Current Status and Prospects of Renewable Energy in Laghouat, Algeria

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ABSTRACT

The rapid urban expansion of Algerian cities has led to increased energy consumption, transportation congestion, and environmental degradation, significantly affecting the country's carbon footprint. With the rise of global concerns about climate change, carbon mitigation has emerged as a key goal for sustainable urban development. In this paper, we will present a set of statistics on the different sources on which Algeria relies for energy production, and the province of Laghouat has been taken as a sample for the study by presenting and analyzing the region's energy potential. The analysis showed that the region is energy-rich with diverse sources, where solar energy ranks first due to the region's high solar potential, which is characterized by direct natural radiation exceeding 950 W/m^2, in addition to more than 35000 h/yr of sunshine. It also contains the Seklafa Dam, considered one of Algeria's largest dams, enabling it to produce significant energy if exploited properly. Moreover, wind energy has significant potential, which can be exploited to generate significant wind power. This study provides valuable insights into the renewable energy situation in Laghouat and serves as a scientific resource for researchers and industrial institutions to identify appropriate solutions to advance the renewable energy sector.

I. Introduction

Laghouat is one of the main energy provider regions in Algeria. The gas field of Hassi R'mel and the power stations of Tilghimt play a significant role in the economy of the country. However, issues related to fossil fuel consumption make them non-sustainable. Therefore, a transition to clean energy is required. In this regard, the energy landscape in the region will change to a more clean and sustainable energy scheme. Laghouat has significant potential in terms of renewable energy, which makes it a promising region for clean power generation. The existence of power stations connected to the national grid is an advantage where generated power could be input. Therefore, the region has benefitted from various programs for developing renewable energy, including solar PV and CSP (concentrated solar power).

This paper aims to highlight achievements in this framework and discusses the prospects regarding the potential in terms of wind energy, hydropower, in addition to solar energy. The manuscripts present first the potential renewables that can be exploited, followed by main achievements in the national program for the development of renewable energy, and then discussions are undertaken to highlight the prospects of the region in terms of potential green power generation.

II. Renewable energy potential in Laghouat

II.1. Solar Energy

Laghouat is one of Algeria's states and consists of 24 municipalities. Tiaret borders it to the north, El Bayadh to the west, Ghardaia to the south, and Djelfa to the east. The city of Laghouat serves as the state capital. Therefore, it is situated in the center of the Saharan Atlas and steppe regions (Figure 1).

Laghouat is an energy-rich state due to its underground fossil fuel reserves and its distinguished location with significant solar potential. Laghouat is situated in the Algerian Sahara, part of the sun belt, known for its high solar energy potential with Direct Normal Irradiation (DNI) exceeding 950 W/m^2 and over 35000 h/yr of sunshine duration [1], ensuring an average daily sunshine duration of about 9.59 h and a daily solar energy density of 7.26 kWh/m^2 [2].

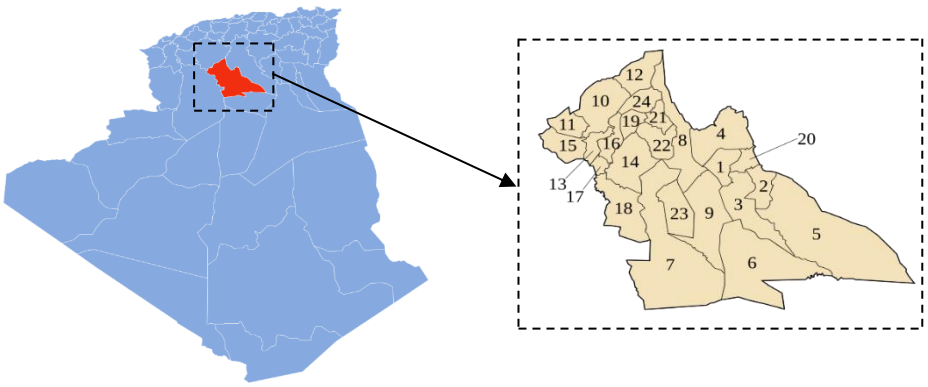


Figure 1. Laghouat state on the Algerian map and its municipalities.

