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Challenges of green electricity generation in Algeria to achieve the 2030-target

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Dedication

I dedicate this humble work

to my dear mother who supported and encouraged me during my school years. To my dear father, may God have mercy on him, I wish you were by my side on this day.

To my brothers and sisters and all of my family.

To my relatives, my friends

, and to those who shared moments of emotion with me while doing this work and always encouraged me.

BOUKHALKHAL NACEUR

in the name of ALLAH, The most beneficent the most mereiful, as Imam ALI "raa" said who never thank people will never be thank.

I dedicale my research project to my family and friends, a special feeling of gratitude to my loving parents "MUM and DAD" whose repreisent the main factors of my success, to my brother and sisters.To my loving grandmother "mayma" for all her prayers for my success..

also I dedicate this research to my teachers and all whom guid me in my studies a special thank to BENHOUIA AMINE for all his efforts.

to the soul of my grandmother, grandfathers and to the soul of Nourddine guenane this work for you all .

MAAMAR RAHMANI

Thanks

First of all, we thank ALLAH Almighty for guiding me through all the years of study and giving me the will, the patience and the courage to complete this work.

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ملخص

تستكشف هذه الرسالة آفاق إمكانات الطاقة المتجددة في الاغواط ،الجزائر، وتحقيق التنمية المستدامة عن طريق مشاريع صديقة للبيئة وباستخدام تكنولوجيات جديدة في مجال الطاقات المتجددة (الطاقة الشمسية و طاقة الرياح) مع خضرنة القطاعات القائمة وتغيير أنماط الاستهلاك غير المستدام، تشتهر الاغواط بوفرة ضوء الشمس والطلب المتزايد على مصادر الطاقة المستدامة. تسخير إمكانات الطاقة المتجددة هذه لتقليل الاعتماد على الوقود األحفوري والاستدامة البيئية . يسلط هذا الملخص الضوء على فوائد الطاقة المتجددة في الاغواط ودورها لتقليل الاعتماد على الوقود األحفوري.

كلمات افتتاحية: الطاقة المتجددة ، الاغواط ، الجزائر، الطاقة الشمسية ، طاقة الرياح ، الوقود الاحفوري

Abstract :

in this work , we are talking about the increasing demand for energy day by day, with industrialization and the globalization of trade, especially with the spread of local equipment. This increase was mainly covered by the over-exploitation of fossil (non-renewable) energy sources. In the face of environmental requirements and the danger of depleting fossil fuels, the challenge is to find clean and renewable energy sources, such as solar, thermal and wind energy, and to find prospects commensurate with these energies.

The city of Laghouat had a share of the renewable energies programs, as the results of the studies confirmed the possibility of applying them on the ground due to its location and suitable climate, Laghouat is known for its abundant sunlight and growing demand for sustainable energy sources.

keyword : Energy renouvelable, Solar energy, energy thermique, wind energy, perception of energy

Nomenclature

CDER : Center for the Development of Renewable Energy

CST : Concentrating Solar thermal.

CSP : Concentrated solar power.

RE : Renewable energy

GHG : Green house Gas.

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

GW : Giga watt.

HTF : Heat Transfer Fluid.

CIA : Central Intelligence Agency.

IEA : International Energy Agency .

IMF : International Monetary Fund .

MW : MEGA Watt.

PV : Photovoltaic.

TES : Thermal energy sstorage.

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General Introduction

Nowadays the supply of electric power is increasing day by day and has become one of the most coveted drivers of the development of societies [1]. Industrial civilization was built around fossil fuels such as coal mining at the end of the 18th century, then oil in the middle of the 20th century. However, these forms of production generate strong environmental pollution through the release of greenhouse gases, which causes irreversible climate change [2]. From the oil crisis of 1973, the industrialized countries gradually opted for new and renewable energies (RE) [1].

There are several renewable energy resources: hydraulic energy, wind energy, solar thermal and photovoltaic energy, energy produced by waves and electricity.waves, geothermal energy and biomass [2]. In general, renewable energies are modes of energy production based on forces or resources whose stocks are unlimited. In particular, water from rivers turning the turbines of a hydroelectric dam ; the wind exerting a force on the blades of a wind turbine ; solar light exciting solar cells ; in addition to hot water from the bowels of the earth that supplies heating networks. In addition, these energy sources are little or not polluting. Solar, wind, water, etc. emit no pollution when they produce energy [1].

In this general context, our study focuses on solar, wind and thermal energy which are likely to be a relatively acceptable and inexhaustible source of energy for our environment. The sun is the first and main source of renewable energy. These rays are retained by glazed thermal sensors and are transformed to produce energy electric heater or for heating water intended for sanitary use. To be able to exploit solar energy, one can use either photovoltaic solar panels, or thermal solar panels [3]. As for wind energy, it is generated due to the pressure gradient resulting from the uneven heating of the earth's surface by the sun. As a very driving force that causes this motion, wind energy derived from the sun is basically an indirect form of solar energy; This means that the wind is driven by the temperature difference [4]. When we talk about wind energy, we are not talking about windmills, but about wind turbines. Which is under the power of the wind and which works to produce mechanical or electrical forces that are used to generate electricity that will be injected into the electrical installations of the house or in the distribution network.

Algeria has significant solar radiation given the values of the duration of sunshine recorded on almost all of the national territory exceeding 2000 hours annually and can even reach 3900 hours on the high plateaus and the Sahara [5]. Algeria is ranked 2nd country in Africa in terms of installed energy capacity renewable, said Monday, a statement from the Center for the Development of Renewable Energies (CDER). With reference to a report by the network of experts REN21 (Renewable Energy Policy Network for the 21st Century) [6], total power generation capacity globally, including hydropower, increased from 2,017 GW in 2016 to 2,195 GW in 2017. Faced with this, the state has set up two programs qualified as national priorities, the first concerns the application of energy efficiency measures, as for the second, it relates to the development of renewable energies which provides for the 2030 horizon of to install a capacity of 22,000 MW drawn up in 2011, and revised in 2015, which plans to install a capacity of 22,000 MW by 2030 [7]. This energy constitutes the major axis of the program which devotes an essential part to solar thermal and solar photovoltaic. Solar should reach by 2030 more than 37% of national electricity production. Despite a fairly low potential, the program does not exclude wind power, which constitutes the second axis of development and whose share should be around 3% of electricity production in 2030. This with the commitment of Algeria, within the framework of the Paris Agreement on the climate, to reduce greenhouse gas emissions by 7% with its own funds and 22% conditioned in international aid with the reinforcement of the capacities of use of renewable energies [8].

The objective of our dissertation is to present renewable energies, their positive and negative aspects, as well as the prospects for their applications. The work carried out in this thesis consists of five chapters and a final conclusion.

The first chapter highlights to conventional energy consumption rate (electricity and gas) for one year in terms of cost and environmental impact.

The second chapter deals with the study of the clean energy potential available over a year (calculation of the annual global sunshine + calculation of the wind resource.

As for the third chapter, it talks about the architectural nature of the infrastructure (Orientation, construction materials, building at one level or several).

Chapter Four focused on estimate daily energy needs through consumption (lighting of rooms, corridors and offices materials and equipment air conditioning domestic hot water heating).

Finally, the fifth chapter talk about horizons of renewable energy applications. We end our work with a general conclusion.

CHAPTRE I

The rate of conventional energy consumption (electricity and gas) for a year in terms of cost and environmental impact

Ⅰ. The rate of conventional energy consumption (electricity and gas) for a year in terms of cost and environmental impact :

Final and national consumption in Algeria is increasing from year to year in general, although there are differences on The level of the sectors, some of which increase from year to year, such as the transportation sector, while others decline, such as the construction and works sector Public and industry in general, and this is due to the arrival of development programs and plans in Algeria to an end, with Thus, Algeria remains among the least polluted countries with the emission of harmful and greenhouse gases compared to many countries in the world. Especially manufactured ones, due in part to the fact that they use energy generated by natural gas Which is one of the lowest environmental pollutants in the world. And Algeria must take into account during its consumption the nature of its energy wealth is depleted, which is This raises the need to pay attention to equality between generations, given Algeria's dependence on one natural resource, and this requires it It is necessary to develop a general financial policy that guarantees the preservation of the value of oil wealth and to use a conservative path to oil prices when calculating permanent wealth, evaluating current oil and gas reserves and replacing them with more alternatives Efficiency and non-permeable solar energy, for example. The completed projects in the field of clean energies are considered insufficient to meet the needs of the internal market. Algeria relies heavily on gas and its derivatives, due to its availability in large quantities and at low prices. It is also less polluting to the environment, and the percentage of supplying natural gas and its derivatives is 98% of the national production The net electricity, while the contribution of water energy in the production of electricity is estimated at only 2%. As for producing Electricity In general, Algeria has developed a strategy aimed at working to establish the necessary infrastructure To develop equipment and construct solar power generation stations using CSP collectors in order to replace demand Domestic solar energy and export in the future to ensure permanent income within the framework of sustainable development [9].

Π .Economic aspects:

Π. 1 National production:

Fifteenth world oil producer and third in Africa (behind Libya and Nigeria) and tenth producer of natural gas and second in Africa, Algeria, 60 years after its independence, Remain trapped in a rentier economy.

Thus, 97% of its foreign currency inflows come from the export of hydrocarbons. The country therefore depends today and more than ever, for its operation, on foreign countries: it is important almost everything, from manufactured goods to services, to the few derivatives of petroleum such as gasoline and diesel.

Table 01: Commercial primary energy production in Algeria [9].

Product	Units	2018	2019	Evolution Quantity	(%)
Natural gas	K Tep	92 106	85 380	-6 726	-7,3
	10^6 m^3	97 467	90 349		
Crude oil	K Tep	53 592	53 579	-213	-0,4
	K Tonnes	48 588	48 394		
Condensed	K Tep	9 990	9 226	-763	-7,6
	K Tonnes	8 825	8 151		
LPG in the fields	to Ter	9 343	9 186	-157	-1,7
	K Tonnes	7 918	7 785		
Primary electricity	to Ter	188	192	5	2,4
	GWh	783	835		
Solid fuels:	K Tep	22	10	-12	-53,5
Drink	$10^3 m^3$	113	53		
TOTAL	**K Tep**	**165 241**	**157 374**	**-7 867**	**-4,8**

The table talks about the value of production and consumption in Algeria in 2018-2019

II .2 Evaluation of the economic cost of energy in Algeria:

It is known theoretically and practically that any source of energy results in economic and financial costs And societal must be tolerated in order to enjoy the luxury of this energy, and there are many ways and indicators that can be applied to calculate this cost. Within this framework, we will calculate these indicators and the difference in cost between The international market and the national market, and what the society or the state bears in terms of the price difference or the support provided in this framework.

Table 02: National consumption by form of energy

Produit	Unités	2018	2019	Evolution Quantité	(%)
Gaz naturel	K Tep	24 982	25 947	965	3,9
	10^6 m^3	26 436	27 458		
Produits pétroliers	K Tep	16 105	16 730	625	3,9
	K tonnes	15 405	16 010		
Electricité	K Tep	18 337	18 714	377	2,1
	GWh	76 572	81 384		
GPL	K Tep	2 638	2 860	223	8,4
	K tonnes	2 235	2 424		
Pétrole brut*	K Tep	1 151	1 070	-81	-7,1
	K tonnes	1 044	970		
Condensat	K Tep	28	27	-1	-1,9
	K tonnes	24	24		
Produits solides dont :	K Tep	90	67	-23	-25,9
Coke Sidérurgique	K tec	97	80		
Bois	$10^3$$m^3$	113	56		
Autres:	K Tep	1 633	1 486	-147	-9,0
GNL**	10^6 m^3	267	295		
GHF	10^6 m^3	1 461	1 278		
Total	**K Tep**	**64 964**	**66 902**	**1 939**	**3,0**

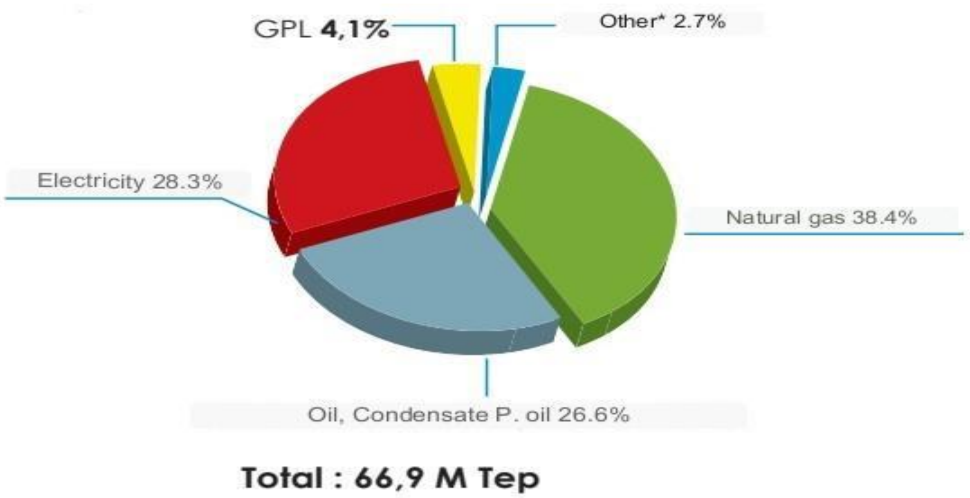


figure 01: Commercial primary energy production in Algeria [9].

III. Total energy indicators:

Energy efficiency is one of the important axes within the national energy policy Programs that aim to save energy and rationalize its consumption, in the sense of using less energy for the same The level of national production of goods and services. The calculation of energy efficiency indicators allows measuring the contribution of energy to the well-being of citizens on the one hand and Efficiency of energy conversion and consumption methods in order to provide the same service. We will also calculate some total energy indicators that allow to assist in making decisions appropriate in the field of the most efficient use of energy, and these indicators are represented in:

-Energy density.

-Final consumption ratio (CEF) compared to national consumption.

III.1 Calculate the energy intensity index:

The energy intensity index, which is the ratio of energy consumption to the gross domestic product It calculates the energy efficiency of an economy. In general, the lower the value of this indicator, the higher the efficiency Energetic. And we will calculate this indicator or this percentage based on the final consumption of energy in Algeria and not On the basis of national consumption (i.e. dimensions of consumption of the energy system, including liquefied petroleum gas units), This is in order to avoid making mistakes while making comparisons at the international level.

III.2 Individual energy consumption:

It is the amount of energy consumed by an individual, whether it is related to national or final consumption ,Calculated by dividing national or final consumption by population.

III.3 The nature of domestic production and consumption:

Algeria is considered among the richest countries rich in fossil energies, and its production and consumption pattern is characterized by excessive reliance on this type of energies, which constitutes one of the factors that may mitigate or discourage the determination and rush of officials towards turning to renewable energies for fear of negative effects on the system. The energy energy of the country and oil prices, this translates Algeria's tendency towards the exploitation of shale gas in the horizons of 2030 due to the huge reserves that it possesses and as an alternative to oil, and this is what maintains the dominance of the rentier sector over the country's economic system, so it is necessary to follow the policy of the principle of gradualism in the implementation of various programs related to energy exploitation and avoid haste under the pretext of keeping up with the status current

IV. Evaluation of the environmental cost of energy in Algeria:

The increase in energy consumption around the world is linked to the growth of the population on the one hand, and the search for levels of well-being Better for individuals on the other hand, and this continuous growth in energy needs leads to many problems, including: The depletion of countries' resources and the exacerbation of environmental pollution resulting from it, and even the harm to the health of members of society. Every source of consumed energy emits quantities of harmful gases and dust, the most important of which is in the atmosphere Carbon dioxide, sulfur dioxide and nitrogen dioxide, which lead to very serious effects on The atmosphere causes global warming, which melts the polar ice caps, which in turn raises sea levels and oceans, which results in the sinking of entire areas of the earth, and makes life difficult for humans on earth in a way Larger. Accordingly, we will try to work on determining the environmental and societal costs of energy consumption of all kinds Algeria, by addressing the emission of carbon dioxide and greenhouse gases in general, as well as the impact of Environmental pollution always affects the consumption of the ozone layer in Algeria, and we will try to link pollution levels consumption of various energy products.

V. National energy efficiency program:

The energy efficiency program follows Algeria's desire to promote more responsible use of energy and exploring all avenues to preserve the resources and systematize useful and optimal consumption. The objective of energy efficiency is to produce the same goods or services, but using as little energy as possible. This program includes actions which favor the use of the forms of energy best suited to the different uses and requiring the modification of behavior and the improvement of equipment. This program provides for the introduction of energy efficiency measures in the three sectors of construction, transport and industry and also the encouragement of creation of a local industry for the manufacture of high-performance lamps, water heaters solar panels, thermal insulators by encouraging local or foreign investment In summary, the implementation on the ground of the national efficiency program energy will gradually reduce the growth in energy demand. Thus, the accumulated energy savings would be around 93 million TEP, including 63 million TEP by 2030 and the rest beyond this horizon. That is to say the importance of this energy saving program which involves the implementation of a certain number of measures with, in particular, the involvement stakeholders, including public and private industry and the adaptation of the legal framework governing energy efficiency. By adopting the national renewable energy development program and energy efficiency and by updating it in 2015 Algeria confirms its choice of optimal development and diversification of its energy resources, and for the Environmental Protection.

VI. Prospects for the energy transition in Algeria:

Algeria has adopted an ambitious program in the field of developing renewable energies that guarantees promising prospects that, if successful, will enable it to achieve an estimated share of about 27% of the national revenue for electricity production from renewable energy, part of which is allocated to cover domestic consumption and the rest is directed to export, which will provide Algeria with an energy resource. It is important, in addition to achieving financial and economic abundance and creating job opportunities, which contributes to improving living conditions and raising the level of individual and gross national income. Renewable energies can be exploited to achieve energy security for the country and achieve sustainable development while preserving the cleanliness and integrity of the environment. So starting with studying and ending with achievement. For future projects, it was announced that the technology pole for renewable energies will be established in Ghardaïa. It will be completed by the Applied Research Unit in Renewable Energies of the Center for the Development of

Renewable Energies, with the support and supervision of the General Directorate of Scientific Research and Technological Development. The project includes four technological platforms represented in photovoltaic solar energy and It also includes a platform for achieving hydrogen from renewable sources and others for solar energy applications in agriculture.

