The Importance of Using Concentrator Solar Energy Technologies in Anbar Province

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Abstract:

The aim of the research is a techno-economic analysis of the use of concentrated solar energy technologies in the Iraqi city, considering the concentrated solar energy technology is a renewable energy technology that derives its resources from the sun and is replenished at a rate that exceeds its use. It is also inexhaustible and environmentally friendly energy from its environmental footprint, unlike traditional fossil energy which produces greenhouse gases and a major cause of global warming.

This research measures the costs of concentrated solar energy technology to Reduce the effects caused by other energies and work to fill part of the shortfall in the total electricity production, even at a specific percentage, in preparation for spreading a culture of these clean technologies, and proposing investment in concentrated solar power (CSP) technology and choosing the best sites according to radiation rates. Direct solar radiation on which these technologies depend for their work. By comparing the cost between these clean technologies and traditional fossil techniques. In this research, the province of (Al-Anbar) was selected and the economic criteria for the construction of a concentrated solar power plant were studied. The study showed that the technology of concentrated solar energy has a direct impact on the cost of producing electrical energy and reduces the cost of producing kilowatt-hours by (9-11) cents the range to discount rate (5-7) and capacity factor ranged (40 %,45%) , regardless of the environmental problems produced by plants that operate on fossil fuels.

Key Words: Solar Energy Cost, Trough System Cost, Economic Feasibility , Concentrated Solar Power (CSP)

1. Introduction

Iraq is witnessing a severe crisis in the field of electric power generation over the past years, which has left negative social, economic, and environmental impacts on the country. Iraq may need 30,000 MW of electric power, and what it actually produces is 19000 MW. According to the estimates of the Iraqi Ministry of Electricity.[1,2.3,4]

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To compensate for the shortfall in electrical energy, it is preferred to compensate shortage with clean electrical energy sources. [5.6]

The research methodology relied on the previous research studies in economic analysis of concentrated solar energy technologies, and the importance of applying them to an Iraqi case (Anbar Province). By comparing the cost between these clean technologies and traditional fossil techniques. In this research, the province of (Al-Anbar) was selected and the economic criteria for the construction of a concentrated solar power plant were studied.

The research concluded that there are a lot of positive data that drive to use of concentrated solar energy technologies in the Anbar Province.

From previous studies in a 2009 by Zhang the study of the current energy supply in China which relies for the most part on fossil fuels and its limited reserves, and with large increases in prices caused by changes in supply and demand, was a themed study (Concentrating Solar Power - State of the Art, Cost Analysis and Pre-Feasibility Study for the Implementation in China), The study concluded that there will be an increase in the demand globally for energy by about 55% in 2030 compared to 2006.

Duridy in 2016 he has the study in a feasibility study of implementing concentrated solar power (CSP) technology in Palestine, to fill the shortage of generating electric power from traditional sources and relying on them, representing 31% of the total production energy, and not sufficient to cover the local need, the study proved that concentrated solar energy technology is one of the best solutions to fill the energy shortage.

In 2017, power plants in Kenya experienced some problems due to the dependence on hydroelectric power, which was in a weak state of hydrology, which led to the deployment of expensive diesel power plants. It was a study of the technical and economic feasibility of large-scale concentrating solar power deployment in Kenya, because of the high cost of heating water and producing steam from fossil fuel sources, The study concluded that may be the use of concentrated solar power in the heating water process and producing steam instead of using boilers for the heating process.

1.1 Concentrator Solar Power

Concentrated solar power "is a technology used to generate electricity using heat provided by solar radiation that is focused on a small area called the receiver or absorber. Using mirrors, sunlight is reflected off the receiver where the heat is collected by a thermal fluid carrier. Thermal fluid is used either directly in the case of steam generation or via a secondary circuit to drive turbines and generate electricity. CSP systems capture only direct solar radiation, which makes them more suitable and promising for areas with a high percentage of clear sky days".[3,7]

Currently, there are four main CSP technologies available such as Parabolic Trough Concentrate (PTC), Solar Power Tower (SPT), Linear Fresnel Reflector (LFR), and a parabolic dish system (PDS) is a parabolic dish system. These CSP technologies are currently operating on a medium to large scale.[7,8]

Investing in expanding generation capacity requires an assessment of the competitive value of future clean generation technologies, which have been identified as part of a complex set of computational systems.[9]

The determinant of investment in solar energy technologies is the high investment compared to fossil fuel energy as well as compared to other clean energies.[8,10]

The cost of all components of the power plant is estimated by international research circles. Not all of these prices have been announced in detail and explicitly. By studying the different prices offered by all suppliers, it is possible to plot a breakdown of the investment costs, as shown in the figure (1). [11]

