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Technical and cost study of concentrated solar power (CSP) plants

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بسم الله الرحمن الرحيم

Dedicate

First of all I would like to thank God

What allowed me to reach this place by which this event will be dedicated to mom and dad. I hope they will appreciate this gesture as proof of this Thank you from their daughter who achieved what she wanted, so thank you to them. God bless them!

I will also dedicate it to all family members

SEHAILIA, as well as to the GHAZAL family and to my brothers, sisters and friends. I also take this opportunity to say a word of thanks to our thesis supervisor, Mr. CHERRAD Noureddine, who has

contributed in some way or from another to the development

of this work and to all my professors and colleagues

who have contributed to my

access to this position.

SEHAILIA AHLAM

Acknowledgment

First of all, we want to thank our God, our creator, for the courage and patience he has given us to do this work.

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Table of contents

Contents

Chapter II

Solar potential and technical study of concentrated solar power technology.

Part: 1: Solar potential.

Part: 2:Technical study of concentrated solar power technology.

Chapter III

Cost study of concentrated solar power technology.

Chapter IV

Results & discussion

List of tables

List of tables

List of Figures

List of figures

Chapter I

Production and demand energy in the world

Chapter II

Solar potential and technical study of concentrated solar power technology.

Part: 1: Solar potential.

Part: 2:Technical study of concentrated solar power technology.

Chapter III

Cost study of concentrated solar power technology.

Chapter IV

Results & discussion

List of Abbreviations

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BP: British Petroleum.

CIF: Cost, insurance and freight.

CIS: Commonwealth of Independent States.

CO2: carbon dioxide.

CSP: Concentrated Solar Power.

DCF: Discounted cash flow.

DLR: Deutsches Zentrum für Luft- und Raumfahrt.

DOE: Department of Energy.

DNI: Direct Normal Irradiation.

DSG: Direct Steam Generation.

DSE: Dish-Stirling Engine.

EJ: Exajoules.

FOB: Free on board.

GGE: Greenhouse gas emissions.

GSA: German Space Agency.

HCE: heat collector element.

HTF: Heat Transfer Fluid.

LCOE: Average lifetime cost of electricity generation.

LFR: Linear Fresnel Reflector.

O&M: Operations and maintenance.

OPEC: Organization of the Petroleum Exporting Countries.

PDC: Parabolic Dish Collectors.

PDC$_{S}$: Parabolic Dish Collectors system.

PTC: Parabolic Trough Collector.

PV: Photovoltaic.

PDS: Parabolic Dish Systems.

USA: United States of America.

USD: United States Department

SAM: System Advisor Model.

SPT: Solar Power Towers.

WACC: Weighted Average Cost of Capital.

General introduction

General introduction

Man has taken steady steps in the field of harnessing the energy and has discovered many sources for it. We find that it is embodied in its various forms, whether it is coal, gas, oil, electricity, or others. But we find that fossil fuels top the list of energy sources today, as it constitutes 92% of the total Sources of energy production, but there is no doubt that in the end, these sources remain subject to extinction in the coming future because it is non-renewable sources, which are found underground in a limited quantity. In addition, due to the high use of energy in the world in the coming decades the prediction of energy experts that global oil supplies will meet demand only until the global oil monopoly reaches its peak sometime between 2013 and 2020 [1].

This is why the decline in oil production, which is the most important source at the present time in the list of traditional energies after the peak production, will create a global gap in energy and a larger gap in the global economy, especially since many countries have their economies based on these traditional energies, and therefore people must search for new sources of energy.

Therefore, scientists have begun searching for alternatives to fossil fuels called renewable energy, which is known to be the most environmentally friendly source compared to fossil fuels that cause global warming. Thus, the extent of the damage that our planet is exposed to in exchange for our well-being through the use of traditional energies is clearly demonstrated, and similar to the fact that renewable energy is permanent and continuous energy that is not implemented by human consumption of it as happens with traditional energies, and on the contrary, the more human development of it, the more beneficial it is. and more [2].

Among the renewable energies found in the world are wind, solar and water energy. Solar energy is a sleeping giant among these energies, by touching the world through the light it emits and the heat radiation that we can take advantage of through technologies to generate energy in order to meet our needs in the future. Accordingly the use of technologies to generate energy, and the most important of these technologies are photovoltaic cells technology and concentrated solar energy technology, is the subject of the world.

Through our topic, we will study the technology of concentrated solar energy, which depends on the use of mirrors and lenses to focus sunlight on one point to convert solar energy into heat and then into electricity through mechanisms for converting thermal energy into electrical energy, such as turbines. The exploitation and development of this technology will be the hope for the advancement of the economy of the country and the world and for a healthy and clean environment. Thus the object of the present work is technical and cost study of concentrated solar power (CSP) plants. The work is subdivided as follows:

Chapter I: In the first chapter, we will go extreme to the definition of energy and its reserves in the world in all its forms, and the production and consumption of it by the individual.

Chapter II: In this chapter, we will learn about the technology of concentrated solar energy, how it works and its types, and we will also discuss the comparison between it and photovoltaic energy and the types of concentrated solar power.

Chapter III: In this chapter, we will study the CSP cost and its economic future, as well as opportunities in the future to reduce the cost of its installation.

Chapter IV: In this chapter, we will discuss the results obtained through this study

Chapter I

Production and demand energy in the world

1. Introduction:

In the coming decades, energy use will increase in the world. People want energy services, such as heating, cooling, cooking and lighting, mobility, modern communication, information processing and the power of machines [3].

Energy experts predict that global oil supplies will only meet demand until the global oil monopoly reaches its peak sometime between 2013 and 2020. Decreased oil production after peak production will develop a global energy gap, which must be bridged by unconventional and renewable energy sources. energy resources. And that renewable energy becomes prevalent in the twenty-first century and among these energies are solar and nuclear energy, but only if its technology is greatly improved to ensure affordability and ease of use [1].

From here, we will discuss in this chapter the production, demand and reserves of energy in the world. Some data in this context will also be presented and discussed.

2. Definition of energy:

Energy is the engine of all natural phenomena: the growth of plants, the wind, river currents, waves, falling objects ... In physics, it is defined as the capacity of a system to produce work. It comes in multiple facets (thermal, kinetic, electrical ...), and one of its major properties is that it can be converted from one shape to another [4].

3. Energy developments [5] :

- Primary energy consumption decreased to 1.3% the 2017 year, less than half the rate in 2018 (2.8%);
- The increase in energy consumption was specific to renewable energy sourcesand natural gas, that contributed three quartersexpansion. All fuels have grown by less than 10 yearsPrevious, regardless of nuclear;
- China was the largest energy engine, producing more than three-quarters of global net energy growth.

4. Driving forces behind global energy demand:

Economic growth and population growth are among the most important factors driving increased global energy demand. Therefore there is a link between energy demand and economic production. Expansion of industrialization and improvement in living standards will contribute significantly to the increasing global demand for energy. The world population is also expected to increase. Especially the proportion of the world's population living in developing countries, and given these trends, providing access to commercial energy in developing countries will be an increasingly large and urgent challenge. At present, developed countries produce a third of the world's oil, but they consume two-thirds of it, while developing countries produce two-thirds but only consume a third. (see Table 1)[1].

Table 1: World crude-oil production versus demand in 2000 (bn barrels) [1].

Region	Production (bb)	Share (%)	Demand (bb)	Share (%)Developed
Countries	8	29	18	64
Developing countries	10	71	10	36
World	27	100	28	100
USA	2	7	7	25

5. Energy reserves in the world:

This measure was taken from an international organization that annually conducts this study, which is the total global energy reserves [5]**.**

5.1. Primary energy:

5.1.1. Consumption:

Energy consumption increased by **1.3%** in relation to the 2018 year. Growth was driven by renewable (**3.2 EJ**) and natural gas (**2.8 EJ**), which together contributed three-quarters of the increase. All fuels grew at a slower rate, except for nuclear power, with coal consumption falling for the fourth time in six years (**-0.9 EJ**).

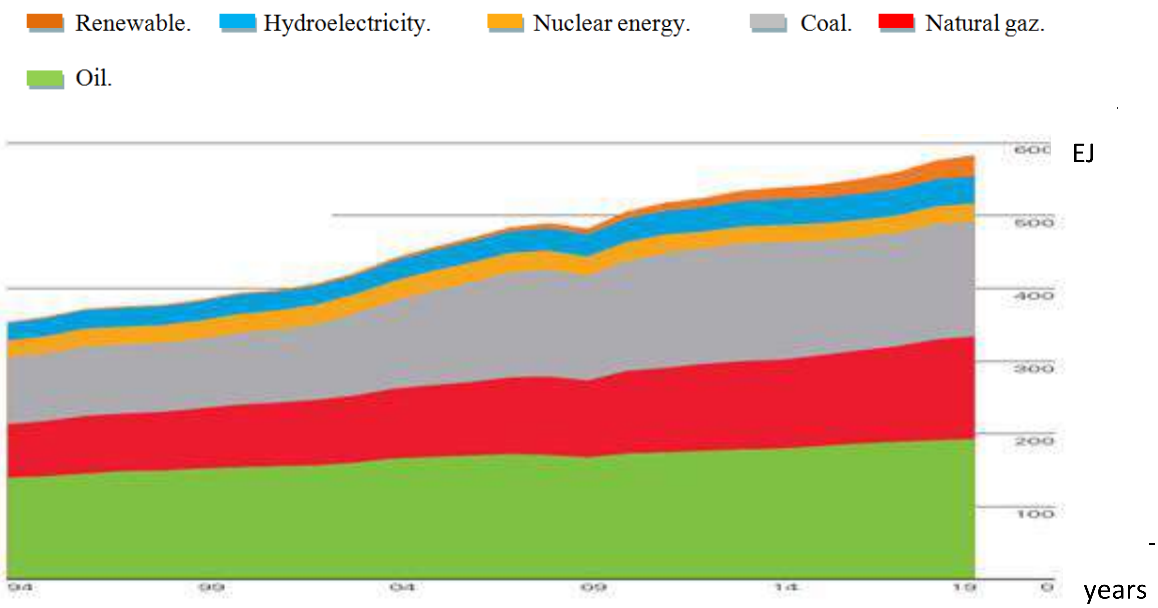


Figure I.1: World consumption Exajoules[5].

Oil continues to hold the largest share of the energy mix (33.1%). Coal is the second largest fuel but decreased in 2019 by 27.0%, with the share of both natural gas and renewable increasing to 24.2% and 5.0%, respectively. Nuclear energy constitutes only 4.3% of the energy mix, while the share of hydropower has remained stable at around 6% for several years.

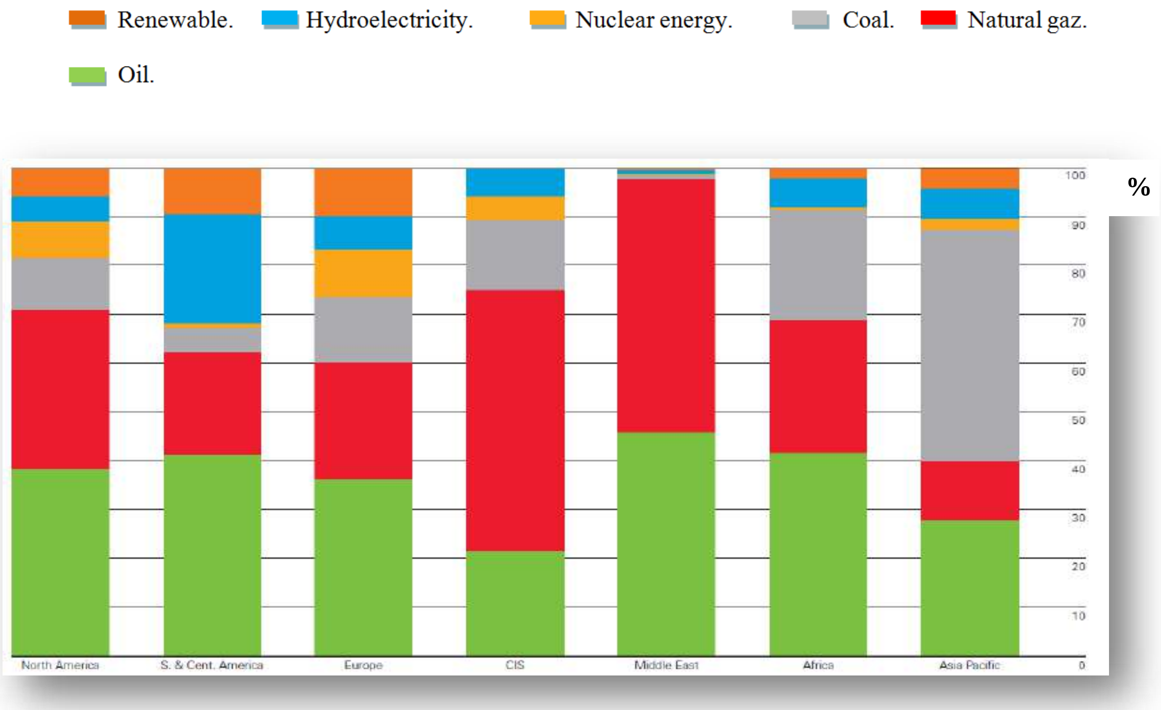


Figure I.2: Regional consumption pattern 2019 Percentage[5].

Oil remains the dominant fuel in Africa, Europe and the Americas, while natural gas is dominant in the CIS and the Middle East, accounting for more than half of the energy in both regions. While coal is the dominant fuel in Asia and the Pacific in 2019.

5.2. Oil:

5.2.1. Total proved reserves:

These results were based on the power reserve of the BP organization shown in the appendix . The world's total oil reserves for the year 2018 and 2019, where oil reserves for some countries decreased in 2019 compared to the 2018 year, and some other countries kept the reserves at the same percentage, and on the other hand we see an increase in reserves such as Colombia and India. However, despite this fluctuation in the reserves of countries, it led to a decrease in global oil reserves.

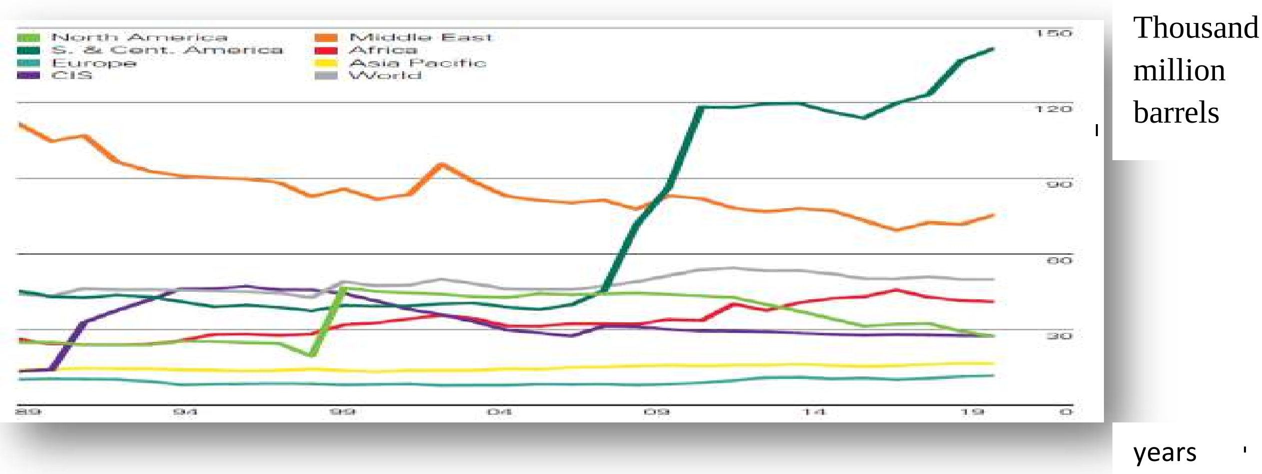


Figure I.3: oil reserves over the years[5].

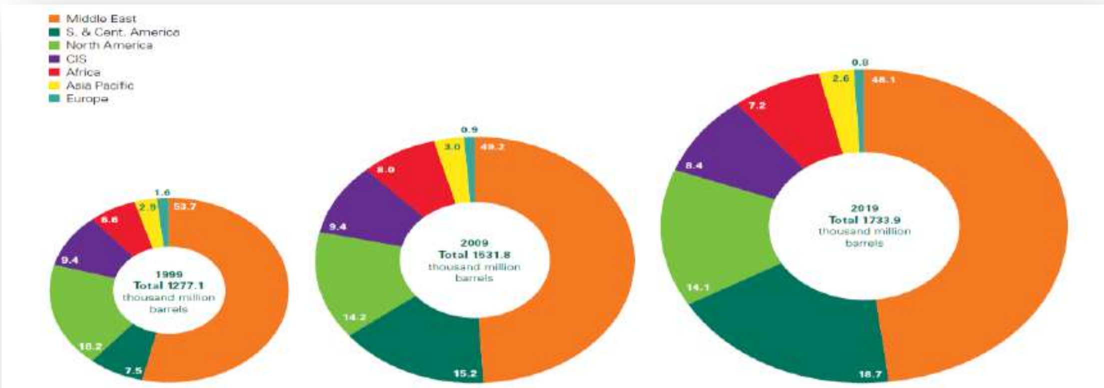


Figure I.4: Distribution of proved reserves in 1999, 2009 and 2019[5].

Global proven reserves of oil reached 1734 billion barrels at the end of 2019, South and Central America has the highest percentage, while Europe has the lowest percentage, OPEC owns 70.1% of global reserves, the largest countries in terms of reserves are Venezuela 17.5% of global reserves, then Saudi Arabia 17.2% and Canada 9.8%.

5.2.2.Productionin thousands of barrels per day:

America is the largest oil producer, followed by Saudi Arabia, while the Middle East is the first product in terms of continents, followed by North America. While Global oil production decreased by 60 thousand barrels per day in 2019, as strong growth in US production (1.7 million barrels per day) decreased OPEC production (-2 million barrels per day), with decreases in Iran (- 1.3 million b / d) J) Venezuela (-560,000 b / d) and Saudi Arabia (-430,000 b / d).

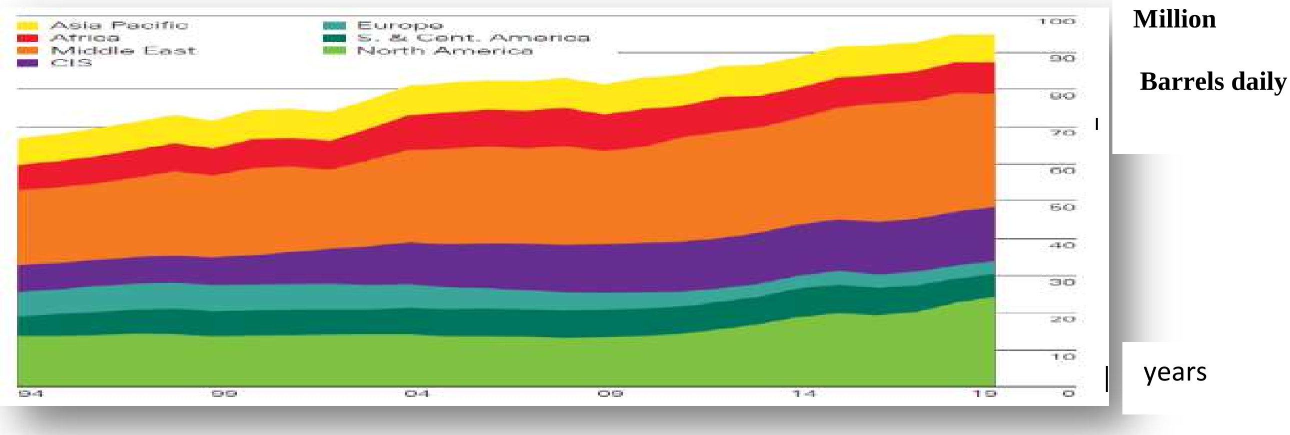


Figure I.5: Production by region Million barrels daily[5].

5.2.3.Consumptionin thousands of barrels per day:

America is the largest consumer of oil, followed by China, while Asia Pacific is the first consumer in terms of continents, followed by North America. While Oil consumption increased by less than 0.9 million b/d, and China led the growth (680,000 b/d).