II.2. Wind Energy

Algeria has planned to develop and deploy wind energy and achieve 23% of renewables in wind power by 2030 (rescheduled to 2035). So far, only one wind power plant of 10.2 MW has been installed in the Kaberten region of Adrar state. The assembly comprises 12 GAMESA G52/850 wind turbines. The 850 kW turbines, featuring 55 m-high towers and a rotor diameter of 52 m, capitalize on the region's robust winds, averaging 8.5 m/s (Figure 2). The park supplies 10 MW of nominal power to the grid [3].



(a) (b)

Figure 2. Wind farm station in Kaberten region of Adrar state: (a) aerial view and (b) ground view of the wind farm.

Laghouat has a significant potential for wind energy, which can be exploited to generate significant wind power, given that the region of Laghouat is underestimated as a potential wind region in the Algerian wind mapping carried out in 2004, and the planning of the Algerian power grids did not plan the implementation of the wind power plants in the region until nowadays [4]. Over the last decade, wind speed data [5,6] show an average wind speed ranging from 6.2 to 7.125 m/s, corresponding to an average energy density of 236.77 W/m^2 [6].

Several studies focused on creating a wind map [7,8] for the country to develop wind energy [9]. Other numerical studies were conducted to highlight potential wind farm installations in various sites in high plateaus [10] and southern zones, for instance, in Adrar [11], which showed the highest potential. Explorations date back to 1951, when potential sites were spotted for wind farm projects, including one in Laghouat [12]. Later, numerical investigations and onsite measurements emphasized the importance of wind energy in Laghouat [5,6]. Numerous investigations of the wind field at various locations surrounding the city of Laghouat yield a yearly average wind speed as follows: 6.12 m/s in the southern region, 4.46 m/s in the western region, 3.85 m/s in the southeast region, and 6.50 m/s in the southwest region [4,13]. Wind speed analysis showed a shape parameter higher than 2, which demonstrates acceptable uniformity of wind speed in Laghouat year-round. The data indicate the efficiency of wind farm installations in the region.

II.3. Hydropower

Recently, one of the biggest dams in the country, Seklafa Dam, has been constructed in Laghouat [14]. It is considered one of the most important dams in the region. It was built under the supervision of the Cosider Foundation in the M'zi Valley, and its length is estimated at 250 m. The Seklafa Dam is located in the Mokrane mountain area in the Laghouat state and is considered the dam that provides the most drinking water and irrigation for agricultural lands, as it supplies 850 ha and 14 municipalities (Figure 3). The dam supplies water for agriculture and domestic use. Additionally, this dam, among others in the state [15,16] is a potential source of hydropower in the state. The high storage capacity of Seklafa dam (40 million m^3/yr) makes it a potential for hydropower generation. It could support the power generation mix in the state. The challenge of low precipitation trends in some areas could be addressed using pumped storage power by solar PV or wind energy [17]. This technique could revive several power plants in the country.



Figure 3. View of Seklafa Dam.

On the other hand, this dam is not limited to economic development but is also a distinguished tourist destination. Its strategic location in the M'zi region between the mountains has attracted many tourists to the state in search of exploration and tranquility.

III. Transition to clean power generation in Laghouat

III.1. Gas-fired electricity

The energy sector has witnessed remarkable development, given the attention given by the state to strengthening it through major projects aimed at expanding and strengthening the electricity and gas grid. Figure 4 shows the development of the number of beneficiaries of electricity and gas services after implementing the various programs decided by the state over three time periods: 1962-2000, 2001-2010, and 2011-2022. The chart shows a significant increase in the number of beneficiaries of both services over the years, with a sharp increase recorded in the recent period (2011–2022), where an increase of about 60% for electricity and 48% for gas was observed [18]. This

indicates the economic and social development witnessed by the region, the rise in the standard of living, and the increased reliance on electricity and gas in various aspects of life. In addition, the number of beneficiaries of electricity always exceeds the number of beneficiaries of gas in all periods. This reflects the increasing importance of electricity in modern life and its widespread use.

