Mohamed Kheider University of Biskra
Faculty of Sciences and Technology
Electrical Engineering Departement

MASTER THESIS

Sciences and Technologies
Electrical Engineering
Electrical Grids

Submitted and Defended by:
Moustiri Imad Eddine
And
Lachouri Mohamed Akram

June 2022

Managing political market agencements: solar photovoltaic policy in Algeria

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Dedication

To my parents,

"You gave me life as well as the will to live and the courage to succeed. All that I can offer you cannot express the love and gratitude I have for you.

As a testimony, I offer you this modest work to thank you for your sacrifices and for the affection with which you have always surrounded me.

Know that all that I am, all that I will be or aspire to be would never be possible without you.

May ALLAH, the most high, grant you health, happiness and long life.

I hope that your blessing is always with me, and that I never disappoint you. "

Especially to my mother,

"The strong shoulder, the understanding watchful eye and the person most worthy of my esteem and respect.

No dedication can express my feelings and gratitude for all the supports and sacrifices he has shown to me. May Allah preserve you and provide you with health and long life. "

To my brothers,
To my friends,
To my family,
To all my promotion,
To all those who believed in me,

M.Imad Eddine

Dedication

To my dear mother, who represents for me the symbol of strength, She is the bravest woman in the world, She devoted herself body and soul to raise and teach me, She armed me with patience and courage and filled me with her unconditional love, No words can express the deep love I have for you, Without you, nothing would have been possible.

To the man, my precious gift from God, who owes my life, my success and all my respect: my dear father Dr.Toufik

To my dear sister who never ceased to advise, encourage and support me throughout my studies. May God protect her and offer her luck and happiness.

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I dedicate this modest work to you.

L.Mohamed Akram

SUMMARY

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CHAPITER III : Statistics and discussion on the state of PV in Algeria

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General Introduction

With the development of technology and industrial evolution, the need for electricity in huge quantities has become a concern for power producers to meet these continuously growing needs.

Unfortunately, most of the world's electricity production is done through fossil fuel based power plants, which contributes enormously to the pollution of the atmosphere by toxic gases.

In front of this situation, the recourse to the renewable energies turns out to be the good solution where the solar energy represents the most widespread type.

In this research, we will focus on solar photovoltaic energy in Algeria by raising several issues :

What is the solar potential of Algeria ? What is the status of the corresponding regulations? What are the different institutions working in the field of solar energy? What is the state of application of solar photovoltaic sources in Algeria ?

Finally, what are the proposed solutions for the proper development of this solar photovoltaic energy in our country.

Our study will be based on the collection of statistics issued in different national and international institutions and the realities of the application of solar photovoltaic energy in Algeria in various fields.

To complete this work, this thesis is divided into three chapters distributed as follows:

The first chapter will have for objective an overview on the production of electricity, on the other hand the second chapter will be devoted particularly to the description of the photovoltaic solar energy, finally in the last chapter we will give some statistics and discussion on the state of PV in Algeria.

Chapiter I

General Information on The Photovoltaic System

Introduction

This chapter presents in its first part photovoltaics history and their different areas of operation and the component used for the installation of the PV, also we present the different type of panels by recalling their differences.

The second part will be the presentation of the world statistics in photovoltaic system and their classification countries.

1. History of PV

The discovery of the photovoltaic effect dates back to 1839, the year in which the French physicist Alexandre Edmond Bequeret discovered the possibility of producing electricity thanks to light and the presence of semi-conductor materials such as silicon.

After 1913, the first photovoltaic cells were born, but it was not until 1916 that Robert Millikan managed to produce a direct current. The first real solar panel, with an efficiency of 6%, was developed in 1954 by researchers at Bell Laboratories. Solar panels are born, but are still too expensive. Space research is seizing the subject in order to equip its satellites which need a sustainable energy. Following the Bell Laboratories achievement of 6% efficiency, research progressed to 9% efficiency. [EUR 19]

In 1958, the first cells travelled on board the Vanguard 1 satellite. Then it was the turn of the first solar panels, fixed on the Explorer 6 satellite, in 1959. Research continues to adapt solar panels for terrestrial use. The University of Delaware was responsible for the first home powered by photovoltaic cells in 1973. Several factors are making solar energy an increasingly popular resource: the rising cost of fossil fuels and the awareness of the depletion of natural resources are among them. The domestic use of solar panels is growing year after year. [EUR19]

2. Photovoltaic conversions

Photovoltaic devices use semiconducting materials to convert sunlight directly into electricity without creating any air or water pollution they are made of at least two layers of semiconductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces an electric current. To increase their utility, a number of individual photovoltaic cells are interconnected together in a sealed, weatherproof package called a module. [MES 20]

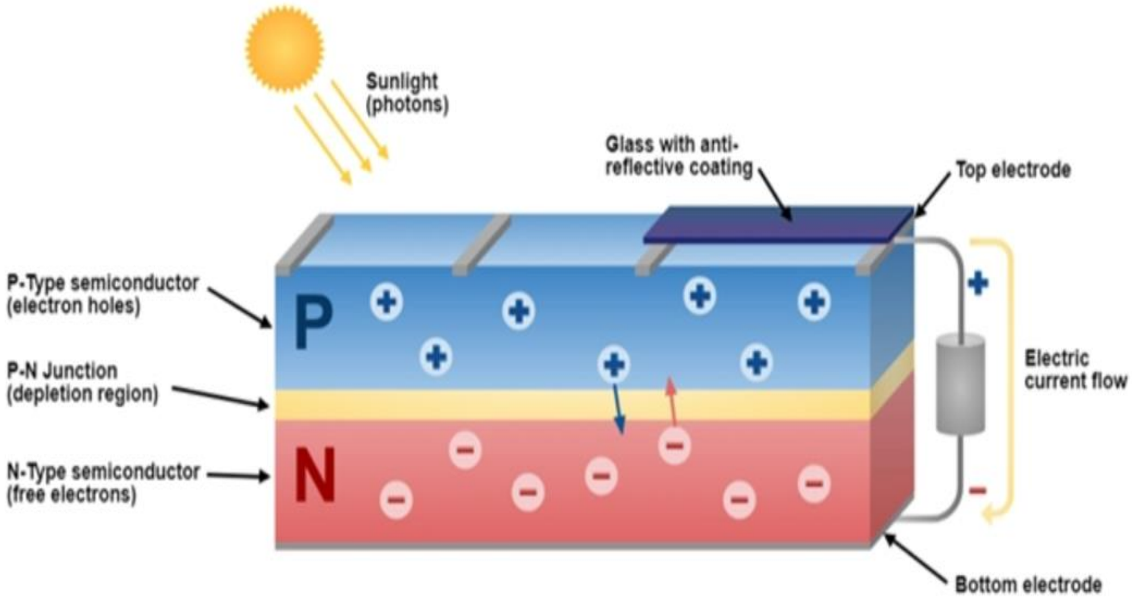

Figure 1: PN junction and photovoltaic conversion [MES 20]

3. Principle of functioning

PV stands for 'Photovoltaics' and means converting light into electricity. The solar panels generate DC electricity from sunlight which is fed through an inverter to convert it into AC electricity. The inverter is connected to your consumer unit (fuse board) so the electricity can be used in home. Solar PV systems use cells to convert sunlight into electricity. The PV cell consists of one or two layers of a semi conducting material, usually silicon. When light shines on the cell it creates an electric field across the layers causing electricity to flow. The greater the intensity of the light, the greater the flow of electricity. PV cells are referred to in terms of the amount of energy they generate in full sunlight: known as kilowatt peak or kWp. On days of high solar availability there will be a considerable volume of energy produced which you may not be able to use. PV system will be connected to the electricity grid so that the grid can take any excess electricity that you cannot use. [ECO 22]

1: Sun

2: The panels

3: The inverter

4: The electricity

5: Powering the home

6: The National Grid

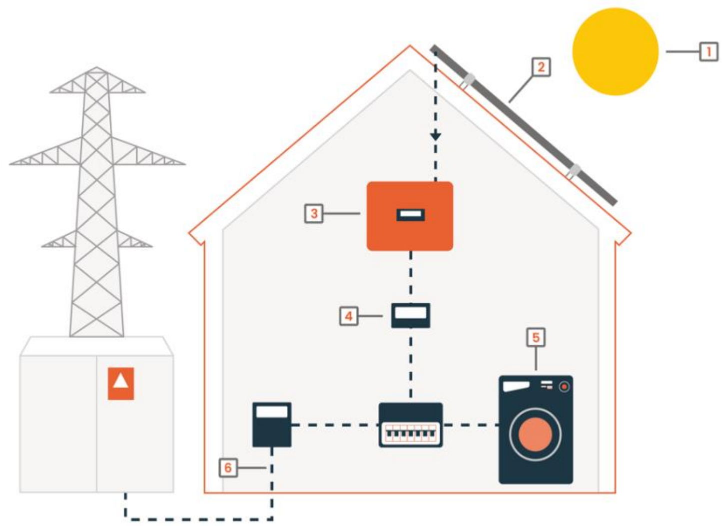

Figure 2: Graph which illustrates how sunlight is turned into solar energy to power the home. [ECO 22]

4. Element of PV system energy

4.1. Solar photovoltaic (PV) panels

also known as a module, is a unit consisting of special cells that generate an electric current in sunlight that are linked together. When the sun shines over the cells, an electric field is created. The stronger the sun, the more electric energy is produced. Nevertheless, the cells do not need direct sunlight to work, and they can still produce electricity on a cloudy day. A group of modules wired in series is called a string. The string determines the operating voltage of the system which is of great importance to your voltage drop and inverter type. The cell, the modules and the string formation leads to the end result which is the Array.[ECO 22]