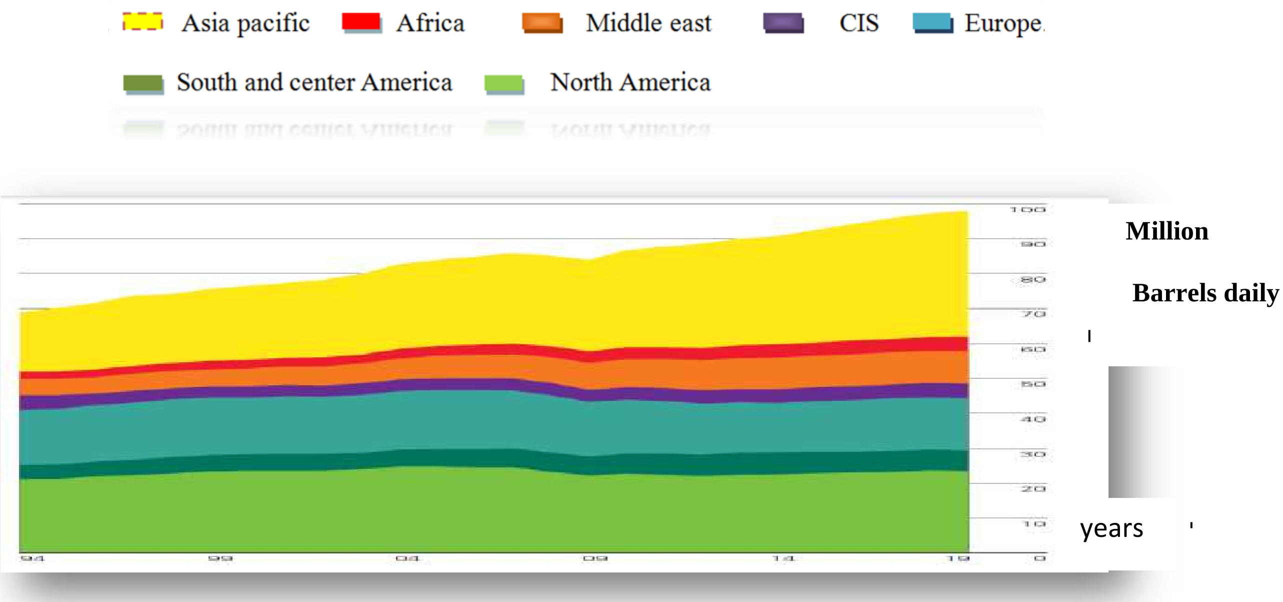


Figure I.6: Consumption by region Million barrels daily[5]**.**

5.3.Natural gas[5]**:**

5.3.1.Total proved reserves:

The proven gas reserves in the world increased by 1.7 trillion cubic meters to reach 198.8 trillion cubic meters in 2019. As the reserves of China (2 trillion cubic meters) and Azerbaijan (0.7 trillion cubic meters) increased, decrease in the Indonesian reserves by 1.3 trillion Cubic meters. Russia (38 trillion cubic meters), Iran (32 trillion cubic meters) and Qatar (24.7 trillion cubic meters) are the countries with the largest reserves.

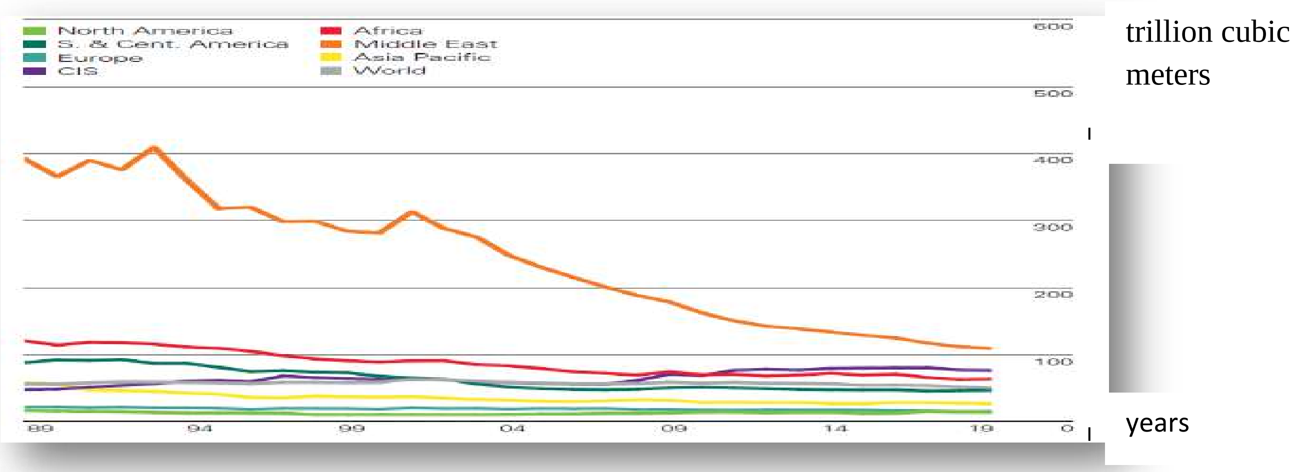


Figure I.7: Natural gas reserves over the years[5]**.**

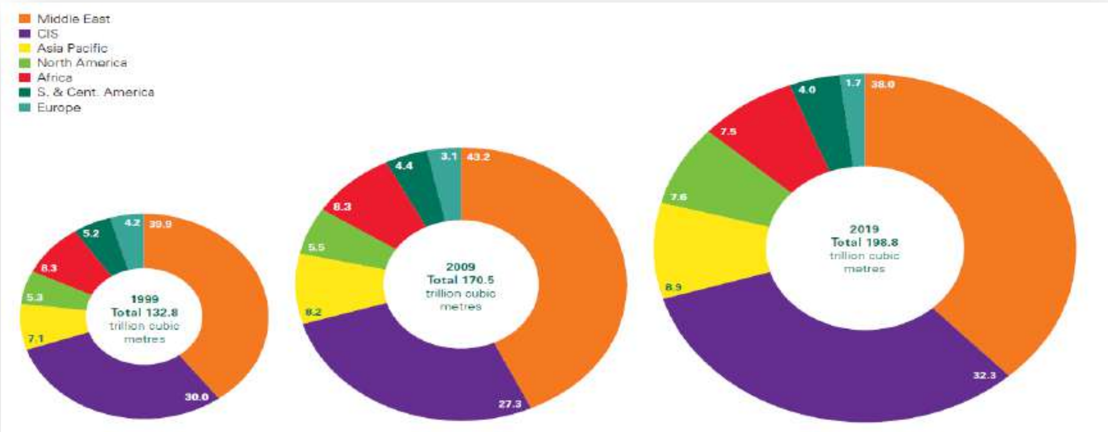


Figure I.8: Natural gas distribution of proved reserves in 1999, 2009 and 2019 Percentage[5].

5.3.2. Production in billion cubic meters:

There is fluctuation in production in some countries such as Mexico and Canada, while has risen the production of other countries such as America and the Russian Federation. North America occupies the first place in terms of production then CIS. Gas production grew by 132 billion cubic meters (3.4%), with the United States accounting for nearly two-thirds of this increase (85 billion cubic meters). Australia (23 billion cubic meters) and China (16 billion cubic meters) were also major contributors to the growth.

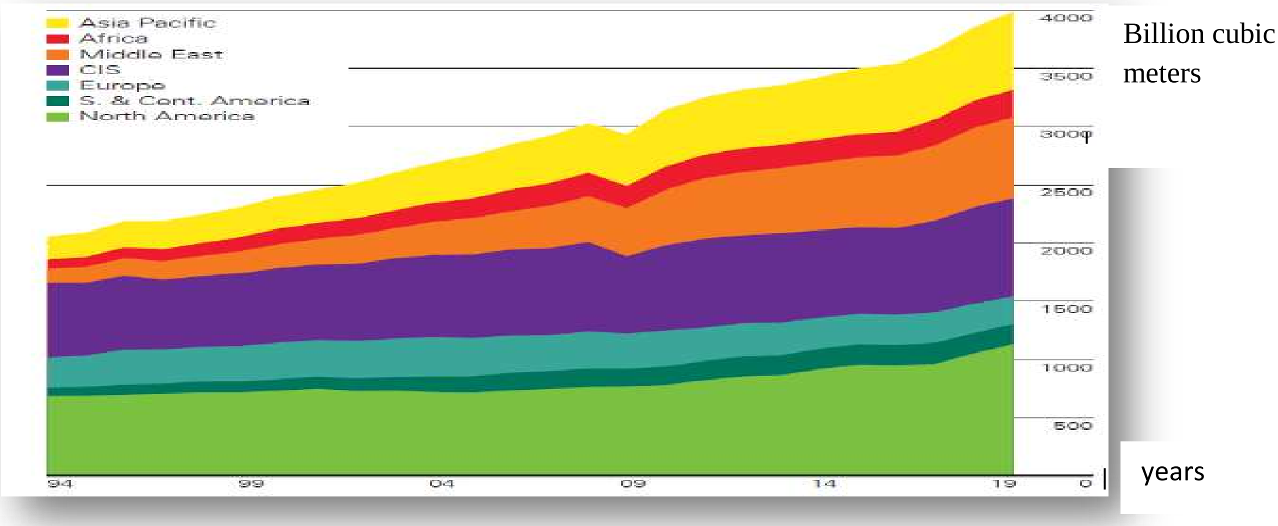


Figure I.9: Production by region Billion cubic meters[5].

5.3.3.Consumption in billion cubic meters:

There are fluctuations in consumption in some countries such as Germany and the Russian Federation, while the consumption of some other countries, such as America and China has increased, and North America ranks first in terms of consumption then Asia Pacific. Natural gas consumption increased by 78 billion cubic meters, or 2%. Growth was driven by the United States (27 billion cubic meters) and China (24 billion cubic meters), while Russia and Japan saw a decline (10 and 8 billion cubic meters, respectively).

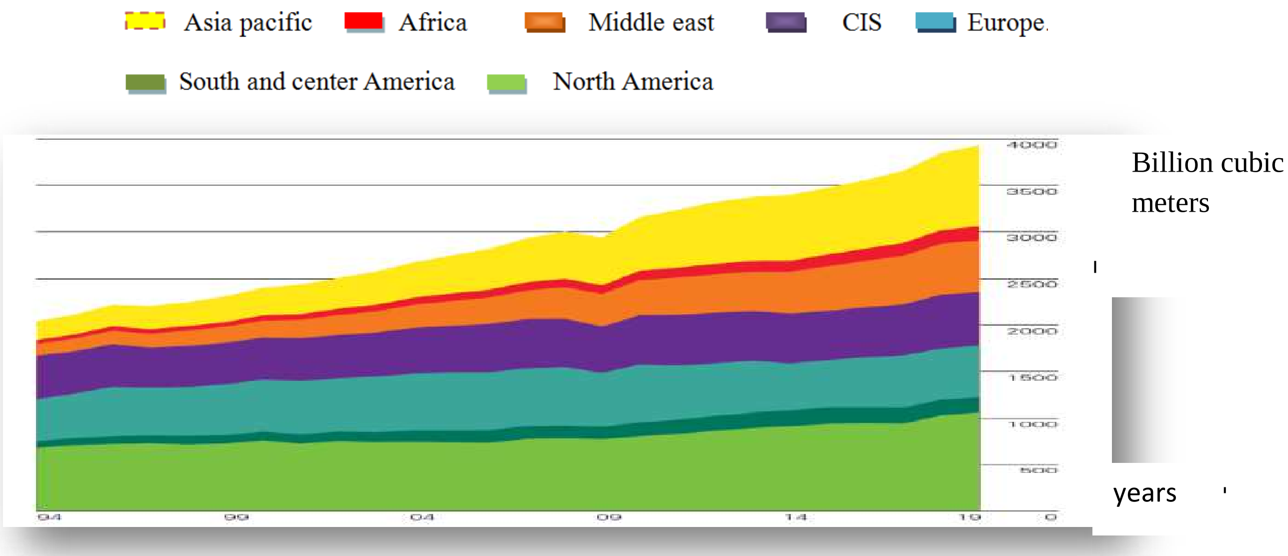
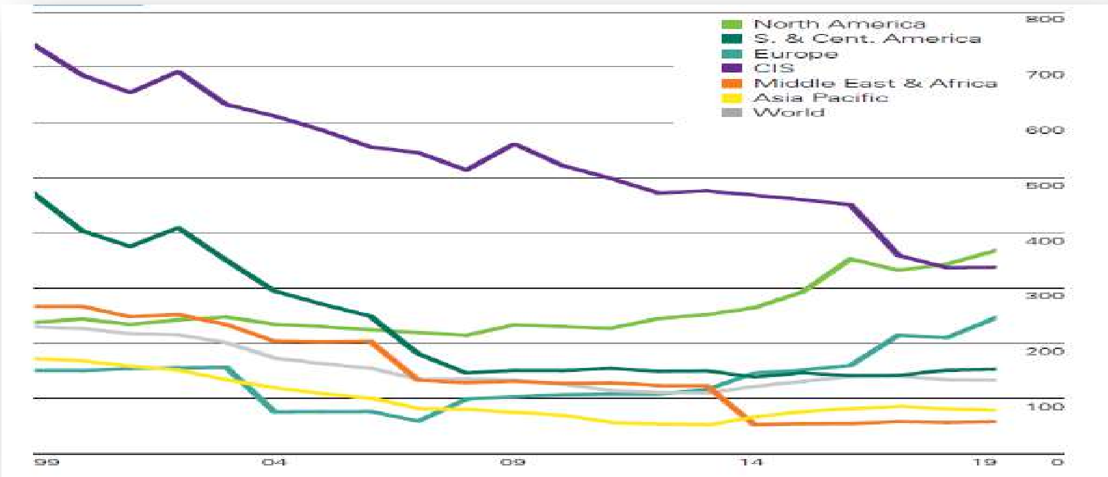


Figure I.10: Consumption by region Billion cubic meters[5].

5.4.Coal[5]:

5.4.1.Total proved reserves:

World coal reserves in 2019 stood at 1070 billion tones and are heavily concentrated in just a few countries: US (23%), Russia (15%), Australia (14%) and China (13%). The current global R/P ratio shows that coal reserves in 2019 accounted for 132 years of current production with North America (367 years) and CIS (338 years) the regions with the highest ratios.



billion tones

years

Figure.I.11: Coal reserves over the years[5].

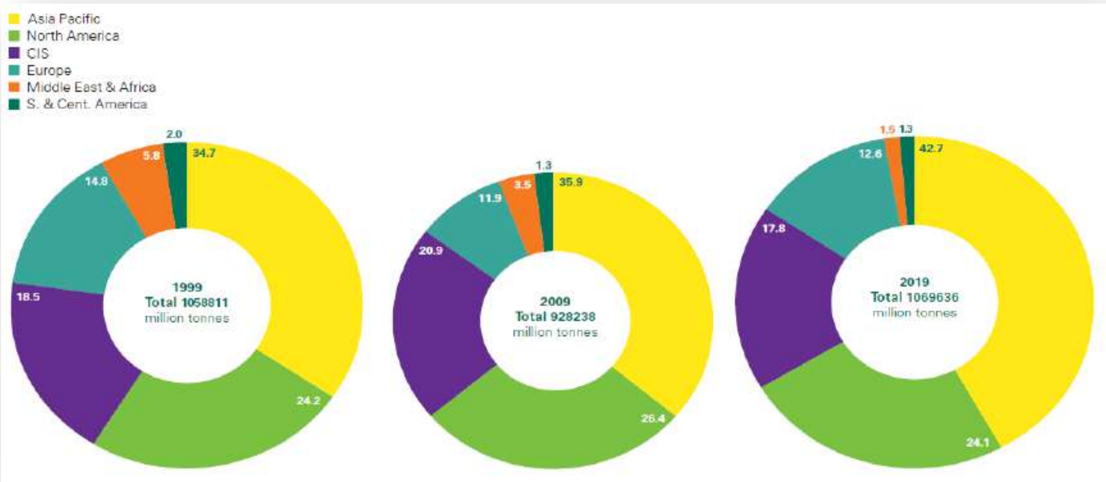


Figure I.12: Distribution of proved reserves in 1999, 2009 and 2019 Percentage[5].

5.4.2.Production:

There are fluctuations in production in some countries such as America and Canada, while production in some other countries has increased, such as Russia and China. Asia Pacific ranked first in terms of production, global coal production increased 1.5%, with China and Indonesia providing the only big increases (3.2 EJ and 1.3 EJ, respectively). The biggest drops in production also came from the United States (-1.1 EJ) and Germany (-0.3 EJ).

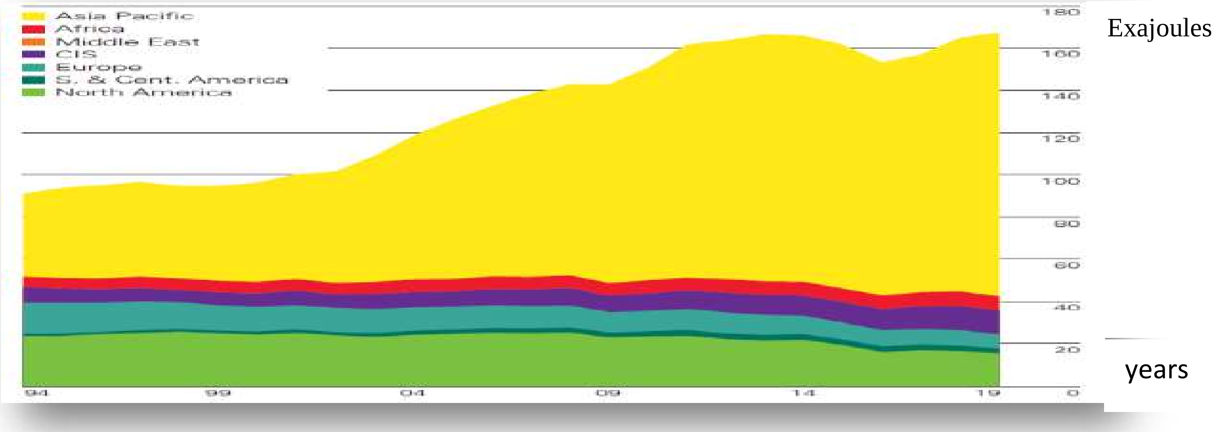


Figure I.13: Production by region Exajoules[5].

5.4.3.Consumption:

There is a decrease in consumption in some countries such as America and Canada,while consumption has increased in some other countries such as Russia and China, and the Asia-Pacific region ranked first in terms of consumption, global coal consumption decreased by 0.6% (-0.9 EJ). There were significant increases in China (1.8 EJ), Indonesia (0.6 EJ) and Vietnam (0.5 EJ). Its owner fell sharply, led by the United States (-1.9 EJ) and Germany (-0.6 EJ).

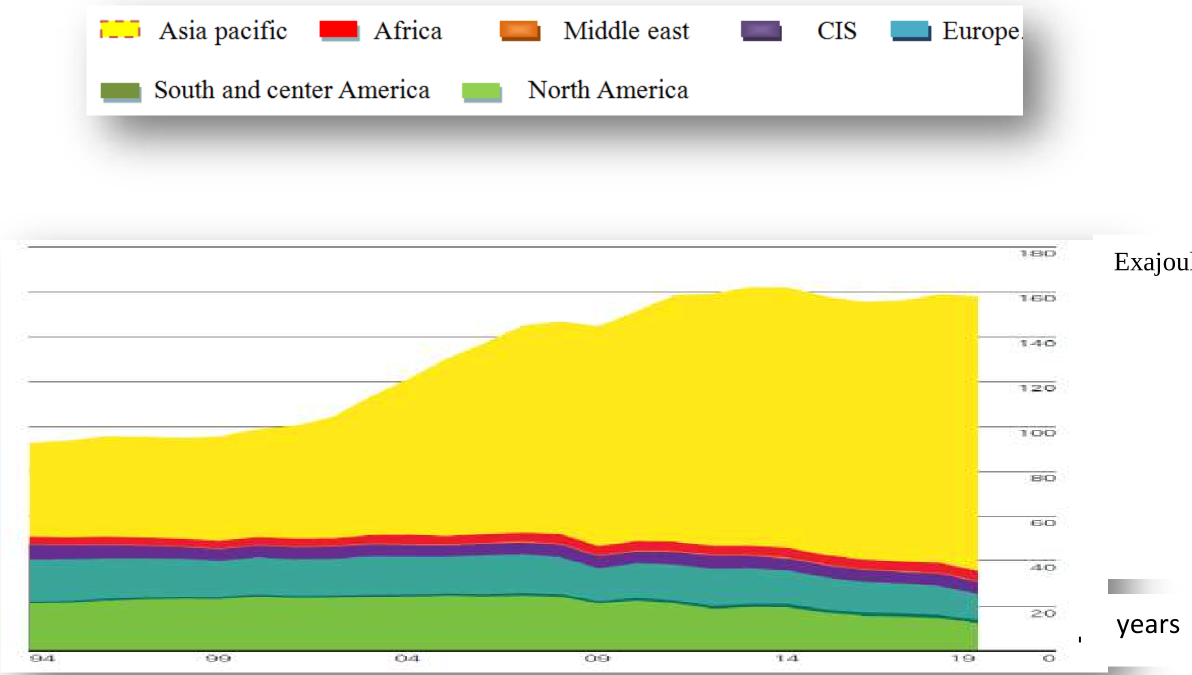


Figure I.14: Consumption by region Exajoules[5].

5.5. Nuclear energy[5]:

5.5.1. Consumption:

There is a decrease in consumption in some countries such as America and Canada, while consumption has increased in some other countries such as Russia and China.North America ranked first in terms of consumption, followed by Europe. Nuclear consumption increased by 3.2% (on an input basis), its fastest growth, and China recorded the largest increase of any other country, year 2018 the increase was the largest in China ever (0.5 EJ). Japan also recorded remarkable growth of 0.15 EJ, or 33%.