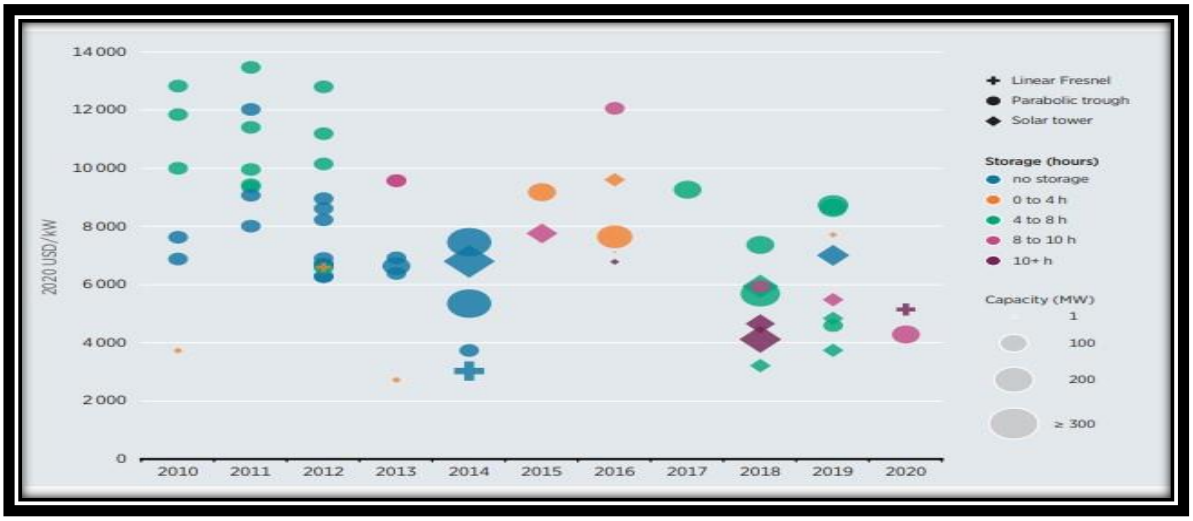

Figure (1) investment costs in CSP plants

The cost of building a concentrated solar power plant differs from each other according to its technologies that were mentioned previously, and as shown in Figure No. (1), the (plus) sign symbolizes the linear Fresnel station, the (circle) sign symbolizes the parabolic basin station, and the (rhombic) sign indicates On the stations of the solar tower, as the figure shows the colors related to the storage capacity, where the blue color indicates that there is no thermal storage, the orange color indicates a thermal storage capacity of 4 hours, the green color has more than 4 hours of thermal storage, and the pink color indicates a thermal storage capacity of 8 hours, Finally, the violet color indicates a storage capacity of more than 8 hours. The cost of building the parabolic cutting station in question, as symbolized by the purple circle sign that symbolizes a thermal storage capacity of more than 8 hours, ranges from $4,000 to $5,000 per KW. Where the cost of establishing the plant is divided into certain proportions based on the latest report issued by the International Renewable Energy Agency, as shown in the following figure:-

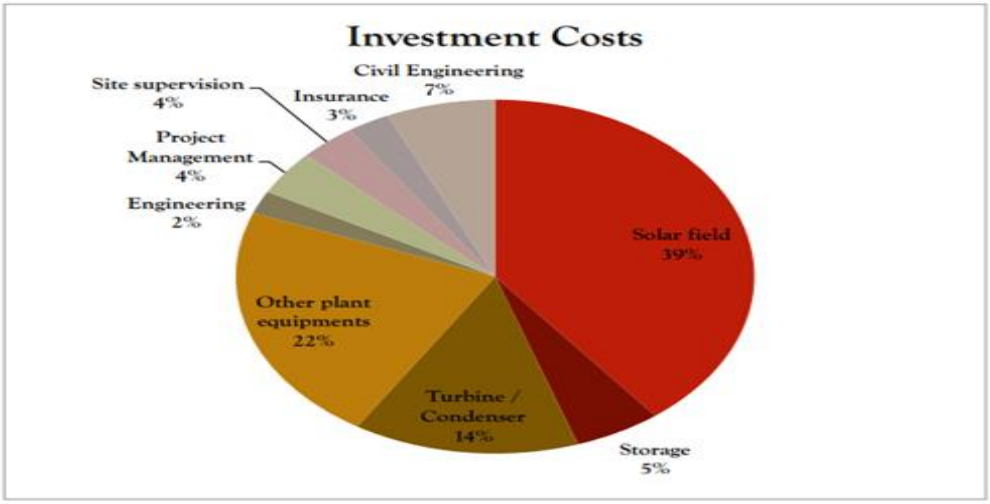

Figure (2) Distribution of investment costs in CSP plants

1.2 The level cost of electricity (LCOE) and level cost of storage (LCOS)

The level cost of electricity (LCOE) and level cost of storage (LCOS) "are the average revenue per unit of electricity generated or discharged and consumed that would be required to recover the

costs of building and operating a generation plant and energy storage facility, respectively, during an assumed financial lifetime and business cycle".[8,12]

The LCOE is often used as a convenient summary measure of the overall competitiveness of different generation technologies . Although both concepts are similar (LCOE ,LCOS) they differ in terms of energy storage ,the technology used to generate it and the costs associated with operating the plant and include the solar field, (decreasing energy, and water treatment).[10,13]

