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Department of Mechanical Engineering

Memoire

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Theme :

Prospects of renewable energy potential in Laghouat area

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بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيْمِ

Appreciation

This work was carried out at Ammar Telidji - Laghouat University at the Faculty of Technology by students ***SILAA Nafissa*** *and* ***BOUMEGOUAS Hamza*** *under the supervision of* ***Pr. TEGGAR Mohamed****.*

To begin with, we would like to thank ***Mr. TEGGAR Mohamed****, for the way he supervised our work also the way he taught us through the years of our journey in the mechanical engeneering departement.*

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Dedication I

- *To ALLAH*
- *To Mom and Dad*
- *To my sister*
- *To Leflifa*
- *To my two brothers*
- *To Lola Maria Mettache*
- *To my Angelo*
- *To mi gâté*
- *To Coca Cola*
- *And my most beautiful, strong, important and precious self.*

"Wake up to reality! Nothing ever goes as planned in this accursed world. The longer you live, the more you realize that the only things that truly exist in this reality are merely pain."

-Uchiha Madara

SILAA Nafissa

Dedication II

From the bottom of my heart, I dedicate this work:

To the women who suffered without letting me suffer, who never said no to my demands to make me happy, to the flame of my heart, my life and my happiness:

My dear mother and my dear sister

To the man who always sacrificed himself to see me succeed, who never stopped giving me:

My dear father Mohamed

To my brothers Taher and Ali

To all my friends, especially Rahim Maamar Abdelmalek Lola.

BOUMEGOUAS Hamza

Summary

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Symbols/Units

KW : kilowatt.

MW : megawatt.

GW : gigawatt.

TW : terawatt.

hm^3 : cubic hectometer ($1hm^3$ = 100,000,000 l).

Tcf : (1 Tcf = 1,000,000,000,000 cubic feet) is a volume measurement.

GDP : Measures the monetary value of final goods and services produced in a country in a period of time.

USD : United States Dollar.

Abbreviations

RE: Renewable energy.

PV: Photovoltaic.

CSP: Thermodynamic Solar

OPEC: Organization of the Petroleum Exporting Countries.

PNEREE: National Renewable Energy and Energy Efficiency Program.

IEA: International Energy Agency.

GWEC: Global Wind Energy Council.

ONM: National Office of Meteorology.

PAT: Pump As Turbine.

NSAS: Northern Sahara Aquifer System.

PNUD: United Nations Development Program.

UNESCO: United Nations Educational, Scientific and Cultural Organization.

CDARS: Study of the General Development Plan for the Saharan Regions.

ANRH: National Agency for Hydraulic Resources.

CREDEG: Electricity and Gas Research and Development Center.

CDER: Renewable Energy Development Center.

IRENA: International Renewable Energy Agency.

SKTM: Shariket Kahraba Wa Taket Moutadjadida.

NREL: National Renewable Energy Laboratory.

RIN: National interconnected network.

PIAT: Pole In salah Adrar Timimoune.

RIS: Interdisciplinary network around statics.

MES: Manufacturing execution system.

DWS: Drinking water supply.

NRN: Normal reservoir level.

NME: Minimum operating level.

PCU: Power Conditioning Unit.

URAER: Applied Research Unit in Renewable Energy.

Abstract

This memoire explores the prospects of renewable energy potential in Laghouat, Algeria, with a focus on solar energy and its application in photovoltaic (PV) pumping systems. Laghouat is known for its abundant sunlight and growing demand for sustainable energy sources. Harnessing this renewable energy potential to reduced dependence on fossil fuels, and environmental sustainability. PV pumping systems, which combine solar energy with efficient water pumping technologies, offer a promising solution for water supply and irrigation in Laghouat's agricultural, rural, and remote areas. This abstract highlights the benefits of renewable energy in Laghouat and the role of PV pumping systems in sustainable water management.

Keywords: renewable energy, solar energy, Laghouat, Algeria, photovoltaic pumping systems, water supply, irrigation, sustainable development

Résumé

Ce mémoire explore les perspectives du potentiel des énergies renouvelables à Laghouat, en Algérie, en mettant l'accent sur l'énergie solaire et son application dans les systèmes de pompage photovoltaïques (PV). Laghouat est connue pour son ensoleillement abondant et sa demande croissante de sources d'énergie durables. Exploiter ce potentiel d'énergie renouvelable pour réduire la dépendance aux combustibles fossiles et la durabilité environnementale. Les systèmes de pompage PV, qui combinent l'énergie solaire avec des technologies efficaces de pompage de l'eau, offrent une solution prometteuse pour l'approvisionnement en eau et l'irrigation dans les zones agricoles, rurales et reculées de Laghouat. Ce résumé met en évidence les avantages des énergies renouvelables à Laghouat et le rôle des systèmes de pompage PV dans la gestion durable de l'eau.

Mots-clés : énergies renouvelables, énergie solaire, Laghouat, Algérie, systèmes de pompage photovoltaïques, approvisionnement en eau, irrigation, développement durable

ملخص

تستكشف هذه المذكرة آفاق إمكانات الطاقة المتجددة في الأغواط ، الجزائر ، مع التركيز على الطاقة الشمسية وتطبيقاتها في أنظمة الضخ الكهروضوئية (PV). تشتهر الأغواط بوفرة ضوء الشمس والطلب المتزايد على مصادر الطاقة المستدامة. تسخير إمكانات الطاقة المتجددة هذه لتقليل الاعتماد على الوقود الأحفوري والاستدامة البيئية. تقدم أنظمة الضخ الكهروضوئية ، التي تجمع بين الطاقة الشمسية وتقنيات ضخ المياه الفعالة ، حلاً واعدًا لإمدادات المياه والري في المناطق الزراعية والريفية والنائية في الأغواط. يسلط هذا الملخص الضوء على فوائد الطاقة المتجددة في الأغواط ودور أنظمة الضخ الكهروضوئية في الإدارة المستدامة للمياه.

الكلمات المفتاحية: الطاقة المتجددة ، الطاقة الشمسية ، الأغواط ، الجزائر ، أنظمة الضخ الكهروضوئية ، إمدادات المياه ، الري ، التنمية المستدامة

General introduction

General introduction :

As the world grapples with the challenges of climate change and the need to transition away from fossil fuels, renewable energy has emerged as a promising alternative. Renewable energy sources, including wind, solar, biomass, and hydropower, offer a viable and sustainable path towards reducing greenhouse gas emissions and meeting growing energy demand. In this context, the Laghouat area in Algeria presents a unique opportunity for developing renewable energy potential.

Located in the north-central region of Algeria, Laghouat is home to a diverse range of energy resources, including abundant solar and wind potential, as well as biomass and hydropower resources. The region's strategic location, abundant natural resources, and favorable policy environment make it an attractive destination for renewable energy investment and development.

Laghouat holds significant potential for renewable energy development, particularly in the form of solar energy. With abundant sunlight throughout the year and a growing demand for clean and sustainable energy sources, Laghouat is poised to harness its renewable energy potential to drive economic growth, reduce dependence on fossil fuels, and mitigate environmental impacts. One promising application of renewable energy in Laghouat is the utilization of photovoltaic (PV) pumping systems. These systems combine the power of solar energy with efficient water pumping technologies to address water supply and irrigation needs in agricultural, rural, and remote areas. This introduction explores the prospects of renewable energy in Laghouat and the role of PV pumping systems in sustainable water management, highlighting the benefits they offer to the region's development and the transition to a greener future.

Laghouat enjoys abundant solar resources, with high levels of solar irradiation year-round. The region's geographical location and favorable climatic conditions make it an ideal candidate for solar energy utilization. By tapping into this renewable energy potential, Laghouat can reduce its reliance on conventional energy sources and contribute to Algeria's clean energy targets. Solar power, in particular, offers a sustainable and readily available resource that can be harnessed through various technologies, including PV systems, to generate electricity and drive socio-economic growth.

PV pumping systems have gained recognition as a practical and efficient solution for water pumping needs in Laghouat. These systems leverage solar energy captured by PV panels to power water pumps, eliminating the need for grid electricity or diesel generators. PV pumping systems provide a sustainable and cost-effective approach to water supply and irrigation in agricultural areas, supporting the growth of crops, livestock farming, and rural development. They offer numerous advantages, including reduced operational costs, minimal environmental impact, and increased accessibility to water resources, especially in remote or off-grid locations.

The adoption of renewable energy, specifically PV pumping systems, in Laghouat can yield several benefits for the region and its inhabitants. Firstly, it promotes energy independence by utilizing locally available solar resources, reducing reliance on imported fossil fuels. This enhances energy security and resilience in Laghouat. Secondly, the deployment of PV pumping systems improves water management practices, ensuring reliable water supply for agricultural activities, livestock watering, and rural communities. This, in turn, enhances agricultural productivity, food security, and economic development. Additionally, the use of renewable energy contributes to a cleaner environment, reducing greenhouse gas emissions and mitigating climate change impacts.

Our objective in this thesis is to have an idea on each and every potential of renewable energy in Laghouat area and demonstrate at the end one of the best promising ways to profit from these unlimited sources of energy.

I Chapter One: State of the art

I.1. Introduction :

The state of the art discussed refers to the current level of advancement, innovation and development in a renewable energies field of technology and knowledge. It constantly evolves as new research and discoveries emerge. It is difficult to be determined in this field, as it can vary greatly, but some areas that are currently in a state of rapid advancement include renewable energy.

Today, a large part of the world's energy production is provided by fossil fuels, the consumption of these sources gives rise to greenhouse gas emissions. greenhouse and therefore an increase in pollution. The additional danger is that a excessive consumption of the stock of natural resources reduces the reserves of this type of energy in a dangerous way for future generations, and also in the face of multiple crises economic and oil science has taken an interest in so-called renewable resources which constitute a strategic sector and occupy a privileged place in the fields of research and development.

This moment of time we distinguish several sources of renewable energies, hydroelectric energy, geothermal energy, biomass energy, wind energy and photovoltaic energy (which will be all studied in this thesis). The main advantage of these renewable energies is that their use is limitless and does not pollute the atmosphere and they do not produce greenhouse gases such as carbon dioxide and nitrogen oxides which are responsible for global warming.

This work is part of the development and use of renewable energies, in particular knowing that the energy in the Laghouat area has been fossil for decades now, which tends to be considered as a massive energy source in the country to meet the immediate needs of population and contribute to energy independence, in exchange of this limited source we will we be seeing all potentials of this area.

I.2 Global energy status :

Global energy demand has been growing from 2011 to 2018 by approximately 30% and is expected double by 2022 [1] . Hence, many countries are moving toward RE to reduce dependency on fossil fuels and to mitigate CO2 emissions. Many countries have shown interest in RE sources in order to meet their energy demands. Huge investment alongside new policies and RE programs were introduced in developing countries for generation diversification and to shift to higher RE penetration. Nowadays, the cost of RE technologies is at an all-time low compared to past decades. Moreover, the abundance of renewable resources such as solar irradiation, wind, geothermal, and biomass has led to interest by governments to reconsider the usage of renewable energies instead of conventional fossil fuels [2].

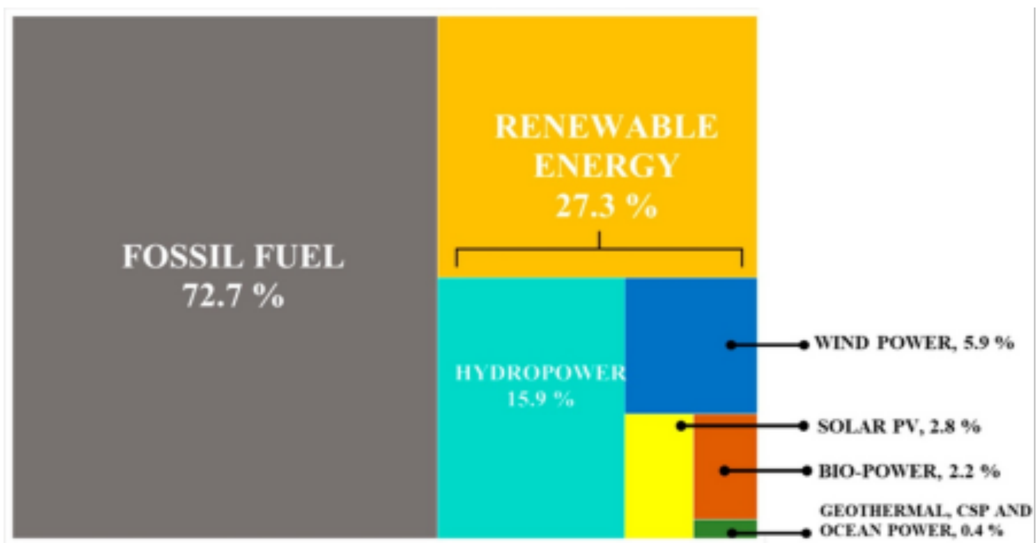

Figure I. 1: Global energy mix.

Fig I.1 shows the global energy mix in 2019 [1]. Fossil fuels contributed 72.7% of the total global generation, with RE contributing 27.3%. The global fossil fuel mix reduced by 2.8%, complemented by RE sources for the past three years [3]. The RE contribution to global energy is increasing in each year as compared to the previous year. Hydropower contributed 58% of the total global RE generation in 2019, followed by wind (21.6%), solar photovoltaic (PV) (10.3%), bio-power (8%) and other generation sources, such as geothermal, concentrated solar thermal power (CSP) and ocean power contributed 1.5% [4].

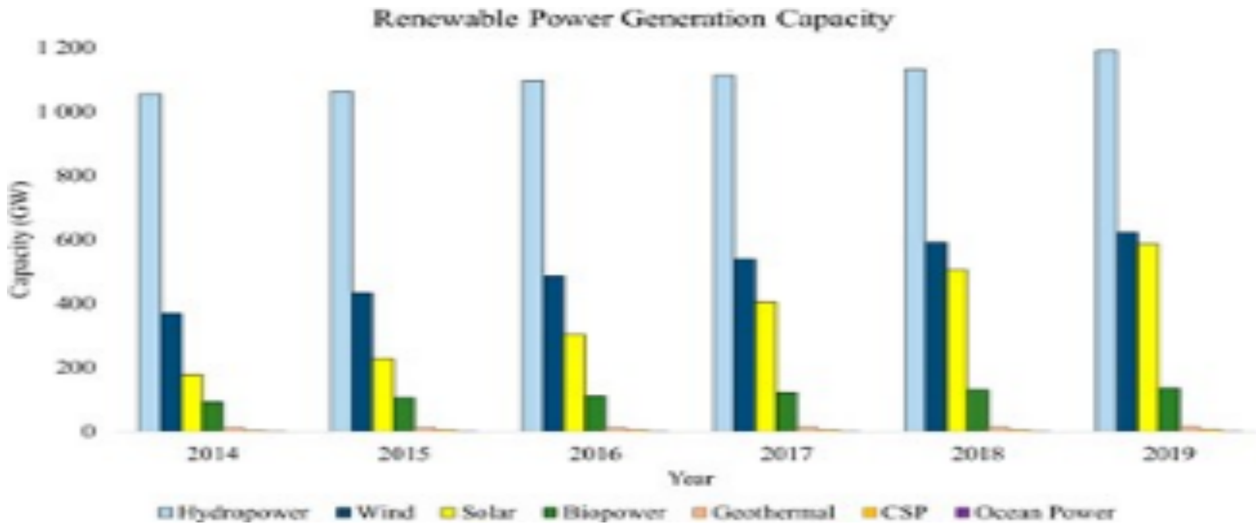

Figure I. 2 : Renewable power generation capacity.

The year 2019 recorded the most significant increase in RE capacity due to reducing project expenses, significant investments, and the development of technology in the field. Additionally, global funding of RE has been increasing throughout the years, leading to higher levels of RE generation. More than 200 GW of RE has been added this year, contributing toward a total of 2588 GW of RE installed capacity [1,4] . The distribution of the global RE technology mix is shown in **Fig I.2**.

I.2.1 Hydro-power :

Hydro-power is energy derived from falling or moving water [5]. Hydro-power stations vary in terms of type, storage, size, and the height of the water. Generally, hydro-power is classified based on its generation capacity, where small hydro is a scheme below 10 MW, mini-hydro is a scheme below 2 MW, micro-hydro is a scheme below 500 kW, and pico-hydro is a scheme below 10 kW [6,7,8].

Hydro-power plays an essential role in RE and in global energy production, contributing 15.9% to the global power in 2019 with a total capacity of 1150 GW. Hydro-power generation rose by 1.4% in 2019 from 1134 GW to 1150 GW. The investment in large hydro-power plants has been accompanied by an obvious increase in world energy consumption through an increase in demand over the last ten years [1,5].