VII. What is renewable energy?

crops, urban waste and industrial sources of biological incineration, biogas, biofuels, solar thermal, geothermal energy recovered in the form of heat or electricity, direct cold and heat pumps Renewable energies (RE): these are energies derived from processes natural in perpetual renewal. There are several forms of renewable energy, in particular the energy generated by the sun (photovoltaic or thermal), the wind (wind turbine), water from rivers and oceans (hydraulic, tidal, etc.), biomass, whether solid (wood and waste of biological origin), liquid (biofuels) or gaseous (biogas) as well as the heat of the earth (geothermal). Purely renewable energies electricity include hydro, wind, tidal, solar photovoltaic. Thermal renewables include firewood (collects or sells), wood residues and incinerated).

CHAPTRE II

Study of the clean energy potential available during a year

I. Study of the clean energy potential available during a year

I .1 Study of the clean energy potential :

There is an increasing demand for renewable electricity sources, due to the global efforts to reduce CO_2 emissions. Despite the promising effects, only a limited amount of electricity is currently produced globally from solar power. In order to help countries realize the importance of tapping into solar energy, it is crucial to reveal the potential amount of electricity that could be thus produced. For this reason, open data were used to produce an interactive web map of the global solar energy potential. For the calculation of the potential, generally used in the literature, was modified by introducing a better way of calculating rooftop areas, and accounting for temperature, which highly reduces PV panels' efficiency. Mean annual temperature data were introduced to improve its accuracy, and an approach to estimate rooftop and façade areas as a function of GDP was developed [10]. The current global solar potential technically available was estimated at about 613 PWh/y. Furthermore, the cost of photovoltaic generation was computed and extremely low values, 0.03 -0.2 $/kWh, were derived [11].

The demand for renewable sources of electricity is fast growing as a result of the global efforts to reduce CO_2 emissions. In particular, solar energy plays a promising role for both developed and developing countries and it is foreseen as the most promising renewable energy source due to its benefits [12, 13, 14]. First and foremost, solar energy is clean, since it can produce electricity without emitting greenhouse and toxic gases such as CO_2 and NO_x. Furthermore, it can have positive effects from an economic standpoint, not only because after the initial investment it reduces electricity bills, but also because the renewable energy sector has the potential to create new jobs. In addition, technologies exploiting solar energy are relatively easy to install on rooftops and therefore they can provide a way to produce clean electricity in rural locations [10]. In spite of the advantages of solar energy, the current global solar production is just a minor fraction of what is potentially available to develop, since solar energy covers only 0.05% of the total primary energy supply [10]. In order to change this, researchers need to provide policy makers with tools to easily assess the amount of electricity that can potentially be generated from solar energy by their countries, compared to what is currently generated and consumed. This requires a comprehensive estimation of the potential for each country to produce electricity from centralized and decentralized solar facilities.

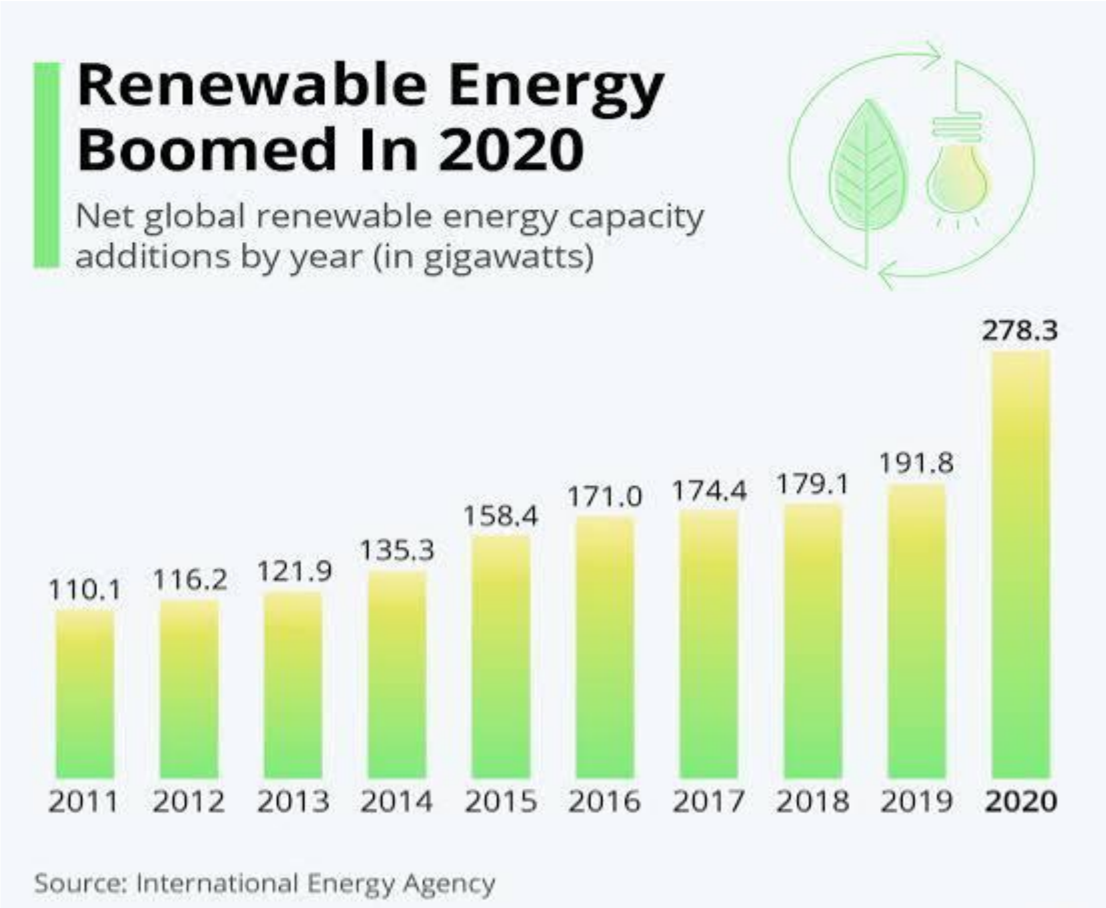


Fig 02 : Net global renewable energy capacity additions by year in GW (International Energy Agency., 2020).

I .1.1 Estimation of the Global Solar Energy Potential and Photovoltaic Corr with the use of Open Data :

Administration (EIA) for the year 2017, which is the most recent to provide full global coverage. This dataset refers to the total solar electricity production. i.c.. the sum of PV generation plus production from concentrated solar power plants, which produce energy transforming solar energy into heat and not through the photovoltaic effect. We also collected average annual electricity consumption data, for 2011, from various sources: namely EIA and the CIA (Central Intelligence Agency) World Factbook. For estimating rooftop and façade areas, GDP data for each country were collected from the International Monetary Fund (IMF) database for the year 2017.

Methodology Based on the World Energy Council Report there are four definitions for renewable energy potentials: Theoretical potential, Geographical potential. Technical potential, and Economic potential. In order to compute the global solar potential the approach referred to as top-down approach was followed. Starting from the global solar irradiance dataset, which represents the total amount of solar energy physically available on the earth's surface, the amount of exploitable energy was finally reduced according to environmental factors and technical limitations. Additionally, the cost for PV electricity generation was calculated. The results were computed at 1 km resolution and the total technical potential per country was obtained by summing the cell values inside each country's boundaries [11].

I .1.2 Geographical Potential :

Geographical potential is the solar irradiation incident to the fraction of the earth's surface suitable for the development of solar facilities. For the computation of geographical potential the equation of Hoogwijk [15, 11]. was used as a basis:

$$Gi=10^3.Ii.h.Aa.i \qquad (1)$$

where Gi (kWh/y) is the geographical potential of cell i,

Ii (W/m2) is the time-averaged irradiance in cell I (extracted from the NASA irradiation data), h (h/y) is the number of hours in a year, and Aa,i (km2) is the available area for PV installation in cell i.

Due to the solar irradiance dataset used for this research, Eq(1) had to be adapted as follows:

$$Gi = 365 . Ri . Aa.i \qquad (2)$$

where Ri (kWh/m2 per day) is the daily irradiance in cell i, while 365 denotes the number days in a year

The only unknown variable in Eq. (2) is the area, and for its calculation two slightly different approaches for centralized and decentralized systems were followed.alized and decentralized systems were followed [15, 11]

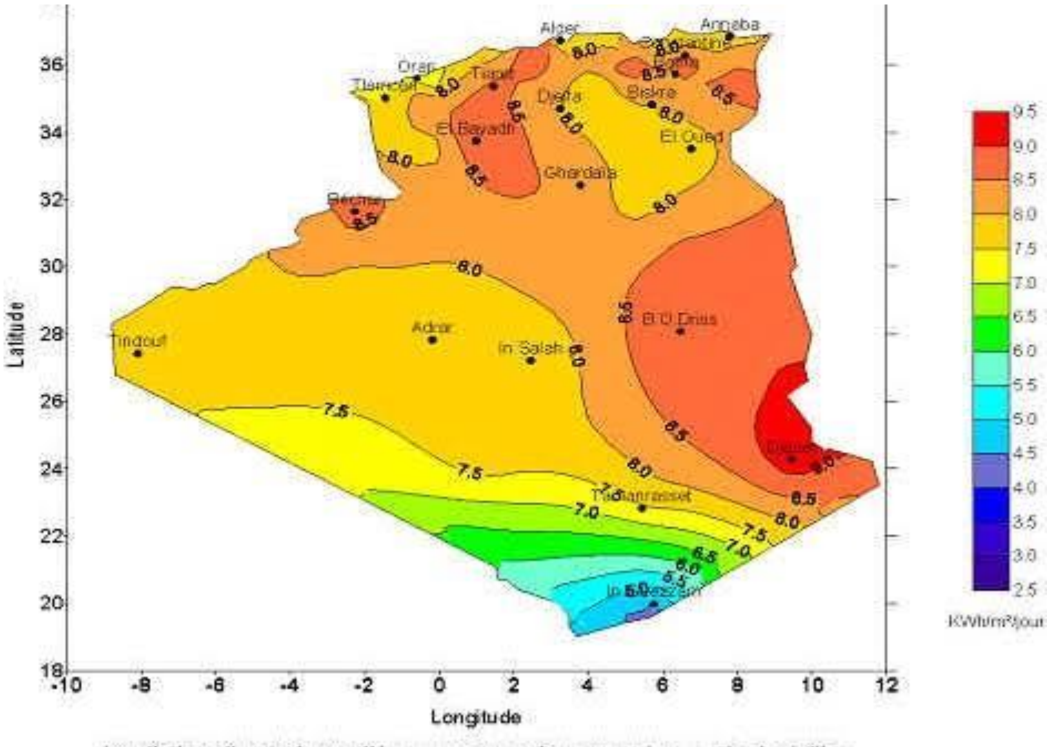


Fig 03 : Average daily global solar radiation in kwh/m² during the year

A picture showing the thermal areas, as the Algerian is dropping solar in it

I .2 Estimation of global solar radiation in Algeria for different types of sky

Knowledge of solar radiation is essential for the calculation of various performance of solar-related systems, such as solar water heaters, photovoltaic modules, but also for the construction of buildings in the perspective of better thermal insulation adapted to the geographical location and also for the heating of homes and premises with solar energy. The examples of use only increase over time. However, the development of these sectors cannot be done without in-depth knowledge of solar radiation.

This is why a radiation calculation program in EXCEL for the 48 wilayas of Algeria has been developed. Its purpose is to generate data calculated for the optimization of photovoltaic and thermal solar systems. It also shows that it is possible to persuade the instantaneous evolutions of diffuse, direct and global irradiations for different orientations and inclinations even if the sky has cloud disturbances [16].

I.2.1 Model of Liu & Jordan:

Liu and Jordan(1961) developed a theoretical method for deriving the mean hourly solar radiation from the mean daily total radiation, with the assumption that the atmospheric transmission is constant throughout the day, and this is independent of solar altitude [17].

[18], said that the generalized Liu & Jordan relation is given in the following form:

$$G = Sh \,.\, Rb + dh((1 + \cos(\beta))/2) + \rho\,(Sh + dh)((1 - \cos(\beta))/2) \quad (3)$$

The direct irradiation on an inclined plane is expressed by the following relationship

$$Si = Sb \,.\, Rb \quad (4)$$

Where, the inclination factor Rb of the direct radiation is:

$$Rb = (\cos(L - \beta) \,.\, \cos(\delta) \,.\, \cos(\omega) + \sin(L - \beta).\, \sin(\delta))/(\cos(L) \,.\, \cos(\delta) \,.\cos(\omega) + \sin(L) \,.\, \sin(\delta)) \quad (5)$$

With δ, the declination of the sun, o, the hour angle, L, the height of the sun and β the inclination of the plane.

The following expression represents diffuse irradiation on an inclined plane:

$$Di = dh((1 + \cos(\beta)/2) \quad (6)$$

On the other hand, the irradiation reflected on an inclined plane can be expressed by the following relationship:

$$Dre = \rho \,.\, (Sh+dh) \,.\, [1- \cos(\beta)/ 2] \quad (7)$$

I.2.2 THE ORETICAL APPROACH OF PERRIN DE BRICHAMBAUT

The atmospheric haze factor is used to calculate the direct and diffuses the irradiation received on a plane. Absorption and scattering caused by constituents of the atmosphere can be expressed by this factor [19, 20].

In this model, the atmospheric disturbance factor of Linke * TL under clear skies is

Given by the following relationship :

Estimation of global solar radiation in Algeria for different types of sky.

$$* TL = T0 + T1 + T2 \quad (8)$$

-To represents the cloudiness due to gaseous absorption, both by the fixed constituents of the atmosphere and by ozone and especially by water vapour. A modeling of this factor according to the only geo-astronomical parameters made it possible to propose the following expression:

$$Ahe = \sin((360/365).(j-121)) \quad (9)$$

$$To=24-0,9\sin(\varphi)+0.1(2+\sin(\varphi)) \times Ahe-0.2z -(1,22+0,14\ Ahe)(1-\sin(h)) \quad (10)$$

Where z is the altitude of the place, j the number of the day in the year, the latitude of the place and h the height of the sun.

T1 is the disorder corresponding to the absorption by gases in the atmosphere (O2, CO2 and O3) and the Rayleigh molecular scattering given by the approach :

$$T1 = 0,89 \quad (11)$$

T2 is the disorder relating to diffusion by aerosols coupled with a slight absorption (depending on both the nature and the quantity of the aerosols).

Depending on the Angstrom's haze coefficient β. T_2 is given by

$$T_2\ (0,9+0,4 \text{ x } Ahe) \times (0,63).z \quad (12)$$

The direct clear sky irradiation obtained on a horizontal plane is given by

$$I = In \cos(i) = I0\ .\ C\ t\text{-}s\ .\ \exp\ [-*\ TL\ (0,9+ 9,4 / 0,89z\ .\ \sin(h))^{-1}]\ .\ \cos(i). \quad (13)$$

-1 represents the solar constant which is, by definition, the energy flux received by a unit surface.

In our case, the value retained for the solar constant is 1367 W/m²

-C t-s is the earth-sun correction

The diffuse irradiation on a horizontal plane is given by the following expression:

$$D= I0\ \exp\ (-1+1,06 \text{ x } \log(\sin(h)))+a-\sqrt{a+b^2} \quad (14)$$

$$\text{Or} \quad a= 1,1 \quad (15)$$

$$b= \log(*\ TL-To)-2.8+1.02x(1-\sin(h))^{2} \quad (16)$$

The global irradiation received on a horizontal plane is represented by the following relationship:

$$G=1+D \quad (17)$$

Direct radiation :

The direct radiation received on a horizontal surface can be calculated by

$$S^* = I^* \sin(h) \quad (18)$$

Direct radiation on a plane perpendicular to solar radiation is calculated by the relationship :

$$I^* =1370\ \exp\ [-TL/0,9+9,4\ \sin(h)] \quad (19)$$

Where TL is Linke's turbidity factor :

$$TL=2,4+14,6\ \beta +0,4(1+2\beta)\ In(Pv) \tag{20}$$

Any plate :

For an orientation plate and any inclination:

$$S(i.\alpha) = I^{*}\ (\cos (h) \sin (i) \cos(a - a) + \sin (h) \cos (i) \tag{21}$$

- With i the angle made by the vertical of the locus and the normal of the plate.
- alpha: angle of orientation between the south and the projection of the normal of the plate on the horizon.
- a: azimuth.

Diffuse radiation :

$$D(i.\alpha) = DH\ .\ 1+\cos i/2 + 1-\cos i/2\ ab\ GH \tag{22}$$

With ab : coefficient of the albedo (fraction of the radiation returned by reflection and diffusion by a body)

• The universal mean

$$ab=0,2 \tag{23}$$

Sun tracking :

We also define the hour angle to by :

$$\omega =15° (TS-12) \tag{24}$$

The height h of the Sun can then be deduced from :

$$Sin(h)-sin(L)\ sin(\delta)+cos(L)cos(\delta)cos((\omega) \quad (25)$$

And the azimuth has by the relation :

$$Sin(a) = cos(\delta)\ sin(s)\ /cos(h) \quad (26)$$

β is the atmospheric cloudiness coefficient which can be taken as equal to:

β = 0,05 in rural area

β = 01 in urban area

β = 0,2 in an industrial or polluted area

Pv is the partial water vapor pressure expressed in mmHg.