For CSP plants, the overall maintenance and operating costs are large compared to photovoltaic and wind energy, and they differ from one site to another depending on the difference in irradiation, plant design, and technology and labor costs. Typical operating and maintenance costs for CSP plants are previous or in operation, The LCOE method allows a comparison between power plants and the cost of different structures. [8,14]

We get the LCOE result from comparing all costs, which arise from over the life of the power plant as construction and operation of the plant, with the sum of the amount of energy generated over the life cycle of the plant. The calculation can be made either on the basis of the net present value (NPV) method or the so-called annuity method. When the net present value method is applied, investment expenses, as well as payment flows of income and expenses over the life of the plant, are calculated by debiting a common reference date.[8 ,11] For this purpose, the present values of all expenditures are divided by the present value of electricity generation. The power generation discount seems initially incomprehensible from a physical point of view, but is the result of financial mathematical transformations. The basic idea is that the electricity generated tacitly corresponds to the revenue from the sale of this energy. Thus, the higher this income will be in the future, the lower the associated present value will be. Total annual expenses throughout the entire operating period consist of investment expenses and operating costs, which arise during the life of the plant. To calculate the LCOE for new stations, the following applies :- [13,15]

$$LCOE\clubsuit = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^2}} \quad \text{..... (1)}$$

Where:

I_t = is the investment expenditure in year t, M_t = Operating and maintenance expenses in the year, F_t = fuel expenditure in year, Et = Electricity generation in year, r = discount rate, N = lifetime of the system

LCOE is the required electricity price for a project where revenue equals costs, including a return on capital invested equal to the discount rate.

Depending on the above equation, the average cost of producing kilowatt-hours for concentrated solar energy, and as mentioned above that the cost of kilowatt-hours with conventional energy.[11,13,16]

The main" inputs to calculating LCOE and LCOS are capital costs, fixed operations, maintenance (O&M) costs, and variable costs which include operating and maintenance costs, fuel, financing costs, and the assumed utilization rate for each plant type". Fuel cost, flat variable cost includes purchase cost.[10,13,17]

Technologies that have "no fuel costs and relatively small variable costs, such as solar and wind generation technologies, LCOE changes roughly in proportion to the estimated capital cost of the technology. For technologies with a significant fuel cost, both the fuel cost and capital cost estimates significantly affect the LCOE. Incentives, including state tax credits", also affect an LCOE.[18,19]

As with any forecast, these factors are uncertain because their values can vary regionally and temporally as technologies develop and fuel prices change. The CSP hybrid technology is

♣ This equation is used to show the cost of the electrical energy produced, which includes construction costs and operating and maintenance costs, as shown in the subsequent proposals, which are shown in figures (5,6,7,8,9)

represented by LCOE and not LCOS because we assume that it operates as an integrated unit that provides electricity to the grid.[20]

2. Experimental Work:

Anbar is an Iraqi governorate located in western Iraq. It is considered the largest governorate in Iraq and occupies an area of one third (1/3) of the area of Iraq. It includes within its borders the western plateau, and its altitude ranges from 375- 900 meters above sea level. It is characterized by the diversity of surface terrain from arid deserts to rocky lands and hills. And the highlands extending over large areas. Contain many valleys; the direct solar radiation in Anbar Governorate, rated between, 1882- 2383 KWh /m^2/ Y, and this is a good indication of the dependence of concentrated solar energy on direct solar radiation

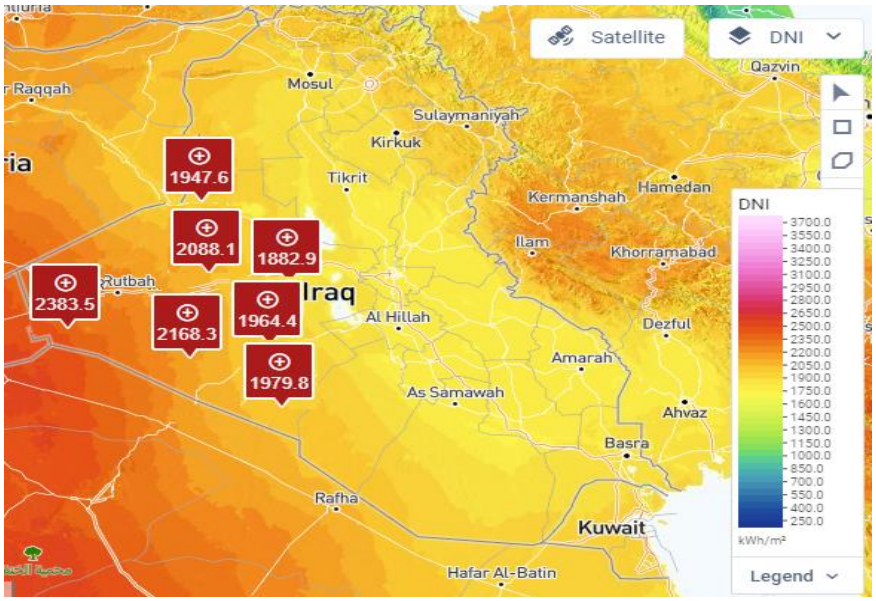

Fig (3) direct solar irradiance rates DNI in Anbar

Plant-scale CSP plants require a large area of opens land (about square KM) free from obstructions. Typical land use by CSP plants has been estimated by the NREL National Renewable Energy Laboratory at 25,000- 40,000 m^2/MWh .It also has the availability of surface and ground water resources in the city.[11]