To generate electricity, solar cells are made of semiconductor materials that convert light into electricity. The most common material used as a semiconductor in solar cell manufacturing is silicon. There are three major types of solar panels: monocrystalline, polycrystalline, and thin-film. Each type has its own unique advantages and disadvantages, and the solar panel type best suited for your installation will depend on factors specific to your own property and desired system characteristics.[JAC 21]

4.1.1. Monocrystalline solar panels (Mono-SI)

This type of solar panels (made of monocrystalline silicon) is the purest one. You can easily recognise them from the uniform dark look and the rounded edges. The silicon's high purity causes this type of solar panel has one of the highest efficiency rates, with the newest ones reaching above 20%. Monocrystalline panels have a high power output, occupy less space, and last the longest. Of course, that also means they are the most expensive of the bunch. Another advantage to consider is that they tend to be slightly less affected by high temperatures compared to polycrystalline panels. [ASK 15]

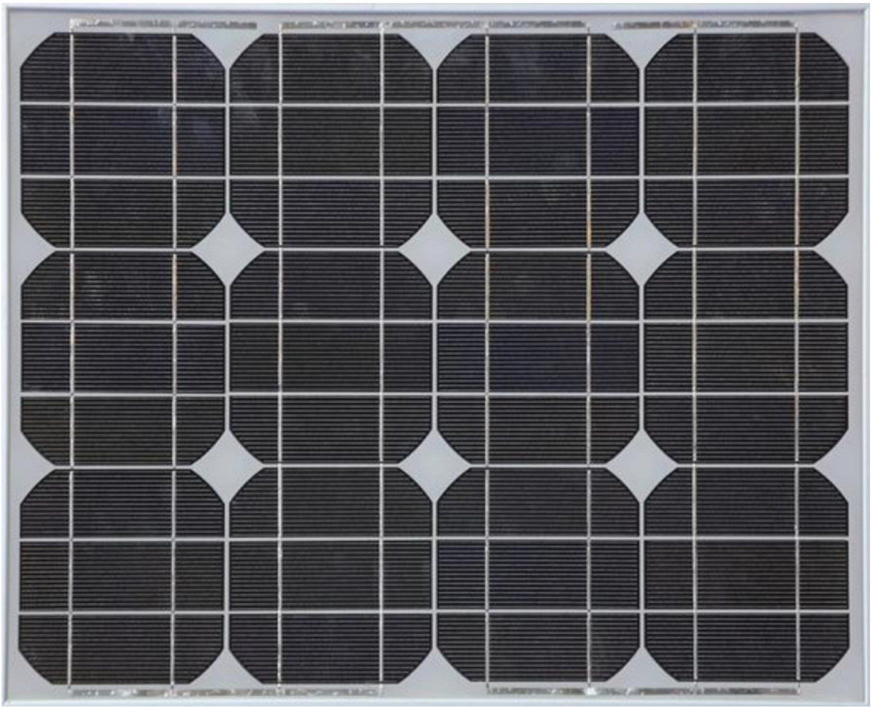

Figure 3: Monocrystalline solar panels [ASK 15]

4.1.2. Polycrystalline solar panels

polycrystalline solar panels are produced by melting solar grade silicon and casting it into a mold and allowing it to solidify. The molded silicon is then sliced into wafers to be used in a solar panel. Polycrystalline solar cells are less expensive to produce than monocrystalline cells because they do not require the time and energy needed to create and cut a single crystal. And while the boundaries created by the grains of the silicon crystals result in barriers for efficient electron flow, they are actually more efficient in low-light conditions than monocrystalline cells and can maintain output when not directly angled at the sun. They end up having about the same overall energy output because of this ability to maintain electricity production in adverse conditions. The cells of a polycrystalline solar panel are larger than their monocrystalline counterparts, so the panels may take up more space to produce the same amount of electricity.

They are also not as durable or long-lasting as other types of panels, although the differences in longevity are small. [TAR 19]

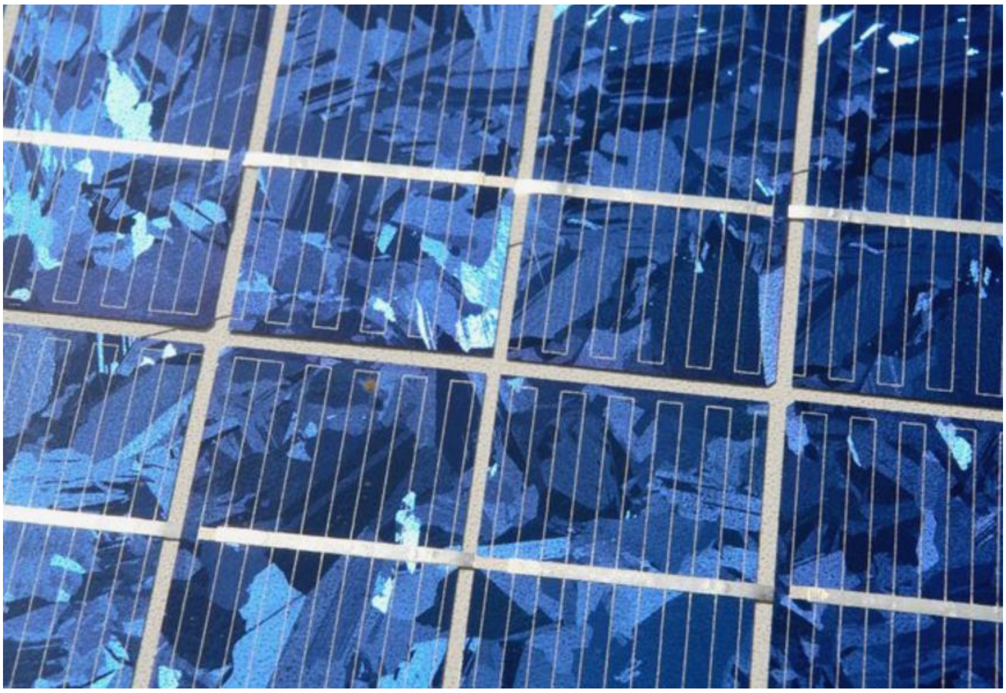

Figure 4: Polycrystalline solar panel [TAR 19]

4.1.3. Thin-Film solar panels (TSFC)

Thin-film is the least expensive solar panels. They are manufactured by placing one or more films of photovoltaic material (such as silicon, cadmium or copper) onto a substrate. These types of solar panels are the easiest to produce and economies of scale make them cheaper than the alternatives due to less material being needed for its production. They are also flexible which opens a lot of opportunities for alternative applications and is less affected by high temperatures. The main issue is that they take up a lot of space, generally making them unsuitable for residential installations. Moreover, they carry the shortest warranties because their lifespan is shorter than the mono- and polycrystalline types of solar panels. However, they can be a good option to choose among the different types of solar where a lot of space is available. [ASK 15]

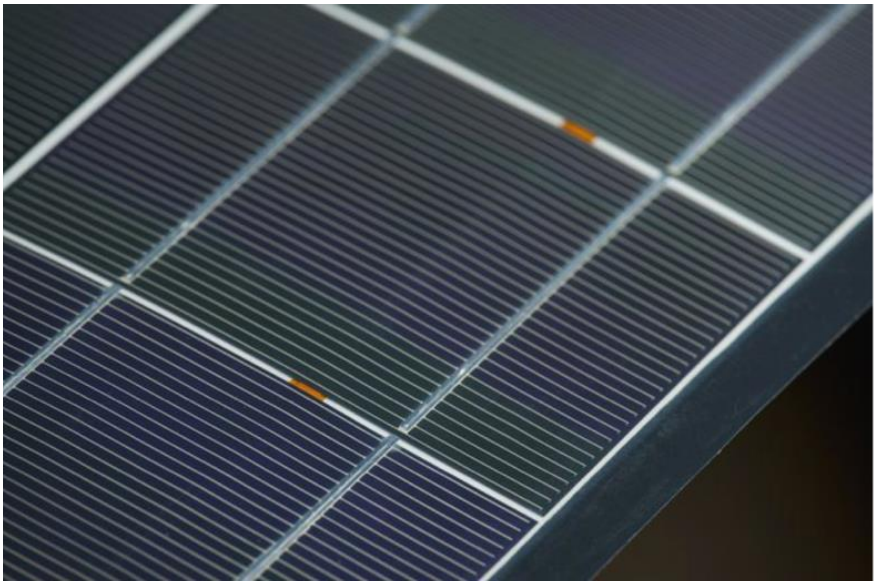

Figure 5: Thin-Film solar panel [ASK 15]

Table 1: Represent the difference between the 3 types of solar panel

Solar Cell Type	Efficiency Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	shorter warranties & lifespan

4.2. The inverter

The solar inverter is one of the most important components of the solar PV system and is the brain of the system. Generally located in the loft space, it converts the direct current (DC) output into alternating current (AC). The power from the array, converted by the inverter, is then connected via isolators – one on the DC (PV module) side and another on the AC side - into the consumer unit via an MCB (miniature circuit breaker).[ECO 22]

There are three types of inverters

- Micro-inverters (Grid-tie)
- String inverters (Grid-tie)
- Hybrid inverters (Off-grid)

4.2.1. Micro-inverters

A micro-inverter, as its name suggests, is a tiny version of an inverter. it is installed below the solar panel. It will handle the power of one to two solar panels and deliver AC electricity (120/230V, 60Hz) to house, and will be transferable to the utility grid. Multiple micro-inverters are connected in parallel to increase the total power output of the solar system. [ROM 21]

