21.75 exajoules in 2023, followed by solar energy, which also witnessed a continuous increase in consumption until it reached 15.35 exajoules in 2023, and finally we find geothermal energy and biomass, which in turn witnessed an increasing and continuous consumption until it reached 8.74 exajoules in 2023.

3. The reality of renewable energies in Algeria :

Algeria, like other countries and with its natural capabilities, must enter into the scope of exploiting its energies and natural resources in order to reduce the costs it bears from traditional fossil energies that harm the environment.

3.1. The National Development Program for Renewable Energy and Energy Efficiency (PNEREE) for the year 2011

As part of its ambitious drive towards a sustainable future, Algeria launched in 2011 its flagship national program (PNEREE), a comprehensive initiative aimed at developing renewable energies and enhancing energy efficiency. To achieve a strategic goal of producing 40% of electricity by 2030. Based on an expected annual consumption of 150 terawatt hours, the program aims to add 22,000 megawatts of renewable energy generation capacity, of which 10,000 megawatts are allocated for export. The program relies on three main sources of renewable energy and will be implemented in four main phases: (Baji, 2023-2024, p. 170)

Table 03. Stages of the National Renewable Energy Development Program.

Stage	The process
2011-2013	Completion of all pilot projects with a capacity of 110 megawatts to select different technologies.
2014-2015	The program has started implementation with about 650 megawatts
2016-2020	Deployment by 2020 with a capacity of not less than 4,600 MW, of which 2,600 MW is allocated for the local market and 2,000 MW is .allocated for export
2021-2030	The programme is being implemented on a large scale with the aim of achieving the relevant goals by 2030, with 22,000 megawatts allocated, 55% of which is for local consumption and the rest

Source: (Energy Transition in Algeria, , 2020, P: 47)

3.2. Completed renewable energy projects

Algeria has established many stations and projects for renewable energy of all kinds, perhaps the most important of which are the following:

3.2.1. Solar energy projects: As a pioneering move towards energy diversification, Algeria launched its first hybrid solar-gas power plant on July 14, 2011. Named Hassi R'mel, and situated in Tighelmt, the plant boasts a 150-megawatt capacity, with 30 megawatts from solar. Costing 350 million euros, this project exemplifies energy generation in remote zones, independent of conventional grids. Algerian state banks provided 80% of the project's funding, and a 70-person team, largely Algerian, manages the facility. Relatedly, the ambitious Desertec initiative seeks to connect large solar thermal plants, potentially incorporating other renewables like wind, to power an electricity grid across Africa, Eastern Europe, and the Middle East. (Ben Arous, 2015, p. 14)

In addition to the following stations: (Baji, 2023-2024, pp. 172-173)

_ Djanet Photovoltaic Plant "2015": Launched in September 2014 by Sonelgaz subsidiary SKTM, a 3 MW photovoltaic plant, situated 10 km southwest of Djanet, commenced operations on February 19, 2015, spanning 6 hectares. It aimed to diminish reliance on traditional energy, safeguard the environment, and generate 12 jobs.

_ M'Sila Solar Station "2016": This 20-megawatt solar-powered station in Ain El Melh, M'Sila province, produces electricity from solar energy, targeting reduced gas emissions.

_ Ouargla Solar Station "2016": Located in El Hadjira, Ouargla province, this station occupies 80 hectares, with 60 hectares dedicated to solar panels. It provides electricity to 50,000 homes, creates 50 jobs, and saves 4,000 tons of gas annually, reducing carbon emissions by 31,000 tons.

_ Tamanrasset Photovoltaic Stations "2016": These two stations enhance the region's electricity grid and reduce fuel consumption in power plants. The first station has a capacity of 13 megawatts, and the second, 5 megawatts.