2.1 The Temperature

The temperature ambient rated in Al-anbar governorate, is 23.8º, and these rates may have an impact on the performance of the system and determine the percentage of losses and losses in the temperatures of fluids that are heated by solar concentrators.[Fig.4]

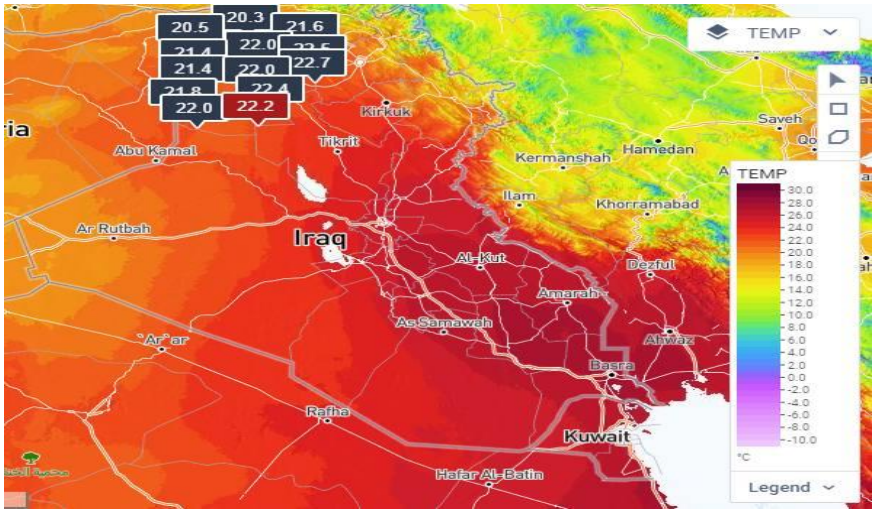

Fig (4) temperature ambient rated in Al-anbar governorate

2.2 The Performance and Structural Design of the Solar Field

The performance and structural design of the solar field is affected, that is, it is not designed for wind speeds exceeding 30-70 km/h or 8.3-19.5 m/s. Wind speed rates in this location are within the limits of 2.5 m/s. The slope area in this city is variable from (0-5) º.[1]

The area of Anbar Governorate is 138,500 km and the population density of the governorate is (1,771,656) people, i.e. an average of (12.4) per km. Although most of the area of Anbar Governorate is desert, the average population per km is (50) people in cities. Therefore, most of the sites chosen for the construction of the CSP plant are far from the residential units.[4]

The population density rate in Al-Anbar governorate showed (50) people per km^2, which contributes to the provision of manpower for the station and thus reduces the cost of using labor from outside the governorate, which affects the cost of producing KW of electric power.

In addition, the population density has an impact in determining the amount of demand for electrical energy, and thus determining the size of the required systems.

3. Field Work

3.1 Al-Rutba Plant

Anbar Governorate depends on the supply of electric power on a diesel power plant in the city of Al-Rutba, with a design capacity of (15.75) MW, and the production capacity of this station in 2019 was (21,750) MWh, while the planned capacity was to produce (955,000) MWh, where the percentage of production losses ranged around 97%, the table (1) show the plant's expenses, the energy produced for the same year, and the average KW/h cost.

The table (1) below is for the plant's expenses, the energy produced for the same year, and the average KW/h cost.

No.	Account Name and Number	Amount of Money in Dinars	Type
1-	Financial salaries and wages (31)	630,685,932	-------
2-	Fuel cost (321/19)	2,524,545,040	Merchandise Supplies (32)
3-	Oils and Greases (3223)	41,800,000	
4-	Maintenance Services (331)	145,993,000	Service Supplies (33)
5-	Depreciation (37)	13,393,750	
The Total Cost		3,356,417,722	
Energy Produced in KW/h		21,750,267	
Average KW/hCost		154.316	

3.2 The Hadiath plant

The Hadiath plant with a design capacity (230) MW and the production of this plant in 2019 was (578,555 MW/h) and for the planned energy (751,000 MW/h), and the percentage of losses in processing is within the limits as well as the plant Hadiath Dam is powered by hydroelectricity with a production capacity of (660 MW), and the production of this station for 2019 was (997668 MWh) According to the data of the Iraqi Ministry of Electricity in table (2) . And there are other stations parked in Ramadi and Fallujah that run on diesel fuel.