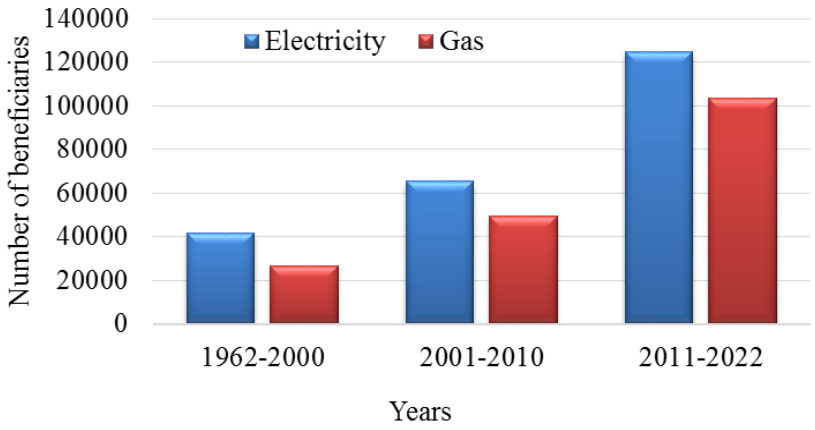


Figure 4. Development of connecting housing to gas and electricity grid [18].

III.2. Clean power generation in Laghouat

Through its renewable energy program, Algeria intends to position itself as a major player in producing electricity from the photovoltaic and wind sectors by integrating biomass, cogeneration, geothermal energy, and beyond 2021, solar thermal energy. These energy sectors will be the drivers of sustainable economic development and capable of driving a new economic growth model. By 2030, 37% of installed capacity and 27% of national electricity production will be renewable [19]. This plan will contribute to mitigating carbon emissions estimated at 193 Mt and save 63 million metric tons of oil equivalent (Mtoe) [18].

a) Hybrid solar-gas power plant

Hassi R'mel is located in Laghouat, about 120 km from the state capital, and it is considered one of the richest municipalities in the region. Hassi R'mel boasts gas fields, and the proposed solar and gas power plant project serves as both an ecological solution and an alternative energy source. The hybrid station (Solar Power Plant 1: SPP1) is located in the area called Tilghimt (3°20' North, 33°07' East) at an altitude of about 700 m above sea level and is 40 km from the center of Hassi R'mel. This site was selected due to its solar potential on the one hand and, on the other hand, its proximity to the Hassi R'mel gas field and the high-voltage transmission line in Tilghimt [20]. The area has solar potential, with direct normal irradiation (DNI) exceeding 950 W/m^2 during the summer and more than 1800 h of sunshine per year out of 3000 h in Algeria.

The area is characterized by flat terrain, available water sources, and temperature ranges from -10°C to 50°C throughout the year. The average relative humidity is 24%, rainfall is less than 100 ml/yr, and the average wind speed is less than 5 m/s; all of these features make it suitable for the project. The station generates 150 MW (net power according to ISO), with a solar contribution of 20%, or about 30 MW. The solar field consists of parabolic cylindrical collectors, each 150 m long and 5 m in diameter, covering a total surface area of around 180,000 m², distributed over two surfaces. Each surface contains 28 rings of four modules, arranged in two rows. The module comprises 12 segments, each with several mirrors (Figure 5).



(a) (b)

Figure 5. (a) Satellite image of Hassi R'mel station, (b) Parabolic cylindrical mirrors [21].

Figure 6 depicts SPP1 annual electricity production over the period from 2015 to 2022. The power production ranges between 1000 kWh/yr and 1200 kWh/yr. It is noted that there are some slight fluctuations from year to year; these fluctuations may be caused by various factors, such as weather conditions (which affect solar energy production) or technical failures. The solar portion of the generated power is small, around 6%.

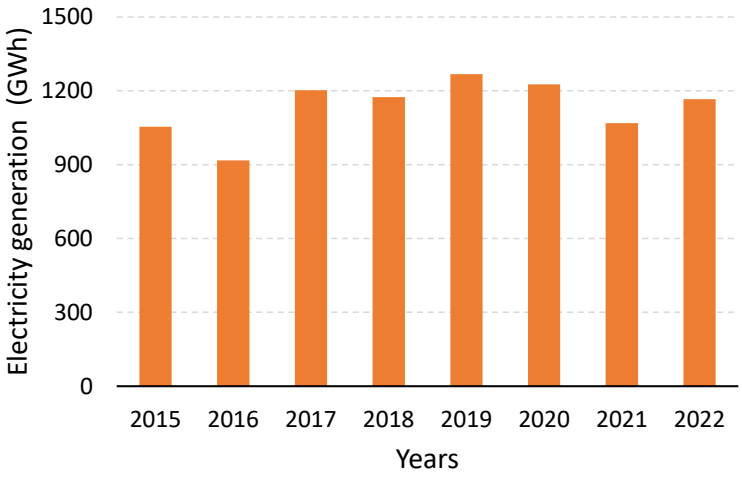


Figure 6. Annual electricity production between 2015-2022 [22].