I.2.2 Wind :

Wind energy is contemplated as one of the most efficient technologies in RE generation. The system uses kinetic energy from the wind to turn turbines for power generation [9].

The amount of wind energy available varies daily and seasonally. The total amount of wind energy able to be harnessed significantly depends on the characteristics, performance, and size of the wind turbines [2,9] . The total global wind generation in 2019 was 651 GW, representing a 10.2% increase from 2018 [10,11].

I.2.3 Solar :

Solar PV uses PV modules to convert energy from the sun into electricity [1]. Solar PV contributes 2.8% to the total global energy. PV generation increased by 115 GW (22.5%) in 2019 from 512 GW to 627 GW [12]. Hence, it has become the world's fastest-growing RE energy technology, and is the most expanded and competitive in the power generation market, through facilities such as adequate frameworks and policies offered by the governments of most countries [9,13].

I.2.4 Bio-power :

Bio-power includes solid biomass, liquid bio-fuels, bio-gas, and landfill gas [1]. This technology uses materials such as biomass to generate electricity or heat through methods such as direct firing, co-firing, anaerobic digestion, pyrolysis, and gasification [1]. Bio-power is a spatially spread resource. Bio-power has also been shown to produce high greenhouse gas emissions but at levels less than its fuel fossil counterpart [1]. Bio-power contributed 2.2% to the total global power generation in 2019. The bio-power generation capacity was 136 GW in 2019, representing a 4.6% increase from 130 GW in 2018 [1].

I.3 Energy status in Algeria :

Algeria is the largest county in Africa and the 10th largest in the world. It has an area of 2,381,741 km2 and an estimated population of 42.2 million people, with an average of 17.71 inhabitants/km2 [14]. It is located in the north of Africa with a 1644 km long coastline, as shown in Fig 3 [15]. The

Southern part of the country consists of a significant portion of the Sahara Desert. This region is hot year around. However, the coastal area of the country is mountainous and hilly, with an average rainfall of 400 to 670 mm and temperatures ranges from 25 ◦C to 11 ◦C.

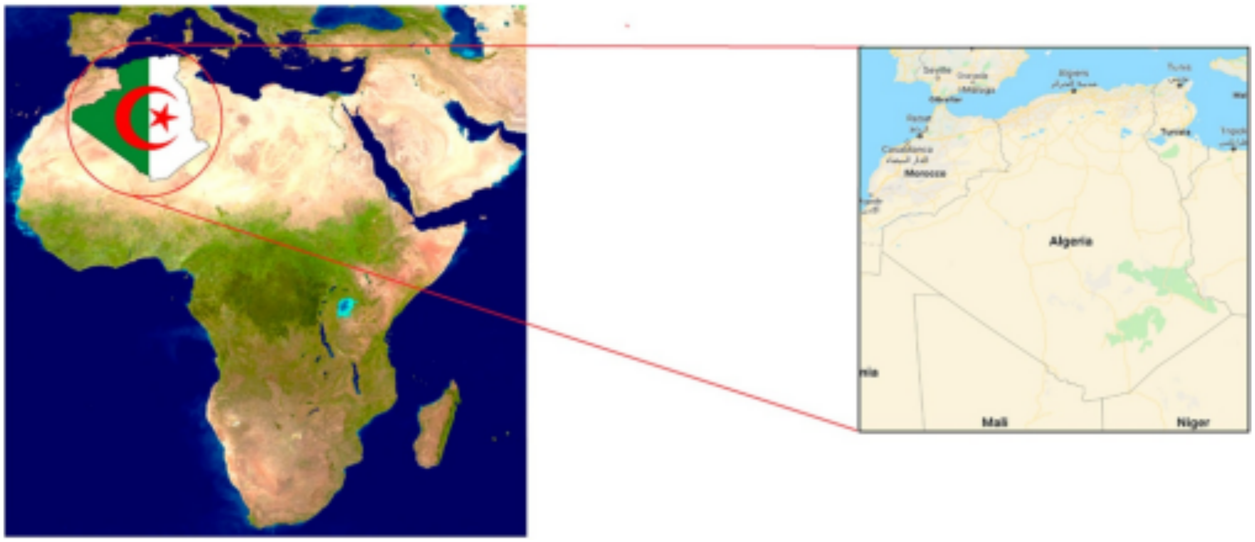

Figure I. 3 : Demonstration of Algeria.

Algeria has the 4th most influential economy in Africa, with a Gross Domestic Product (GDP) of USD 178.3 billion [16]. The country's economy is mainly based on the production and export of oil and gas. Sonatrach is a national company responsible for the hydrocarbon sector. Algeria is among the countries that have an abundance of fossil and fuels and is a member of the Organization of Petroleum Exporting Countries (OPEC) [17,18]. Oil and Gas basins in the country are located in seven areas: the Ghedames and Illizi basins in the east; the Timimoun, Ahnet and Mouydir basins in the central region; the Reggane and Tindouf basins in the southwest, as illustrated in **Fig I.4** [16]. The country has the 3rd most extensive reserves of gas and the 7th most significant oil reserves in the world. In 2018, Algeria produced 12.2 billion barrels and 159 trillion cubic feet (Tcf) of oil and natural gas reserves, respectively [4].

Figure I. 4 : Location of gas and oil basins in Algeria.

As mentioned previously, In Algeria 99.98% of the total electricity production comes from fossil fuels, in particular natural gas, which is the most available energy. This went from 7,492 MW in 2005 to 17,238.6 MW in 2015. The rest (0.02%) is provided by renewable energies made up of hydro, wind and photovoltaic [19,20,21].

Through the launch of an ambitious program for the development of renewable energies (RE) and energy efficiency, Algeria is initiating a green energy dynamic based on a strategy focused on the development of inexhaustible resources. and their use to diversify energy sources and prepare the Algeria of tomorrow. Thus, Algeria is embarking on a new sustainable energy era [22].

Algerian energy policy has set itself the following objectives:

- The development and conservation of hydrocarbon resources.
- The development of the domestic use of natural gas.
- The development of renewable energies.
- Improving energy demand management.
- Strengthening energy efficiency by strengthening the role of the specialized state agency.

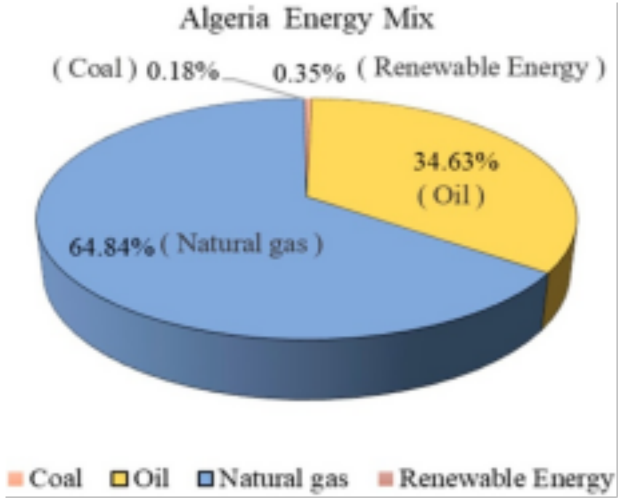

Figure I. 5 : Algeria fossil fuel generation mix in 2019.

Fig I.5 shows the current energy mix of Algeria. The country relies heavily on fossil fuels—such as natural gas and oil, which contribute 64.84% and 34.63%, respectively—for electricity generation. Algeria showed substantial growth in the production of gas, and oil from the year 2000 to 2018, contributable to a 33.3% increase in the population [10,17]. Although 28% of Algeria's population is located in rural areas, 100% of households in the country have access to electricity [14].

Electricity production rose to 76.4 TWh in 2018 from 76.0 TWh in 2017, proportional to the population growth of almost 1 million people [23]. The load demand increased by 7.4% from 2007 to 2017. The country's population and energy consumption profile are shown in **Fig I.6**. By 2030, generation is expected to rise to approximately 150 TWh, with an additional 5.2% increment each year. The promulgation of the new law No. 02/01 February 2002, corresponding to the distribution of the electricity grid and gas, functioned as a steppingstone for reorganizing the sector and opening the electricity market. The outcome of this law includes significant grid expansion for electricity transmission from the year 2002 to 2015. Moreover, Algeria was is able to export more than 880 GWh of electricity in 2017 to the neighboring countries such as Tunisia and Morocco [24,25].

Due to the increase in energy demand each year, the Sonalgaz company estimated that 34,441 km of transmission lines are planned to be implemented from 2017 to 2027. Currently, 9930 km transmission lines are under development, with another 24,511 km planned, which includes national and international interconnections [26].

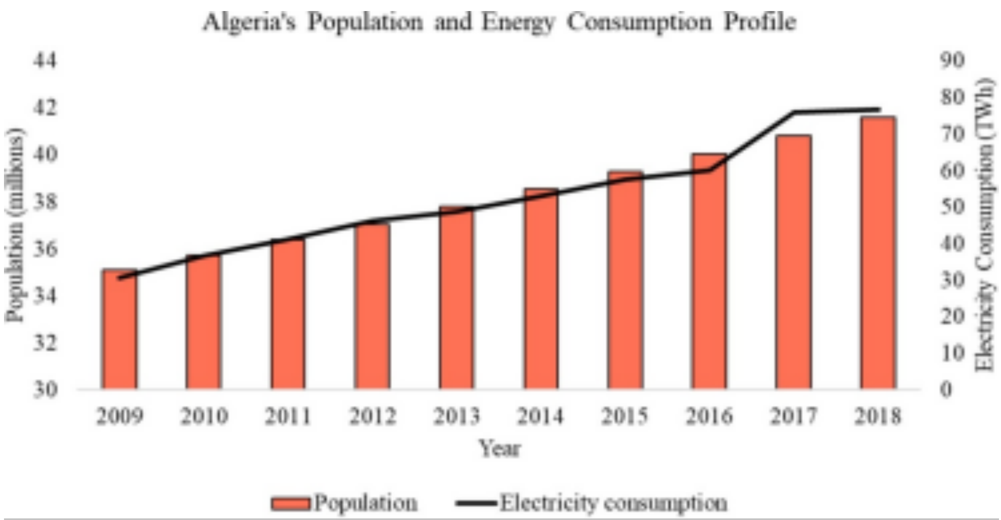

Figure I. 6 : The evolution of population and electricity consumption in Algeria.

I.4 Renewable electricity generation in Algeria :

Fossil-energy-related CO2 emissions in 2014 were 122.93 Mt CO2, or 3.16 tonnes per inhabitant, 29% below the world average: 4.47 tonnes, but 3.3 times the African average: 0.96 tonnes (France: 4.32; Morocco: 1.57) [27].

According to the 2012 Algerian Renewable Energy and Energy Efficiency Development Program (PNEREE), Algeria is aiming for 22,000 MW of installed renewable energy capacity by 2030, of which 12,000 MW will be dedicated to meeting domestic electricity demand and 10,000 MW to export [28].

For 2015, the International Energy Agency's (IEA) annual report on solar power mentions Algeria, announcing that it installed 270 MWp during the year, bringing its total solar capacity to 300 MWp, but the GWEC (Global Wind Energy Council) report on wind power makes no mention of Algeria [29, 21].

At the end of February 2015, the Algerian government adopted its 2015-2030 renewable energy development program. An initial phase of the program, launched in 2011, had pilot projects and studies of the country's potential. The new program sets targets for installations by 2030:

- 13,575 MWp of photovoltaic solar power ;
- 5,010 MW of wind power ;
- 2,000 MW of thermodynamic solar power (CSP);
- 1,000 MW biomass (waste-to-energy)
- 400 MW co-generation ;
- 15 MW geothermal energy.

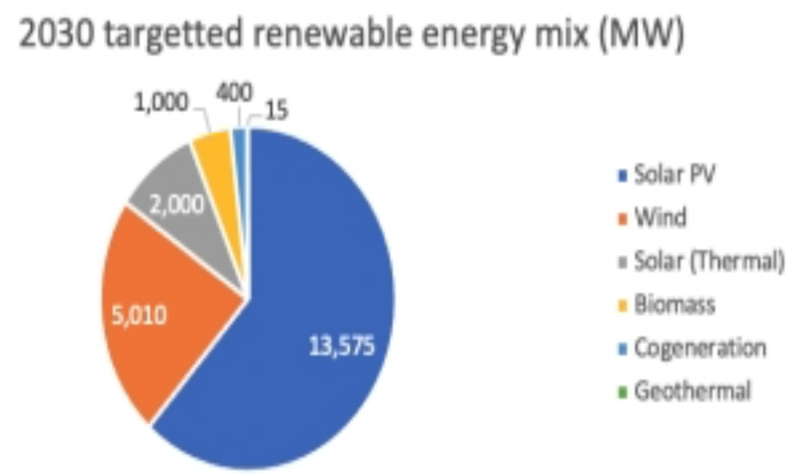

Figure I. 7 : Powers of renewable energies by 2030.

This brings the total to 22 GW, of which more than 4.5 GW must be completed by 2020. By 2030, 37% of installed capacity and 27% of electricity production for national consumption will come from renewable sources [30].

The Sonelgaz Group is committed to new and renewable energies. As part of its renewable energy development program, the group is planning to build 67 solar power plant projects, including 27 photovoltaic plants, 27 hybrid plants, 6 solar thermal plants and 7 wind power plants. The most powerful solar power plants will be of the solar thermal type, with a maximum capacity of 400 MW for one of them. For optimum efficiency, they will all be installed in the southern regions, notably in the wilayas of Adrar, Ghardaïa, El Oued and Béchar [31,22].

Fig I.7 represents the renewable energy development program by 2030.

I.5 Renewable energy potential in Algeria :

The government has been launching policies and funds for RE development in the country since 1998. Algeria has promising RE sources, such as hydro-power, wind, geothermal, biomass, and solar, due to its geographical location [2,32].

I.5.1 Solar potential in Algeria :

Per inhabitant electricity consumption in Algeria reached 1,363 kWh in 2014, just 45% of the world average of 3,030 kWh, but 2.4 times the African average of 568 kWh (France: 6,955 kWh; Morocco: 912 kWh). With 86% of its territory made up of Saharan desert, and thanks to its geographical position, the quality of Algeria's solar radiation places it among the three countries with the best solar deposits in the world.

The energy received annually on a horizontal surface of $1m^2$ is close to 3 kWh/m^2 in the north and over 5.6 kWh/m^2 in the south.

The duration of sunshine over almost the entire country exceeds 2,000 hours annually, reaching 3,700 hours in the Sahara, with an average of 6.57 kWh/m2/day. If we were to compare solar energy with natural gas, Algeria's solar potential is equivalent to a volume of 37,000 billion cubic meters, or more than 8 times the country's natural gas reserves, with the difference that solar potential is renewable, unlike natural gas. The following table shows Algeria's solar potential in figures and by location [34,35,36].

	Coastal Area	Inner Area	Desert Area
Area %	4	10	86
Average sunshine duration (h/year)	2650	3000	3500
Average energy received (kWh/m2/year)	1700	1900	2650

Table I. 1: Solar potential in Algeria.

There is a network of 78 meteorological measurement stations operated by the National Meteorological Office (ONM) distributed throughout the country. **Fig I.8** and **Fig I.9** show the country's irradiation and temperature distribution [26].

