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Evaluation of concentrating solar power production capacity in the Algerian energy mix.

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Thanks

In the name of Allah, the Most Merciful, the Most Gracious; all praise belongs to Him for His continuous blessings upon us throughout our life. Our faith in Him kept us strong in tough times, and His guidance led us from one success to another. Thank you, Allah.

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Abbreviations

AHP.	Analytic Hierarchy Process.
BWM.	Best Worst Method.
Cons.	Consumption.
CSP.	Concentrated Solar Power.
DNI.	Direct Normal Irradiance.
Elec.	Electricity.
EQW.	EQual Weighted.
HTF.	Heat Transfer Fluid.
LCOE.	Levelized Cost of Electricity.
LFC.	Linear Fresnel Collector.
NREL.	National Renewable Energy Laboratory.
NREP.	National Renewable Energy Program.
PAPG.	Pole-Adrar- Power-Grid.
PNERA.	National Renewable Energy Programme in Algeria.
Prod.	Production.
PTC.	Parabolic Trough Collector.
PV.	Photovoltaic.
PVGIS.	Photovoltaic Geographical Information System.
RE.	Renewable Energy.
SAM.	System Advisor Model.
SM.	Solar Multiple.
TES.	Thermal Energy Storage.
TMY.	Typical Meteorological Year.

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Abstract

This study focuses on the integration of Concentrating Solar Power (CSP) into the Algerian power mix, which is predominantly reliant on conventional electricity generation fueled by natural gas. The objective is to increase the share of renewable energy, particularly CSP, in the national power production mix. The study proposes three scenarios based on CSP integration, with an objective of achieving an 8% share in the park, equivalent to 2000 MW. The methodology involves spatially distributing electricity demand by region, considering population density and technical parameters. The feasibility of installing CSP plant is then assessed based on three test; the first one is namely energy balance, which is developed in this study. The second and the third tests are land suitability and technical functionality of CSP. The installation capacity and performance factor are analyzed using the System Advisor Model (SAM). The results demonstrate the significant contribution of CSP plants, for each scenario where its contribution is more attractive in the third scenario with a maximum share equivalent to 20 projects distributed in ten regions. Tamanrasset region achieving the highest annual electrical output reached 383.163 GWh and capacity factor of 43.7%. The findings emphasize the potential of CSP in the height scenario that reached an annual electrical output of 9.3 TWh present approximately the half of national electrical energy demand in the residential sector (24.95 TWh). This research provides valuable insights for policymakers, energy planners, and stakeholders involved in shaping Algeria's energy mix with targets to enhance energy security, reduce carbon emissions, and stimulate economic growth in Algeria.

Keywords: Concentrating Solar Power (CSP), energy mix in Algeria, Electrical Power, scenarios, SAM.

Résumé

Cette étude se concentre sur l'intégration de l'Énergie Solaire Concentrée (CSP) dans le mix énergétique algérien, qui dépend principalement de la production d'électricité conventionnelle alimentée par le gaz naturel. L'objectif est d'augmenter la part des énergies renouvelables, en particulier le CSP, dans le mix national de production d'électricité. L'étude propose trois scénarios d'intégration du CSP, avec pour objectif d'atteindre une part de 8% dans le parc, soit l'équivalent de 2000 MW. La méthodologie consiste à répartir spatialement la demande d'électricité par région, en tenant compte de la densité de population et des paramètres techniques. La faisabilité de l'installation d'une centrale CSP est ensuite évaluée sur la base de trois tests ; le premier est appelé bilan énergétique, qui est développé dans cette étude. Les deuxièmes et troisièmes tests portent sur la pertinence des terrains et la fonctionnalité technique du CSP. La capacité d'installation et le facteur de performance sont analysés à l'aide du modèle d'analyse du système (SAM). Les résultats démontrent la contribution significative des centrales CSP, pour chaque scénario, où sa contribution est plus attractive dans le troisième scénario avec une part maximale équivalente à 20 projets répartis dans dix régions. La région de Tamanrasset atteint la plus haute production annuelle d'électricité, atteignant 383,163 GWh et un facteur de capacité de 43,7%. Les résultats soulignent le potentiel du CSP dans le scénario le plus élevé, qui atteint une production annuelle d'électricité de 9,3 TWh, représentant environ la moitié de la demande nationale d'énergie électrique dans le secteur résidentiel (24,95 TWh). Cette recherche fournit des informations précieuses pour les décideurs politiques, les planificateurs énergétiques et les parties prenantes impliquées dans la définition du mix énergétique de l'Algérie, avec pour objectifs d'améliorer la sécurité énergétique, de réduire les émissions de carbone et de stimuler la croissance économique en Algérie.

Mots-clés : Énergie Solaire Concentrée (CSP), mix énergétique en Algérie, électricité, scénarios, SAM.

ملخص

تركز هذه الدراسة على دمج الطاقة الشمسية المركزة (CSP) في مزيج الطاقة الجزائري، والذي يعتمد في الغالب على توليد الكهرباء التقليدي الذي يعمل بالغاز الطبيعي. الهدف هو زيادة حصة الطاقة المتجددة ، ولا سيما الطاقة الشمسية المركزة ، في مزيج إنتاج الطاقة الوطني. تقترح الدراسة ثلاثة سيناريوهات تستند إلى تكامل الطاقة الشمسية المركزة ، بهدف تحقيق حصة 8٪ ، أي ما يعادل 2000 ميغاواط. تتضمن المنهجية التوزيع المكاني للطلب على الكهرباء حسب المنطقة ، مع مراعاة الكثافة السكانية والمعايير الفنية. يتم بعد ذلك تقييم جدوى تركيب محطة الطاقة الشمسية المركزة على أساس ثلاثة اختبارات ؛ الأول هو توازن الطاقة ، والذي تم تطويره في هذه الدراسة. الاختبار الثاني والثالث هما مدى ملائمة الأرض والوظيفة الفنية لمحطة الطاقة الشمسية المركزة. يتم تحليل قدرة التثبيت وعامل الأداء باستخدام نموذج مستشار النظام .(SAM) توضح النتائج المساهمة الكبيرة لمحطات الطاقة الشمسية المركزة ، لكل سيناريو حيث تكون مساهمتها أكثر جاذبية في السيناريو الثالث مع حصة قصوى تعادل 20 مشروعًا موزعة في عشر مناطق. منطقة تمنراست تحقق أعلى إنتاج سنوي للكهرباء بلغ 383.163 جيجاواط ساعة وعامل قدرة 43.7٪. تؤكد النتائج على إمكانات الطاقة الشمسية المركزة في سيناريو الارتفاع الذي وصل إلى ناتج كهربائي سنوي قدره 9.3 تيراواط ساعة يمثل ما يقرب من نصف الطلب الوطني على الطاقة الكهربائية في القطاع السكني (24.95 تيراواط ساعة). يوفر هذا البحث رؤى قيمة لواضعي السياسات ومخططي الطاقة وأصحاب المصلحة المشاركين في تشكيل مزيج الطاقة في الجزائر مع أهداف لتعزيز أمن الطاقة وتقليل انبعاثات الكربون وتحفيز النمو الاقتصادي في الجزائر.

الكلمات المفتاحية: الطاقة الشمسية المركزة (CSP)، مزيج الطاقة في الجزائر، الطاقة الكهربائية، السيناريوهات، SAM.

General introduction

General introduction

The world's energy demand is increasing rapidly due to economic and population growth [1], primarily driven by non-renewable fossil fuels. This reliance on fossil fuels has negative environmental consequences due to greenhouse gas emissions. In Algeria, the government is actively exploring renewable energy sources, including Concentrating Solar Power (CSP), which concentrates sunlight to generate electricity. Evaluating the potential production capacity of CSP in Algeria is essential to determine its viability and identify suitable development areas. Factors such as land availability, solar resources, technical and economic feasibility, and competitiveness with other energy sources must be considered. The research aims to achieve the specified target of 2000MW of CSP solar energy production in ten preferred locations in Algeria using three scenarios. This evaluation will be conducted using the System Advisor Mode (SAM) software developed by NREL, comparing it with Algeria's total energy consumption in 2022. The research is organized into three chapters, covering the energy mix in Algeria, energy sources, production locations, the national program for renewable energy development, and the characteristics of CSP power stations the first chapter gives a description of electrical energy park in Algeria and the Algerian energy sources as well as the spatial locations of energy production. In addition, Algerian electricity network and the National Program for the Development of Renewable Energy are detailed. At the last section of this chapter, the principal components of CSP power plants and its technical characteristics are given.

The first chapter gives a description of electrical energy park in Algeria and the Algerian energy sources as well as the spatial locations of energy production. In addition, Algerian electricity network and the National Program for the Development of Renewable Energy are detailed. At the last section of this chapter, the principal components of CSP power plants and its technical character risticsare given.

In the second chapter, we will present the working methodology for simulating a 100 MW PTC station in a different location in the territory of Algeria. The scenarios (low, medium, high) are explained. And the electric energy balance in the regions, which includes the consumption and production of electric energy in the regions, as well as the demand for energy. Next, we define the station based on the difference between production and consumption, as well as solar radiation levels. We assign a certain number of regions to each scenario based on their proportion.

The SAM simulation system for modeling simulation will be defined as the best program among others by describing the system and identifying its capabilities and areas of use.

General introduction:

In the final chapter, we aim to present a comprehensive assessment and feasibility analysis of CSP deployment in three different scenarios (low, medium, high), highlighting a comparison of performance between CSP plants across Algeria.

Moreover, the study explores the possibility of implementing concentrated solar power plants in the proposed area, taking into account various parameters such as gross and net electric power generation, tier one losses, energy utilization factor, and annual water consumption.

The last section of the study presents detailed results related to the monthly thermal energy transfer from the solar field to the energy mass, in addition to the hourly thermal energy dynamics within the storage system. This analysis focuses on four representative days, with particular emphasis on the Tamanrasset region.

Chapter 1: Algerian Energy Mix & Concentrated Solar Power System

Chapter 1: Algerian energy mix and concentrated solar power system.

1.1 Introduction:

Algeria is a country rich in renewable energy sources, with a diverse mix of solar, wind, hydro, and geothermal energy resources. The Algerian government has been actively promoting the development of renewable energy since the late 1990, with a focus on increasing the share of renewable energy in the country's energy mix. One of the most promising renewable energy sources is concentrated solar power (CSP), which has the potential to contribute significantly to the country's energy needs.

This study aims to evaluate the potential of CSP in Algeria by analyzing its current energy mix, identifying the challenges and opportunities for CSP deployment, and assessing its economic and environmental benefits. In this chapter, we will discuss and clarify the following points: energy mix, electric energy mix in Algeria, sites for electric energy production in Algeria, the electric grid, the national program for renewable energy in Algeria, and an overview of concentrated solar energy.

1.2 Energy mix:

The energy mix refers to the combination of different sources of energy used to meet the energy needs of a particular country or region [1].These energy sources can include fossil fuels like coal, oil, and natural gas, renewable energy sources like solar, wind, hydro, and geothermal power, and nuclear energy [2].The exact makeup of the energy mix can vary depending on factors like geography, climate, availability of resources, and government policies [3].The energy mix is an important consideration for energy planners, policymakers, and stakeholders in ensuring energy security, reducing greenhouse gas emissions, and transitioning to a sustainable energy future [4].

1.3 Mix of electrical energy in Algeria:

Algeria's energy mix is dominated by fossil fuels, with natural gas and oil accounting for the majority of its energy consumption [5].However, the country has been investing in renewable energy sources in recent years to diversify its energy mix and reduce its dependence on fossil fuels[6] [7].

In terms of electricity generation, Algeria has a mix of thermal power plants, hydroelectric power plants, and renewable energy sources[2].According to the International Energy Agency (IEA), in 2021, natural gas accounted in Algeria for around 97.69% of the country's electricity generation, while hydroelectric power accounted for 0.84% and other renewable (mainly wind and solar) accounted for 1.47% [8-11].Algeria has set a target of generating 27% of its electricity from renewable sources by 2030 [6].Note the two figures below figure1.1andfigure 1.2.

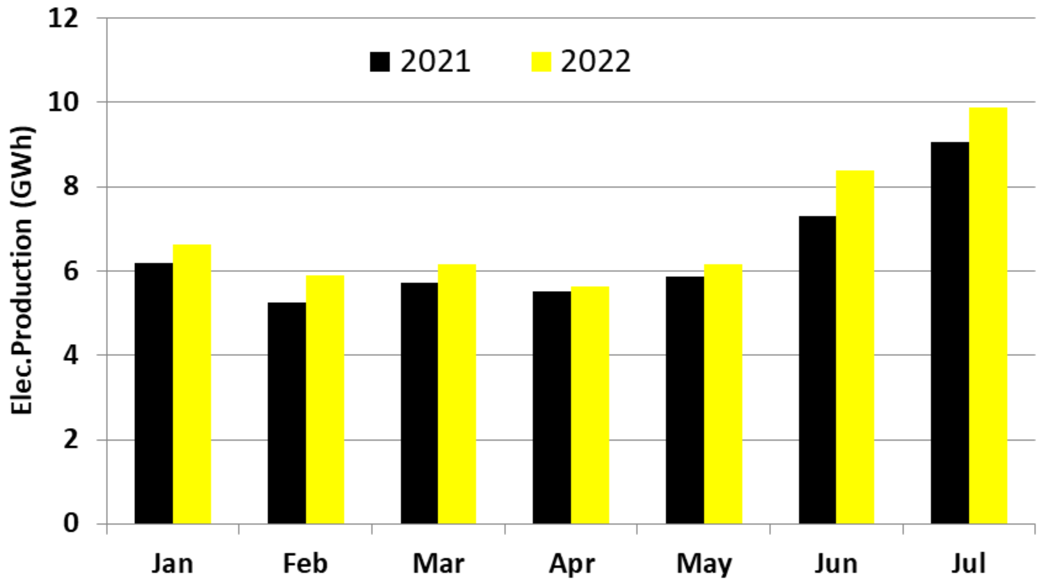


Figure 1.1: Evolution of electricity production [12].

In Figure 1.1, this represents the evolution of electricity production in Algeria from January to July between 2021 and 2022. Where we notice a significant increase in production for the year 2022 compared to 2021, in addition, we can also note that production rises to the highest value in the month of July in two years.

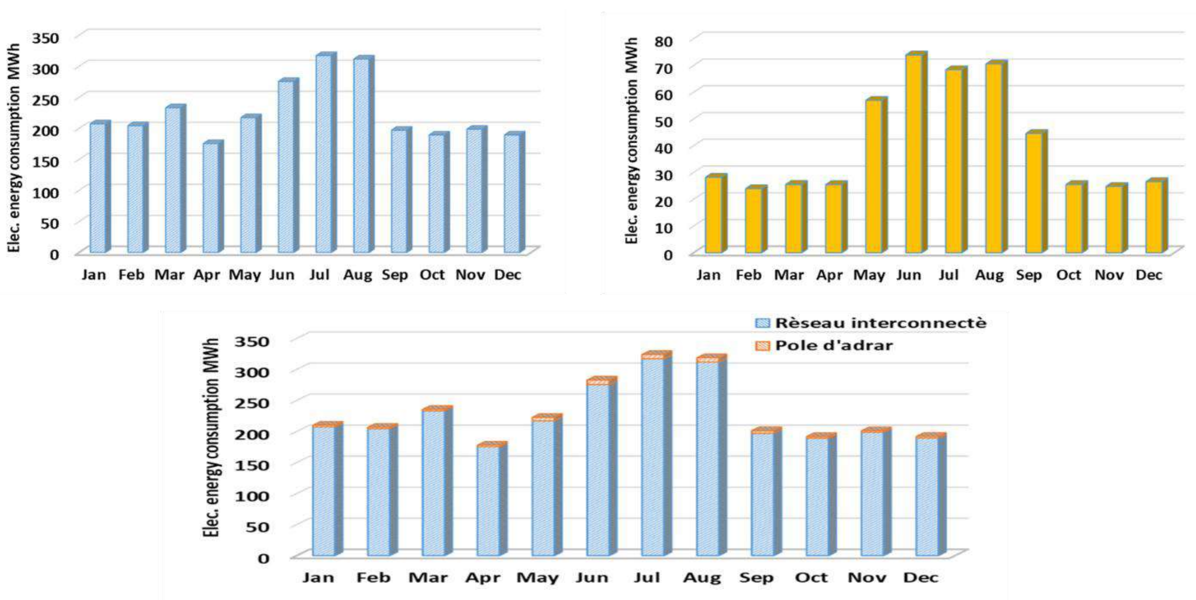


Figure1.2 : Total electrical energy consumption of interconnected Network and Adrar pole Network [12].

Figure 1.2, represents Algeria's electricity consumption on the two networks, the interconnection network and the Adrar pole, for the year 2022. We note that the electricity consumption of the interconnection network is very high compared to the Adrar pole, where the interconnection network records more than 300000 MWh, while the Adrar pole records more than 7000 MWh. We also note that electricity consumption rises in the summer months and decreases in the winter months.

1.4 Energy production in Algeria:

Energy production locations in Algeria refer to the various areas within Algeria where energy is produced, including oil, natural gas, and renewable sources such as solar and wind [2] [13].Algeria is a major producer of oil and gas, and much of its energy production occurs in the southern regions of the country, particularly in the Sahara Desert [14]. The country is also home to several large solar power projects [15],including the Hassi R'Mel integrated solar combined-cycle power plant and many other PV projects across the Algerian territory [16], which are helping to expand Algeria's renewable energy capacity [17]. The characteristics of the Algerian electric power generation and the major regions of electrical power production are given in figures1.3, figures 1.4 and figure 1.5.