Pv: saturated vapor pressure Pv=33 mm Hg.

Rayonnement solaire au sol

Solar radiation on the ground	Direct	S*	
	Diffuse	D*	G*S*+D*
	Global	G*	

$$ET= -[0,0002 -0,4797\ cos(\omega`j)+3,2265\ cos(2\ \omega\ `j)+0,0903\ cos(3\ \omega\ `j)$$

$$7,3509\ sin(\omega\ `j)+9,3912\ sin(2\ \omega\ `\ j)+0,3361\ sin(3\ \omega\ `\ j)\ ] \quad (27)$$

$$W` = 0,984.$$

II. Estimating global wind and turbine energy potential using open data :

Wind energy becomes today a promising option to complement the conventional energy source, especially in region where the existing power plants are not sufficient to match the increasing electricity demand. This success is principally due the rapid growth of the wind technology which led the wind power to be more competitive by reducing the cost of electricity produced. This prompted the Algerian government to adopt a new energy policy by promoting and to supporting the development of this clean energy. An important result of this policy is the government intention to construct a wind farm in the south west desert of Algeria.

The Algerian wind map, related to measured data at 10 m above ground level, established by Kasbadji-Merzouk, in 2006 [21], shows that a maximum of mean wind speed is reached in a South-West (Adrar region) of a country with a value of 6.5 m/s, (see Fig 4). In fact, Adrar is situated in the middle of the Algerian Sahara. The area of the Adrar district is about 427 968 km2. The inhabitant is concentrated at the main city of Adrar and population density has been estimated in January 2011 to 1.01 inh/km2 [22].

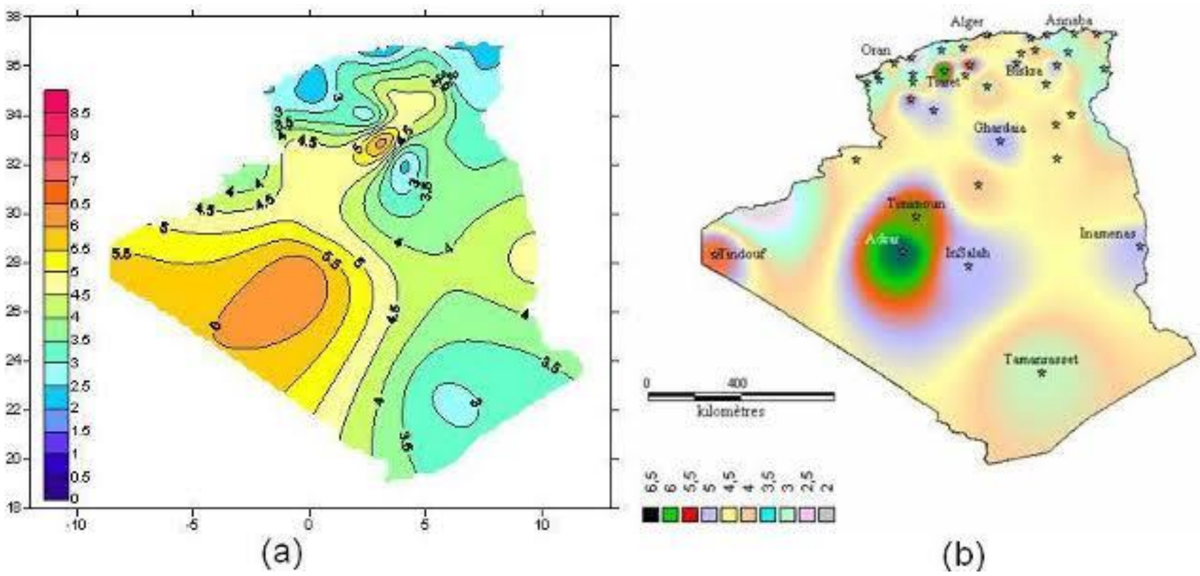


Fig 04 : the windiest regions in Algeria [3].

Table 03 : Energy produced annually by each wind engine.

Kaberten site results							
	Height, m a.g.l.	Scale factor, m/s	Shape factor	V m/s	P W/m²	Net AEP GWh	Wake loss [%]
Turbine1	250	10,2	2,69	9,08	687	8,519	0,01
Turbine 2	245	10,2	2,69	9,08	686	8,513	0,03
Turbine 3	249	10,2	2,69	9,07	686	8,508	0,03
Turbine 4	247	10,2	2,69	9,07	686	8,510	0,03
Turbine 5	248	10,2	2,69	9,07	686	8,508	0,01

(DJAMAI& Kasbadji Merzouk. 2011).

Table 04 : Monthly variations of mean wind speed and power density at the studied site [23].

Elevation	10 m		50 m	
Parameters	V(m/s)	P(W/m^2)	V(m/s)	P(W/m^2)
January	3.44	79.30	4.60	150.14
February	3.48	62.55	4.69	127.19
March	3.90	110.02	5.13	200.31
April	4.50	109.07	5.88	211.28
May	4.35	86.75	5.73	176.75
June	3.81	55.51	5.13	121.33
July	3.33	39.60	4.55	89.92
August	3.19	33.57	4.40	78.51
September	3.30	40.18	4.51	90.48
October	2.92	36.76	4.03	80.67
November	3.10	50.30	4.23	103.62
December	3.55	67.03	4.77	134.86

(Boudia & al., 2012).

It can be observed that the monthly mean wind speed at 10 m varies between 2.92m/s in October and a maximum value of 4.50 m/s in April, while at the eventual hub height (50 m) the monthly wind speed varies between 4.03 and 5.88 m/s. Furthermore, at 10 m, the mean power density varies between 33.57 W/m² in August and 109.07 W/m² in April.

Table 05 : Seasonal variations of mean wind speed and power density at the four stations .

Elevation	10 m		50 m	
Parameters	V(m/s)	$P(W/m^2)$	V(m/s)	$P(W/m^2)$
Autumn	3.16	47.20	4.31	99.72
Winter	3.61	81.05	4.81	155.57
Spring	4.25	89.04	5.61	178.31
Summer	3.28	37.89	4.49	86.54

(Boudia & al., 2012).

The seasonal Weibull wind distribution at 10 m for the studied and the seasonal variation of the mean wind speed and the mean power density at 10 and 50 m above the ground level are listed in Table 3. For the studied site, the minimum value of mean wind speed at 10 m is in Autumn season with 3,16 m/s ; while the maximum value of mean wind speed is in Spring season with 4,25 m/s. Furthermore the mean power density varies between 37,89 and 89,04 W/m² at 10 m and between 86,54 and 155,57 W/m² at 50 m.

II .1 The concept of wind energy:

In the energy generated from moving giant fans installed on poles in high places due to the air, and the electric energy is produced from the wind by the fans, which are like engines (or) (turbines), and in general they have three arms A rotary bearing on a pole that converts the kinetic energy of the wind into electrical energy. When the wind passes over the "blades" of the fans, it causes them to rotate, and this rotation operates the turbines and produces electrical energy. The amount of energy produced from the wind turbine depends on the wind speed and the diameter of the arm. Wind speed increases with height above the ground, and these turbines are placed in large numbers on large areas of land to produce the largest amount of electricity.

II .2 The importance of wind energy:

According to the report of the global status of renewable energy issued in July. Renewable Energy Policy Network for the 21st Century The most successful renewable energies following waterfall energy.

Wind energy is attributed to being currently the most mature in both respects technically and economically, as for the environmental aspect, one of the International Energy Agency's reports is entitled energy Technologies Insights, 2010 provides a comparison of the associated environmental impacts with the technologies of electricity production plants in different ways, it was found that wind power plants are the least in terms of carbon dioxide emissions, the main cause of global warming nuclear plants, then solar plants, then combined cycle plants operating with natural gas.

CHAPTRE III

Important renewable electricity generation in Algeria

I. Renewable electricity generation :

Energy resources are not evenly distributed across the globe and the global energy consumption is likely to grow faster than the increase in the population. The world will continue to depend on fossil fuels since over 80% of world's primary energy comes from fossil fuels which have detrimental impacts on the environment and produce the heat trapping green house gases (GHG) carbon dioxide as the products of combustion and methane as an inadvertent product of drilling, mining and transporting those fuels. The fuel consumption was growing from 6630 million tons of oil equivalent (Mtoe) in 1980 to almost double of the energy consumption which had reach 11,295 Mtoe in 2008 .World total energy supply in 2000 and 2009 is also estimated and shown in Table 06. According to the estimation done by the International Energy Agency (IEA), a 53% increase in global energy consumption is foreseen by 2030, energy security is becoming a serious issue as fossil fuels are non-RE and will deplete eventually in near future. In addition, the world's oil resources will peak within a fewdecades to come (80 years at the most), and in the search forother sustainable alternatives to mitigate some political, eco-nomic and environmental currently associated with the heavy reliance on fossil fuel, it is inevitable that the world is heading towards RE and new energy (hydrogen) economy by promoting clean energy technologies, pursuing energy efficiency and devel- oping RE forms which are three orders of magnitude larger thancurrent global energy use. Algeria is enjoying enormous potential of RE namely solar, wind, geothermal and biomass and hoping to increase its RE status by generating as much electricity from green sources as it currently produces from its natural gas power plants by 2020. Algeria has large potential for solar electricity production since it is located in the so-called Sunbelt . The government is planning to start a new RE developmentplan ,according to Algeria's Energy Minister who said, ''It's a huge program and a huge challenge. The governmentwill work alongside and assist operators in its implementation''.Although Algeria has begun a few initiatives to promotesustainable energy, generating as much energy from RE as itscurrent production of natural gas is a pipedream, some specificfactors place Algeria in a perfect position to take a leading role asa European energy supplier and future provider of clean energy.The population distribution in Algeria also shows that there is agreat potential market for RE, among which solar energy shouldbe highlighted because of its homogeneous presence throughoutthe entire region

.Moreover,economic,development,and,diversification, population growth, the huge hydrocarbon endowment, the vast potential forsolar energy could also drive the development and implementationof a regional vision for hydrogen economy.

Table 06: World total energy supply in 2000 and 2009.

Source	**Energy class (%)**	
	2000	**2009**
Fossil fuels	**86**	**66**
Renewable	**13**	**26**
Nuclear	**07**	**08**

I .1 Renewable electricity generation (low scale);

- **PV Solar energy :**

PV is an elegant means of producing electricity on site, directly from the sun without concern for fuel supply or environmental impact. Solar power is produced silently with minimum main-tenance, no pollution and no depletion of resources. One of the strengths of PV is to be found in its decentralised applications and cutting out the cost of transporting the energy. This is particularly true for supplying isolated consumers in areas of low population density, where the demand consists essentially in satisfying basic energy requirements (light, refrigeration, pumps, television and radio).

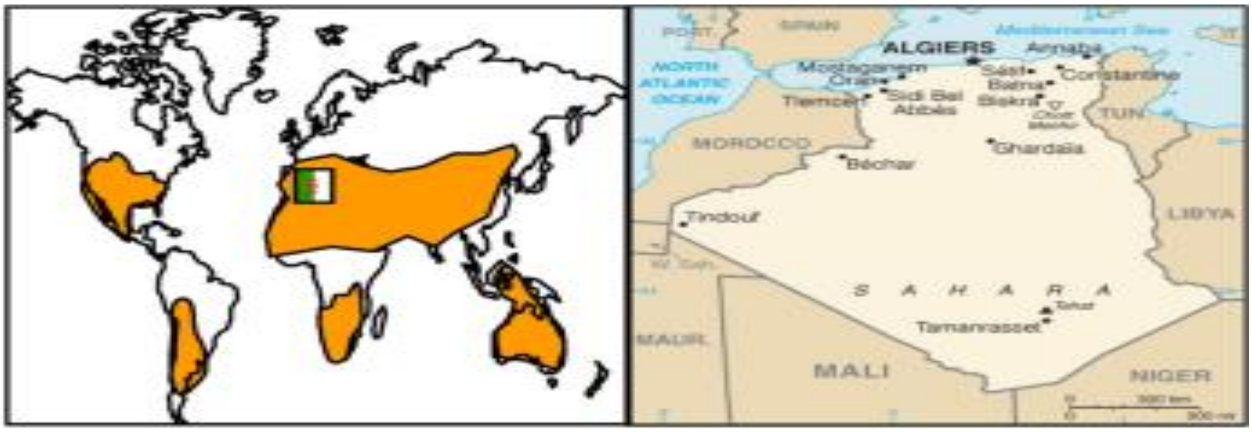


Fig 05: Solar suitable sites in the world and the Map of Algeria situated in the solar belt of the middle of the world [24]

I .2 Renewable electricity generation (large scale):

Technological advancements in large scale manufacturing and continued improvement of power converter technologies. In Algeria, the use of grid connected photovoltaic systems began in 2011, relatively very late compared to other countries. However, since the huge solar potential with more than 3000 sunny hours per year and 5 kWh/m2 received energy over the quasi-totality of the national territory (as shown in Fig 06), it was not surprising when the government announced a new program (2011/2030) in the renewable energy development strategy. The new target of the Algerian energy and environmental policy is to achieve a share of 40% of renewable energy (mostly from grid connected photovoltaic) in electricity supply by installing up to 22,000 MW of power generating capacity from renewable sources by 2030 (Fig 07). The first phase of the renewable energy program (2011/2013) was dedicated to pilot projects and testing available technologies. In the second phase (2014/2015) the program was revised according to the results of the pilot projects. The adopted renewable technologies by the government will be deployed on a large scale for the third phase of the program (2015/2020/2030) To meet this target, several centralized utility-scale grid connected PV stations are projected for the next decade.

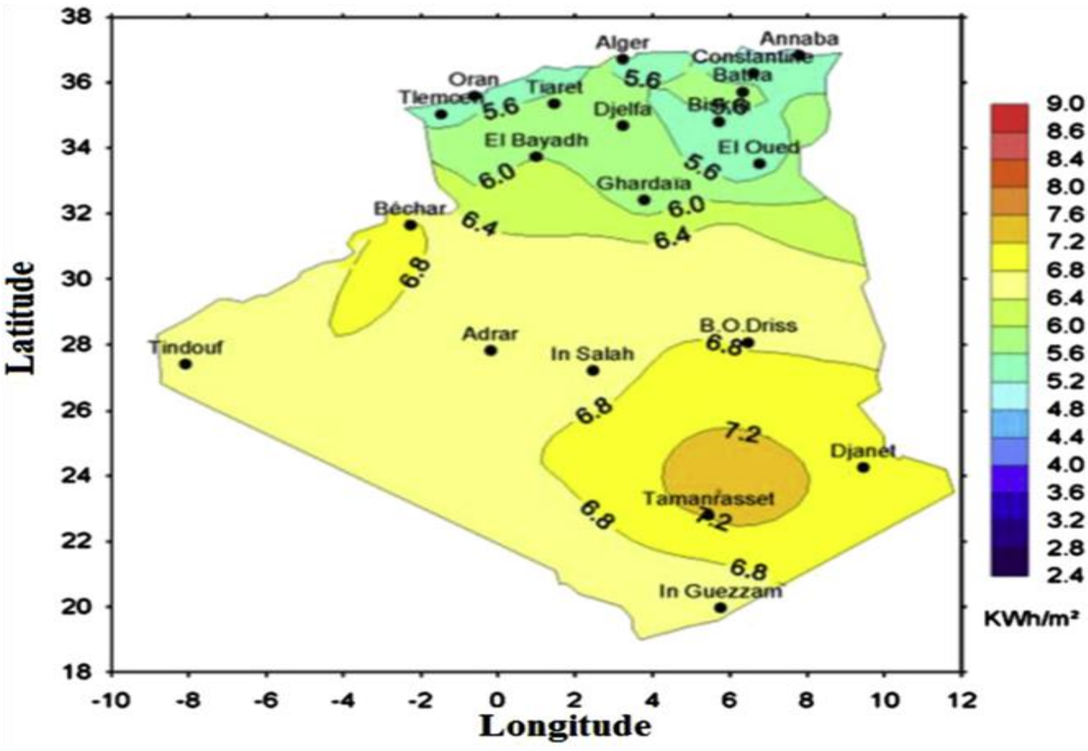


Fig 06: Global horizontal solar radiation in Algeria.

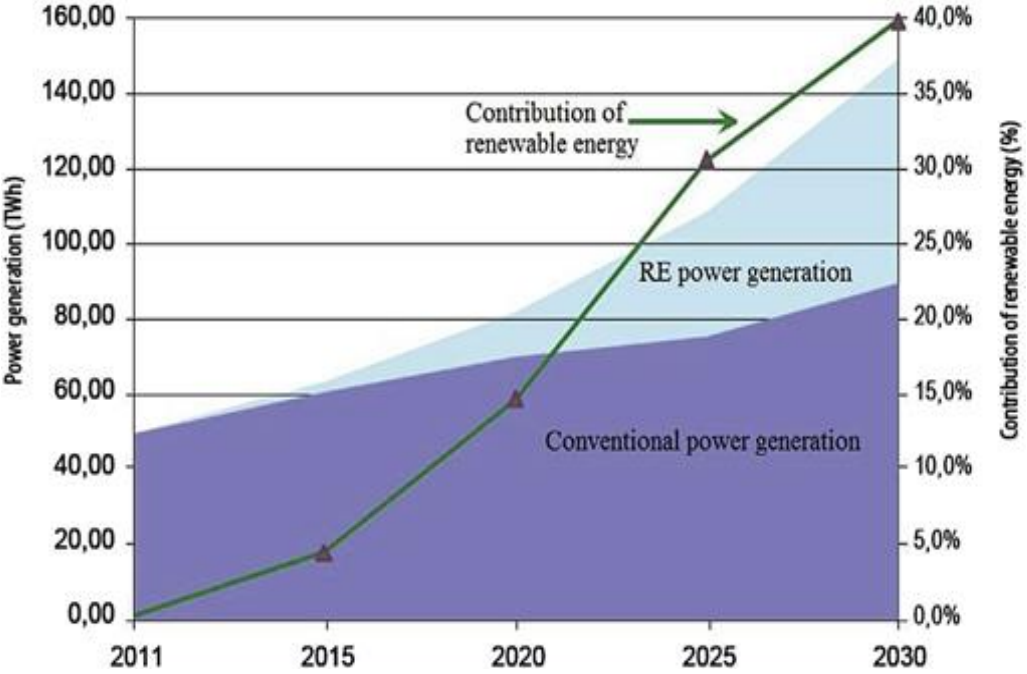


Fig 07 Electricity production and renewable energy share growth, outlook 2030.

