

Overview and impact of the renewable energy plants connected to the electrical network in southwest Algeria

Asma Chabani^{1,*}, Salim Makhloufi², Salah Lachtar^{3,4}

¹ LEESI Laboratory, Department of science Material, university of Adrar. Algeria

² LEESI Laboratory, Department of hydrocarbons and renewable energies, university of Adrar. Algeria

³ Unité de Recherche en Energie Renouvelables en Milieu Saharien, URERMS, Centre de Développement des Energies Renouvelables, CDER, 01000 Adrar, Algeria

⁴ LGEB- laboratory, Department of Electrical Engineering, University of Biskra, Algeria

Abstract

Many countries have initiated strategies to produce energy from alternative sources, reduce the economic dependence on conventional sources, and limit dioxide carbon emissions. Algeria is one of the countries producing conventional energy sources (petrol and gas), the growing of fossils energy consumption in Algeria reduces its oil product exports. This paper focuses on a comprehensive view of the global electrical energy situation and exactly the renewable energy sector in Algeria with specific details of the electrical network named Pole InSalih-Adrar-Timimoun (PIAT). Also, three renewable energy centers were revised completely technically, Also, an investigation of the Algerian renewable energy plan in horizons 2030 was attained in this paper

Keywords: Algerian electrical network, photovoltaic power plants, wind power plants, renewable energy, quantification.

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1. Introduction

The Covid-19 pandemic that emerged at the end of 2019 has led to an economic shutdown in many economies in the world, especially the developed ones, to a drop in oil prices, which led to a contraction in the economies of oil-exporting countries, as oil prices fell to their lowest levels. According to the annual report of the Bretton Woods Foundation (2019-2020), which states that in many oil-exporting countries, measures to reduce oil production in the face of declining prices will lead to a decrease in their economic activities by 5 %, compared to an expected growth of 2 %, which will significantly slow down the economic growth. As the World Bank in his last report published in June 2020 expects a 4.2 % contraction of global GDP for this year 2021, this was the deepest global recession since World War II and is equivalent to three times the global recession that occurred in 2009. As the World Bank's report stated last year (2020), that in

developed economies, it is expected real GDP in the United States was dropped by 6.1 % in 2020, and expected to rise by 4 % this year. In the Eurozone, the drop in real GDP was 9.1 % in 2020 and is expected to climb to 4.5% this year. In Algeria, the decrease in real GDP was 6.4 % in 2020, while it expects to increase to 1.9 % this year [1].

The Algerian government is racing against time to get out of the fuel mantle as the only source of income that the country has relied on for decades and to enter into a new era that depends on diversifying the economy to achieve stable and secure development. Algerian government's vision is based on stimulating investment in all the local potentials available outside of hydrocarbons that will drive development in the country, especially clean energy sources, in particular, solar and wind energies.

Algeria started the green energy dynamics by launching an ambitious program to develop renewable energies and energy efficiency in line with the approach adopted by the government on February 3, 2011. The updated renewable

*Corresponding author. Email: asm.chabani@univ-adrar.edu.dz

energy program consists of installing renewable energy of about 22,000 MW by 2030 for the national market while maintaining the export option as a strategic goal, if possible [2]. This program aims to achieve energy savings by 2030 by 63 million Top (Tonne of oil equivalent) for all sectors, which will reduce carbon dioxide emissions by 193 million tons. This program was expected to be implemented in two phases, as the first phase, extending from 2015-2020, was to achieve 4010 MW power between PV and wind. However, what has been achieved at this phase until 2018 is 444.1 MW PV, of which 53 MW was from the share of PIAT and 10.2 MW of wind are all from the PIAT share as well, the other RE stations are distributed between the interconnected North Network (RIN) and the Southern Isolated Networks (RIS). The second phase extended from 2021 to 2030, is devoted to developing the electrical interconnection between RIN and PIAT, it will allow the installation of large renewable energy plants in the regions of InSalah, Adrar, Timimoun, and Bechar and their integration in the national energy system to support the northern RIN network [3]. Most of these stations will be installed within the framework of the Desertec program as part of developing renewable energies and taking into account the current potentials and absorption capabilities of the national grid for the transmission and distribution of electrical energy and energy from renewable sources, and this program will be adapted to develop renewable energies with a capacity of 15,000 MW by 2035, including 4000 MW will be implemented by 2024 (more information on this topic is in section 3). The realization of these capacities will not only save nearly 240 billion m³ of natural gas but also avoid the emission of 200 million tons of CO₂, as well as the effective development of a network of small and medium companies throughout the production chain dedicated to renewable energy [4].

Several research papers have dealt with the potentials of renewable energy that Algeria abounds in, and how to benefit from it in economic development and improve the social conditions citizens, among these works, Zhou et al are interested in strategy studying of energy resources management in Algeria [5]. Boudghene focused on sustainability challenges in Algerian renewable energy assessment [6]. Fathi et al assessed the technical and economic implications of the cleaning protocol for photovoltaic power plants in the Algerian Sahara [7]. Farouk et al worked to identify the wind map, based on the study of meteorological data [8]. Himri et al worked on studying the prospects for wind energy projects in Algeria [9].

Arhun et al. concentrate on the transformation of kinetic energy to electrical energy based on walking pressure, this type of energy classified as an alternative and decentralized source. Also, the authors use the correlation method to the analysis energy output of the kinetic system, authors propose to use devices installed in the big street to capture public movement and feed the lighting grid [10].

Numerous works have been done on renewable power generation. Here are presented some innovative ideas proposed recently in the literature.

Nia et al. focus on walking energy generation, compare and classify the most powerful technologies used for transforming

walking energy to electricity. Several different forms, though certain pavement plates are created for the gathering of electricity, are found on the body of the consumer to collect kinetic energy. The paper concludes that the pavement that has been fitted with harvesters is more confident as it is independent of anatomical parameters than the technology used inside the bodies [11].

Patlins et al. presents a process of generating electricity by power generating paving slabs. A prototype of an energy-generating slab with an electro machine unit that can operate with one or two stepper motors have been made. Experimental studies show that It is possible to estimate the potential of the power generating paving slabs as an alternative source of energy, taking into account the data obtained from experimental studies and knowing the density of the humans flow [12].

In [13], the authors chose to focus on determining the best load resistance for mono-crystalline and polycrystalline panels for electrical energy produced which corresponds to the requirement for maximum load power transmission, the experimental findings are provided in the form of volt-ampere characteristics and the reliance on charge current of the PV panels. The findings show the encouraging possibility of using sustainable road pavement to produce green energy. The objective of this paper is to present the electrical situation in Algeria with a complete overview of the last program and project planned in horizon 2030 with a full description of three different renewable energy stations.