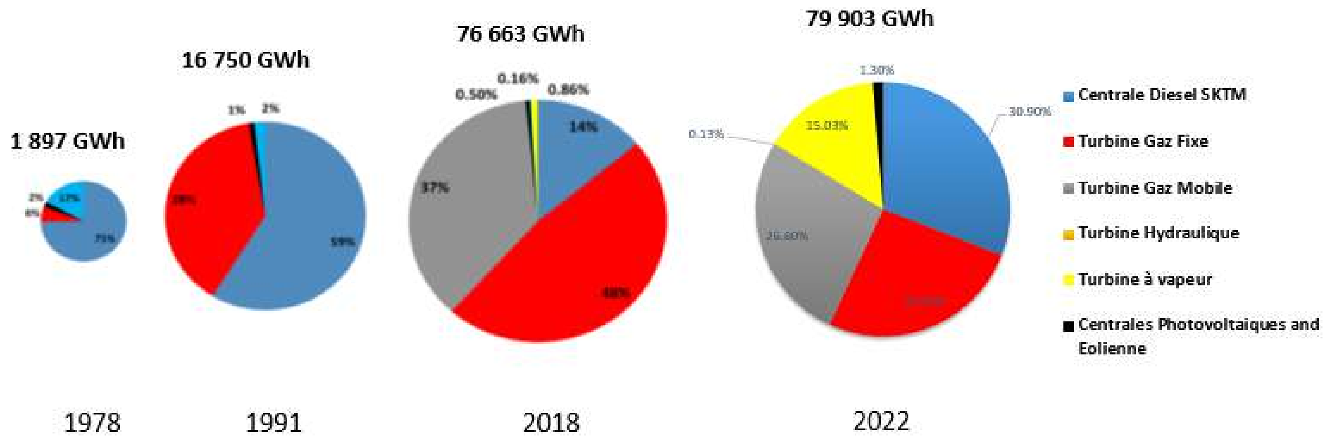
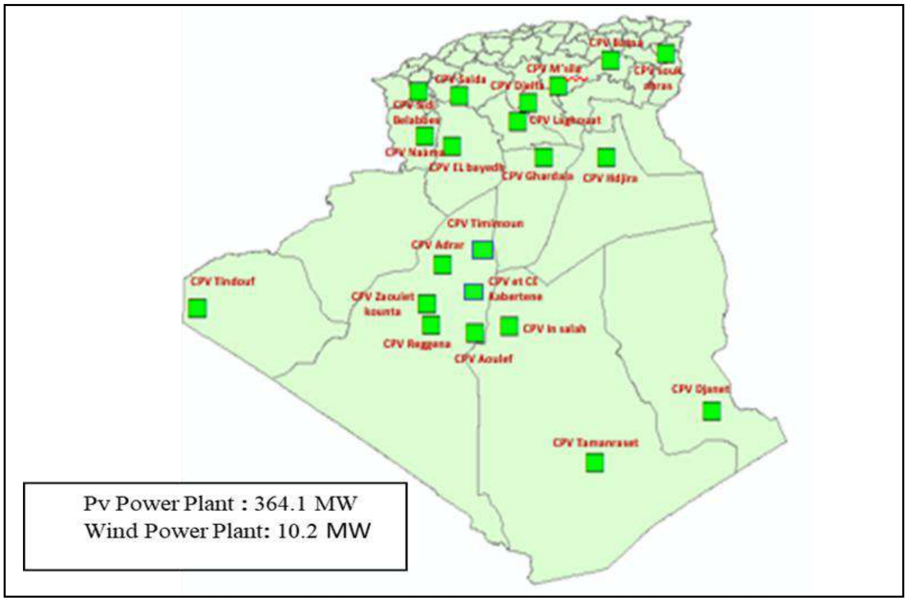


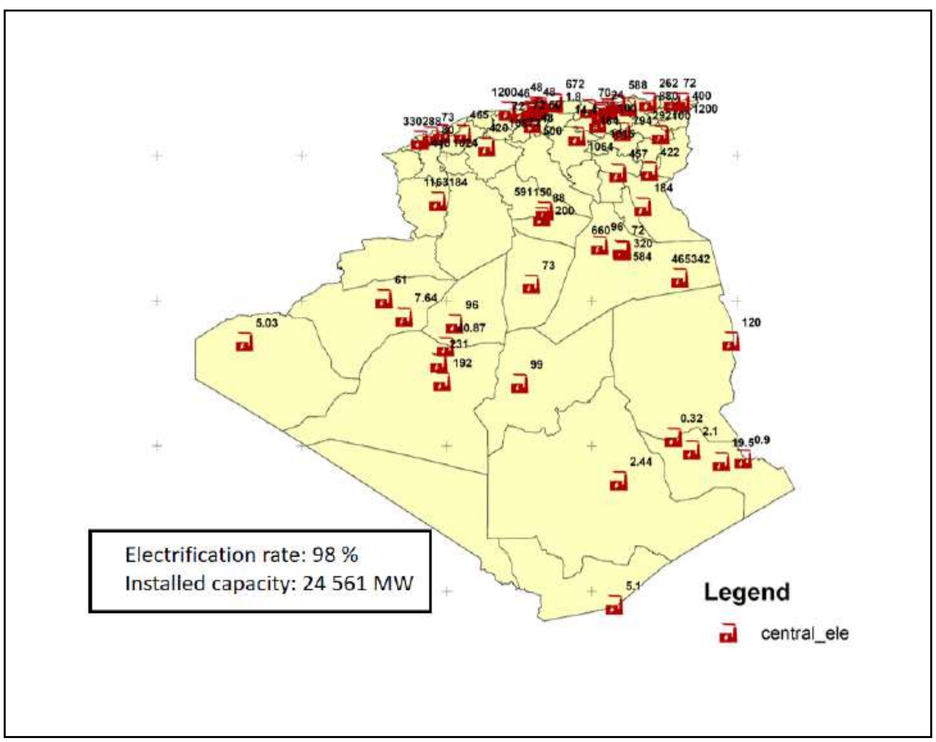
Figure1.3: Energy generation evolution in Algeria [18].

Figure 1.3 represents the evolution of power generation in Algeria from 1978 to 2022 in GWh, where we can see a significant development in the quantity of production in 2022, as well as an increase in the types of electricity generation stations. This indicates a significant division in the production stations compared to previous years. Production has reached 79,903 GWh.



Figures1.4: Photovoltaic and wind power plants.

Figure 1.4 represents a map of solar and wind power generation stations in Algeria, where we can observe their significant distribution in the central and southern regions of Algeria, unlike the north. This is due to the availability of vast open areas and high solar radiation. We also notice the presence of one wind power generation station located in the Kabertene region, which is part of the Adrar province.



Figures 1.5: Map of Conventional electricity generation stations.

Figure 1.5 represents a map of conventional electricity generation stations in Algeria, where we can observe the significant distribution of the stations in the north and central regions of Algeria. In the south, we notice the availability of a large number of Diesel SKTM production stations.

1.5 Power grid in Algeria:

Algeria has an extensive power grid more than 400293 km of power grid lines, and it serves almost the entire population [19] [11].Recently the coverage capacity of the electrical installations networking Algeria is 98 % and more than 80 % in the north of the country [20]. Power grids have three main functions: power generation, transmission and distribution, as shown in (Figure 1.6) [21].

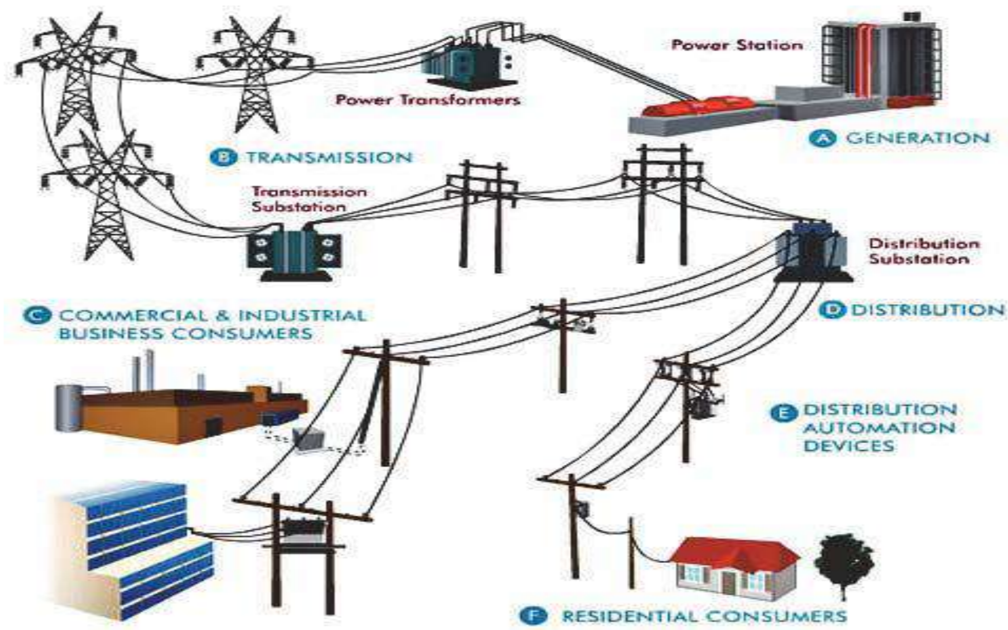


Figure 1.6: The Electric Grid [14].

In 2021, the Electricity Transmission Network 32720 km, and an Installed Capacity reached 24561MW where the moment national electric power company Sonelgaz still the monopolist of this sector in Algeria [19] [11]. The electricity grid in Algeria is sub-divided into transmission grids (High voltage) and distribution grids (Medium and low voltage) [22].

In the Algerian context, the electricity company SONELGAZ has utilized photovoltaic-based solar energy to provide power to isolated villages and remote households in southern Algeria [13]. The National Interconnected Network (NIR): spread over the north of the country and covering the Bechar, HassiMessaoud, HassiR'Mel and Ghardaia regions, it is powered by 40 power stations connected through a transmission network in 220 kV and 400 kV, enabling the transfer of energy from the production sites to the consumption centers[19] [22]. The Figure 1.7 shows a map of the Algerian electrical grid and the park exploited in 2021.

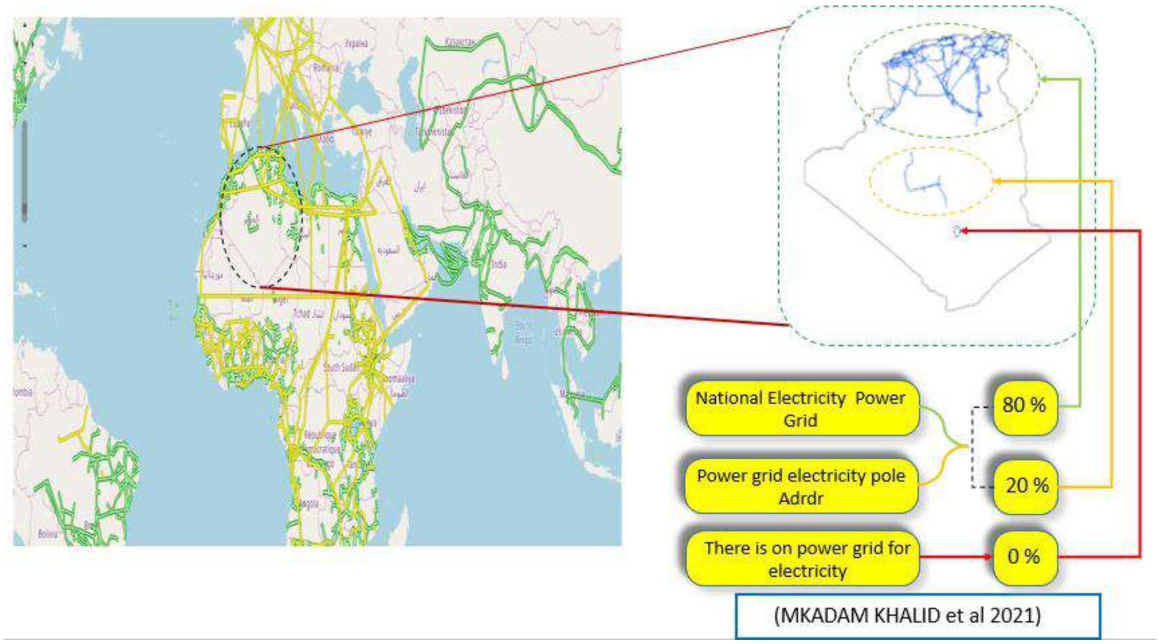


Figure 1.7: Map of the Algerian electrical grid (with own processing).

Figure 1.7 represents the distribution of the electricity network in Algeria, where we observe its division into two parts: one in the north, which contains the largest network in Algeria and another in the Adrar pole and the far south of Algeria where there is no electricity network. Therefore, they are supplied with diesel stations and solar power stations.

1.6 The national renewable energy program in Algeria (PNER):

Algeria has implemented policies and funding initiatives for renewable energy (RE) development since 1998. The country's geographic location offers promising RE sources, including hydropower, wind, geothermal, biomass, and solar energy [23].Algeria has started its green energy dynamic with the launch of an ambitious for National Renewable Energy Program (PNER) is a government initiative aimed at developing the country's renewable energy Algeria's and increasing the share of renewable energy in its energy mix, the program also aims to achieve energy efficiency as it will reduce carbon dioxide emissions in Algeria. The program was launched in 2011 and revised in 2015. The program sets a target of producing 22,000 MW of renewable energy by 2030, which is equivalent to 27% of the country's electricity demand [24] [25] [19].

Program National includes several initiatives, such as the development of photovoltaic, wind power and concentrated solar power technology. It also includes measures to improve energy efficiency and reduce energy consumption in the industrial, commercial and residential sectors [19].Notice the shape below figure 1.8 under the renewable energy program.

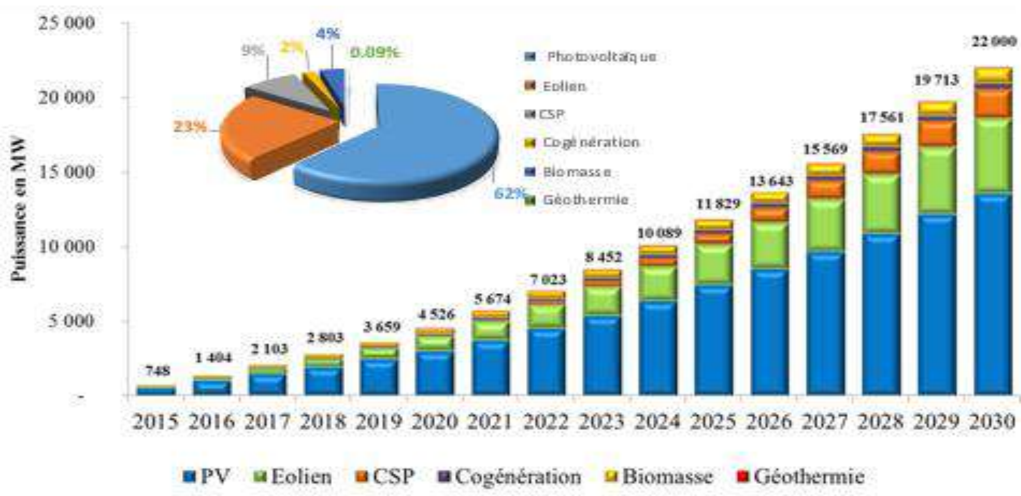


Figure 1.8: Division of program by technology sector PNER in Algeria [26] [27](with own processing).

Algeria aims to become a significant contributor to the generation of electricity from Concentrated Solar Power (CSP) technology, which is expected to play a crucial role in achieving long-term sustainability [28] [29] [30]**.** Broken down by technology in the table 1.1.

Table 1.1: Program of Renewable Energy created by Sonelgaz 2015-2030 [29]**.**

Unite : MW	**First phase**	**Second phase**	TOTAL
	2015-2020	2021-2030	
Photovoltaïque	3 000	10 575	13 575
Eolien	1 010	4 000	5 010
CSP	-	2000	2 000
Cogeneration	150	250	400
Biomasse	360	640	1 000
Géothermie	5	10	15
TOTAL	**4 525**	**17 475**	**22 000**

In Figure 1.8 and Table 1.1, we can see the National Renewable Energy Development Program in Algeria from 2015 to 2030, where it aims to reach 22,000 MW. We also notice that the percentage of CSP in this program is 9%, which is equivalent to 2000 MW.

PNER is an important step towards achieving Algeria's energy transition goals and reducing its dependence on fossil fuels. It also presents opportunities for economic development, job creation and technology transfer in the renewable energy sector.

1.7 Renewable energy (RE):

Renewable energy (RE) refers to energy sources that can be replenished naturally and are not finite [19].They are often referred to as "clean energy" because they produce little to no greenhouse gases or other harmful pollutants during their operation [31].Examples of renewable energy sources include solar, wind, hydro, geothermal, and biomass [32].

Solar energy involves harnessing the power of the sun by using solar panels to convert sunlight into electricity [33].Wind energy involves using wind turbines to generate electricity by converting the kinetic energy of wind into electrical energy [34].Hydroelectric power uses water turbines to generate electricity from the kinetic energy of flowing water [35].Geothermal energy harnesses the heat from the earth's core to generate electricity [36].Biomass energy involves using organic matter such as wood or agricultural waste to generate electricity [37].

Renewable energy is considered an important part of the solution to climate change as it reduces reliance on fossil fuels and reduces greenhouse gas emissions [38].While renewable energy sources require some initial investment, they are generally considered to be a more sustainable and cost-effective option in the long run [39].

Among the types of renewable energy, we will discuss in this memo concentrated solar energy, specifically with the identification of the equivalent basin.

1.8 Solar energy:

Solar energy refers to the energy derived from the radiation of the sun [40].It is a renewable and sustainable source of energy that has become increasingly popular due to its many benefits, including reducing greenhouse gas emissions and providing a cost-effective and reliable source of energy [19].There are two main ways to harness solar energy [41]:photovoltaic (PV) technology, which converts sunlight directly into electricity [42],and the second technology, which we are currently studying, is solar thermal energy, which uses the heat from the sun to generate electricity or provide heat for various applications [43].Solar energy has vast potential for powering homes, businesses, and industries, and is expected to play a significant role in the transition to a cleaner and more sustainable energy future [44] [45].

1.9 Overview of the CSP technologies:

There is a growing interest in finding sustainable alternative energy sources, particularly solar energy. Among the most promising solar technologies is Concentrated Solar Power (CSP), which has the potential to significantly reduce fossil fuel consumption and carbon dioxide emissions, leading to a revolutionary shift in the global energy landscape [46].

Concentrated Solar Power (CSP) is a relatively new technology with several advantages, such as integrated storage, high economic viability, and reduced greenhouse gas emissions [47]. CSP has demonstrated remarkable potential to fulfill a substantial portion of the global energy demand [48]. While simultaneously minimizing adverse impacts on the environment [49].

There are four main technologies of CSP technologies named as Parabolic Trough Collector (PTC) technology, Linear Fresnel Collector (LFC) technology, solar tower or central receiver technology, and parabolic dish or Sterling dish technology [50] [51]. The Parabolic Trough Collector is the most widely used and successful type of Concentrated Solar Power technology. Please refer to figure 1.9 for an illustration.

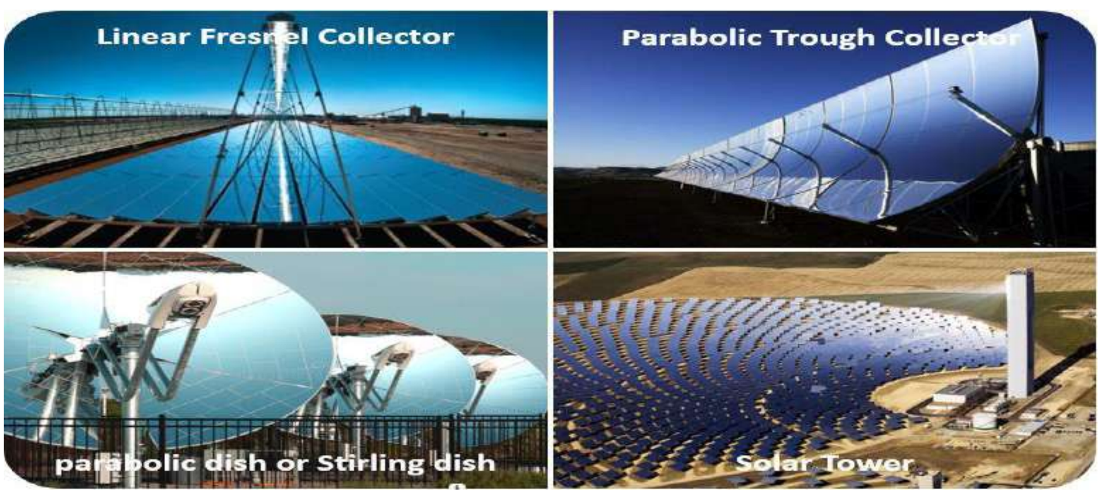


Figure 1.9: Concentrated Solar power (CSP) technologies [19].

This study is centered on the Parabolic Trough technology, a type of Concentrated Solar Power technology [52] [53]. It involves an analysis to determine the feasibility of implementing this technology in three different scenarios [18],which could be influenced by various factors such as location, climate conditions, and energy demand [36]. The three scenarios will be categorized as follows: low=50 MW, medium=100 MW and high=150 MW.

1.10 PTC-CSP Working principle and the thermal energy storage option:

Parabolic Trough Collector technology is composed of a set of parabolic reflectors that are arranged in parallel to form a solar field [19]. and of long, curved mirrors arranged in a line, concentrate solar radiation on pipes surface located at the mirrors' focal center [54]. and they also contain heat transfer fluid (HTF), and the reflectors used are usually coated with silver-coated acrylic[55]. In the Parabolic Trough Collector technology, sunlight is concentrated by a factor of approximately 70 to 80 times on the receiver pipes, which allows for operating temperatures to reach between 350 °C and 550 °C [19].The energy received by the Heat Transfer Fluid (HTF) is then transferred to water, which produces steam that can drive a conventional steam turbine for electricity generation [55].