The table (2) below is for the plant's expenses, the energy produced for the same year, and the average KW/h cost

No.	Account Name and Number	Amount of Money in Dinars	Type
1-	Financial salaries and wages (31)	4,759,069,586	-------
2-	Fuel cost (321/19)	15,959,419,790	Merchandise Supplies (32)
3-	Fuel Transportation Fees (321/35)	28,128,498	
4-	Chemicals Materials (321/27)	233,963,025	
5-	Oils and Greases (3223)	3,491,937,217	
6-	The Rest of the Other Commodity	1,027,037,109	
7-	Maintenance Services (331)	477,510,000	Service Supplies (33)
8-	The Rest of the Other Utilities	638,257,530	
9-	Depreciation (37)	416,569,732	
The Total Cost		27,031,892,487	Total cost
Energy Produced in KW/h		578,555,460	
Average KW/h Cost		46.723	

4. Results and Discussion

4.1 We have two models of stations in Anbar governorate, the cost of kilowatt-hour from the data in table No. (1) Was calculated by summing up the station's expenses AL-Rutba Plant, and dividing it by the energy produced. It was found that the KW/h cost for this station was (154,316) dinars, and that the proportion of commodity requirements expenses out of the total expenses was (76.4%). From table No. (2) The KW/h was calculated by collecting the station's expenses Hadiath Plant, and dividing it by energy production. It was found that the KW/h cost of the station was (46.723) dinars, and the proportion of commodity requirements expenses out of the total expenses is (76.7%),.

Of these values for the cost of electricity for the two stations, which are relatively expensive, it is possible to suggest concentrated solar energy systems, even if the cost of electrical energy is close to the cost of electricity for the two stations. The gain and benefit is the use of clean, non-polluting and somewhat environmentally friendly energy technologies.

4.2 The average temperature in Anbar Governorate is 23.8º, and these rates may have an impact on the performance of the system and determine the percentage of losses and losses in the temperatures of fluids that are heated by solar concentrators.

4.3 The westernmost elevation of Anbar Governorate is 900 meters above sea level until it reaches the east of the Euphrates River at 350 above sea level, the average land slope in Anbar Governorate is (2º) and this rate may have an impact on the station's performance.

4.4 The area adjacent to the Haditha Dam is suitable land for building the station due to the availability of resources that contribute to the production of electrical energy for the CSP plant, including the availability of water and power transmission lines that contribute to not losing production by moving it to remote places so that it becomes a hybrid plant operating with hydroelectric power as well as with concentrated solar energy.

4.5 It was shown in figure No. (1) That Anbar Governorate is characterized by an abundance of direct solar radiation, which ranges from 1883 kilowatt-hours to 2384 KW/h and this, is a good

indicator for the establishment of these stations, which reduces the area of the solar field and thus affects the average cost of establishing a station. But there are several other factors that affect the construction of the station, such as proximity to transmission lines and availability of water, as well as power transmission lines, and these increases or decrease the cost of the project.

4.6 Project development steps, It is the first step in building concentrated solar power plants. The initial site is allocated to the solar trough field, as well as to the solar system area, all power units, the thermal storage system and other buildings. This activity also includes cleaning and leveling the planned land for the site, and the cost of this step is (13,017,857) $.

4.7 To build the field of solar energy (trough system), the cost of the system consists the following topics are shown in the table (3) .

Table (3) the cost of the system topics of solar energy (trough system)

Labor Cost Site and Solar Field	
Item	Prices in $
Solar Field	13,947,188
Site Preparation and Infrastructure	26,130,938
Steel Construction	11,221,857
Piping	7,855,312
Electric installations and others	17,794,687
Total Labor Cost Site and Solar Field	76,949,982
Equipment Solar Field and HTF System	
Mirrors	28,654,866
Receivers	32,035,496
Steel construction	48,294,717
Pylons	4,829,472
Foundations	9,658,943
Trackers (Hydraulics and Electrical Motors)	1,931,789
Swivel joints	3,219,647
HTF System (Piping, Insulation, Heat Exchangers, Pumps)	24,147,359
Heat Transfer Fluid	9,658,943
Electronics, Controls, Electrical and Solar Equipment	11,268,767
Total Equipment Solar Field and HTF System	173,699,999

The table (4) shows the Energy Unit / Energy Balance: The costs of this part.

Table (4) the Energy Unit / Energy Balance part.

Conventional Plant Components and Plant System	
Item	Prices in $
Power Block	25,740,000
Balance of Plant	25,579,125
Grid Connection	13,030,875
Total Conventional Plant Components and Plant System	64,350,000

4.8 It includes steam turbines and generators, steam turbines and auxiliary generators, water supply and condensate systems, condenser system and cooling turbine, and a system Water treatment, fire protection, compressed air systems, electrical appliances and equipment.

4.9 In order to store energy until the evening or when the sun goes down, it needs to build an energy store, the table (5) show thermal storage; the concentrated solar power plant is based on thermal storage to operate in the absence of solar radiation. The cost of this part is:.