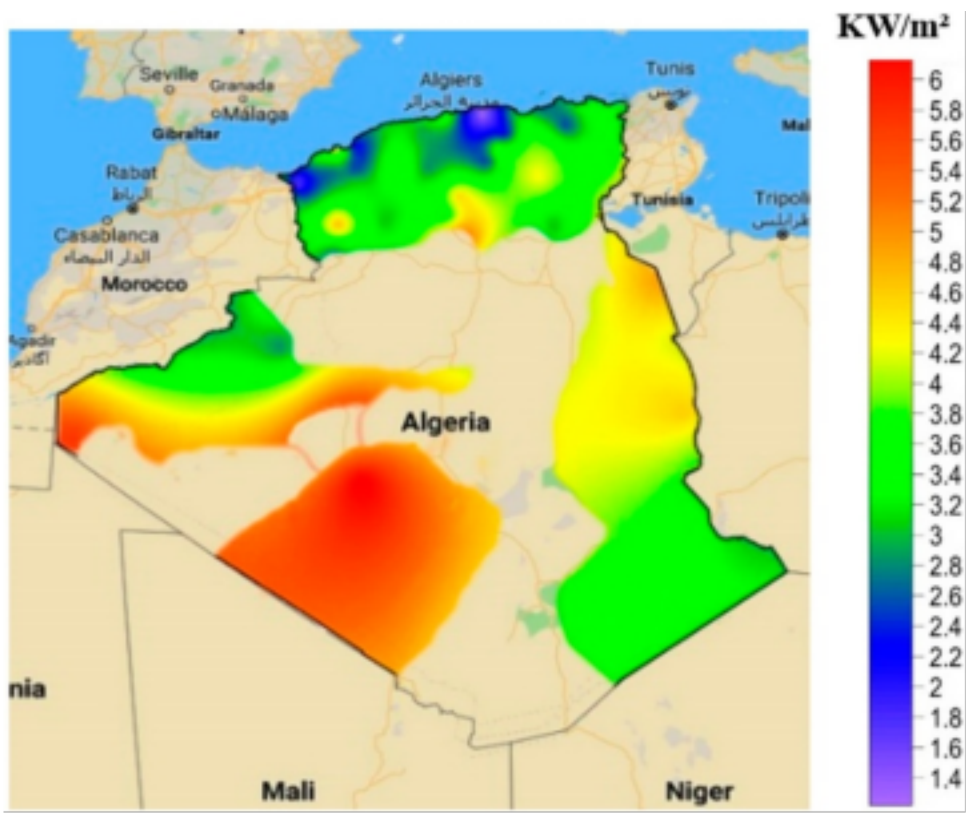

Figure I. 8 : The solar irradiation in Algeria kW/m^2.

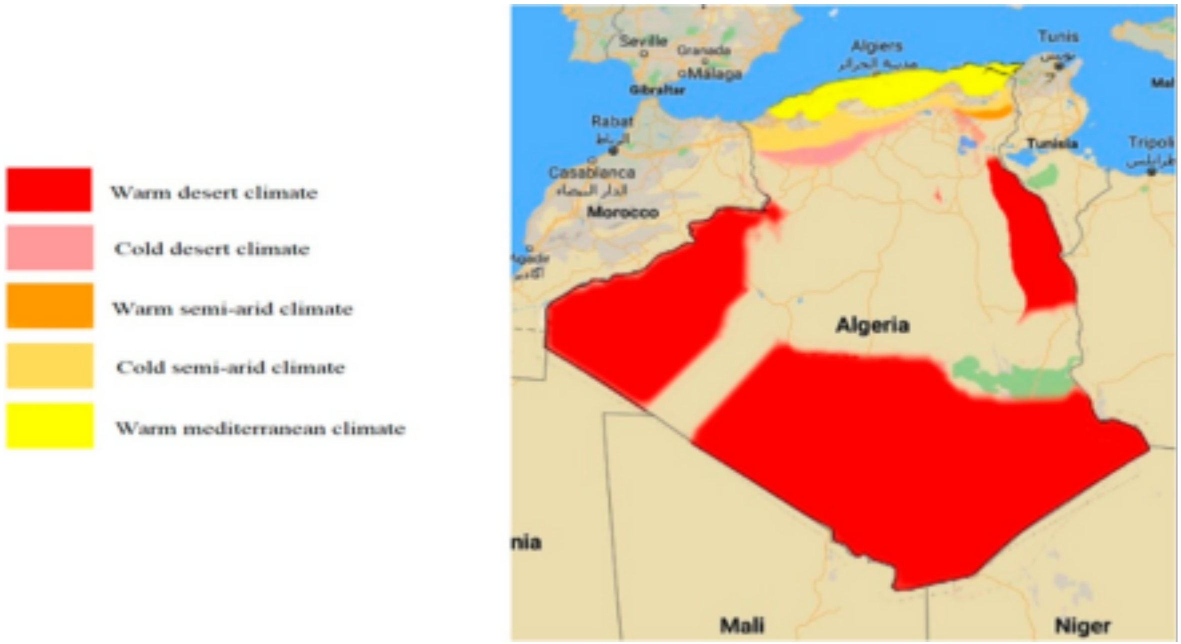

Figure I. 9 : The temperature distribution in Algeria.

The solar generation potential in the desert area of the country is illustrated in Fig 10. The desert area of the country covers 2048.297 km2 of land [3]. This area has the potential to generate 168*1012 kWh/year via utilization of 50% of the available space factor and an efficiency of 10%.

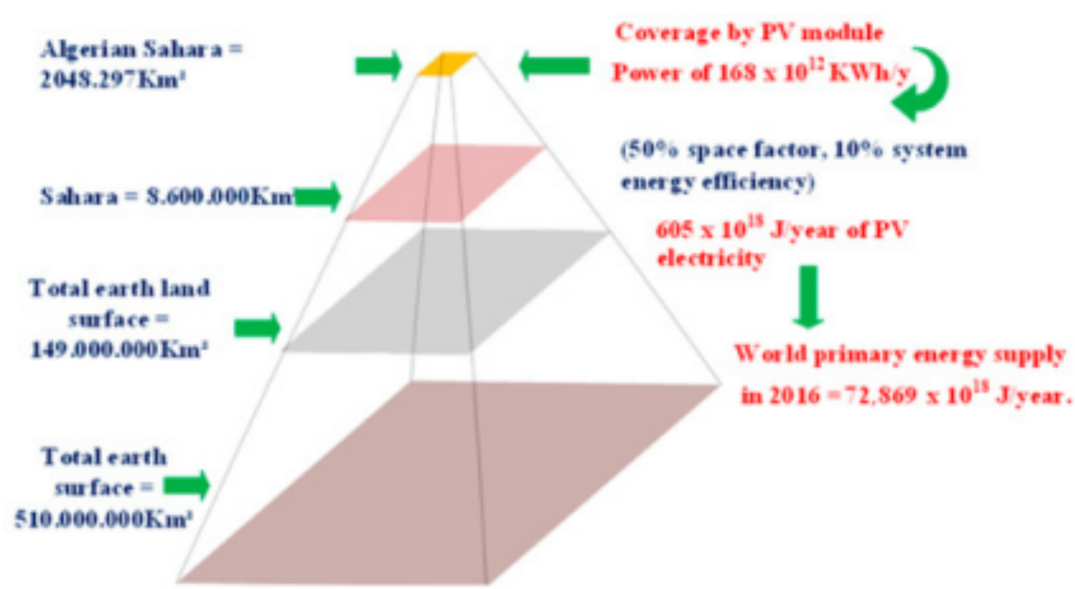

Figure I. 10 : Potential solar generation for the Sahara Desert.

I.5.2 Hydro-power potential in Algeria :

Algeria has promising potential for hydro-power generation due to the availability of dam sites and a high average rainfall. Currently, very few studies have investigated the potential of hydro-power in the country.

The average rainfall that falls over Algerian territory is estimated at 65 billion cubic meters per year, with 103 potential dam sites [37]. **Fig I.11** shows potential sites for dams and rivers that are in the northern region of the country.

Figure I. 11 : Potential dam and river locations in Algeria for hydro-power generation.

Continental interbedded groundwater is highly sought after for its water as a mobilized resource in the Northern Sahara. A very high flow and outlet pressure characterize this groundwater, which is 50 to 400 l.s-1 for flow, and 5 to 40 bar for pressure. A survey of the Northern Sahara Aquifer System was essential to prove the existence of this potential. This energy appears in artesian form, which remains considerably for a long time in most of the well. We have realized that this energy is immense, as well as the expanded volume of groundwater, and the importance of its use in agriculture [38].

Unfortunately, this potential remains untapped to this day and the energy from this water is completely wasted. Several turbo-generator and/or inverter pump integration trials (PATs) were conducted.

Groundwater can be found in many forms. They may be in the form of free groundwater "aquifers", where the water level in the borehole corresponds to that of groundwater. Some groundwater are found confined deep down impermeable layers and thus contain under pressure of water. At the end of the 19th Century, the emergence of borehole in the Northern Sahara Aquifer System (NSAS) was intended to give new impetus to the development of the Sahara (PNUD-UNESCO, 1972) [38].

Qualified in 1945 as "the greatest hydraulic system of the Sahara" by Savornin (1947) in Dubost (2002), and studied extensively in Dubost (2002). Covering an area of 600 000 km2 and containing 50 000 billion m3 of water in reserve (Hellal & Ourihane, 2004). It was presented in the sixties (Cornet, 1961) as the final solution to aridity and underdevelopment of the region **Fig I.12** [38].

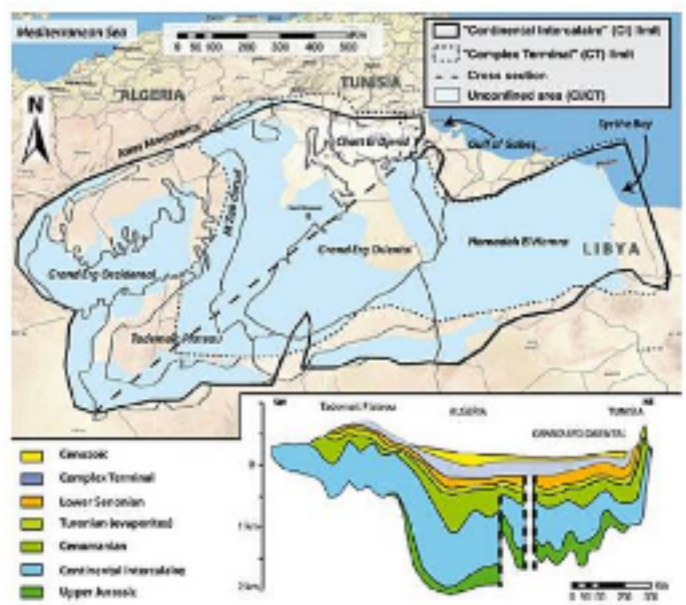

Figure I. 12 : Distribution of Continental Intercalary groundwater.

The water quality of the continental intercalary, according to CDARS (1999a), varied between good (total mineralization <1,5 g.l-1) to very good (<0,5 g.l-1) on its outcrop zones, and was saltier near the sector of In Salah and relatively good in Ghardaia, Ouargla and El Oued (<2,5 g.l-1) (**Table I.2**).

This increased salinity is associated with increasing temperature, which exceeds 50°C for depths over 1500 m [38].

Characteristics	**Value**
Area (km^2)	600000
Total Thickness (m)	50 à 1000
Depth (m)	60 à 2400
Roof depth (m)	20 à 2000
Flow ($l.s^{-1}$)	50 à 400
Transmissivity (10^{-3} $m^2.s^{-1}$)	10 à 30
Storage coefficient (10^{-4})	6 à 1200
Average supply ($Hm^3.an^{-1}$)	270
Calculated theoretical reserve (m^3)	35000 * 109
Temperature (°C)	25 à 70
Salinity ($g.l^{-1}$)	0,5 à 6

Table I. 2 : General data on the groundwater of the Continental Intercalary in Algeria.

The groundwater of the Northern Sahara Aquifer System (NSAS) is considered as renewable. A recent study showed that rainwater and runoff bring to the system an average of 1,4 km3 per year, or about 2 mm per year to the resource surface of the groundwater [39,40,41].

The first application of geothermal energy from the Continental Intercalary groundwater was conducted in 1990 for heating greenhouses in southern Algeria [42].

The exploitation of geothermal energy for greenhouses heating is too modest compared to the great potential geothermal resources in southern Algeria [43].

In Algeria, aquaculture is still in its beginning. Some projects of fish farming have been promising in South Algeria with use of the Continental Intercalary water [44].

The exploitation of the Continental Intercalary groundwater almost exclusively goes to agricultural use with nearly 1,95 billion cubic meters. The consumption of drinking water represents less than 10 % of the global exploitation [45].

Continental Intercalary model as conducted by the PDGDRS's study has long established several simulations of various operating assumptions of the Continental Intercalary groundwater. We have recapped the report of the CDARS, to show the necessary elements, noticeably, the persistence of artesian flow for a long time period in some areas of the Northern Sahara (up to year 2038).

An inventory of all water points of the Northern Sahara and evaluation of the collected flows were completed by ANRH (National Agency of Hydraulic Resources). The results of this survey are presented in the **Table I.3**.

Region	**Exploited borehole**		**Total**	**Non-exploited borehole**		**Total**
	Artesian	**Pumped**		**Abandoned**	**Recapped**	
Ouargla	15	9	24	3	1	28
El Oued	11	-	11	1	3	15

Ghardaia	25	51	76	2	11	89
Touggourt	1	4	5	1	1	7
In Salah	17	64	81	29	10	120
Ilizi	29	10	39	14	4	57
Adrar	-	442	442	90	2	534
Gaci Touil	7	-	7	2	-	9

Table I. 3 : Water use and state of the Continental Intercalary borehole.

No	Station	Capacity (MW)
1	Draguina (Bejaia)	71.5
2	Ighil emda (Bejaia)	24
3	Mansoria (Bejaia)	100
4	Erraguene (Jijel)	16
5	Souk el djemaa (Relizane)	8.085
6	Tizi meden (Tizi ouzou)	4.458
7	Ighzenchebel (Algiers)	2.712
8	Ghrib (Ain defla)	7
9	Gouriet (Bejaia)	6.425
10	Bouhanifia (Mascar)	5.700

Table I. 4 : Hydropower plants in Algeria.

I.5.3 Wind potential in Algeria:

Algeria, located in North Africa, has a diverse geography and a long coastline along the Mediterranean Sea. These geographical features provide abundant wind resources, making wind power a promising renewable energy option for the country. With increasing global concerns about climate change and the need to transition towards cleaner energy sources, wind power presents a significant opportunity for Algeria to reduce its dependence on fossil fuels and promote sustainable development.

Algeria possesses substantial wind power potential, primarily in coastal and highland regions. The northern coast of more than 1600 km2 with mountainous topography, including areas such as Tlemcen, Oran, and Annaba, exhibits consistent and favorable wind patterns, making it an attractive location for wind power projects. Additionally, the highland regions, including the Atlas Mountains, offer elevated terrains and strong winds, further enhancing the wind power potential in the country.

Wind power is a clean and renewable energy source, reducing reliance on fossil fuels and mitigating greenhouse gas emissions. It diversifies the energy mix, reducing dependence on imported fossil fuels and enhancing energy security.The development and operation of wind farms stimulate local economies, create job opportunities, and attract investments in the renewable energy sector.As it can lead to lower electricity prices, especially with advancements in technology and economies of scale. Wind power contributes to environmental sustainability by reducing carbon emissions and minimizing air pollution associated with conventional power generation.

Moreover, wind data measured has been studied over ten years from four locations in the country. Additionally, CDER conducted a study to determine the optimal locations for wind generation in the country. The study by the RE Development Center (CDER) provides a comprehensive study of the wind potential in the country from 74 meteorological stations [46].

Based on these studies, Algeria has good potential for wind generation in several regions, such as M'Sila, Bou Chekif, Djelfa, and Mecheria. These locations have windy conditions throughout the year, with speeds ranging from 6 to 7 m/s. Although, there are other locations with high wind speeds, such as In Salah and Adrar, these locations are not suitable for wind generation installation due to geographical conditions and the unavail- ability of the electrical transmission network. On the other hand, extreme temperatures up to 50 ◦C limit installation in the south desert locations in the country. **Fig I.13** illustrates the available wind speed across regions in the country and **Fig I.14** is an annual map of wind speed across Algeria at 10 m high [47,48].

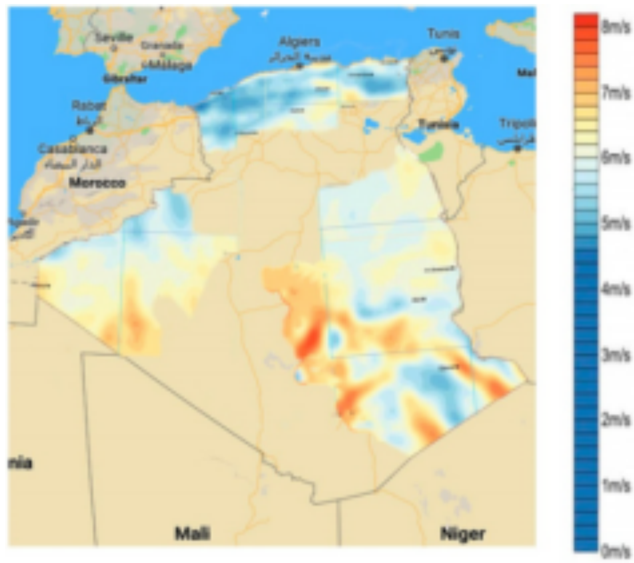

Figure I. 13 : Available wind speed across regions in the country.