To ensure continuous electricity generation during periods of low sunlight, such as at night or on overcast days, a storage system can be integrated into the plant. The use of thermal energy storage can improve the overall performance of the plant [56].Notice the shape below figure 1.10.

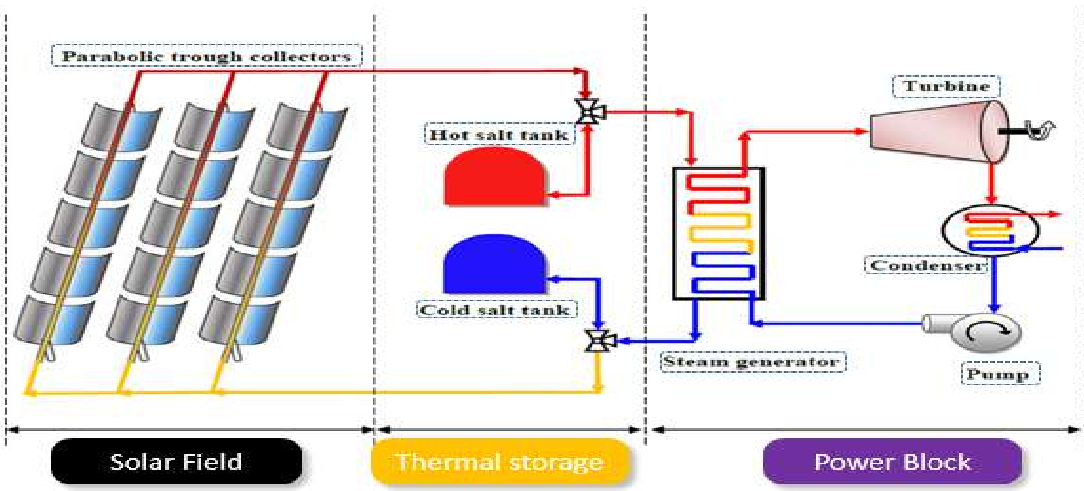


Figure 1.10: Parabolic trough system schematic [55](with own processing).

1.11 CONCLUSION:

We discussed the importance of energy in Algeria in this chapter, as well as the different types of renewable energy and their capabilities, especially solar thermal energy, which has the potential to replace a part of traditional energy production. We also focused on the development of Algeria's energy sector, the locations of production stations, and the various forms and applications of solar energy technology, which deepened our understanding of this technology and its potential as a source of renewable energy.

In the next chapter, we will examine the energy consumption in the different provinces of Algeria, and consider a hypothetical model of a 100 megawatt concentrated solar power plant (CSP) to determine its potential and effectiveness in the selected region.

Chapter 2: Methodology and Data Collection

2.1 Introduction:

Based on the overview of solar energy around the world, as one of the important resource in the future and the different technology used to convert the solar energy into electricity, in this chapter, we will address the presentation of the working methodology for simulations of a 100 MW PTC station in different site of Algeria territory.

Three different scenarios (low, medium, high) were proposed, based on the balance of electrical energy in the regions, which includes the difference between production and consumption of electrical energy in the same regions. Afterward, we classified the regions into regions with exceed power and others with deficit power based on the balance analysis, as well as the solar radiation levels for each one and degree of suitability land given in the literature. Additionally, we assign and number of project for each selected regions per scenario based on their percentage.

Finally, The SAM simulation system will be described and selected for CSP simulations as one of best program among others and identifying its potential and areas of use.

2.2 Methodology:

2.2.1Developed model scenarios:

In the context of evaluating the potential of concentrating solar power (CSP) in the national territory and its influences on the Algerian energy mix, a developed model is used to simulate different scenarios for the deployment of CSP technology. The model takes into account various factors such as solar radiation potential, land availability, electricity demand, and existing energy infrastructure [57].

Different scenarios are developed based on varying assumptions regarding the adoption rate of CSP technology. The model simulates the energy output of each scenario over a set period, allowing for a comparison of the potential benefits and drawbacks of each.

This approach allows for a comprehensive analysis of the potential of CSP technology in the Algerian energy mix and can inform policy decisions regarding the future development of renewable energy infrastructure in the country.

The updated renewable energy program consists of installing a renewable power capacity of around 22 000 MW by 2030 for the domestic market, with maintaining the option of exportation as a strategic objective, if market conditions allow [27].

The (CSP) has been programmed in the renewable energy program to reach 2 000 MW by 2030, which represents a rate of 8% of the actual electrical installed capacity which reached 24.9GW in 2021 [27]. We propose three scenarios with a final objective of 2000 MW from CSP corresponding to a rate of 8%. The first scenario (Low) with a rate of 2%, the second scenario (Medium) with a rate of 5% and finally the third scenario (High) with a rate of 8%.

For each scenario we will identify the regions for installing CSP projects, the number of projects by region and the capacity of each project. For this reason, an electrical energy balance is developed based on the actual capacity installed for each region and electrical energy needs in the same location.

2.2.2. Electrical energy demand by regions:

Electrical energy demands by region present an important factor to evaluate the necessity of installing a concentrating solar power plant in the same region. Soit is crucial to examine the electrical energy demand by region to determine the feasibility of solar power to fulfill that demand. Electrical energy demand by region pertains to the electrical energy required for the residential sector which is directly conducted by the population density for each specific administrative region (wilaya)in Algeria. Based on the annual rapports of the ministry of energy (named Bilan énergétique national), the Algerian Electrical net consumption reached 84 240 GWh, where the final electrical energy consumption equal to 63 442 GWh [58].

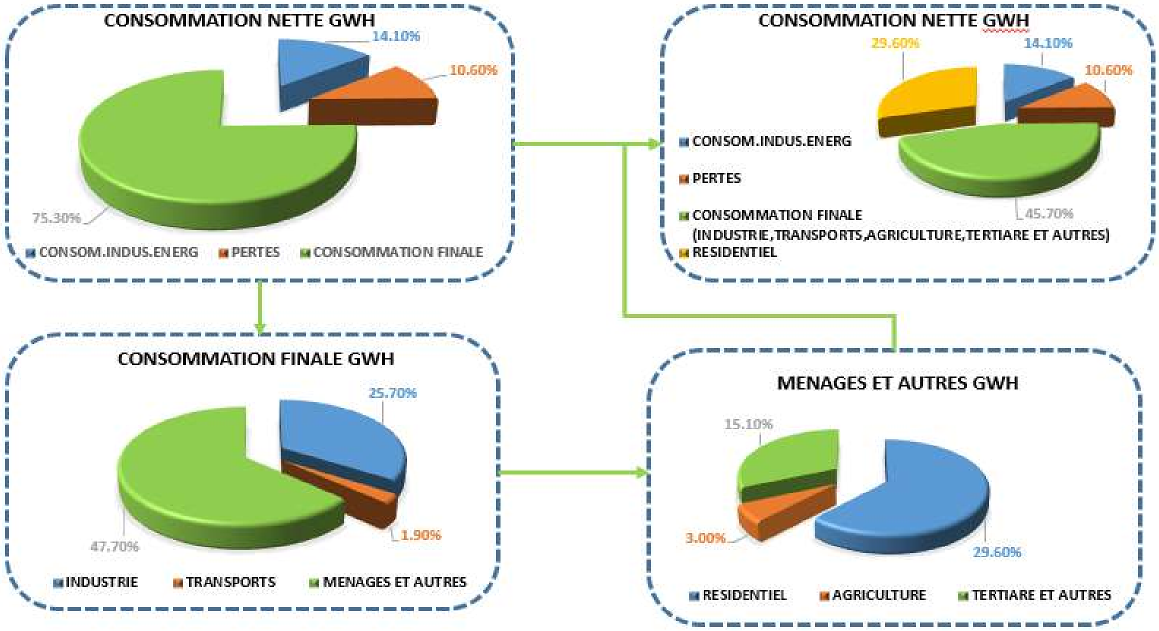


Figure 2.1: Net and final electrical energy consumption in Algeria by sector [58].

As detailed in Figure 2.1, the residential sector presents 29.6% of the electrical net energy consumption equivalent to 24 954 GWh [11]. We observe that the largest consumption corresponds to the residential sector, unlike the other sectors.

The second step consists to determine the electricity consumption for each region. The repartition of electrical requirements was determined based on the population percentage given by the National Office of Statistics (ONS) for 2021and the total electricity consumption for the residential sector from the ministry of energy. So the total consumption is weighted by the population percentage of each region to obtain the consumption rate for each Wilaya.

The results are given in figure 2.2, where the 58 region of Algeria territory are ranked from the highest (Algeria) to the lowest (BordjBadjiMokhtar) consumption, corresponding to population number of 4050000, 25000respectively. The consumption is divided into five intervals with a range of 300 GWh for each. As detailed in figure2.2, the Algeria region present the very high consumption equal to 2000 GWh. For more details, see Annex (A.1).

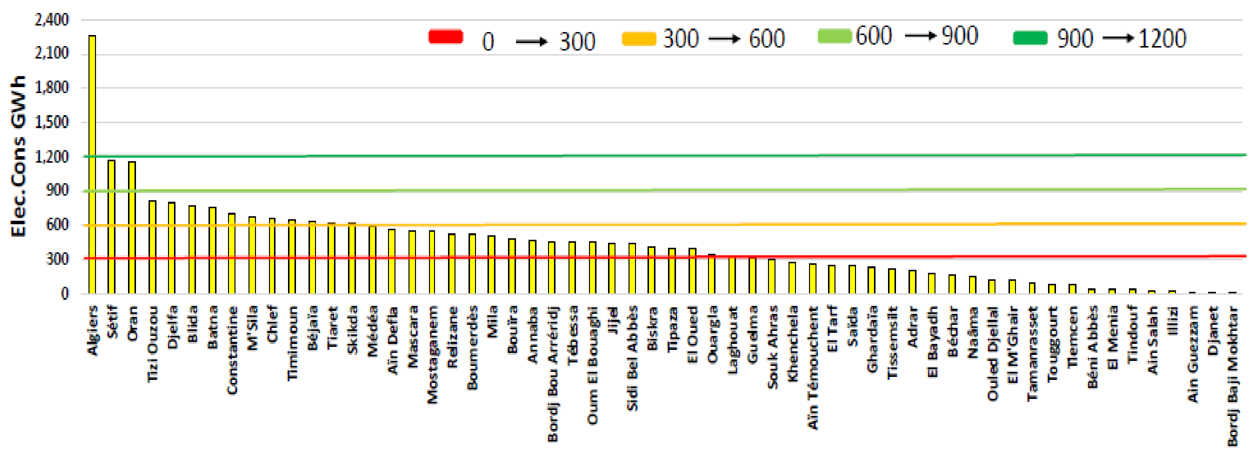


Figure 2.2: Ranking of electrical energy consumption by regions.

In the other hand, it is important to give a detailed evolution of the electrical consumption by month. For this reason, an important works of data collections analysis and processing were presented. The Operating System website (OS) as filial of Sonelgaz, is consulted to downloading the daily load profile as (.xls) data (courbe de charge) for 365 days of the year 2022. Tow loads profile are available Interconnected Network and Adrar pole Network (named RI and Adrar Pole). As presented in figure 2.3.

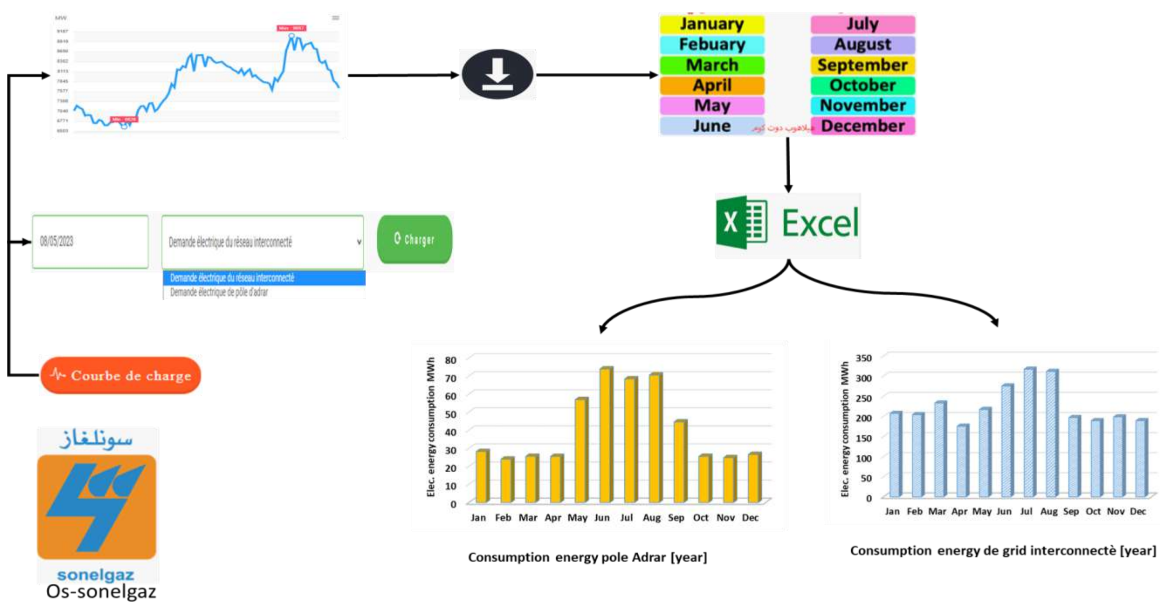


Figure 2.3: Electrical Profiles load in Algeria for 2022.

2.2.3Energyproduction by regions:

In order to evaluated the electrical energy production by region we are based the existing of the power plant (conventional (TG, TV, CC and Diesel) and renewable (PV and Wind)) in the region and the capacity installed. The repartition of electrical production was determined based on the installed capacity percentage calculated from the distributed capacity at the actual existing electric park (developed in this study). The total electricity production is given from the ministry of energy rapports where 79 903 GWh from conventional plants and 608 GWh from PV and Wind parks, where the total production equal to 80 511 GWh [58].Sothis total production then weighted by the installed capacity percentage of each region to obtain the production rate for each Wilaya, see Annex (A.1).

2.2.3.1Locations of power plants in Algeria:

In order to determine the capacity by region, it is firstly necessary to determine the locations of each power station, more than 60 plants (for conventional plants) and (22 for PV and wind). Based on the plant name and by using Open Infrastructure Map and Google Map Satellite Image, the geographical coordinates (longitude and latitude) are identified and confirmed. The capacity of each plant is given from Sonelgaz website. All the data are structured and saved as Excel file. Using ArcGIS software, especially X-Y tools to generate map of the generation stations as shown in the figure 2.4.

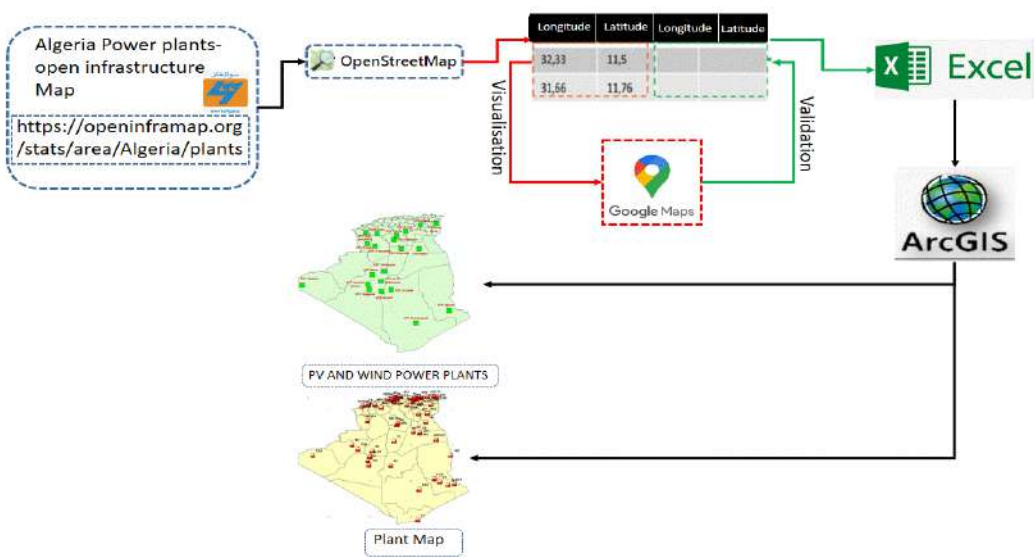


Figure 2.4: Electrical power plant maps: conventional power plant and solar power plant.

The production of regions was divided into 5 categories. That rely solely on electricity imports. The second category ranges from 1 to 1250 GWh in production. The third category ranges from 1250 to 2500 GWh. The fourth category ranges from 2500 to 3750 GWh. The fifth category ranges from 3750 to 5000 GWh. There are two regions with significant production exceeding 5000 GWh, namely Ouargla and Jijel.see figure 2.5. See Annex (A.1).

The detailed production by region are given in figure 2.5, where the 58 region of Algeria territory are ranked from the highest (Ouargla) to the lowest (Ghardaîa) production, corresponding to installed capacity 3291 MW, 1.1 MW (only PV) respectively. It is important to indicate that 17 regions have not any type of power plants, which corresponding to the first category zero-production regions (see figure 2.5). The productions divided into four intervals with a range of 1250 GWh for each, as detailed in figure 2.5. There are two regions with significant production reached more than 5000GWh, namely Ouargla and Jijel with 10659.85 GWh and 6831.71 GWh respectively. For more detail see Annex (A.1).

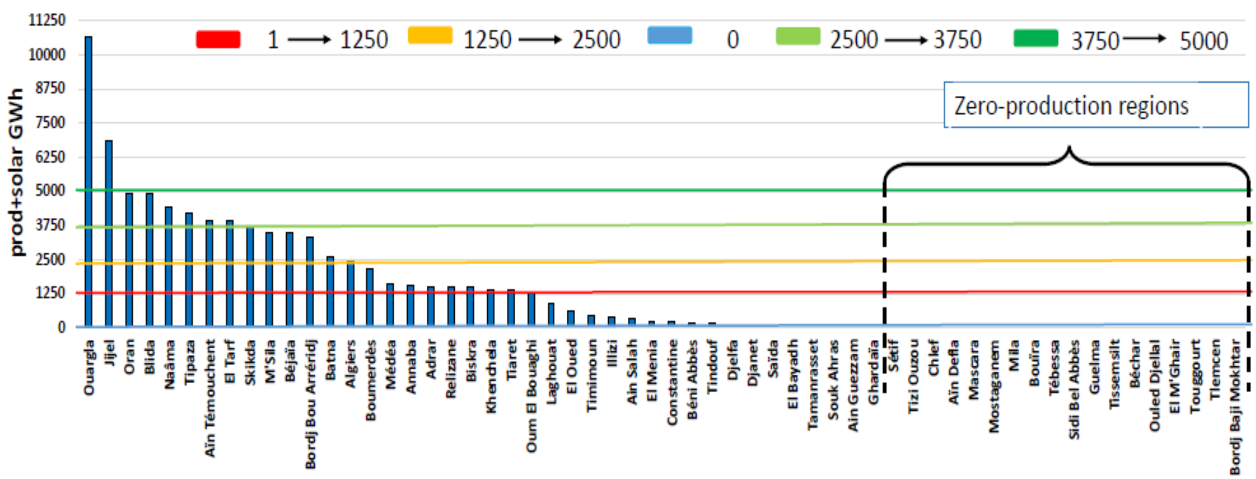


Figure 2.5: Ranking of electrical energy production by regions.