I .3 The advantages and disadvantages of renewable energy

- **The Advantages of Renewable Energy :**

a) renewable energy is created from sources that naturally replenish themselves – such as sunlight, wind, water, biomass, and even geothermal (underground) heat.

b) Perhaps the most significant benefit of renewable energy is that there are no greenhouse gasses or other pollutants created during the process

c) Cleaner Air and Water

d) Renewable Energy Creates New Jobs.

- **The Disadvantages of Renewable Energy:**

a) Higher Capital Costs

b) Electricity Production Can Be Unreliable

c) Energy Storage Is a Challenge

d) It's Impacted by Environmental Conditions.

I.4 Renewable Energy Has Its Challenges but There's a Huge Upside:

Despite some existing limitations and challenges, it's clear that renewables will one day supply all of our homes, businesses, and vehicles with emission-free energy. And while it's unlikely that a single energy source will ever meet all of our needs, the combination of solar, wind, biomass, geothermal, hydro, and battery storage has the potential to power our entire world without creating any pollutants or greenhouse gasses.

I.5 The cost of renewable electricity generation installations:

Table 07 :COE and Operating cost of a wind power system installation [25].

Wind Farm	Operating Cost ($)	COE ($)
VESTAS	727,291.70	0.100
NEG MICON	803,231.60	0.098
NORDEX	761,932.40	0.093
POWER WIND	636,833.00	0.068

It is closely related to the countries achieving their energy security through the adoption of a policy of transition towards relying more on renewable energies instead of traditional energies, whose production requires greater effort more expensive, as investment in the field of renewable energies is characterized by being less expensive than its counterpart in energies fossils, and this is mainly due to the improvement and development of technology and technology used in the production of fossils. Renewable energy and its low cost, and would open the door to investment in renewable energies. The foreign investor, which provides the opportunity to obtain advanced technology in this field in addition to train human resources to control the exploitation of this technology, and to exploit renewable energie positive impact on the state budget and the national economy as a whole by saving energy and reducing the financial burden. The resulting exploitation also gives it a greater opportunity for export, all of this would help to achieve economic stability of the country and avoiding economic crises, or at least mitigating their consequences.

II Wind energy

Wind energy is one of the clean and promising energies most likely to replace fossil fuels. Technological advances have allowed competing with conventional energies regarding production costs. In this context, Algeria has developed an ambitious program to increase the share of renewable energy in the total energy production by 2030, in which wind energy takes second place after photovoltaics [9].

II.1 Énergie éolienne :

Wind energy comes from the kinetic energy of the wind. Indeed, if we consider a mass of air m which moves with the speed v, the kinetic energy of this mass is:

$$Ec = 0{,}5mV^2 \quad (28)$$

Ec : Kinetic energy (J(joul))

m : Mass (Kg)

V : Speed (m/s)

If this energy could be completely harvested using a device with area A, located perpendicular to the direction of the wind speed, then the instantaneous wind power would be:

$$Pe = 0{,}5\rho AV^3 \quad (29)$$

Pe : Useful power (watt)

ρ : Volumic mass (Kg/m^3)

A : section (m^2)

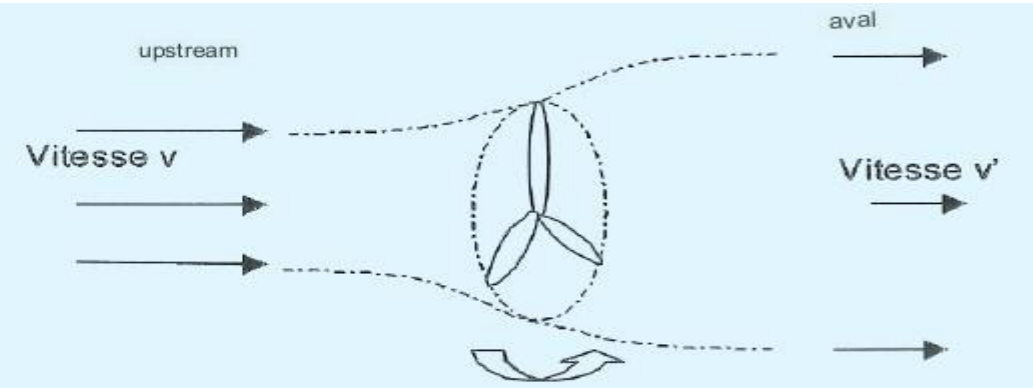


Fig 08 : Wind power [9].

II.2 The Wind Energy Sensor:

A wind system is nothing but the application of a process to capture wind energy and convert it into useful energy. The useful energy produced can be mechanical; in this case, the wind spins a wind turbine rotor which drives a mechanical device, such as a gearbox or a system of levers, which in turn drives a water pump. [9] Useful energy can also be electrical, as in the case of a wind turbine that runs a generator.

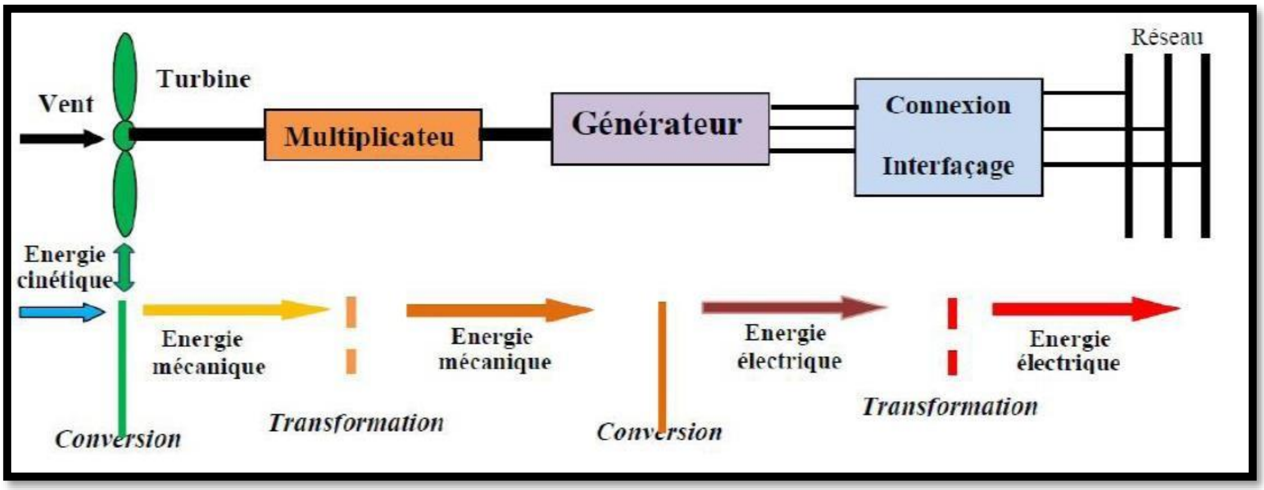


Fig 09 :Principle of energy conversion [9].

II.3 The different types of wind turbines:

Wind turbines are classified according to the geometric arrangement of the shaft on which the propeller is mounted. There are mainly two main families:

-Vertical axis wind turbines

- Horizontal axis wind turbines

- **Vertical axis wind turbines:**

Vertical-axis wind turbines were the first structures developed to produce electricity, paradoxically at odds with the traditional horizontal-axis windmill. They have the advantage of having the controls and the generator at ground level, so easily accessible. Many variations have been tested since the 1920s, many without success. But three structures have reached the stage of industrialization [26] :

a. The Rotor of Savonius.

b. The Darrieus Rotor.

c. The Musgrove rotor taking an 'H' shape.

Fig 10: Savonuis type wind turbine [9].

Fig 11: Darrieus type wind turbine [9].

- **Horizontal Axis Wind Turbines:**

Horizontal wind turbines can be built with two or three blades. The largely dominant technology today is the three-bladed turbine, sometimes two-bladed and with a rotor facing the wind. The turbine can be located at the front of the nacelle or at the rear: facing the wind (Upwind) or leeward (Downwind).

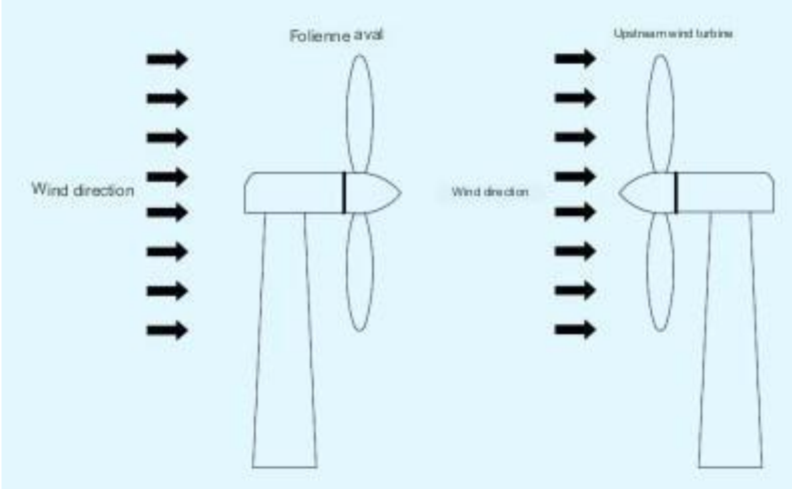


Fig 12 : Horizontal axis wind turbines [9].

It is currently observed that horizontal axis wind turbines are the most used compared to those with vertical axis since they are less expensive, as well as they are less exposed to mechanical stress.

- **Slow wind turbines:**

Slow-running wind turbines are equipped with a large number of blades (between 20 and 40), their high inertia generally imposes a diameter limitation of around 8 m. Their power coefficient quickly reaches its maximum value during the increase in speed but also decreases rapidly thereafter. These multi-blade wind turbines are especially suitable for low-speed winds. They start empty for winds of the order of 2 to 3 m/s and their starting torques are relatively strong. However, they are less efficient than fast wind turbines and are mainly used for pumping water.

- **Fast wind turbines:**

Fast wind turbines have a fairly small number of blades, which generally varies between 2 and 4 blades. They are the most used in the production of electricity because of their efficiency, their weight (less heavy compared to a slow wind turbine of the same power) and their high efficiency. However, they have the disadvantage of having difficulty starting. Their rotational speeds are much higher than for previous machines and are all the greater as the number of blades is low. Table proposes a classification of these turbines according to the power they deliver and the diameter of their propeller [9].

Table 08 :classification of wind turbines

Ladder	Propeller diameter	Power delivered
Small	Less than 12m	Less than 40kW
Mean	12 to 45 m	40 kW to 1 MW
Big	46m and more	1 MW

(Hammouche., 1990)

II.4 Stages in the implementation of a wind project:

The implementation of a wind project generally includes seven stages:

1. Selecting a site.

2. The project feasibility study.

3. The project implementation plan.

4. Project approval.

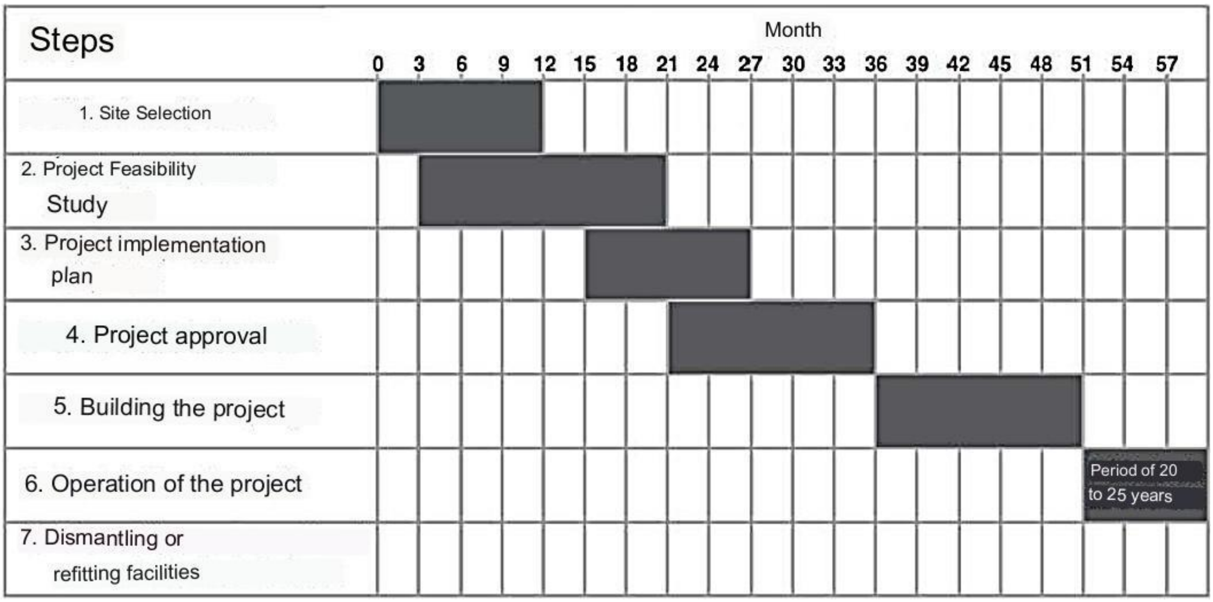
5. The construction of the project.

6. Operation of the project.

7. Dismantling or refitting facilities.

The first four steps are associated with the project planning process, a crucial phase of implementation. Three to six years are required between the pre-selection of a site and the commissioning of wind power equipment. The operating period will therefore only begin after this preparatory stage and will last 20 to 25 years. Subsequently, if the contracts are not renewed, provision will have to be made for the dismantling of the installations. The sequence of these steps is presented in the following table [9].

Table 09: The main steps in the realization of a wind project



II.5 Wind speed:

Wind pressure is given by the formula P = 0,00256 .V2

where V is the wind speed in meters per second. The unit of wind pressure is kg/m^2. For example, if the wind speed is 31,92 m/s, then the wind pressure is 0.00256 .31.922 = 2234,4 N/sq.

Wind speed is expressed in meters per second(m/s) or other units according to the following relationship: 1 m/s = 3,6 Km/h = 1,94 noeuds

Instruments used to measure wind speed are called anemometers. Wind speed is usually measured in noeuds (nautical miles per hour), but it is converted to meters per second in meteorological reports and research: 1 noeuds = 0,514 m/s = 1,852 km/h (1,688 f/s = 1,15 miles/h) [9].

CHAPTRE IV

Mathematical formulation of clean power systems

I . Modeling of the solar photovoltaic panel :

Photovoltaic solar energy is a non-polluting source of energy. Modular, its components lend themselves well to innovative and aesthetic use in architecture. Algeria's energy strategy is based on accelerating energy development solar. The government plans to launch several solar photovoltaic projects with a total capacity of approximately 800 MWp by 2020. Other projects with a capacity of 200MWp per year should be achieved over the period 2021-2030.

The modeling of a photovoltaic module necessarily involves a choice judicious equivalent electrical circuits. To develop an equivalent circuit. For develop an accurate equivalent circuit for a PV cell, it is necessary to understand the physical configuration of the elements of the cell as well as the electrical characteristics of each element [27]. The quasi-totality of the national territory exceeds 3000 h annually and may reach 3900 h in high plains and Sahara. With this huge quantity of sunshine per year, Algeria is one of the countries with the highest solar radiation levels in the world [24].

Solar electricity devices are often referred to as PV or concentrating solar power (CSP). PV is considered as one of the key technologies that are at the heart of the energy technology revolution because they can make the largest contributions to reducing greenhouse gas emissions [28].

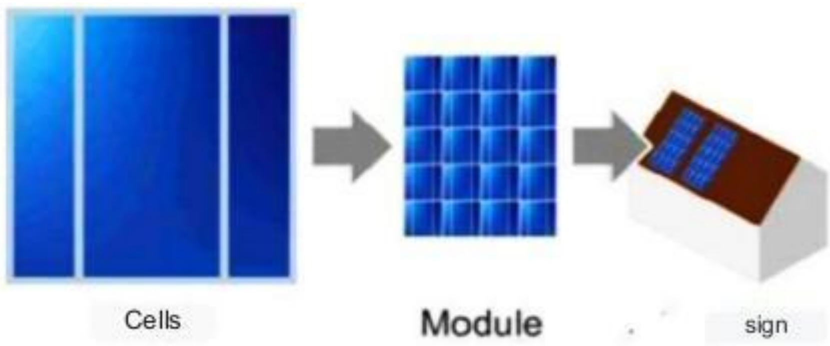


Fig 13 : photovoltaic modules [27].

I.1 Solar panel modeling:

To develop an accurate equivalent circuit for a PV cell, it is necessary to understand the physical configuration of the elements of the cell as well as the electrical characteristics of each element, taking more or less detail. According this philosophy, several mathematical models are developed to represent a strongly nonlinear behavior, resulting from that of semiconductor junctions which are the basis of their achievements. These models differ from each other by the mathematical procedures and the number of parameters involved in the calculation of the voltage and current of the photovoltaic module. Two models of the GPV will be presented:

- Single diode (or simple exponential) model.
- Two diode (or double exponential) model. [27].