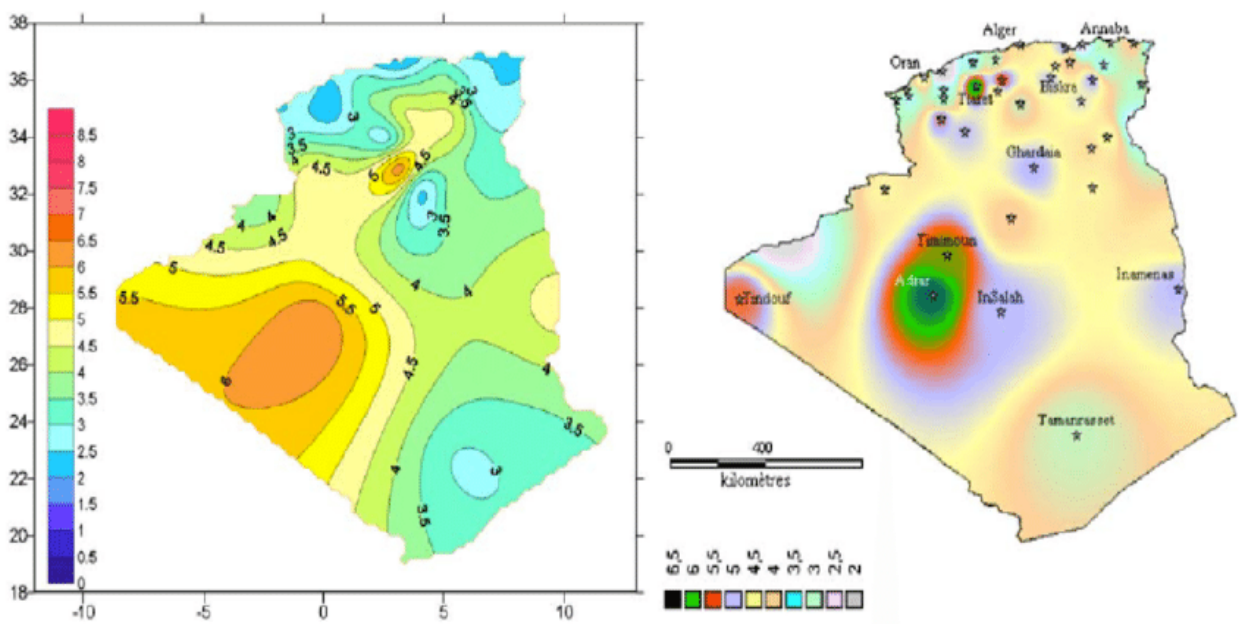

Figure I. 14 : Annual map of wind speed in Algeria at 10 m high.

The future of wind power in Algeria is promising, with several potential pathways for growth:

Capacity Expansion: Algeria aims to significantly increase its wind power capacity to meet its renewable energy targets. Expanding wind farms and implementing new projects in suitable locations will play a crucial role in achieving these goals.

Technological Advancements: Continued advancements in wind turbine technology, including larger capacities, enhanced efficiency, and improved reliability, will further optimize wind power generation in Algeria.

Offshore Wind Development: Algeria's long coastline offers untapped potential for offshore wind farms, which can harness stronger and more consistent winds, further boosting renewable energy production.

Research and Development: Continued investment in research and development, including wind resource assessments, wind mapping, and technological innovations, will contribute to maximizing the wind power potential in the country.

Algeria can leverage its abundant wind resources to drive economic growth, enhance energy security, and contribute to a greener and more sustainable future.

I.5.4 Bio-power potential in Algeria:

Algeria, with its diverse agricultural and forestry sectors, possesses substantial biomass resources that can be utilized for bio-power generation. Bio-power, which encompasses the production of electricity, heat, and biofuels from organic materials, presents an opportunity for Algeria to diversify its energy mix, reduce greenhouse gas emissions, and promote sustainable development.

We aim to explore the potential and benefits of bio-power in Algeria. we provide insights into the current status of bio-power development, the challenges faced, and the future prospects of this renewable energy source. Also highlights the importance of bio-power in advancing Algeria's sustainable development goals, promoting rural development, and addressing waste management challenges.

Algeria's biomass resources comprise agricultural residues, forest biomass, livestock waste, and organic municipal waste. These resources can be utilized for various bio-power technologies, including anaerobic digestion, biogas production, biomass combustion, and biofuel production. Assessing the quantity and quality of biomass resources is essential for determining the bio-power potential in different regions of the country.

Algeria has good biomass energy potential in the form of solid wastes, date palm biomass, crop wastes and forestry residues. Solid waste is the best source of biomass potential in the country. According to the National Cadastre for Generation of Solid Waste in Algeria, annual generation of municipal wastes is more than 10 million tons. Solid wastes are usually disposed in open dumps or burnt wantonly. In recent time, they are starting to use recycled jutebags to minimize the impact of solid wastes [49].

Bio-Power Resources	**Annual Biogas Potential (Million m3)**	**Potential Energy (GWh)**
Agribusiness and industry waste		
Amurca available from the olive oil industry	10,5	17,74
Pomace available from the olive oil industry	-	215,5
Whey available from the dairy industry	2,35	3,97
Urban waste		
The organic fraction of household waste	974	1646
Sewage from wastewater treatment plants	22,91	38,72
Total	1009,76	1706,43

Table I. 5 : Potential bio-power in Algeria.

Limited studies have been conducted for assessing the bio-power potential in the country. Developers from CDER provided an overview of the potential bioenergy in the country that focuses on domestically available biomass resources for energy generation [50].

Meanwhile, they investigated the potential of solid waste for biomass energy generation in Algeria [51]. The bio-power potential in the country, based on the work conducted, is summarized in **Table I.5**.

The development of bio-power in Algeria offers several benefits:

Renewable Energy Generation: Bio-power utilizes organic materials, such as agricultural residues and waste, which can be continuously replenished, reducing reliance on finite fossil fuel resources.

Waste Management: Bio-power projects can contribute to effective waste management by utilizing organic waste materials that would otherwise end up in landfills, reducing methane emissions and promoting circular economy principles.

Rural Development: Bio-power projects in rural areas can create employment opportunities, stimulate local economies, and provide additional income streams for agricultural and forestry communities.

Energy Independence: Bio-power reduces dependence on imported fossil fuels, enhancing energy security for Algeria.

Carbon Emission Reduction: Bio-power significantly reduces greenhouse gas emissions compared to traditional fossil fuel-based power generation, contributing to climate change mitigation.

The future of bio-power in Algeria holds great potential for sustainable energy development:

Feedstock Diversification: Exploring a wide range of biomass feedstocks, including agricultural residues, forestry biomass, and organic waste, will expand the bio-power potential and ensure a sustainable and diversified supply.

Research and Development: Continued research and development efforts, focusing on bio-power technologies, feedstock optimization, and efficient conversion processes, will drive innovation and enhance the performance of bio-power systems.

Policy Support: Strengthening policy support through long-term renewable energy targets, incentives, and regulatory frameworks will attract private investments, encourage technology adoption, and foster market growth.

International Cooperation: Collaborating with international partners, sharing best practices, and accessing financial assistance and accessing financial assistance and technical expertise can support Algeria's bio-power development efforts.

Bio-power represents a significant opportunity for Algeria to utilize its abundant biomass resources for clean and sustainable energy generation. Overcoming challenges related to feedstock availability, technology, and policy support, Algeria can leverage bio-power to enhance its energy security, promote rural development, and contribute to environmental sustainability and waste management.

I.5.5 Geo-thermal potential in Algeria :

Due to the abundance of hot springs in the country, geothermal energy is a promising way to increase the use of RE. Only a few studies that looked into Algeria's potential geothermal resources have been published. A database of low-temperature geothermal sites in Algeria, for instance, was created by CDER developers and contains details like thematic maps, thermal springs [52], and hot water resources [53]. They also compiled the geothermal data and settings for Algeria from the CDER's geothermal exploration data [54]. They recently carried out research to assess the potential for geothermal energy production in 31 thermal springs in north central Algeria, including Ouarsenis, Biban, and Kabylie [55].

Fig I.15 illustrates the geothermal potential locations in Algeria.

Figure I. 15 : Geothermal potential locations in Algeria.

Based on the previous studies [53,54], there are more than 240 hot springs available and distributed from east to west and located at a moderate altitude in the mountainous regions in the country. The highest recorded temperature was 98 ◦C for the eastern area, 68 ◦C for the western area, and 80 ◦C for the central area. Meanwhile, the southern area has an average temperature of 50 ◦C.

Fig I.15 shows the available locations for geothermal energy generation in the country. Meanwhile, **Fig I.16** shows the geothermic chart of 41 hot spring samples in the country.

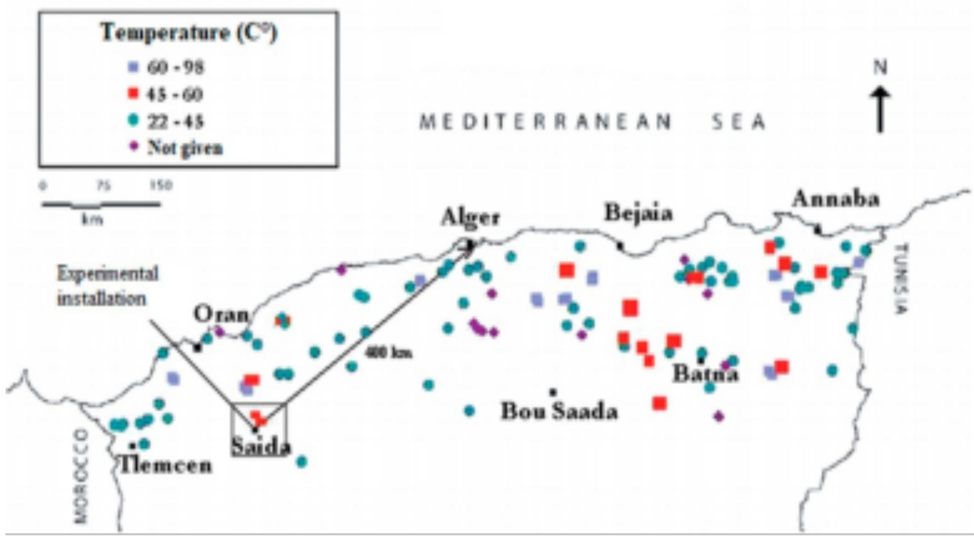

Figure I. 16 : The geothermic chart in Algeria.

The formation of the intercalary continental constitutes a vast number of hot waterreservoirs in the southern region of the country. This reservoir, known as the “Albian aquifer”, is exploited through boreholes and has an average temperature of 57 °C and4 m^3/s flow, with a potential generation of up to 700 MW [54].

Table I.6 shows the locations of hot springs in the country. The Arabic term “Hammam” means hot springs.

Thermal Source	Location	Temperature (°C)
Hammam Rabbi	Saïda	49
Hammam Bouhadjar	Aïn Témouchent	66,5
Hammam Ain Mentila	Relizane	31
Hammam Righa	Aïn Defla	67
Hammam Melouane	Blida	38,5
Hammam El Mesrane	Djelfa	42

Table I. 6 : Thermal source locations in Algeria.

I.6 Conclusion :

In conclusion of our first chapter, Algeria has made significant strides in the development and implementation of renewable energy sources. The country's vast renewable energy potential, coupled with its commitment to reduce greenhouse gas emissions and diversify its energy mix, has led to the emergence of several successful initiatives and projects. Algeria has leveraged its abundant solar resources to establish one of the largest solar farms in the world, and has embarked on ambitious plans to increase its solar capacity further. The government's support for renewable energy, as reflected in the National Renewable Energy Program, has created a favorable environment for investment and collaboration, attracting both domestic and international players. Furthermore, the introduction of feed-in tariffs and regulatory frameworks has facilitated the integration of renewable energy into the national grid. Algeria's commitment to wind energy has also been evident, with the commissioning of wind farms.

However, despite these commendable efforts, challenges such as the need for further investment, infrastructure development, and technology advancement remain. Nonetheless, Algeria's renewable energy sector is poised for continued growth and success, driven by a combination of governmental support, technological advancements, and favorable market conditions.

With its ongoing commitment to sustainable energy, Algeria is on track to achieve a greener and more resilient energy future, reducing its dependence on fossil fuels and contributing to global efforts in mitigating climate change. These initiatives have not only contributed to the reduction of Algeria's reliance on fossil fuels but have also fostered job creation and economic growth in the renewable energy sector.

II Chapter Two: RE potential in Laghouat

II.1 Introduction :

As the world grapples with the challenges of climate change and the need to transition away from fossil fuels, renewable energy has emerged as a promising alternative. Renewable energy sources, including wind, solar, biomass, and hydropower, offer a viable and sustainable path towards reducing greenhouse gas emissions and meeting growing energy demand. In this context, the Laghouat area in Algeria presents a unique opportunity for developing renewable energy potential.

II.2 Data of Laghouat :

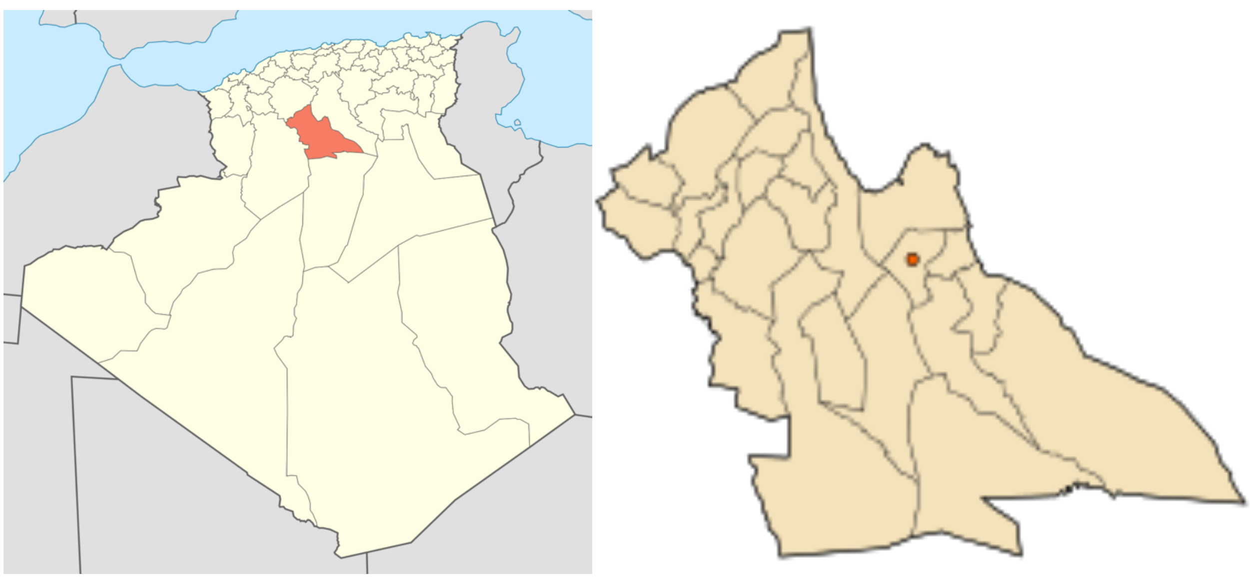

Figure II. 1 : Location of Laghouat province (map).

Located in the north-central region of Algeria as shown in **Fig II.1**, Laghouat is home to a diverse range of energy resources, including abundant solar and wind potential, as well as biomass and hydropower resources. The region's strategic location, abundant natural resources, and favorable policy environment make it an attractive destination for renewable energy investment and development.

Geographic data	
Latitude	33.80°
Longitude	2.86°
Altitude	769 m

LAGHOUAT INFORMATION

Find all the statistics and **information Laghouat** or click on the section of your choice in the left menu.

Country	Algeria
Wilayah	Laghouat
Type	Wilayah
ISO 3166-2	DZ-03
FIPS	AG25
HASC	DZ.LG

Figure II. 2 : Informations on Laghouat province.

LAGHOUAT DATA	
Cities and villages	24
Population	455,602 inhabitants Laghouat 144,747 inhabitants El Houaita 2,789 inhabitants
Area	35,413 km² (13,673.04 sq mi) Bennasser Benchohra 10,050 km² Taouila 255.0 km²
Population Density	12.9 /km² (33.3 /sq mi) Laghouat 362 /km² Bennasser Benchohra 1.0 /km²
Average altitude	1,022 m (3,353 ft)
Time zone	UTC +1:00
Zone	12:53:08 - 20 June 2023

Figure II. 3 : Data of Laghouat province.

