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Is Iraq Ready to Use Solar Energy Applications: A Review

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Abstract: *Iraq is a country rich in fossil fuels; it is one of the oil-exporting countries and has the second reserve in the world. It also has reserves of natural gas in fourth place in the world. The abundance of fossil fuels in the country has led to total reliance on it and forgetting to work with renewable sources such as solar energy. The occurrence of Iraq near the solar belt area makes the intensity of solar radiation available in it high, which means the ease of use of various solar applications for the production of electric muffler and source of heat is inexhaustible. In this study, many of the research and studies of Iraq and the world have been reviewed, which prove scientifically and methodically the use of all solar applications is successful in Iraq.*
All the studies reviewed support Iraq's willingness to take advantage of solar energy applications in a way that reduces total dependence on fossil fuels. For example, the use of solar energy to heat water for domestic purposes in the winter will reduce the required electricity and as a result reduces the consumption of fossil fuels.
High levels of solar radiation make applications such as thermal storage as in the Trombe Wall successful in Iraq. The production of electricity by the concentrating power stations (CPS) or using solar cells is quite possible and studies have proved its successfulness. There is still an urgent need to study the negative impact of dust accumulation on solar applications and methods of disposal or reduce the impact on the performance of these applications.

Keywords: *Iraq, solar Energy application, water and air heaters, CSP, PV*

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I. Introduction

Iraq is located in southwestern Asia and forms the eastern border of the Arab countries. It is one of the first countries in the world where the oil was discovered and has a huge reserve of it qualified Iraq to take the second place in the world after Saudi Arabia. Iraq is located between latitudes 29 ° 5 ', 37 ° 22' north, and longitude 38 ° 45 'and 45 ° 45' E (Fig. 1). The area of Iraq is 438 320 km^2, bordered by Saudi Arabia and Kuwait to the south, Turkey to the north, Syria to Jordan from the west, the Arabian Gulf to the southeast, and Iran to the east. The 2015 census shows that the number of Iraqis is 34,589,572 with a growth rate of 2.4%. The capital of the country is Baghdad, which has a population of 8 million in 2017 [1].

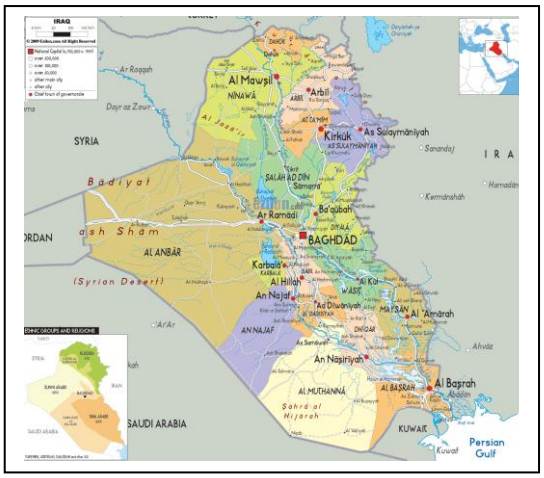

Fig. 1, Iraq map

Iraq's geography is diverse, from the Upper Tigris and the Euphrates to the highlands in the north and south-east, while western Iraq is a desert stretching from the borders of Syria, Jordan and Saudi Arabia. The

climate of Iraq is characterized by a very hot continental climate and very dry most of the year [2]. This desert climate is mild and cold in the winter. The highest temperatures are in the summer months (June, July, and August) and temperatures range between 43°C and 53°C. In the winter of Iraq, which is not more than five weeks most in January, the temperatures are ranged from 1°C to 8°C [3 and 4]. This dry and hot climate can cause prolonged droughts and frequent sand storms. The northern wind caused dust storms especially in spring and autumn [5].

Iraq has a very distinguish location near the solar belt countries enables the country to receive a high quantity of solar radiation up to (6.5-7) kilowatt-hours/m^2. Sun brightness ranges from 2,800 to 3,300 hours per year. The highest actual brightness of the sun is in June at 11.4 hours/day, and the lowest brightness in January by 6.3 hours / day [6]. The maximum temperatures range from 16°C in January to 44.4°C in July. The minimum temperatures range from 4.4°C in January to 25.4°C in July. Wind speed in this country is below average and ranges from 2.5 m/s in December and January to 4.1 m/s in July. Relative humidity ranges from the lowest 25.5% in October to January high of 73.8% [7]. Table 1 represents the variable environmental condition for Iraq at 2016.