This paper is divided into five sections; the first focuses on the energy situation in Algeria with the last statistics and the different electrical grid plan.

The second section shows an overview of the renewable energy situation and exactly on solar and wind energy potential. The national electrical network and Pole InSalih-Adrar-Timimoun (PIAT) are described in sections three and four respectively. The last section shows the renewable energy impact on the economy and environment of the PIAT.

2. An overview of Algeria's energy sector

Until recently, Algeria relies entirely on fossil energy for its electricity. Natural Gas comes first in terms of consumption for its abundance locally, followed by oil, which negatively affects the reserves of these two substances and their export revenues, on which the national economy depends almost completely. So, Oil and Gas export revenues are the backbones of the Algerian economy, accounting for nearly 30% of Gross Domestic Product (GDP), 60% of budget revenues, and about 95% of export earnings [14]. Algeria is currently the third Gas supplier to Europe after Russia and Norway, with quantities amounting to 11% of Europe's needs [15]

Algeria consumes about 20 billion cubic meters of gas annually, as the number of electric power stations in the country is 107, producing 20963 MW ready for exploitation until the end of 2018 [16], making Algeria the fourth country in Africa after Nigeria, South Africa, and Egypt, respectively. Most of these plants depend on producing electric energy

using gas turbines. With the increased demand for electricity annually, which is imposed by the acceleration in economic and demographic growth, the Ministry of Energy has come to approve renewable energy stations, especially solar energy, through the production fields of the Electricity & Renewable Energy Company (SKTM), which allows at the long term an economy of about 300 billion m³ of gas, which means an additional volume of the country's reserves equivalent of 7 to 8 years of current natural gas consumption. SKTM is considered as one of the production sectors that belongs to the National Electricity & Gas Company (SONELGAZ), created in April 2013, in a context marked by a major factor which is the necessity to satisfy the demand for electricity in the Algerian Sahara (great south), in the best conditions of quality and continuity service, depending on the development and promotion of renewable energies.

In this context, Algeria launched the renewable energy program, which aims to produce 22,000 MW of electricity from renewable sources such as solar and wind energy in the medium and long term, and this will enable the creation of about 700,000 jobs. Also, renewable energy stations provide economic benefits such as reducing Among the costs of producing electric energy, starting from exploiting the capabilities of transferring clean energies, preserving the environment, and reducing Gas emissions while reducing the use of the latter in electricity generation to avoid the dangers of air pollution, in fulfillment of Algeria's obligations in terms of climate protection agreements.

But, this year comes in an exceptional circumstance on all countries of the world after the outbreak of the global health crisis due to COVID-19 and its economic turmoil in global markets which led to a sharp drop in the price of oil, Algeria is facing a joint economic shock that has led to a decline in Algeria's total oil revenues this year 2020 to 21.2 %. These exceptional conditions will increase the trade deficit to a peak of 18.8% of GDP in 2020 [17]. The economic indicator for 2019 is presented in the table. 1.

Table 1. Economic indicators for 2019

Population, Million	42.7
GDP, Current USD billion	206.3
GDP per capita, current USD	4834

As a step to reduce total dependence on fossil fuels, currently Algeria relies on the five-energy strategy that was implemented in 1998, when the government launched special funds to develop remote areas in general and southern (Sahara) in particular. This program was the first step to encourage the establishment of isolated stations to produce electrical energy using renewable energies, especially solar energy. These energies are represented in five main sources: natural gas, oil, solar energy, wind energy, and hydropower. In this context, the International Energy Agency estimated that Algeria has vast areas in the Sahara that enjoy strong sunlight all year capable of producing 162 TWh of electricity [18].

3. Potential energy potential in Algeria

Solar energy is one of the most abundant and renewable sources of energy in the world, and it is a solar beam that can be used in several matters, the most important of which is electricity generation, and since it is spread all over the world differently, it is considered a clean source of energy, and therefore, the Exploiting 1% of this energy appropriately will meet the largest of the world's energy needs in the future [19]. Algeria is one of the most important sources of solar energy in the world due to its geographical location, which is characterized by abundant radiation throughout the year, especially in the Sahara region, according to the World Energy Council report (WEC) [20] as shown in Fig. 1 and table 2 [21,22]. This region is characterized by ideal conditions for the production of solar energy in the world, as it enjoys a severe decrease in humidity, lack of clouds and lack of rain throughout the year, and vast flat and empty lands. All these conditions are enormous potential for energy generation compared to the requirements regional and global energy, as 10% of the Algerian desert can provide the EU's energy needs [23]

Table 2. Solar potential by climatic region in Algeria

Areas	Coastal area	High plans	Sahara
Surface (%)	4	10	86
Area (km²)	95.27	238.174	2.048.297
Mean daily sunshine duration (h)	7.26	8.22	9.59
Average duration of sunshine (h/year)	2650	3000	3500
Received average energy (kWh/m²/year)	1700	1900	2650
Solar daily energy density (kWh/m²)	4.66	5.21	7.26
Potential daily energy (TWh)	443.96	1240.89	14.870.63

Algeria is indeed one of the most important sources of solar energy in the world with a duration of sunshine of 3000 hours per year and reaches 3900 hours in Sahara. With this enormous sunshine quantity per year, Algeria presents the most important solar potential of the whole Mediterranean basin, according to the data provided by the Center for Development of Renewable Energy (CDER), MEM, and WEC. This potential for solar energy exceeds 6 billion GWh/year. A study conducted by the German Aerospace Centre (DLR) and the CDER, mainly based on satellite image processing, concluded on assessing the economic potential for solar energy generation in Algeria.

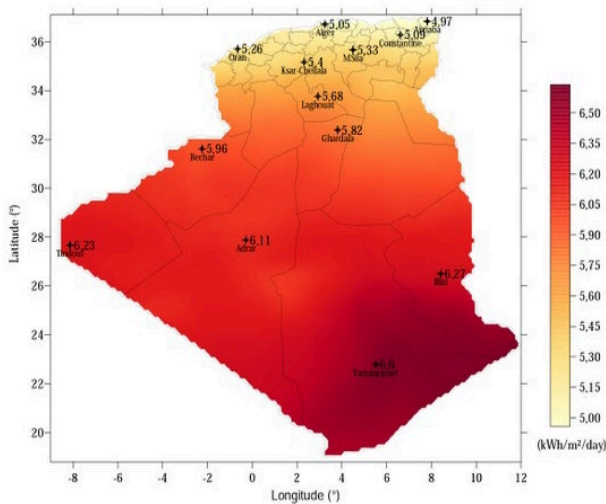


Figure 1. Potential for solar energy supply in the different Algeria region (Wh/m²) [24]