_ Djelfa Photovoltaic Station "2016": Situated in Ain El-Ibel, 30 km south of Djelfa, this 20-megawatt station, operational since 2016, covers 40 hectares owned by the Electricity and Renewable Energy Company. It produces 32,500 megawatt-hours of solar energy annually, at an estimated cost of 3.91 billion Algerian dinars. (Nasreddine, 2017/2018, p. 103)

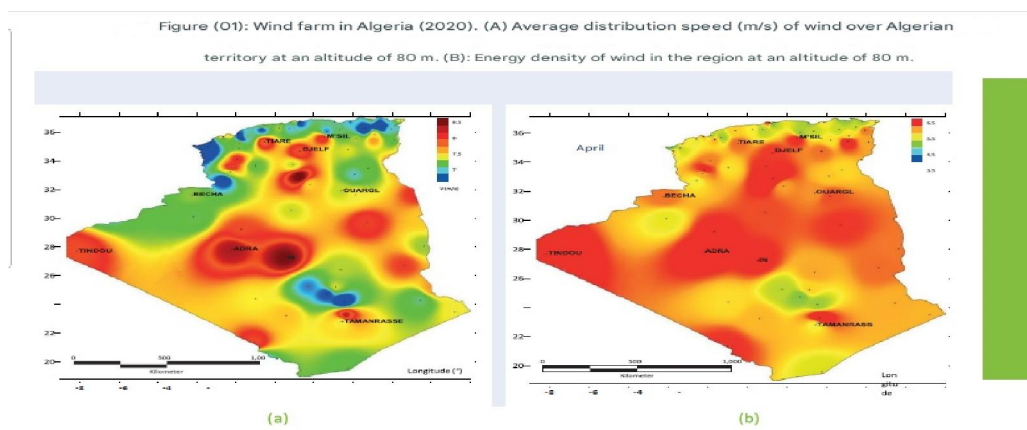
The average sunshine in Algeria exceeds 2000, considering that Algeria has important solar energy field among the countries of the world, and if compared to natural gas, solar energy

is equivalent to 37000 billion cubic meters, which is more than 8 times the natural gas reserves in Algeria. (Baji, 2023-2024, p. 165)

3.2.2 Wind energy projects: Algeria's wind resources exhibit substantial variation owing to its diverse geography and climate. Northern areas, characterized by Mediterranean coastlines and mountains, experience moderate wind velocities, whereas southern regions, notably the southwest (4 m/s) and Adrar (over 6 m/s), register higher speeds. Typical wind speeds fall within 2 to 6 m/s, indicating potential applications, such as water pumping, particularly in the high plateaus. In-depth evaluations are required to determine the economic viability for each region. (bekhiti & merrah, 2019, p. 10)

As part of a strategy to diversify renewable energy, Algeria established its first experimental wind farm in Adrar, covering 30 hectares with a production capacity exceeding 10 megawatts. This facility comprises 12 turbines, each with an 850-watt capacity. The project was provisionally awarded to the Algerian-French group CEGELEC, whose bid was deemed the most competitive. Furthermore, two smaller wind farms have been constructed, one in Had Sahari (Djelfa) and another in Maamoura (Saida), indicating the country's incremental development of wind energy ventures. The following figure shows a wind farm in Algeria:

Figure 01. The following figure shows a wind farm in Algeria.



Source : (mahmoudi, 2023-2024, p. 137)

The figure shows that wind speeds in southern Algeria are higher than those in northern Algeria. This is particularly true in the southeast, where wind speeds in Tindouf, Ain Oussera and Tamanrasset range from 8 to 7 m/s, compared to 7 to 6 m/s in coastal areas such as the capital Oran and Bejaia. The energy extracted from wind depends on several factors, including: the strength and speed of the wind; the design, shape, type of materials and specifications of the turbine system; the basis of the power generation; and the storage and control systems used.

3.2.3. Other renewable energy projects : Aspiring to leadership in the renewable energy sector, Algeria prioritizes solar and wind energy as key investment assets offering substantial economic returns. Concurrently, investments in alternative sources like hydropower, geothermal energy, and biomass are crucial for risk diversification and enhancing the energy system's resilience, despite their lower short-term profitability. This necessitates a thorough cost-benefit analysis to optimally balance sustainable growth with economic efficiency.