2.2.4 Electrical energy balance by region:

The electricity balance by regions defined based on the difference between the electrical energy consumption of the region and the electrical energy production at the same region during a given period of one year. So the balance is applied for 58 regions (wilays) in Algeria.

When evaluating the production capacity of concentrating solar power in the Algerian energy mix, the electricity balance by region involves calculating all state-owned electricity sources and electricity consumption by the population within each province or region. It also evaluates how much electricity energy demand can be met in each province or region through concentrating solar power.

Electricity production refers to all electricity that enters the province or region, such as solar panels or conventional power generators, while electricity output refers to all electricity energy that consumed in the residential sector in the same province or region. The calculation is based on Excel data sheet (given in Annex (A.1)) and the results are given in the figure 2.6.

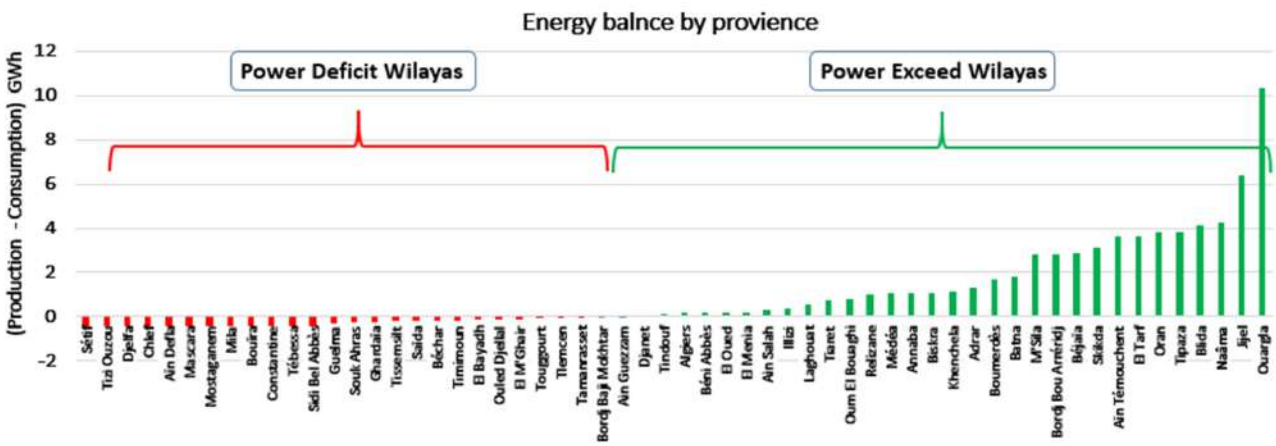


Figure 2.6: Electrical energy balance by region.

For the deficit wilaya, we have exactly 27 regions, ranked from the low (AinGuezzam) to the lowest (Setif) region as given in figure 2.7. The deficit wilaya are divided into three intervals with a range of 400 GWh for each. As detailed in figure 2.7, the Setif region present the very high needs equal to -1173.66 GWh. For more details, see Annex (A.1).

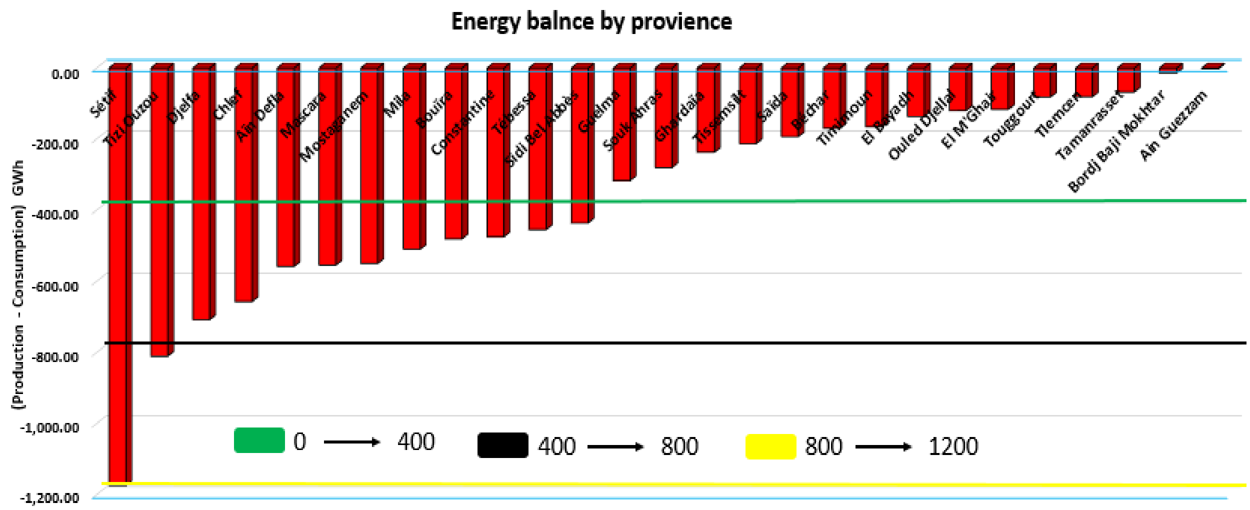


Figure2.7: Electrical energy Deficit by region

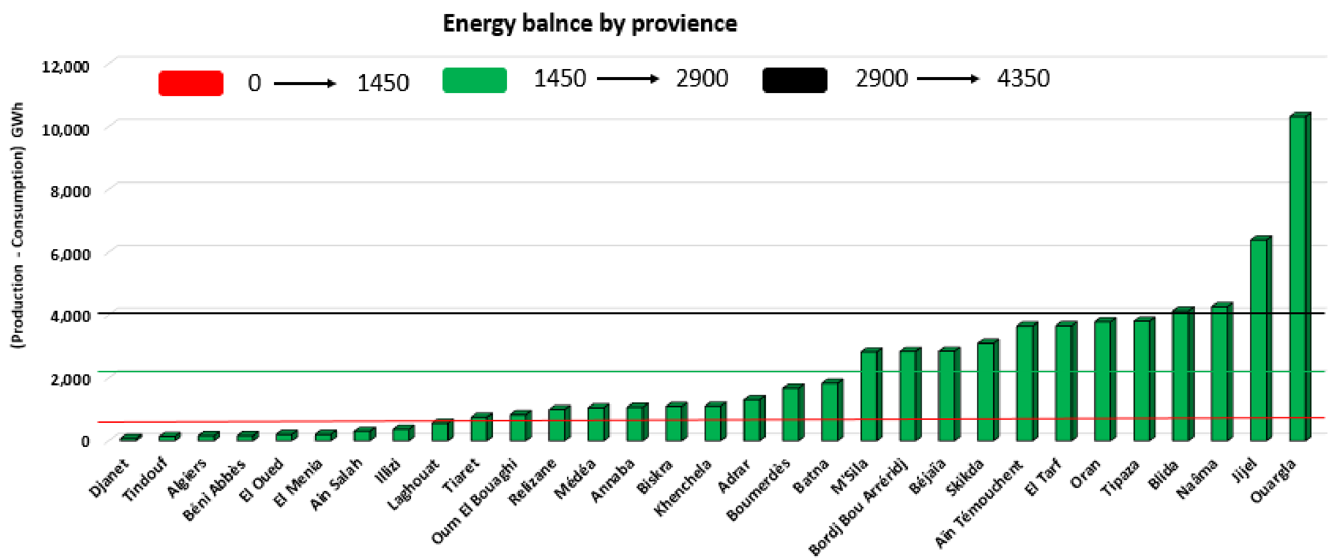


Figure2.8: Electrical energy exceed by region

For the exceed wilaya, we have exactly 31 regions, ranked from the high (Djanet) to the highest (Ouargla) region as given in figure 2.8. The exceed wilaya are divided into three intervals with a range of 1450 GWh for each. As detailed in figure 2.8, the Ouargla region present the very high production equal to 10 314,62GWh. For more details, see Annex (A.1).

Table 2.1: Division of Wilays according to Electrical Energy Balance.

Wilayas	Clase	Prod-Cons (GWh)	Wilays Code
Deficit	-3	-1200 à -800	19 , 15
	-2	-800 à -400	17 , 2 , 44 ,29 ,27 , 43 , 10 , 25 , 42 ,22
	-1	-400 à 0	24 , 41 , 47 , 38 , 20 , 8 , 49 , 32 , 51 , 57 , 55 , 13 , 11 , 50 , 54
Exceed	1	0 à 1450	56 , 37 , 16 , 52 , 39 , 58 , 53 , 33 , 3 , 14 , 4 , 48 , 26 , 23 , 7 , 40 , 1
	2	1450 à 2900	35 , 5 , 28 , 34 , 6
	3	2900 à 4350	21 , 46 , 36 , 31 , 42 , 9 , 45 , 18 , 30

2.2.5Site selection for CSP simulation:

Site selection for the CSP based power plant is a critical issue for the project developers and installers [59].Algeria's position in the Sun Belt area and its climatic features, which entail ample sunshine year-round, minimal humidity and rainfall, and vast tracts of flat, unoccupied land near transportation and power transmission networks, offer numerous benefits for harnessing Solar energy, including vast potential for generating power that surpasses the world's energy needs [20].

The process of selecting a suitable site for a parabolic trough concentrated Solar thermal power plant (PTCSTPP) is influenced by a multitude of factors, including environmental considerations, the availability of solar energy, supporting infrastructure, land and water resources, communication facilities, and social factors. This comprehensive site selection procedure takes into account all these parameters to ensure efficient power generation [59], yet the availability of good solar resources (DNI) is the utmost importance factor. In addition, proximity to road and power grid also the availability of land area and sunshine duration... etc. [60] [18]. According to literature, Gouareh et al performed an extensive investigation on solar technology, specifically concentrated solar power (CSP) in Algeria. They created a map indicating the most suitable locations for CSP installations in Algeria using a Multicriteria Decision Making Analysis through a GIS. Three scenarios were used in the study: the EQW scenario, which assigned equal weight to each criterion, disregarding their relative importance, and two other scenarios that utilized different MCDM techniques: the Analytic Hierarchy Process for the AHP scenario and the Best Worst Method for the BWM scenario. The study concluded that the

BWM scenario produced the best results, as depicted in Figure 2.9, when compared to the other two scenarios.

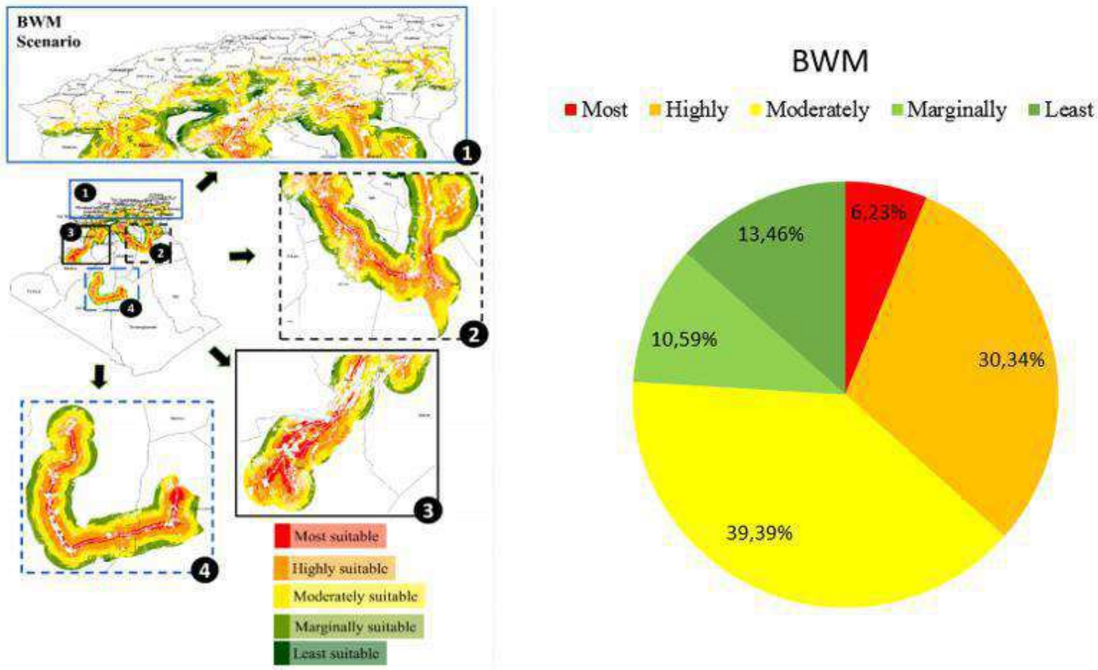


Figure 2.9: Final suitability map for CSP plants (BWM scenarios) [19] [18].

2.2.6Solar radiation (DNI):

Direct Normal Irradiance (DNI) is a measure of the amount of solar radiation received per unit area by a surface that is always held perpendicular to the sun's rays. DNI represents the amount of solar radiation that can be captured and concentrated by direct sunlight, making it particularly important for concentrating solar power (CSP) technologies, which require high levels of direct solar radiation to produce electricity efficiently.

DNI varies depending on factors such as time of day, season, location, and weather patterns, and it is typically measured in units of W/m^2. Accurate data on DNI is essential for developing efficient and effective CSP systems and for locating CSP plants in areas with the most favorable solar resource.

The direct normal irradiance (DNI) is synonymous with the direct beam radiation and it is measured by tracking the sun throughout the sky. In CSP applications, the DNI is important in determining the available solar energy. It is also for this reason that the collectors are designed to track the sun throughout the day. The annual DNI value will also greatly influence the Levelized Electricity

Cost (LEC). Based on the information presented here it can be seen that desert regions appear to provide the best resources for CSP implementation [18].

2.2.7Tes tanalysis of regions:

- **Test 01 :** DNI <1800

Based on Gouareh et al study, the minimum DNI requirement for CSP plants functionality required a DNI higher than 1800 kWh/m².year.for this reason a significant portion of Algeria's land territory was excluded [18]with an area of 57,504.149 km². These excluded areas are mainly located in the northern regions of the country, particularly in 15 provinces within the coastal regions, as illustrated in Figure.2.10

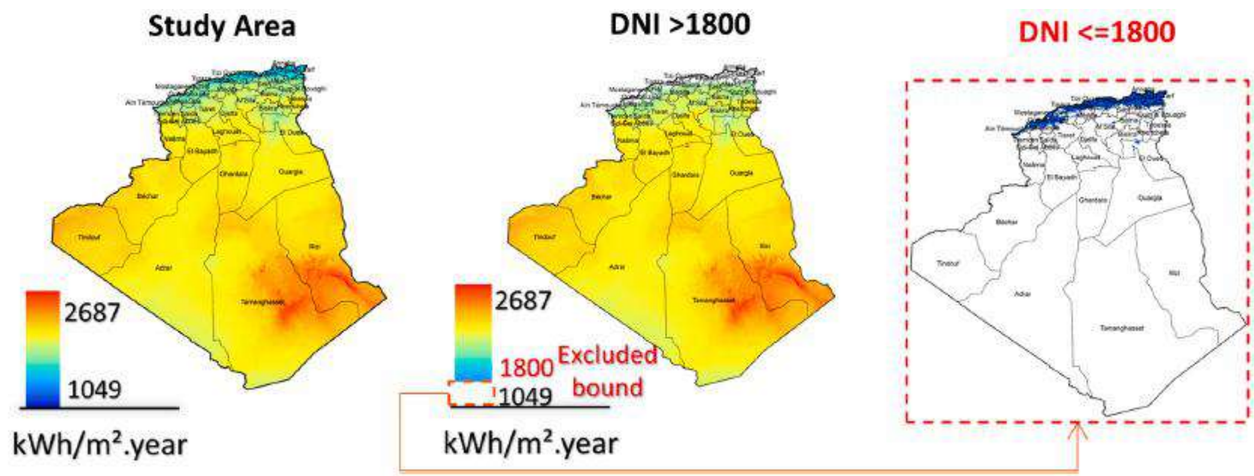


Figure2.10: Lands with DNI less than 1800 kWh/m².year [18].

By analyzing the figure 2.10 we excluded the regions where DNI <1800 kWh/m². year from the table 2.1 by crossing it. The table 2.2 shows the final results after applying the first test.

Table2.2: Exclusion regions with DNI <1800 kWh/m². year.

Clase	(Prod-Cons) in GWh	Code de wilayas concernées
-3	-1200 à -800'	19 , 15
-2	-800 à -400'	17 , 2 , 44 , 29 , 27 , 43 , 10 , 25 , 42 ,22
-1	-400 à 0'	24 , 41 , 47 , 38 , 20 , 8 , 49 , 32 , 51 , 57 , 55 , 13 , 11 , 50 , 54
1	0 à 1450	56 , 37 , 16 , 52 , 39 , 58 , 53 , 33 , 3 , 14 , 4 , 48 , 26 , 23 , 7 , 40 , 1
2	1450 à 2900	35 , 5 , 28 , 34 , 6
3	2900 à 4350	21 , 46 , 36 , 31 , 42 , 9 , 45 , 18 , 30

- **Test 02:** CSP site in Algeria:

Based on Gouareh et al study, the area shown in figure 2.9in white colorin the map, which make up 89% of the total area, indicate unsuitable locations where CSP plants are not feasible. The rest of the colors indicate the possibility lands with degree of suitability.

By applying the Test 2 the region with white colorin the mapare excluded from the table 2.2 by crossing it. The table 2.3 shows the final results after applying the second test.

Table2.3: Exclusion regions by applying test 1 and test 2.

Clase	(Prod-Cons) in GWh	Code de wilayas concernées
-3	-1200 à -800'	19 , 15
-2	-800 à -400'	17 , 2 , 44 , 29 , 27 , 43 , 10 , 25 , 42 ,22
-1	-400 à 0'	24 , 41 , 47 , 38 , 20 , 8 , 49 , 32 , 51 , 57 , 55 , 13 , 11 , 50 , 54
1	0 à 1450	56 , 37 , 16 , 52 , 39 , 58 , 53 , 33 , 3 , 14 , 4 , 48 , 26 , 23 , 7 , 40 , 1
2	1450 à 2900	35 , 5 , 28 , 34 , 6
3	2900 à 4350	21 , 46 , 36 , 31 , 42 , 9 , 45 , 18 , 30

2.1 Selection regions by scenario:

After examining all the regions based on solar radiation DNI (test 1) and the CSP suitability site (test 2) in Algeria. 17 regions (not crossed) are selected as possible for setting up CSP of 100MW unit plants. Based on the last test (energy balance as detailed before) and depending on the case of each region. we proceed to select the regions that meet these criteria and have the highest electricity demand. For the three scenarios (low, medium and height), as detailed below:

- In the first scenario, we select three regions.
- In the second scenario, we select four regions, including those from the first scenario.
- In the third scenario, we select three additional regions, in addition to those from the first and second scenarios. See to Table 2.4.

Table 2.4: The selected regions for each scenario.

	Scenerio	capacity MW	regions	The nomber of projects in regions
Low	2%	500	Djelfa,Tébessa,Saïda	Djelfa(2=100MW;100MW) Tèbessa(2=100MW;100MW) Saïda (1=100MW)
Medium	5%	500 + 750	Djelfa,Tébessa,Saïda Béchar,Timimoun,El Bayadh,Ouled Djellal	Djelfa(2=100MW;100MW) Tèbessa(2=100MW;100MW) Saïda(1=100MW) Bèchar(2=100MW;100MW) Timimoun(2=100MW;100MW) ElBayadh(2=100MW;100MW) ouled Djellal(2=100MW;50MW)
High	8%	500 +750 +750	Djelfa,Tébessa,Saïda Béchar,Timimoun,ElBayadh,Ouled Djellal El M'Ghair,Touggourt,Tamanrasset	Djelfa(2=100MW;100MW) Tèbessa(2=100MW;100MW) Saïda(1=100MW;100MW) Bèchar(2=100MW;100MW) Timimoun(2=100MW;100MW) ElBayadh(2=100MW;100MW) ouled Djellal(2=100MW;50MW;50MW) El M'Ghair(2=100MW;100MW) Tougourt(2=100MW;100MW) Tamanrasset(2=100MW;100MW)

After identifying the station number, capacity by region for each scenario a simulation software processing is necessary.