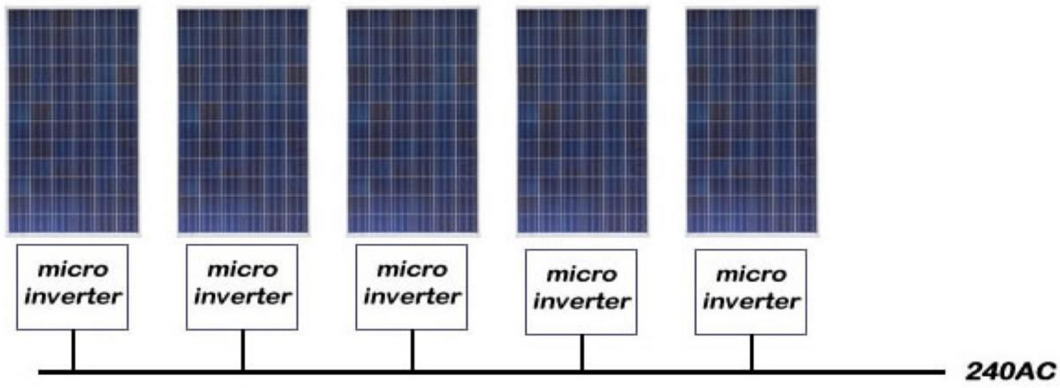

Figure 6: Installation of micro-inverters [ROM 21]

4.2.2. String inverters

Grid-tied string inverters are the most popular type of inverter. They are designed to deliver clean AC power from a string of solar panels to the electricity grid. They also allow self-consumption of your solar electricity during the day. The DC production of the solar array is transferred to the central inverter to be converted into AC electricity. The inverter is connected to the utility grid and to the house power circuit. Similar to micro-inverters, string inverters can also be coupled to an AC battery. [ROM 21]

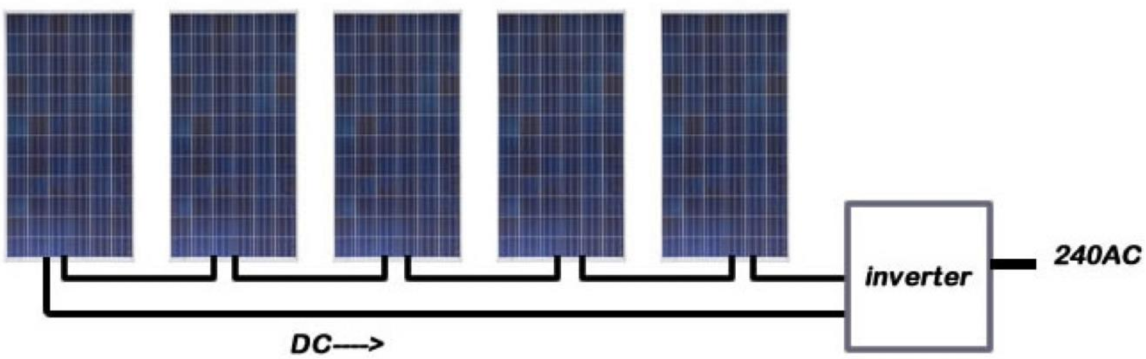

Figure 7: Installation of string inverters [ROM 21]

4.2.3. Hybrid inverters

Hybrid inverters, also called Off-grid inverters, are specially designed to deliver AC power at any time in the absence of grid electricity. Therefore, they include a battery charger for electricity storage. They are also called “Smart Inverters” as they automatically regulate the charge/discharge current of the battery in the function of the electric load and the solar production. DC electricity from the solar panels is converted into AC, similar to a grid-tied inverter. In addition, DC power is also fed into the battery during charging. If the sun is not enough, the inverter will get DC electricity from the battery and convert it into AC. [ROM 21]

Figure 8: Installation of Hybrid inverters [ROM 21]

4.3. Generation Meter

The generation meter is where you will be able to monitor what your system is generating. The meter will have a flashing red light when your system is generating, the brighter the day the faster the flashes will be. [ECO 22]

4.4. STORAGE

Batteries allow for the storage of solar photovoltaic energy, so we can use it to power our homes at night or when weather elements keep sunlight from reaching PV panels. Not only can they be used in homes, but batteries are playing an increasingly important role for utilities. As customers feed solar energy back into the grid, batteries can store it so it can be returned to customers at a later time. The increased use of batteries will help modernize and stabilize our country's electric grid.[USD 22]

There are four main types of battery technologies that pair with residential solar systems:

- ✓ Lead acid batteries
- ✓ Lithium ion batteries
- ✓ Nickel based batteries
- ✓ Flow batteries

Each of these batteries backup power technologies has its own set of unique characteristics. These are two of the most used batteries

4.4.1. Lead acid batteries :

Lead acid batteries are the tried-and-true technology of the solar battery world. They are the cheapest energy storage option, making them the most cost effective. They are also reliable. Plus, because the technology has been around for years, they can be easily disposed of and recycled. The reliability of lead-acid batteries is great for off-grid solar systems, or for emergency backup storage in case of a power outage. [CAT 21]

4.4.2. Lithium-ion batteries

Lithium-ion batteries are the new kids on the energy storage block. As the popularity of electric vehicles began to rise, EV manufacturers realized lithium ion’s potential as an energy storage solution. They quickly became one of the most widely used solar battery banks. Lithium-ion batteries are best for residential solar installations because they can hold more power in a limited space, and allow you to use more of the energy stored within the battery, which is great for powering a home. [CAT 21]

5. Most Solar Energy that Produces in the World

While more can be done to harness the energy of this bright fireball in the sky, some countries have taken the lead in capturing solar energy and using it as a viable source of electricity. after everything. Over the years, China has come a long way in positioning itself as a leader in solar power generation alongside the United States, India, Japan and Vietnam. While solar was once seen as a niche market, these countries are proving that this renewable energy source is the logical answer to the global search for alternatives to fossil fuels.

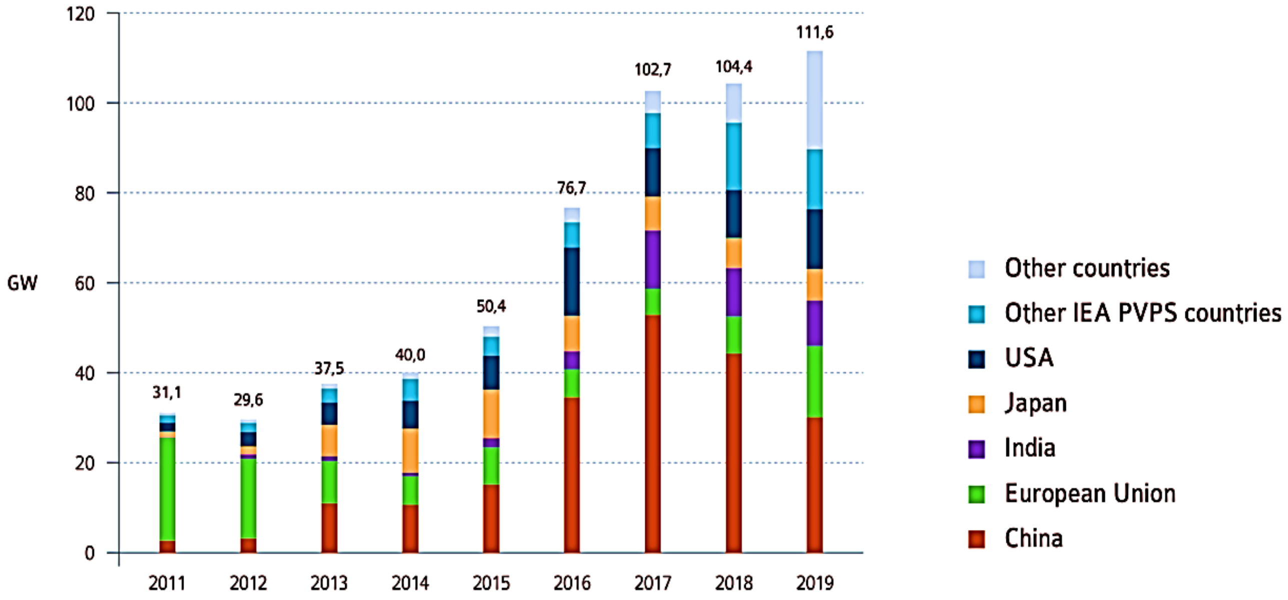

Figure 9: Evolution of annual PV installation [IEA 20]

5.1. CHINA

China was in first place and installed more than 30,1 GW in 2019, according to China's National Energy Administration ; an installation level that is significantly lower than the 44,3 GW and 52,9 GW newly installed capacity in the country in 2018 and 2017, respectively. The total installed capacity in China reached 205,2 GW, and by that the country kept its market leader position in terms of total installed capacity. The Chinese market represented 27% of the global installation in 2019, a significant decrease compared to the three previous years, especially in 2017, where the market share of China reached 51%.[IEA 20]

The vast majority of photovoltaic products, or solar panels, are being installed in remote areas by giant solar farms that sell the energy to utilities.[JUS 21]