Table (5) thermal storage cost

Thermal Storage System	
Item	**Price in $**
Salt	22,904,237
Storage Tanks	8,168,644
Insulation Materials	800,847
Foundations	2,883,051
Heat Exchangers	6,246,610
Pumps	1,922,034
Balance of System	4,324,576
Total Thermal Storage System	47,250,000

There are other costs include the expenses include insurance, emergency and financing expenses, and these expenses are estimated at $75 million.

4.10 The total project cost can be summarized as shown in the table (6) :

The table (6) total project cost•

Subject	Cost $	Percentage %
Solar Filed	175,500,000	39
Civil Engineering	31,500,000	7
Site Supervision	18,000,000	4
Project Management	18,000,000	4
Engineering	9,000,000	2
Other Plant, Equipment	99,000,000	22
Turbine , Condenser	63,000,000	14
Storage	22,500,000	5
Insurance	13,500,000	3
Total	450,000,000	100

Operation and maintenance costs are the costs associated with operating the plant and include the solar field, decreasing energy, and water treatment, for CSP plants, the overall maintenance, and operating costs are large compared to photovoltaic and wind energy and they differ from one site to another depending on the difference in irradiation, plant design, and technology and labor costs. Watt this is likely a good estimate of the status levels for O&M in the relevant markets for projects built in 2019 globally.

The proposals of these stations are not a radical alternative to fossil energy insofar as they are supportive of reducing dependence on fossil fuel stations.

4.11 Relying on the equation of levelized cost, the average cost of producing kilowatt-hours for concentrated solar energy is equal to (106)• dinars, and as mentioned above, the cost of kilowatt-hours with conventional energy is (154)• dinars, and the difference between the cost of kWh with conventional energy and the cost of kWh with energy concentrated solar equals (48) dinars.

4.12 Must study of some factors affecting the level of electricity cost, which determine its value approved in the construction of stations globally, figure. (3) Shows stability in the level cost of electric energy produced at a rate of (cents) per kWh , Assuming the station life remains constant for 25 years, at a capacity factor 45 %, with the cost of constructing the station from 4500 $ per kW. Fixed O&M Cost (25 $/kW/yr.), Variable O&M Cost (0.0020 $/kWh) .And a difference in the average cost of renewable energy, which ranged from (7.3 to 16.4) cents/ kWh according to various discount rate. The average of costs (11.7) cents / kWh.

• Based on figures (1) (2), it was assumed that a station with a capacity of 100 MW would be built at a cost of $4,500 per KW, based on the latest report issued by the International Renewable Energy Agency for the year 2020.

• levelized cost , discount 3% = (7.2cent) , 1$ = 1470 Dinars . (1470 / 100 cent =14.7 dinars) , (7.2cent * 14.7 dinars = 106 dinars)

• table (1) , **Average KW/h Cost**

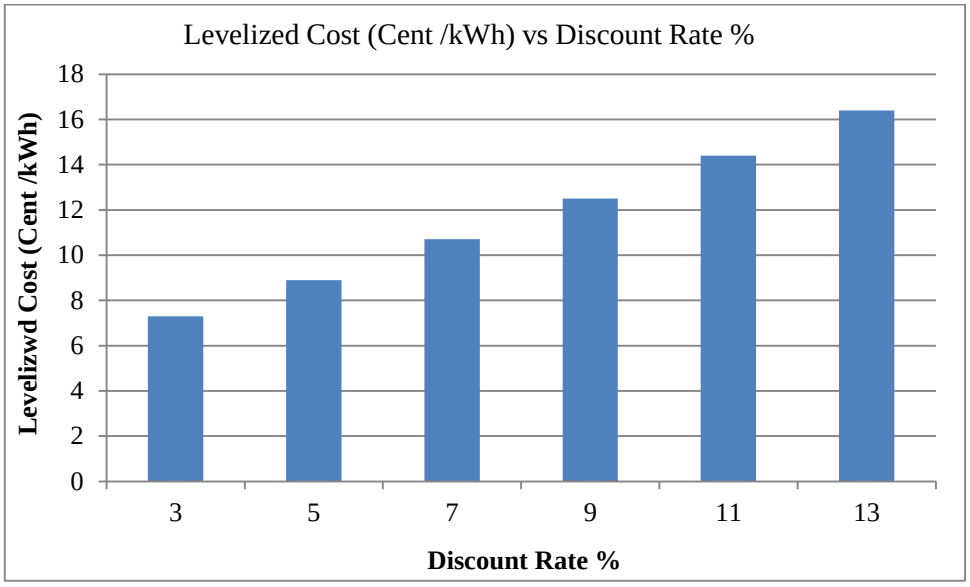

Fig (5) varies the level cost of electricity according to discount rate %

4.13 Figure (5) shows a change in the level of the cost of electric energy produced with a change in the periods the discount rate of an any project (a proxy of cost of capital) is important for all investors. It is a key driver in determining the fair value or market price for projects. However, this data is extremely hard to gather, meaning many investors rely solely on their own experience and advice from valuation experts in evaluating the cost of capital. There is ranged between (5 to 9.4) cents/kWh .Change in the cost of renewable energy, which was due to the change in the periods of station lifetime to know the lifetime that should be taken into account in negotiating and obtaining loans when construction solar power plants in order to avoid the high cost of renewable energy and the level of cost of electric energy produced. If we assume that these results are according to a hypothetical plant discount rate (3%) , with the cost of constructing the station from 4,000$ /kWh. at a capacity factor 45 %, the capacity factor is simply the ratio of energy generated over a time period (typically a year) divided by the installed capacity, and fixed O&M cost (25$/kW/yr.), with variable O&M Cost (0.0020 $/kWh) .