The theoretical economic potential data were obtained are gathered in the RE guide report by the MEM [22,25], where the Thermal Solar (TS) producible is estimated at 169,000 TWh/year, and the PV Solar is estimated at 13.9 TWh/year. The recently targets planned by the Algerian government regarding RE, the Dii Desert Energy (Desertec) mega-environmental project, which is based on the utilization of solar energy available in the North African desert, including the Algerian desert, aims to provide neighboring regions and Europe with green electricity in a sustainable manner. The project started in 2003 under the auspices of Club Roma. Its investment cost is estimated at at least 400 billion Euros, which makes it cover the equivalent of 20% of Europe's electricity needs. The project has been frozen by successive governments in the past decade because it is considered a useless project. According to the program presented by the new president, the use of renewable energies, especially solar energy, is on his agenda. On February 13 2021, the Minister of Energy announced the relaunch of the Desertec project, to ensure that Algeria will be able to produce at least 15,000 MW of electricity by 2035. To this end, the Minister of Energy clarified that the SONELGAZ was responsible for

implementing renewable energy development programs through solar power plants in the Algerian Sahara. The RE, in particular, the PV or Concentrated solar power (CSP) are currently a response to resolve the environmental problems and greenhouse gas emission which are considered the main cause of global problem warming, and a permanent solution to increased energy requirements [26,27].

3.1 PV solar energy

Recently, many research centers all over the world have harnessed huge potential for developing solar PV energy technology, which is one of the key technologies able to cover the growing global demand with clean energy and the lowest cost. In this context, several countries, including Algeria, have adopted various programs to support their conventional electrical networks with solar PV systems, to cover the increase in demand due to economic growth.

A- PV solar energy realizations

In the Table 3 below, we review all the solar PV power plants connected to the grid, which are represented by 23 photovoltaic stations spread across the entire national territory that entered service until January 2018, based on the renewable energy managed by the electricity and renewable energy company (SKTM):

B- PV solar energy development program

Algeria started the green energy dynamic by launching an ambitious program to develop renewable energy (RE) and energy efficiency. This vision of the Algerian government is based on a strategy that focuses on developing endless resources such as solar energy and using it to diversify energy sources and prepare Algeria thanks to a mix of initiatives for a new era in sustainable energy.

This updated program consists of installing about 22,000 MW of renewable energy by 2030 for the national market. This program was accompanied by the adoption of an appropriate legal framework for the RE promotion, not only through multifaceted incentives devoted to investment in the RE industry and its uses but also the promotion of the related production equipment industry [3,22].

Since its launch from 2011 to 2018, only 344.1 MW of PV energy has been achieved (Table 3), with some promising private initiatives, especially in the production of PV panels locally.

Table 3. PV solar energy realizations

Province	PV Power plant location	Surface (Hectare)	Installed Capacity (MW)	commissioning date
RIN				
GHARDAIA	Oued Nechou	05	1.1	10/07/2014
DJELFA	Ain-El-Ibel (I)	40	20	08/04/2016
LAGHOUAT	El Khnag (I)	40	20	08/04/2016
SOUK AHRAS	Oued El Keberit	20	15	24/04/2016
NAAMA	Sedrate Leghzal	32	20	03/05/2016
SAIDA	Ain-Skhouna	60	30	05/05/2016
SIDI-BEL-ABBES	Telagh	30	12	29/09/2016

EL BAYADH	Biodh Sidi Chikh	40	23	26/10/2016
M'SILA	Ain-El-Melh	40	20	26/01/2017
OUARGLA	El-Hdjira	60	30	16/02/2017
DJELFA	Ain-El-lbel (II)	80	33	06/04/2017
LAGHOAT	El-Khnag (II)	80	40	26/04/2017
BATNA	Oued El-Ma	04	02	16/01/2018
TOTAL RIN (PV SE)			266.1	
PIAT				
ADRAR	Kabertene	06	03	13/10/2015
ADRAR	Adrar	40	20	28/10/2015
ADRAR	Zaouiet.Kounta	12	06	11/01/2016
ADRAR	Reggane	10	05	28/01/2016
ADRAR	Timimoun	18	09	07/02/2016
TAMANRASSET	In-Salah	10	05	11/02/2016
ADRAR	Aoulef	10	05	07/03/2016
TOTAL PIAT (PV SE)			53	
RIS				
TAMANRASSET	Tamanrasset	26	13	03/11/2015
TINDOUF	Tindouf	18	09	14/12/2015
ILLIZI	Djanet	06	03	19/02/2015
Total RIS (PV SE)			25	
Total SKTM (PV SE)			344.1	

This ambitious program was resumed this year (2020) thanks to a call for tenders for the first 4050 MW of production over the next two years. The energy component of the program provides for the creation of a partnership to finance, build and operate several PV power plants of 1030 MW each [28].

The Algerian government intends to develop the electrical interconnection between the North and the Sahara (RIN-PIAT), which 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. By this deadline, PV solar farms could be economically viable [3]

3.2 Wind energy

Wind energy is one of the cleanest and least expensive energies since over the past two decades, wind energy generation has increased significantly across the world. According to the Global Wind Energy Council (GWEC) [29], installed capacity jumped from 591 GW in 2018, to 621 GW in 2019. The European Union countries led by Germany, France, Sweden, UK, and Turkey were the leaders in wind power plants with a total capacity of 182.652 GW.

Recently, China launched a massive and ambitious program with a total of 229 GW installed until the end of 2019, equivalent to a quarter of the production capacity of wind energy in the world, followed by the USA, which has 105 GW and India with 37 GW registered at the end of 2019.

On the African continent, wind energy development is still weak, as it was only 6.673 GW distributed mainly in South Africa, Egypt, and Kenya. It was recently supported by wind

energy projects with a production capacity of 944 MW at the end of 2019.

Being committed to a new stage in developing renewable energies, Algeria plans to reach, by 2030, nearly 40 percent of national electricity production from renewable energy sources, despite the choice of solar energy as the predominant one. Wind energy comes in the second line of production in this program. Before studying the possibility of establishing a wind farm in a specific area, it is necessary to carry out studies on wind fields across various sites to know the accurate meteorology of winds. Therefore, the Renewable Energies Development Center (CDER) has conducted in-depth studies to locate wind fields across the country's territory [22]. These studies of wind energy data collected over 5 years from 75 sites of the Weather station for the National Weather Observatory across the national territory, concluded that 8 sites have enormous wind energy potentials. These areas were identified in descending order according to the strength of the wind, In-Saleh, Tiaret, Adrar, Tindouf, Biskra, Oran, Bejaia, and Bordj Bou Arreridj. The average wind speed in some locations is 5 m/s and 8.5 m/s at an altitude of 80 m (Fig. 2).