2.2.9 Software selection:

In this study, a 100 MW PTC-type CSP plant will be simulated under different climatic conditions at various sites (corresponding to the selected Wilayas) across Algeria. The simulation will be carried out using the System Advisor Model (SAM), which is a performance model developed by the National Renewable Energy Laboratory (NREL) [61]. The SAM software was chosen for PTC-CSP modeling due to its ability to provide detailed performance analysis from a complete system-level simulation perspective, availability of input datasets for plant component design parameters, and ability to run a large number of simulations using scripts and codes written in multiple programming languages to conduct parametric and sensitivity analyses [62].

Simulation of PTC systems using SAM software provides enormous information for the desired objective with minimum effort and cost. Unlike experimental studies, simulation does not include uncertainty but necessarily has assumptions and simplifications. Therefore, it gives us the possibility of testing the influence of several variables on system performance. Modeling and simulation of a PTC involves the generated electricity, electrical power output, and capacity factor analyses, among others. The results can be gathered and/or decoupled, analyzed, and presented separately, providing considerable convenience in results analyses and decision-making [19].

2.2.10Description of the system Advisor Model:

The System Advisor Model (SAM) is a computer program designed to assist decision-making processes in the renewable energy industry. It was developed by the National Renewable Energy Laboratory and can be used by project managers, engineers, incentive program designers, technology developers, and researchers [63]. The SAM program predicts performance and cost-of-energy estimates for grid-connected power projects based on installation and operating costs and system design parameters. The program provides three financial models: projects on the customer side of the utility meter, projects on the utility side of the meter, and no financial model [64] [59].

To create a SAM file, the user must first choose the technology and financing option for the project. The program will then automatically populate input variables with default values. The user must then provide information about the project's location and equipment, including photovoltaic modules, inverters, parabolic trough receivers and collectors, and bio power combustion systems. SAM includes several databases of performance data and coefficients for system components, and the user can simply choose an option from a list. For remaining input variables, default values can be used or chosen based on literature [63].Examples of input variables include operational parameters, the number of modules, tracking type, collector and receiver type, solar multiple, and storage and power block capacity for parabolic trough systems [64].the figure 2.11 present the SAM main window. See figure(2.11).

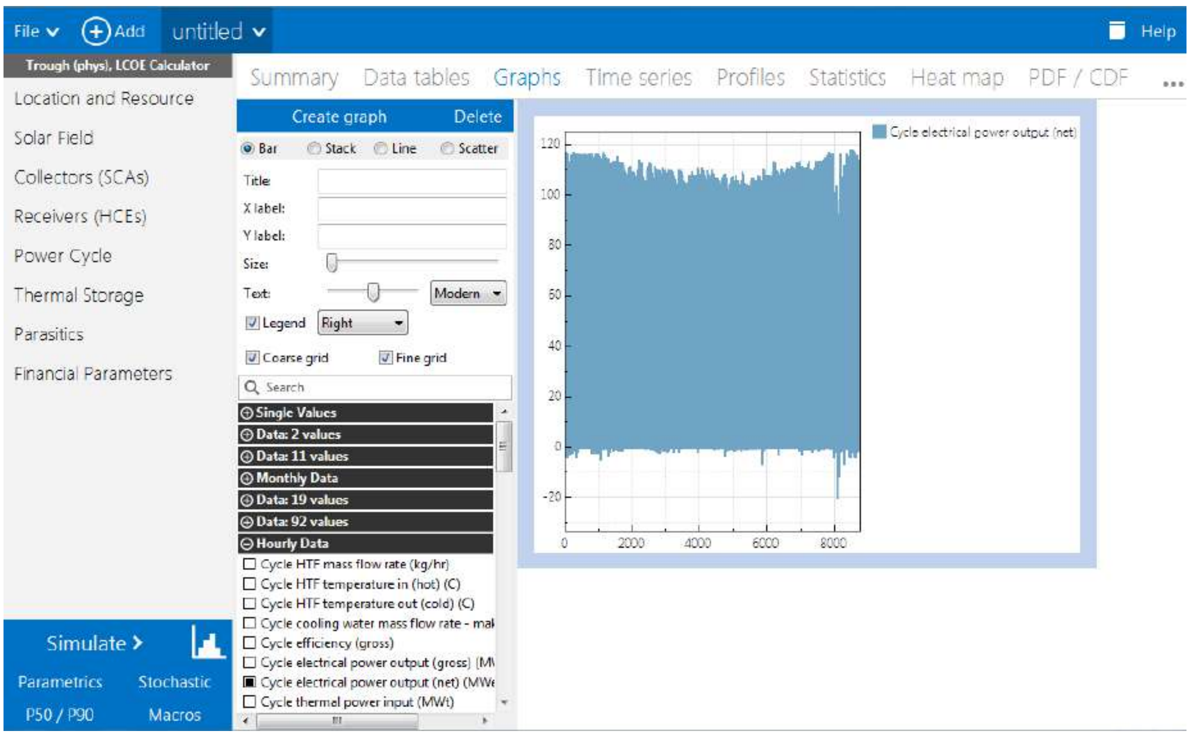


Figure 2.11: The SAM main window showing the results summary for PTC CSP power system.

The figure 2.12 presents the flow chart of a SAM simulation. Where the presented model includes sections permitting to estimate the electricity production. The parameters of each section is given as detailed table in Annex (A.2).

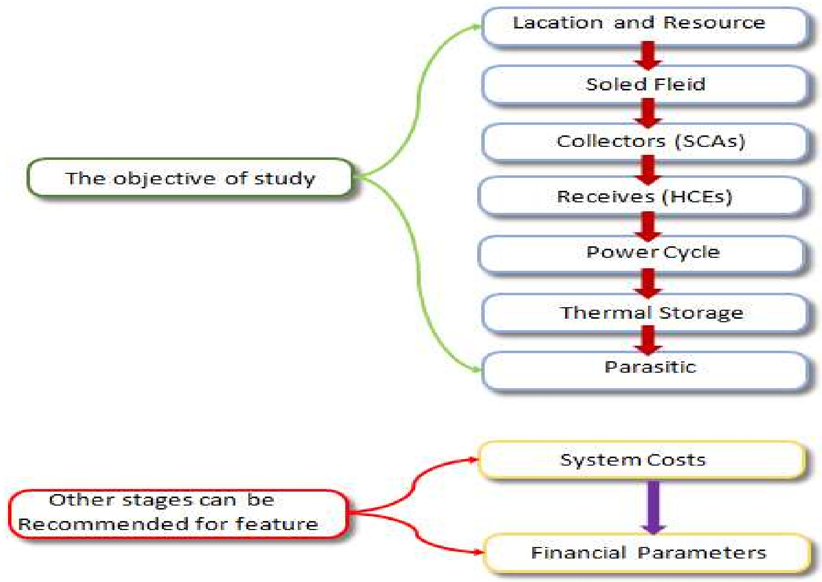


Figure 2.12: Flow chart of a SAM simulation, includes sections permitting to evaluate the electricity production [19].

To run the SAM model, you need to provide a weather file in one of three formats (TMY2, TMY3, or EPW) for your project location [59]. SAM includes a complete set of TMY2 files for US locations, and you can download weather files from the NREL weather file databases using a tool that uses a project site's address or geographic coordinates. You can also create weather files with your own weather data using another tool. After inputting variable values, you run simulations and examine the results. You may need to revise inputs and rerun the simulations until you have a confidence result [19].

SAM provides a range of visualization tools to present the modeling results, from tables showing single-value metrics like first-year annual production, to detailed annual cash flow and hourly performance data presented in tabular or graphical form [65]. The built-in graphing tool allows users to create custom graphs and examine the effect of changing input values using graph sliders without affecting the input pages. All tables and graphs can be exported in various formats for use in reports, presentations, or further analysis with other software [57].SAM also features a full-featured scripting language called LK, which can automate batch-processing simulations and perform complex analyses, as well as reading and writing data from files [64].see figure (2.12).

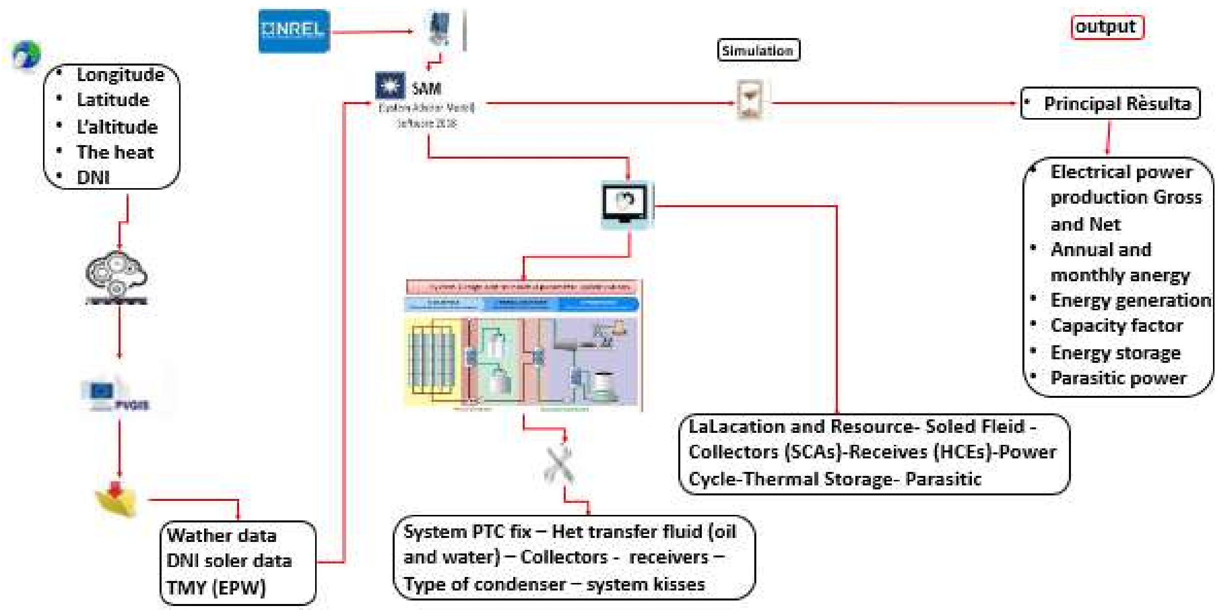


Figure 2.13: Schematic showing the simulation Sam method for a station CSP.

SAM is written in various programming languages, including SSC, C/C++, C#, Java, Windows, Python, LK, MATLAB, and other languages [18].This allows for flexibility in how the model is accessed and used by different users. Additionally, SAM provides a range of applications, including a desktop application with a user-friendly interface and extensive documentation, as well as a PDF output function for creating reports to share with project collaborators [66].The source code for SAM is also available on GitHub, which allows users to contribute their own models, explore the model algorithms, and help fix bugs [65].figure (2.13).

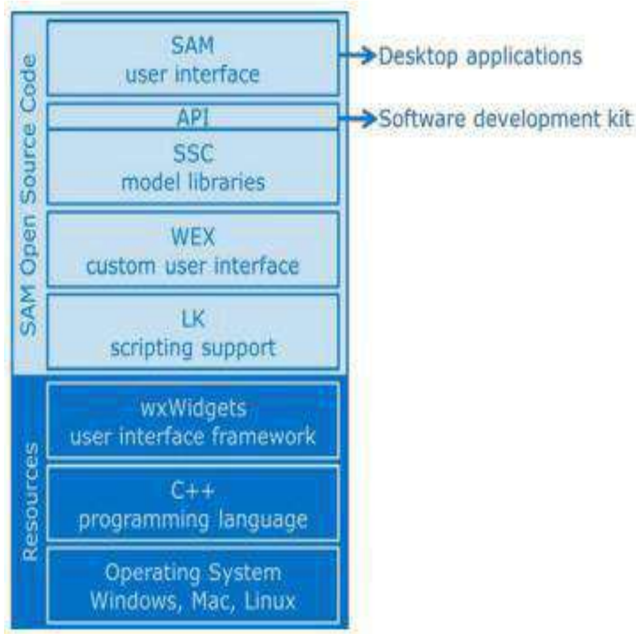


Figure 2.14: Diagram of SAM structure (NREL) [64].

The figure summarized the essential steps of study plan started by the development of electric power balance and scenario identification and finalized by the estimation of PTC CSP electricity production.

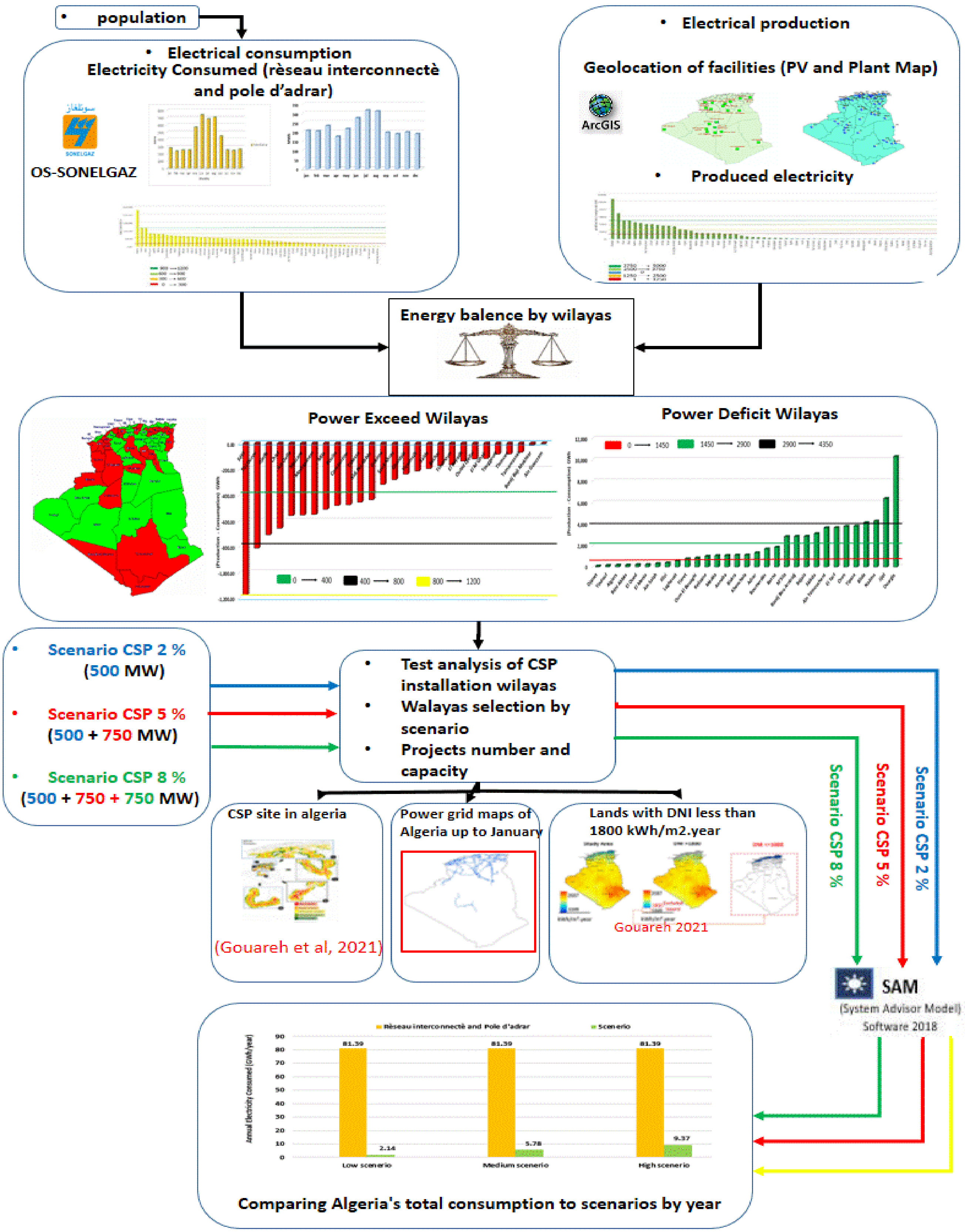


Figure 2.15: Conceptual study plan and electric power balance and scenarios.

2.3 Conclusion:

In this chapter, a 100 MW concentrating solar power (CSP) plant was designed and simulated using the SAM software. The simulation was conducted under three different scenarios (low, medium, and high), The following are covered: the energy demand in Algeria, energy balance in different regions through consumption and production, as well as the location of CSP plant installations in each region. The chapter discussed also the system design, operational parameters, site selection methodology for CSP simulation, and provides a description of the system guidance model and the SAM simulation framework for CSP systems.

Based on the criteria of a concentrated solar power plant, a location within Algeria was chosen and simulated. The obtained results provide the necessary data for designing a concentrated solar power plant in Algeria. The NREL weather database and the SAM software (System Advisor Model) aided the design and simulation of the CSP plant. This analysis allows for the evaluation of the annual and dynamic thermal performance of 100 MW CSP.

In the final chapter, we will analyze the collected data for comparing various aspects of concentrating solar power technologies and presents the most significant results.

Chapter 3: Results &Performance Assessment.

3.1Introduction:

Algeria possesses a significant potential for solar energy, making it a dominant force in the country's renewable energy prospects. This clean energy source presents an opportunity for both economic and social development, particularly through the establishment of industries that generate wealth and employment opportunities. The decision to focus on solar energy as a strategic choice stems from its immense potential. Specifically, the program emphasizes Solar Heat (CSP) as its specialized area.

In this regard, the selected regions for CSP plants have been identified, and the SAM system has been implemented for a 100-megawatt station equipped with a 6-hour thermal storage capacity. This chapter aims to provide a comprehensive evaluation and feasibility analysis of CSP deployment in three different scenarios (low, medium, high), shedding light on the performance comparison among CSP plants across Algeria.

Furthermore, the study explores the possibility of implementing concentrated solar power plants in the proposed area, considering various criteria such as gross and net electrical power generation, level 1 losses, energy use factor, and annual water consumption.

The final section of the study presents detailed outcomes concerning the monthly heat energy transfer from the solar field to the power block, as well as the hourly thermal energy dynamics within the storage system. This analysis focuses on four representative days, with a special emphasis on the Tamanrasset region.

3.2 Results and discussions:

3.2.1Analyzing and evaluating weather resources:

CSP technologies utilize and concentrate Direct Normal Irradiance (DNI) received on the Earth's surface to heat a working fluid and generate energy through a thermodynamic cycle. The variability of solar radiation is the primary source of uncertainty when predicting the efficiency of solar power plants across different solar energy systems. Solar resource assessment plays a critical role in various aspects, including site selection for solar projects, prediction of annual power generation, and assessment of temporal performance. Therefore, understanding the spatial and temporal variability of solar resources is crucial for accurate energy assessment.

When selecting suitable sites for CSP installations in a country, multiple factors come into play, but the availability of high-quality solar resources, specifically DNI, holds paramount importance. The figures 3.1 summarize the yearly received DNI values and CSP projects numbers plants in the ten selected regions. The DNI based map conducted by Gouareh et al. in 2021 is used to give a comprehensive distribution of solar resource in Algeria territory. The DNI values presented in this figure are given by Photovoltaic Geographical Information System (PVGIS).