Hydropower in Algeria contributes a small share (5%, 286 GW) to electricity production, constrained by a scarcity of suitable irrigation sites and inefficient utilization of existing resources. Despite the upgrade of the Ziam station (100 MW), fully realizing the potential of this resource remains a significant undertaking.

Algeria possesses considerable untapped geothermal potential, mainly within the Jurassic limestone formations in the northern region. This is evidenced by over 200 hot mineral springs, often exceeding 40°C, with the Meskhoutin spring reaching 96°C. These springs, discharging at rates over 2 m³/day, represent leaks from larger subsurface reservoirs, indicating a need for strategic investment to leverage the economic returns from this latent resource.

Algeria's biomass potential is divided primarily between its vast desert, encompassing 90% of the territory, and tropical forests, covering the remaining 10%. Consequently, the utilization of waste and organic residues, particularly animal waste, presents a viable economic pathway for natural gas production, promoting sustainable development, especially in rural communities. Such residues encompass household waste, wastewater treatment sludge, industrial organic waste, and agricultural/animal byproducts. Investing in these readily available resources offers a genuine opportunity to strengthen energy security and generate promising employment prospects in rural regions. (zine & lamri, 2013, p. 05)

The attached table includes data on the renewable energy capacities in Algeria, recorded during the period from 2011 to 2023.

Table04. the renewable energy capacities in Algeria 2011-2023

Unit: Megawatt

Years	2011	2012	2013	2014	2015	2016
Solar energy	25	25	25	26	74	244
Wind energy	10	10	10	10	10	10
Hydroelectric energy	228	228	228	228	228	228

Years	2017	2018	2019	2020	2021	2022	2023
Solar energy	425	448	448	448	448	448	448
Wind energy	10	10	10	10	10	10	10
Hydroelectric energy	228	228	228	228	228	228	228

Source: (Baji, 2023-2024, p. 193)

The provided table illustrates Algeria's renewable energy capacities from 2011 to 2023, measured in megawatts. It is evident that while wind and hydroelectric energy capacities remained relatively constant at 10 MW and 228 MW respectively throughout the entire period, solar energy saw significant growth. It grew marginally between 2011 and 2014, and then jumped to 74 MW in 2015 and then 244 MW in 2016, indicating a sharp increase in investment and infrastructure development in solar power from 2015, and it then continued to grow reaching 425MW in 2017 to 448 MW in 2018 and then plateaued at that level until 2023. This suggests a strategic shift towards solar power, potentially driven by cost reductions in solar technology and the desire to diversify the energy mix. However, the static figures for wind and hydroelectric generation highlight a potential underinvestment in these areas and thus further investigation is needed as to why, especially since wind energy is the cheapest among renewable energy resources and hydroelectric is cheaper than other traditional energy resources, that need to be taken into account while making future strategic decisions.

4. Strategies for developing renewable energy in Algeria

Recognizing the energy sector as a foundational element for holistic development, the Algerian government is actively working to advance it through legislative measures, promoting investment in renewables, and creating dedicated centers. These actions underscore Algeria's ambitions for sustainable economic expansion and the generation of substantial employment opportunities, all while navigating the intricacies of global markets.

4.1. National policies in Algeria for the development of renewable energy

As part of its strategy to achieve a real energy transition, Algeria is working to integrate renewable energies and enhance energy efficiency, which contributes to diversifying its energy sources. This trend has been reflected in the establishment of a number of institutions that play a fundamental role in leading this transition.

4.1.1. Institutional structures involved in the energy transition process : Algeria has taken several steps to integrate renewable energies and diversify its energy resources in order to embark on the energy transition process. To achieve this goal, several institutions have been created, as follows: (Baji, 2023-2024, pp. 183-184)

- _ Department of New and Renewable Energies;
- _ Department of Development, Promotion and Valuation of Renewable Energies;
- _ Committee for Energy Efficiency and Renewable Energies.