5.2. EUROPE UNION

Second was European Union which experienced growth for the second year in a row with 15,9 GW, coming closer to the 23,2 GW recorded in 2011. Spain (4,7 GW), Germany (3,8 GW) and the Netherlands (2,4 GW) were the key markets this year, followed by France (below 1,0 GW) and several others. Spain regained market confidence of investors mainly through centralized tenders and corporate PPAs, in total almost 4,8 GW dc have been installed in 2019, a major increase compared to the last 10 years. The cumulative capacity in the country nearly doubled as 9,9 GW dc were operational at the end of 2019. Germany (ninth globally as a country) scored the second rank amongst European countries. It saw its annual installed capacity grow to 3,8 GW, with a significant market development for several years in a row. The total installed PV capacity reached 49,0 GW at the end of 2019. [IEA 20]

5.3. UNITED STATES OF AMERICA

Third was United states with 13,3 GW installed, a significant growth compared to 2018, marking 2019 the second largest single year increase in installations in the U.S. Both the utility sector installations and the residential market increased over 2018 installation levels (with respectively 37% and 15%). At the end of 2019, the U.S. reached 75,9 GW of cumulative installed capacity. [IEA 20]

5.4. INDIA

India's steady rise as a leader in PV capacity has been impressive. After several years of concentrated effort, India showed significant growth in 2019, reaching a 9% share of the global PV market for the year. The nation surpassed Japan (which held a 6.3% share of the market). Most of India's capacity for the year was installed at utility plants, which accounted for the majority of its 10.1 GW new installed capacity for the year. At the end of 2019, the country's cumulative installed capacity was approximately 42.9 GW. [IEA 20]

5.5. JAPAN

As one of the most densely populated countries in the world, Japan does not have the luxury of covering huge swathes of land with solar panels. Despite its lack of abundant open space, Japan is still among the world's leaders in terms of total solar energy produced, with 7 GW of new installed capacity in 2019. [IEA 20]

After the Fukushima nuclear plant disaster in 2011, Japan made a serious commitment to solar energy as part of a plan to double its renewable energy by 2030. Out of necessity, Japan found creative places to install solar panels. [YAM 18]

the island nation has even gone so far as to create floating “solar islands” with thousands of water-resistant solar panels. These next-generation solar farms have several advantages including their ability to be more efficiently cooled by water. [JUS 21]

conclusion

This chapter has been devoted to present the main characteristics and technologies of the components of a photovoltaic system. We have studied the principle of operation of the PV cell and presented their characteristics.

Chapiter II

PV in Algeria

Introduction

In the first part of this chapter, an exhaustive description of the industrial and economic activities in Algeria will be presented after a geostrategic description of the country.

The second part will be devoted to the production capacities of electricity in Algeria in addition to the renewable energy potential and more precisely the solar potential.

Finally, the third part will have as objective the presentation of the applications of the solar energy in different domains.

1. Description of Algeria

Algeria, officially the People's Democratic Republic of Algeria, is a country in the Maghreb region of North Africa. The country is the largest country by total area in Africa and in the Arab world, and is bordered to the northeast by Tunisia, to the east by Libya, to the southeast by Niger, to the southwest by Mali Mauritania and Western Sahara, to the west by Morocco and to the north by the Mediterranean Sea. It has a semi-arid geography, with most of the population living in the fertile north and the Sahara dominating the geography of the south. Algeria covers an area of 2,381,741 square kilometres, making it the world's tenth largest nation by area, and the largest nation in Africa. With a population of 44 million, Algeria is the ninth-most populous country in Africa, and the 32nd-most populous country in the world. The capital and largest city is Algiers, located in the far north on the Mediterranean coast. [MAR 21]

2. Agriculture

Agriculture in Algeria composes 25% of Algeria's economy and 12% of its GDP (gross domestic product) in 2010. Prior to Algeria’ colonization in 1830, nonindustrial agriculture provided sustenance for its population of approximately 2-3 million. Domestic agriculture production included wheat, barley, citrus fruits, dates, nuts, and olives. After 1830, colonizers introduced 2200 individual farms operated by private sectors. Colonial farmers continued produce a variety of fruits, nuts, wheat, vegetables. Algeria became a large producer of wine during the late 19th century due to a crop epidemic that spread across France. Algeria's agriculture evolved after independence was achieved in 1962. The industry experienced multiple policy changes modernize and decry on food imports. Today, Algeria's agriculture industry continues to expand modern irrigation and size of cultivable land.

3. Industry

Algerian industry has been dominated by oil and natural gas in two ways. First, the hydrocarbon sector is by far the largest industrial sector. Second, the revenues generated by the export of oil, gas, and related products have been the main source of investment capital for other industries. The Algerian government continues to increase the role of industry in the economy by encouraging diversification to tackle a budget deficit that resulted from low oil and gas prices. Economic contribution of the sector has increased to reach 5.6% of total GDP. According to figures from the National Statistics Office (ONS), industry grew by 3.1% in terms of added-value in 2018. The fastest-growing industrial segment in the second quarter of the year, in annualized terms, was wood, paper and cork (10.1%), followed by water and energy (8.2%), and agro-industry (3.7%). With low oil prices imposing limits on state-led capital expenditure, the government is seeking to attract more private sector investment both domestic and foreign as part of more general economic diversification efforts, and to reduce the country's import bill by stepping up local production. [PRI 22]

4. Economy

Algeria's economy is dominated by its export trade in petroleum and natural gas, commodities that, despite fluctuations in world prices, annually contribute roughly one-third of the country's gross domestic product (GDP). Until 1962 the economy was based largely on agriculture and complemented France's economy. Since then, the extraction and production of hydrocarbons have been the most important activity and have facilitated rapid industrialization. The Algerian government instituted a centrally planned economy within a state socialist system in the first two decades after independence, nationalizing major industries and implementing multiyear economic plans. However, since the early 1980s the focus has shifted toward privatization, and Algeria's socialist direction has been modified somewhat. Standards of living have risen to those of an intermediately developed country, but food production has fallen well below the level of self-sufficiency. [BRI 22]

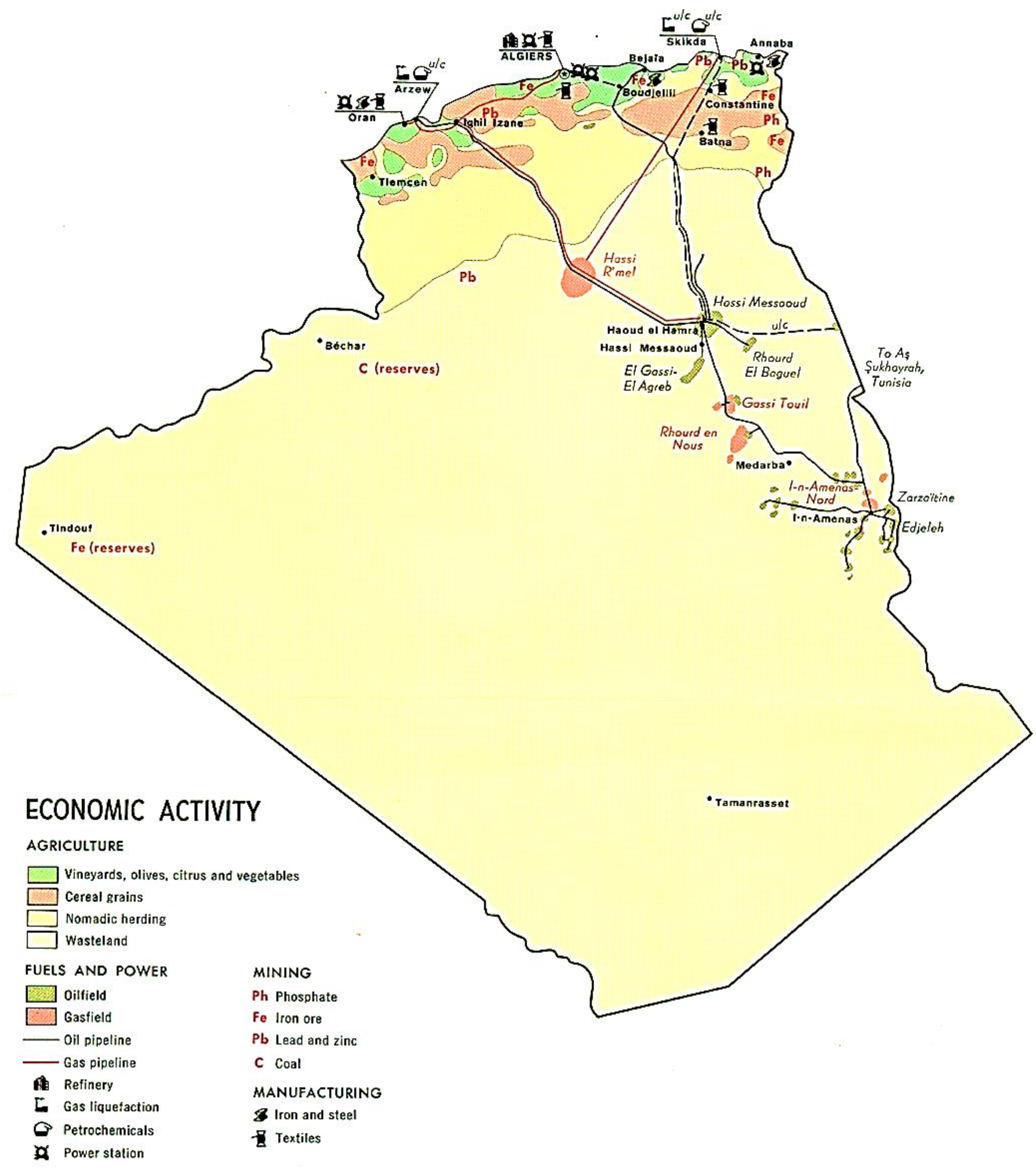

Figure 10: Economic Activities in Algeria [BRI 22]