This station has advantages, including:

- The hybrid combined cycle technology provides greater flexibility in the valuation of gas that could have been used to produce electricity to meet national needs and for export.
- The size of the solar field has been planned so that the insurance rate exceeds 5% to benefit from the advantages provided by the Algerian legislative system related to the decree on diversification of costs associated with the granting of production grants that stipulate a rate greater than 5%.
- Regarding greenhouse gas emissions, the kWh produced in the case of the hybrid, compared to the production of electricity from simple gas turbines, will emit half the amount of greenhouse gases.

b) Photovoltaic power plant

Kheneg is located in Laghouat, about 9 km from the state capital, and is considered one of the closest municipalities to it. The solar power station covers 120 ha and is located 5 km from the municipality of Kheneg and 10 km from the center of Laghouat (33°43' North, 2°48' East). In the field of renewable energy, the Kheneg solar power plant ranks first nationally and in Africa, with a capacity estimated at 60 MW (20 + 40) and a production capacity of 100 MW/yr, which is approximately seven times the state's needs. The station spans 120 ha and comprises 240.000 solar panels distributed over 5460 arrays, 2040 three-level connection boxes, 120 corrugated boxes, and 60

transformers. It is connected to the 60 kV high-voltage electricity transmission network via a lift station that contains three transformers with a capacity of 20 MV each (Figure 7).

The total annual electricity production of the station is 104.000 MWh, 102.000 MWh, and 86.000 MWh for the years 2020, 2021, and 2022 (end of October), respectively. The regular decrease recorded in the station's annual production is due to a purely technical natural reason related to the aging of the solar panels, whose lifespan is estimated at 25 years, in addition to the lack of maintenance.

The station is expected to meet the following expectations:

- Diversifying electricity generation sources and developing production methods from renewable sources.
- Preserving the primary resources.
- Protecting the environment by reducing greenhouse gas emissions (61.500 t/yr of reducing carbon dioxide emissions).



(a) (b)

Figure 7. (a) Satellite image of Kheneg station, (b) real image of Kheneg station.

c) Building-integrated solar PV

By implementing the development programs planned from 2009 to 2020, the state of Laghouat has witnessed a qualitative leap in connecting to solar energy, benefiting 1949 families and between 60 schools and treatment halls across the state's municipalities, as we recorded at the end of 2021. As part of the presidential supplementary program of the Directorate of Energy and Mines, the state of Laghouat has benefited from 400 solar energy units, which have been distributed to scattered housing units far from electrical networks across all the state's municipalities (Figure 8).

By the end of 2023, school buildings' installed solar PV capacity achieved 8.63 MWc. The number of schools covered by this program was 1163 throughout the country; 122 were in Laghouat state. This clean power share represents 0.8% of the total installed capacity in the country outside hydroelectricity. 55% (4.77 MW) of this installed capacity is of low-voltage grid-connected type (PV ON-Grid), while the remaining 45% (3.86 MW) of the capacity is of off-grid type (PV OFF-Grid) with a storage system (batteries). The installed solar PV capacity in isolated areas achieved 23.06 MWc, representing 4.9% of the national off-grid renewable energy and nearly half (48.2%) of the total capacity of off-grid EnR facilities [23].