I.1.1 Ideal model

The previous reflection allows us to arrive at the equivalent electrical model of the photovoltaic cell, called the ideal model. This is the simplest model for represent the solar cell, because it only takes into account the phenomenon of diffusion. The simplified equivalent circuit of a solar cell consists of a diode and a source current connected in parallel. The current source produces the current photon Iph which is directly proportional to the solar illumination G [29].

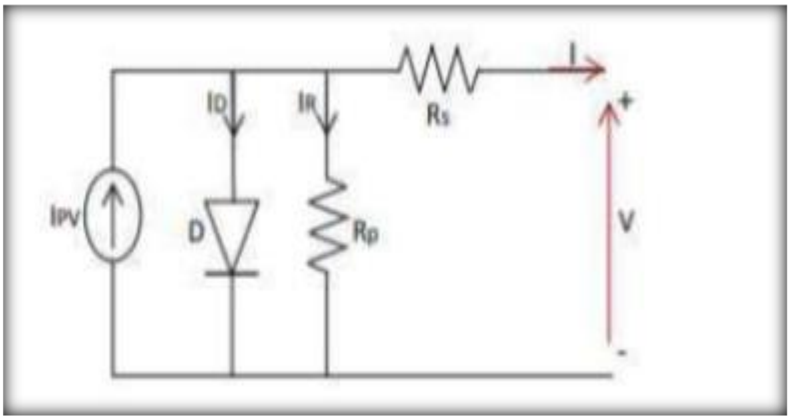


Fig 14 : Equivalent circuit of a PV cell – Ideal model.

The current voltage I-V equation of the equivalent circuit is given as follows :

$$I_D = I_S\left(e^{\frac{V_D}{nV_t}} - 1\right) \tag{30}$$

Or :

V_D : Difference in electric potential between the two ends of the diode.

I_s : Diode reverse saturation current.

n : Diode ideality factor.

V_t : Thermal tension as a function of temperature T given by the following equation :

$$V_t = \frac{K \times T}{Q} \qquad (31)$$

Or

k and q respectively represent the Boltzmann constant (1,3806503.10^{-23} J/K) and the electron charge (1,602176.10^{-19} [30])

So the eq

uation of the current delivered by a photovoltaic cell is described as follows:

$$I = I_{PV} - I_S\left(e^{\frac{V_D}{nV_t}} - 1\right) \qquad (32)$$

I.2 The parameters of a photovoltaic panel :

The essential parameters of a PV panel are quoted as follows :

a- The open circuit voltage

It is the voltage across the cell when it is not connected to a load. Her value decreases with temperature and changes little with irradiation. It is obtained when the cell current is zero [31].

b- The short-circuit current

The short-circuit current corresponds to the value of the current when the cell is in short circuit condition. The short-circuit current is very close to the photo-currentIpv.

c- The maximum power

$$\eta = \frac{P_{max}}{E.S} \qquad (33)$$

The maximum power delivered by a photovoltaic cell corresponds to the maximum of the product of the maximum voltage applied and the maximum current measured at the cell terminals The maximum power measured under reference conditions (STC: Standard Test

Condition), i.e. under sunshine of 1000 W/m² and at a temperature of 25°C

d- Yield the energy efficiency of a cell

is defined as the ratio between the maximum generated power and the power of the solar radiation, which arrives on the photovoltaic cell [32].

Or

η: Energy efficiency.

E : Illuminance (W/m²).

S: Active area of the cell (m²).

P_{max} : Maximum power(W).

e- The spectral response of the PV cell

The spectral response is one of the characterization methods used for the determination of the device parameters during the research and development stage and during the production of solar cells. The spectral current distribution is sensitive to the variation of solar spectra.

f- The form factor

it represents the ratio between the maximum power that can deliver the noted cell $\boldsymbol{Pmax}$ and the power formed by the rectangle Icc . Vco

This factor is defined by the following relationship:

$$FF = \frac{P_{max}}{I_{CC}.V_{CO}} \qquad (34)$$

$\boldsymbol{P_{max}}$: Maximum power(W).

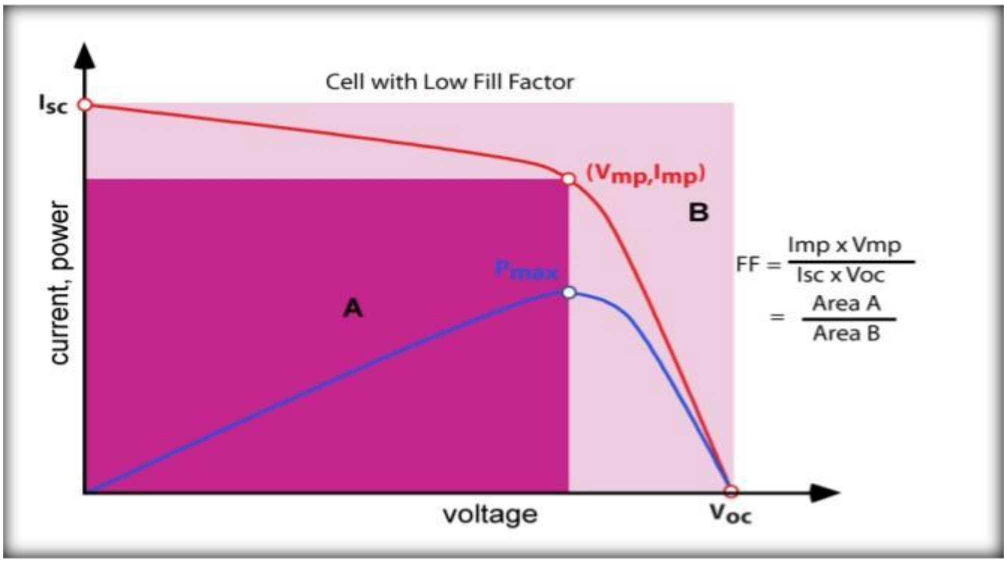


Figure 15 : Form factor for a PV cell [27].

II. Modeling of the wind :

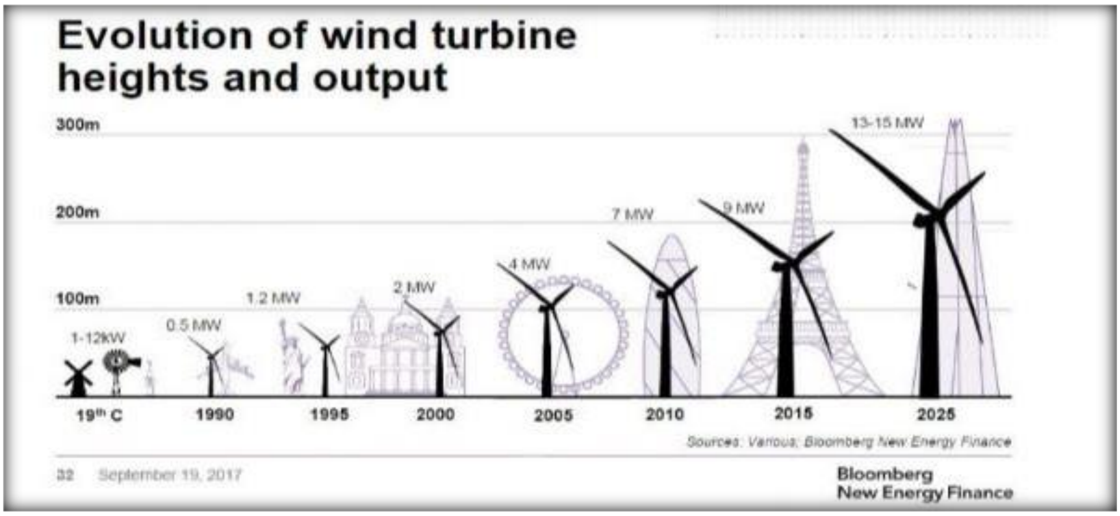


Fig 16: Évolution of wind turbine heights and output (Bloomberg New Energy Finance., 2017).

II.1 Mathematical formulation:

To know better the velocity division density function in this place, it is essential to evaluate the wind density from the meteorological measurements, acquired with the help of the auxiliary metrological station of Laghouat [33].

The frequency analysis of the wind speed high lights the predominant speed classes [34]. Therefore, the task of choosing the wind turbines that provide the best performance and the economic analysis of the power plant is easier [35].

II .1.1 Weibull's law :

Analysis of wind speeds is essential for wind energy.It is important to express the frequency distribution of wind speed to assess the wind energy potential of a site. Modelling studies of the wind speed distribution have been oriented towards models combining power and wind speed. The usual models are as follows [36] :

• Weibull distribution

• Weibull hybrid distribution

• Rayleigh distribution

- **Weibull distribution :**

The Weibull distribution (named after the Swedish Physicist W. Weibull, who applied it to study the tensile Strength of materials in 193**0)** has been used to represent wind speed distributions for application in wind load studies over a period of time and can give a good fit to experimental Data [37]. The Weibull distribution was used for the statistical study of ground data. The probability density and cumulative frequency of this distribution [38], is given by :

$$f_{(v)} = \left(\frac{k}{A}\right)\left(\frac{v}{A}\right)^{K-1} exp\left[-\left(\frac{v}{A}\right)^{k}\right] \quad (35)$$

Where, $f_{(v)}$is the frequency distribution of the measured velocities ; k is the Weibull form factor and it indicates the shape of the distribution and takes a value between 1 and 3

A small k-value means very variable winds, while constant winds give a higher k-value ; and A is the Weibull scale factor in m/s, a measure of the time series characterizing wind speed. A is proportional to the mean wind speed value and A > 0 [39, 40].

- **Rayleigh distribution :**

The Rayleigh distribution is a special case of the Weibull distribution for the case where the form factor k is equal to 2 ; its probability density is given by :

$$f_{(v)} = \int_{-\infty}^{v} f_{(v)}.dv = 2\left(\frac{v}{A^2}\right) exp\left[-\left(\frac{v}{A}\right)^{2}\right] \quad (36)$$

In this study the wind energy potential was evaluated by the Weibull distribution which is the most used in this field and its parameters were determined..

II.1.2 Betz's law:

All of the kinetic energy of the wind cannot be captured by the wind turbine because the speed of the wind downstream of the rotor is never zero. Some of the kinetic energy of the wind is lost. The German physicist Betz showed that the maximum recoverable energy by the rotor is equal to 16/27, or about 59% of the total wind energy. This limit has never been reached and each wind turbine is defined by its own power coefficient Cp expressed as a function the normalized specific speed λ. Betz's theory models the passage of air before and after the wind turbine blades as being a current tube with:

V1: The wind speed before the blades of the wind turbine.

V: the wind speed at the level of the blades of the wind turbine, of the order of a few m/s.

V2: the wind speed after taking energy from the wind turbine blades

Where the vectors V1>V>V2 are parallel to the axis of the rotor [41].

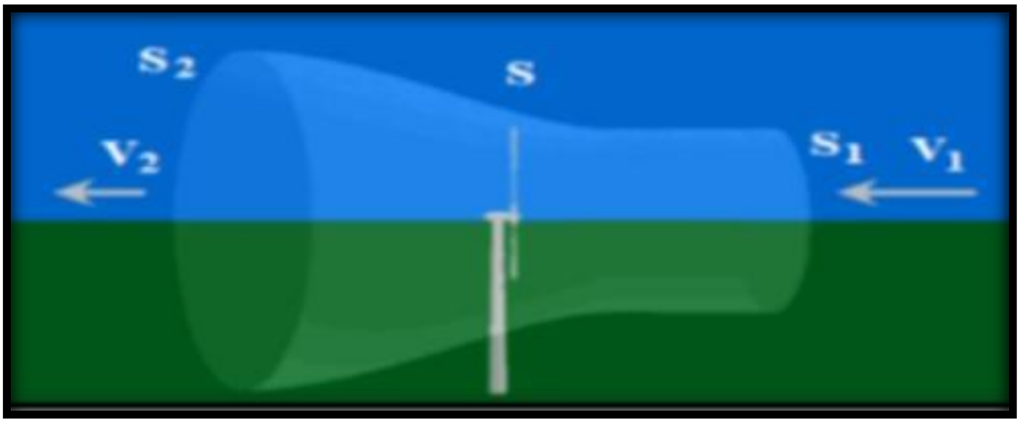


Fig 17 : Current tube around a wind turbine [41].

The recoverable power of the wind is expressed by :

$$P = C_P \left(\frac{1}{2}\right).P.S.V^3 \tag{37}$$

The recoverable power on the wind turbine is due to the variation of kinetic energy of the wind expressed by :

$$\Delta E_e = \frac{1}{2}.\rho.S.V.(V_2^2 - V_1^2) \tag{38}$$

The force exerted on the wind turbine creates a power Pm. The quantity theorem movement gives :

$$F = \rho.S.V.(V_1 - V_2) \tag{39}$$

$$P_m = F.V = \rho.S.V.(V_1 - V_2).V = \rho.S.V^2.(V_1 - V_2) \tag{40}$$

Pm : corresponds to the power absorbed by the rotor, i.e. the mechanical power supplied to Vthe aerogenerator.

We can determine the speed V2 for which the power is maximum :

$$P_m = \Delta E_e \tag{41}$$

Either :

$$\rho.S.V^2.(V_1 - V_2) = \frac{1}{2}\rho.S.V.(V_2^2 - V_1^2) \tag{42}$$

Simplifying we have :

$$V = \frac{V_1 + V_2}{2} \tag{43}$$

We deduce the maximum power coefficient Pmax for a wind turbine :

$$P_{max} = \rho.S.V_1^3.\left(\frac{8}{27}\right) \tag{44}$$

$$P_{max} = \rho.S.V_1^3.\left(\frac{8}{27}\right) = \frac{1}{2}.C_{Pmax}.\rho.S.V_1^3 \tag{45}$$

The power coefficient represents the ratio between the power of the rotor and the power available in the wind taking into account the Betz limit, C_{pmax} is :

$$C_{Pmax} = \frac{16}{27} \approx 0{,}59 \tag{46}$$

The maximum rotor power will be equal to :

$$C_{Pmax} = \frac{P_{Rotor}}{P_{Vent}} \tag{47}$$

Taking into account all the other efficiencies of a wind turbine such as that of the generator or the reducer, the overall efficiency of a machine is around 50% of the Betz limit.

$$C_{Pmax} = \frac{P_{Rotor}}{P_{Vent}} = \frac{P_{Rotor}}{\frac{1}{2} \times \rho \times A \times V^3} = \frac{16}{27} \tag{48}$$

In conclusion, in many cases

$$P_{reellerotor} = 0{,}3 \times P_{Vent} \quad (49)$$

$$P = \frac{1}{2}\frac{d}{dt}(mv^2) = \frac{1}{2}\left(2mv\frac{dv}{dt} + v^2\frac{dm}{dt}\right) \quad (50)$$

In the absence of the turbine, the wind velocity, Vw, is constant so the term goes to zero. Using the results from equations (30) and (42) and remembering that the cross-sectional areas, A1, AT, A, in this case, are equivalent, the total power, Protat can now be expressed as :

Equation (51) exprès le P total (toi que vous donnez c' est dernier equation 48/49 et50)

$$P_{total} = \frac{1}{2}v_w^2\frac{dm}{dt} = \frac{1}{2}v_w^2\dot{m} = \frac{1}{2}\rho A_T v_w^3 \quad (51)$$

P_{total} :is the total (kinetic energy + pressure energy) transferred by the fluid in the system. The unit for this variable is(w)

V_W: is the relative velocity of the fluid relative to the system or surface that the flow is passing through. The unit for this variable is (m/s)

dm/dt: is the rate of change of mass of the fluid that passes through the system or surface in a given time. The unit for this variable is (kg/s),

$\dot{m}$: is the mass flow rate of the liquid, and expresses the mass of the liquid that passes per unit time. The unit for this variable is (kg/s),

ρ: is the liquid density. The unit for this variable is (kg/m^3)

A_T: is the cross-sectional area of the system or surface through which the flow passes. The unit for this variable is (m^2)

Similar to the results found for the extractable turbine, the total power of the wind is proportional to the cube of the wind velocity. Now that we have expressions for the power extracted at the turbine (P_T) and the total power available from the wind (P_{total}), we can now create an expression for the efficiency of the of the ideal wind turbin

$$\eta = \frac{P_T}{P_{total}} \quad (52)$$

using the results from equations (16) and (19), theefficiency factor is :

The curves in figure.18 show the evolution of the power coefficient Cp for real horizontal axis turbines with 1, 2, 3 and 4 blades, note that its value remains well below of the Betz limit, which is equal to 0.59 and practically depends on the profile of the blades.

For a three-bladed machine, the power coefficient is maximum for $\lambda \cong 7$, i.e. for a peripheral speed at the tip of the blade equal to 7 times the speed of the wind. It is for such normalized speed that aerodynamic efficiency is maximized. At diameter and speed given wind conditions, a two-blade must have a higher rotational speed than a three-blade. On aerodynamically, we can compare the different types of turbines by comparing their aerodynamic coefficients of power or torque as a function of normalized speed λ [41].