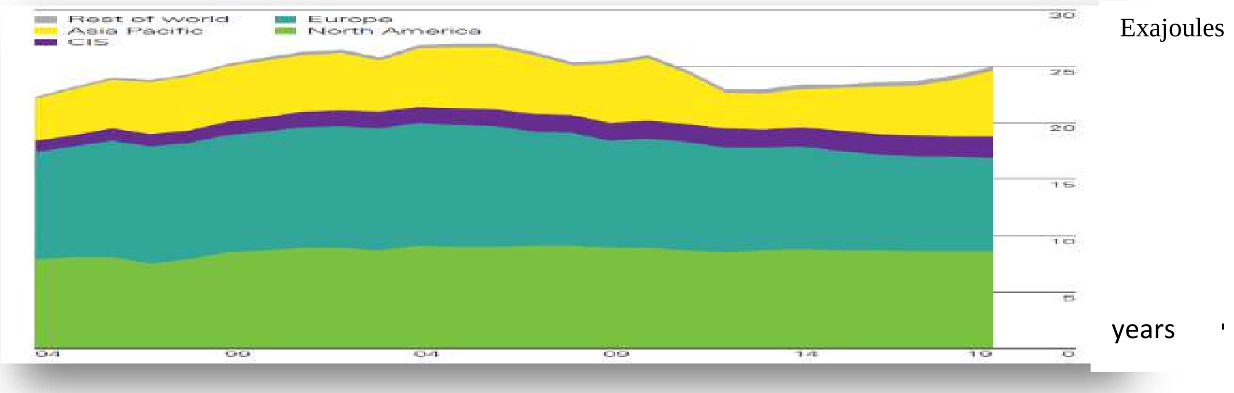


Figure I.15: Nuclear energy consumption by region Exajoules[5].

5.6. Hydroelectricity :

5.6.1.Consumption:

There is a decrease in consumption in some countries such as America and Canada, while consumption has increased in some other countries such as Russia and China. Asia Pacific ranked first in terms of consumption, followed by Center America. Hydroelectric consumption increased by 0.8%, led by China (0.6 0.6EJ), Turkey (0.3 EJ) and India (0.2 EJ). The United States and Vietnam saw the largest drops (both of them -0.2 EJ).

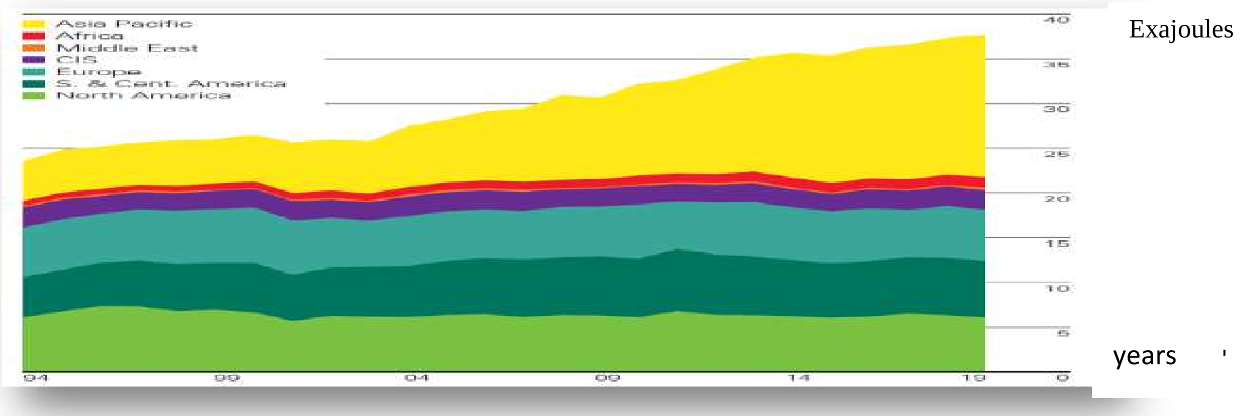


Figure I.16: Hydroelectricity consumption by region Exajoules[5]

5.7. Renewableenergy[5] :

5.7.1. Renewable consumption:

There is an increase in consumption in most countries such as America and Canada, and a noticeable increase in China. The Asia-Pacific region ranked first in terms of consumption, followed by North America. Renewable energy consumption increased by 3.15EJ in 2019.

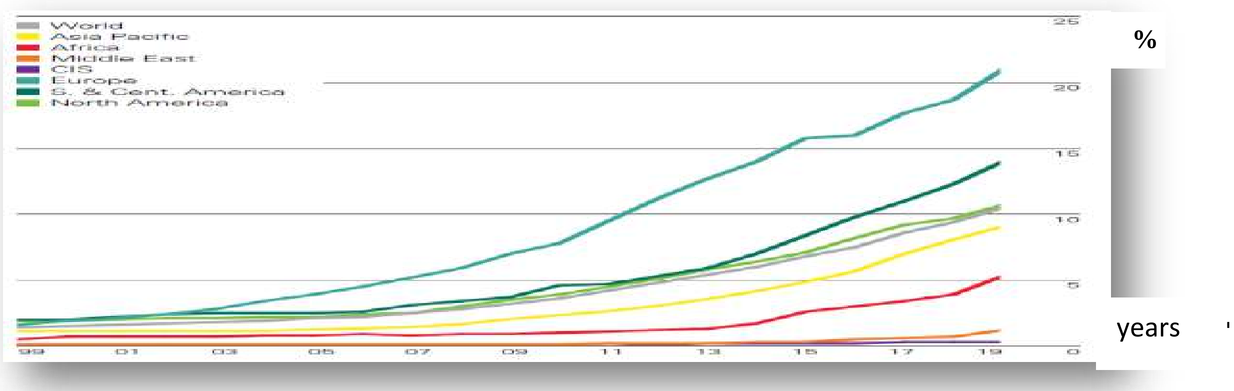


Figure I.17: Renewable share of power generation by regionPercentage [5].

5.7.2.Renewable energy generation by source:

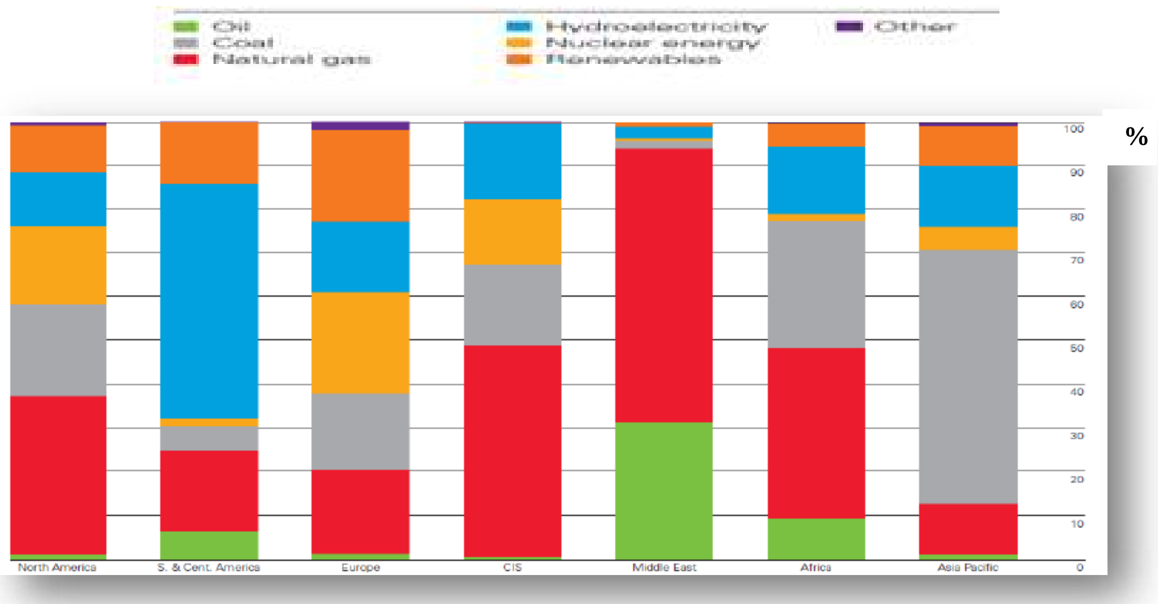
That wind energy has the largest share in renewable energy production in 2018 and 2019 years in a row, followed by solar energy. China is the largest power, followed by America, and Asia Pacific ranks first, followed by North America. Renewable energy increased by 337,5 Terawatt-hours in 2019 compared to the 2018 year.

5.8. Electricity:

5.8.1.Electricity generation:

The generation of electricity Terawatt-hours, as China is the driving force in this field, with the largest value in total, followed by America, and Asia Pacific occupies the first place in terms of electricity generation, followed by North America.The value of the electricity generated this year increased by 352Terawatt-hours in 2019 compared to the 2018 year.

Natural gas is the dominant fuel used for power generation in North America, CIS, the Middle East and Africa. South and Central America gets more than half of its power from hydroelectricity, with a share far higher than any other region. In Asia, coal is the dominant fuel. In Europe, nuclear energy is the top source of electricity, but only just,as generation is spread fairly evenly between five different fuels: the shares of nuclear, coal, natural gas, renewable and hydro are all in a narrow range of 16-23%.



FigureI.18:Regional electricity generation by fuel 2019 Percentage [5].

5.8.2.Electricity generation by fuel:

At the global level, coal is the dominant fuel for power generation, however its share fell 1.5 percentage points to 36.4% in 2019, and the lowest level in our data series. The shares of both natural gas and renewable rose to record levels last year (to 23.3% and 10.4% respectively) and renewable generation surpassed nuclear for the first time. Regionally, there is significant variation in the penetration of renewable: Europe has the highest penetration at 20.9% – twice the global average, followed by South & Central America at 13.9%.

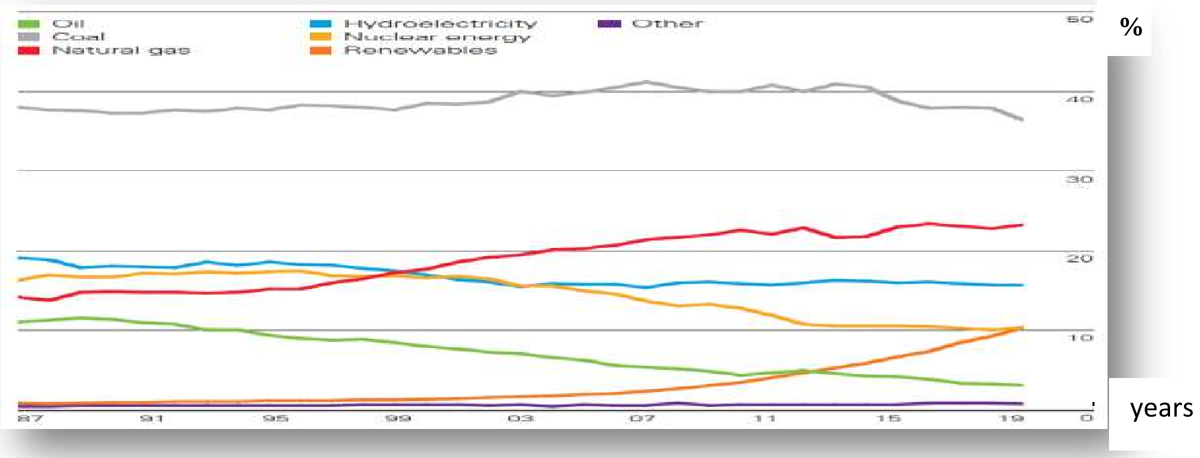


Figure I.19: Share of global electricity generation by fuel Percentage [5].

6. Conclusion:

In this chapter we dealt with what energy is and how it has evolved over time and what are the reasons for the increase in energy demand, which was caused by the development of services, technology, and the increase in population density. We also took the most important titles in this chapter, which is based onthe global energy reserves, where the largest reserves are traditional energies, but they will not last because the values are decreasing with the years, and the world will have to resort to other solutions, which are renewable energies.

In the next chapter, we will talk about technologies to benefit from solar energy, and we will specialize in one technology and study itstechnical side.

Chapter II

Solar potential and technical study of concentrated solar power technology

Part: 1

Solar potential

1.1. Introduction:

Studies carried out by the German Aeronautical and Space Center (DLR) show that the installation of solar thermal power plants (Concentrating Solar Power, CSP) on less than 1% of the desert surface of the region of North Africa and the Middle East “MENA” would produce enough electricity and water for EU-MENA The national renewable energy potential being strongly dominated by solar energy. Algeria considers this energy as an opportunity and a lever for economic and social development, in particular through the establishment of industries that create wealth and jobs. In this chapter, we will study the distribution of solar potential in the world and in particular Algeria [6].

1.2.Solar Field in the World:

Concentrated solar energy requires high direct sunlight and low humidity, it is particularly suited to the American Southwest, the Middle East, North Africa, the Mediterranean region, the deserts of Australia or Chile. The United States and Spain are currently the two most important and attractive markets. Recent attempts to map the DNI resource in the world have been made based on satellite data. The desert regions of the globe (Greater Sahara, South-West of the United States of America, Australia, South Africa) receiving up to 2900 kWhm/year of direct radiation largely provide the surface necessary for a massive production of energy by concentrating technologies . We can illustrate the distribution of global solar deposit in figure below **[6]**.

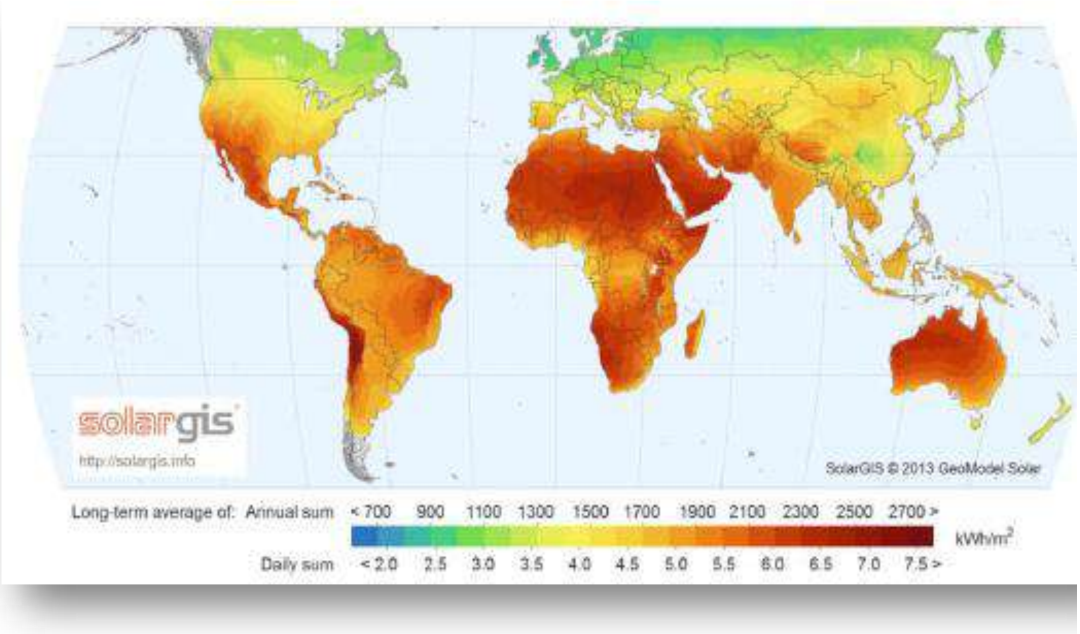


Figure II.1.1. World map of global solar horizontal irradiation [7].

The countries of the Maghreb have high solar potential. The solar irradiation rates carried out by satellites by the German Space Agency (DLR) show exceptional levels of sunshine of the order of 1200 kWh/m/year in the North of the Great Sahara. On the other hand, the best solar irradiation rates in Europe are of the order of 800 kWh/m/year limited to the southern part of Europe.

Following an evaluation by satellites, the German Space Agency (GSA) concluded**,** that Algeria represents the most important solar potential of the whole Mediterranean basin, that is: 169,000 TWh/ year for solar thermal, 13.9 TWh /year for photovoltaic solar power and 35 TWh/year for wind power. The distribution of solar potential by climatic region is shown schematically in figure II.1.2.

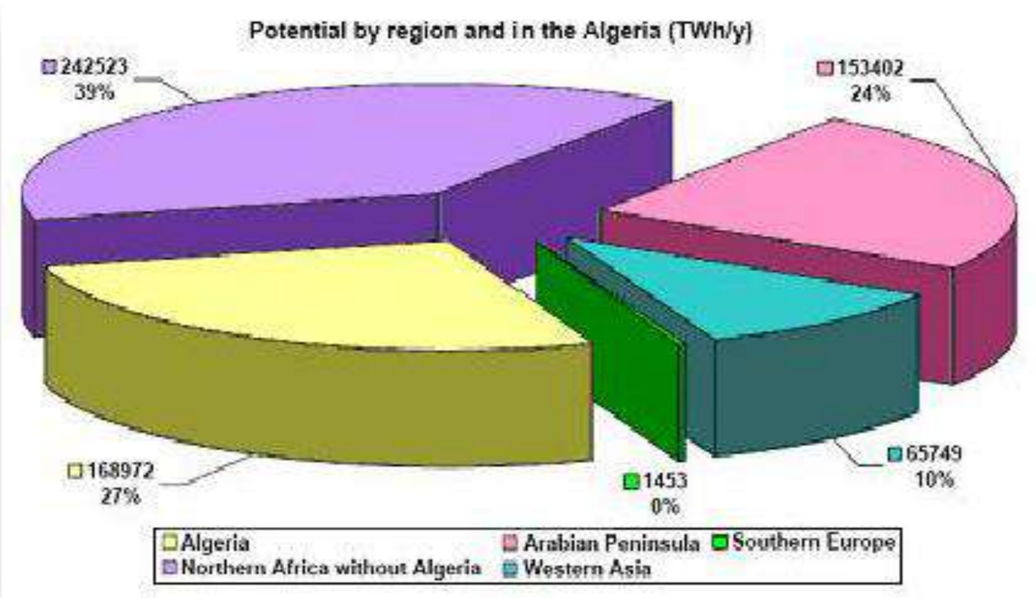


Figure II.1.2Presentation of the ratios of the solar potential of Algeria compared to the countries of North Africa o countries of the Middle East and of the Southern countries of Europe [6].

1.3.Algerian solar field [6]:

The average annual sunshine is estimated at 2000 hours, with an average sunshine of 6.57 kWh/m^2/day. With a territory made up of 86% of the Saharan desert and due to its geographical position, Algeria has the largest solar field in the world. If we were to compare solar to natural gas, Algeria's solar potential is equivalent to a volume of 37,000 billion cubic meters, or more than 8 times the country's natural gas reserves, with the difference that the solar potential is renewable, unlike natural gas.

According to the two graphics maps below, we can detect the sunniest areas in Algeria from the daily irradiation rates in the month of December and the month of July.

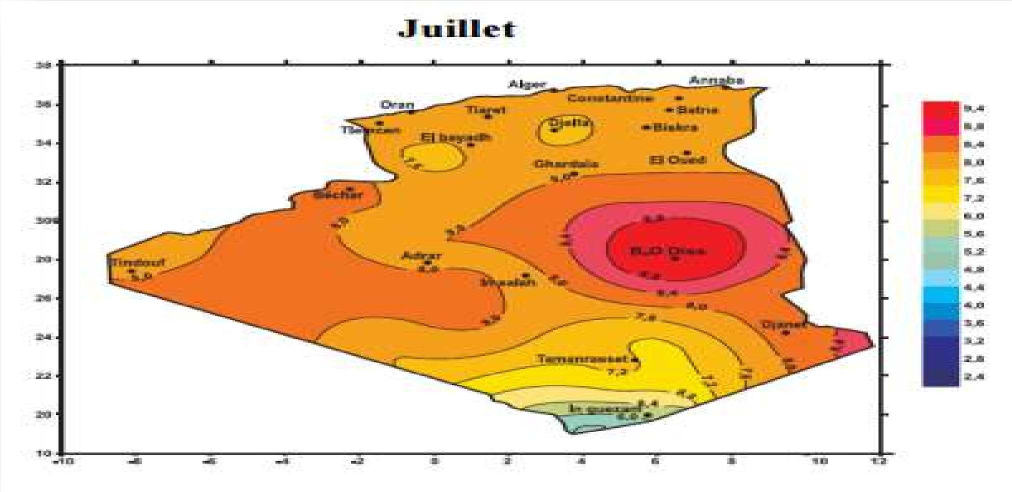


Figure II.1.3.daily irradiation on the horizontal plane in July [6].