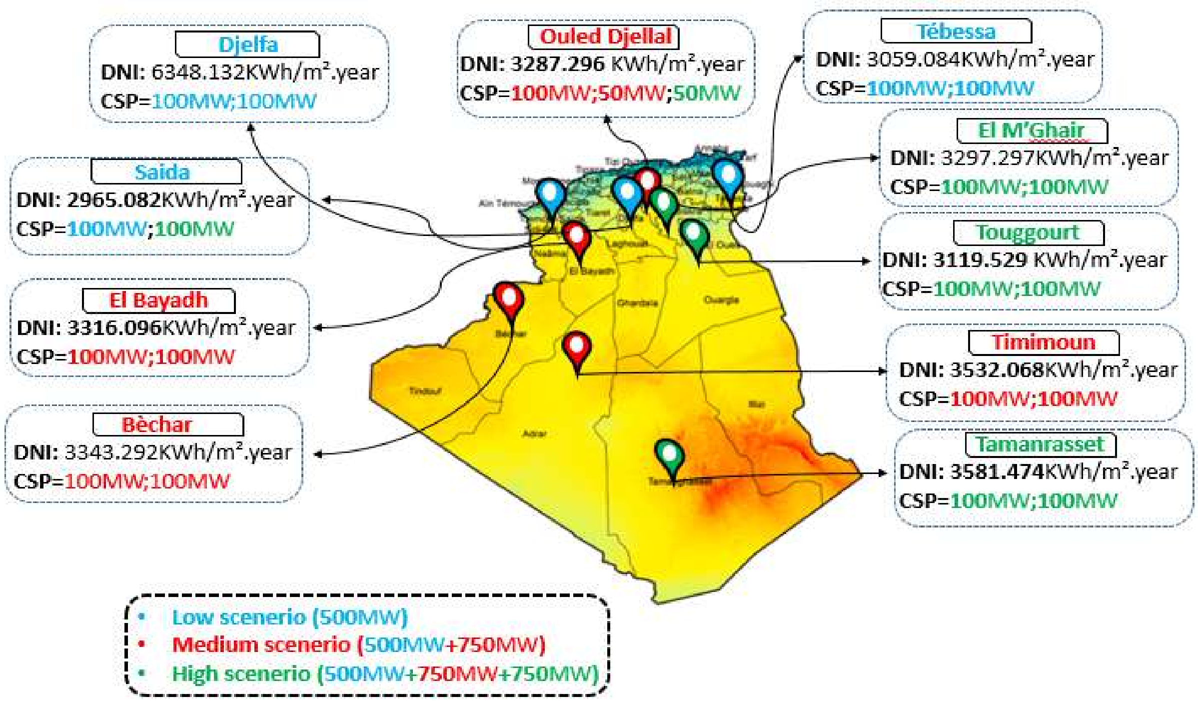


Figure 3.1: Yearly DNI received and CSP projects in the selected regions.

3.3Electrical Energy production by scenarios:

The performance and energy production of 100 MW PTC-CSP plants is analyzed in this study was for the three selected scenarios. Where we will neglect 3 GWh from net production because it presents the energy consumed for the inter usage of the station.

Low scenario 2% (500MW): As three regions are selected with CSP project of 100MW for each, the figure below presents the monthly net electrical production for (Djelfa, Tebessa and Saida).

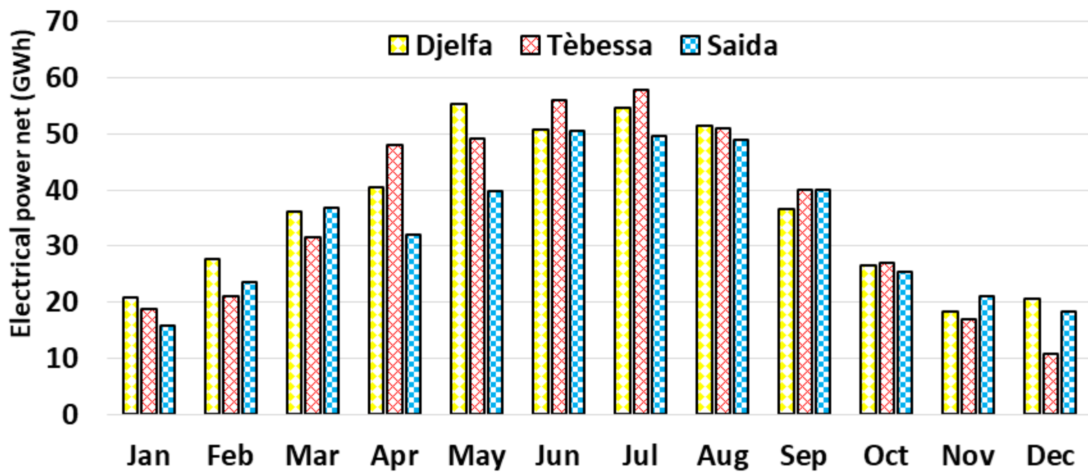


Figure 3.2: Annual electricity source net (GWh) for the selected site.

According to figure 3.2, the CSP plants in the low scenario exhibit a significant increase in annual energy production during the summer months. This surplus of energy proves highly beneficial for meeting the high electricity demands during the summer season. Conversely, the energy production is notably low during the winter solstice.

The Tebessa and Saida region present the highest and lowest values in July and December, respectively, with energy outputs of 57.9251 GWh and 10.8715 GWh.

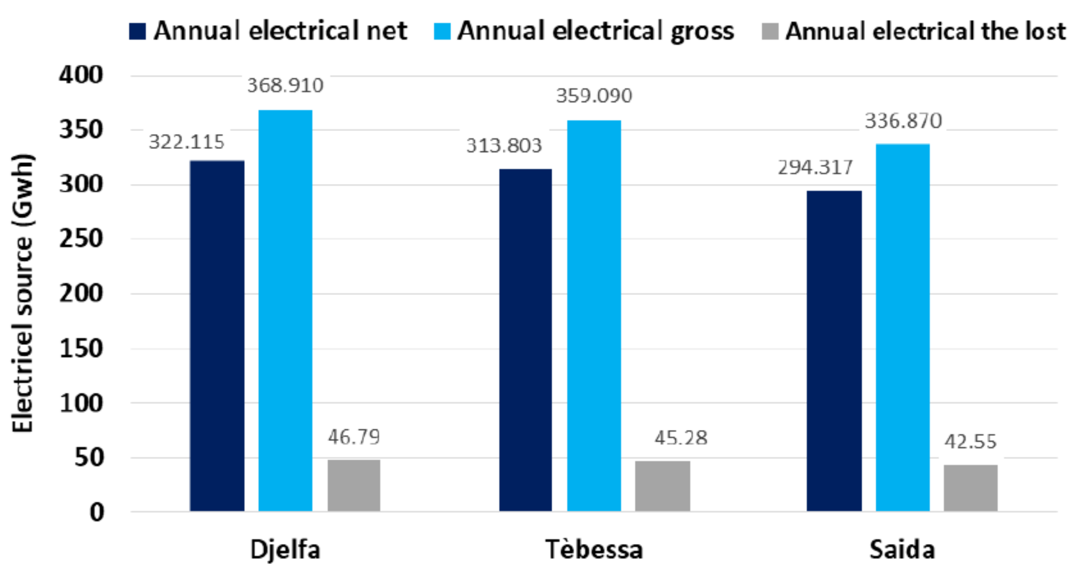


Figure 3.3: Electrical source - Power cycle (gross, net and the lost (Parasitic)) output (GWh).

According to the results presented in Figure 3.3, it is evident that the total electrical output or gross production is more significant compared to the net electricity production. It is crucial to consider the energy losses in the gross (total) supplied equipment from the PTC CSP. On the other hand, it is noteworthy that the losses reached a maximum value in the Djelfa region, amounting to 46.27 GWh compared to other regions, relative to the total electrical energy production in that area (368.910 GWh in Djelfa). The energy losses and the gross output of the energy cycle for the other two regions vary from maximum to minimum, respectively (45.28 GWh, 359.090 GWh in Tebessa) and (42.55 GWh 336.870 GWh in Saida). There is a difference of 32.04 GWh between the highest (Djelfa) and the lowest (Saida). The energy losses repress entaproxi motely 12 % but its absolute value increases with the increase in the production of electrical energy from region to another.

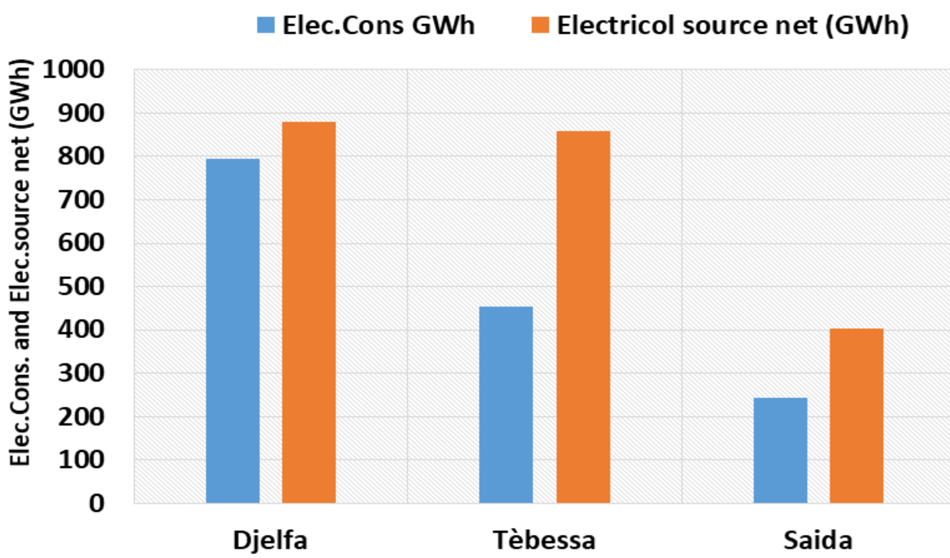


Figure 3.4: Electrical consumption and source net GWh.

The figure 3.4, presents a comparison between Electrical consumption and yearly net production for the three regions. The net production is higher than the total consumption, as we note that through the low scenario, the highest production and consumption are in the Djelfa region, respectively, 880,69GWh and 793,61 GWh, As for the lowest production and consumption in the Saida region, respectively, 402.51 GWh and 241.84GWh.

Medium scenario 5% (1250MW): Given the selection of four regions in addition to the low scenario regions with a CSP project of 100 MW per region, the figure below presents the monthly net electrical production for (Djelfa, Tebessa, Saida, Béchar, Timimoun, ElBayadh, Ouled Djellal, El'Mghair, Touggourt and Tamanrasset).

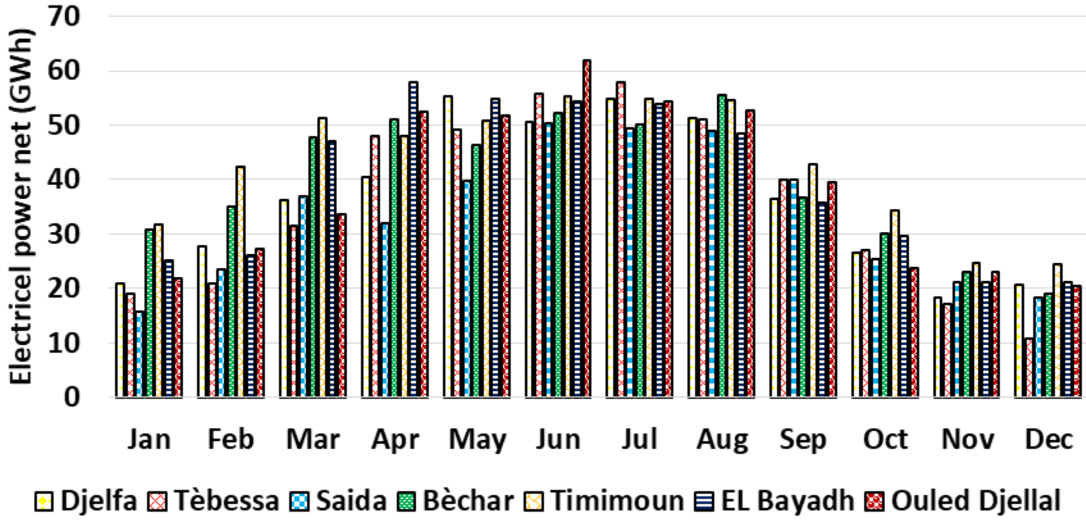


Figure 3.5: Annual electricity source net (GWh) for the selected site.

According to Figure 3.5, the CSP plants in the medium scenario exhibit a significant increase in annual energy production during the summer months. This surplus of energy proves highly beneficial for meeting the high electricity demands during the summer season. Conversely, the energy production is notably low during the winter solstice. The Ouled Djellal and Saida region present the highest and lowest values in Jun and December, respectively, with energy outputs of 62.0332 GWh and 10.8715GWh.

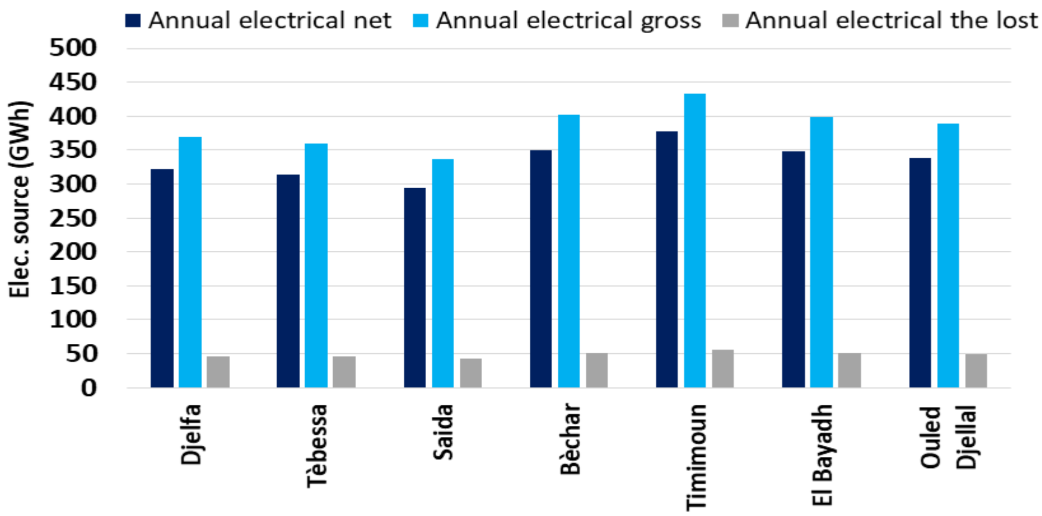


Figure 3.6: Electrical source - Power cycle (gross, net and the lost (Parasitic)) output (GWh).

According to the results presented in Figure 3.6, it is evident that the total electrical output or gross production is more significant compared to the net electricity production. It is crucial to consider the energy losses in the gross (total) supplied equipment from the PTC CSP. On the other hand, it is noteworthy that the losses reached a maximum value in the Timimoun region, amounting to 55.63GWh compared to other regions, relative to the total electrical energy production in that area (432.576 GWh in Timimoun). The energy losses and the gross output of the energy cycle for the other two regions vary from maximum to minimum, respectively (51.57 GWh, 401.351GWh in Béchar), (50.65 GWh, 399.252 GWh in ElBayadh), (49.68 GWh, 388.504 GWh in Ouled Djellal), (46.79 GWh, 368.910GWhin Djelfa), (45.28 GWh, 359.090 GWh in Tebessa), (42.55GWh, 336.870 GWh in Saida). There is a difference of 95.7 GWh between the highest (Timimoun) and the lowest (Saida). The energy losses repress entaproxi motely 12 % but its absolute value increases with the increase in the production of electrical energy from region to another.

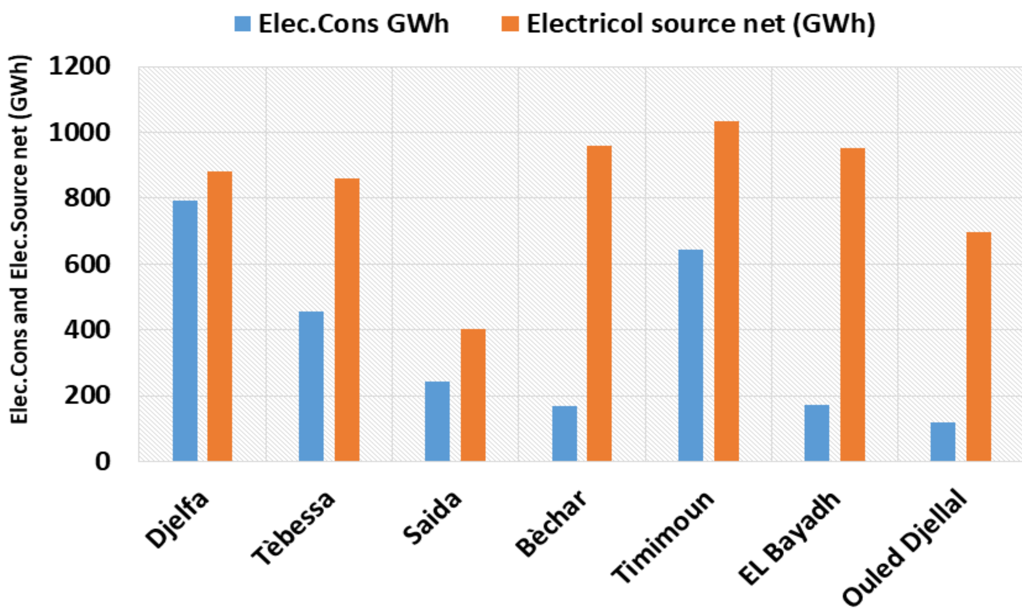


Figure 3.7: Electrical consumption and source net GWh.

The figure 3.7, the net production is higher than the total consumption during a month, as we note that through the medium scenario, the highest production and consumption are in the Timimoun and Djelfa region, respectively 1032 ,57 GWh and 793,61 GWh, As for the lowest production and consumption in the Saida and Ouled Djellal region, respectively, 402.51 GWh and 119,27 GWh.

High scenario 8% (2000 MW): Considering the selection of three regions in addition to the low scenario regions and the medium scenario with a CSP project of 100 MW per region, the figure below shows the monthly electrical production by region.

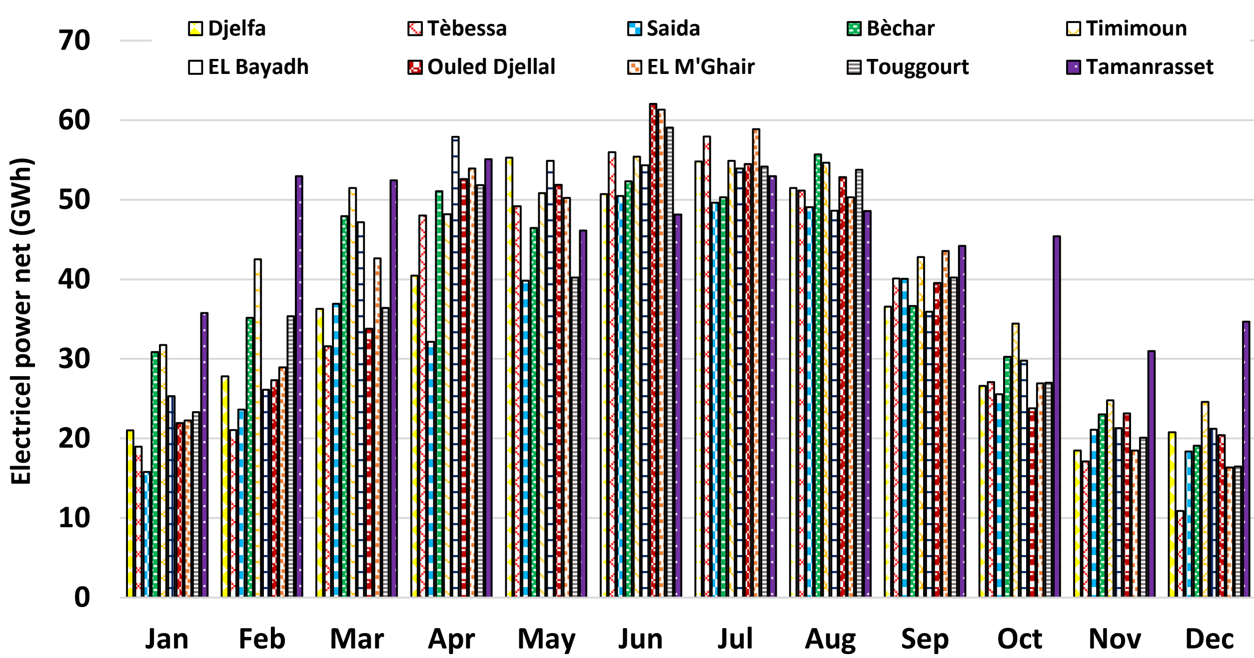


Figure 3.8: Annual electricity source net (GWh) for the selected site.