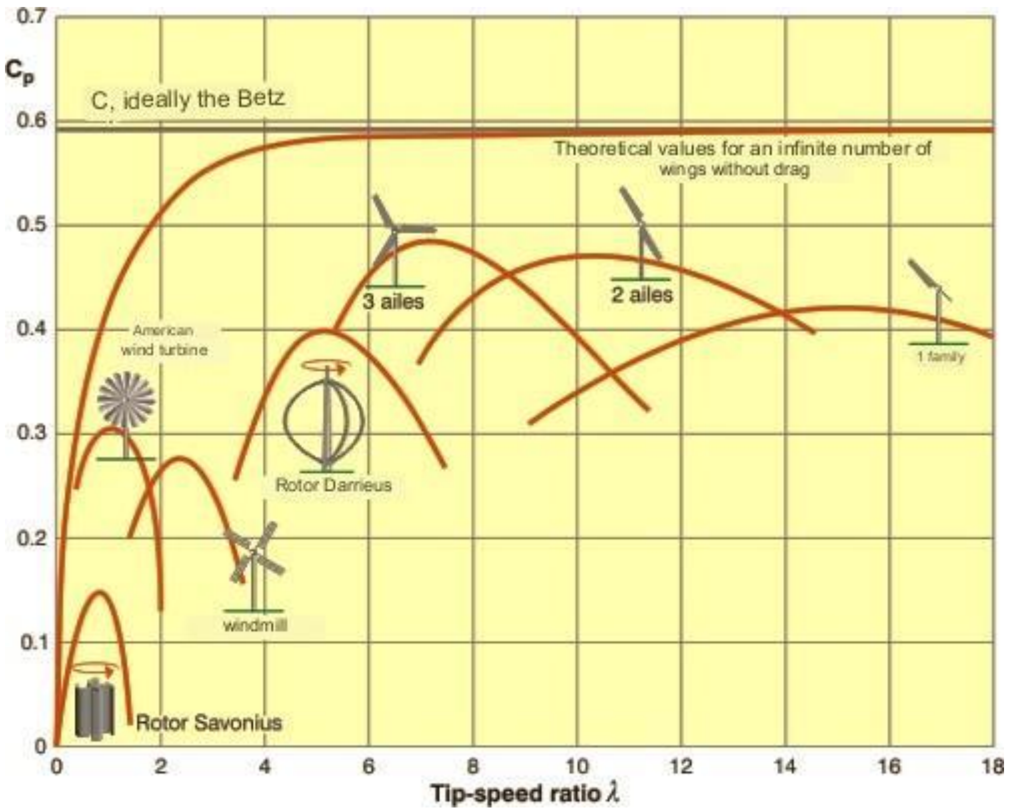


Fig 18 : Cp as a function of λ for different turbines [41].

According to fig 18,the curves giving the torque coefficient in the systems on the vertical axes indicate that it evolves in the same way. These Cp (λ) curves clearly show the advantage of horizontal axes in terms of power, even if this judgment is to be qualified when observing the restored energy, especially in sites with little wind (urban areas, etc.). Cp (λ) curves are flatter for horizontal axes with low number of blades(3, 2 or 1 blade) in relation to the vertical axes or the multi-blades [41].

III. Thermal solar energy :

Solar thermal consists of transforming solar radiation into heat, and recover mainly by heating the water. It is mainly used for produce domestic hot water, but it can be used as a supplement for the home heating. If the temperature is high enough, we can then activate a cycle thermodynamics to produce electricity (and heat). This sector is that of thermodynamic solar power plants, or concentrated solar systems [42]. One of the main challenges to be reversed according to global development indicators is the high concentration of greenhouse gases (GHG) due to the use of fossil fuels in electricity generation applications and industrial

processes [43, 44]. One of the means to achieve a reduction in GHGs is the use of technologies to convert solar energy into electricity. Among the main ones, we have photovoltaic (PV) and concentrating solar thermal (CST). The most used solar collectors are shown in [45, 46], such as flat-plate, parabolic compound, evacuated tube (heating of fluids to temperatures up to 200 ◦C; parabolic trough, Fresnel lens, parabolic dish, and heliostat fields (heating of fluids to temperatures up to 400 ◦C are the main technologies used for concentrating solar energy. In reference [47], the authors present free applications that allow the design of solar fields. This work focuses on parabolic trough solar thermal power plants, which consist of a Solar Collector Field (SCF) [48], thermal energy storage (TES) [49], Power Conversion System (PCS) (Michael & al., 2014), and auxiliary elements such as pumps, pipes, and valves. Solar collectors use solar radiation to heat fluids such as oil or water. Thermal energy is used for heating or the production of steam for electric generators. Works such as [50], describe the use of solar thermal plants for electricity generation. For heating or the production of steam for electric generators, thermal energy is used. The main goal of a parabolic trough solar field is to collect the maximum solar energy to produce as much trical power as possible [51]. To achieve the best performance of the plant, electrical power depends on the outlet temperature and the oil flow. The controls applied for these plants must be able to maintain the plant’s performance on days when solar irradiance is low. Xiufan and Yiguo employ a mathematical model of a PTC based on HTF energy balance, absorber tuve, and glass envelope [52]. [53] , incorporate the heat loss of the absorber based on the energy balance. Research like Camacho and Gallego [54], propose changes in the outlet temperature set point according to the value of the solar irradiance, but the oil flow is not covered by the proposed model.

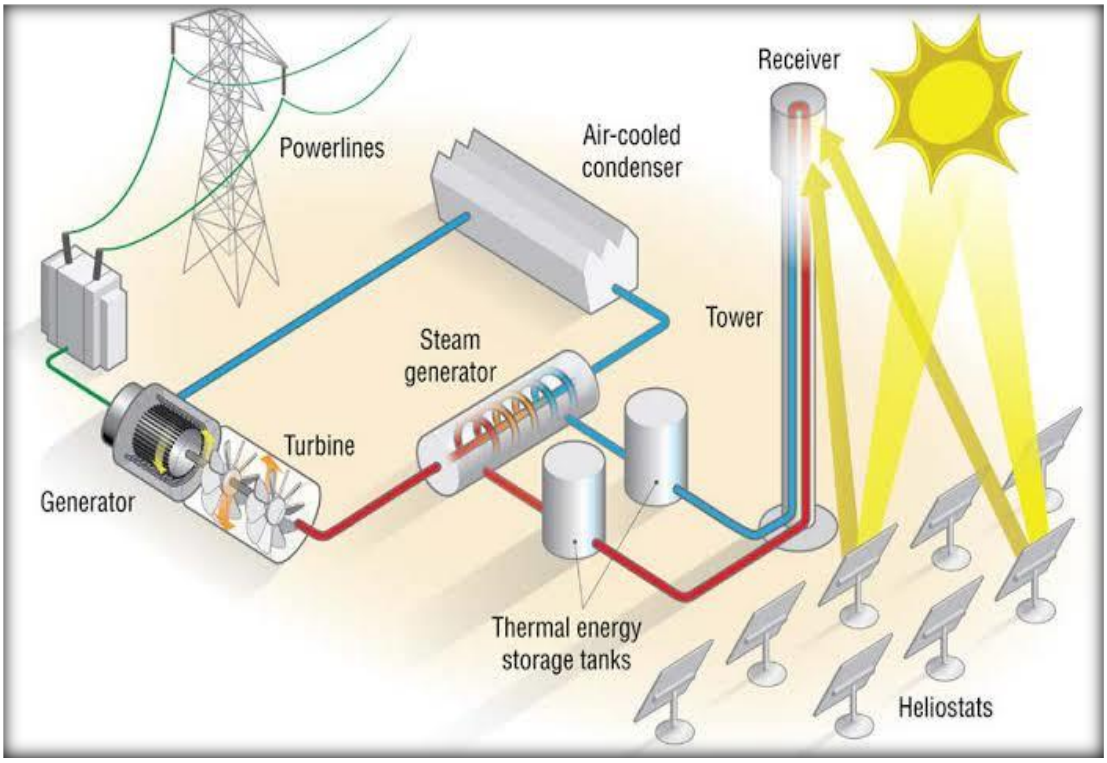


Fig 19: Operation of solar thermal panels (Burger., 2014).

III.1 Solar Collector Field

In this section, the mathematical models based on differential equations of a parabolic trough collector loop are presented. The model of the whole field is described as the placement of several parabolic collector loops. The model of distributed parameters was tested and validated in studies such as [55], which are currently used in research papers ratifying its applicability [56, 57, 58].

III.2 Parameter Model

Each SCF loop has four sectors connected in series , the sectors contain 12 collector modules. The SCF has a total area of 2635.2 m2 that receives solar irradiance in the absorber tubes [59]. Equation (1) describes the variation in internal plant energy, which provides the evolution of the outlet temperature, Tloop,out(t). As can be seen, the outlet temperature of the loop depends on several inputs, the manipulated one, Qloop(t) is the volumetric flow, and the other ones act as disturbances: Tloop,in(t) is the inlet temperature, Ta(t) is the ambient temperature, Tm(t) is the mean fluid temperature and I(t) is the solar irradiance. The equations modeling the dynamics of the outlet temperature of the loops are:

$$PC_p A_{CS} \frac{\partial T_{LOOP,out}(t)}{\partial t} = IK_{opt} n_0 G - \frac{\rho}{C_f} C_P Q_{loop}(t) \frac{T_{loop,out}(t) - T_{loop,in}(t - d_{tout-tin})}{L_{eq}} - H_l \frac{T_m(t) - T_n(t)}{L_{eq}}$$

(53)

PC_p : It represents the pressure of the loop at the specified point. This variable signifies the ratio of pressure to the heat capacity of the loop.

A_{cs} : It denotes the cross-sectional area of the loop at the specified point. This variable represents the flow area within the loop.

$(\partial T_{(LOOP,out)}(t))/\partial t$: It represents the rate of change of temperature at the specified point with respect to time. It signifies the rate at which the temperature of the fluid exiting the loop changes

IK_{opt} : It represents the thermal enhancement factor of the loop. This variable denotes the process targeted to enhance heat transfer efficiency within the loop

n_0: It represents the fluid flow rate within the loop. It signifies the quantity of fluid entering the loop at a given time.

G: It represents the mass flow rate of the fluid within the loop. It signifies the quantity of fluid passing through the loop at a given time.

ρ: It represents the density of the fluid within the loop. It denotes the density of the fluid in the loop.

C_f: It represents the specific heat capacity of the fluid per unit mass within the loop. This variable signifies the ability of the fluid to absorb heat.

C_P: It represents the specific heat capacity of the fluid per unit pressure within the loop. This variable signifies the ability of the fluid to absorb heat.

Q_{loop} (t): It represents the heat flow rate within the loop at a given time. This variable denotes the amount of heat transferred within the loop at a given time.

$T_{(LOOP,out)}$ (t): It represents the temperature of the fluid exiting the loop at a given time.

$T_{LOOP,in)}$ (t-d_(tout-tin)): It represents the temperature of the fluid entering the loop at a time delayed by (tout - tin), where tout and tin are the respective times of the fluid exiting and entering the loop.

L_{eq}: It represents the equivalent length of the loop. This variable denotes the length scale used in the equation.

H_l: It represents the convective heat transfer coefficient of the loop. This variable signifies the effectiveness of heat transfer between the fluid and the loop.

Where:

$$T_m(t) = \frac{T_{loop,out}(t) - T_{loop,in}(t - d_{tout-tin})}{2} \quad (54)$$

T_m (t): Represents the average temperature of the loop at a specific time (t).

T (loop,out) (t): Represents the temperature of the fluid exiting the loop at time (t).

T (loop,in) (t - d_(tout-tin)): Represents the temperature of the fluid entering the loop at time (t - d_(tout-tin)).

d (tout-tin): Represents the time interval between the fluid exiting the loop (tout) and the fluid entering the loop (tin).

Where ρ is the fluid density and Cp is the specific heat capacity depending on the temperature in the fluid. Works such as [60] and [45] provide data on the thermal transfer fluid or HTF (Heat Transfer Fluid), which is Santotherm-55. This oil circulates through the collector system. Santotherm-55 is capable of reaching 305 ◦C without degrading. Acs is the collector tube's cross area, Leq is the length of the equivalent collector tube, Hl is the thermal losses coefficient expressed by (3), m primary circuit mass flow rate and Δh increased enthalpy. Kopt is the optical efficiency, no is the geometric efficiency, G collector aperture, dtout−tin is the delay between the outlet temperature and the inlet temperature, and Cf is a conversion factor to calculate the mass flow rate inside this hypothetical equivalent collector tube. It takes into account the number of parallel collectors in each loop-row, np, number of serial tubes in each collector, nt, and kg·h−1 conversion.

$$-H_l = \frac{\dot{m}\Delta h}{\frac{T_{loop,out}(t) - T_{loop,in}}{2} - T_a} \quad (55)$$

H_l: Represents the convective heat transfer coefficient between the fluid in the loop and the surrounding environment.

m ̇: Represents the mass flow rate of the fluid within the loop. It indicates the quantity of fluid passing through the loop per unit time

Δh: Represents the specific enthalpy difference of the fluid. It signifies the change in heat content of the fluid between the inlet and outlet points.

$T_{(loop,out)}$ (t): Represents the temperature of the fluid exiting the loop at a specific time (t).

$T_{(loop,in)}$: Represents the temperature of the fluid entering the loop.

T_a: Represents the ambient temperature or the temperature of the surroundings.

III.3 PCS Model

III.3.1 Concentrating Solar Radiation (CSP) Systems:

The CSP system (Concentrated Solar Power) refers to all the techniques aimed at transforming the energy of solar radiation into heat, and then converting this heat into mechanical energy through a thermodynamic cycle, then work into electricity through an alternator. There are two types of concentration systems:

- **Linear concentration**:

These systems are composed of fairly long reflectors which follow the sun thanks to a single axis of rotation, a tube in which the heat transfer fluid circulates is placed in the focal line of the concentrator, it is the receiver, they include:

➢ Cylindrical-parabolic concentrators

➢ Linear Fresnel concentrators.

- Point concentration:

These are Stirling parabolas or heliostats (power towers and solar ovens). This type of concentrator tracks the sun on two axes, in azimuth and elevation [42]. This energy can be used in isolated systems or fed into the grid. The thermal energy Wt model is given by $P(T_{SCF,out})$ is calculated by the simplified model of the solar field in Equation (4) CM Cirre [61].

$$P(T_{SCF_{out}}) = IK_{opt} n_0 G - \frac{H_1}{L_{eq}} (T_{SCF_{out}}; T_{SCF_{in}}; T_a) L_{eq} n_l \qquad (56)$$

$P(T_{SCFout})$: Represents the temperature of the fluid exiting the cooling system or the coolant liquid at the current time.

IK_{opt}: Represents the efficiency factor of the cooling system.

n_0: Represents the number of active units in the cooling system.

G: Represents the flow rate of the fluid in the cooling system.

H_1: Represents the heat loss resulting from heat transfer from the fluid to the surrounding environment or heat dissipation in the system.

L_{eq}: Represents the total thermal resistance of the cooling system.

$T_{(SCF\_in)}$: Represents the temperature of the fluid entering the cooling system at the current time.

T_a: Represents the ambient temperature or the temperature of the surroundings.

n_l: Represents the number of single layers in the cooling system

Where H1 is the linear of thermal losses. The investigation of CM Cirre [61] was to make several tests with different flows and inlet temperature, outlet temperature, and ambient temperature.With the tests, the linear regression is obtained (5).

$$H_1 = 1970\left(\frac{T_{loop,out}(t) - T_{loop,in}}{2} - T_a\right) - 34{,}651 \quad (57)$$

To convert the thermal energy Wt into electrical energy We, the maximum efficiencies of the complete DCS set formed by the SCF, the storage system and the PCS are used. Therefore, to perform the conversion, the system efficiency values found by CM Cirre are used. Thermal storage efficiency chosen is η_{alm} = 0,98 and the thermal into electric power conversion is η_{PCS} = 0,22 . The estimated energy that can be provided by the DCS is shown by Equation (6).

$$P(T_{SCF_{out}}) = IK_{opt}n_0G - H_1 n_l \overline{\eta_{alm}\bar{\eta}_{PCS}} \quad (58)$$

$P_{(T\_(SCF\_out))}$:the power output of the system or device at the temperature T(SCF_out).

IK_{opt}: Represents the optimal efficiency factor of the system.

n_0: Represents the number of active units or elements in the system.

G: Represents the flow rate of the fluid or working medium.

H_1: Represents the heat loss or dissipation in the system.

n_l: Represents the number of layers or stages in the system.

η_{alm}: Represents the local efficiency or efficiency at a specific point in the system.

η_{PCS}: Represents the average or overall efficiency of the power conversion system.

Solar collectors absorb the sun's rays which transmit their energy to a fluid (water or air), in order to be used for a specific need such as heating, production of domestic hot water, and solar air conditioning used for the production of cold. A solar thermal installation is sized to meet a specific need for producing heat. In construction, for example, this technology is of great interest for the production of domestic hot water [42].

Fig 20: Thermal solar panels [42].

III.3.2 Technology of concentrated solar power plants:

All thermodynamic solar technologies aim to transform energy solar rays into thermal energy (heat at high temperature), which is then used to produce mechanical then electrical energy through a cycle thermodynamics coupled to an electric generator [42].

III .3.2.1 Tower solar plant:

In this type of plant, many mirrors are used which concentrate the radiationsolar on a boiler placed at the top of a tower. The mirrors or "heliostats" are designed to rotate with the path of the sun and thus reflect the sun's rays onto the focal point. THE solar radiation should be directed to the focus at the top of the tower with a largeaccuracy. The concentration factor varies from 600 to several thousand, which allows reach high temperatures, from 800°C to 1000°C.

Fig 21: Solar tower power plant [42]

Advantages and disadvantages :

➢ **Advantages**:

✓ Inexhaustible source of energy.

✓ No polluting emissions.

✓ Enables the enhancement of desert areas.

➢ **Disadvantages**:

✓ Requires strong sunlight.

✓ These plants need a large space and a large floor area.

III .3.2.2 Parabolic solar power plant:

This plant is an assembly of several autonomous units. Each unit being a mini-power plant, it produces electricity. We combine several to produce more of electricity. Each parabolic mirror concentrates solar radiation at its focal point.mirror where solar energy is transformed into electrical energy. This kind of power plants can reach up to 1000 c on the receiver, thus yields exceeding those of other solar thermal technologies [42].