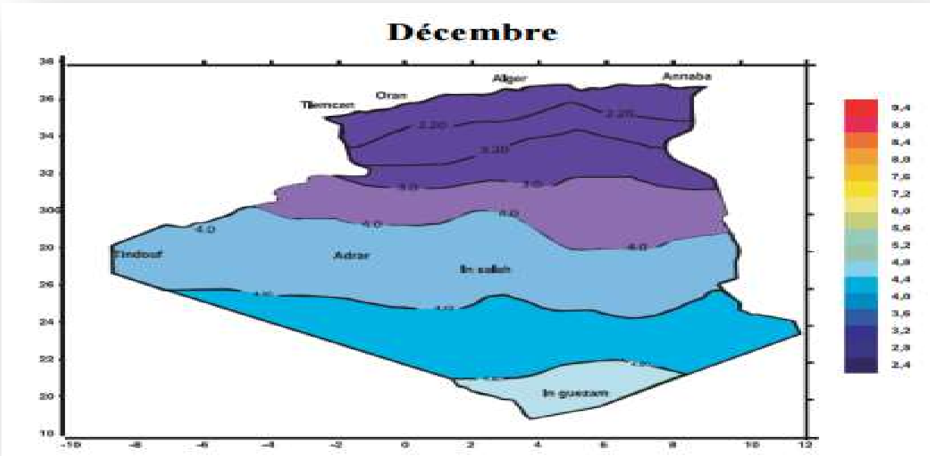


Figure II.1.4.daily irradiation on the horizontal plane in December [6].

1.4. Conclusion:

Faced with the dual climate and energy challenge, and with absolute dependence on gas in the field of electricity production, Algeria must move towards energies significant environmental advantages (low atmospheric pollution and low greenhouse gas emissions (GGE). For Algeria, solar appears as a strategic choice because of the abundance of this solar resource classified among the largest deposit in the world.

Part: 2

Technical study of concentrated solar power technology

2.1. Introduction:

One of the most prominent technology, the most environmentally friendly means of energy production, and one of the renewable energy technologies, is concentrated solar power plants. Studies have found that concentrated solar power (CSP) will be one of the most prominent competitors in the future technology arena for renewable energies, as it can represent up to 25% of the world's energy needs by 2050. And by highlighting that this technology works best in regions with solar radiation, experts expect greater growth in regions such as Africa, Mexico and the southwestern United States[8].

This technology can produce more than enough energy for the entire country with a large surplus of energy[9]. If it is exploited in a country like Algeria thanks to its vast desert and strategic geographic location near Europe (the highest potential of concentrated solar energy in the Mediterranean and Middle East regions ~ about 170 TWh/year), this makes Algeria one of the main countries to ensure the success of this technology. With abundant natural gas reserves in the Algerian desert, this will enhance the technical potential of Algeria in obtaining solar hybrid power plants with solar energy to generate electricity around the clock.

Moreover, we mention that concentrated solar energy technology has uses other than electricity. Researchers are testing a solar thermal reactor to produce solar fuels, making solar energy fully transferable in an energy form of the future.

In this chapter, we will discuss technique of CSP and identify its types, and present a comparison between PV and CSP.

2.2. Concentrated Solar Power Technologies (CSP):

CSP is one of the techniques that is used to generate electricity by using the heat provided by solar radiation concentrated on a small area called the receiver using mirrors, the sunlight is reflected on a receiver where the heat is collected by a thermal fluid carrier. The thermal fluid is used directly in the case of steam generation or via a secondary circuit to power the turbine and generate electricity[10].

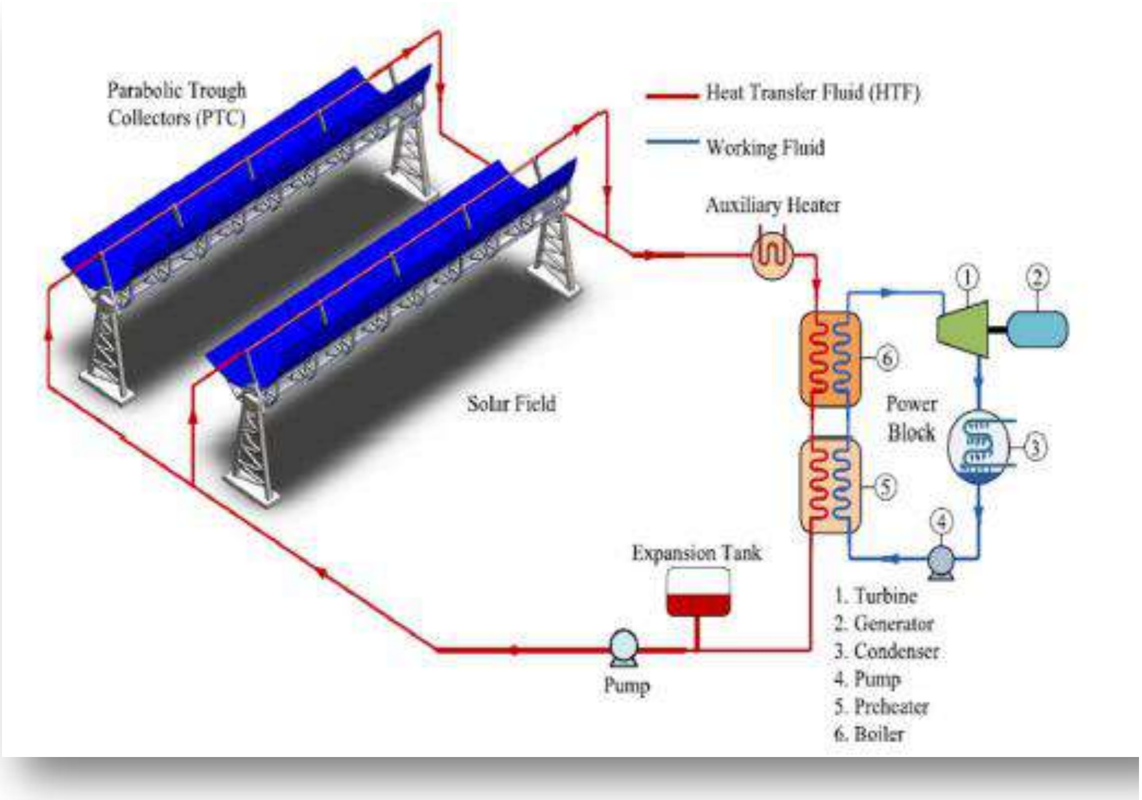


Figure II.2.1: Schematic of a solar power plant.[11].

2.2.1.Basic principles: Solar irradiation and potential:

Global solar irradiation consists of direct irradiation and diffuse irradiation. Solar energy can be used for direct thermal use, for example for heating, cooking, to generate electricity from photovoltaic systems (The use of direct and diffuse irradiation), and finally to produce heat and then electricity from concentrated thermal systems. As these latter systems only use direct irradiation, they can only be installed in areas with strong sunlight. Thus, a sunshine of 1,800 kWh/m^2/year is the minimum estimated threshold necessary to obtain sufficient efficiency. The measurements of the solar deposit primarily concerned, initially, the duration of sunshine. With the advent of modern solar technologies, the assessment of energy content has gained in importance. Currently, data on the solar deposit is available from national and international meteorological agencies, institutions responsible for the development of solar technologies as well as research institutions **[6, 12, 13]**.

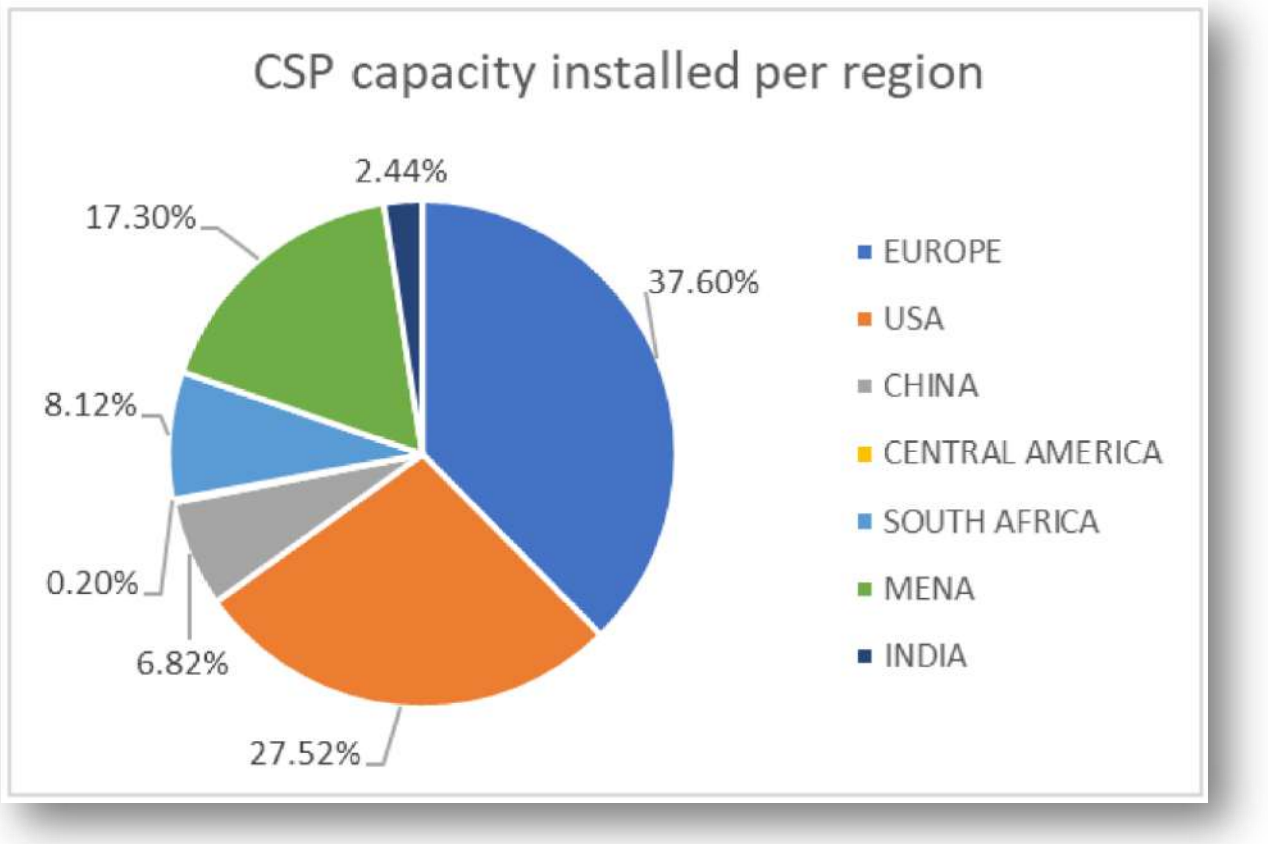


Figure II.2.2: CSP capacity installed[14].

2.2.2.The components of a CSP plant:

The basic components of a CSP plant are **[6, 12, 13]**:

2.2.2.A.Solar field:

Which represents the equivalent of the fuel supply (coal, oil, gas, uranium) for thermal power stations? In Fresnel-type CSP plants, the solar field also plays the role of the boiler, since the production of steam also takes place at the level of the solar field. The solar field is made up of parabolic cylindrical mirrors, which concentrate the solar rays on a black tube (the sensor) forming the focal axis of the mirrors. The solar rays are absorbed on the black surface, transformed into heat, which is transferred to the heat transfer fluid passing through the collector.

2.2.2.B.Pipe network:

This transfers the heat transfer fluid from the solar field to the electricity production unit and returns it to the solar field after cooling operation.

2.2.2. C.Power unit (that is to say the electricity production unit):

Which contains high pressure water pumps, heat exchangers for preheating water, steam producer, steam heater, steam turbine, generator, cooling tower and demineralization unit (not mentioned in the diagram), required to prevent the formation of very abrasive salt crystals in the turbine. The optional components of a CSP plant are:

2.2.2. C.1.Additional heat source:

Incorporating an additional heat source reduces the impact of intermittent solar radiation on power generation. Another effect is the reduction of the average production cost per kWh; this was the case for solar power plants in California given the lightning enrichment of fossil fuels, the reduction in investment costs of solar power plants and the increasingly restrictive CO_2 emissions reduction targets.

2.2.2. C.2.Expansion of the solar field and introduction of a heat storage system:

This option has several advantages:

a. Improve production stability by considerably reducing production quality losses resulting from variations in irradiation, for example due to cloud passages;

b. Allow solar energy-based production after sunset; vs. Allow production to start before sunrise;

c. Increase the capacity factor, which can reach, depending on the storage capacity, the level of power plants meeting full-hour needs and even that of base plants. Thus, a CSP plant with a storage capacity allowing 15 hours of operation at nominal power is comparable to a basic plant, since the ratio of annual production to nominal power exceeds 6,500 hours per year;

d. Allow a reduction in the production cost per kWh.

2.2.3.Sizing:

What can be defined first is the power of the plant. This quantity is generally subject to a certain number of constraints, which are either technological (a technology is generally available between two powers, one minimum and the other maximum), or legislative (for example, in Spain, the unit power of a solar power plant cannot exceed 50 MW to benefit from the advantages of the law on renewable energies).

Other possible constraints are the capacity of the system to absorb intermittent resources (capacity and composition of the generation fleet, load curve as well as the state of the network). If the demand is greater than one of the two imposed constraints, it is possible to install several units to meet the power demand. The production volume may be the second target quantity. In general, for intermittent resources such as solar radiation and wind, the volume of production is defined by the installed capacity and by the characteristics of the deposit on the site. Annual production may vary a little from year to year, but the average size is practically constant. Thus, to increase the volume of production, it is necessary to increase the installed power.

Concentrated solar power plants nevertheless have an exception. It is possible to increase the annual production volume without increasing the power of the turbine, thanks to the storage of the excess heat produced in an enlarged solar field, which allows the increase of the factor of capacity and improvement of the quality of electricity produced. Thus, in a basic concept, the solar field ensures the coverage of the heat demand for the production of steam allowing the correct operation of the generator at nominal power during the hours when the sunshine exceeds 95% of the maximum value at the site. Under these conditions, a concentrated solar power plant in the Ouarzazate region, in the south-east of Morocco, would produce around 2,250 MWh per MW installed. The introduction of a thermal storage interface and the corresponding widening of the solar field would allow the extension of production after sunset, as well as a modulation (depending on the characteristics of the storage system) of the production according to demand. The total duration of daily production at nominal power can reach 24 hours in summer. (See point 2 in optional components above). In the case of a photovoltaic (PV) or wind power system, the increase in production can only be done from an increase in installed power. In fact, production in the absence of the primary source (solar radiation or wind) can only be done with the storage of electricity produced during the time the primary source is available. It should also be noted that the storage of electricity is generally more expensive than the storage of heat. This difference in the characteristics of the storage component between CSP and PV systems is very significant. Such a difference between wind power and hydraulics (reflectors, to obtain exploitable temperatures for the production of electricity. The radiation can be concentrated on a linear or point receiver. The receiver absorbs the energy reflected by the mirror and transfer of thermodynamic fluid. In-line concentrator systems generally have a lower concentration factor than point concentrators**[6, 12, 13]**.

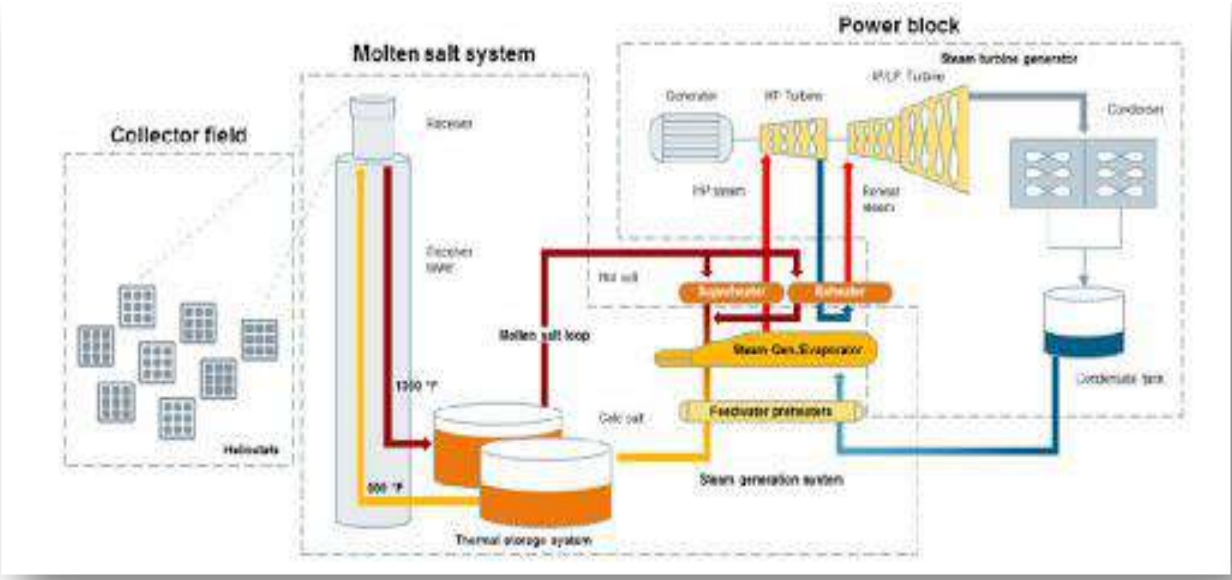


Figure II.2.3: the basic components of a CSP plant[6].

2.3. Technical parameters:

2.3. A. Maximum temperature of the heat transfer fluid:

The temperature that can be reached at the absorber of a CSP plant depends **(**in addition to the level of heat loss by convection, conduction and radiation**)** the concentration factor of solar radiation and the flow rate of the heat transfer fluid. Heat losses increase dramatically with increasing temperature. The temperature of the heat transfer fluid at the outlet of the solar field essentially depends on two parameters, the flow rate and the thermal stability of the fluid. The synthetic oil currently used in cylindro-parabolic mirror systems still has good thermal stability at 400 ° C. A heat transfer fluid that can withstand a higher temperature would allow an increase in the efficiency of the electricity production system. The R&D activities are aimed, on the one hand, at the development of oils with greater thermal stability and, on the other hand, at the direct production of water vapor in the solar field. The fluids used in tower power plants or in the Stirling system withstand much higher temperatures, but do not adapt as well as the synthetic oil used to the technical conditions of parabolic cylinders. Figure II.2.4 gives us more detail on the absorber temperature for CSP technologies **[6, 12, 13]**.

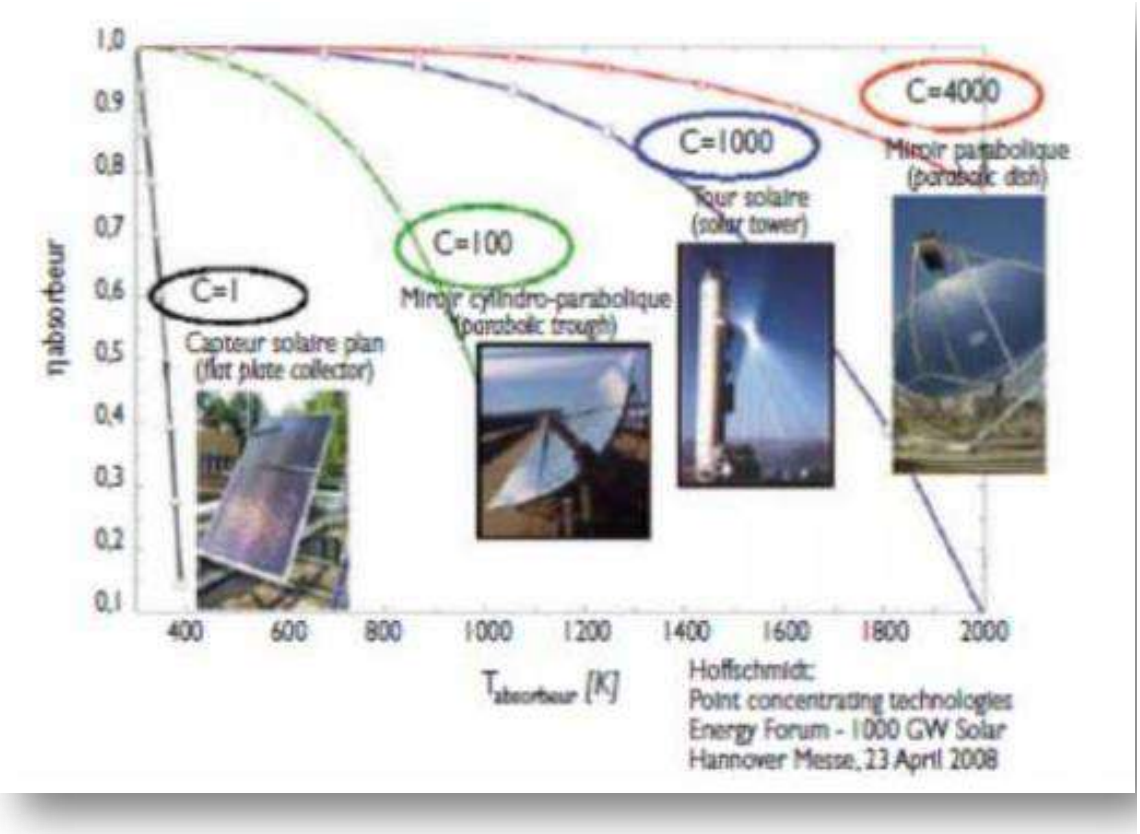


Figure II.2.4: absorber temperature depending on the technology[6].