According to Figure 3.8, the CSP plants in the High scenario exhibit a significant increase in annual energy production during the summer months. This surplus of energy proves highly beneficial for meeting the high electricity demands during the summer season. Conversely, the energy production is notably low during the winter solstice. The Ouled Djellal and Saida region present the highest and lowest values in Jun and December, respectively, with energy outputs of 62.0332 GWh and 10.8715 GWh. Where we note that the Tamanarsset region varies in production values by 5%, which is almost moderate.

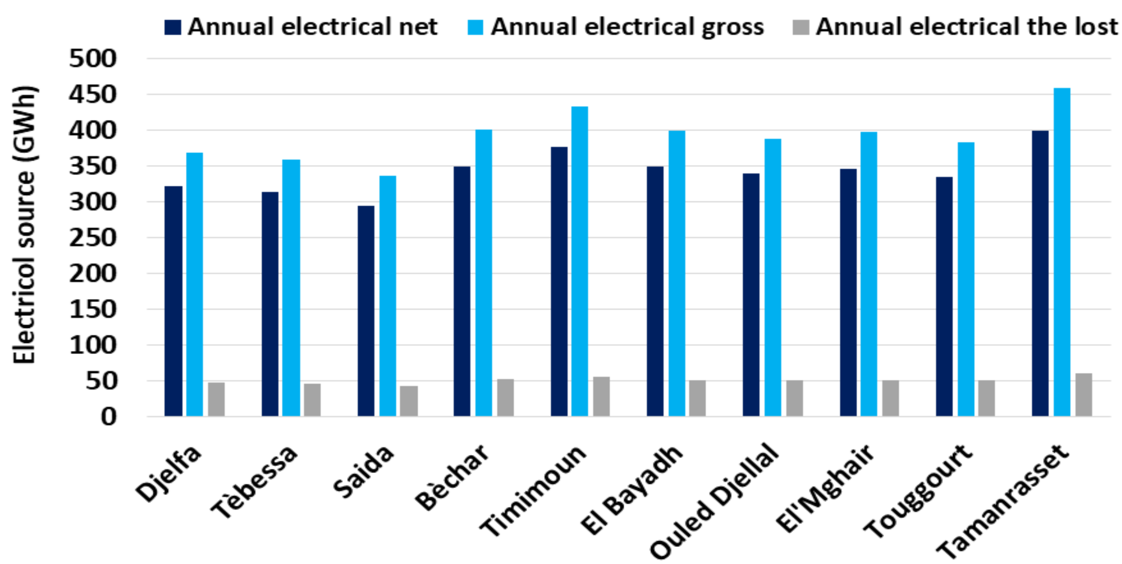


Figure 3.9: Electrical source - Power cycle (gross, net and the lost (Parasitic)) output (GWh).

According to the results presented in Figure 3.9, it is evident that the total electrical output or gross production is more significant compared to the net electricity production. It is crucial to consider the energy losses in the gross (total) supplied equipment from the PTC CSP. On the other hand, it is noteworthy that the losses reached a maximum value in the Tamanrasset region, amounting to 60.13GWh compared to other regions, relative to the total electrical energy production in that area (459.261 GWh in Tamanrasset). The energy losses and the gross output of the energy cycle for the other two regions vary from maximum to minimum, respectively (55.63GWh, 432.576 GWh in Timimoun), (51.57 GWh, 401.351GWh in Béchar), (50.89GWh, 397.052 GWh in El'Mghair), (50.65 GWh ,399.252 GWh in ElBayadh), (49.68 GWh, 388.504 GWh in Ouled Djellal), (49.63GWh, 383.642GWh in Touggourt), (46.79 GWh, 368.910GWh in Djelfa), (45.28 GWh, 359.090 GWh in Tebessa), (42.55GWh, 336.870 GWh in Saida). There is a difference of 122.4 GWh between the highest (Tamanrasset) and the lowest (Saida). The energy losses repress entaproxi motely 13 % but its absolute value increases with the increase in the production of electrical energy from region to another.

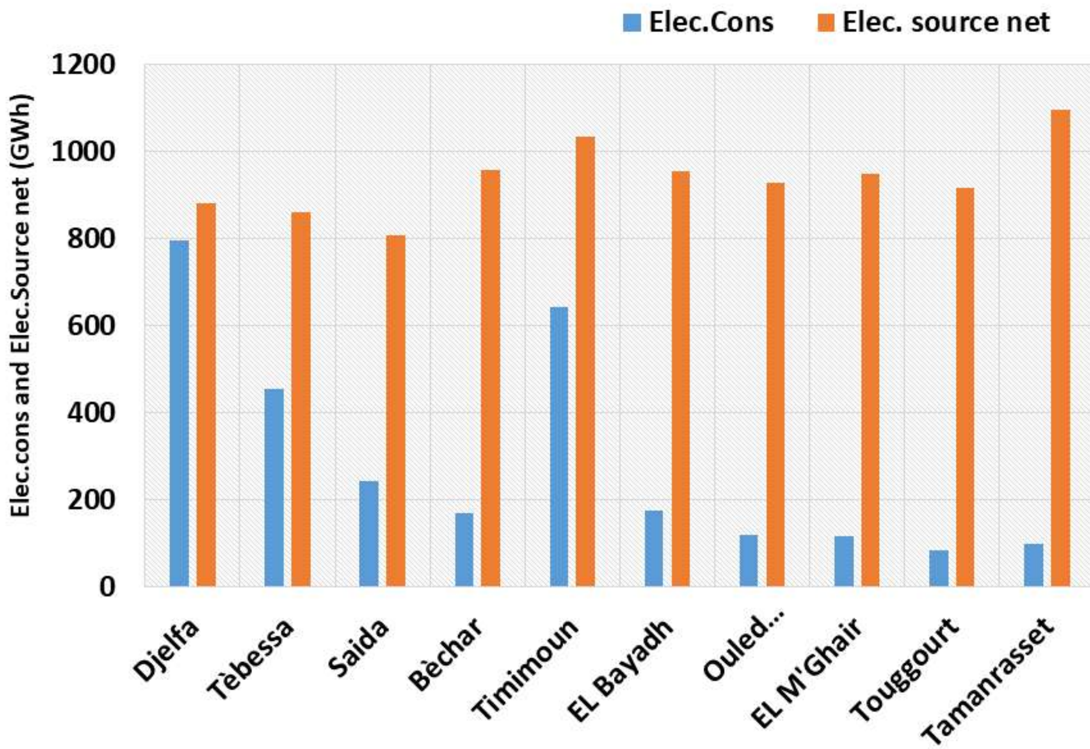


Figure 3.10: Electrical consumption and source net GWh.

The figure (3.10), the net production is higher than the total consumption during a month, as we note that through the High scenario, the highest production and consumption are in the Tamanarsset and Djelfa region, respectively 1094, 69 GWh and 793,61 GWh, As for the lowest production and consumption in the Saida and Touggourt region, respectively, 402.51 GWh and 81,65 GWh.

3.4Comparison of Algeria's total consumption with scenarios (low, medium and high):

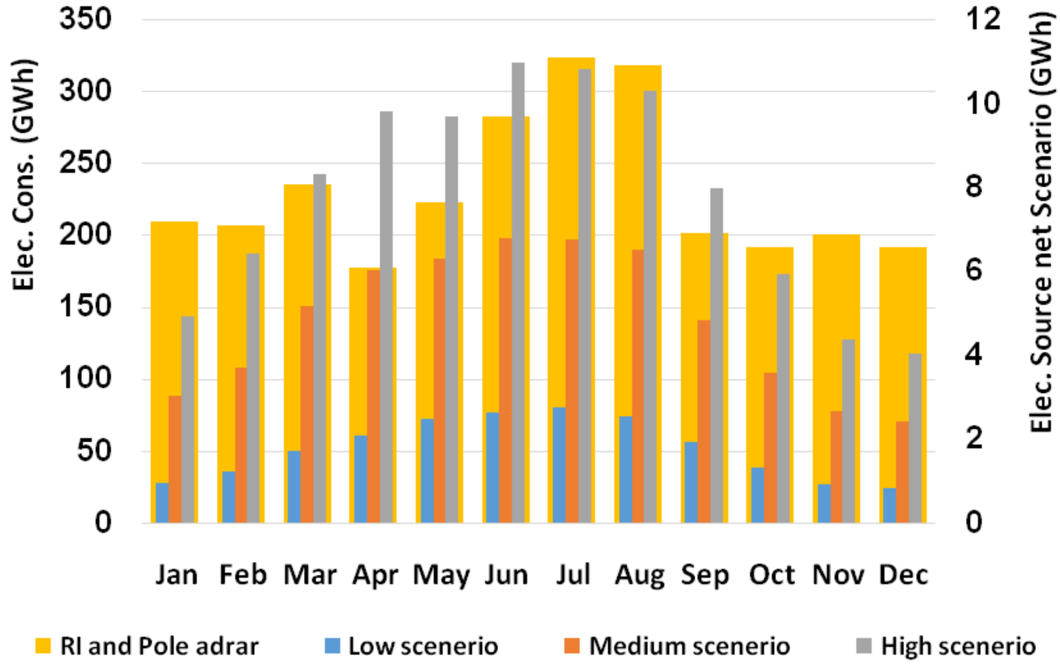


Figure 3.11: Comparison of Algeria's total consumption and scenarios Elect. net production by months.

We notice in Figure 3.11 that Algeria's total consumption and production scenarios are high in the summer months and low in the winter months, as it reached the highest value of 320 GWh in July and the highest production rate in the high scenario in June, by 10.5 GWh.

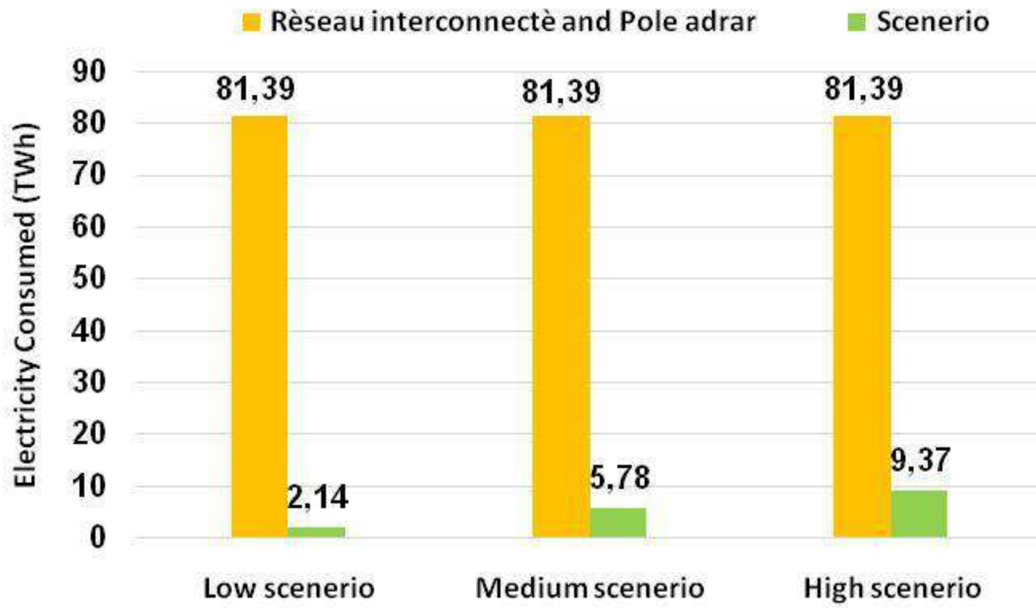


Figure 3.12: Comparing Algeria's total consumption to scenarios by year.

We notice in Figure 3.12 that the low scenario records the lowest production in relation to Algeria's total consumption in a year, at a rate of 2.1412 TWh, and the medium scenario records a rate of 5.78008 TWh, while the high scenario records a rate of 9.37251 TWh as the highest value.

3.5 Parasitic power present in the CSP-PTC plant system:

A simulated Concentrated Solar Power (CSP) plant utilizing the System Advisor Model (SAM) has been designed with a capacity of 100 MW to provide support to the electrical grid in the mentioned regions. Upon analyzing the outcomes, a set of parasitic forces were identified, including TES and HTF cycle pump, auxiliary heater operation, condenser operation, field collector drives, fixed load, generation-dependent load, and HTF solar field pump. These parasitic forces can be classified into two types: thermal and electrical. The results of the parasitic force magnitude will be presented below for a single day in the months of June and December. As an example, the Tamanrasset region.

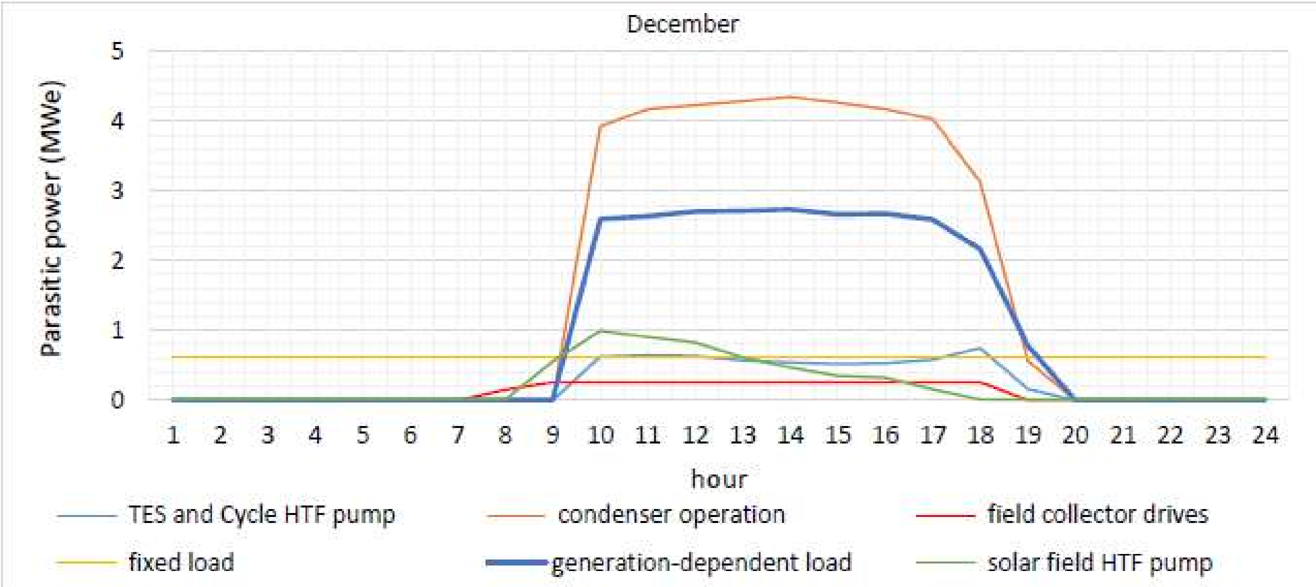


Figure 3.13: Hourly parasitic Power (MWe) of typical day in December,

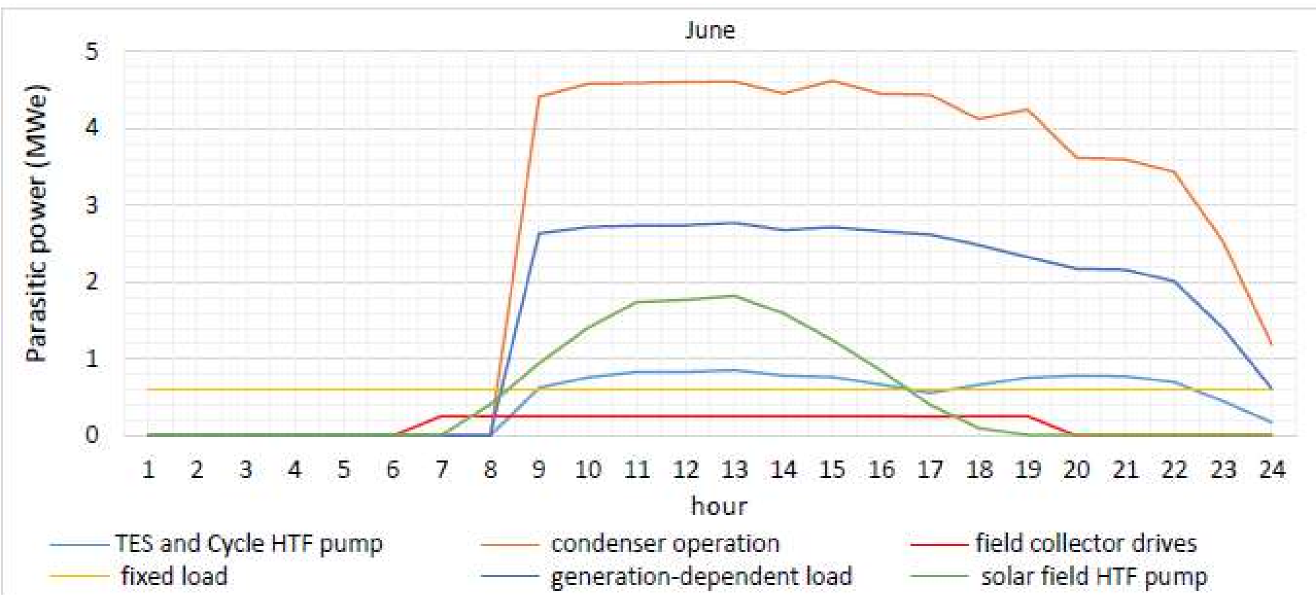


Figure 3.14: Hourly parasitic Power (MWe) of typical day in June.

By examining Figures 1.3 and 1.4, which represent a typical day in Tamanrasset during the months of June and December, it is evident that the energy losses in the power plant system vary both on a monthly and daily basis. Specifically, the energy loss is greater during the summer months and lower during the winter months. Additionally, the energy consumption of subsystems shows a correlation with the increase in electrical energy production. The condenser operation exhibits the highest energy consumption, with the peak parasitic power increasing from 6:00 to 24:00 during summer days. The operating value of the condenser ranges from 0 to 4.8 MWe, with a decrease towards the end of the day. During winter days, the condenser also records the highest energy consumption, with the parasitic capacity peaking between 9:00 and 19:00. The operating value of the condenser ranges from 0 to 4.5 MWe and becomes null at 19:00. The HTF rotary pump's energy consumption ranges from 0 to 2.9 MWe during the mentioned time periods, while the TES rotary pump's energy value ranges from 0 to 1.8 MWe from 7:00 to 24:00 in June and from 9:00 to 18:00 in December. The constant load maintains a value of 0.611 MWe throughout the day in both June and December. Similarly, the field complex motors operate solely during daylight hours, consuming 0.256 MWe. Load dependent generation shows an increase in peak parasitic energy from 8:00 to 24:00 during summer days, with the load dependent generation value ranging from 0 to 1.8 MWe. In winter, the increase in parasitic energy value starts from 9:00 and ends at 18:00.