A- Wind energy realization

As part of the application of the renewable energy program "2011-2030", the first 10.2 MW wind farm was installed and put into service in 2014, in the Kabertene region in Adrar. This electricity production plant, the first of its kind on a national scale, consists of 12 wind turbines of 850 kW of power, located on an area of 33 hectares [22].

B- Wind energy development program

Algeria is keen to integrate wind energy into the energy mix, which is seen today as a major issue. The 2030 target set by the Ministry of Energy is a deadline that must be reached

inevitably by launching and implementing projects in a very short time to ensure the 5 GW of the wind energy envisaged. Indeed, embodying the renewable energies program, especially the wind component, requires the construction of about twenty wind farms, each consisting of a hundred high-capacity wind turbines (1.5 MW - 3 MW), and thus involve large-scale work [3].

What has been accomplished from wind energy farms until this year 2020 is one farm, in Adrar city with a power of 10 MW (Table 4). Waiting for the remainder of the government's plan to invest in wind energy by installing 5 GW of wind energy out of 22 GW of renewable energy by 2030 [30].

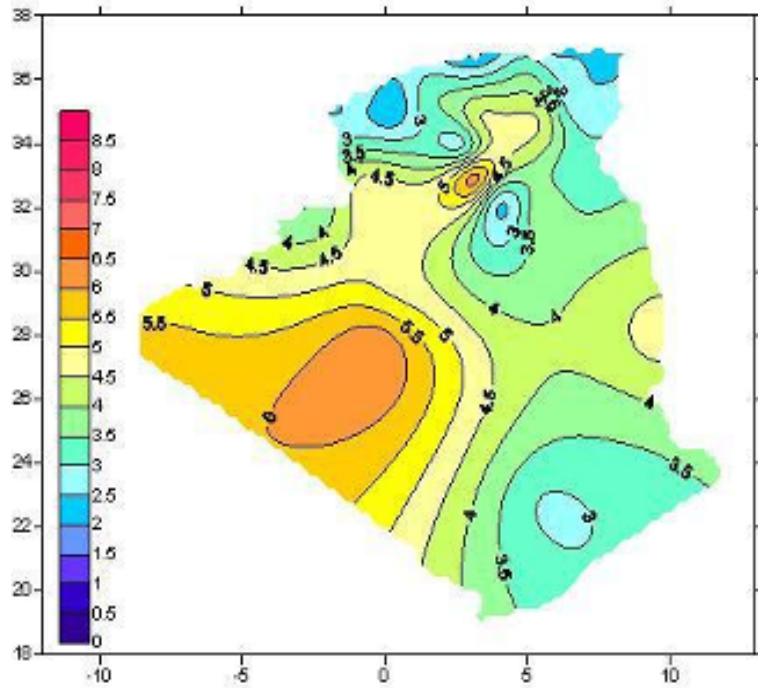


Figure 2. Wind fields Algeria chart at 10 m altitudes on the surface of the Earth [5]

Table 4. Algeria total wind farm installed capacity

Province	PV Power plant location	Surface (Hectare)	Installed Capacity (MW)	commissioning date
ADRAR	Kabertene	33	10.2	04/07/2014
Total SKTM (WE)			10.2	

3.3 Hydraulic energy

From the biggest program proposed by the Algerian government to produce green energy, hydraulic energy can cover the electrical and water consumption of this country. The annual quantity of rainfall estimated at 65 billion m³, just 25 billion m³ are used due to few barrage numbers (from 103 location just 50 barrages are used) [31]. In 2019, Algeria generates more than 228 MW (0.21% of global power production) using hydraulic power, this type of power characterizes by low Levelized cost compare to other resources due to natural storage and freely resource [32,33].

3.4 Geothermal potential

Algeria have mediterranean climate instable and uncomfortable in winter and summer seasons that makes use of heating or air-conditioner necessity. Algeria have more than 200 geothermal location, divided in three section, north-east, north-west and south-west with temperature equal to 5°C/100m, Fig.3 bellow illustrates geothermal resource in Algeria [34,36].

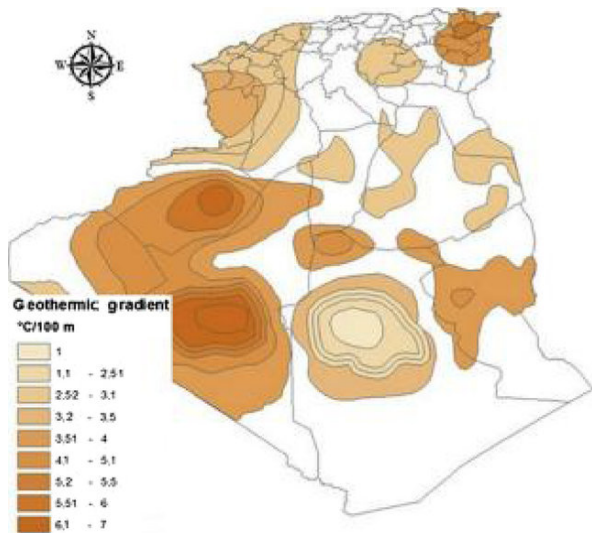


Figure 3. geothermal maps of Algeria [35]

4. Algeria electrical network description

The electricity network in Algeria consists of three main electrical networks, namely, the interconnected national network (RIN), which extends the north of the country, to the Pole (PIAT), and the isolated southern networks (RIS).

These networks depend on the production of electric energy on several different gases, diesel, steam, combined cycle, and hydropower stations, assured by the Algerian National Electricity Production Company (SPE). These networks were supported by renewable energy stations within the framework of the national plan for renewable energies that started in 2013 when the Renewable Energy Electricity Company (SKTM) was created in the same year, and it was entrusted with the task of building and operating these stations.

RIN is a network consisting of 40 stations for the production of electric energy, and it is available on two transport lines, one with a capacity of 400 kV and the other with a capacity of 220 kV, covering all the north of the country with electricity (residential compounds and all of its facilities and industrial areas).

PIAT is a network consisting of 28 power plants, most of which are gas turbines, interconnected with a capacity of 220 kV and covering large areas in the southwest of the country (InSaleh-Adrar-Timimoun).

RIS is a group of electrical stations isolated between them, spread across 26 sites in the middle and far south of the Sahara. This electrical network covers remote areas far from the main networks.

These three networks can be summarized by numbers in the following table 5 according to the latest report published by the Algerian Electricity and Gas Company for the year 2020 [37].

Table 5. Evolution of the main parameters of the 3 electricity networks (2000-2020).