2.3.B. Concentration factor: [6, 15]

The performance of the system is characterized by its concentration factor. This coefficient makes it possible to evaluate the intensity of the solar concentration: the higher the concentration factor, the higher the temperature reached will be.

Concentration factor is equal to surface of the receiver/surface of the mirror. The thermal energy coming from the collected solar radiation is converted by means of a heat transfer fluid then a thermodynamic fluid. In some cases, the heat transfer fluid is used directly as a thermodynamic fluid. The choice of heat transfer fluid determines the maximum admissible temperature, guides the choice of technology and materials for the receiver and determines the possibility and convenience of storage.

• **The oils:** are single-phase fluids which have a good exchange coefficient. Their temperature range is limited to around 400 ° C. It is the most commonly used fluid in parabolic collector plants.

• **Molten salts:** based on sodium and potassium nitrates offer a good exchange coefficient and have a high density. They are therefore also very good storage fluids. Their outlet temperature can reach 650 ° C. Their association with a tower concentrator and a Rankine cycle is an already proven combination.

• **Gas:** such hydrogen or helium can be used fluids like thermodynamics and drive Stirling engines which are associated with parabolic collectors.

• **Liquid water:**is, a priori, an ideal transfer fluid. It offers an excellent heat exchange coefficient and has a high thermal capacity. In addition, it can be used directly as a thermodynamic fluid in a Rankine cycle. However, its use involves working at very high pressures in the receivers due to the high temperatures reached, which poses a problem for parabolic cylinders.

• **Organic fluids:** (butane, propane, etc.) have a relatively low evaporation temperature and are used as a thermodynamic fluid in a Rankine cycle. Air can be used as a heat transfer fluid or as a thermodynamic fluid in gas turbines.

2.3. C. Storage, continuous production:

A major advantage of certain thermodynamic solar technologies is their storage capacity, which allows power stations to operate continuously. Indeed, when the sunshine is greater than the capacity of the turbine, the excess heat is directed to thermal storage, which is filled during the day. The stored heat makes it possible to continue producing in the event of a cloudy passage as well as at nightfall. Several storage methods can be used: molten salt, concrete, phase change materials, etc **[6, 15]**.

2.4. Electricity generation systems:

Several electricity generation systems are possible: solarized gas turbine, Steam Rankine cycle, Stirling engine, Organic Rankine cycle, etc. The choice of a system depends on the type of fluid and the collection and storage technique envisaged. Rankine steam cycles are, in the current state of technology, the most widely deployed.

Hybridization with a fossil or biomass heat source increases the availability of installations and produces heat in a guaranteed manner. It thus promotes the stability of national and continental electricity grids**[6, 15]**.

2.5. Concentration systems:

Solar energy being sparse, it is necessary to concentrate it, via reflecting mirrors, to obtain exploitable temperatures for the production of electricity. The radiation can be concentrated on a linear or point receiver. The receiver absorbs the energy reflected by the mirror and transfers it to the thermodynamic fluid. In-line concentrator systems generally have a lower concentration factor than point concentrators. Figure II.2.5 shows the solar concentration means**[6, 15]**.

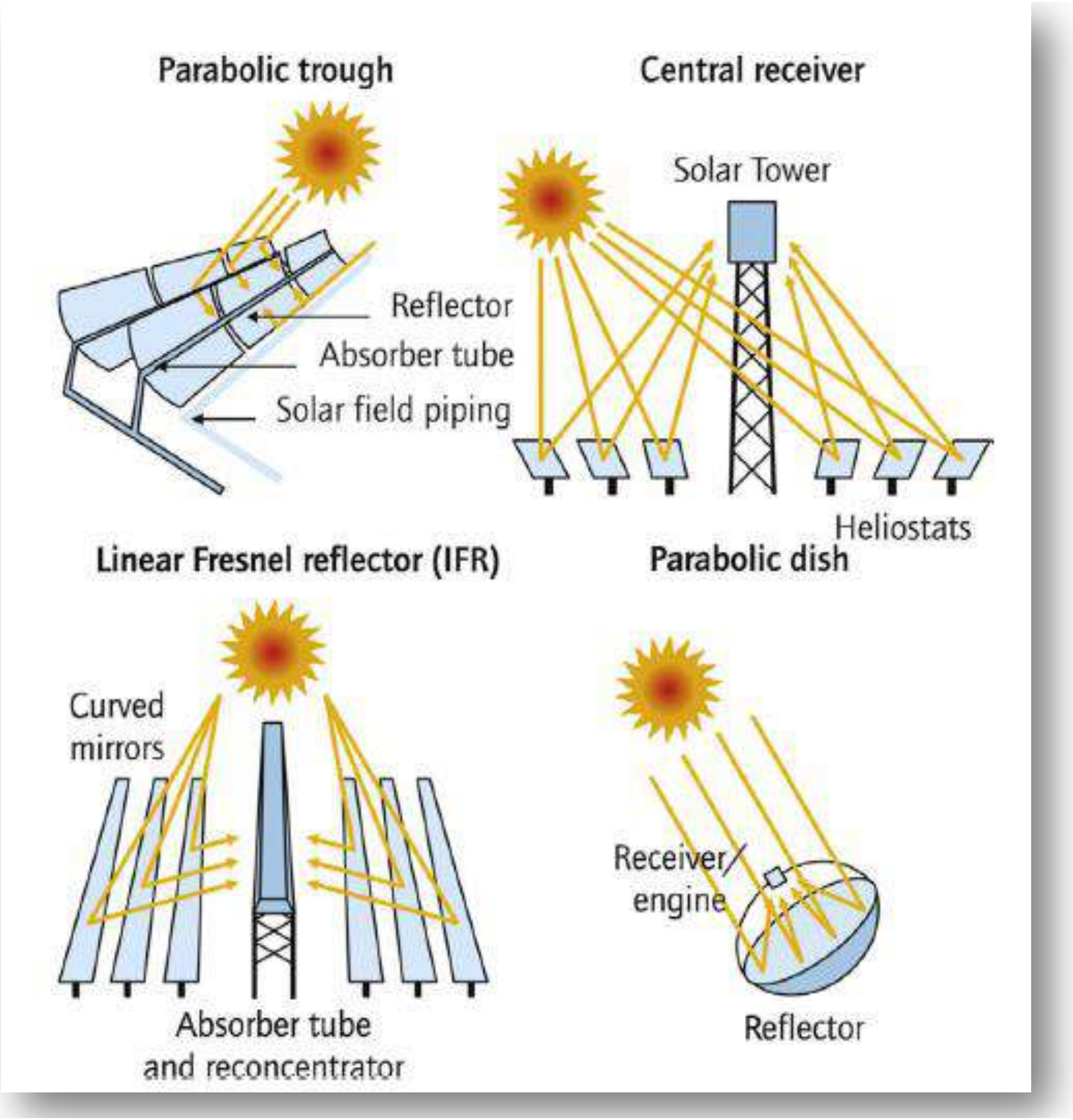


Figure II.2.5: Currently Available CSP Technologies: (a) SPT; (b) PTC; (c) LFR; (d) PDC [7]

2.6. Different types of solar concentrators:

2.6.1. Parabolic Trough Collector (PTC):

The PTC plant consists of a set of parabolic mirrors curved in one dimension to the concentration of sunlight on the absorber tube installed in the midline of the parabola and these mirrors and absorber tubes move in along with the sun, from sunrise to sunset. The set of parallel reflectors connected to the solar field is called as shown in the figure II.2.6[16, 17].

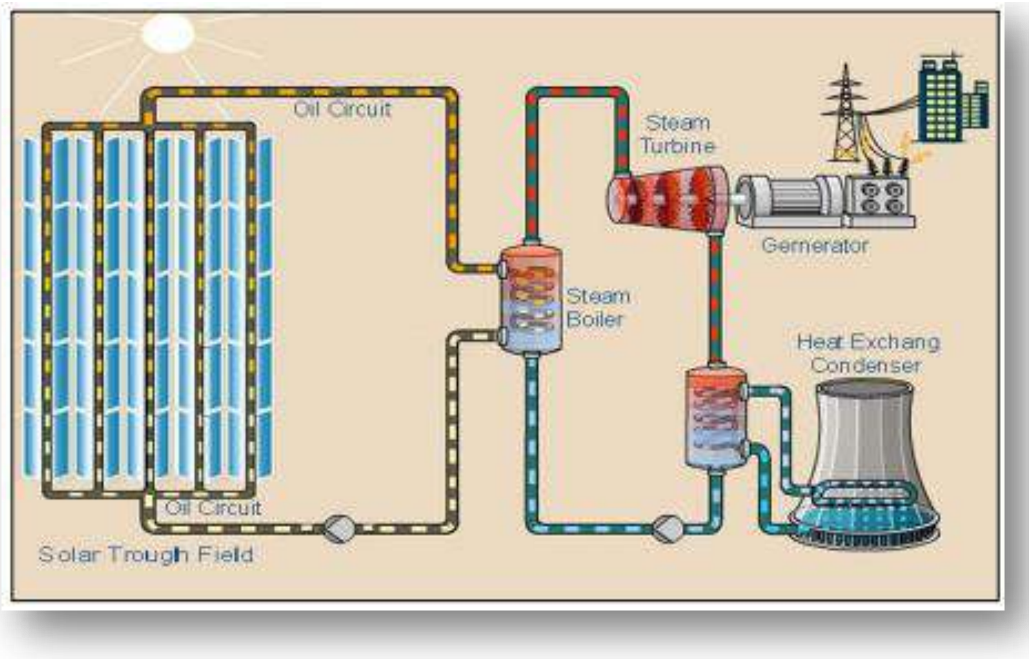


Figure II.2.6: a Parabolic Trough Collector (PTC) Plant[10].

Usually, thermal fluid is used as heat transfer fluid like Therminol VP-1, after which Rankin steam power cycle is triggered. Other configurations use a direct system to generate steam without the need for a secondary circuit as shown in the figure II.2.7[16, 17].

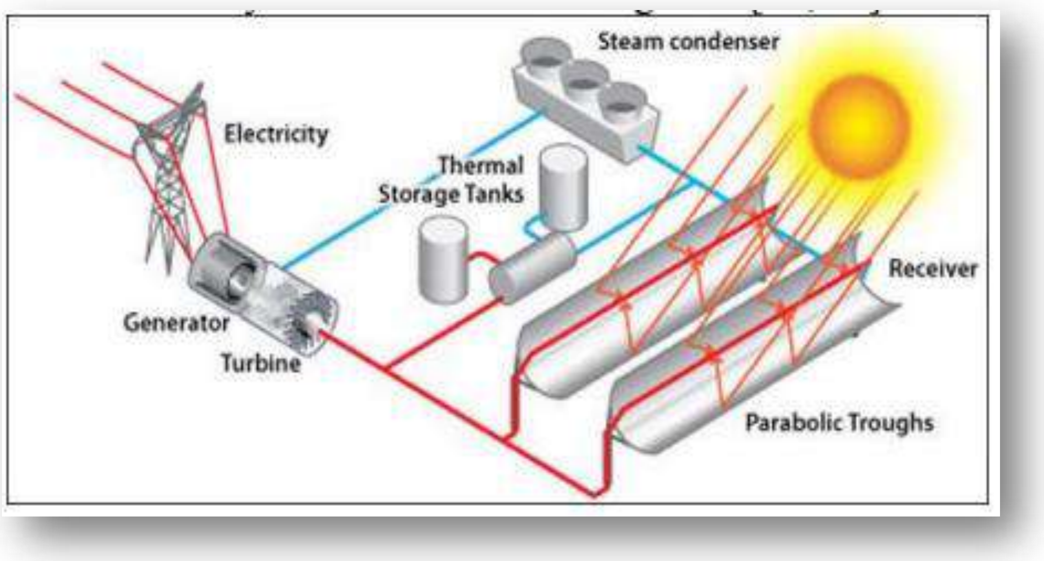


Figure II.2.7: Direct Steam Generation of Parabolic Trough Plant. [10]

Absorber tube as shown in figure II.2.8, also called heat collector (HCE) element, is a metal tube coated with glass, between which there is air or vacuum to reduce heat loss by convection and allow thermal expansion. The metal tube is covered with selective material with high absorption of solar radiation and low thermal transitions, and the metal glass seal is important in reducing heat loss[17, 18].

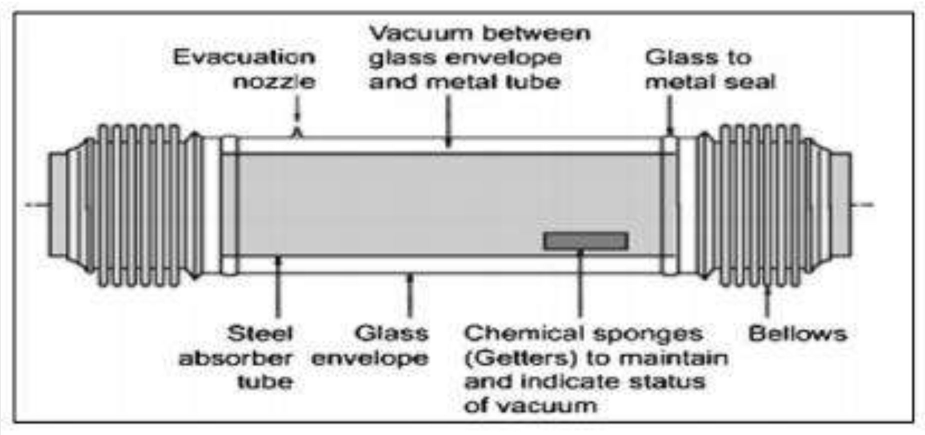


Figure II.2.8: Absorber Element of a Parabolic Trough Collector [17].

2.6.2. Solar Power Towers (SPT):

SPT, also known as Central Receiving Systems (CRS) as shown in Figure II.2.9. A field of reflective mirrors that track the rays of the sun, called the heliostats, that reflect and focus the sun's rays onto a central receiver located at the top of a stationary tower[10].

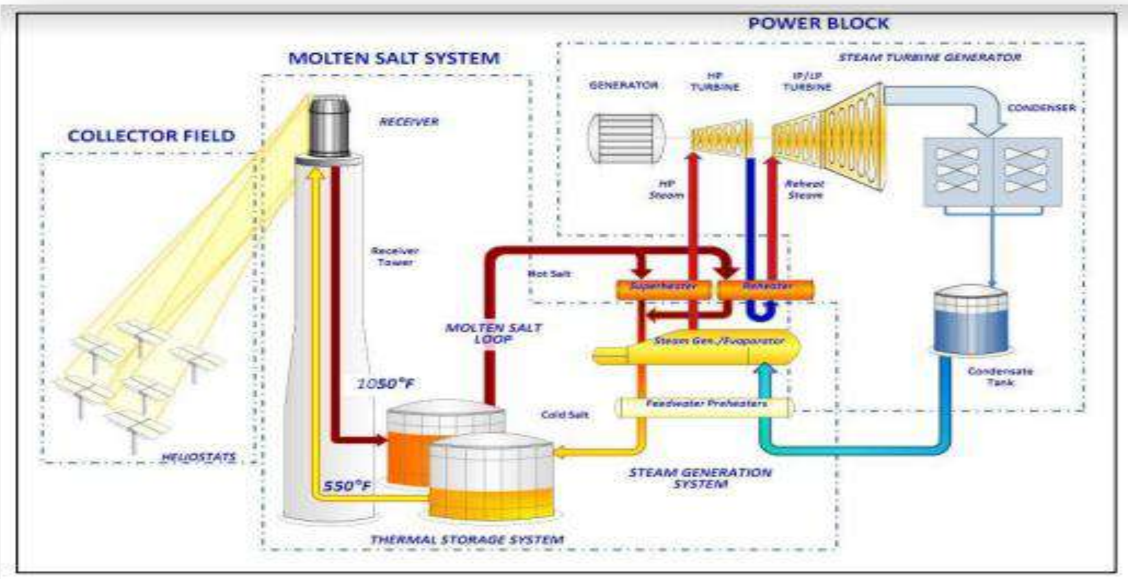


Figure II.2.9: Solar Power Tower Plant Using Molten Salt as HTF and Storage[10].

Heliostats are flat or slightly concave mirrors that follow the sun in a two axis tracking. In the central receiver, heat is absorbed by HTF, which then transfers heat to heat exchangers that power a steam Rankine power cycle. Some commercial tower plants now in operation use different fluids, including molten salts as HTF and storage medium as shown in Figure 9 while others uses DSG as shown in figure II.2.10. The concentrating power of the tower concept achieves very high temperatures, thereby increasing the efficiency at which heat is converted into electricity and reducing the cost of thermal storage. In addition, the concept is highly flexible, where designers can choose from a wide variety of heliostats, receivers and transfer fluids. Some plants can have several towers to feed one power block[10, 18].

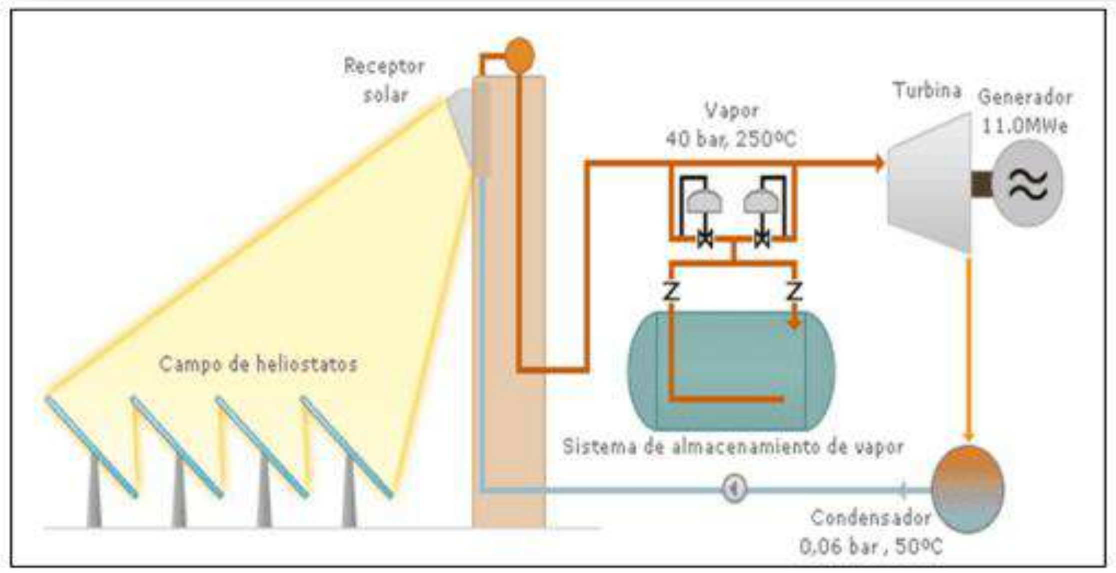


Figure II.2.10: Direct Steam Generation of Tower Power Plant [10].

2.6.3. Linear Fresnel Reflector (LFR):

An LFR almost like the parabolic shape of a trough systems uses long rows of flat or slightly curved reflective mirrors to reflect sunlight in a linear receiver facing downwards as shown in the figure II.2.11 [10].

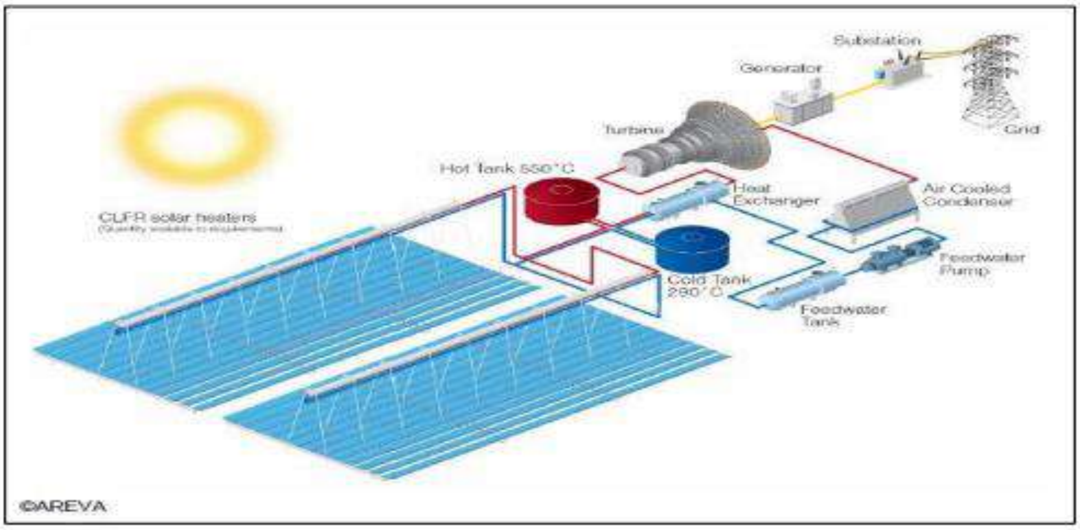


Figure II.2.11: Linear Fresnel Reflectors Power Plant with Molten Salt as HTF and Storage.[10]

The receiver is a fixed structure mounted on a tower above the length of linear reflectors. Reflectors are mirrors that can track the sun's rays on a single or double axis system. The main advantage of LFR systems is that their simple design of mirrors and fixed receivers requires less costs, and this facilitates direct steam generation as shown in figure II.2.12, thus eliminating the need for heat transfer fluids and heat exchangers[10].