4.1.2. Public bodies participating in the implementation of the energy transition program :

We mention some of them:

- National Agency for the Promotion and Rationalization of Energy Use APRUE;
- Electricity and Gas Regulatory Authority CREG;
- Renewable Energy Development Center CDER;
- Semiconductor Technology Research Center for Energy Science CRTSE;
- Electricity and Gas Research and Development Center CREDEG;
- Electricity and Renewable Energy Company SKTM;
- New Energy Algeria NEAL ;
- National School of Renewable Energies, Environment and Sustainable Development.

4.1.3. Sources of financing renewable energy in Algeria : The sources of financing renewable energy in Algeria are multiple and are discussed below: (boulegrinat, 2023-2024, pp. 187-188)

- The National Renewable Energy Fund

It was created in accordance with the provisions of the Finance Law of 2010 (Law No. 09-09), and its role is to finance projects registered within the framework of renewable energy development. The Finance Law of 2011 subsequently changed the name of the National Renewable Energy Fund to the National Renewable and Combined Energy Fund and allocated 1% of hydrocarbon revenues to support this fund, as this percentage was estimated at 0.5% when the fund was created.

-The National Fund for Energy Control, Renewable and Combined Energies (FNMEER) It was created in accordance with Executive Decree No. 319-15 of December 13, 2015, which determines how its account is managed.

- Incentives

They are as follows:

- Project holders in the field of renewable energy can benefit from the advantages granted by Law No. 03-01 of August 20, 2001 relating to investment development, which are represented in sufficient tax, customs and financial incentives and benefits, legal security and freedom of investment and non-recourse to nationalization, freedom of capital transfer and finally the approval of international arbitration;

- Granting financial and customs privileges to activate activities and projects that compete in improving energy efficiency and promoting renewable energy;

- Providing subsidies to cover the additional costs resulting from the pricing system applied to electricity;

- Reducing customs duties and value added tax on imports for components.

- Feed-in tariff

The feed-in tariff ensures that producers receive clear and transparent tariffs that provide them with a reasonable return on their investment. A clear maturity period of 20 years has been set for solar and wind projects, and 15 years for cogeneration projects, which enhances investor confidence in this sector.

- Power Purchase Agreement (PPA)

The power purchase agreement scheme in Algeria will be implemented of commissioning of the plant. However, this initial 20-years period may be reduced if the commissioning date referred to in the power purchase agreement is delayed, as a result of the action or inaction (IPPs). The duration of the power purchase agreement shall then be reduced in proportion to the delay. (seddouk & necir, 2017, p. 277)

4.1.4. Obstacles to energy transition in Algeria : The energy transition in Algeria faces obstacles and restrictions, which requires corrective measures, legislative reforms and increased financial allocations to ensure its success: (bouleguinat, 2023-2024, pp. 155-156)

The financing problem: The country's dependence on fossil fuels and the high costs of renewable energy could negatively affect its income and financial stability if fossil fuel prices fall. The weakness of the local banking sector and the inability to predict oil prices require foreign partnerships and international cooperation to secure financing.

Political factor: The development of renewable energy requires political will, freedom to invest, and the removal of restrictions on investors, such as specific technologies and plant capacities, in order to be profitable.

The nature of local production and consumption: Algeria's heavy reliance on fossil fuels in energy production and consumption hinders its efforts to adopt renewable energy sources, which underscores the importance of seizing available opportunities to implement renewable energy programs gradually and thoughtfully.

Weak human qualification and training for renewable energy: The lack of qualified supervisory personnel in Algeria's renewable energy program will hinder progress in this area. Foreign partnerships in the field of training and exchange of expertise are needed to encourage scientific research, as Algeria relies on imported expertise and foreign companies, which costs the state hard currency.