II.3 Energy and RE in Laghouat :

Laghouat area, focusing on four key sources of renewable energy: wind, solar, biomass, and hydropower. By analyzing the region's natural resources, technological capabilities, and policy environment, this paper aims to provide a comprehensive assessment of the potential for renewable energy development in Laghouat.

In Laghouat, the sources of electricity production include a mix of conventional and renewable energy sources:

II.3.1 Natural Gas:

Laghouat benefits from Algeria's extensive natural gas reserves, and natural gas power plants play a significant role in electricity production. These power plants use natural gas as a fuel source to generate electricity through the combustion process. Sonelgaz: which is the national electricity and gas company in Algeria. It is responsible for the generation, transmission, and distribution of electricity across the country, including Laghouat [25].

Figure II. 4 : Electricity consumption (KWh per inhabitant).

II.3.2 Solar Energy:

Laghouat boasts significant potential for solar power generation. The region's abundant sunshine, with over 3,000 hours of sunlight per year, creates ideal conditions for solar energy. A study by the International Renewable Energy Agency (IRENA) estimates that Laghouat has a solar potential of 2,500 kilowatt-hours per square meter per year (kWh/m2/year), which is among the highest in the world. This makes the region well-suited for large-scale solar power projects, which can be developed both in the form of utility-scale solar farms and distributed solar systems [18,22,28].

Given Laghouat's geographical location and abundant sunlight, solar energy is a prominent source of electricity production in the region. Solar power plants, such as the Laghouat Solar Power Plant, utilize photovoltaic (PV) panels to convert sunlight into electricity. The Laghouat Solar Power Plant is a notable facility dedicated to harnessing solar energy for electricity generation in Laghouat. It utilizes photovoltaic panels to convert solar energy into electricity.

Laghouat Solar PV Park is a 60MW solar PV power project. It is located in Laghouat, Algeria. The project is currently active. It has been developed in multiple phases. Post completion of construction, the project got commissioned in 2016.

the head of the Sonelgaz group noted that the power plants in the regions of Tilghemt and Timzighet, Laghouat region, will have to operate, before the end of next May (2023), at full speed to reach an electricity production capacity. of 965 Megawatts, against 200 MG currently.

Project type	**Total capacity (MW)**	**Active capacity (MW)**	**Pipeline capacity (MW)**	**Project status**	**Project location**	**Project developer**
Solar PV	60	60	-	Active	Laghouat, Algeria	China Hydropower Engineering Consulting Group; SKTM; Sinohydro; Yingli Green Energy Holding

Table II. 1 : Solar PV park project in Laghouat.

The first phase: (Experimental)

• Construction of two (02) PV and wind technology park sites

PV: Oued Nechou 1,1 MWp plant (Ghardaia)

Wind: Kabertene 10.2 MWp plant (Adrar)

The second phase: (Deployment)

Algeria has embarked on the path of renewable energies in order to provide global and sustainable solutions to environmental challenges and to the problems of preserving energy resources of fossil origin through the launch of an ambitious program for the development of renewable energies which was adopted by the Government in February 2011 and revised in May 2015 and February 2020.

• Algeria is embarking on a new sustainable energy era. The updated renewable energy program consists of installing power from renewable sources in the order of 16,000 MW by 2035, including 4,000 MW by 2024 for the national market, with the maintenance of the option of export as a strategic objective, if market conditions allow it.

• As part of the Government's decision of June 19, 2013 to launch a procedure for prospecting suppliers of photovoltaic equipment and EPCs intended for the realization of a total capacity of 400 MWp,

• Sonelgaz, through its subsidiary SKTM, has undertaken the construction of 20 photovoltaic power plants with a total capacity of 343 MWp in the highlands (East, Center and West), South and Great South spread over 14 wilayas.

In Table II.2 the power produced by

• Number of power plants installed: 21 Power Plants (21 PV Key).

• Installed Power: 344.1 MW (344.1 MWp PV).

• Energy Produced from the MES: 936 GWh (936 GWh PV).

Centrales	P. Installed (MWc)
Network RIN	
Oued Nechou PV (Ghardaia)	1,1
Sedret Leghzel (Naàma)	20
Oued El-Kebrit (Souk Ahras)	15
Ain Skhouna (Saida)	30
Ain El-Bel (Djelfa 1 et 2)	53
Lekhneg (Laghouat 1 et 2)	60
Telagh (Sidi Bel-Abbes)	12
Labiodh Sidi Chikh (El-Bayadh)	23
El Hdjira (Ouargla)	30
Ain El-Melh (M'sila)	20
Oued El-Ma (Batna)	02
Total SKTM (RE)	354,3

Table II. 2 : Power produced by solar/wind park (SKTM).

II.3.3 Wind Energy:

One of the most promising sources of renewable energy in Laghouat is wind power. The region's favorable topography, with its high plateaus and mountain ranges, creates ideal wind conditions for wind power generation. According to a study by the National Renewable Energy Laboratory (NREL), Laghouat has an annual average wind speed of 7.5 meters per second (m/s) at a height of 80 meters. This makes the region well-suited for large-scale wind power projects, which can be developed both onshore and offshore.

Laghouat's favorable wind conditions make wind energy a viable source of electricity production. Wind farms, equipped with wind turbines, harness the kinetic energy of the wind to generate electricity. Renewable Energy Development Center (CDER): The CDER is an Algerian research institution focused on renewable energy. While not specific to Laghouat, CDER is involved in renewable energy projects nationwide, including solar and wind energy research and development.

Laghouat may have wind farms that contribute to electricity production. Specific names of these wind farms would need to be obtained from local sources or authorities.

It's important to note that the energy landscape is subject to change and new initiatives may emerge.

• Number of power plants installed: 01 Power Plants (01 Wind Power Key).

• Installed Power: 10.2 MW (10.2 MWp Wind).

• Energy Produced from the MES: 82 GWh (82 GWh Wind).

Mentioned in **Table II.2.**

Centrales	**P. Installée (MWc)**
1- Réseau PIAT	
Éolienne Kaberténe	10,2
Adrar	20
Kaberténe	03
In Salah	05
Timimoune	09
Reggane	05
Zaouiat Kounta	06
Aoulef	02
2- Réseau RIS	
Tamanrasset	13
Djanet	03
Tindouf	09

Table II. 3 : Power produced by wind park (SKTM).

II.3.4 Hydro-power Energy:

Finally, Laghouat also has the potential for hydropower generation, although this source of energy is limited due to the region's arid climate and lack of significant water resources. However, there are several small-scale hydropower projects in the region that utilize natural springs and rivers to generate electricity.

We have here the technical sheet of the SEKLAFA dam construction project in the wilaya of Laghouat which demonstrate the limited but promising hydro-power source in Laghouat.

Location: the SEKLAFA dam is located on the M'Zi wadi, about 80km northwest of the town of Laghouat and 26km southeast of the town of Aflou.

Oued: M'Zi.

Municipality: Oued M'Zi.

Daira: Oued Moura.

Wilaya: Laghouat.

Irrigation : irrigation of 1,400 ha

DWS (AEP) : drinking water supply to 03 municipalities (oued m'zi, tajmout and ain madhi).

A) Technical characteristics :

A.1) SEKLAFA dam :

Hydrological data	
Catchment area	802 km^2
Design flood	466,00 m^3 /s
Design flood volume	14 ,5 Hm^3
The total capacity of the initial tank	42,1 Hm^3
Total capacity of the tank after raising the spillway by 1.5 m	48,8 Hm^3
Valley Bottom Score	994,0 NGA
Rating of the limit of use LU	1018,0 NGA
Standard retainer dimension RN	1032 NGA
Area of the water body at RN	4.2 km^2

Table II. 4 : Hydrological data of SEKLAFA dam.

Type of dam	Conventional concrete gravity dam
Ridge length	224,5 m
Width of crowning	06 m
Maximum height	47 m
Coronation Coast	1038 NGA
Spillway Spillway	WES type weir

Injection gallery	
Length	216 m
Cross section	1,80*2,7
Provisional diversion	
Maximum flow of the temporary diversion gallery	466 m^3/s
Inverted U-shaped diversion tunnel	
Width	6,0 m
Height	7,0 m

Table II. 5 : Technical information about the Skalafa dam.

Spillways	
Weir weir type WES	
Threshold length	40 m
Threshold rating	1032 NGA
Rectangular channel	
Length	52 ,5 m
Width	40 m
Height of walls	3 m
Slope	0,75/1: (H /V)
Hydrant	
Intake sluice	
Number	03
Levels of intake thresholds (AEP and irrigation)	1018,0 - 1023,0 -1027,0 m NGA

Bottom drain	
Max flow	25 ,5 m^3/s
Diameter	1,5 m
Length	52 m
Level at entry	1004,0 m NGA

Table II. 6 : Dimensional information about the Skalafa dam.

Watershed :

Total area 802 km^2

Contributions:

average annual input ……………………………………13 hm^3/year.

solid input over 50 years, including pumped input ……… 10 hm^3.

Flood discharges for a return period of :

10 years ……………………………………466 m^3/s

20 years ……………………………………594 m^3/s

50 years ……………………………………767 m^3/s

100 years …………………...……………899 m^3/s

500 years …………………...……………1218 m^3/s

1000 years ………………………………1357 m^3/s

10000 years ………………...……………1821 m^3/s.

Features of restraint :

Total capacity …………………………………..……42.1 hm³

Dead volume (after 50 years) ……………………..……10 hm³

Useful capacity considered (after 50 years) …………… 30 hm³

Normal reservoir level (NRN) …………….…………1032.0 m NGA

Minimum operating level (NME) ………………………1018.0 m NGA

Surface of the reservoir for the (NRN).…………………4.2 km²

Net evaporation …………………………………………1600 mm/year

Characteristics of the dam :

- Initial total capacity………………………………………………..42.1 hm³
- Initial total capacity after raising the spillway by 1.5 m…….……... 48.8 hm³
- Crowning elevation …………………..…………………………..…..1038 m NGA
- Maximum height above the foundation ……………………...……47.0 m
- Length of crowning ………………………...……….……………..224.5 m
- Crowning width ……………………………….…………….………..6.0 m
- slope of vertical facings upstream downstream ……………..………. 0.75:1 (H:V)

A.2) CHERGUI dam :

The Chergui dam is located about nine (09) km upstream of the Seklafa dam.

It transfers 3.1 hm3/year to the Seklafa dam through a reinforced concrete transfer channel.

Hydrological data :	
Catchment area	247 km^2
Design flood	507,00 m^3/s
Total capacity of the tank	0,5 Hm^3
Rating of the limit of use LU	1052,5 NGA
Standard tank dimension RN 1055.0 NGA	1055,0 NGA
Highest water mark PHE 1058.0 NGA	1058.0 NGA
Area of the water body at RN	0.6 km^2
The intake of CHERGUI	
Type of taking	Backfill-concrete (Mixed)
Height	15 m
Length	355(140 concrete part, 215 m backfill part)

Table II. 7 : Hydrological data about the CHERGUI dam.

Type:

Composite dam with a conventional concrete gravity section and an embankment section.

Location:

On the Chergui wadi, a tributary of the M'zi wadi on its left bank.

Watershed :

Total area 247 km^2

Contributions:

Average annual input 3.1 hm^3/year

Solid input over 50 years 3 hm^3

Flood discharges for a return period of:

10 years ……………………….…137 m³/s

10 years ……………………….…207 m³/s

20 years ……………………….…261 m³/s

50 years ……………………….…333 m³/s

100 years …………………....…388 m³/s

500 years …………………....…515 m³/s

1000 years ………………….…570 m³/s

10000 years ……………..….…753 m³/s

Characteristics of the wadi :

Bottom level ………………………1044.5 m NGA

Features of restraint :

Total capacity ………………………………………0.5 hm³

Dead volume (after 50 years) ………………………0.5 hm³

Useful capacity considered (after 50 years) ..………0 hm³

Normal reservoir level (NRN) …………………..…1055.0 m NGA

Minimum operating level (NME) ……………..……1052.5 m NGA

Surface of the reservoir for the NRN ………………0.6 km²

Net evaporation ………………………………..………1600 mm/year

Characteristics of the dam:

Concrete section:

- height of the coping (plus 1.0 m of wall) …..…1059.0 m NGA

- crowning width …………………..…………3.5 m

- maximum height above the foundation …..……15.0 m

- length of the coping …………...………………140 m

- slope of the facings ……………………………vertical upstream and downstream 0 .75:1 (H:V)

- volume of concrete ……………………………18,000 m³

Fill section

- Coping elevation …………………………1059.5 m NGA

- crowning width …………………………...6.0 m

- maximum height above the foundation …..15.0 m

- length of the coping ………………………215 m

- slope of the facings ……………………….2: (H:V) upstream and downstream

- volume of backfill ………………………...45,100 m³

Spillway

- peak flow (T=1000 years) ………………………………507.0 m³/s

- laminated throughput (design, T=1000 years) …………negligible lamination.

Spillway – weir type WES

- length of threshold 40 m

- elevation of the sill ..1055.0m

- design load 3.00m

- maximum hydraulic head (T=1000 years) 3.40m

- maximum level in the basin (T=1000 years) 1058.40m

USBR Type III Dissipation Basin:

- width 40.0m

- length 17.0m

- elevation of the side walls 1051.2 m

- elevation of the threshold 1041.6m

Bottom drain

- Maximum throughput ………….. 5.6 m^3/s

- Type …………………………….. constituted by a rectangular void in the concrete of the dam.

- Dimensions……………………….0.60×0.80 m2

- Length…………………………….8 m

- Entry level …………………….……1046.80 mNGA.

Transfer channel :

Type	Open air
Length	3,3 km
Slope	0,1%

Type I	1500 m (rectangular with 2.5 m width and 2.5 m height)
Type II	1500 m (trapezoidal with 2.5 m width and 2.0 m height and slope inclination 3:1(v:h))
Type III	300 m (trapezoidal with 2.5 m width and 1.5 m height and inclination of the embankments 1:2(v:h))
Desander	Length : 50,0 m Width : 8,25 m Depth : 7,45m
Transferred volume	3 hm^3 /an

Table II. 8 : Transfer channel in the CHERGUI dam.

II.4 Conclusion :

In conclusion of this chapter, Laghouat, a province in Algeria, has demonstrated significant potential for renewable energy development and has taken substantial steps towards harnessing its renewable resources. The province is rich in solar irradiation, making solar energy a particularly viable option for clean and sustainable power generation. Laghouat has seen the implementation of several solar projects, including the Laghouat Solar Power Plant, which has contributed to the province's renewable energy capacity and reduced its carbon footprint. Furthermore, Laghouat's geographical location offers favorable conditions for wind energy, and the province has recognized this potential by initiating wind farm projects, such as the Laghouat Wind Farm. These endeavors have not only contributed to diversifying Laghouat's energy mix but have also stimulated economic growth and job creation in the renewable energy sector. The commitment of local authorities and the support of the Algerian government have been instrumental in driving the renewable energy transition in Laghouat. However, challenges persist, such as the need for additional investments, enhanced grid infrastructure, and the adoption of energy storage technologies to ensure a reliable and efficient renewable energy system. Nevertheless, with its abundant renewable resources and the ongoing efforts to promote clean energy, Laghouat is poised to continue its journey towards a more sustainable and environmentally friendly future.

III Chapter Three : PV pumping system

III.1 Introduction :

Photovoltaic (PV) pumping systems have emerged as a sustainable and efficient solution for water pumping in various applications, ranging from agriculture to rural water supply. These systems utilize solar energy harnessed through photovoltaic panels to power pumps, eliminating the need for conventional electricity sources or fossil fuels. PV pumping systems offer numerous benefits, including reduced operational costs, environmental sustainability, and increased accessibility to water resources in remote areas. This introduction provides an overview of PV pumping systems, their components, working principles, and the advantages they bring to different sectors.

III.2 Generality on PV pumping system :

PV pumping systems consist of three key components: photovoltaic panels, a pump, and a power conditioning unit. The photovoltaic panels, also known as solar panels, are composed of solar cells that convert sunlight into direct current (DC) electricity. The power conditioning unit converts the DC electricity into the appropriate form for the pump, ensuring optimal operation. The pump, driven by the converted electrical energy, draws water from a source, such as a well or reservoir, and delivers it to the desired location .