3.6 Technical output factors at PTC CSP plant of 100 MW:

This work emphasizes the sustainable realization of the PTC-CSP technology for electricity generation under the arid climatic conditions with scarce water resources, the technical evaluation took into account the different design configurations using the dry cooling option of the plant due to the lack of water resources on the one hand and on the other hand its impact on the energy produced by the PTC-CSP plant and the Capacity Factor system.

Table 3.1: Technical output factors of PTC-CSP plant of 100 MW.

	Annual Electricity source net (GWh/Year)	Capacity factor (%)	Gross to Net conversion (%)	Total annual water usage (m^3)
Djelfa	309.230	35.3	87.3	77 774
Tebessa	301,250	34.4	87.4	76 739
Saida	282.544	32.3	87.4	74 721
Béchar	335,786	38.3	87.2	81 394
Timimoun	361,870	41.3	87.1	84 561
El Bayadh	334,655	38.2	87.3	80 994
Ouled Djellal	325,264	37.1	87.2	79 923
El M'Ghair	332,312	37.9	87.2	80 889
Touggourt	320,650	36.6	87.1	79 634
Tamanrasset	383,163	43.7	86.9	87 238

In general, the water usage in the PTC-CSP power plant is divided into three main parts Parabolic trough washing, steam generation, and the cooling system. A large difference exists between the two cooling systems; the power plant with the evaporative cooling system consumes about 14 times more water than the one with the air-cooled system.

This is because the power plant with the dry air cooling system only uses water for steam generation and the washing of the mirrors.

For the Djelfa site, the 100 MW CSP plant achieves a total net conversion of 87,3 % and the overall plant efficiency is close to 35,3 %. 77 774 m^3 of water is required annually to wash the parabolic system and Annual electricity source net 309 230 GWh/year. For the Tebessa site, the 100 MW CSP plant achieves a total gross-to-net conversion of 87,4 % and the plant's overall efficiency is close to 34.4%. 76 739 m3 of water is required annually to wash the parabolic system and Annual electricity source net 301 250 GWh/Year. For the Saida site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,4 % and the overall plant efficiency is close to 32,3 %. 74 721 m^3 of water is required annually to wash the parabola and Annual electricity source net 282 544GWh/Year. For the Bèchar site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,2 % and the overall plant efficiency is close to 38,3%.

81 394 m3 of water is required annually to wash the parabola and Annual electricity source net 335 786 GWh/Year. For the Timimoun site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,1 % and the overall plant efficiency is close to 41,3 %. 84 561 m3 of water is required annually to wash the parabola and Annual electricity source net 361 870 GWh/Year. For the El Bayadh site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,3 % and the overall plant efficiency is close to 38,2 %. 80 994 m3 of water is required annually to wash the parabola and Annual electricity source net 334 655 GWh/Year. For the Ouled Djellal site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,2 % and the overall plant efficiency is close to 37,1 %. 79 923 m3 of water is required annually to wash the parabola and Annual electricity source net 325 264 GWh/Year. For the El M'Ghair site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,2 % and the overall plant efficiency is close to37,9 %. 80 889 m3 of water is required annually to wash the parabola and Annual electricity source net 332 312 GWh/Year. For the Touggourt site, the 100 MW CSP plant achieves a total net-to-net conversion of 87,1 % and the overall plant efficiency is close to 36,6 %. 79 634 m3 of water is required annually to wash the parabola and Annual electricity source net 320 650

GWh/Year. For the Tamanrasset site, the 100 MW CSP plant achieves a total net-to-net conversion of 86,9 % and the overall plant efficiency is close to 43,7 %. 87 238 m3 of water is required annually to wash the parabola and Annual electricity source net 383 163 GWh/Year.

The results obtained for the concentrated solar power plant with 100 MW installed and the results are summarized in the table 3.1. It was found that the increase in water consumption is linked to the energy production, as it was noticed by comparing the results obtained for the ten sites that the higher site (Tamanrasset) energy production, correspondent to the higher water uses with it.

3.7 Performance analysis of the PTC-CSP plant design in Tamanrasset region:

Data of figure 3.16 show the thermal power produced by the field, thermal energy to the Power block, DNI-cosine and DNI for the proposed CSP plants in Tamanrasset.

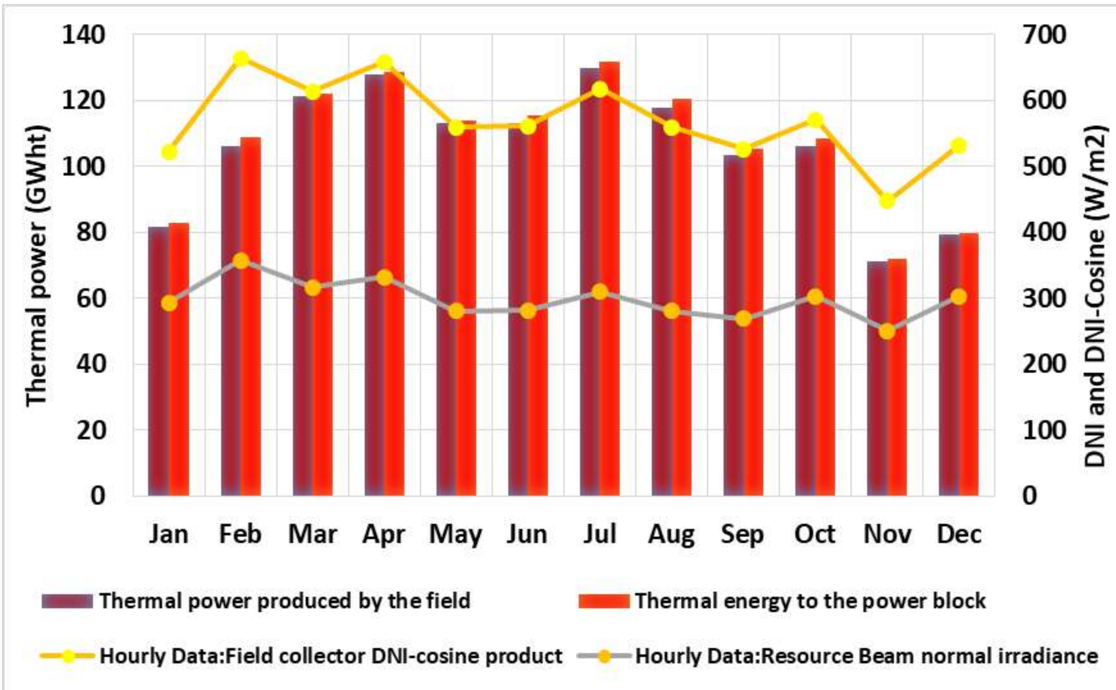


Figure 3.15: Thermal power changes for the station PTC-CSP in the Tamanrasset region within a year.

The overall electrical energy generated by the power plant relies on the incident radiation and the heat energy input cycle within the power block's turbine. Monthly data reveals that the CSP system experiences certain losses during the conversion process from radiation in the solar field to the

Thermal energy transferred to the power block. However, these losses are relatively minor when compared to the overall energy production of the plant, as illustrated in figure 3.16.

3.8 Conclusion:

The design, performance analysis and optimization of a 100 MW parabolic trough collector Solar Power Plant with thermal energy storage has been carried out for ten locations in the Algeria region. The SAM software has been used to assess the performance of the designed CSP plant in ten locations of whose annual average DNI is greater than 1 800 KWh/m2 day.

The initial analysis of the proposed design revealed that the CSP plant in Tamanrasset has an annual energy yield of 383.163 GWh whereas that in Timimoun recorded 361.870 GWh. whereas that in Béchar recorded 335.786 GWh and that in El Bayadh recorded 334.655 GWh and that in El M'Ghair recorded 332.312 GWh and that in Ouled Djellal recorded 325.264 GWh and that in Touggourt recorded 320.650 GWh and that in Djelfa recorded 309.230 GWh and that in Tebessa recorded 301.250 GWh and that in Saida recorded 282.544 GWh.

The capacity factor as an indicator of the plant performance is around 32.3% in the studied regions, where Tamanrasset present a capacity factor of 43.7%. in the last part of the scenarios in chapter give us an important results about the contribution of CSP plant on the consumption Electrical Power in Algeria, which amounted to 81 391.371 GWh from direction on the other hand 17.29 GWh in the scenarios, That is, the scenarios contributed 2.12% on the conception, where the plant (with thermal energy storage system of 6 hours).

the proposed 100 MW parabolic trough-based CSP plant with TES system is found to be very important suggestion for the (Djelfa, Tebessa, Saida, Béchar, Timimoun, Elbayadh, Ouled Djellal, ElM'Ghair, Touggourt, Tamanrasset) regions and can contribute to

the sustainable energy planning in the future where the capacity can be raised by considering more than one plants in the same region where the lands are largely available across the Algerian territory.

General conclusion

The world agrees that renewable energy is the best option for generating electricity and also for reducing environmental risks as a result of fossil energy. Therefore, the bulk of the world's thinking is to go for renewable energy as the ideal solution.

While Algeria adopted this option and supported it by establishing solar power stations to contain a huge amount of solar energy, and the most important of these stations is PTCCSP, a station to support the electric grid, which was the subject of our study in this through the application and simulation of this station in ten selected regions through three scenarios (low, medium, high) According to the ratings It is selected according to the ratings according to the DNI in the area and some conditions such as proximity to the electric grid......etc. To simulate this in the ten regions with the help of the SAM program, which gave us some results from the amount of electricity produced by the station, the capacity, capacity and storage time.

In the first chapter, we discussed the mix of electrical energy in Algeria, the Algerian energy sources as well as the places of energy production in Algeria in addition to the Algerian electricity grid and the national program for the development of renewable energies, renewable energy and solar energy. We also referred to the components of CSP power stations and some characteristics of the station. In the second chapter, we have presented the working methodology for simulating a 100 MW PTC station in a different location on the territory of Algeria. The scenarios (low, medium, high) are also explained And the balance of electrical energy in the regions, which includes the consumption and production of electric energy in the regions, as well as the demand for energy. Next, we defined the simulated regions based on the difference between production and consumption, as well as solar radiation levels. We assign a certain number of regions to each scenario based on their proportion.

The SAM simulation system for modeling simulation was identified as the best program among others by describing the system and identifying its capabilities and areas of use.

In the last chapter, we have dealt with the parameter and performance result of the concentrated solar power plant designed in ten locations (Djelfa, Tebessa, Saida, Bechar, Timimoun, El Beady, Ouled Jalal, El'Maghir, Touggourt and Tamanrasset) with an average annual DNI greater than 12 kWh / m 2 / day. Show preliminary analysis of the proposed design

The concentrated solar power plants in the low scenario produce 2 140 GWh, while in the medium scenario they produce 5 780 GWh, while in the high scenario they produce 9 370 GWh.

General conclusion:

As a result of this study, which we conducted by simulating the CSP-PTC station, we concluded that the best production of the station is in the summer as well as among the best was the Tamanrasset region, and the lowest production was in Saida, and the production was weak in the winter months with the rest of the regions.

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Annexes :

Annexes 1:

Wilayas	Pop.	Elec. Cons. (GWh)	Conv. Prod. (GWh)	Renw. Prod. (GWh)	Total Prod. (GWh)	Energy Balance (GWh)
BordjBajiMokhtar	25,000	13.97	**none**	**none**	0	-13.97
Djanet	26,598	14.87	79.9	4.87	84.77	69.90
AinGuezzam	31,936	17.85	15.98	**none**	15.98	-1.87
Illizi	42,217	23.59	391.52	**none**	391.52	367.93
Ain Salah	50,390	28.16	319.61	8.12	327.73	299.57
Tindouf	63,646	35.57	151.82	14.62	166.44	130.87
El Menia	64,487	36.04	239.71	**none**	239.71	203.67
BéniAbbès	75,000	41.92	199.76	**none**	199.76	157.84
Tlemcen	145,000	81.04	**none**	**none**	0	-81.04
Touggourt	146,108	81.66	**none**	**none**	0	-81.66
Tamanrasset	172,475	96.39	7.99	21.12	29.11	-67.28
El M'Ghair	207,000	115.69	**none**	**none**	0	-115.69
Ouled Djellal	213,413	119.27	**none**	**none**	0	-119.27
Naâma	260,028	145.33	4378.68	32.49	4411.17	4,265.84
Béchar	302,849	169.26	**none**	**none**	0	-169.26
El Bayadh	309,786	173.13	**none**	37.36	37.36	-135.77
Adrar	362,404	202.54	1398.3	112.4	1510.7	1,308.16
Tissemsilt	380,436	212.62	**none**	**none**	0	-212.62
Ghardaïa	426,646	238.45	**none**	1.79	1.79	-236.66
Saida	432,720	241.84	**none**	48.73	48.73	-193.11
El Tarf	443,299	247.75	3907.26	**none**	3907.26	3,659.51
AïnTémouchent	461,316	257.82	3907.26	**none**	3907.26	3,649.44
Khenchela	492,027	274.99	1374.33	**none**	1374.33	1,099.34
Souk Ahras	544,219	304.16	**none**	24.37	24.37	-279.79
Guelma	566,946	316.86	**none**	**none**	0	-316.86
Laghouat	595,646	332.90	795.06	97.46	892.52	559.62
Ouargla	617,711	345.23	10611.12	48.73	10659.85	10,314.62
El Oued	710,757	397.23	599.27	**none**	599.27	202.04
Tipaza	720,425	402.63	4206.86	**none**	4206.86	3,804.23
Biskra	745,585	416.70	1486.2	19.49	1505.69	1,088.99
Sidi-bel-Abbes	778,846	435.28	**none**	**none**	0	-435.28
Jijel	792,978	443.18	6831.71	**none**	6831.71	6,388.53
Oum El Bouaghi	809,275	452.29	1278.45	**none**	1278.45	826.16
Tebessa	812,611	454.16	**none**	**none**	0	-454.16
BordjBouArréridj	820,976	458.83	3299.99	**none**	3299.99	2,841.16

Annaba	842,615	470.92	1534.14	**none**	1534.14	1,063.22
Bouïra	859,065	480.12	**none**	**none**	0	-480.12
Mila	912,052	509.73	**none**	**none**	0	-509.73
Boumerdès	927,577	518.41	2189.34	**none**	2189.34	1,670.93
Relizane	932,805	521.33	1510.17	**none**	1510.17	988.84
Mostaganem	983,044	549.41	**none**	**none**	0	-549.41
Mascara	991,614	554.20	**none**	**none**	0	-554.20
AïnDefla	998,846	558.24	**none**	**none**	0	-558.24
Media	1,050,652	587.19	1630.02	**none**	1630.02	1,042.83
Skikda	1,100,000	614.77	3715.49	**none**	3715.49	3,100.72
Tiaret	1,110,000	620.36	1366.34	**none**	1366.34	745.98
Béjaïa	1,125,000	628.74	3475.78	**none**	3475.78	2,847.04
Timimoun	1,150,000	642.72	463.44	14.62	478.06	-164.66
Chlef	1,175,000	656.69	**none**	**none**	0	-656.69
M'Sila	1,200,000	670.66	3459.8	32.49	3492.29	2,821.63
Constantine	1,264,079	706.47	231.72	**none**	231.72	-474.75
Banta	1,350,000	754.49	2580.87	3.25	2584.12	1,829.63
Blida	1,380,000	771.26	4898.05	**none**	4898.05	4,126.79
Djelfa	1,420,000	793.62	**none**	86.09	86.09	-707.53
TiziOuzou	1,450,000	810.38	**none**	**none**	0	-810.38
Oran	2,075,000	1,159.68	4946	**none**	4946	3,786.32
Sétif	2,100,000	1,173.66	**none**	**none**	0	-1,173.66
Algiers	4,050,000	2,263.48	2421.06	**none**	2421.06	157.58
Total	**44098.105**	**24 645.72**	**79903**	**608**	**80511**	

Annexes 2:

Table A2.1Technical parameters of 100PTC CSP Plant.

Categories	Values	Referenceou assumption
.Location and Resources:	Djelfa ,Tebessa ,Saida ,Bèchar ,TimimouneBayadh ,OuledDjellal ,El M'Ghair,Touggourt ,Tamanrasset	Gouareh,2021 LMKADEM,2021
Latitude and Longitude.	According to the location	From NREL (wader data)
Solar Field:		
(Solar Field Parameters)		
Solar Multiple.	2	Assume
Irradiation at design.	887 W/m^2	From NREL
Design-Point ambient temp.	150 C°	Liaqat,2018- LMKADEM,2021
Design-point wind Velocity.	5 m/s	NREL, SAM
No. of Field Sub Sections.	2	NREL, SAM
Row spacing.	15 m	NREL, SAM
Deploy angle - Stow angle.	10° - 170°	NREL, SAM
HTF Pump Efficiency.	0.85	NREL, SAM
(Heat Transfer Fluid)		
Field HTF fluid.	Therminol VP-1	Liaqat,2018 - Assume
Design loop inlet temp.	293 °C	Liaqat,2018-LMKADEM,2021
Design loop outlet temp.	391 °C	Liaqat,2018-LMKADEM,2021
Min field velocity.	0.153546 m/s	Liaqat,2018-LMKADEM,2021
Max Field Velocity.	1.99737 m/s	Liaqat,2018-LMKADEM,2021
Min single loop flow rate.	1 kg/sec	Liaqat,2018-LMKADEM,2021
Max single loop flow rate.	12 kg/sec	Liaqat,2018-LMKADEM,2021
Header design min flow Velocity.	2 m/s	Liaqat,2018-LMKADEM,2021
Header design max flow Velocity.	3 m/s	Liaqat,2018-LMKADEM,2021
(Design Point)		
Actual No. of loops.	189	NREL, SAM, Assume
Single loop aperture.	5248 m^2	Liaqat,2018, SAM, Assume
Total aperture reflective area.	991872 m^2	Liaqat,2018-LMKADEM,2021
Field thermal output.	623.596 MWt	Liaqat,2018
(Mirror Washing)		
Water usage per wash.	0.7 l/m^2, aper	NREL, SAM, Assume

Washes per year.	63	NREL, SAM, Assume
(Single Loop Configuration)		
Number of SC/HCE assemblies per loop.	8	Liaqat,2018, SAM, Assume
Receiver:		
Receiver.	Solel UVAC 3	Liaqat,2018, SAM, Assume
Absorber tube inner diameter.	0.066 m	Liaqat,2018
Absorber tube outer diameter.	0.07 m	Liaqat,2018
Power Cycle:		
Design Grosse output.	111 MWe	Liaqat,2018, Assume
Estimated gross to net - conversion factor.	0.9	Liaqat,2018, SAM-LMKADEM,2021
Estimated net output design (nameplate).	100 MWe	Liaqat,2018, SAM, Assume
Rated cycle conversion efficiency.	0.356	Liaqat,2018, SAM-LMKADEM,2021
Design inlet temperature.	391 °C	Liaqat,2018, SAM, Assume
Design outlet temperature.	293 °C	Liaqat,2018, SAM-LMKADEM,2021
Boiler operating pressure.	100 Bar	Liaqat,2018, SAM
Cooling condenser type.	Air cooled	SAM , Assume
Thermal Storage:		
Field HTF fluid.	Hitec Solar Salt	Liaqat,2018, SAM, Assume
Full load hour of TES.	6 hr	Liaqat,2018, SAM, Assume
Storage Volume.	10482.8 m^3	Liaqat,2018, SAM, Assume
Parasitic:		
Balance of plant parasitic.	0.02467 MWe/Mwcap	Liaqat,2018-LMKADEM,2021
Auxiliary heater, boiler parasitic.	0.02273 MWe/Mwcap	SAM, Liaqat,2018
Piping Thermal loss coefficient.	0.45 $W/m^2.K$	Liaqat,2018-LMKADEM,2021