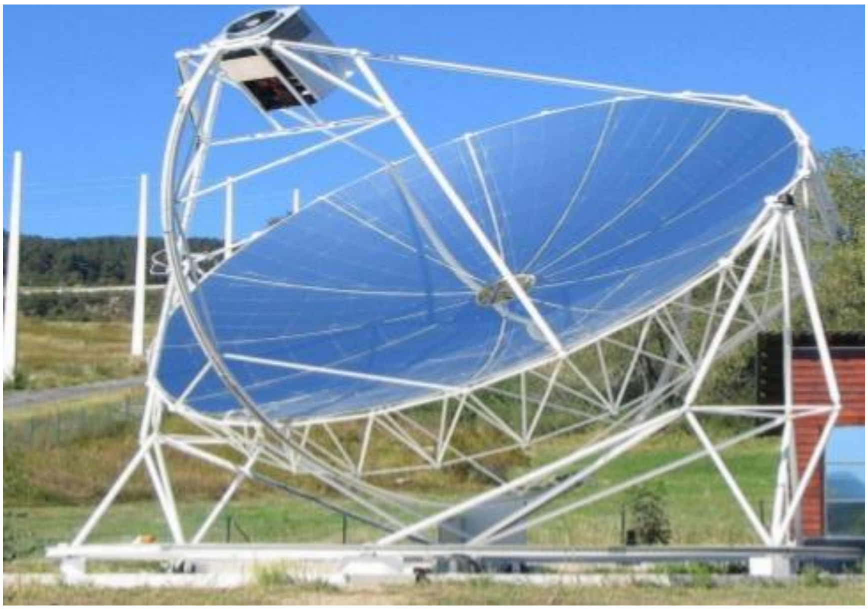


Fig 22: Parabolic solar power plant (DISH-STIRLING project in Font-Romeu-Odeillo).

Advantages and disadvantages :

➢ Advantage:

✓ Inexhaustible and free source of energy.

✓ No polluting emissions.

✓ Good performance.

✓ Small independent units.

Disadvantages:

✓ Intermittent operation.

III .3.2.3 Solar power plant with cylindrical-parabolic collectors:

This type of power plant consists of parallel rows of long cylindrical-parabolic mirrors which rotate around a horizontal axis to follow the path of the sun. The sun's rays are concentrated on a horizontal receiving tube, in which circulates a heat transfer fluid whose temperature generally reaches 400°C [62]. This fluid is then pumped through exchangers to produce superheated steam which drives a turbine or a electric generator.

Fig 23: Cylindrical-parabolic solar power plant [42].

Advantages and disadvantages :

➢ **Advantage**:

✓ Inexhaustible and free source of energy;

✓ No emission of pollutants;

✓ Can operate without intermittence.

➢ **Disadvantages:**

✓ Requires sensitive and costly tracking for a low climate zone to shine;

✓ Significant land area.

III .3.2.4 Fresnel solar power plant:

Fresnel mirror power plants, also called Compact Linear Fresnel Reflector (CLFR), operate in the same way as a cylindrical-parabolic reflector plant with the difference that the reflectors are plane and in greater number. Each plane reflector is autonomous and orientable along an axis in order to direct the light radiation towards the tube in which the heat transfer fluid circulates [42].

Fig 24: Solar power plant with Fresnel mirrors [42].

Advantages and disadvantages :

The main advantages:

✓ Plane mirrors are easier to manufacture and cheaper than

parabolic and cylindrical-parabolic.

✓ The mechanical stresses imposed by wind pressure are reduced thanks to the

flat arrangement of mirrors, less infrastructure.

Disadvantages:

✓ Approximately 30% lower optical performance compared to reflectors parabolic and cylindrical-parabolic.

III .3.2.5 Solar updraft tower:

The solar chimney consists of three main components which are the collector

solar, chimney or tower, and wind turbine. A solar chimney takes advantage of the wind created in a chimney, by the differences of density due to the heating of the air, to turn a turbine and generate electricity.

Two basic principles are behind the production of electricity in the solar tower, the greenhouse effect and the flow of air. Hot air is lighter than cold air, so it will be channeled towards the tower and rises. The solar irradiation passes through the glass placed all around the central chimney, the collector, is absorbed by the ground below and re-emitted to the air under the effectgreenhouse, the air is therefore heated by the sun and causes a wind (the creation of a pressure difference in the column of the tower, driving the air from the base of the tower to its upper outlet). A wind turbine, which is usually located at the base of the tower, is put in the path of the air flow to convert the kinetic energy of the flowing air into mechanical energy, and the generator driven by the turbine converts mechanical energy into electrical energy [63].

Fig 25: Manzanares Stack Effect Power Plant [63].

Advantages and disadvantages of the solar chimney:

Advantages:

- ✓ It is a source of sustainable and free energy, does not pollute.
- ✓ 24/7 operation without stopping because the heat is always present in the greenhouse even at night thanks to the heat storage system.
- ✓ Reliability, because the solar chimney is not likely to break down, in addition to that and thanks to the simplicity of its operation, they require very little maintenasyste
- ✓ All types of solar rays, direct and diffused, are exploited. so can work in the cloudy conditions. This is an advantage for tropical countries.
- ✓ No need for cooling water like other power plants. This is a very important advantage for sunny countries which already have problems with drinking water.
- ✓ A solar chimney with a spacious collector and a tall chimney can produce 100 to 200 MW continuously.

- ✓ Building materials (mainly glass and concrete) and readily available. So even in poor countries, it is possible to build the solar chimneys using their own raw material resources (concrete and glass), which creates a large number of jobs and reduces the capital investment requirement and cost. of the production of electricity.
- ✓ Use of simple technology.
- ✓ A long lifespan (80 to 100 years).

The inconvenients

- ✓ The collector occupies a huge area, and presents a mess of the landscape.
- ✓ The construction of the solar chimney requires enormous quantities of materials (the availability and transportation of materials).
- ✓ the investment cost (These plants require a very large investment).
- ✓ Production is not constant during the day or the year.

A thermal storage system is advantageous in many places where the peak energy demand occurs after sunset. For a good mastery of this technology, in-depth studies are necessary, namely: Find a compromise between electricity consumption and thermal storage,Therefore it is necessary to check the load curves (consumption according to the Time).

CHAPTRE V

Possibilities and prospects of renewable energies in Algeria (Laghouat)

Chapitre V : Possibilities and prospects of renewable energies in Algeria

Algeria is one of the Mediterranean and North African countries with the most large source of solar energy, with sunshine between 2000 and 3900 hours per year, and a power of 3000 to 6,000 Wh/M2; But with all these stats and benefits. Algeria remains among the last country to develop renewable energies in the region. Indeed, despite the will expressed in the texts and the ambitious strategy traced by the public authorities, the capacities actually installed, between 2010 and 2019, are estimated at around 390 megawatts (MW), barely 1.8% of the 22,000 MW making up the total capacity in renewable energies to be deployed by 2030. renewable energies represent a challenge to be taken up by Algeria, relying on EnR, for the electricity needs of the national market, will allow the creation of several thousands of direct and indirect jobs. This challenge reflects our country's commitment to economic and social development that respects the environment and is sustainable. The challenge is great but it is not impossible, what will make the difference is the great will and the efforts of the state and also the various economic and local actors [8].

I. National Renewable Energy Development Program :

Through this renewable energy program, Algeria intends to position it self as a major player in the production of electricity from the sectors photovoltaic and wind power by integrating biomass, cogeneration, geothermal energy and other beyond 2021, solar thermal. These energy sectors will be the drivers of a sustainable economic development capable of driving a new growth model economic. 37% of installed capacity by 2030 and 27% of electricity production intended for national consumption, will be of renewable origin. (Ministry of energy). The national potential in renewable energies being strongly dominated by the solar energy, Algeria considers this energy as an opportunity and a lever for economic and social development, in particular through the establishment of industries creators of wealth and jobs. (International Exhibition of Renewable Energies) however, this does not exclude the launch of numerous projects for the realization of wind farms and the implementation of experimental projects in biomass, geothermal and in cogeneration [8].

EnR electricity production projects dedicated to the market national will be carried out in two stages :

- **First phase 2015 – 2020 :** This phase will see the realization of a power of 4010 MW, between photovoltaic and wind, as well as 515 MW, between biomass, cogeneration and geothermal energy.
- **Second phase 2021 – 2030 :** The development of the interconnection between the North and the Sahara (Adrar), will allow the installation of large renewable energy plants in the regions of In Salah, Adrar, Timimoune and Bechar and their integration into the national energy system. At this deadline, the solar thermal could be economically viable.

In the renewable energy program and defined phases, we note, among other things: that by 2020, the installation of a total power of approximately 2,600 MW is expected for the national market and a possibilité of exporting around 2,000 MW, whereas from here 2030, it is planned to install a power of nearly 12,000 MW for the market national as well as the possibility of exporting up to 10,000 MW. (Maghreb, 2017).

Algeria's strategy in this area aims to develop real industry renewable energies combined with a training and capitalization program for knowledge, which will eventually make it possible to employ the local Algerian genius, in particular in engineering and project management. The EnR program, for the electricity needs of the national market, will allow the creation of several thousand jobs direct and indirect [8].

I.1 Consistency of the renewable energy development program

The consistency of the renewable energy program to be achieved for the market over the period 2015-2030.

Table 11: Consistency of the energy development program renewable.

Unit :MW	1st phase (2015-2020)	2nd phase (2021-2030)	Total
Photovoltaic	3000	10575	13575
Wind	1010	4000	5010
CSP	-	2000	2000
Cogeneration	150	250	400
Biomass	360	640	1000
Geothermal	05	10	15
Total	4525	17475	22000

Source: Ministry of Energy https://www.energy.gov.dz cite in .

I.2 National Energy Efficiency Program:

The energy efficiency program follows Algeria's desire to promote more responsible use of energy and exploring all avenues to preserve the resources and systematize useful and optimal consumption. The objective of energy efficiency is to produce the same goods or services, but using as little energy as possible. This program includes actions which favor the use of the forms of energy best suited to the different uses and requiring the modification of behavior and the improvement of equipment. This program provides for the introduction of energy efficiency measures in the three sectors of construction, transport and industry and also the encouragement of creation of a local industry for the manufacture of high-performance lamps, water heaters solar panels, thermal insulators by encouraging local or foreign investment. In summary, the implementation on the ground of the national efficiency program energy will gradually reduce the growth in energy demand. Thus, the accumulated energy savings would be around 93 million PET, including 63 million PET by 2030 and the rest beyond this horizon. (Ministry of energy). That is to say the importance of this energy saving program which involves the implementation of a certain number of measures with, in particular, the involvement stakeholders, including public and private industry and the adaptation of the legal framework governing energy efficiency. By adopting the national renewable energy development program and energy efficiency and by updating it in 2015 Algeria confirms its choice of optimal use and diversification of its energy resources, and for the protection of the environment .

II. Possibilities and prospects of renewable energies in the wilaya of Laghouat :

In view of the importance of renewable energies, we suggest conducting a study on the possibility of applying them in a number of regions in the wilayat of Laghouat, based on an analysis of a reference case of the physical and natural environment and landscapes and humans of the site before implementing the project, and that sufficient data must be available to identify, evaluate and prioritize the potential impacts of these projects.

II.1 geographical study wilaya of Laghouat :

The wilaya of Laghouat is located in the center of the country 400km from the capital Algiers. The meaning of the name Laghouat means « oasis ». The capital of the wilaya is the city of the same name Laghouat. The other big cities of the wilaya of Laghouat are Aflou, Aïn

Madhi, Kourdane and Makhareg. The wilaya is geographically limited to the north by the wilaya of Tiaret, to the east by the wilaya of Djelfa, to the west by the wilaya of El Bayadh and to the south by the wilaya of Ghardaïa. The climate of the wilaya of Laghouat is arid continental with average temperatures of -5°C in winter and over 40°C in summer.

Fig 26 : Location of the Wilaya of Laghouat [64].

With the exception of the large gas field of Hassi R'mel, the vocation of the wilaya of Laghouat is agro-pastoral in nature. At the last census, the population of the wilaya amounted to 484,252 inhabitants. [64]

II.2 The study of the possibility of installing a wind farm in the municipality of Oued M'Zi :

The municipality of Oued M'Zi:

a) Geographical study of region :

Oued M'Zi is a town in the wilaya of Laghouat in Algeria, located about 50 kilometers northwest of the wilaya of Laghouat and 5 km from the city of Tadjmout; it is bounded in the northern part by the foothills of Djebel Ammour, on the northeast side by the commune of Oued Morra, on the northwest side the commune of El Ghicha, on the southwest side the commune of Ain Madhi, and on the east side by the municipality of Tadjmout. It covers an overall area of 425 km² or 1.7% of the wilaya, for a population estimated at 3129 inhabitants in 2008, the density is 7.4 inhabitants/km² .

b) A climatic study of region :

The town is characterized by cold winters and white frosts, where the average minimum temperature is 2°C and maximum 14°C. for the summer, it is characterized by intense heat accompanied by sandstorms. The average maximum temperature reaches 40°C. and the minimum is 24°C. The wind observed at a given location is highly dependent on local topography and other factors, instantaneous wind speed and direction vary more than hourly averages. The average hourly wind speed in Oued M'Zi experiences mild seasonal variation over the course of the year. The windiest time of the year, from December 8 to June 12, with average wind speeds above 22 km/h.

This municipality of Oued Mzi is home to the Saqlafa dam, which has a water storage capacity of 42 million cubic meters/year, which makes it possible to irrigate 600 hectares of agricultural land near the dam and supply 12 municipalities. from the south of the wilaya to drink water .

c) Regulatory aspect:

The construction of an onshore wind farm also requires a set of regulatory procedures. Unlike offshore wind turbines, the construction of onshore wind turbines requires obtaining a building permit granted by the municipality. Onshore wind turbines are indeed Installations Classified for the Protection of the Environment (ICPE) since the publication of a decree in August 2011 (decree no. 2011-984). Thus for wind turbines whose mast measures between 12 and 50 meters and whose power is greater than or equal to 20 MW or for any wind turbine whose mast exceeds 50 m, the installation is subject to the authorization regime. For wind turbines with a power of less than 20 MW and whose mast measures between 12 and 50 m, the installations are subject to the declaration system (decree no. 2011-984). In our case, the installation of a wind farm will therefore be subject to the authorization regime [65].

d) Economics:

In order to assess the economic aspect of setting up a wind farm, we will take into account:

- the investment cost (construction and maintenance)

- economic profitability (savings and resale price of the energy produced).

In-depth knowledge of the wind potential likely to be exploited for the production of electricity constitutes essential data for any sizing of a wind farm and remains essential, this point of view, essential for any preliminary study in this direction. The wind being characterized by temporal and spatial variability, different statistical methods and extrapolation techniques data are applied for the study of the wind deposit and the establishment of the atlas. With this in mind, NASA has developed more than 380 meteorological satellite data and of solar energy ready for analysis at four temporal levels: hourly, daily, monthly (per year 12 months + annual averages) and climatology, which are continuously updated. For an optimal evaluation of the wind resource available on a given site, it is necessary to calculate the average power density (W/m²) of the wind which indicates the energy available after conversion into electricity at the output of a wind turbine Based on the fact that a site is said to be eligible for the installation of a profitable wind farm if it has a power density of between 200 and 400 W/m² at 50 m in height. One of the aspects of this thesis concerned the specific study of the characteristics of the wind deposit of the site of the commune of Oued M'Zi in the willaya of Laghouat. The second, the possibility of installing a wind farm in this area through a study of detailed technical and economic feasibility. The results obtained can be summarized as follows:

- An annual average wind speed is 6 to 7 m/s.
- The wind rose made it possible to deduce that the direction of the prevailing wind is the southwest.
- The Weibull scale parameter varies between 6.80 m/s and 7.92 m/s and the form factor varies between 2.51 and 3.47.
- The average power density at 236.769 w/m².

In general, the wind potential of the Oued M'Zi site is very important to strengthen production of electricity in the wilaya of Laghouat. For the second scenario of resale and the electrical energy produced, a study must be carried out to show the importance and economic feasibility of this scenario [65].

II .3 El Study of a hybrid station for the production of renewable energy (photovoltaic - wind) connected to the network, at the site of El kheng :

II .3.1 Sizing of the photovoltaic power plant

II.3.1.1 Presentation of the study area :

The site of El KHNEG is located in the southwestern part 13 km from the city of Laghouat at altitude of 812 m above sea level. Table 12 shows the coordinates geography of the site

Table 12 : Geographical coordinates of the El KHNEG site [65]

geographical data	
Laltitude	33.74° Nord
Longitude	1. Est
Altitude	812 m

(BOUCHIBA., 2021).

It should be mentioned that the region has had a photovoltaic power station with a capacity of 20 MW since 2013, then the production capacity of thisstation has been increased by implementing another neighboring station with a capacitsite 40MW production. Figure illustrates the location of the implementation.

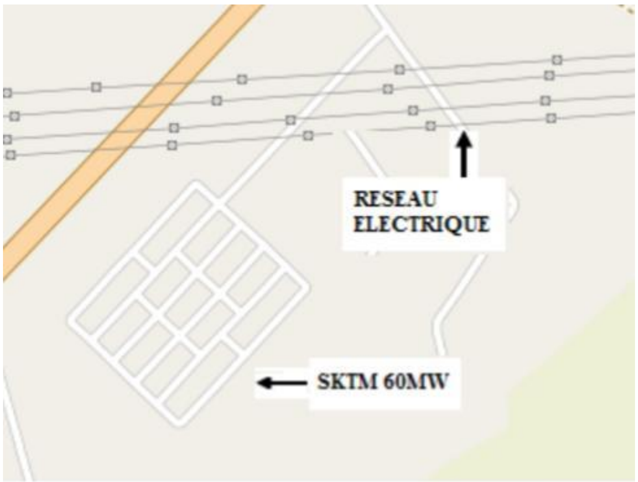


Fig 27 : The studied site – region of El kheneg [65].

II .3.1.2 Solar energy potential:

The average duration of insolation in the Algerian South is of the order of 3500 h/year is the largest in the world, of the order of 9 h/d, we note that it is always higher than 8 h/d over most of the territory. The region of the great South, in particular the South-East and the South-West presents the greatest potential of the entire Algerian territory [65].