Parameters	Year 2000	Year 2020	Evolution 2000-2020 (%)
Installed capacity (MW)	5907	20963	355%
Electricity transmission network (Km)	12285	29644	241%
Electricity distribution network (Km)	192481	338380	176%
Number of electricity customers (Unit)	4 544 289	9 605 685	211%
Electrical production (GWh)	-	72395	-

It is also possible to mention the history of the development and growth of the conventional and renewable produced electricity energy for these 3 networks combined from 1980 to 2018 according to the reports of (Bilan énergétique National) internet network site in the following table:

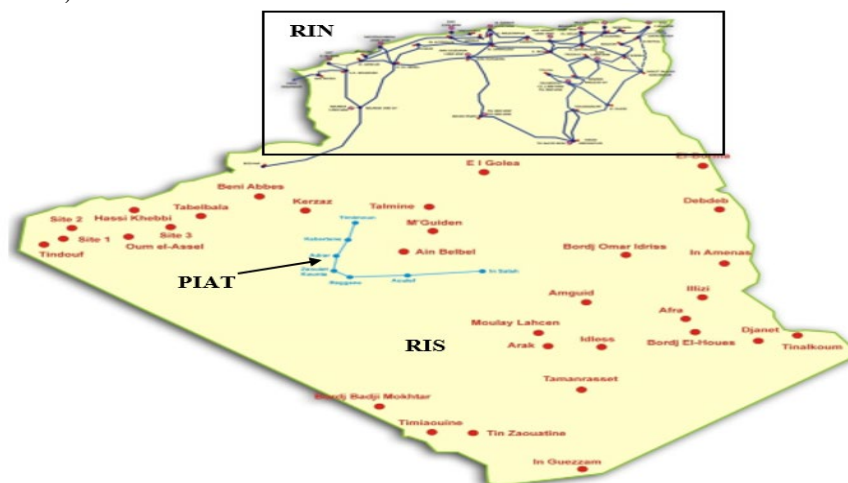


Figure 4. Algerian electricity network**Table 6.** Development and growth of conventional and renewable electric energy in Algeria between (1980-2018) [38]

Electrical production by type of primary energy	Steam turbine	Gas turbine	Combined cycle	Hydraulic	Diesel	Photovoltaic wind	Total (GWh)
1980	3621	2223	-	251	125	-	6220
1990	8397	6704	-	135	216	-	15452
2005	16624	15679	386	555	281	-	33525
2006	14558	16463	3419	218	264	-	34922
2007	14142	17011	5321	226	250	-	36950
2008	13384	20339	5704	277	283	-	39987
2009	11857	19940	10318	342	313	-	42770
2010	9692	19564	15341	173	403	-	45173
2011	9654	22055	15701	378	464	-	48252
2012	9422	24075	18623	389	416	-	52925
2013	9582	17400	27685	98	227	-	54992
2014	10221	20211	28444	193	248	2	59319
2015	10227	26970	26122	145	276	33	63773
2016	11511	24441	29664	72	281	264	70997
2017	9992	30752	29204	56	314	579	76017
2018	10682	36580	28244	117	374	666	76663

5. PIAT electrical network details

As part of the implementation of the National Renewable Energy Program (NREP), the PIAT electrical network is a typical example of the integration of renewable energy where there is the greatest potential for solar and wind energies in this Sahara area.

Table 7 below mentions all the PIAT conventional power plants, which commissioned from its inception in 1982 to 2017 (SKTM):

Table 7. Conventional power plants installed capacity for PIAT electrical grid.

Conventional power plants	Number of Generators	installed Capacity (MW)
Adrar	10	186
Zaouiet Kounta	08	160
In-Salah	04	96
Timimoun	04	80
Kabertane	02	40
Total	28	562

As for installed capacity from renewable energies power plants integrated into PIAT electrical grid, there are 7 photovoltaic power plants and one for wind farm (see respectively tables 3 and 4) with a production capacity of 63.2 MW, equivalent to 11% of the total energy produced.

5.1 Technical details of some renewable energy plants

In this section, technical details information of some renewable energy plants installed closer to Adrar city and its environs are presented.

A- 20 MW Photovoltaic power plant (Adrar)

This 20 Mwc photovoltaic power plant installed in the West Adrar city, it occupies an area of 40 Hectares with 81840 panels, which is entered into service on October 12, 2015, it is connected to a 30 kV PIAT electrical distribution network.



Figure 5. Panoramic photograph of the 20 MW PV power plant (Adrar).

This station consists of twenty (20) identical photovoltaic sub-fields, each one comprising a conversion station, a transformer station and a field of solar modules with a production of 1 MWc, forming 93 arrays, each array consists of 44 panels divided into 2 strings, each string consists of 22 panels connected in series. The panels are manufactured using polycrystalline silicon by Yingly Solar (Fig.5). The panel technical specifications are given in Table 8.

Table 8. Panel technical specifications

Designation	Characteristic
Mark	YINGLI SOLAR
Module type	YL245P-29b
Cell type	polycrystalline Silicon
Application class	A
Pmax (W)	245 W
Vpm (V)	29.6 V
Imp (A)	8.28 A
Voc (V)	37.5 V
Isc (A)	8.83 A
Max series fuse	15 A
Vmax	1000 V

The inverter technical specifications are given in Table. 9.

Table 9. Inverter technical specifications

Designation	Characteristic
Mark	SUNGROW
Type	SG 500MX
Protection class	I
Protection IP	IP 21
Operating temperature	-30°C à +55°C
Input – DC	
Vmax	1000V
Isc	1344 A
Min-VMPP	500V
Max-VMPP	850V
Max-Input current	1120 A
Overvoltage category	II
Output – AC	
Max-Output power	500 KW
Nominal output voltage	3315 V
Nominal output frequency	50 Hz
Max output current	1008 A
Power factor	[-0,9 -1] [0,9 1]
Overvoltage category	III

The power transformer technical specifications are given in Table. 10.

Table 10. Power transformer technical specifications

Designation	Characteristic	
Mark	SUTEN CHINE	
Refreshing	ONAN	
Isolation	Oil	
Winding	Copper	
Nominal power	1250 KVA	160 KVA
Primary voltage	2x315 V	30 KV+/-5%
Secondary voltage	30 KV+/-5%	400 V
Isolation level	36 kV	
Coupling	DY11	DYN114
Vcc	6%	

B- 3 MW Photovoltaic power plant (Kaberten)

This 3 MW photovoltaic power plant shown in Fig.5 is installed in the Kaberten area 60 km North-West of Adrar city. It occupies an area of 6 hectares with 12276 panels, which is entered into service in July 2014, it is connected to the same 30 kV PIAT electrical distribution network. This station consists of three (3) identical photovoltaic sub-fields, each comprising a conversion station, a transformer station, and a field of solar modules with a production of 1 MW. All the equipment at this PV power plant (3 MW) is identical to that at the 20 MW Adrar, such as solar panels, inverters, and power transformers. The dimensioning of these two PV power plants is shown in Table. 11.