5. Production of electricity in Algeria

Production in Algeria relies on natural gas for 96 percent of Algeria's 21,400 megawatts (MW) of installed capacity, with the remaining 4 percent comprising a combination of oil, solar, hydro, and wind technologies. By 2028, however, the Commission for Energy and Gas Regulation (CREG), Algeria's energy regulator, projects total installed capacity will increase by nearly 45 percent to 36,000 MW. Under this proposed plan the share of natural gas would fall to 84 percent while that of solar technologies would increase to 15 percent of installed generation capacity. While unlikely to meet the nation's renewable energy targets, this scenario would represent an important shift toward integrating substantial renewable energy generation into the nation's power network. [MIC 20]

6. Request power

The maximum power called reached July 12th 2021 at 14:30, a historical record of 16,065 megawatts (MW), an increase of 9.2% compared to the busiest day at the same period in the year before 14,714 MW, recorded on July 28th 2020 at 15:00, This high demand for electricity is due to the exceptional heat wave that affects the whole country for several days, According to Sonelgaz, "the recorded temperatures are indeed 9°C higher than the seasonal norms the average temperature of the day of July 12th 2021 was 39°C. It is higher by 7°C compared to the peak day of July 2020".The last historical peak in consumption had been recorded on Wednesday, August 7th 2019 at 14:30. The maximum power demand had reached 15,656 MW, an evolution rate of 2.6%.[ALG 21]

Production 5644.5 GWh

Table 2: Production in Algeria

Central	Production	Rate of evolution 2018/2019 %
Steam turbine	849.5 GWh	+7 %
Gas turbine	3673.2 GWh	-11.2 %
Combined cycle	3866.4 GWh	+32.9 %
Hydraulics	17.1 GWh	-
Diesel	83.7 GWh	-19.4 %
Photo voltaic	52.4 GWh	+1.3 %
Wind	0.2 GWh	-34.2 %

Delivery 5548.3 GWh

Table 3: Delivery of electricity

		Rate of envolution 2018/2019 %
Clint high tension	990.3 GWh	-2.3 %
Distribution network	7206.9 GWh	+18.7 %
Auxiliary	20.1 GWh	-5.7 %

Losses 210 GWh

Table 4: losses of electricity

Loss of the interconnected network	208.6 GWh	+16.2 %
Loss Rate interconnected network	3.72 %	+10.2 %
Loss of the Transport network	210.1 GWh	+14.3 %
Transport loss rate	3.7 %	+8.3 %

7. Solar potential in Algeria

In Algeria, the average annual sunshine is estimated at 3000 hours, with an average of 6.57 kWh/m2/day, with a territory composed of 86% of Saharan desert and by its geographical position, Algeria has the largest solar field in the world. If we compare the solar potential to natural gas in Algeria, the Algerian solar potential is equivalent to a volume of 37,000 billions cubic meters, or more than eight (8) times the country's natural gas reserves, noting that the solar potential is renewable unlike natural gas. [TEW 21]. The evaluation of a region's solar deposit is based on two criteria:

- Irradiation
- Insolation

7.1. Solar irradiation

Solar irradiation expresses the amount of energy received, at ground level, per unit area. It depends on many factors, mainly cloud cover, length of day, time of day, orientation and inclination of the surface, latitude of the place, its degree of pollution and the angular height of the sun above the horizon. [VAI 80]

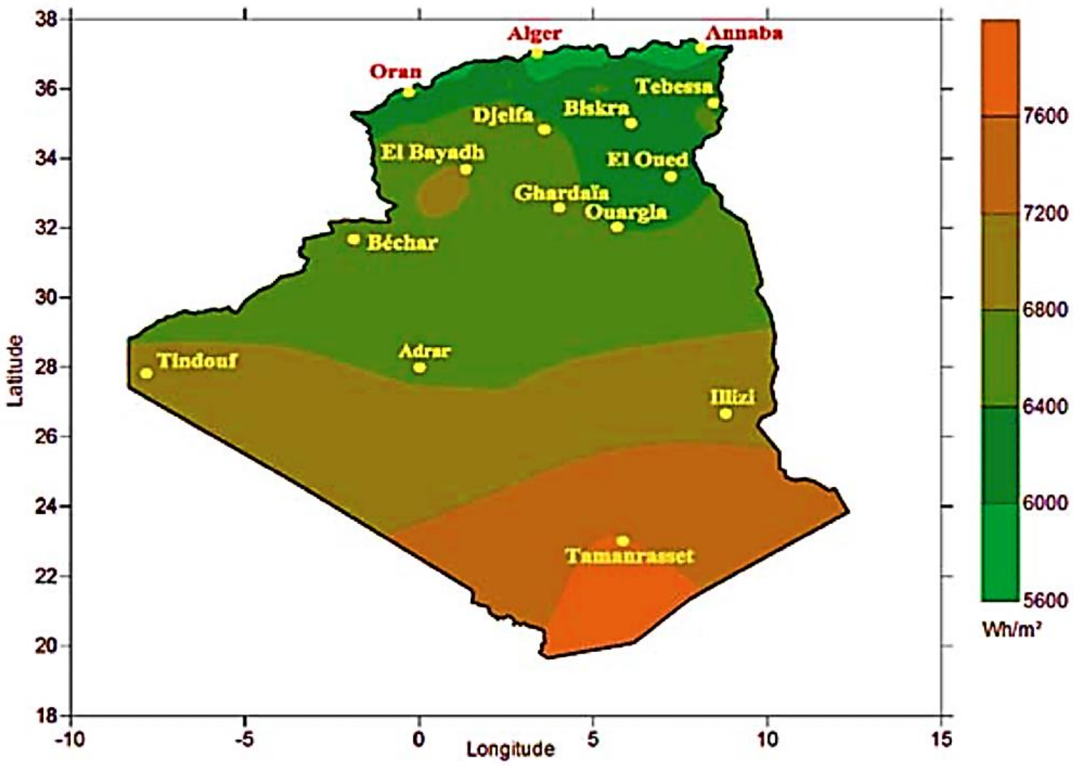

Figure 11: Annual average of the global irradiation received on a horizontal surface case of a totally clear sky in Algeria [VAI 80]

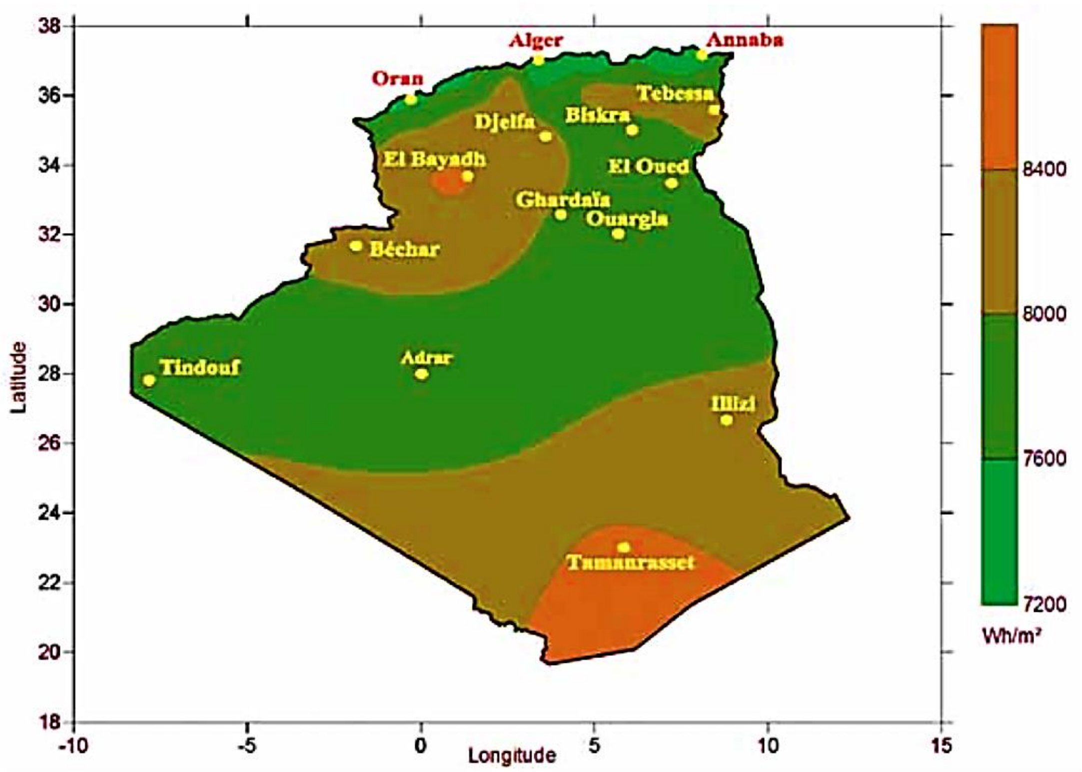

Figure 12: Annual average of global irradiation inclined to the latitude of the place case of a totally clear sky in Algeria [VAI 80]

7.2. Solar insolation

Insolation is the incident solar radiation onto some object. Specifically, it is a measure of the solar energy that is incident on a specified area over a set period of time. Generally insolation is expressed two ways. One unit is kilowatt-hours per square meter (kWh/m2) per day which represents the average amount of energy hitting an area each day. Another form is watts per square meter (W/m2) which represents the average amount of power hitting an area over an entire year.