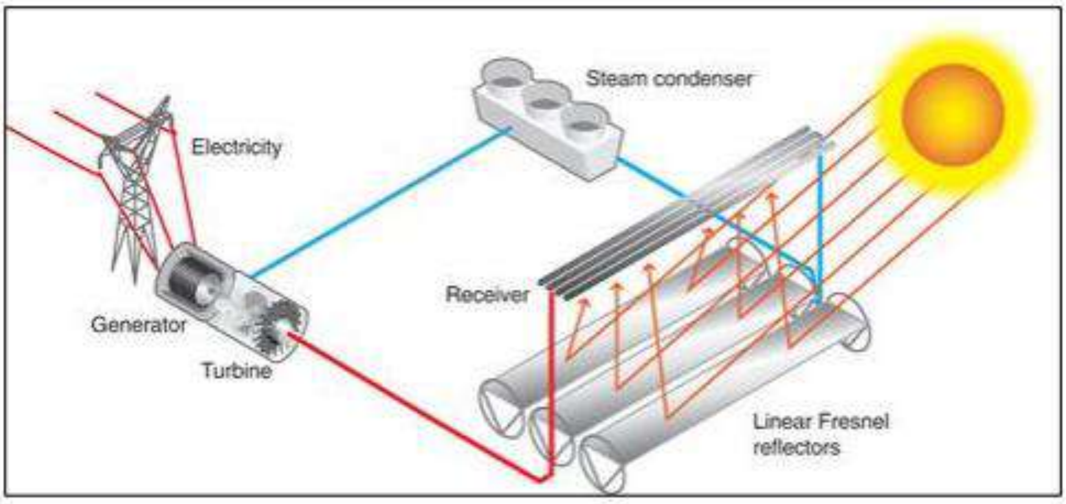


Figure II.2.12: Direct Steam Generation of Fresnel Linear Reflector Power Plant.[10]

However, LFR stations are less efficient than PTC and SPT at converting solar energy into electricity, and it is difficult to incorporate storage capacity into their design [18].

2.6.4. Parabolic Dish Systems (PDC):

PDC, also known as Dish-Stirling Engine (DSE) as shown in figure II.2.13, focuses the sun's rays at a focal point above the center of the plate.

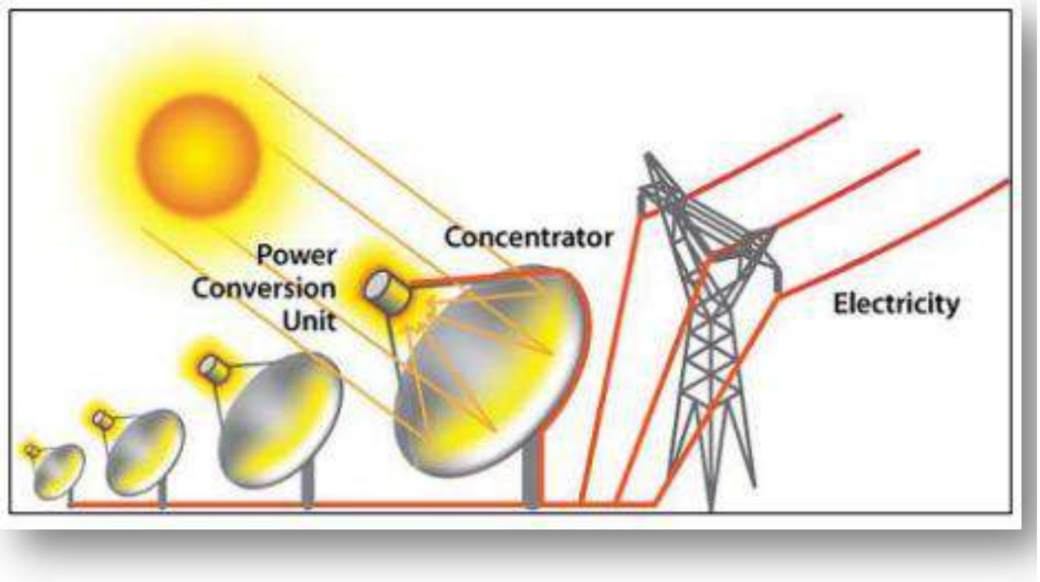


Figure II.2.13: Parabolic Dish Collectors [10].

The whole system tracks the sun, as the dish and receiver move together, eliminating the need for both the HTF and the cooling tower.

PDCs offer the highest conversion efficiency of other CSP systems. PDCs are expensive and have low compatibility with respect to thermal storage and hybridization. Each parabolic dish has a low power capacity, and each plate produces electricity independently[18, 19].

2.7.Comparison between Leading CSP Technologies:

Table II.2.1: Comparison between Leading CSP Technologies[[20], [19], [21]].

Parameter	Parabolic Trough	Solar Tower	Linear Fresne	Dish-Stirling
Typical Capacity (MW)	1-300	1-200	1-200	0.01-0.025

Maturity of Technology	High (Commercially Proven)	Medium (Pilot Commercially Projects)	Low (pilot projects)	Low (demonstration Projects
Technology risk	Low	medium	medium	Medium
Max slope of Solar field(%)	< 1-2	< 1-4	< 1-2	< 1-4 array units 10 % more split unit
Operating T (oC)	20-400	300-565	50-300	120-1500
Solar Concentration Ratio[1]	15-45	150-1500	10-40	100-1000
Termo-dynamic	Low	High	low	High
Capacity factor	< 50%, no Storage > 50%,yes Storage	< 50%, no Storage > 50%,yes Storage	< 50%, no Storage > 50%,yes storage	No storage
Cooling water (L/MWh)	3000or Dry	3000 or Dry	3000 or Dry	None
Washing Requirements (L/MWh)	300	300	300	75
Land occupancy	Large	medium	medium	Small
Investment cost ($/KW)	4000-5000(no Storage) 6000-9000(3-8h storage)	4000-5000 (water steam ,no Storage) 8000-10000 (6-10h storage)	3500-4500 (noStorage) unspecified Cost(Storage)	4500-8000 (depending on Volume production) No storage

				systems in Dish-stirling
Relative cost	Low	High	Very low	Very high

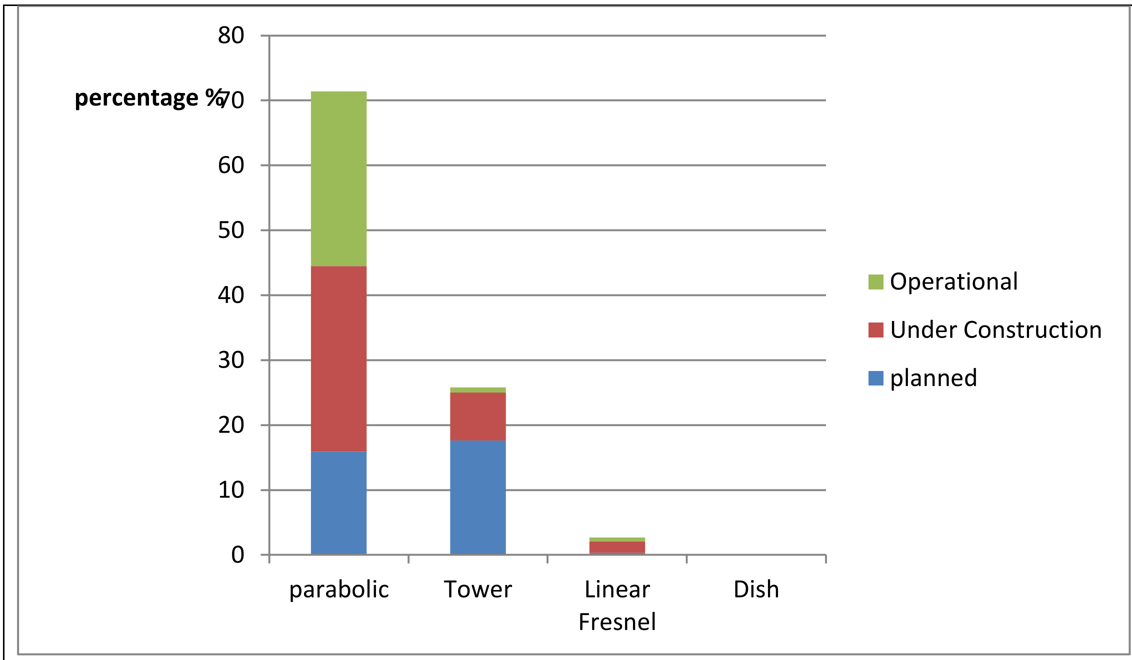


Figure II.2.14: CSP Pipeline Per Technology Type[22].

2.8. Comparison between PV and CSP:

In this table, we compare two pathways for PV and CSP on the three criteria (maturity, construction and operation, energy)[23].

Table II.2.2: comparison between PV and CSP[23].

	technology	photovoltaic		Concentrated solar Power	
maturity	Cost reduction potential	40 to 45**%**	-	Mature technology	+
	operationality	Fast	+	long	-
	complexity	Components available	+	Complex construction	-

construction and operations				Component purchase May take 2 years	
	operational	Few staff on site remote-controlled operations	+	Staff required On Sit for operations and maintenance	-
energy	Storage option	No	-	6-12h	+
	Network connection	Medium voltage	-	High tension	+
	Cloud sensitivity	Shutdown in The Presence of clouds	-	Mitigation of the Impact of the presence of cloud thanks to the storage capacity	+

This table shows that CSP technology has the advantage of very efficient PV storage[24]. The need for on-site personnel and the need to build power plants make this technology create jobs.

2.7.Conclusion:

In this chapter we dealt with the explanation of CSP technology, we found that the presence of four types of concentration means the emergence of four types of power stations to generate electricity, namely: Parabolic Trough Collector (PTC): the most mature followed by Solar Power Towers (SPT), then Dish Stirling and Linear Fresnel which is low in use. We've also seen a wide comparison between these different types of concentrated solar power and a comparison between CSP technology and photovoltaic.

Chapter III

Cost study of concentrated solar power technology

1. Introduction:

Concentrated solar power (CSP) is an important technology in many parts of the world and has great potential to meet part of the energy demand in the future because it is equipped with low-cost thermal energy storage to provide renewable, distributable energy. It can also produce large quantities of variable temperatures for industrial processes[25].

In this chapter, we will discuss an economic study on this technology related to the intensity of its use and the percentage that it will participate in reducing dependence on fossil energy.

2.Current market penetration:

While the CSP technology was successfully producing electricity, with no new plants operating until 2006, **r**ecent years have seen significant acceleration of activity. Table 1 summarizes the current deployment of the CSP through 2010 **[26]**.

Table 1: Current and predicted global deployment of CSP plants [26]

Status	Projects	Capacity (GW)
Operational	39	1.27
Under construction	29	1.93
In development	67	17.53

The world expects that the deployment of CSP plants will continue to accelerate and thus help reduce capital costs through learning by doing.

3.Concentrating solar power (CSP) plants:

It is capital intensive but has virtually no fuel cost.

A parabolic plant without thermal energy storage has as low costs as 4,600 USD / kWh, but low capacity factors are between 0.2 and 0.25. Adding six hours of thermal energy storage increases the capital costs from $ 7,100 / kWh to $ 9,800 / kWh, but allows for capacity factors to be multiplied.

Solar powerplants can cost between $ 6,300 and $ 10,500 per kilowatt when the energy storage is between 6 and 15 hours. This plant can achieve power factors from 0.40 to 0.80 **[27]**.

Table 1: CSP costs and performance in 2011[27]				
	Installed cost (2010 USD/kW)	Capacity factor (%)	O&M (2010 USD/kWh)	LCOE (2010 USD/kWh)
Parabolic trough				0.14 to 0.36
No storage	4 600	20 to 25		
6 hours storage	7 100 to 9 800	40 to 53	0.02 to 0.035	
Solar tower				
6 to 7.5 hours storage	6 300 to 7 500	40 to 45		0.17 to 0.29
12 to 15 hours storage	9 000 to 10 500	65 to 80		

3.1.Operations and maintenance (O&M):

The costs are relatively high for CSP plants, in the range of $ 0.02 to $ 0.035 per kilowatt-hour. But there is an opportunity to reduce the cost **[27]**.

3.2. Cost of electricity (LCOE):

LCOE Of concentrated solar power plants is currently high. Assuming the cost of capitalIs 10%, and the LCOE for parabolic stations today ranges from $ 0.20 to $ 0.36 per kWh, and those for solar towers are between $ 0.17 and $ 0.29 / kWh. However, in areas with excellent solar resources, it can be as low as 0.14 USD to 0.18 USD / kWh. LCOE relies mainly on capital costs and local solar energy supplier. For example, the LCOE for a given CSP would be about a quarter lower for direct natural irradiance by 2700 kWh/m^2/year compared to a site with energy of 2100 kWh/m^2/year.

3.3. Cost reductions:

Cost reductions will come from advances in research and development, a more competitive supply chain, improvements in solar energy field performance, and solar energy efficiency to electricity and thermal energy storage systems. By 2020, cost of capital reductions ranging from 28% to 40% could be achieved and perhaps even higher reductions.

4. Different measures of cost:

Different measures of cost can be measured in many different ways, and each calculation method has its own vision. Costs that can be examined include equipment costs (such as wind turbines, PV modules, and solar inverters), financing costs, total installed cost, fixed and variable (O&M) operating and maintenance costs (O&M), fuel costs and flat cost of energy (LCOE).

The three indicators that have been selected are:

- Equipment cost (factory gate FOB and delivered at site CIF);
- Total installed project cost, including fixed financing costs ;
- The cost of electricity LCOE.

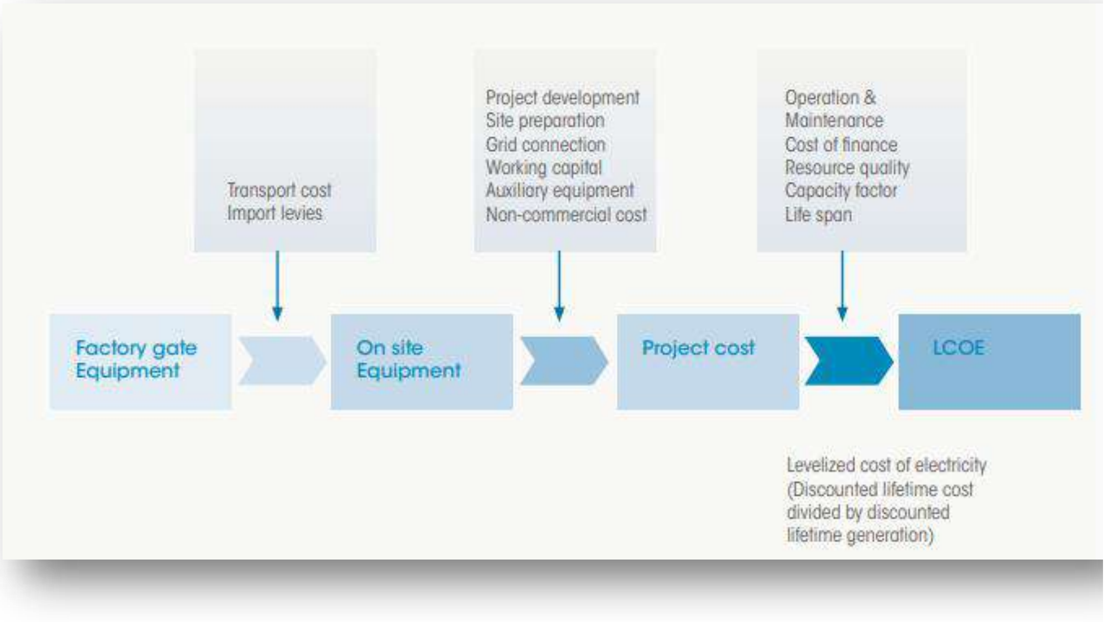


Figure 1.1: Renewable power generation cost indicators and boundaries[27].

5. Cost of electricity generation:

It varies by technology, country and project renewable energy source, capital and operating costs, and efficiency / performance of the technology. The approach used in the analysis presented is based on a discounted cash flow (DCF). This method of calculating the cost ofrenewable energy technologies is based on discounting financial flows (annual, quarterly or monthly) on a common basis, taking into account the time value of money. Given the capital-intensive nature of most renewable energy production technologies and the fact that fuel costs are low, or often zero, the Weighted Average Cost of Capital (WACC), often also referred to as the discount rate, used to assess the project to a critical impact on the LCOE. The formula used to calculate the LCOE of renewable energy technologies is as follows [27].

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \qquad \textit{(III.1)}$$

Where:

LCOE = the average lifetime cost of electricity generation;

$\mathbf{I_t}$ = investment expenditures in the year t;

$\mathbf{M_t}$ = operations and maintenance expenditures in the year t;

$\mathbf{F_t}$ = fuel expenditures in the year t;

$\mathbf{E_t}$ = electricity generation in the year t;

r = discount rate;

n = life of the system.

6. The sizing of the solar power plant:

There are many parameters that determine the optimum design of the installation. An important element is the role of thermal energy storage. The latter increases costs, but it allows greater production capacity when the sun is not shining and / or maximization of production at peak times. Costs increase, due to investment in thermal energy storage; therefore the size of the solar field is increased in order to allow the operation of the plant and the storage of solar heat to increase the capacity factor. Although much depends on the specific design of the project and whether the storage is used just for generational change, or to increase the capacity factor, the data currently available suggests that the marginal cost is economically justifiable.

The solar multiple is the actual size of the solar array relative to what would be required to achieve nominal electrical capacity at the point of the design. In order to ensure that the power supply is actually used during the year, the solar multiple is usually greater than unity is between 1.3 and 1.4. It can be even larger (up to 2.0) if the plant has a six-hour storage system. NREL has developed a model for performing performance and economic analysis of CSP plants. The model allows comparing the different technological options and configurations with the aim of optimizing the plant design figure III.8.2 shows the relationship between the capacity factor (20% to 60%) and thermal energy storage in hours (h) for different solar multiples in regions with the good solar resource. The trade-off between the costs of the solar array and the storage system must be weighed against the expected increase in revenue that will result from the increased production and the ability to generate dispatch power at times when the sun is not shining **[27]**.

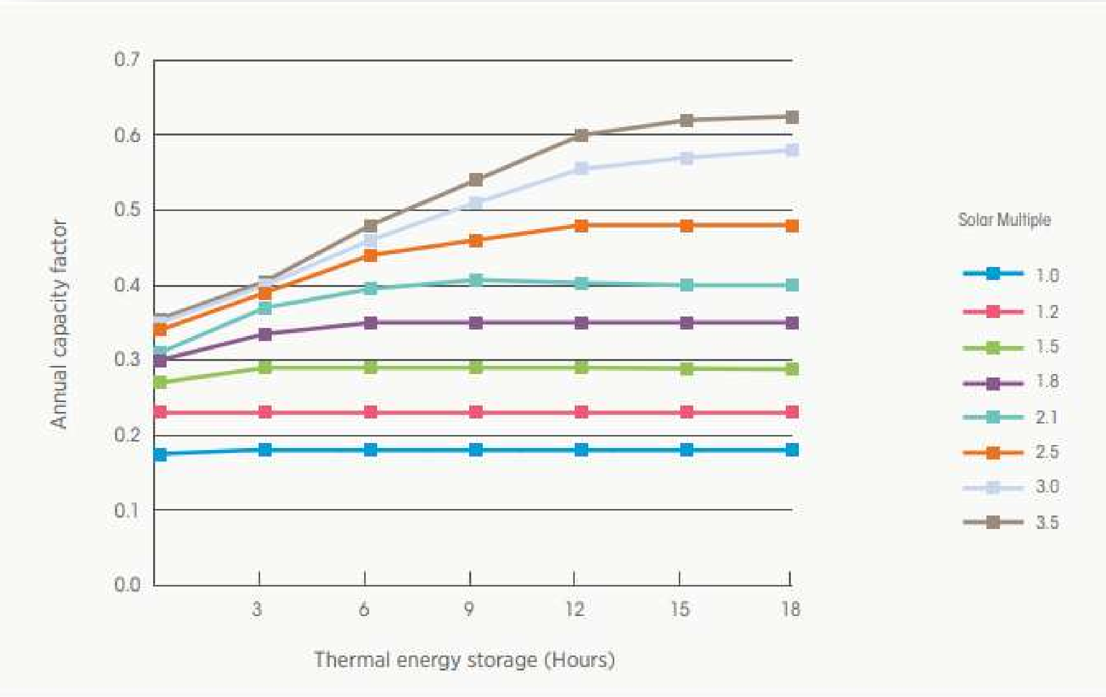


figure 2.2: Annual capacity factor for a 100 mw Parabolic Trough Plant as a function of Solar field Size and Size of Thermal energy Storage [27].

7. Capital cost:

Previous assessments have shown that the cost of capital is dominated by the cost of capital for the two most recent CSP technologies, towers and basins, and it is sometimes difficult to compare studies. One of the key parameters is the "solar multiplier", which is the ratio of the maximum heat capacity of the field to the capacity of the energy mass. This parameter is important for optimization because it determines the heat energy available for power generation **[26]**.