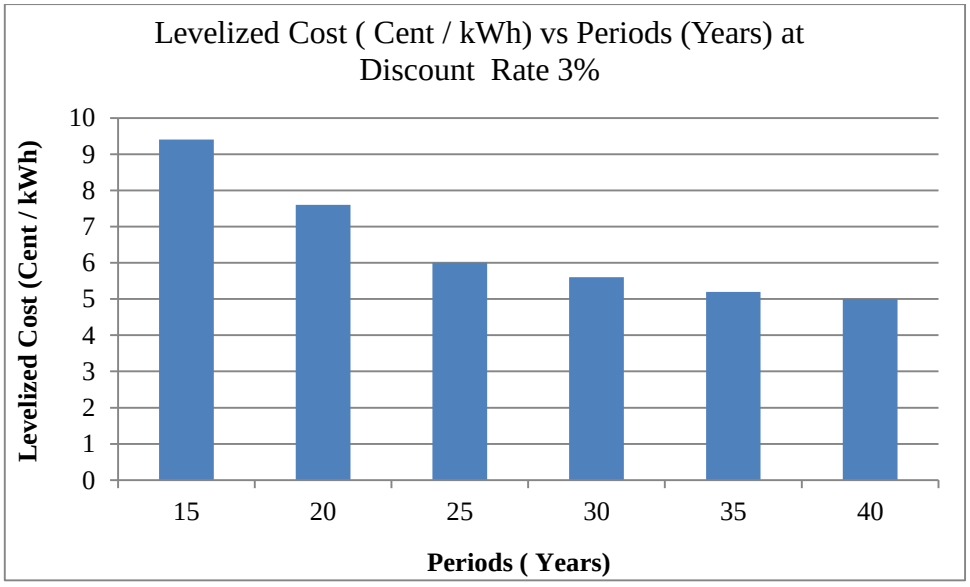

Fig (6) change levelized cost of electricity with period's lifetime of station

4.14 The discount rate indicator plays an important role in the rise and fall of the cost of renewable energy. Figure (6) showed a significant change in the rate of renewable energy cost as the flow of periods with increased in the discount rate , as it was assumed that the discount rate was 7% and the production life of the station was changed (15-40) years, and the variation in the indicator that the discount rate change the levelized cost from (8.4- 12) cents / kWh .

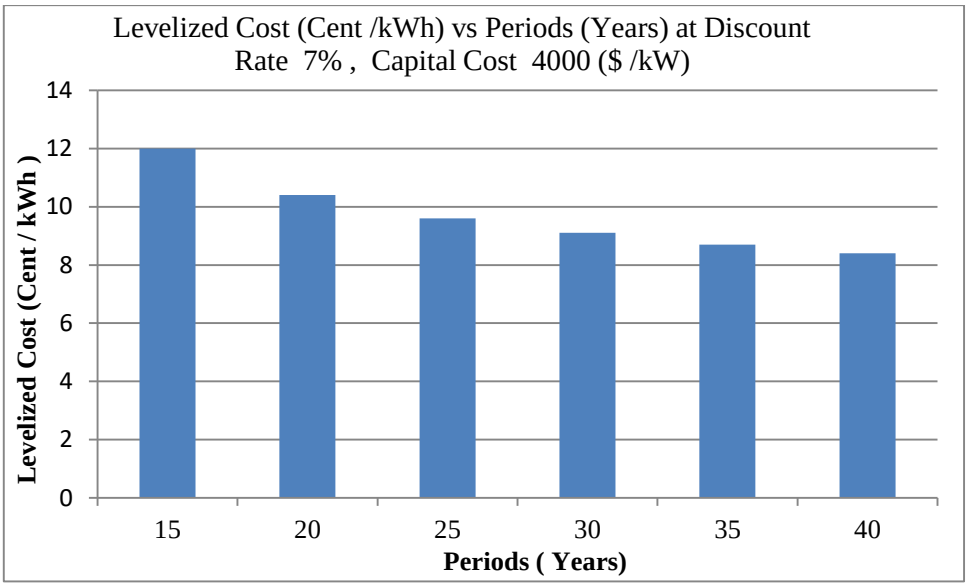

Figure. (7) Change the levelized cost with periods of life time station

4.15 For a more detailed observation of the variables that affect the cost level of electricity produced with the lifetime of the station, with the imposition of the discount rate (3%) with the cost of construction the station (4500) $/Kw, we will show in figure (7) that the levelized cost of electricity will change within the range (5.7 -10.4) cents / kWh. This means that the level of electricity cost may be within the internationally permitted ranges with the increase in the cost of building the station per kilowatt, and it is an acceptable cost within the given data that is (Capacity Factor (45 %) , fixed O&M cost (25 $/kW-yr.), Variable O&M Cost (0.0020 $/kWh)).