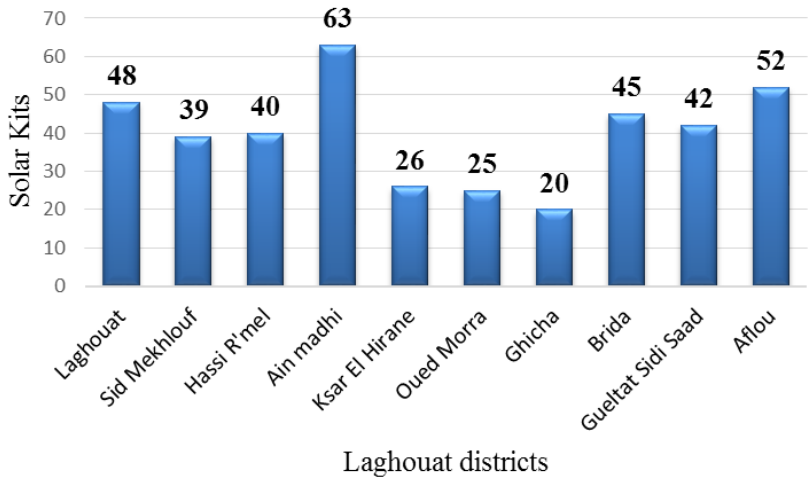


Figure 8. Solar-connected housing units by district.

The state also benefited from various programs and from many pieces of equipment, which were distributed as shown in Table 1.

Table 1. Equipment distributed by type.

Provider	Quantity	Type
Local Administration Directorate	122	Solar energy kits
Laghouat Municipality	210	Solar energy kits
Sidi Makhlouf Municipality	05	Solar energy kits
Forest Governorate	1196	Solar energy kits
Forest Governorate	21	Solar energy kits

In addition to equipping some institutions, such as the new governorate headquarters, the oasis botanical garden, and 12 school complexes with solar panels. Moreover, the environment directorate of Laghouat state has provided many municipalities with solar water heaters, as shown in Figure 9.

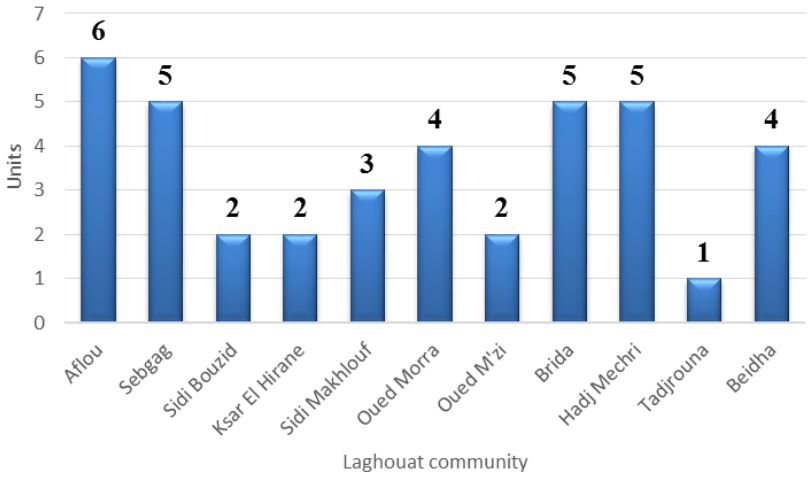


Figure 9. Solar water heater units by community.

IV. Prospects of clean power generation in Laghouat

As part of developing electricity generation methods, the state, which pays special attention to energy transition and renewable energies, has developed a program to install two solar power plants in Laghouat (Hassi Delaa 1 and 2), each with a capacity of 300 MW. The state technical committee selected the site with an area of 600 ha for each station in the municipality of Hassi Delaa (Table 2). The stations will produce 1618 GWh/yr, a potential output for

the clean power grid. This will save 404 m^3 of natural gas, which will be reserved for exportation and increase the income of the country's economy. Furthermore, the two power plants will avoid more than 1360 Mkg of carbon emissions.

Table 2. The expected annual production, the natural gas stock expected to be saved, and the amount of carbon avoided.

Projects	Capacity (MW)	Expected production (GWh/yr)	Natural gas savings (Million m^3)	Expected CO_2 mitigation (Million kg)
Hassi Delaa 1	300	808	202	680.371
Hassi Delaa 2	300	808	202	680.371

V. Conclusion

This paper assesses the potential of renewable energy in Laghouat and the realizations achieved and prospects according to both plans and opportunities regarding the significant potential the region has in terms of renewables. This study shows that more advancements in renewable energy can be made. Following are directions for future prospects.

- The Seklafa Dam has considerable potential for hydropower if exploited in the future.
- The region is suitable for efficient wind farms with significant power generation.
- This increases the energy mix for flexibility and sustainability of power generation.
- Further efforts should be devoted to encouraging medium and long-term investments to boost the deployment of more renewables, including biomass.
- Assessment of the performance of the realized installations should also be made to direct future deployment.

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