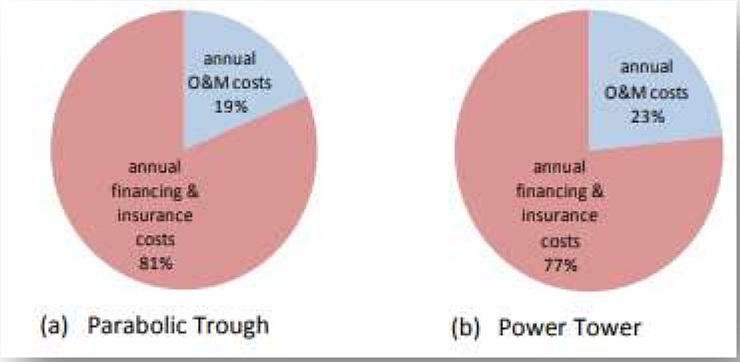


Figure III.3: Contribution of capital and operating costs to the cost of electricity for trough and tower plants .

8. Capital cost estimates from previous studies:

Figure III.4 shows the relative contribution of different plant areas to the total capital cost. Note that while the solar field appears to be cheaper for towers than for basins, the field costs for basins include linear collector elements, while the tower analog - tower and receiver - are separated for power towers **[26]**.

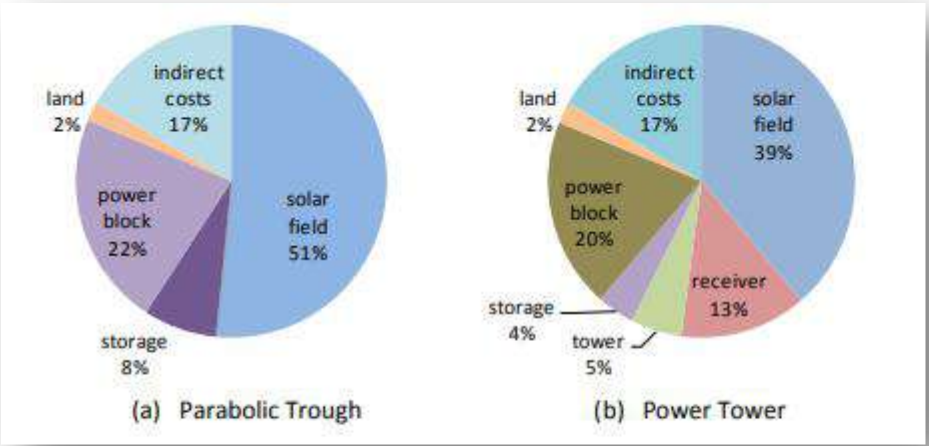


Figure III.4: Capital cost breakdowns from literature for parabolic troughs and power towers[26].

9. Cost reduction studies:

The US Department of Energy (DOE) commissioned two recent studies to determine the technical potential for reducing the cost of electricity from CSP - the Line Focus Solar Power Plant Cost Reduction Plan (Turchi et al., 2010) and the Power Tower Technology Road Map and Cost Reduction Plan (Kolb et al., 2010). Figure 6 shows the projected reductions that could be achieved by 2020 for the tower stations, and 2017 for the trough stations., And is also expected to decline significantly **[26]**.

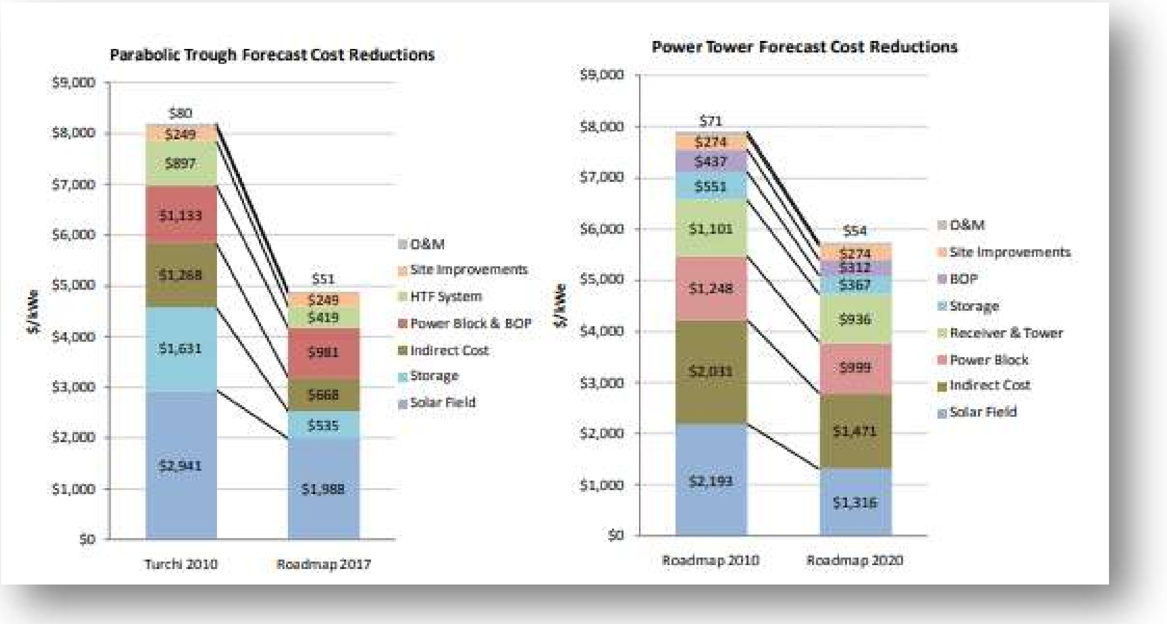


Figure III.5: Projected parabolic trough and power tower cost reductions over the current decade [26].

10. Analysis of losses and opportunities:

SAM designs the power flows in a CSP plant by determining losses in each station's subsystem as a whole. Figure 7 shows average annual data from SAM for a tower station with 6 h storage.and where are the main loss areas in between **[26]**.

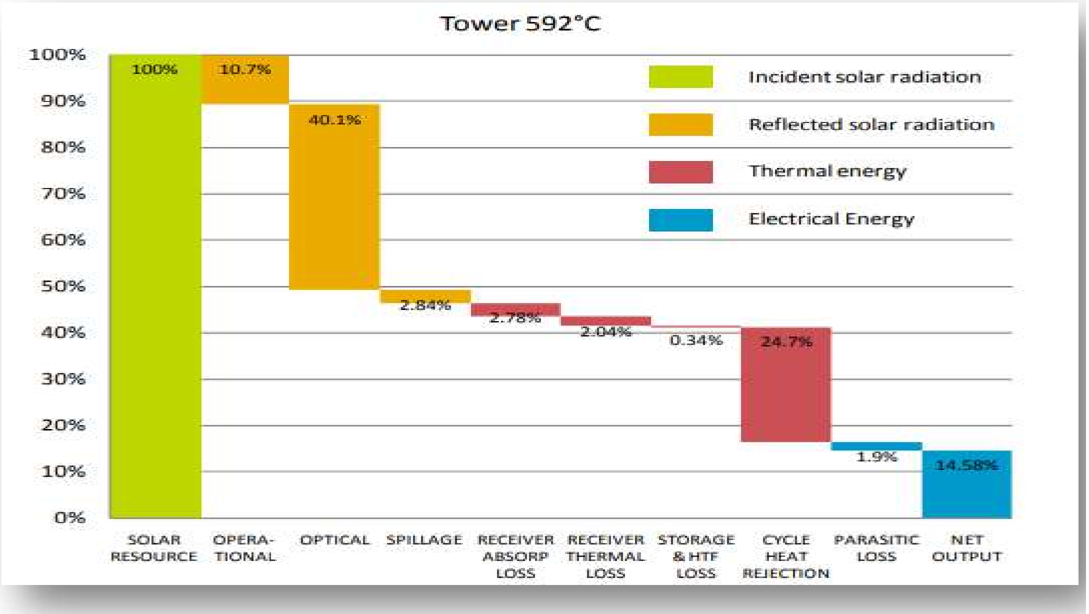


Figure III.6: Energy flow diagram for a power tower CSP plant[26].

The components of the energy diagram are as follows:

- ✓ **Solar Resources**

It represents the theoretical amount of available energy,

- ✓ **Operational**

Represents the energy that is not collected due to the lack of use of the solar field, as well as the times when the energy cycle is fully charged and no additional thermal energy is required.

- ✓ **Optical**

It represents the amount of energy lost due to engineering factors and the incomplete reflection of the available energy.

- ✓ **Spillage**

It represents the proportion of reflected energy that does not occur on the receiver surface due to mirror quality or errors in positioning

- ✓ **Receiver absorption losses**

Refer to the amount of energy that is reflected by the receiver surfaces.

- ✓ **Receiver Thermal Losses**

The receiver represents the thermal losses of the receiver

- ✓ **Storage & HTF Loss**

Represents the amount of thermal energy that is lost from piping and thermal storage systems.

- ✓ **Cycle heat rejection**

Refers to the thermal energy that the power cycle is not able to convert toelectricity,

- ✓ **Parasitic Loss**

Refers to the energy consumed by the plant itself to produce electricity,

- ✓ **Net Output**

It is the electricity produced by the plant; after all internal losses have been accounted for.

11.Impact of the solar resource and plant design decisions on the LCoE of CSP plants.

It is important to note that the LCOE of CSP plants is strongly correlated with the DNI. Assuming a base of 2 100 kWh/m2/year (a typical value for Spain), the estimated LCOE of a CSP plant is expected to decline by 4.5% for every 100 kWh/m^2 /year that the DNI exceeds 2 100 (figure 6.1) **[27]**.

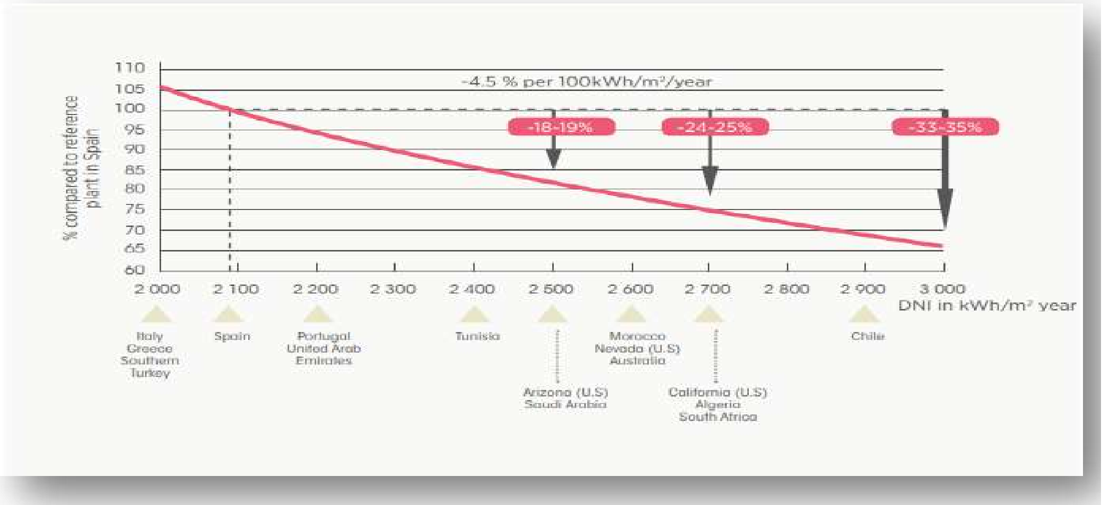


Figure III.7: The LCOE of CSP plants as a function of DNI[27].

12.Conclusion:

In this chapter, we dealt with the study of the cost of CSP technology, as we learned that the power tower station and the equivalent station provide the best performance due to the future reduction in costs, and the development that will occur in developing two technologies with increased efficiency will be the reason for any lower costs.

Chapter IV

Results & discussion

1. Introduction:

In this chapter we will present an analytical and comparative study of the research results that we have achieved from the literature to show the relationship between solar radiation and electricity production and the economic future of CSP technology.

2. Primary energy:

2.1. Energy consumption:

The following chart represents the changes in primary energy consumption. We note that the world is increasing in energy consumption due to the development of technology and industry and the needs of people, which are increasing in demand for energy.

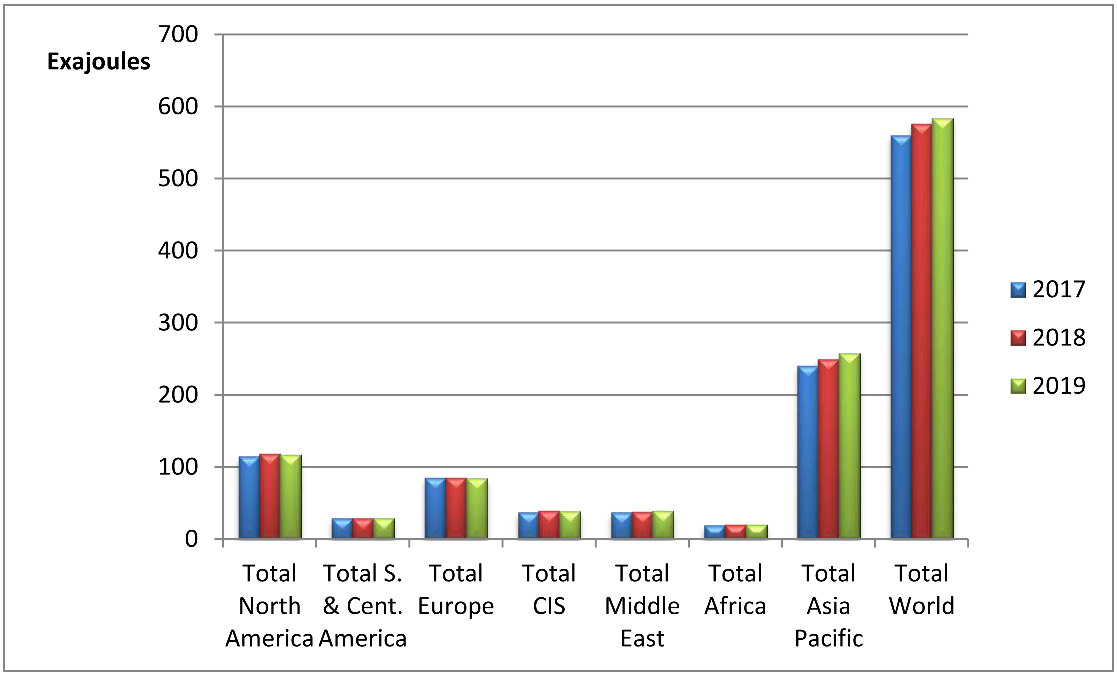


Figure IV.1.The changes in primary energy consumption.

2.2.Energy consumption by fuel:

The chart of figure represents energy consumption by source, as we note that the first source is the oil with the highest percentage, as it represents the first source of energy.

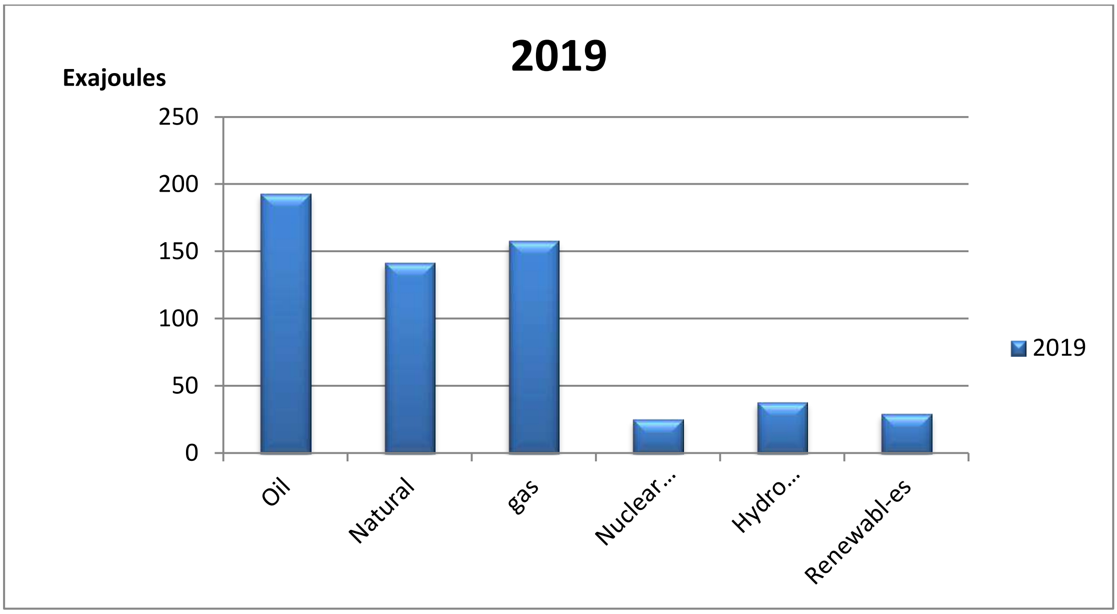


Figure IV.2.The energy consumption by fuel.

3. Oil:

3.1.Proven oil reserves:

The chart of figure below represents the world's oil reserves, where we note that the world's oil reserves are decreasing with the passage of time to consider it the first source of energy production.

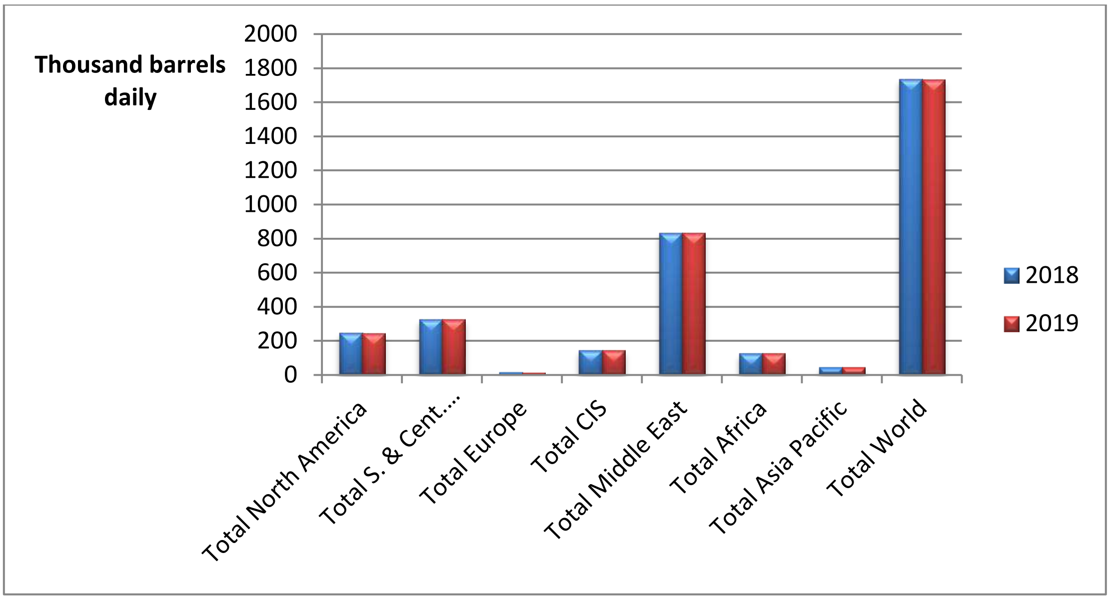


Figure IV.3.The total proven oil reserves in the years 2018-2019.

3.2.Comparison of oil consumption and production:

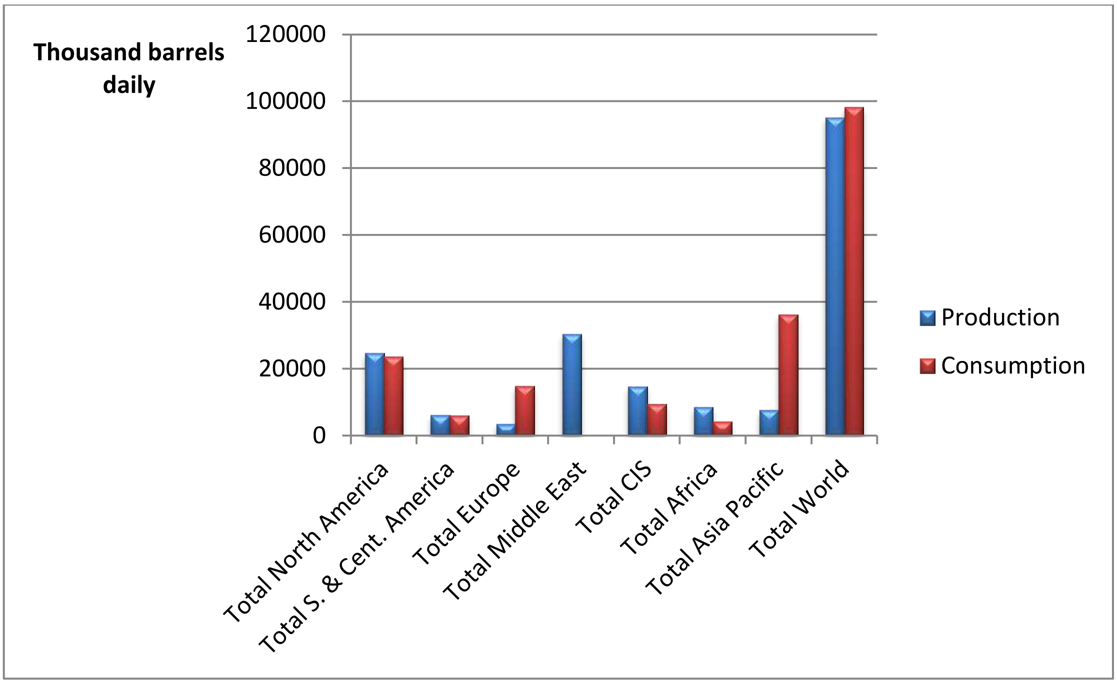


Figure IV.4.The Production and Consumption oil in thousands of barrels per day in the year 2019.