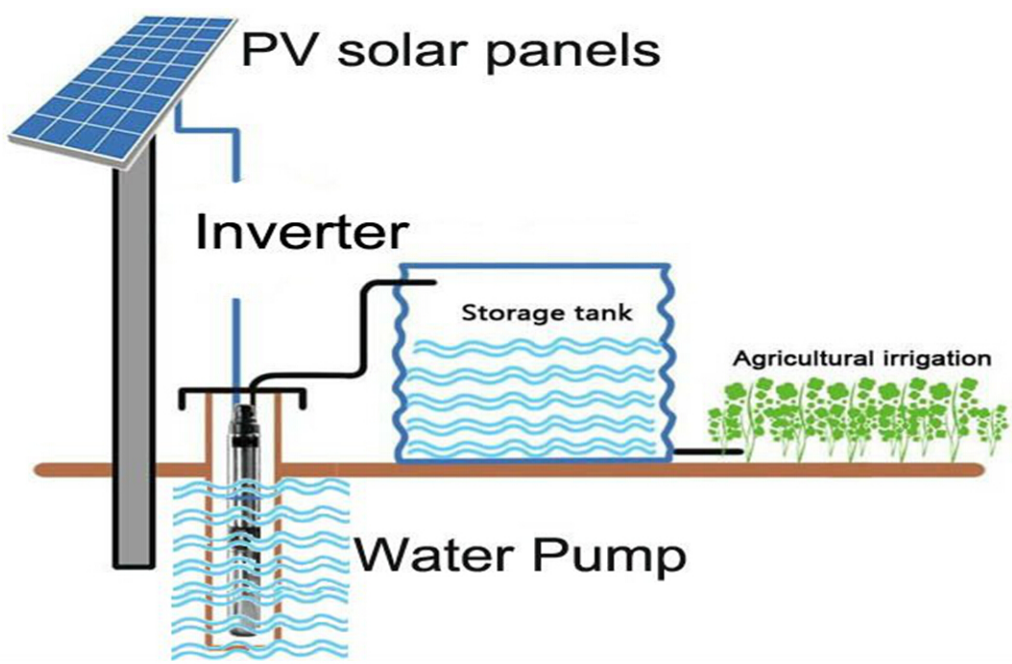

Figure III. 1 : PV pumping sytem.

III.2.1 Working principles :

The working principle of a PV pumping system is relatively straightforward. When sunlight falls on the photovoltaic panels, it generates an electric current due to the photovoltaic effect. This current is then directed to the power conditioning unit, where it undergoes conversion and adjustment to match the pump's power requirements. The converted electricity powers the pump, which subsequently draws water from the source and pumps it to the desired destination, such as irrigation fields or storage tanks. PV pumping systems can operate in both grid-connected and standalone configurations, depending on the specific requirements and availability of electricity infrastructure.

III.2.2 PV pumping system components :

PV pumping systems consist of several key components that work together to harness solar energy and pump water. The main components of a typical PV pumping system include:

Photovoltaic (PV) Panels: These panels, often referred to as solar panels, are composed of solar cells that convert sunlight into direct current (DC) electricity through the photovoltaic effect. PV panels are the primary component responsible for capturing solar energy **Fig III.2**.

Figure III. 2 : PV panel prototype in URAER.

Mounting Structure: PV panels are mounted on a structure, such as a rooftop or a ground-mounted rack, to ensure proper orientation and optimal exposure to sunlight. The mounting structure provides stability and support for the panels **Fig III.3**.

Figure III. 3 : Mounting structure for a PV panel in URAER.

Power Conditioning Unit (PCU): The PCU is an essential component that converts the DC electricity generated by the PV panels into the appropriate form for the pump. It adjusts the voltage and current levels to match the pump's requirements and ensures efficient operation **Fig III.4**.

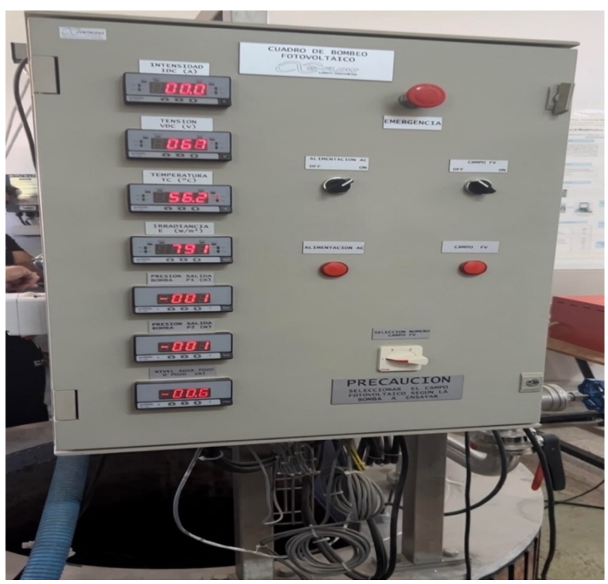

Figure III. 4 : Power Conditioning Unit (PCU) in URAER.

Pump: The pump is responsible for drawing water from a source, such as a well, river, or reservoir, and delivering it to the desired location. Depending on the application, different types of pumps may be used, such as centrifugal pumps **Fig III.5,** The sizing of a centrifugal pump involves three parameters which are flow rate, speed and height. This is increased by pressure drops and discharge pressure in the pipe. The centrifugal pump transmits the kinetic energy of the motor to the fluid by a rotational movement of paddle or vane wheels. The water that enters the center of the pump will be pushed outwards and upwards thanks to the centrifugal force of the blades.

Figure III. 5 : Submerged centrifugal pump.

Or the volumetric pump **Fig III.6** transmits the kinetic energy of the motor in back-and-forth motion allowing the fluid to overcome gravity by successive variations of a volume connected alternately to the suction port and the discharge port. A positive displacement pump always has a moving part in a hollow part that moves the liquid by varying the volume contained in the hollow part. The main interest of volumetric pumps is to be able to convey a fluid under very high pressures.

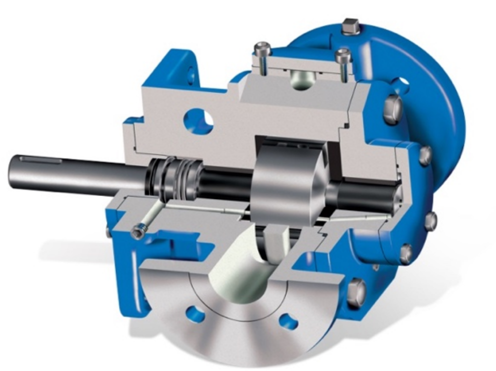

Figure III. 6 : Example of a positive displacement pump.

Water Storage and Distribution System: In some cases, a water storage tank **Fig III.1** or reservoir is incorporated into the system to store water for later use or to provide consistent water supply during periods of low solar energy availability. A distribution network, including pipes or irrigation systems, may also be integrated to transport water to specific locations.

Sensors and Controllers: To optimize the system's performance and ensure efficient water management, sensors and controllers may be employed. These devices monitor factors such as solar radiation, water levels, and pump operation, allowing for automated control and regulation of the system.

Electrical Wiring and Connections: The electrical wiring connects the PV panels, PCU, pump, sensors, and controllers, forming a complete electrical circuit. Proper wiring and connections ensure the efficient transfer of electricity and data throughout the system.

Optional Battery System: In certain PV pumping systems, a battery bank may be included to store excess electricity generated during peak solar conditions. The stored energy can then be used during periods of low sunlight or at night, ensuring continuous pump operation.

Each of these components plays a crucial role in the functionality and efficiency of a PV pumping system. By effectively utilizing solar energy, these systems offer a sustainable and cost-effective solution for water pumping needs in various applications, such as agriculture, livestock watering, irrigation, and rural water supply.

III.3 Configuration of a PV pumping system :

III.3.1 The photovoltaic generator :

Photovoltaic modules interconnected in a single electricity generation unit, mounted on various structures (support or frame, roofs and others).

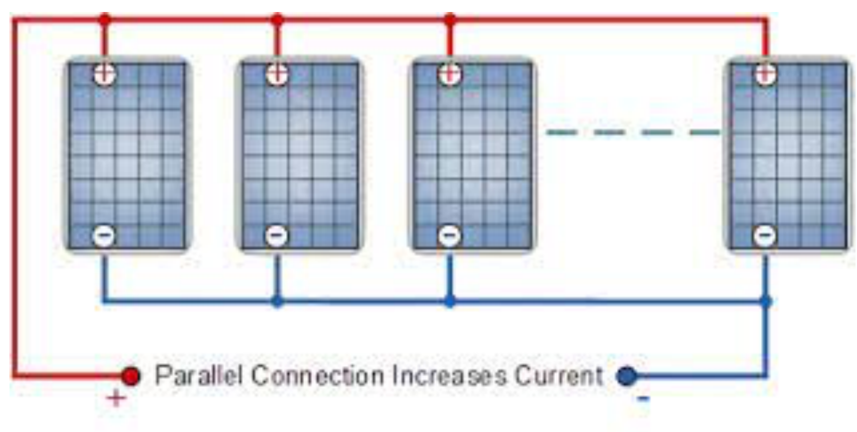

Figure III. 7 : Parallel connected PV panels

III.3.2 The motor pump unit:

The classification of pumps can be done according to different criteria: design of the pump, its position in the system and the type of motor used [56,63].

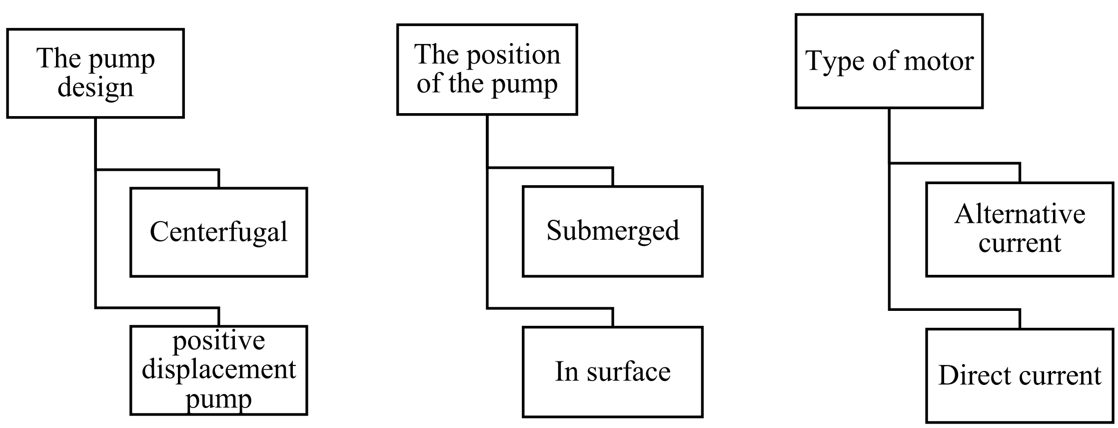

Figure III. 8 : Classification of pumps.

III.3.3 Voltage inverter :

The voltage inverter, also known as the power inverter, is a critical component of a PV pumping system that converts the direct current (DC) electricity generated by the photovoltaic (PV) panels into alternating current (AC) electricity.

In PV pumping systems, the voltage inverter adjusts the DC voltage from the PV panels to match the voltage requirements of the pump and the electrical grid, if applicable. It typically converts the low voltage DC power (such as 12V, 24V, or 48V) into a higher voltage AC power suitable for powering the pump.

The voltage output of the inverter should be selected based on the pump's voltage rating and the system's design parameters. It is important to ensure compatibility between the inverter's voltage output and the pump's requirements to ensure proper operation and efficiency. Common AC voltage outputs for PV pumping systems include 110V, 220V, 230V, or 380V, depending on the region and local electrical standards.

It is worth noting that in some cases, PV pumping systems may operate without an inverter if the pump can directly utilize the DC power from the PV panels. However, the use of an inverter allows for greater flexibility, as it enables the integration of AC-powered pumps and provides the ability to interface with the electrical grid or storage systems.

The selection of an appropriate voltage inverter should consider factors such as the pump's voltage requirements, the total power capacity needed, system efficiency, and any grid connection requirements [57,58].

III.4 Advantages of PV Pumping Systems :

PV pumping systems offer several advantages over conventional pumping solutions:

Renewable and Sustainable: Solar energy is a clean and renewable energy source, making PV pumping systems environmentally friendly and sustainable. They significantly reduce greenhouse gas emissions and dependence on fossil fuels.

Cost Efficiency: Once installed, PV pumping systems have lower operational and maintenance costs compared to conventional pumping systems. They do not require fuel or grid electricity, resulting in long-term cost savings.

Accessibility in Remote Areas: PV pumping systems provide a reliable water supply in remote or off-grid locations, where access to electricity infrastructure is limited. This enhances agricultural productivity, supports livestock farming, and improves access to clean drinking water in rural communities.

Scalability and Modularity: PV pumping systems can be easily scaled up or down to meet specific water demand requirements. Multiple systems can be installed in parallel or expanded gradually, allowing for flexibility and adaptability.

Reliability and Durability: PV pumping systems have fewer mechanical components, reducing the risk of failure and minimizing maintenance needs. Additionally, solar panels have a long lifespan and can withstand harsh weather conditions, ensuring reliable operation over an extended period.

III.5 Conclusion :

In this chapter we have seen generalities, components and configuration of the PV pumping systems that represent a sustainable and economically viable solution for water pumping in various sectors. The advantages of their utilization of solar energy reduces environmental impact, lowers operational costs, and improves water accessibility in remote areas. As technology advances and costs continue to decrease, PV pumping systems are becoming increasingly prevalent and offer significant potential for enhancing water management practices, agricultural productivity, and rural development worldwide.

IV Chapter Four : Sizing and Simulation of PV pumping system.

IV.1 Introduction :

Solar pumping is the pumping of water by solar powered pumps and this process is more economical due to low operating and maintenance costs and affects the environment less than internal combustion engine pumps. The pumps solar panels are not used in areas not connected to water or in short supply electricity from other sources (extended outage) and efficiency is not a practical solution to skin surface problems desert areas.

In this chapter, we apply a volume algorithm in a pumping system photovoltaic, to meet local needs in the region of laghouat.

IV.2 Water sizing :

IV.2.1 Hydraulic concept :

Flow: Flow (Q) is the amount of water the pump can deliver during an interval of given time. It is expressed in m3 /h, Lmin-1 or Lh-1.In solar pumping , the flow often expressed in m3/h.

IV.2.2 Total dynamic head (TDH) :

The general pressure drop depends on:

• The pressure drop is logically directly proportional to the length of the pipe: it increases when the pipe length increases.

• When the diameter decreases, the pressure drop increases considerably. The liquid has more difficulty flowing so friction increases for an identical flow rate.

• The higher the flow rate (higher speed), the greater the frictional forces for the same diameter.

IV.2.3 The total head gauge Hmt :

This is the difference in pressure in meters of water column between the suction and discharge ports. This height can be calculated as follows:

$Hmt = Hg + \Delta p$ [59]

With:

• Hg: Geometric height between the pumped water table (dynamic level) and the utilization plane (see Figure 3). It is calculated by the following formula: Hg = A + B + C [60]

• Δpc: Pressure losses produced by the friction of water on the walls of the pipes. They are expressed in meters of water and are a function of distance lines (D), their diameter and the pump capacity.

The calculation of the linear head loss, that corresponding to the general flow in a rectilinear duct, is given by the following this equation: ΔP=gΔH= LV2

• Δp: linear pressure loss in Pa,

• l: pressure loss coefficient (number without dimension),

• p:density of water in kg /m3,

• V: flow velocity in m/s,

• D: diameter Hydraulic tube in m,

• L: length of tube in m.

• Ns=C+B: The static level in a well or borehole is the distance between the ground and the pump before the water surface.

• Nd=C+B+A: The dynamic level of a well or borehole is the distance the soil and the surface of the water for pumping to a given flow rate. For the calculation of the HMT, the dynamic level is calculated for an average flow rate.

• Folding=Nd-Ns: The difference between the dynamic level and the static level.

• Maximum Drawdown: is the maximum acceptable drawdown before stopping the pump.

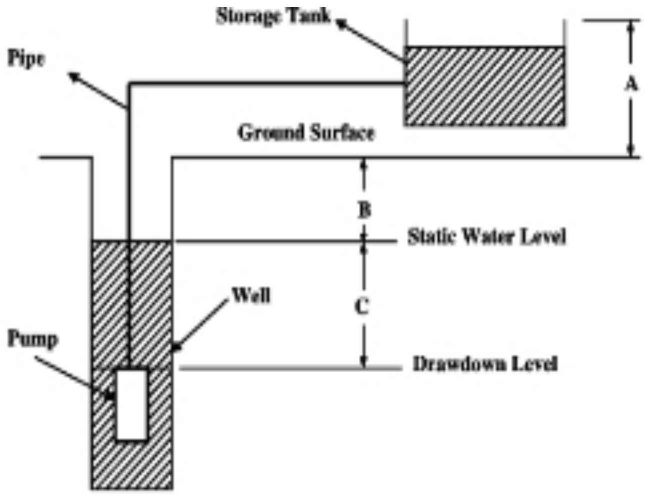

Figure VI. 1 : Static and total dynamic head.