Table 11: PV power plant dimension

Power plant sizing	Kaberten (3 MW)	Adrar (20 MW)
Sub-fields number	03	20
Power plant total panels	12276	81840
Panels number per Sub-field	4092	4092
Total panels surface	6644 m ²	44294 m ²

C- 10 MW wind turbine power plant (Kaberten)

This farm shown in Fig.6 is installed in the Kaberten area, depends on wind energy, and its electrical energy production is based on Doubly Fed Induction Generators (DFIG) manufactured by (GAMESA), each other has a 0.85 MW nominal power, with a produced energy is 690V_{ac}. the station is composed of twelve (12) wind turbines with a total production of 10 MW, each separated from the other with a parallel connection to facilitate the maintenance, and it covers an area of 33 hectares and is associated with the 30 kV PIAT electrical distribution network.

According to its technical specification presented in the Table. 12, each of these turbines can reduce greenhouse gas emissions by 1000 tons/year. The DFIG technical specifications are given in the table below:

Table 12: DFIG and converter technical specifications

Designation	Characteristic
Mark	GAMESA
Type	G52-850
Height	55 m
Blades number	3 blades of 60 m length
Total nominal power delivered by the machine (stator/rotor sum power)	850kW
Annual energy produced	3.42 GWh (Sav: 8.5 m/s, air: 1.225kg/m3)
Stator nominal power	812kW
Rotor nominal power	59KW
Nominal voltage	690kW
Icc max	± 19,5 kA
Voltage Limits in Normal Operation	10% (Perm) +20 % (0,1 s) - 20% (1 s)
Confirm with network regulations	P.O.12.3
Nominal frequency operating network	50/60 Hz
Allowed frequency range	±2 Hz (cont.) ±4 Hz (5s.)
Scalable Cos Φ range	0,95 cap./ind
Generator synchronous speed	1500 tr/min (F=50 Hz) 1800tr/min (60Hz)
Generator nominal speed	1620 tr/min (F= 50Hz) 1944tr/min (F= 60 Hz)
Generator nominal slip	8%

Speed range with triangle connection	1050 –1900 tr/min
Admissible operating temperature range	-30 °C/+ 50 °C
Admissible storage and transport temperature range	40°C/+ 60°C
Maxi humidity level allowed during operation	95 % (without-condensing)
Grid nominal voltage	690V
Converter nominal current – Grid side	71 A RMS
Converter max current – Grid side	91 A RMS
Converter min current – Grid side	59 A RMS
Icc max	19.5 A RMS
Converter power – Rotor side	59 kW
Converter nominal voltage – Rotor side	183V
Converter nominal current – Rotor side	268A
Converter max voltage – Rotor side	608V
Converter max current – Rotor side	354A
Max slip	26.6%

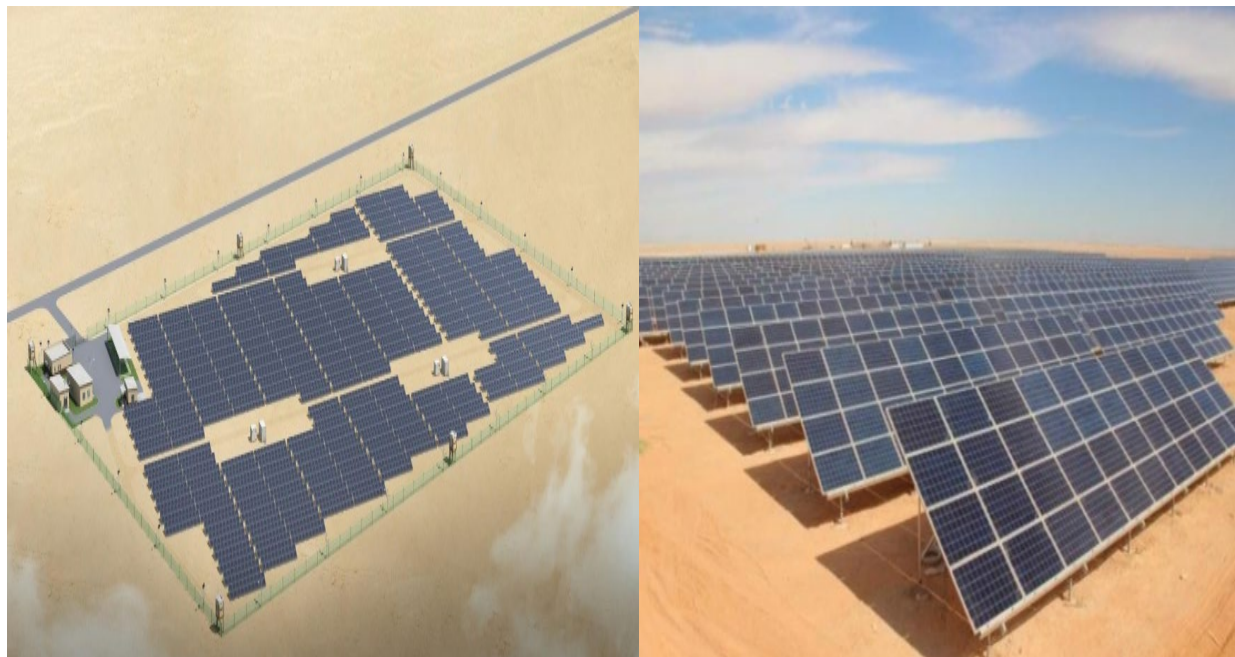


Figure 6. Panoramic photograph of the 3 MW PV power plant (Kaberten)



Figure 7. Panoramic photograph of the 10 MW wind turbine farm (Kaberten)

The power transformer technical specifications are given in Table. 13.

Table 13. Power transformer technical specifications

Designation	Characteristic
Power	1 MW
Loss	5%
Transformation ratio	690V/30kV
Operating voltage	30kV -15/+10%
Iron loss	2300W
Copper loss	14300W à P max

5.2 PIAT electrical transport grid and production

The PIAT electricity transmission network shown in Fig.7 is a set of 220 kV high-voltage line and substation works and equipped with a telecommunications network for monitoring, controlling, and remote control of equipment. This network is managed by the Manager of the Electricity Transport Network, called GRTE Spa, a SONELGAZ Group filial, it was created on January 1, 2004, Following Law No. 02-01 of February 5, 2002, GRTE has a natural monopoly on the transmission of electricity throughout the national territory. In this regard, the Manager has the authorization to operate the transport network issued by the Ministry of Energy and Mines, after advice from the Electricity and Gas Regulation Commission (CREG). Besides, GRTE is responsible of the operation, maintenance, and development of the electricity transport network, intending to guarantee adequate capacity for transit and reserve needs. The grid users are power plants, electricity distribution companies, and customers. GRTE operates the total network described in Table. 14.