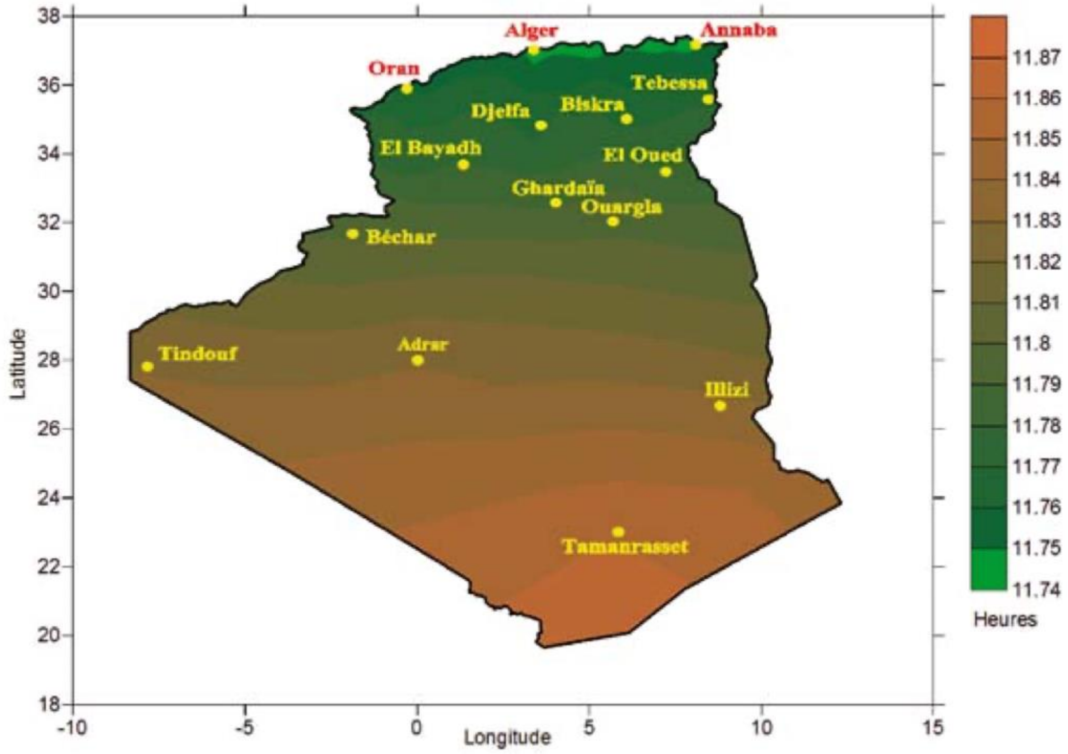

Figure 13: Annual average of the duration of calculated insolation case of a totally clear sky in Algeria

8. Application of photovoltaic in Algeria

8.1. Hassi R'mel hybrid power plant

The Hassi R'mel SPP1 is a hybrid power plant. This means that it runs on natural gas and solar energy. It produces 150 MW (net ISO power) with a solar contribution of 20% of nominal power, that is 30 MW. This power plant is composed of two parts, the solar field and the combined cycle:

The solar field is made up of cylindrical parabolic collectors, distributed over two surfaces. Each surface contains 28 loops of four modules, distributed in 2 rows. The module consists of 12 segments, each with several half-roofs. The direct component of the incident solar radiation is concentrated by the mirrors on a receiver located at the focal point of the parabola. A heat transfer fluid (HTF) circulates inside the receiver. The heated fluid, whose temperature can reach 393°C, passes through a series of heat exchangers to transfer its heat to water and thus produce steam (solar steam generator).

The combined cycle consists of two gas turbines (running on natural gas) with a nominal power of 45 MW each. The combustion heat from these turbines is recovered in two horizontal boilers with natural circulation. These boilers operate a power turbine with a nominal capacity of 80.08 MW. It should be noted that the strong point of this hybrid power plant is the addition of the steam produced by the solar field to the steam produced by the gas turbines to feed the steam turbine. The electrical power produced by the plant increases accordingly.

The region of Hassi R'mel is characterized by the following weather conditions:

- A relative humidity of 24%,
- An atmospheric pressure equal to 0.928 bar,
- Wind speeds that vary between 2.14 and 4.15 m/s,
- Temperature extremes ranging from -10°C in winter to +50°C in summer (see Table 1),
- Direct Normal Irradiation (DNI) which can reach a maximum of 950 W/m2 in summer.
- [ELG 11]

Table 5: Extreme temperature values recorded in the region of Hassi R'mel

Season	Minimum Temperature	Maximum Temperature
Summer	21°C	50°C
Winter	-10°C	20°C

8.2. Public lighting

Solar powered lighting is an economically reliable option in many applications. Not only in areas where the cost of electricity supply is too expensive, but also in situations where reducing operating costs is a priority. The solar street light or solar street light is a type of street light that is powered by solar energy, that is, it is equipped with solar panels that capture sunlight during the day, which produces electricity, which is stored in batteries and then released at night for lighting. The lamp post thus becomes autonomous in energy.

Figure 14: public lighting

8.3. Cathodic protections powered by solar photovoltaic energy

Many metallic structures, such as gas and water pipes, pipelines, etc. are damaged by corrosion, which can be defined as the destruction of a metal by chemical or electrochemical reaction. The solution is to protect the metal by bringing it into contact with another metal, thus creating a battery and a current flowing from one to the other. A generator is used to accelerate the process, impose the current in the desired direction and maintain the intensity. This means of protection is called cathodic protection. Its realization by photovoltaic generator whatever the external conditions proves to be the most advantageous and the only really adequate one, the installations being most of the time in isolated site. The photovoltaic system for this application includes: a field of photovoltaic modules, an electrochemical storage system, a power regulation and conditioning system. some applications:

The first is a section of the pipeline GO1 intended for the transport of natural gas processed at Hassi R'Mel whose total length of the section considered is 168.299 km, diameter of the structure 1.2144 m, predominant thickness 0.0127 m

The second is a steel pipeline of total length equal to 300.00 km, diameter 0.762 m and thickness of the pipe 0.01031 m. [KHA 07]

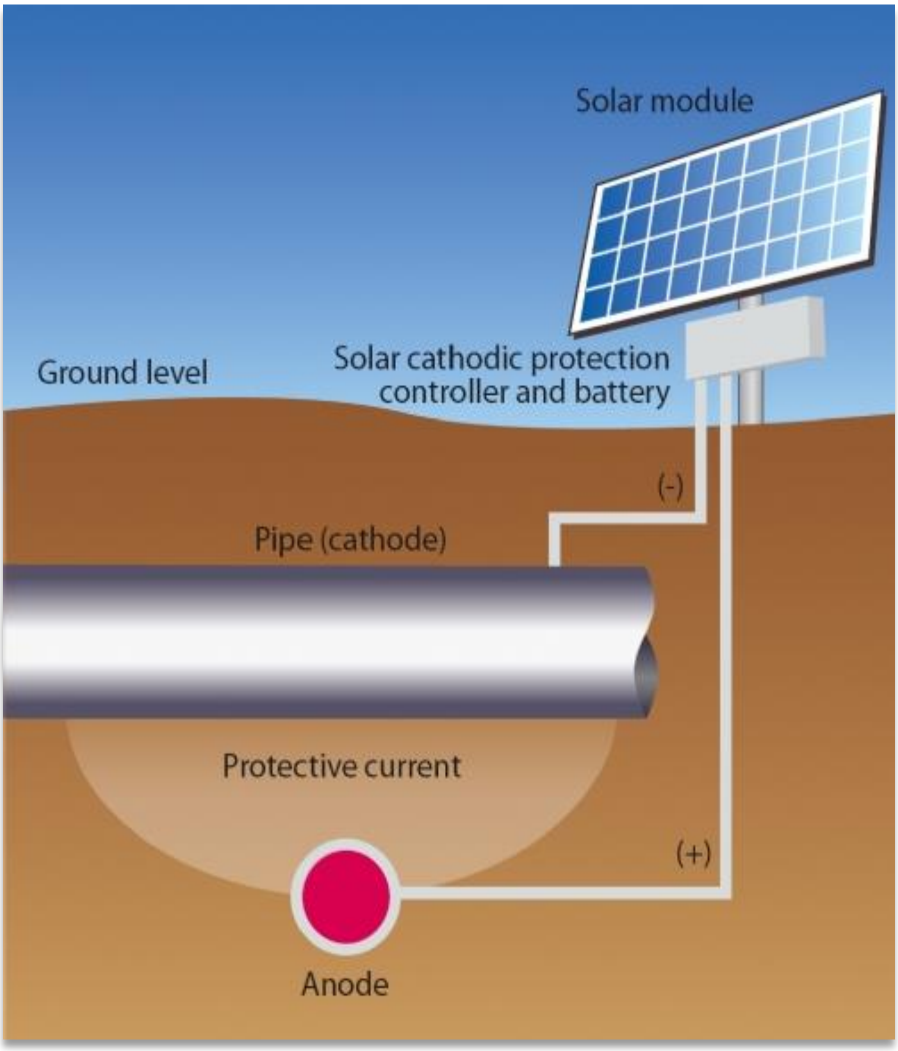

Figure 15: Cathodic protections powered by solar energy [KHA 07]

8.4. Villages powered by solar energy

Sonelgaz has put all its expertise in the service of a technology and has carried out a rural electrification program using photovoltaic solar energy, financed by state allocations, for the benefit of 1000 households spread over 4 wilayas of the Deep South, namely: Tamanrasset, Adrar, Illizi and Tindouf. Thus, twenty villages in deep Algeria, of low density and often very difficult access, benefit from electricity. Not being able to be supplied until now by the conventional network given the prohibitive costs that would generate its extension. Indeed, the electricity provided has improved the living conditions of these populations, to strengthen their sedentarization, to develop their land ... etc. The energy has even changed the relationship of these populations to time. Their activities continue after dark. [ZOG 09]

Figure 16: village in Tamanrasset powered by solar energy [ZOG 09]

8.5. solar pumping

Pumping water for irrigation, domestic or animal use is a vital need for rural populations and farmers. Generally, water is pumped by means of electric or mechanical motor pumps. In sites not connected to the electricity grid, farmers often have no choice but to use diesel engines or, failing that, traditional methods: manually or by animal traction. Now, photovoltaic solar energy provides the electrical energy needed to operate a motor pump to draw water from depths of up to 350 meters. There are two options for photovoltaic pumping:

with battery, to store the electrical energy produced, which allows the availability of water outside the hours of sunshine

without battery, the availability of water during the night or during days with low sunlight is ensured by a water storage tank.

some uses there are five solar pumping systems sites in the wilaya of OUM-EL-BOUAGHI

Figure17: PV pumping

Conclusion

In our research on the topic, we have concluded that Algeria is one of the richest countries in terms of economic dependence on oil revenues in recent years. This is reflected in domestic and international statistics, but after the global crisis caused by low oil prices in the international market in the first half of 2014, I considered a transition from a pension economy (oil and its derivatives) to an economy based on clean energy. At the end of this chapter we talked about some photovoltaic projects realized in Algeria.