The chart of figure above represents a comparison between the amount of oil production and consumption. We note that the global consumption of oil is more than production, and which caused a gap in meeting energy needs, as some countries resort to importing to fill this gap in Europe, while others have a surplus in production, such as in Africa.

4. Renewable energy:

4.1.Renewable energy consumption:

Thechart below figure represents the consumption of renewable energy. We note that the percentage of consumption of this energy is increasing due to the decreasing oil reserves, and this energy is considered an alternative to fill this gap and there is no imbalance in energy production.

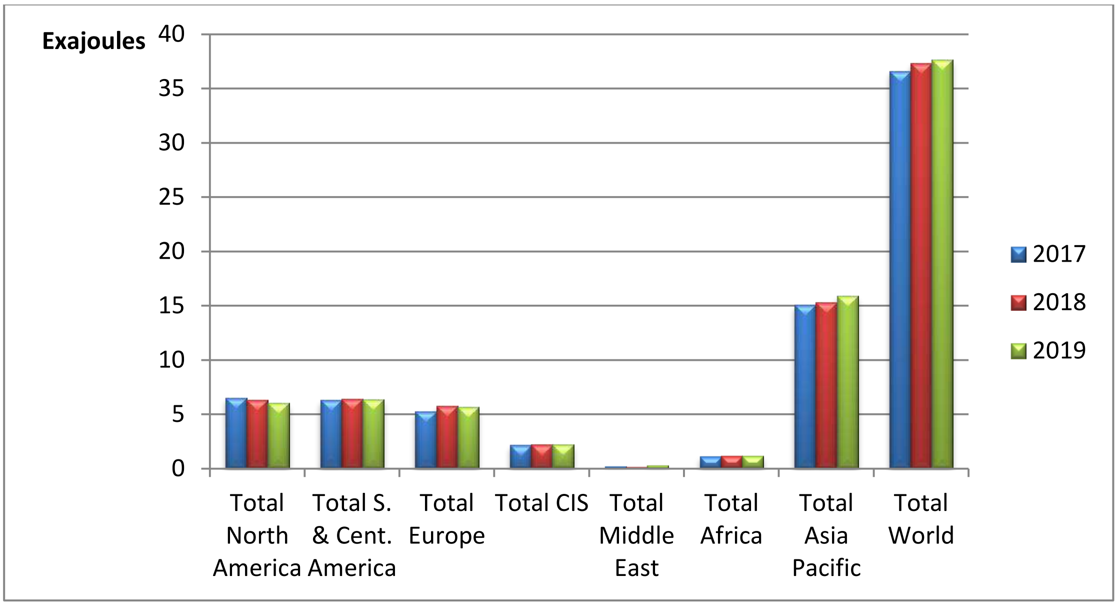


Figure IV.5.Renewable energy consumption in the years 2017-2018-2019.

4.2. Renewable energy generation by source:

The following chart represents energy production by source, where the wind is the first source of renewable energies, but we do not forget the contribution of solar energy, and its percentage will rise if it is exploited by North African and Middle Eastern countries, because it is considered wealth in these regions, unlike Europe.

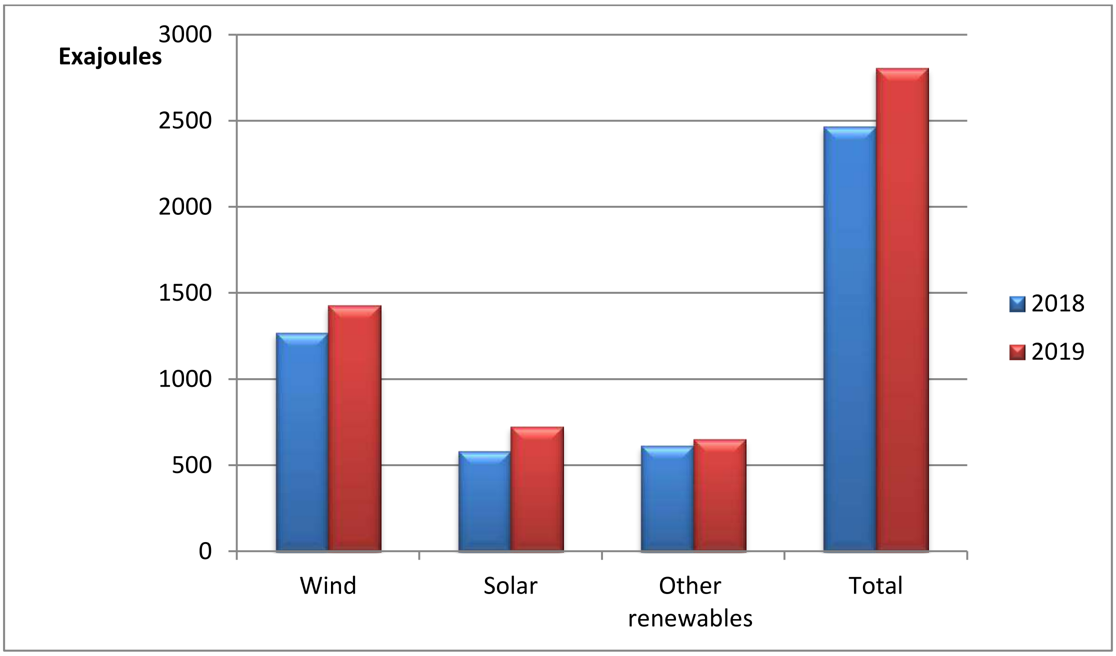


Figure IV.6.Renewable energy generation by source In the years 2018-2019.

5. Electricity:

5.1.Electricity generation:

The chart of figure below represents the generation of electricity. We note that the generation of electricity is now increasing. Electricity is the driving force of the world in order to meet the demand of industry and services.

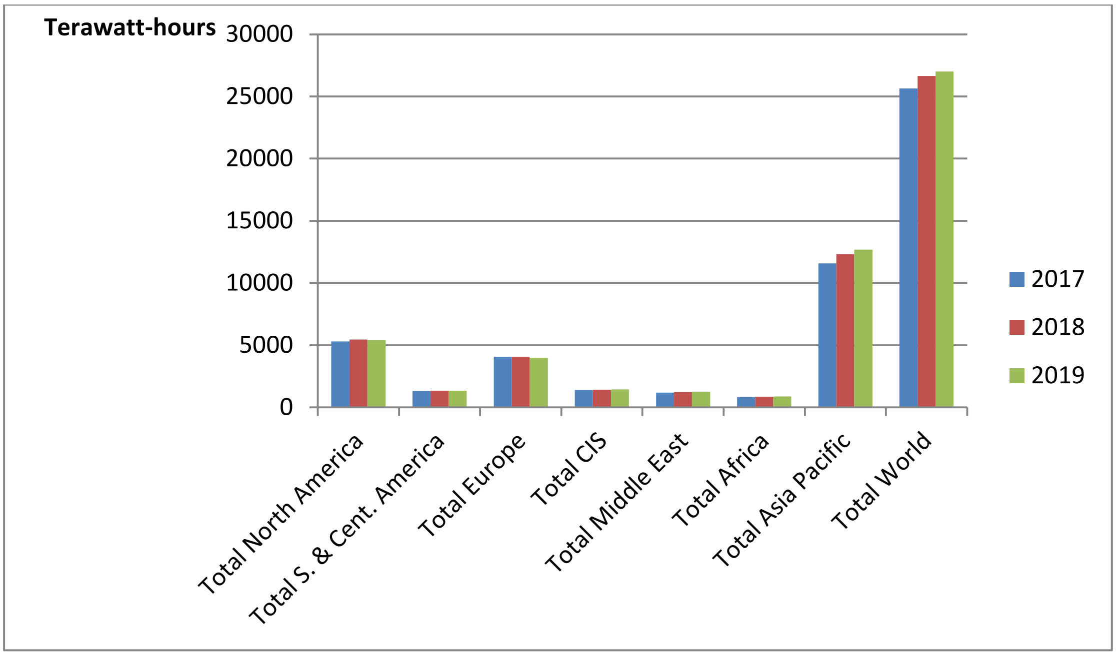


Figure IV.7. Electricity generation In the years 2017-2018-2019.

5.2. Electricity generation by fuel:

The following chart represents the generation of electricity by source, where nuclear energy is the largest product, but it is not permanent, then coal and renewable energies participate in a noticeable proportion, but it will be the dominant source of permanent energy and not fully exploited.

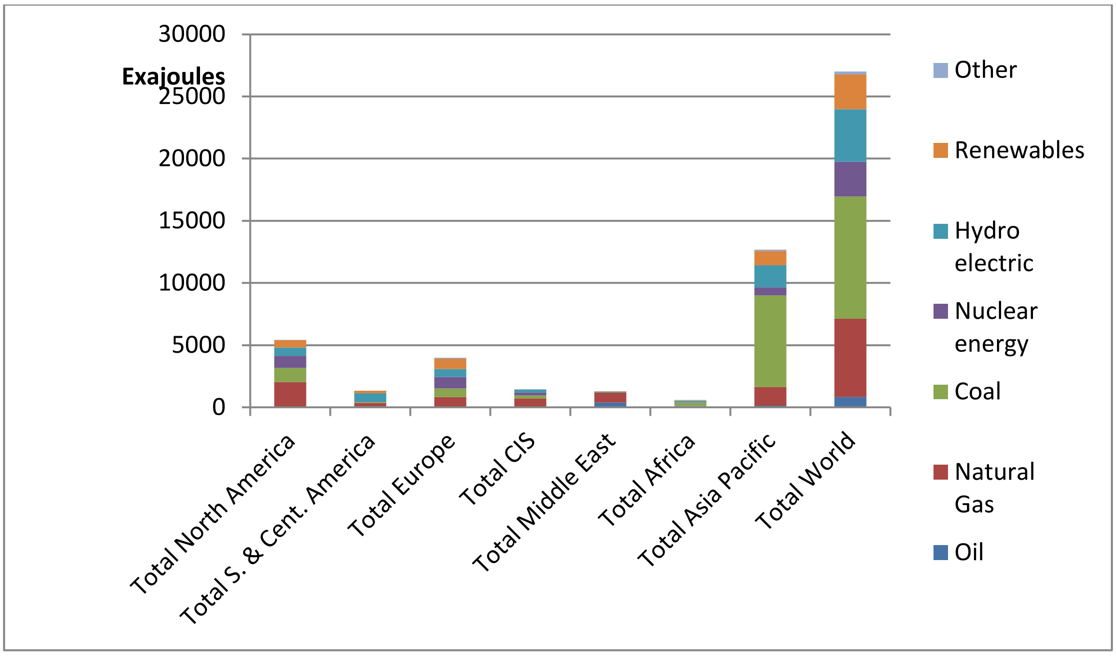


Figure IV.8. Electricity generation by fuel In the year 2019.

5. DNI and electricity generation:

A comparison of the percentage of radiation with electricity generation in unfairness and Iran is represented in figure below, where we note that Algeria has the largest percentage of radiation, which means the largest percentage in electricity generation, and from it we conclude that there is a direct relationship between the percentage of radiation and electricity generation, where the higher the percentage of radiation, the greater the amount of electricity generated.

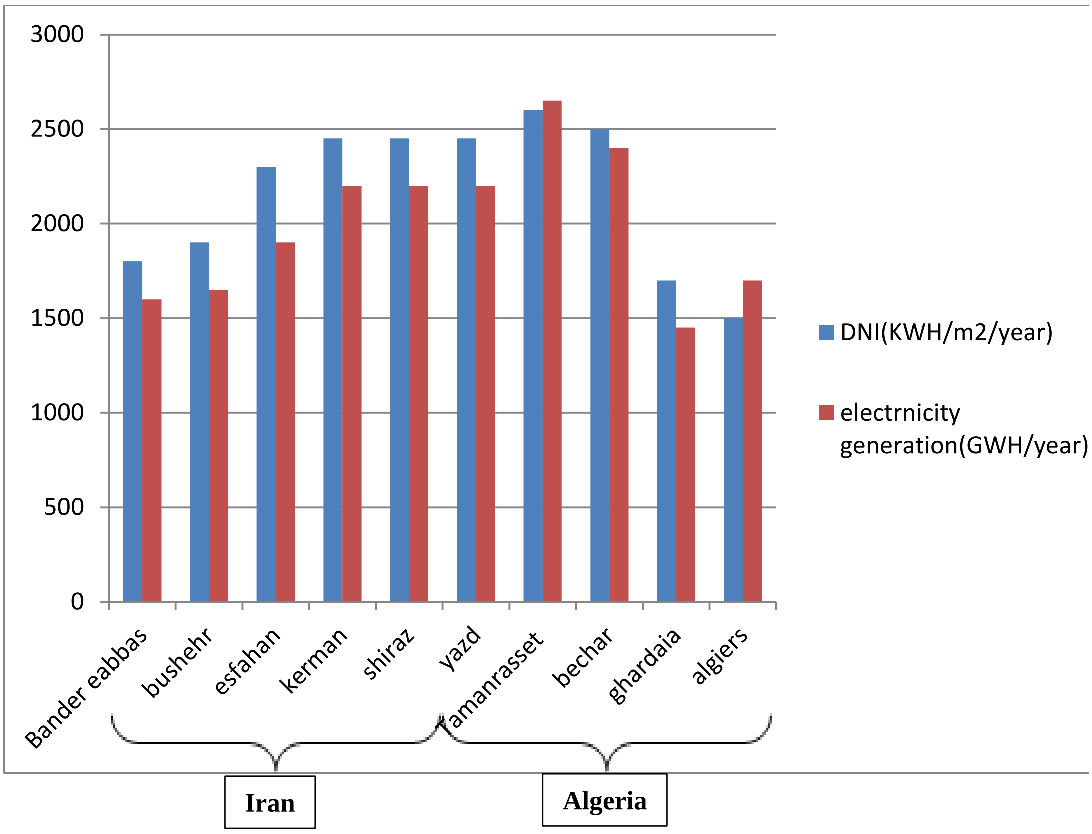


Figure IV.9.Comparing the DNI and electricity generation in cities of Iran and Algeria.

6. Cost study:

The cost study of the concentrated solar energy technology is represented in figure below, where we note that for this technology is the most expensive part is the thermal fluid, but with the passage of years and the exploitation of this technology more, its cost decreases more and becomes more reliable.

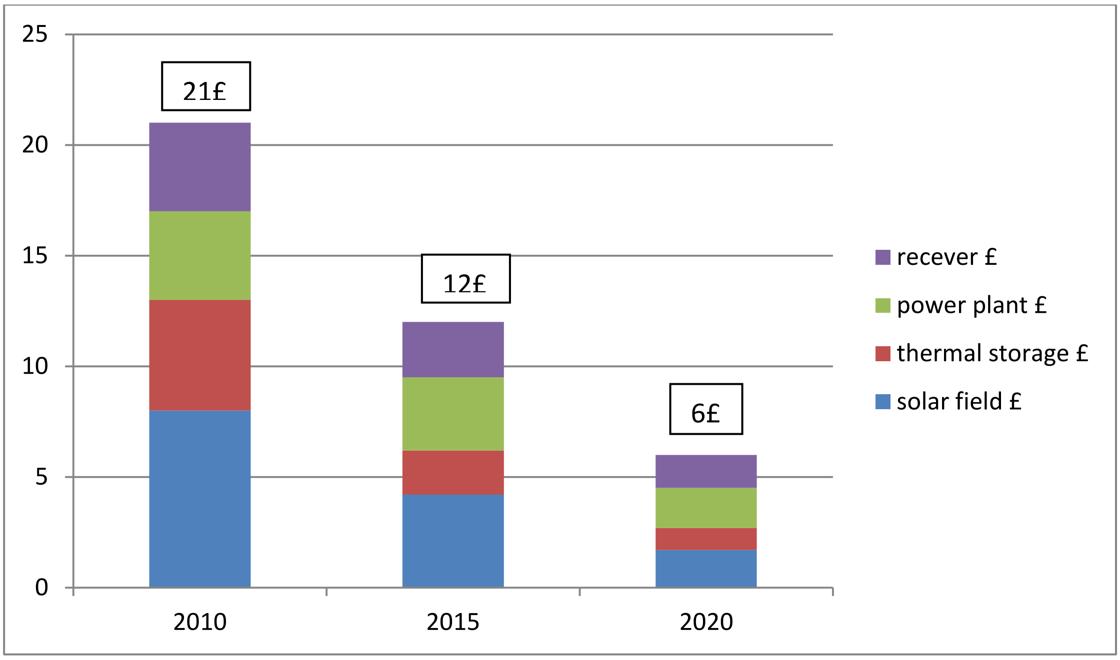


Figure IV.10.The cost changes of CSP technology over the years.

7. Conclusion:

In light of the analytical results that we have reached, CSP technology is the only refuge to make up for the gap that will be created by the decreasing global oil reserves and the increase in consumption and energy demand because it is a future technology that has the ability to heat storage, which is inexpensive compared to fossil fuels.

General conclusion

General conclusion

In this thesis, we discussed the technical study and cost of CSP technology .The growth of some countries depends on the production of energy from fossil fuels, but this fuel is not permanent and will disappear with time. Now, the global energy reserve reports for fossil fuels are declining to increase consumption due to the high demand and people’s need for them. With the passage of time, the demand for energy will increase as fossil fuels become unable to meet people's needs besides being environmentally friendly.

Therefore, the world came to search for other sources, which are renewable energies, and in this research we focused on solar energy, because it is first of all environmentally friendly and produces large energy from light radiation, but if we developed its technology and among this technology, we found that concentrated solar energy technology is the best option for its advantages, which is Storage capacity and storage cost in low and production capacity in the absence of light to about 6 hours.

The study of the cost shows that the CSP technology will have a great economic future, as its cost is decreasing and of course it will achieve a great economic profit for the countries in which it worked and developed it.

As a final result of this research, CSP is a sleeping giant for some countries, including Algeria. This technology depends on the amount of radiation received from sunlight. Algeria is considered one of the first countries in the world to receive a large amount of radiation, reaching 2500KWH/m/ year. Therefore, this energy as a sleeping giant in Algeria, we must exploit it by developing this technology to meet our needs and advance the economy.

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Bibliographic

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Abstract:

The exploitation and development of CSP technology will be the hope for the advancement of the economy of Algeria. The object of this work is the technical and cost study of concentrated solar power plants (CSP) in Algeria. At the end of this research, the CSP is a sleeping giant for Algeria. Algeria is considered to be one of the first countries in the world to receive a large amount of radiation, reaching 2500KWH/m/year, and it must harness it by developing this technology to meet the needs and move the country economy forward.

Keywords: CSP: Technical; economy; cost; radiation; solar; concentrated.

Résumé :

L'exploitation et le développement de la technologie CSC sera l'espoir pour l'avancement de l'économie de l'Algérie. L'objet de ce travail est l'étude technique et de coût des centrales solaires à concentration (CSC) en Algérie. Au terme de cette recherche, le CSC est un géant endormi pour l'Algérie. L'Algérie est considérée comme l'un des premiers pays au monde à recevoir une grande quantité de rayonnement, atteignant 2500KWH/m/an, et elle doit l'exploiter en développant cette technologie pour répondre aux besoins et faire avancer l'économie du pays.

Mots clés: CSC ; technique ; économie; Coût; radiation; solaire; concentré.

ملخص :

سيكون استغلال وتطوير تكنولوجيا الطاقة الشمسية المركزة بمثابة الأمل للنهوض بالاقتصاد الجزائري. الهدف من هذا العمل هو الدراسة الفنية والتكلفة لمحطات الطاقة الشمسية المركزة (CSP) في الجزائر. في نهاية هذا البحث ، فإن CSP هو عملاق نائم للجزائر. تعتبر الجزائر من أوائل الدول في العالم التي تستقبل كمية كبيرة من الإشعاع تصل إلى 2500 كيلوواط ساعة / م / سنة ، ويجب عليها استغلالها بتطوير هذه التكنولوجيا لتلبية احتياجات ودفع عجلة اقتصاد البلاد.

الكلمات المفتاحية: الطاقة الشمسية المركزة, تقنية, اقتصاد, تكلفة, إشعاع, الشمس, المركزة.