Table 14. Transport lines and transformer stations [37]

Electrical grid 2017	Voltage Level (kV)	Length of lines (Km)	Number of transformer stations	Transformation capacity (MVA)	Transformers and a mobile cabin
Total grid	220	30515	319	62083	657
	400	4497	22		
PIAT	220	576.5	9	680	-

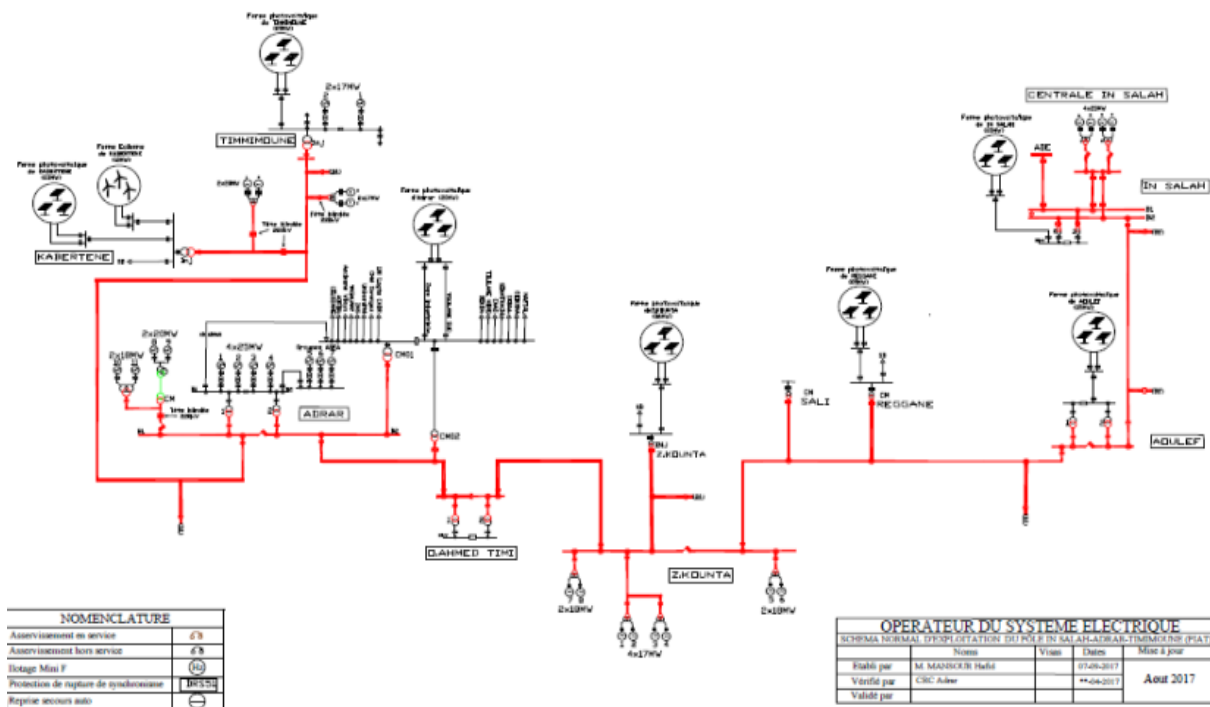


Figure 8. PIAT grid operational diagram, SKTM, 2017

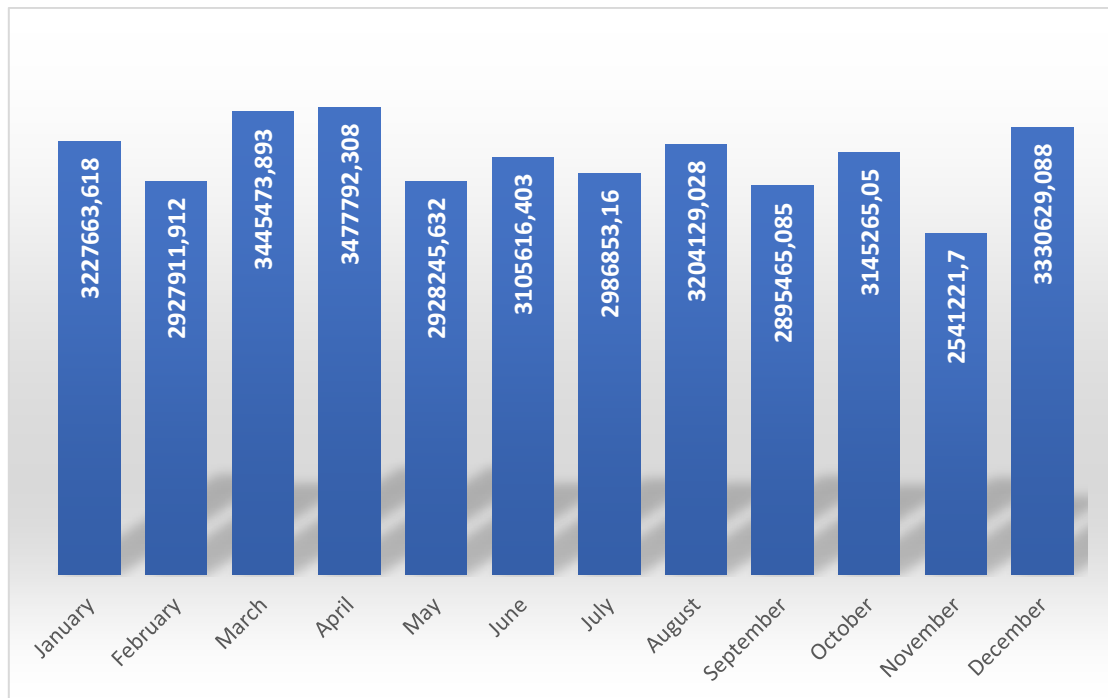


Figure 9. Gas quantity in m³ conserved per month in 2017

6. Impact of renewable energy plants

The energy contribution from renewable energy plants to cover the annual demand for the PIAT network reached 111 GWh in 2017, the equivalent of 37 million m³ monthly

as shown in Fig. 9, which is a large quantity when burned it will emit into the atmosphere the equivalent of 166550 tons of CO₂. But, the contribution of renewable energy stations remains weak compared to the power stations that depend on diesel and NG, which is coming the first with a ratio of 89.76 %, followed by PV power stations with a ratio of 8.51 %, and the wind power comes in last with a

single station producing a ratio of 1.73 % of total PIAT energy.