Chapiter III

statistics and discussion on the state of PV in Algeria

Introduction

In the first part of this chapter, we will discuss the regulations and the ambitious programs aiming for the development of sustainable energy and the energy efficiency.

The second part will be dedicated to the requirement for interpretation in addition to the character of the renewable energy development centers and the companies involved in RE.

Finally, the end of this chapter will be assigned to the expansion of the RE environment, moreover the solution solutions considered.

1. Regulations

In Algeria there are a lot of laws and decrees about renewable energies we are going to mention down below:

Table 6: Example of laws and decrees about solar energies

Type	Date	Name
Law	December 30, 2015	Law no. 15-18 of december 30, 2015 on the 2016 finance law. art. 87, the operations of the account n° 302-101 shall be entitled "national fund for energy management and for renewable energies and cogeneration".
Law	December 30, 2014	Law no. 14-10 of 30 december 2014 on the 2015 finance law, in particular article 108, which provides for the merger of the two special funds: " the national fund for energy management (fnme)" and the "national fund for renewable energy and cogeneration (fner)".
Law	August 14, 2004	Law n° 04-09 of August 14, 2004 relating to the promotion of renewable energies within the framework of sustainable development
Law	February 5, 2002	law n° 02-01 of February 5, 2002 relating to electricity and gas distribution through pipelines
Law	July 28, 1999	law n°99-09 of 28 July 1999 relating to energy management
Decree	October 20, 2019	Executive Decree No. 19-280 of 21 Safar 1441 corresponding to October 20, 2019 on the creation, organization and operation of the Commission for renewable energy and energy efficiency energy efficiency
Decree	March 10, 2021	Executive decree n° 21-95 of 26 rajab 1442 corresponding to March 10, 2021 modifying and supplementing the executive decree n° 19-280 of 21 safar 1441 corresponding to October 20, 2019 carrying creation, organization and functioning of the commissioner of renewable energies and energy efficiency
Decree	January 27, 2011	Executive decree n°11-33 of January 27, 2011 concerning the creation, organization and functioning of the Algerian Institute of Renewable Energies

2. Programs

2.1. Program 1 renewable energy development program

Through the launch of an ambitious program for the development of renewable energies (RE) and energy efficiency, Algeria is initiating a green energy dynamic based on a strategy focused on the development of inexhaustible resources and their use to diversify energy sources and prepare Algeria for the future.

Thus, Algeria is embarking on a new sustainable energy era. Nearly four years after the launch of the development program of renewable energy and energy efficiency, adopted in February 2011 by the government, it appeared in its experimental phase and technology watch, new and relevant elements on the energy scene, both national and international, requiring the revision of the development program of renewable energy and energy efficiency.

Among these elements, we should mention: A better knowledge of the national potential in renewable energies through the studies undertaken during this first phase, including solar and wind potentials. The decrease of the costs of the photovoltaic and wind fields which are more and more asserted on the market to constitute viable fields to be considered (technological maturity, competitive costs...). The costs of the CSP sector (solar thermal) which remain high associated with a technology that is not yet mature, particularly in terms of storage, with a very slow growth of its market development.

Therefore, the updated renewable energy program consists of installing a renewable power of about 22 000 MW by 2030 for the national market, with the option of exporting as a strategic objective, if market conditions allow.

With this new program, renewable energy and energy efficiency are placed at the heart of energy and economic policies conducted by Algeria. Thus, by 2030, 37% of the installed capacity and 27% of the electricity production for national consumption, will be of renewable origin. Through its renewable energy program, Algeria intends to position itself as a determined player in the production of electricity from solar and wind energy by integrating biomass, cogeneration and geothermal energy.

These energy sectors will be the engines of a sustainable economic development able to drive a new model of economic growth

Table 7: The RE projects of electricity production over years

	1st phase 2015-2020	2nd phase 2021-2030	Total
Photovoltaic	3000	10575	13575
Wind	1010	4000	5010
CSP	-	2000	2000
Cogeneration	150	250	400
Biomass	360	640	1000

Geothermal	05	10	15
Total	4525	17475	22000

The RE projects of electricity production dedicated to the national market will be conducted in two stages conducted in two phases :

First phase 2015 - 2020 : This phase will see the realization of a power of 4000 MW, between photovoltaic and wind power with about sixty plants, as well as 500 MW, between biomass, cogeneration and geothermal energy.

Second phase 2021 - 2030 : The development of the electrical interconnection between the north and the south (Adrar), will allow the installation of large renewable energy in the regions of In Salah, Adrar, Timimoun and Bechar and their integration and their integration into the national energy system. At this time, the thermal solar energy could be economically viable the production of electricity is estimated to reach 90 TWh in 2020 and 170 TWh in 2030. The integration of renewable energy in the energy mix is a major challenge in order to preserve to preserve fossil fuels, diversify electricity production and increase the efficiency of the energy mix. diversify electricity production and contribute to sustainable development. All these considerations justify, from now on, the strong integration of renewable energies in the renewable energies in the long-term energy supply strategy, while giving an important role to while giving an important role to energy efficiency. [PRO 16]

2.2. Program 2: Energy efficiency program

The program of energy efficiency and energy savings consists, The energy efficiency and energy savings program consists mainly of the following actions

- The improvement of the thermal insulation of buildings.
- The development of solar water heaters and the realization of solar air conditioning project.
- solar air conditioning projects.
- Improving the performance of lighting.
- Promotion of cogeneration.
- Conversion of power plants to combined cycle whenever possible possible.
- generation of electricity from household waste.

The objective of the energy efficiency program is to gradually reduce consumption. gradually. Its implementation would generate a cumulative energy saving of 90 million toe, of which 60 million toe over the period 2015-2030 and period 2015-2030 and 30 million toe beyond 2030, for the period corresponding to the corresponding to the lifespan of the equipment used and the buildings buildings.

Therefore, it would allow for the year 2030 to reduce the energy demand by about 10%. Energy efficiency should have its place in the national energy context energy context, characterized by a strong growth of consumption, consumption, particularly in the domestic sector with the construction of new the construction of new housing, the realization of public utility infrastructures and the revival of industry.

Algeria, through its policy of energy efficiency, aspires to achieve ambitious objectives in this field, in order to minimize its energy consumption, to protect energy, to protect the environment, and to preserve this wealth for the future generations in a future generations in a logic of sustainable development.

For photovoltaic, the objective is the realization of industrial units in particular the construction of factories for the manufacture of photovoltaic modules to meet the realization of a program of about 13500 MW by 2030. Actions to strengthen the engineering activity and support the development of the photovoltaic industry through the establishment of a partnership that will bring together the various actors with the assistance of research centers. Over the period 2015-2020, the objective is to increase the integration rate of Algerian capacity, including through the construction, in partnership, manufacturing plants of photovoltaic modules. In addition, it is expected that a network of national subcontracting is established for the manufacture of inverters, batteries, transformers, cables and other equipment entering the used in the construction of a photovoltaic plant. Algeria should have, also, over the same period, capacities, design, procurement and implementation through Algerian companies. [PRO 16]

3. Interpretation

The need to complete the regulations governing renewable energy, especially to allow the injection of electricity produced in the power grid and encourage investors is strongly recommended by specialists to boost this promising sector.

4. Institutions

The Renewable Energies Development Center (CDER) is a research center resulting from the restructuring of the High Commissioner for Research, established on 22 March 1988. It is a scientific and technological public institution (EPST) responsible of conducting research and development programs, scientific and technological, of energetic systems using solar, geothermal and biomass energy.