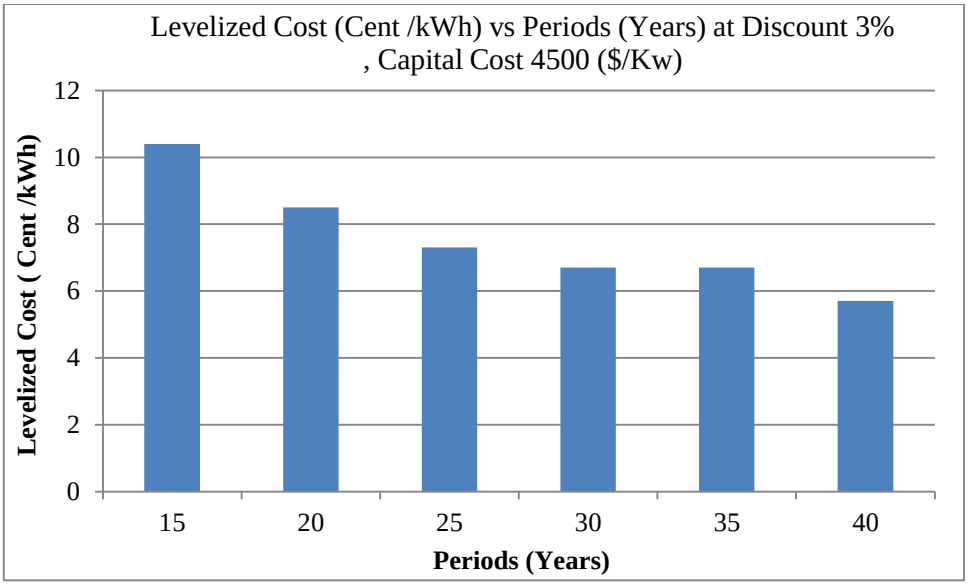

Figure. (8) Change the levelized cost with periods of life time station

4.16 The levelized cost can be change according to the change to capacity factor (%) , we know the capacity factor is simply the ratio of energy generated over a time period (typically a year) divided by the installed capacity, figure (8) show this change the levelized cost and the capacity factor , In order for the level of electricity cost to be within the acceptable rates, the capacity factor must be within the highest rates (35%,40%,45%) , which are related to the efficiency of the productivity rates and the rates of solar radiation on the site and their impact on the surrounding conditions.

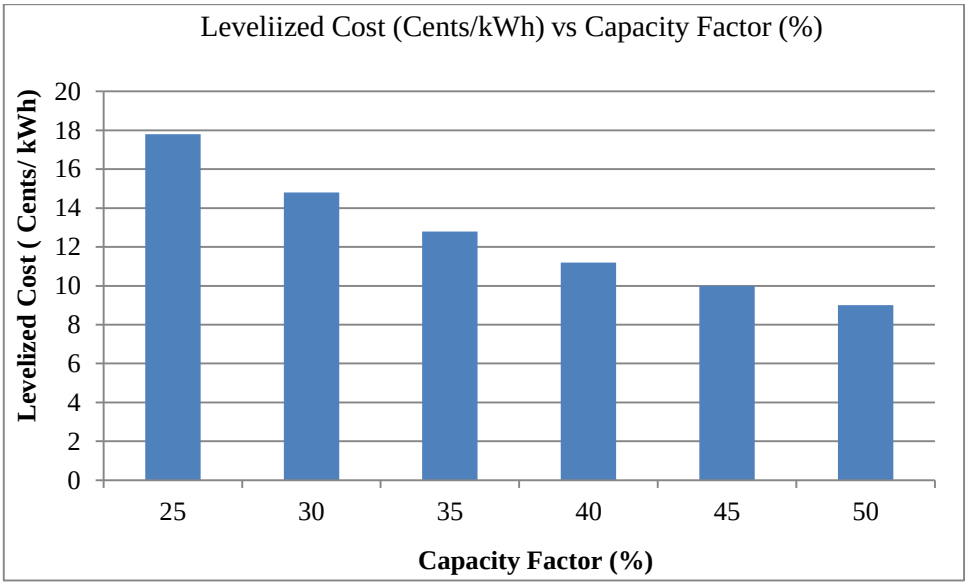

Figure (9) the levelized cost varies with capacity factor %

5. Conclusion

Through the data of the fossil electric power stations and their intersection with the data of the concentrated solar power plants, with the abundance of direct solar radiation rates in Anbar Governorate and the availability of other possibilities for construction CSP plants, it is possible to build CSP plants in several locations in the governorate, and share a certain percentage In supplying electricity, by adopting global parameters in the construction of renewable energy plants to keep the cost of electricity within acceptable levels like capacity factor and discount rate with life time to the plant .

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