Table 1: Monthly averages of climate variables in Iraq for 2016

Months / Climate variables	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.
Theoretical brightness	13,21	11,48	10,83	9,77	10,33	11,28	12,51	13,37	14,28	15,43	14,62	13,44
Actual brightness	10,3	8,4	7,3	6,1	6,3	7,4	8,1	8,5	10,3	11,4	11,3	11,2
Ordinary air temp.	30,9	24,8	16,5	11,5	9,7	12,5	16,8	22,7	29,4	33,0	35,7	34,7
Max. air temp.	40,5	33,7	23,7	17,5	16,0	18,9	23,7	30,1	36,7	41,8	44,4	43,6
Min. air temp.	21,4	16,7	9,6	5,5	4,4	6,0	10,4	15,8	21,6	24,7	25,4	25,3
Atmospheric pressure	1041,6	1049,4	1019,8	1021,2	1059,7	1055,9	1051,8	1051,7	1045,6	1039,5	1038,6	1037,7
Wind speed	2,7	2,6	2,5	2,5	2,6	3,0	3,3	3,3	3,4	3,9	4,1	3,6
Relative humidity	32,9	25,5	58,9	70,4	73,8	59,4	51,6	44,7	33,9	26,4	25,8	26,8

Climate change has become a major threat to the world as its intensity and impact have been visible in most parts of the world. Iraq and its neighbors also had a share of the damage caused by climate change [8, 9]. The most significant manifestation of climate change in Iraq is the increased salinity of river water, drought, reduced agricultural areas and increased dust storms [8, 9].Iraq as an oil country, its' national economy depends entirely on the export of oil. This heavy dependence on one source of wealth makes the economy fragile and vulnerable to the volatility of oil prices. In addition, the infrastructure of Iraq is deteriorating due to wars fought for 40 years and subjected to an unjust blockade for more than a decade and the crises that followed its occupation in 2003 and its exposure to organized international terrorism. All these factors have made Iraq face a great danger today as the fluctuation of oil prices and its continuous decline is putting pressure on the state budget and reducing the state's potential to improve services [10, 11].

Three successive major wars between 1980 and 2003, a two-decade drought, excessive use of poor sulfur-laden fossil fuels and lead compounds cause Iraq's air to become heavily polluted and pose a major threat to the health and well-being of Iraqi citizens. Iraqi gasoline is full of lead and sulfur compounds, while diesel contains a high sulfur content [14]. Heavy oil and gas exploration after 2003 caused serious environmental impacts [13].One of the most significant effects of the past 40 years is the deterioration of the electrical grid and the lack of equipment. Until 2017, the Ministry of Electricity has been unable to equip citizens with electricity more than 12 hours a day in most parts of the country. This sharp imbalance between supply and demand in the processing of electric power caused the transfer of Iraqi citizens to rely on personal and shared generators working with diesel and gasoline [15].

This dependence on generators caused a large consumption of fuel of poor quality, which caused a severe damage to the air quality and the Iraqi environment. The Iraqi citizen has begun to feel the environmental risks associated with pollutants from motor vehicles and generators [16, 17]. Reducing fossil fuel consumption is the biggest challenge that can be passed on by Iraq to the use of renewable energies in electricity generation [18].

Iraq has many renewable energies representing the most important solar energy and promising potential [19]. It is an available energy almost free of charge. Solar energy can be used to produce large amounts of electrical energy via solar concentrators or by using photoelectric cells [20]. Perhaps the easiest to use and

successful is the production of thermal energy to heat the air and water for household uses depending on the levels of solar radiation. The use of photovoltaic cells in remote areas away from the grid to generate electricity is the best option [21, 22].

Photovoltaic cells have been tried and used in street lighting in many parts of the world [23] and have been used to equip communication towers in remote locations, all of which have been successfully completed [24]. In the case of remote communities, hundreds of which are scattered in the desert and mountains of Iraq, several power generators, such as the use of photovoltaic cells and wind power, can be combined with diesel generators [25, 26]. The electric load of the production plants can be reduced even in cities where the electricity grid is available by transferring part of the required energy load, such as health clinics, parking lights and traffic signals using PV units [27]. Today, the use of solar pumps in many remote farms has become an accepted and promising reality [28, 29]. Many water purification and distillation plants have now been deployed in many places in the world [30].