The CDER as a scientific center, actively participates in the national program for research and technological development, as defined by law and policy program at five-year projection on scientific research and technological development. The national programs selected on this program are focused on economic and social priorities in order to meet the strategical needs for the economic development. The CDER, since its creation, works on the application of this strategy through the deployment and integration of several projects and pilot projects at national level. The CDER with its research teams and its three research units:

– Solar Equipment Development Unit (UDES)
– Applied Research Unit for Renewable Energies (URAER)
– Research Unit for Renewable Energies in Saharan Regions (URERMS)

In addition of its commercial subsidiary ER2, which is present all over the country as an excellence center on renewable energies through its scientific productions and its innovations in social-economical sector for the population especially the remote ones. [CDE 22]

Table 8: Examples of institutions concerned by renewable energy

Institutions	Nomination	Location	Year of creation
CDER	Centre de Développement des Energies Renouvelables	Bouzaréah , Alger	1988
UDES	Unité de Développement des Equipements Solaires	Tipaza	1988
URAER	Unité de Recherche Appliquée en Energies Renouvelables	Ghardaïa	2002
URERMS	Unité de Recherche en Energies Renouvelables en Milieu Saharien	Adrar	2004
ER2	Etudes et Réalisations en Energies Renouvelables	Bouzaréah , Alger	2007

Figure 18: Center for the Development of Renewable Energies Logo

5. Companies worked in RE

Table 9: Examples of companies that work in RE

Company	Location	Specialty
Algerian Solar company	38 Rue Ahmed AOUN BELFORT EL-HARRACH ALGER ALGERIE	-Feasibility studies -Site evaluation -Analysis and production report -Project Management -Installation -Maintenance -System and structural modifications -Engineering -Technical and single line drawing -Transport
Sarl Algeria Go Solar Systems	Lot azzouz abdellah bt 2 local n°7 Zeralda 16032 Algeria	Algeria go solar systems is a system installer and supplier of photovoltaic technology. In addition to the development and marketing of solar panels, Algeria go solar systems offers a wide range of continuously renewed products and services for a perfectly tuned photovoltaic installation.
Aures solaire	Zone of activity AINYAGOUT BATNA – ALGERIA	Manufacture of photovoltaic solar panels
Sungy	27 Rue Charles Gaunaud 16000 El Biar Algiers, Algeria	- Pre-project studies Design - Installation Responsibility Safety - Respect for the environment - Maintenance - Monitoring - Data analysis - Reliability - Long term
REMECO	Boumerdes 35000, Algeria	supplier of solar energy equipment solar panel, charge regulator, solar inverters, converter and solar water heater.

Comment: Generally, the companies that work in the renewable energy have several tasks to manage, for example the dimensioning of photovoltaic or wind systems but also for various other applications such as the installation of photovoltaic power supplies for individuals or state institutions. There are also companies that specialize in the import of materials in the photovoltaic supply chain and others that are interested in the collection of data that can be used by the state or by other parties. There are also engineering offices that manage the realization of photovoltaic power supply projects in the field.

1. Research and higher schools

6.1. National Higher School of Renewable Energies Environment and Sustainable Development Batna

The National School of Renewable Energy, Environment and Sustainable Development of the University Shahid Mostefa Ben Boulaid (Batna 2), was inaugurated Wednesday by the Prime Minister, Abdelaziz Djerad who was on a working visit and inspection in the wilaya of Batna. The school, which strengthens the sector of higher education and scientific research at the national and local level, and for which an investment of 700 million DA has been allocated, offers 1,500 teaching places, with 4 amphitheaters and 4 laboratories of applied work and scientific research, according to explanations provided.

6.2. Mohammed Boudiaf University of Science and Technology Renewable Energy

It is a specialty that aims to train its students in the field of renewable energy such as: solar energy, wind energy, etc.. The system followed is a Master's degree with an integrated Bachelor's program : three years of Bachelor's degree to choose after one of the available specialties for two years of Master's degree.

6.3. University of Ghardaïa department Renewable Energy

The Renewable Energy and Environment University course was offered at the University of Ghardaïa in the 2017-2018 academic year. The launch of the degree expands on the courses already offered and reflects the University's willingness to ensure the employability of its graduates and prepare students for future careers to better meet the challenges of the labour market.

6.4. University of Blida department of Renewable Energy

Through their quality and diversity, the programs at Blida 1 University meet your needs for knowledge, know-how and interpersonal skills; develop your knowledge and skills; and prepare you to meet the challenges of the job market and the world around you.

6.5. University Mohamed Khider Biskra department of Renewable Energy

The Department of Electrical Engineering of Mohamed Khider University was created in 2009. Its teachers-researchers are distinguished as much by their teachings as by their research works. By their meritorious and appreciable efforts, they participate actively in the development of the Department. The Department of Electrical Engineering training Renewable Energies is committed to providing new content and building new courses. It must resolutely engage in the path of renewal, develop multidisciplinary, deepen the general culture and offer the student training courses consistent.

7. Proposed solutions

After having a clear idea on the state of the solar photovoltaic energy in Algeria, we noticed several gaps despite some timid steps in this field. To remedy these problems and ensure a good management of this energy in Algeria, we propose some solutions divided into various sectors:

Regulation: Adding specific regulatory texts to promote the use of photovoltaic energy.

Institutions : Create a coordination body between the different actors working in the field of photovoltaic solar energy in Algeria.

Taxes: Reduce customs clearance taxes on solar photovoltaic energy equipment.

Credits: Encourage citizens to use solar photovoltaic energy by lowering the interest rate and making it easier to obtain bank credits.

Media: Intensify awareness campaigns to convince citizens to use solar photovoltaic energy, especially in rural and remote areas.

Startup: Encourage young entrepreneurs to create startups in this field.

Training: Unify training programs in renewable energy for different universities

Vocational training: Create training offers for young people in vocational training centers in the field of renewable energy.

Conclusion

Algeria has introduced laws and regulations aimed at promoting renewable energy (RE) in an effort to curb energy demand and improve environmental conditions in the private or public sector. Therefore, it is essential to understand energy efficiency and energy conservation in education and make the public aware of them. The implementation of various projects allows Algeria to play an important role not only in the Maghreb countries but also in Europe. as part of its climate and environmental protection policy.

General Conclusion

Nowadays, the use of renewable energies is no longer a choice but an unavoidable obligation because the future of our planet has become endangered due to the release of toxic gases, the toxic gases released into the atmosphere produced by fossil power plants can be reduced by the use of clean sources such as solar photovoltaic energy.

In this dissertation, we have tried to give a clear idea on the situation of photovoltaic solar energy in Algeria based on several aspects: regulatory, institutional, training and especially the use on the ground by specifying the areas where this energy and the most used.

During this study, we discovered several anomalies despite positive points for the Algerian government.

The low rate of use of renewable sources in general and solar photovoltaic energy in particular has led us to propose the following solutions:

- ✓ Adding specific regulatory texts to promote the use of photovoltaic energy.
- ✓ Create a coordination body between the different actors working in the field of photovoltaic solar energy in Algeria.
- ✓ Reduce customs clearance taxes on solar photovoltaic energy equipment.
- ✓ Encourage citizens to use solar photovoltaic energy by lowering the interest rate and making it easier to obtain bank credits.
- ✓ Intensify awareness campaigns to convince citizens to use solar photovoltaic energy, especially in rural and remote areas.
- ✓ Encourage young entrepreneurs to create startups in this field.
- ✓ Unify training programs in renewable energy for different universities
- ✓ Create training offers for young people in vocational training centers in the field of renewable energy.

Finally, we hope that through this study, we have contributed to give an idea on the good management of solar photovoltaic energy in Algeria based on recent statistics

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Abstract

The fast rate of exhaustion of fossil sources and the major concern of environmental protection have pushed countries around the world to engage in energy transition. In this thesis, we are interested in the most widespread renewable source on earth which is none other than solar photovoltaic energy and in particular in our country Algeria, where several questions have found their answers in this research: what is the solar potential of Algeria? What is the status of the corresponding regulations? What are the different institutions working in the field of solar energy? What is the state of application of solar photovoltaic sources in Algeria? Finally, several solutions have been proposed for the successful management of this solar photovoltaic energy in our country.

Keywords : Energy transition, renewable energies, solar photovoltaic energy, Algeria, management

Résumé

Le rythme rapide d'épuisement des sources fossiles et la préoccupation majeure de la protection de l'environnement ont poussé les pays du monde entier à s'engager dans la transition énergétique. Dans cette thèse, nous nous intéressons à la source renouvelable la plus répandue sur terre qui n'est autre que l'énergie solaire photovoltaïque et en particulier dans notre pays l'Algérie, où plusieurs questions ont trouvé leurs réponses dans cette recherche : quel est le potentiel solaire de l'Algérie ? Quel est l'état de la réglementation correspondante ? Quelles sont les différentes institutions travaillant dans le domaine de l'énergie solaire ? Quel est l'état d'application des sources solaires photovoltaïques en Algérie ? Enfin, plusieurs solutions ont été proposées pour une bonne gestion de cette énergie solaire photovoltaïque dans notre pays.

Mots-clés : Transition énergétique, énergies renouvelables, énergie solaire photovoltaïque, Algérie, gestion.

ملخص

دفع المعدل السريع لاستنفاد المصادر الأحفورية والاهتمام الكبير بحماية البيئة البلدان في جميع أنحاء العالم للانخراط في تحول الطاقة. في هذه الأطروحة، نحن مهتمون بأكثر مصادر الطاقة المتجددة انتشارًا على وجه الأرض وهو الطاقة الشمسية الكهروضوئية وعلى وجه الخصوص في بلدنا الجزائر، حيث وجدت العديد من الأسئلة إجاباتها في هذا البحث: ما هي إمكانات الجزائر الشمسية؟ ما هي حالة اللوائح المقابلة؟ ما هي المؤسسات المختلفة العاملة في مجال الطاقة الشمسية؟ ما هي حالة تطبيق مصادر الطاقة الشمسية الكهروضوئية في الجزائر؟ أخيرًا، تم اقتراح العديد من الحلول للإدارة الجيدة لهذه الطاقة الشمسية الكهروضوئية في بلدنا.

الكلمات المفتاحية: انتقال الطاقة، الطاقات المتجددة، الطاقة الشمسية الكهروضوئية، الجزائر، الإدارة