VI.2.4 Determination of hydropower :

E hydraulic = Q x TDH x ρ x g / 3600 (J/kWh)

where:

- **Ehydraulic** = hydraulic energy in kWh
- **Q** = daily water output (m3/day)
- **TDH** = total dynamic pumping head (m)
- **ρ** = density of water = 1,000 kg/m3
- **g** = 9.8 kg.m/s2

VI.2.5 Calculation of daily electrical energy required:

The energy required to raise a certain quantity of water to a certain height during a given day is calculated from the following equation**:**

Ee= Eh/(ηmp·ηond) [61]

Where :

- Ee: Electric energy expressed in kWh/day,
- ηmp: The performance of the pump unit, generally between 30% and 60%,
- ηond: The inverter efficiency.

VI.2.6 Determination of available solar energy:

We called on the 'PV Gis' site to see the average daily values and monthly available solar irradiance and it gave us that the average solar energy annual is 197.03 KWh/m2. And for the month of December is 5.8 KWh/m2 [62].

VI.3 Analysis of needs and operating conditions :

The analysis of needs and operating conditions must make it possible to determine the power and type of pump chosen for the given situation.This chapter makes it possible to estimate in a practical way the parameters which will define the pumping system. All manufacturers have their own method to properly size their products. We will limit ourselves here to provide a general method which will make it possible to approximately dimension the elements of a pump in order to give an order of magnitude of these items and compare the costs. There are three technical parameters that delimit the evaluation of a solar pump. In order to obtain the most accurate evaluation possible, it is essential that these three parameters be estimated as accurately as possible.

These three parameters are:

1. the amount of water required per day,

2. the availability of water,

3. the solar resource.

VI.3.1 Estimation of water needs :

Drinking, cooking, washing and bathing are the main uses water for human needs. Animals also need water to their survival. The demand for water is also essential in the areas agriculture and industry, whatever their size.

- 1) Water requirements :

Humains

5 l/day	Survival
10 l/day	Minimum admissible
30 l/day	Normal life conditions in Africa

Animals

Beef 40 l/day

Cheep, Goat 5 l/day

Horse 40 l/day

Doncky 20 l/day

Camel 20 l/day (8 day reserve)

Hence the existence of three standards for calculating water needs:

- 2) the current objective of funding agencies: 20 l/day/person which does not include livestock and market gardening;
- 3) the minimum quantity necessary for economic development of 50 l/day/person, including:

– 20 l/day/person: for personal needs,

– 20 l/day/person: 0.5 head of cattle per person,

– 10 l/day/person: 2 m2 of market gardening per person.

VI.3.2 Water availability :

The concept of the amount of water required is sometimes not even valid because on many occasions the limiting factor will be the water production capacity of a well or borehole. In this case, the sizing of the solar pump will only take into account the availability of water and the justification for the installation of this pump must provide that not all potential users can be served.

The location of the photovoltaic pumping system will be determined by the location of the aquifer resource and the geography of the village. For domestic water, the aquifer resource will be the well or the borehole. For the irrigation of small market gardening areas, the aquifer resource will preferably be surface water (lake or river) in order to obtain a high flow rate. In order to minimize load losses, the solar generator will be installed as close as possible to the pump, in an open place, without shade.

In order to determine the availability of water in a well or borehole, it is necessary to obtain or measure the diameter of the well or borehole, its static level and the dynamic level at several flow rates during one day (8 hours). From information on the aquifer concerned, it is possible to estimate the maximum flow and drawdown conditions for the year. It is also necessary to obtain or measure the quality of the water in order to determine whether it is suitable for the required needs

VI.4 Sizing the photovoltaic system :

Although it is quite complex to predict the precise efficiency of a solar pump for varying operating conditions, here we suggest a simplified method that will allow the pumping system to be sized with an acceptable degree of accuracy. The three most important factors of this approach will have to be estimated carefully in order to obtain a satisfactory dimensioning. These are the water requirements, the sunshine data and the efficiency of the chosen motor pump unit over the operating range of the system.

To illustrate our point and guide the reader through the different sizing steps, we have prepared the following sizing sheets using the example of a solar pump installed in a village near Ouagadougou, Burkina Faso. The example uses a solar powered pump and an AC submersible pump unit. When the photovoltaic system uses a battery, the sizing must include

• Choose or define the load, i.e. determine the flow rate required and the TDH.

• Flow: determine the daily water needs during the period of maximum need. Note that the borehole must be capable of fulfilling these operating conditions;

• TDH: measure the static level, the maximum drawdown, the height of the tank and the head losses due to the piping.

• Stop system configuration (type of pump, motor, etc.).

• Choose the rated voltage at the generator output.

• Choose the type of electrical power conditioning needed and estimate its effectiveness.

• Adjust the load to optimize efficiency and convert it to amp-hours per day

Debit

Domestic water

Family	Nb/Fam	Litters/pers	Total (m^3)
50	10	20	10

Table VI. 1 : Load Analysis Example.

According to our sizing sheet, for a village of 50 families, the daily flow required will be 10 m^3 per day. The TDH of the station has been calculated at 43 meters. The pump will be used within the recommended height limits and the pipes will have a sufficient diameter to minimize losses due to friction.

Under these conditions, we have chosen, for our example, a submersible pump with an AC motor. This choice was determined by the curves provided by the manufacturer, showing that the efficiency of the chosen pump is close to 55%, and the efficiency of the AC motor is approximately

80% at the nominal operating point. The total efficiency of the motor pump unit (Rp) will therefore be 44%

Ee= Eh/(ηmp·ηond)= 2 663 watt-heures

Thus, the daily average load is 2663 watt-hours. At 100 volts (rated AC motor operating voltage), this equals 266 amp-hours per day.

hydropower	1171.75wh/day
daily electrical energy required	2663w
Number of solar modules in series:	5
Number of solar modules in parallel	1
Pump: SQF 2.5-2, 1 x 95027330 flow	1.6 m³/h
Avg. water production per day:	13 m³/day
Average water production per watt per day	26 l/Wp/day

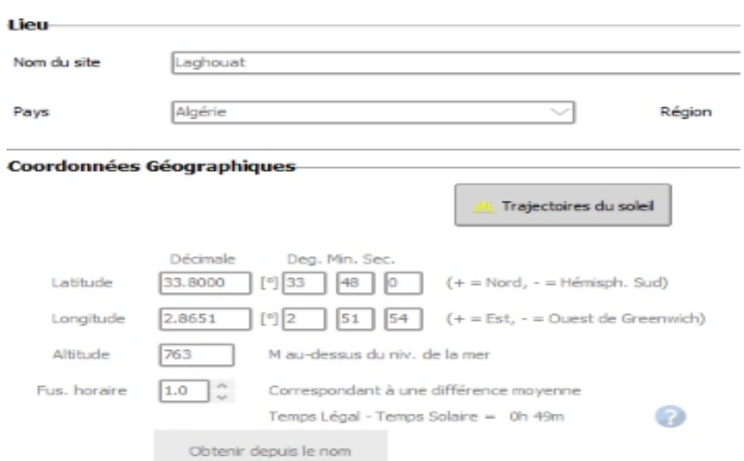

Table VI. 2 : Example of Site Condition Definition by PVsyst 7.3.

VI.4.1 Meteorological data :

The irradiation and temperature of the Laghouat site are summarized in these data. He is advised to precisely describe the source of the data. The PVsyst has Internet access to temperature and solar radiation statistics as well as tools to assess the PV performance for any location in Europe, Africa, and most of Asia.

Site Laghouat (Algeria)

Source des données Meteonorm 8.1 (1996-2015), Sat=100 %

	Irradiation globale horizontale	Irradiation diffuse horizontale	Température	Vitesse du vent	Turbidité Linke	Humidité relative
	kWh/m²/jour	kWh/m²/jour	°C	m/s	[-]	%
Janvier	3.24	1.00	6.0	3.70	2.589	71.9
Février	4.10	1.29	7.4	4.19	2.927	64.5
Mars	5.26	1.59	11.7	4.50	4.031	53.9
Avril	6.57	1.87	15.3	4.50	4.698	47.8
Mai	7.03	2.59	20.5	4.20	5.638	40.9
Juin	7.53	2.69	26.2	3.79	6.370	32.3
Juillet	7.51	2.59	30.9	3.70	7.000	26.1
Août	6.86	2.41	29.5	3.30	6.794	30.5
Septembre	5.62	1.90	23.4	3.30	5.835	44.6
Octobre	4.70	1.32	18.6	3.19	4.508	52.3
Novembre	3.67	0.91	10.7	3.40	3.233	67.7
Décembre	3.02	0.81	7.1	3.40	2.743	75.3
Année	**5.43**	**1.75**	**17.3**	**3.8**	**4.697**	**50.7**

Irradiation globale horizontale variabilité d'une année sur l'autre 3.4%

Table VI. 3 : irradiation and temperature data of the Laghouat by PVsyst 7.3.

VI.4.2 Path of the sun :

Any solar application requires knowledge of the apparent speed of the sun at a certain in right of the surface of the Earth. Two angles - its height HS (angle between the sun and the horizontal plane of the place) and its azimuth AZ - define the location of the sun (angle with the direction of the South, counted negatively towards the East).

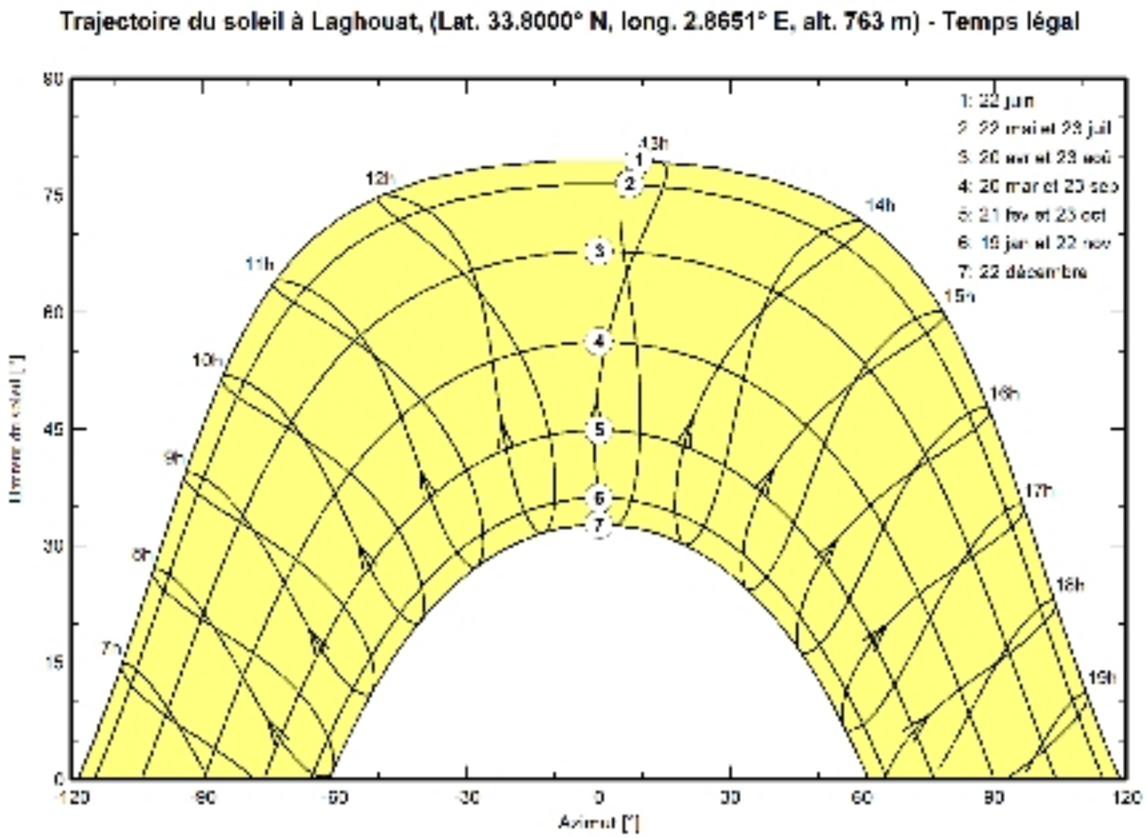

Figure VI. 2 : Path of the sun in laghouat

Inclination of the photovoltaic generator:

The optimal inclination β of the photovoltaic (PV) modules equals '33.3085°'

VI.5 Simulation :

VI.5.1 Results of sizing simulation:

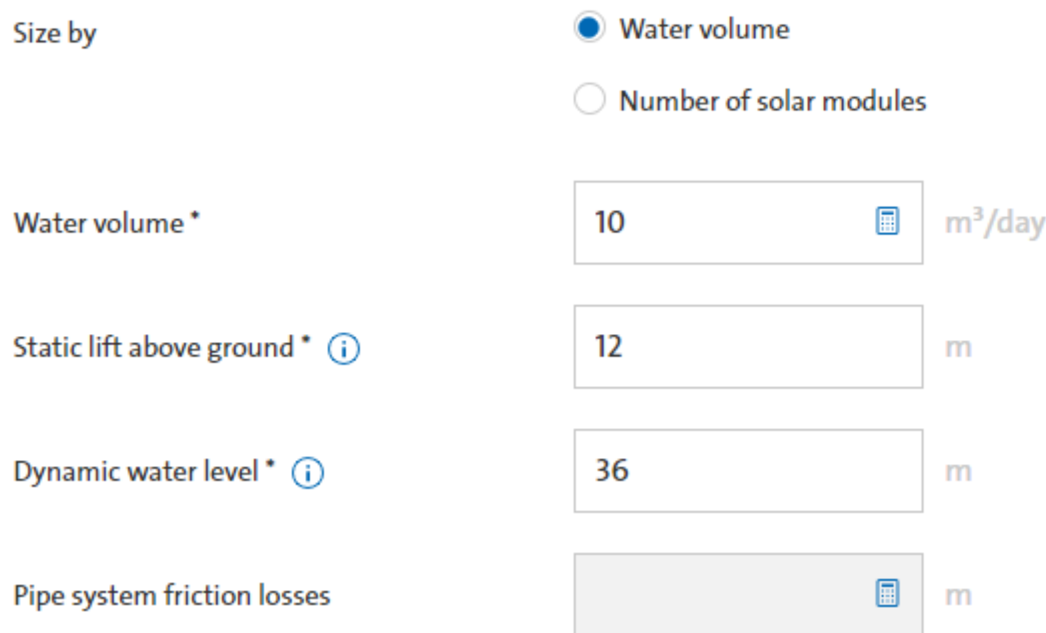

Figure VI. 3 : Data used for the simulation.

Qty.	Description
1	**CU 200**

Note! Product picture may differ from actual product

Product No.: 96625360
The CU 200 control unit is a combined status, control and communication unit especially developed for the SQFlex system. Furthermore, the CU 200 enables connection of a level switch.

The CU 200 incorporates cable entries for ...
-power supply connection,
-pump connection,
-earth connection,
-level switch connection.

Communication between the CU 200 and the pump takes place via the pump power supply cable. This is called mains borne signalling (or Power Line Communication), and this principle means that no extra cables between the CU 200 and the pump are required.
It is possible to start, stop and reset the pump by means of the on/off button.

The CU 200 control unit offers:
-System monitoring
-Alarm indication.

Figure VI. 4 : System supplies recommanded by Grundfos.

The following indications allow the operation of the pump to be monitore
-Water reservoir is full (level switch)
-Pump is running
-Input power.

The CU 200 offers the following alarm indications:
-Dry running
-Service needed in case of:
- no contact to pump
- overvoltage
- overtemperature
- overload.
-Insufficient energy supply.