Fig. 10 shows the annual evolution in demand for power during three different times of the day to study the maximum peak in energy demand, it can be noticed that energy demand in the morning and in the evening is almost the same during a large period of the year, while demand decreases around midnight. It is considered here that the energy demand of industrial activities and the pumping of drinking water for the population, including its use in agricultural activity, is almost stable throughout the year. The household energy demand drops to its lowest level from November to March. This period is known for its mild climate. Whereas, the energy demand begins to increase with the increase in temperatures, from April to reach its highest levels in July, where the total demand for energy reaches 100% compared to the previous period. Then, temperatures begin to drop gradually until the end of October, where the climatic conditions go back to their beginnings.

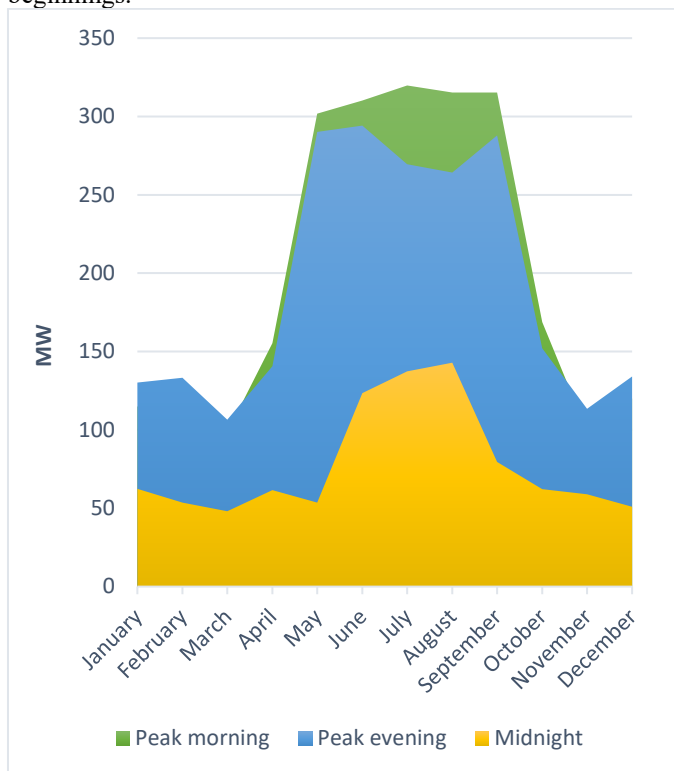


Figure 10. Annual evolution in demand for power

The main reason for the high energy demand is due to the high temperature, where weather conditions force residents to use air conditioners for long hours a day, especially in the morning and in the evening. While, its operation during the night period decreases due to a significant drop in temperature compared to the day, and there is no house without air conditioners since each house has two of them at least. Also, refrigeration equipment in commercial stores and cold rooms with economic activity have to be considered.

7. Conclusion

Renewable energy in Algeria takes a high priority in government program proved by the renewable energy development 2011-2030 plan. Algeria benefits of a high solar potential with more than 3500 sunshine hours per year and wide unexplored ground. Also, wind energy takes important place in national program due to high wind speed (more than 9 m/s annual average).

Algeria is integrated into the utilization and development of renewable energies as a part of a global approach to meet the needs for clean energy needs, reducing greenhouse gas emissions that causing global warming, and ridding the local economy of dependency on fossil resource revenues. In this context, successive Algerian governments have established, over a decade ago, several organizational and structural frameworks for the advancement of this vital sector, among which mentioning:

- Create a favorable policy and regulatory framework that classifies the renewable energy program as a national priority;
- Creation of a subsidiary company devoted to renewable energies and conventional power plants for the Great South Networks (SKTM);
- Establishing several meteorological stations to explore sites that are rich in renewable energies, such as wind speed, direction, humidity, solar radiation, etc.

This program required launching new industrial activities and reviving other industries, among them:

- Launching the project of a solar panels factory in Rouiba area, near Algiers, in partnership with local and foreign specialized companies.
- Reviving the industries that are involved in the manufacture and production of solar panels, such as glass factories, aluminum factories, and electrical products factories.

This program also contributed to stimulating the fields of training, research, and development through a partnership with several universities and national research centers to support the program, among the most important of these centers are CDER and UDES (unity of developing solar equipment), where they were entrusted with the task of mapping renewable energies across the entire national territory, diagnosing PV stations (connected to the network or Independent) and studying the effect of integrating photovoltaic power stations into the Saharan networks.

Also policy and strategy study conducted in partnership with the Centre for Applied Economics in Development (CREAD) to establish the solar PV industry in Algeria, and comparative technical and economic studies of solar photovoltaic technologies between PV and highly concentrated PV (HCPV).

Since 2010, the National Electricity and Gas Company, SONELGAZ, has prepared several training courses in the field of renewable energies in its technical schools, which have trained more than 2000 managers and technicians, including 23 belonging to African companies.

In a review of the results achieved within the framework of the renewable energies program announced in its annual report issued in January 2018, SONEGAS stated the following:

- Integration of renewable energy into the Algerian national electrical system;
- Acquisition of technologies through the implementation of pilot projects for renewable energies (Ghardaia and Kaberten);
- Production of more than 738 GW;
- Participation in covering the national electricity demand (more than 10% for the PIAT);
- Providing hundreds of millions of cubic meters of NG and Diesel (272 m³ during 2.5 years);
- Significant reduction in greenhouse gas emissions (570.000 tons of carbon dioxide was avoided);
- Creating more than 3400 direct and indirect jobs, 411 of which are operation and maintenance;
- Reviving the economies of private security companies and contracting companies by participating in building and securing renewable energy stations (35 local companies specialized in civil engineering);
- Transfer of technology and know-how through supervision during assembly and training in areas (PV systems engineering, operation, and maintenance of a renewable energy plant, control, and monitoring system for the installation of renewable energy and project management);
- Increased efficiency in developing specifications;
- Searching for economically viable solutions to meet the growing demand for energy (competitive price per kWh);

Algeria seeks to be among the leading countries in the long-term renewable energy market by taking measures, the most important of which are:

- Modernization of electrical networks with the introduction of smart technology;
- Supporting and developing the industrial sectors that contribute to the manufacture and installation of products related to renewable energies;
- Development and compliance of locally manufactured renewable energy products with international specifications for export outside the country;
- Adapt commercial management;
- Identify all sites of importance in renewable energies across the entire national territory;
- Providing a qualified workforce by organizing training courses in all specialized schools;
- Administrative facilities and incentives to attract foreign capital for investment and partnership in the renewable energy sector;

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