Renewable energy technology: Modern high-quality technology is among the most important means of quality of service provided, especially in the field of solar energy storage. Therefore, it is necessary to choose the appropriate technology and develop realistic, well-planned programs

that are compatible with the available capabilities, especially if we know that this technology is expensive and is paid for in hard currency.

- Weak legal and regulatory framework:

Algeria has taken legal measures, but its legal framework is weak, lacks precision and strength, which hinders private and foreign investment in the sector of renewable energy. , which requires careful planning and accurate decision-making to avoid wasting time and economic benefits.

4.1.5. Prospects for energy transition in Algeria : Algeria aims to establish a national network of leaders in manufacturing solar photovoltaic equipment, desalination facilities, and exporting renewable energy between 2021 and 2030. It plans to achieve an 80% integration rate by expanding manufacturing capacities, exporting energy and renewable, and in output through enhanced manufacturing hubs and specialized wind turbine development, as well as managing engineering and supply operations and constructing desalination plants.

The Confederation's Energy Committee underscores the imperative of transitioning to renewable energy, as necessitated by current data. The committee has devised a roadmap with 41 recommendations to address challenges, including establishing a supportive legal framework and enabling economic stakeholders to invest. This initiative could generate 300,000 jobs in Algeria by 2050 and contribute to 8.8 million globally. It is clear that renewable energy will receive increased governmental focus going forward, especially in electricity generation and increasing its integration within the energy system. They will hold a significant place within the state's priorities, given their benefits and contribution towards achieving sustainable development goals. (ghazi, 2021, p. 41)

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Algeria must pay more attention to renewable energy to achieve sustainable development and adapt to the global shift towards clean energy. On this basis, Algeria must intensify its interest in this field through:

- The state should establish well-defined and robust legal frameworks, alongside stringent procedures, to ensure the timely completion of diverse renewable energy projects;
- Media and public awareness play a crucial role in informing and educating individuals and society. By disseminating accurate and comprehensive information regarding the economic,

environmental, and technical aspects of renewable energy, the media can enhance public understanding and support the adoption of these sources;

- Providing support and various incentives, such as financial and tax privileges and exemptions, for renewable energy investment projects is essential;

- There is a need to increase research and development efforts into alternative energy technologies, while considering global best practices and benefiting from international collaborations based on mutual advantage.

5. Conclusion

Algeria has prioritized developing renewable energies as a critical component of its transition to a sustainable model, capitalizing on its rich resources in this area to both safeguard the environment and replace traditional non-renewable energy sources with readily available natural alternatives.

From the preceding discussion, the following conclusions can be drawn:

- Renewable energies are considered sustainable because they are sourced from natural elements like wind, water, and sunlight. These sources are inherently renewable and inexhaustible. They stand in contrast to fossil fuels, namely oil, coal, and natural gas, which generate environmental byproducts such as carbon dioxide and other harmful gas emissions.

- Renewable or alternative energy's most significant attribute is their potential to protect human health and the environment, reduce operational costs, and generate new employment opportunities.

- Algeria's strategic focus lies in conserving its diminishing oil reserves through effective management and substitution with alternative energy sources, with a particular emphasis on solar energy implementation.

A set of recommendations is presented:

- Intensifying awareness campaigns on the importance of renewable energy usage, while promoting responsible consumption of other energy resources through effective management to avoid their complete depletion;

- Implementing widespread solar energy systems in all sun-exposed locations, such as mosque rooftops, government buildings, and along roadways;

- Establishing new frameworks and international agreements to promote regional and global cooperation in the deployment of renewable energies, leveraging existing research and studies, which emphasize the transfer of advanced technologies to optimize their use;

- Engaging experts in the development of new energy systems, as their contributions are vital to reducing costs, enhancing economic diversification, and supporting development initiatives nationwide. The widespread availability of natural renewable resources across all regions necessitates employing this expertise to achieve comprehensive and sustainable development.

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