- **Sizing of the 500kW subfield**

The sub-field is the unit constituting the GPV field, in this study we chose 500KW the installed power for each sub-field. In order to obtain the necessary voltage for the inverter, the panels are connected in series. They then form a chain of modules or string. The strings are then combined in parallel and form a photovoltaic field (PV field).

- **Sizing of energy conversion elements**

For the DC-AD energy conversion at the output of the field, the inverters must chosen solar panels are equipped with all the necessary devices to ensure the safety of operation and the protection of people and equipment. According to the essential criteria on the choice of inverters.

II .3.1.3 Simulation of the grid-connected PV plant:

When using renewable energy, it is important to respect the sizing steps that will allow sizing the energy source. Then comes the costing recoverable solar energy depending on location and geography. With this data, it will then be possible to know the quantity of photovoltaic modules required, the quantity of batteries (in the case of an autonomous installation), the most suitable regulator and inverter, and finally the appropriate wiring. At the end the simulation calculates the distribution of energies throughout the year. A complete report with all parameters involved and main results, is designed to be transmitted directly to the user [65].

- **Presentation of PVSYST simulation software :**

PVsyst is software designed for use by architects, engineers and researchers, but it is also a very useful educational tool. It includes contextual help in-depth, which explains in detail the procedure and the models used and offers an approach ergonomic with guide in the development of a project. PVsyst allows you to import weather data from a dozen different sources as well as personal data [65].

- **Project management :**

After the definition of the project, we move on to the choice of the site of the installation then call it meteorological data from the database of the software as it has the alternative of continuing this data online. We can build several variétés of our system with respect to its topology and according to the conditions and the appropriate optimization.The design of the system is based on a quick and simple procedure according to the following steps.

- Specify the desire power or the available surface;
- Choose PV modules from the internal database;
- Choose the inverter from the internal database.

PV installations must be of appropriate sizes energy saving in the most adverse conditions, allowing us to achieve better optimization of photovoltaic installations. Simulations are provided by PVSYS software [65].

II.3.2 Modeling of the wind power plant :

Sizing of the plant:

After processing the real data of the available wind speed of the region of 2012-2014, using the Matlab software (Distribution Fitter) for the statistical study, and the simulation of the data by the Weibull distribution in order to determine the parameters the wind. The latter allowed us to estimate the wind energy potential at different altitudes and dimensioned the wind generator suitable for our site [65].

Presentation of the site

The region has already been presented. The site is in a fairly strategic position in terms of the noise caused by the planned park. In addition, it benefits from a flat and very large surface and a soil made up of sandstone rocks for the installation of wind turbines [65].

Fig 28 : the site studied – region of El kheneg [65].

The wind on this site is regular and propagates in the South-West direction (SW) with stable monthly average speeds between 5,11 m/s. In August, and 10,5 m/s in March note that 6.49m/s is the average annual speed with a potential of 691W/m² at an altitude of 10 m, obtaining the best average wind speeds favoring good electricity production are obtained by extrapolation at an altitude of 40 m, 60m, 80m and 90m corresponding to the heights of the masts. This study forecasts the wind energy of the park in question, based on a choice judicious of the aerogenerator. If the GE1.5sl type wind turbine is chosen: The wind potential of this site at a height of 80 m has an average speed of 9 m/s and an energy density equal to at 1865 W/m² for the preferred direction. The operation of 14 machines provides a power of 21MW for an annual energy production of 96,86GWh. For our second choice of the FL2500 wind turbine presents the potential at a height of 90m, an average annual speed of 9,2m/s and an energy density equal to 1956W/m². Finally, the readings and calculations support the ecological hypothesis of the windy corridor predicted in this site in the Laghouat region, which is considered unprofitable, in terms of potential and energy.

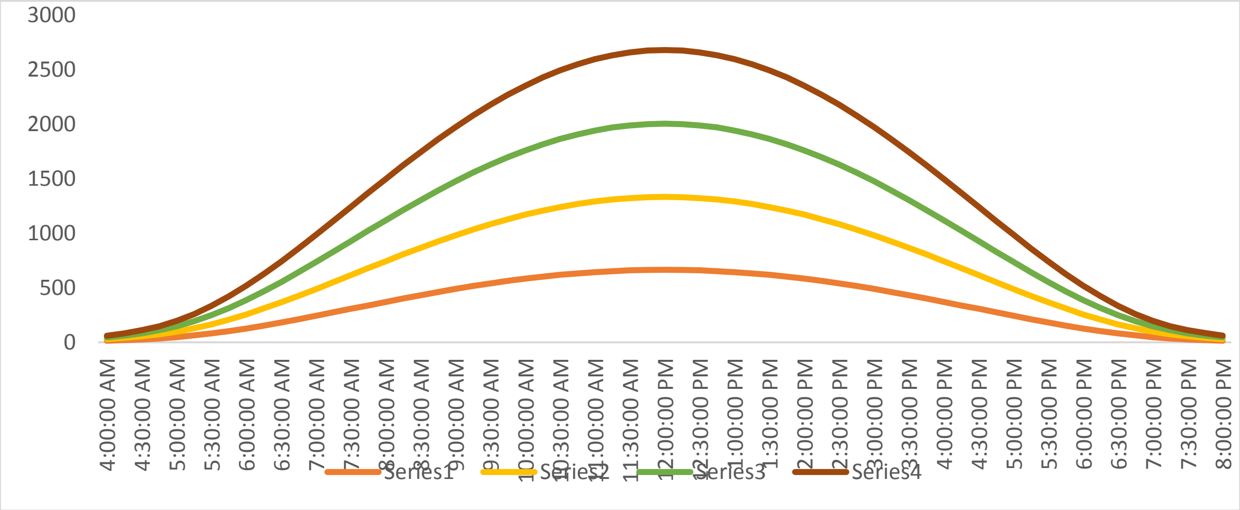
This study will obviously make it possible to propose a new vision of the planning of energy resources in the Algerian network of the region [65].The results of this analysis show that the site of Elkhneg has a significant renewable energy potential, solar and wind, which can contribute to the production of a large part of the regional energy. Therefore, this region is favorable to the hybrid exploitation of this type of energy.

The application of the designed hybrid model makes it possible to quantify and estimate the improved production of the plant already installed. The hybrid system has added a markedly affected improvement on the amount of power produced and on the continuity of service, which can increase the quality of the energy produced and the reliability of the electrical network [65].As perspectives and to accomplish this work, we advise to do:

- A detailed study of the techno-economic type, which focuses on the calculation of the cost installations, yield and cost of KWh produced.
- Look for the wind deposit of new underestimated sites in the region such as Elproduced
- Study the implementation of a wind or hybrid power plant in the region by Hassi R'mel.
- Apply advanced optimization methods to achieve new grid integration techniques [65].

Curve representations for 2023 and each season

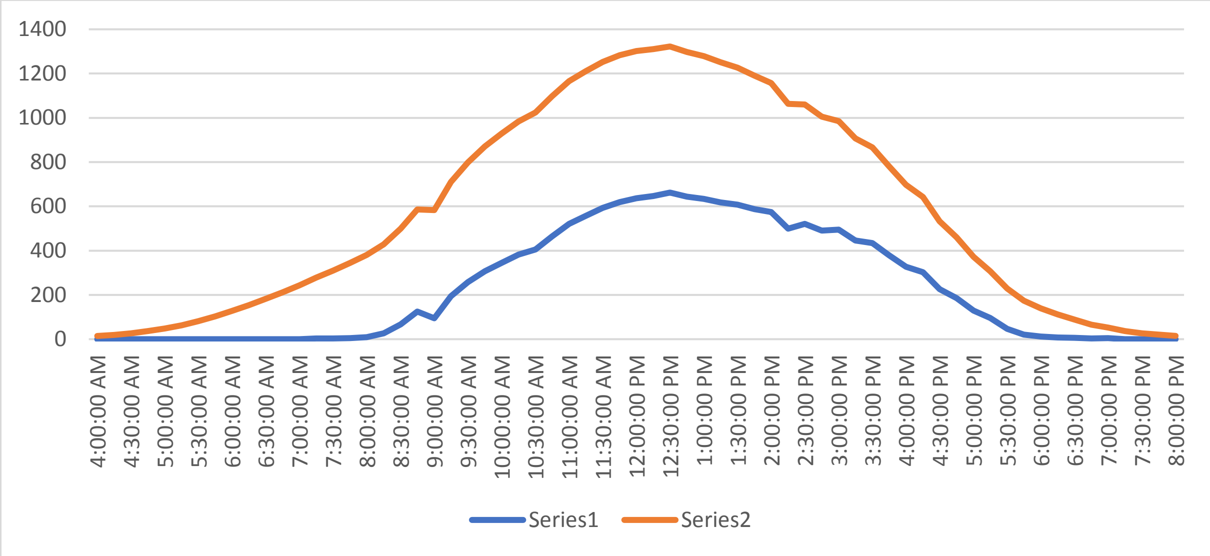
1



"The accuracy of data is crucial in analyzing solar radiation curves, as it contributes to higher precision and more reliable results. It is important to note that the impact of factors that affect radiation, such as heavy clouds or fog, can lead to deviations in the data and reduce its accuracy.

While my data may be slightly larger than yours due to the influence of those distorting factors, it should be noted that multiple factors affect solar radiation, including geographical location, time, and climate variations. As a result, variations in data may arise between different sources.

When analyzing solar radiation curves, it is important to exercise caution and take into account the differences resulting from these influencing factors and their impact on data accuracy. It may be necessary to apply statistical methods or corrections to compensate for these differences and achieve better accuracy in the analysis."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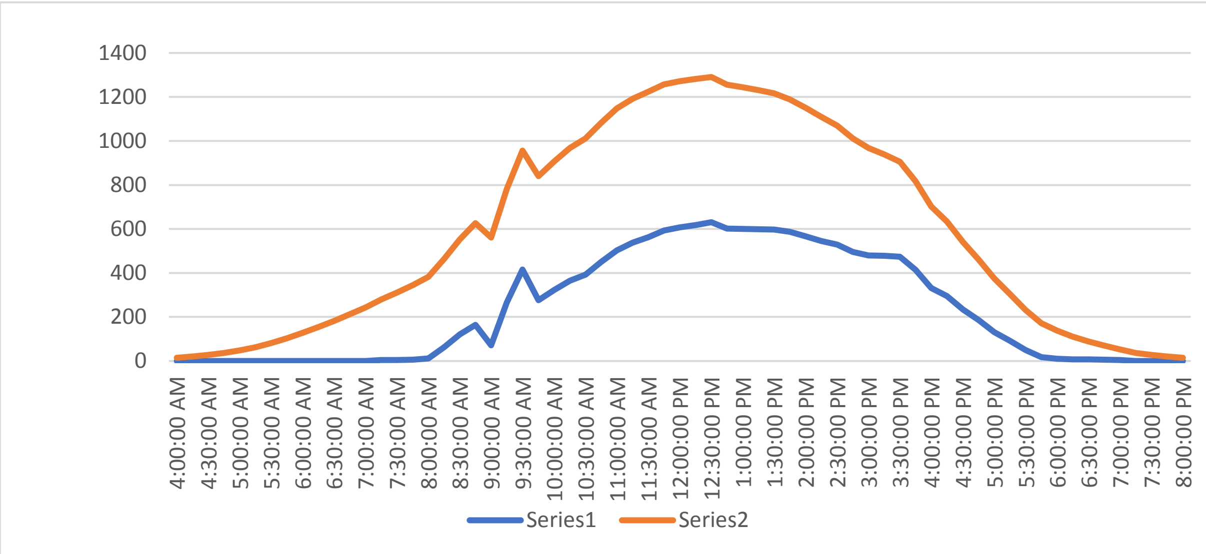
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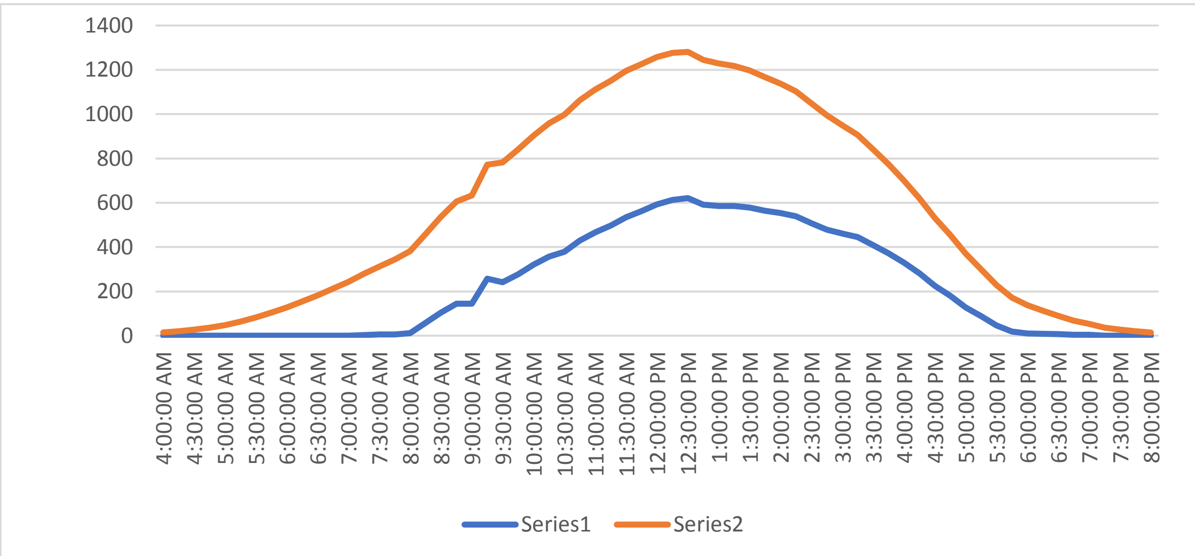
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The elevation of the sun above the Earth during summer occurs due to the Earth's tilt on its axis. The Earth revolves around the sun in an orbit tilted at an approximate angle of 23.5 degrees, which results in the occurrence of seasons. During summer, the sun is positioned more directly above the equator (the Earth's major orbit).

When it is summer in the hemisphere where the North Pole is located, the axis of the Earth is tilted more towards the sun, which means that the sun's rays reach the Earth's surface at a steeper angle. This results in the sun hanging higher in the sky for a longer period, providing more light and heat during the daytime in summer.

On the other hand, during winter, the Earth's axis is tilted away from the sun at a smaller angle. As a result, the elevation of the sun above the horizon is lower, and the sun's rays reach the Earth's surface at a lower angle as well. This means that the sun spends less time in the sky, resulting in less illumination and warmth during winter.

These variations in the sun's elevation and the angles of radiation have an impact on temperatures, the length of daylight and nighttime hours in each season, and contribute to the seasonal changes we experience throughout the year.

1. Spring:

In spring, solar radiation gradually increases as we approach the summer season. The length of daylight gradually increases, and the difference between daytime and nighttime hours decreases. The increased solar radiation during this time of the year results in more energy and heat being delivered to the Earth.

2. Summer:

In summer, the sun reaches its highest point in the sky in the Northern Hemisphere. Sun rays are more direct and reach the Earth at a larger angle, leading to an increased amount of solar radiation and energy reaching the Earth's surface. The summer day is longer than any other season due to the extended daylight hours.

3. Autumn:

In autumn, the sun begins to lower on the horizon, resulting in reduced exposure to solar radiation due to the Earth's tilt on its axis. The length of daylight decreases, and daytime and nighttime hours become equal by the end of the autumn season.

4. Winter:

In winter, the Earth's tilt on its axis positions it farther away from the sun, resulting in an increased distance between the sun and the highest point in the sky. Solar radiation decreases, and the day is shorter during the winter season.

The solar radiation profile from sunrise to sunset provides us with a comprehensive view of the variation in radiation throughout the day. We can observe an increase in solar radiance during the early morning hours reaching its zenith at midday". where the solar radiation is most intense. Then, the radiance gradually decreases towards sunset.

The intensity of solar radiation can be influenced by various factors such as weather changes, clouds, and surrounding terrain. The solar radiation profile reflects the interaction of the sun with the local environment and weather conditions at your specific location.

The solar radiation profile is a valuable tool for understanding and analyzing available solar energy throughout the day and can aid in the design and optimization of solar-powered systems and applications.

The slight difference between the actual radiation curve and the ideal curve, which takes into account factors like attenuation and clouds, suggests that your values are still relatively close to reality despite the lack of complete accuracy in the calculations. This variation could be due to additional unforeseen factors or local environmental conditions affecting the received radiation at your specific location. You can utilize this information to improve the accuracy of future calculations by adjusting the parameters used to achieve a closer match with the ideal curve.

Conclusion

Energy, through its triple economic, environmental and social impact, is at the heart of the issue of sustainable development. Renewable energy is the lifeline for the world in the future, as it is non-polluting and inexhaustible.

Algeria can get enough solar energy to meet its energy needs in particular for sustainable development, agriculture and export to Europe. Algeria can also become a model for other countries thanks to the surface and solar potential, its desert.

The photovoltaic (PV) effect is one way harnessing energy by converting the energy of photons into electricity solar cells.

Solar energy applications for various industrial and optical purposes seek increasing its efficiency by increasing the intensity of the solar radiation falling on it.

The wind potential of the Oued M'Zi site is very important for strengthening the production of electricity in the willaya of Laghouat.

Wind turbines are a source of energy production which in certain cases represents one of the most appropriate solutions.

The solar chimney offers a promising solution for solar energy generation electricity, due to the simplicity of the principle of operation and the low cost that it provides technology.In addition, Algeria must properly prepare for its energy transition, first through a consumption model based on energy saving and energy efficiency, and then through an energy transition model based on diversification of energy sources.

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