In addition, the CU 200 shows the symbols of the energy supply option

Technical:	
Approvals:	CE,EAC,RCM
Installation:	
Range of ambient temperature:	-30 .. 50 °C
Relative humidity:	95 %
Electrical data:	
Power consumption:	5 W
Rated voltage ac:	1 x 90-240 V
Rated voltage dc:	30-300 V

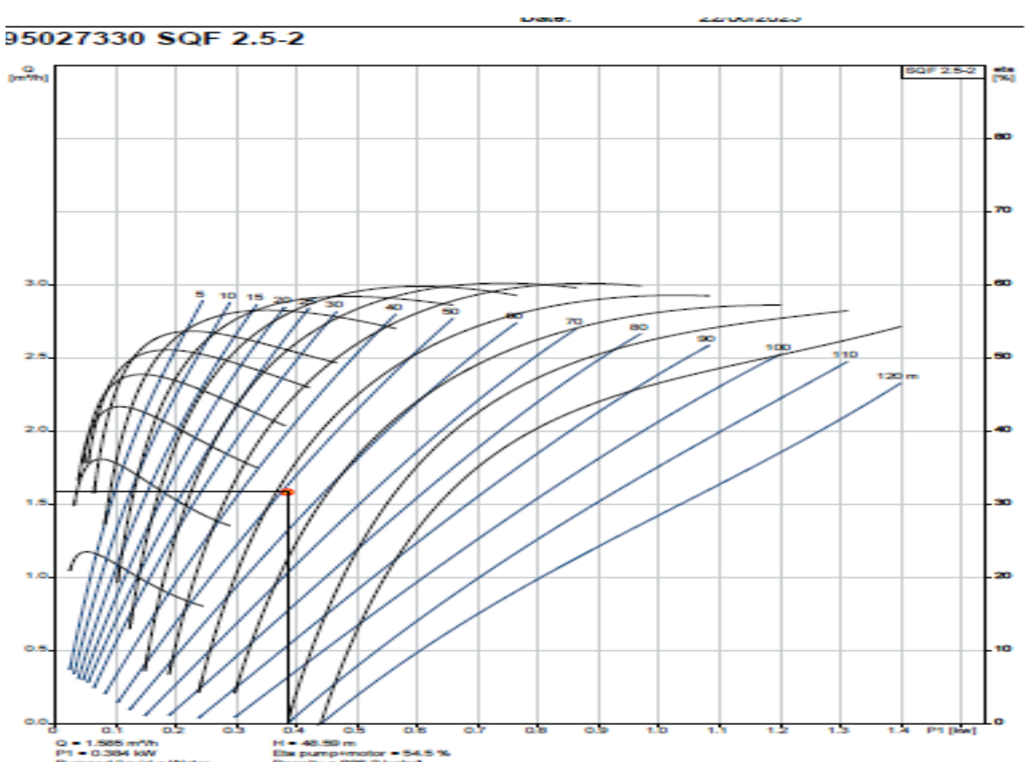

Figure VI. 5 : Pump output as function of power.

System performance - monthly average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water production [m³/day]	11.6	13	14	14.4	13.9	13.8	13.9	13.6	12.8	12	11.7	11.1
Energy production Solar [kWh/day]	3.0	3.4	3.7	3.7	3.6	3.6	3.6	3.5	3.4	3.1	3.1	2.8
Radiation horizontal [kWh/m² day]	3.8	5.0	6.4	7.5	8.2	8.6	8.5	7.6	6.4	5.1	4.1	3.5
Radiation tilt [kWh/m² day]	6.2	7.0	7.6	7.7	7.5	7.5	7.6	7.4	7.0	6.5	6.3	5.8
Avg. Temp. [°C]	7.0	9.4	13.6	17.3	22.7	28.0	31.1	30.5	25.6	19.5	12.4	8.3

Data location: Latitude: 33 DD, Longitude: 3 DD

Figure VI. 6 : Sizing result data.

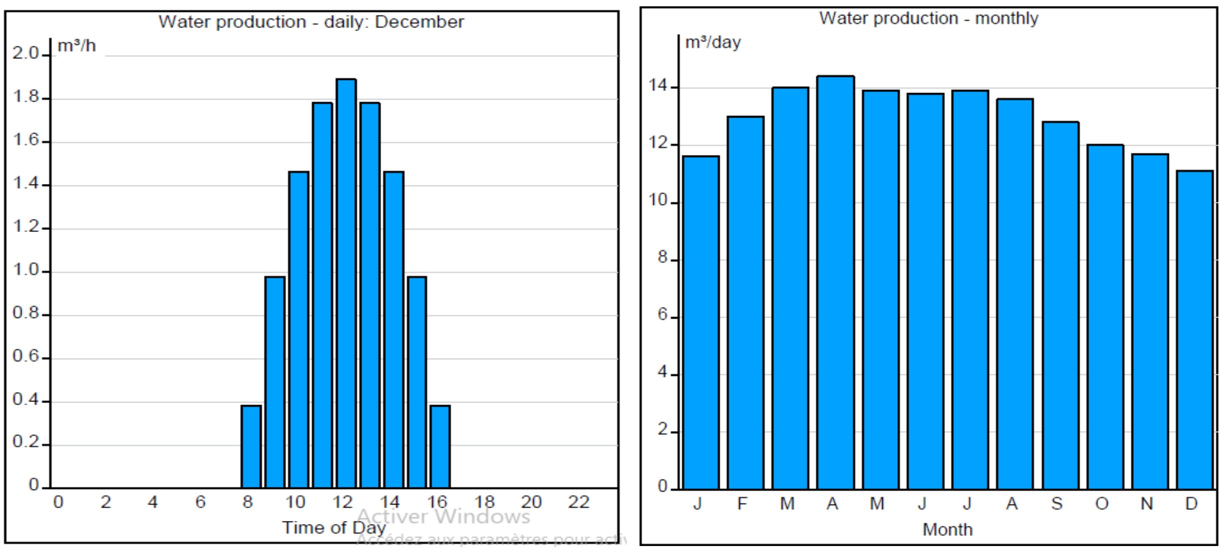

Figure VI. 7 : Sizing curve results.

Figure VI. 8 : Location of Laghouat (map by Grundfos).

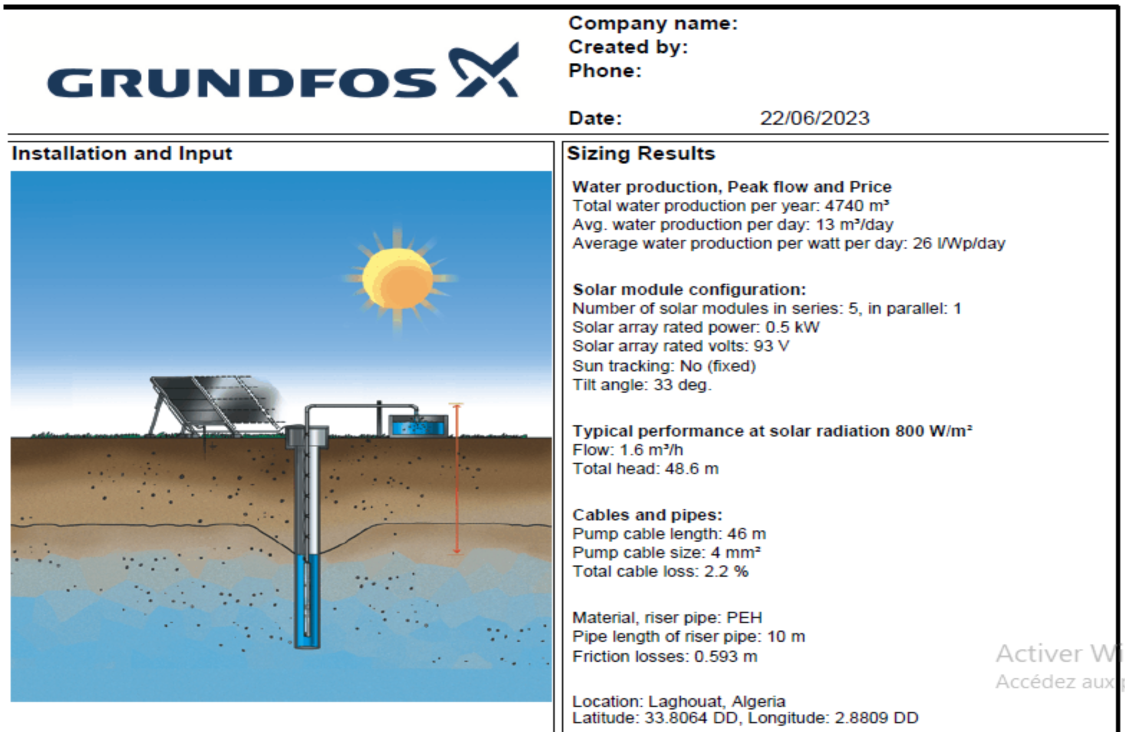

Figure VI. 9 : Installation of PV pumping system with sizing results.

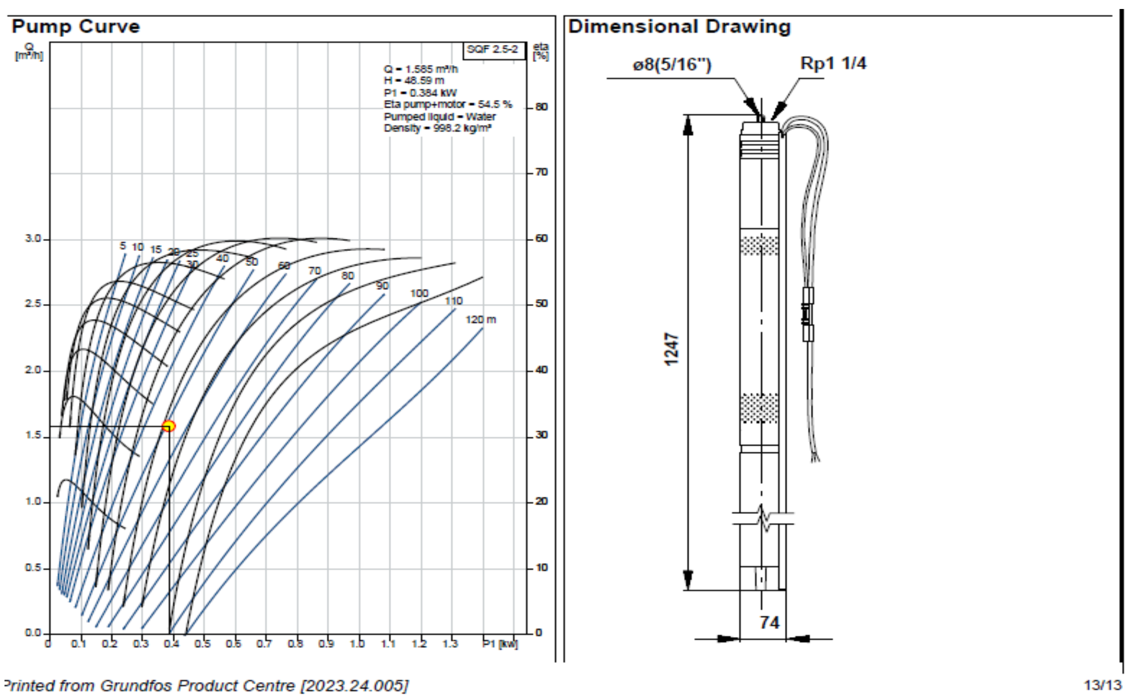

Figure VI. 10 : Pump and pump curve.

VI.5.2 Results of PV panel sizing :

GF 270

Note! Product picture may differ from actual product

Product No.: 99299012

The GF 270 is a polycrystalline solar module. The module is equipped with MC4 plugs for easy connection and comes as 30 pieces per pallet without individual packing.

It must be mounted on a support structure, tilted at an angle ensuring optimum utilization of the solar energy.

Installation:	
Range of ambient temperature:	-40 .. 85 °C
Electrical data:	
Maximum power point voltage:	31.6 V
Open circuit voltage:	38.4 V
Max power point current:	8.76 A
Module shortcut current:	9.11 A
Maximum power output:	270 W
Solar module type:	POLYCRYSTALLINE
Others:	
Brand:	Grundfos
Net weight:	18.3 kg
Shipping volume:	2 m³

Figure VI. 11 : Result of PV panel choice by Grundfos.

Grundfos GO Solar

Choose your pump and modules easily with the Grundfos GO Solar app and use one of the following three methods to size your solar installation. The app includes sizing data for our full line of renewable energy powered products

- PVsyst

PVsyst is designed to be used by architects, engineers and researchers, but it is also a very useful educational tool. It includes in-depth contextual help, which explains in detail the procedure and the models used and offers an ergonomic approach with a guide in the development of a project. PVsyst can import weather data from a dozen different sources as well as personal data.

VI.6 Conclusion :

In conclusion, the successful sizing of sizing a photovoltaic (PV) pumping system has provided valuable insights into designing an efficient and sustainable solution. By considering factors such as water demand, solar radiation, pump efficiency, and storage capacity, we have determined the optimal configuration for the system.

Through accurate measurements and thorough analysis, we have established the appropriate PV array size, pump capacity, and battery capacity to ensure a reliable water supply. The calculated values align with the specific requirements of the application, considering factors such as peak water demand, daily water consumption, and expected solar irradiation.

This successful sizing process has not only resulted in an appropriately designed system but also ensures optimal energy utilization and cost-effectiveness. The PV pumping system will harness the power of the sun to pump water efficiently, reducing reliance on fossil fuels and contributing to a sustainable future.

Overall, this successful calculation and sizing process lay the foundation for the implementation of an effective and reliable PV pumping system, empowering communities with access to clean water while minimizing environmental impact.

General conclusion

The Laghouat area possesses tremendous renewable energy (RE) potential, particularly in solar energy resources. The region's favorable climatic conditions, with ample sunlight throughout the year, make it an ideal location for harnessing solar power. Specifically, the implementation of photovoltaic (PV) pumping systems offers promising opportunities for sustainable energy generation and water management in the region.

The deployment of PV pumping systems in Laghouat holds numerous benefits and advantages. Firstly, solar energy is a clean and renewable source of power, contributing to reduced greenhouse gas emissions and environmental sustainability. By transitioning from conventional pumping systems that heavily rely on fossil fuels to solar-powered systems, Laghouat can significantly mitigate its carbon footprint and combat climate change.

Secondly, PV pumping systems provide a reliable and cost-effective solution for water supply in agricultural practices. Agriculture plays a vital role in Laghouat's economy, and access to a consistent and affordable water source is crucial for its success. By utilizing solar power for pumping water, farmers can reduce their dependence on expensive diesel generators or grid electricity, resulting in improved economic viability and increased productivity.

Moreover, the decentralized nature of PV pumping systems enables greater energy independence and resilience in remote areas where grid infrastructure is limited or unreliable. This decentralization promotes energy security and ensures that rural communities have access to reliable water resources for irrigation and livestock farming, even in the absence of a robust centralized power grid.

However, it is essential to acknowledge the challenges associated with implementing PV pumping systems in Laghouat. One significant obstacle is the initial investment costs, as PV systems require a significant upfront capital investment. Despite the decreasing costs of solar panels and associated equipment, the initial financial burden remains a barrier for many stakeholders. Addressing this challenge requires innovative financing mechanisms, such as government incentives, subsidies, and partnerships with financial institutions to make PV systems more affordable and accessible.

Maintenance and technical expertise are also crucial considerations. PV pumping systems require regular monitoring, maintenance, and troubleshooting to ensure optimal performance and longevity. The availability of skilled technicians and trained personnel is essential for the efficient operation and maintenance of these systems. Therefore, it is imperative to invest in capacity building programs and training initiatives to empower local communities and technicians with the necessary skills and knowledge to install, operate, and maintain PV pumping systems effectively.

In addition to the technical and financial aspects, proper water management practices and efficient irrigation techniques are crucial for maximizing the benefits of PV pumping systems. Sustainable water management practices, such as water conservation, precision irrigation, and crop selection based on local conditions, are integral to achieving long-term water security and minimizing water scarcity issues. Collaboration between agricultural stakeholders, water resource management agencies, and renewable energy developers is necessary to ensure the effective integration of PV pumping systems into Laghouat's agricultural landscape.

To unlock the full potential of renewable energy in Laghouat and promote the widespread adoption of PV pumping systems, supportive policies and regulations are essential. The government should create a conducive regulatory framework that encourages the development and deployment of renewable energy technologies. This can include feed-in tariffs, net metering policies, and streamlined permitting processes to facilitate the integration of PV systems. Additionally, providing financial incentives and subsidies can help offset the initial investment costs and encourage private sector participation in the renewable energy sector.

Thus, the Laghouat area possesses significant renewable energy potential, particularly in solar energy resources, which can be harnessed through the implementation of PV pumping systems. These systems offer a sustainable and cost-effective solution for water supply in agriculture, promote energy independence, and contribute to environmental sustainability. However, addressing the challenges associated with initial investment costs, maintenance requirements, technical expertise, and water management practices is crucial for the successful deployment of PV pumping systems in Laghouat. Through collaboration between various stakeholders, including the government, renewable energy developers, agricultural communities, and water management agencies, Laghouat can unlock its RE potential and pave the way for a sustainable and prosperous future.

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