Excessive dependence on fossil fuels for energy production has reached alarming limits, especially with rising air and environmental pollution. Iraq has enormous potential to operate solar plants to produce electricity and to benefit from all solar applications. Unfortunately, Iraq is still lagging behind most of the world in the transition to solar energy. Attention and public education on the importance of using solar applications and regulating and rationalizing electricity in homes and government departments is one of the most pressing issues to reduce the pressure on the economic security of this country. This article is devoted to reviewing several scientific research studies undertaken to verify the feasibility and use of solar energy applications in Iraq. This study focuses on published scientific research on the use of solar energy in Iraq and neighboring countries that share the same solar conditions.

Solar water heater

Heating solar water for domestic or industrial purposes is the simplest solar energy application. This application is widely disseminated worldwide and its utility is to reduce fossil fuel consumption to warm the water. The ease and maturity of solar water heaters has reached a great extent and is offered to the public at competitive prices. Unfortunately, the use of this application in Iraq is still far from the level of ambition, despite the correct weather conditions. The citizen's awareness of such application is few and does not find encouragement for its use. Perhaps of the reasons for such estrangement is the low electricity unit tariff. The intensity of solar radiation in Iraq in winter is not less than 265 W/m^2, which results in high heating temperatures and very suitable for the uses of citizens [31]. Many researchers worked in Iraq on this subject. Table 2 shows some of these studies.

Table 2, solar water heating studies

Ref. No.	Location	year	The study aim	Critical findings
[32]	Iraq	2014	The possibility of using sensible heat storage media (bubbles) or latent heat media (PCM) to increase the thermal storage time of a solar heater after sunset.	The PCM-equipped solar heater worked for longer periods and the water stays hot inside the tank until the next morning.
[33]	Malaysia	2015	The performance of solar collectors using a water-based evacuation tube containing single-walled carbon nanotubes.	The efficiency of the solar heater increases with solar radiation.
[34]	Malaysia	2015	The performance of solar collectors using a Al2O3-water nanofluid in a flat plate solar collector	The efficiency of the solar heater was increased using AL2O3 nanofluid and the increase was dependent on the nanofluid flow rate. The thermal efficiency of the system increased by 50% more than the working system without nanofluid.
[35]	Indonesia	2017	An experimental study of the performance of a solar water heater using a liquid to transfer heat.	The results show that at the same initial pressure, the use of R141b type cooling fluid is better than the R718 for a solar water heater. Thermal efficiency of the heater reached 34%. The use of a coolant type R141b gives better performance compared to conventional water heater.
[36]	China	2017	Study the daily useful energy of daily solar radiation to evaluate the thermal performance coefficient (COP) of the local solar powered water heater.	After analyzing the effect of daily solar radiation and daily useful energy quantitatively, a numerical equation was derived. Labor tests have proved that the results can be improved by applying this equation.
[37]	Malaysia	2017	Study of the effect of some improvements on a solar water heater. The added improvements	The solar collector is affected by many factors such as: solar collector area, form and

			were a concentrator parabolic dish reflecting solar radiation towards the conical absorption tube of all directions; conical absorption directly absorbs solar radiation from the sun and water heater.	type of absorption tube, solar heat flow rate, and heat loss rate. The proposed system achieved maximum efficiency of 65% when using a parabolic collector and efficiency of 41.04% when an equivalent dish collector is not used.
[38]	India	2017	Study the effect of changing the design of a solar heater system to heat loss of solar collectors collected from all bottles.	The results showed that the proposed tank reservoir has the ability to retain hot water and store it during the sunshine hours with minimal losses.

In Table 2, the researchers studied all the requirements for increasing the solar heater output from the hot run and presented several models with promising results. All the studies in this field neglect the impact of dust on the efficiency of the solar heater, which can be considered the subject of future studies. Perhaps the researchers excuse that this kind of heaters often works in the winter as rain reduces the chances of dust storms. No one has studied the effect of clouds and rainy days on the performance of the solar heater.

The solar air heaters

Solar air heaters are a practical application to take advantage of the intensity of solar radiation in the heating of air rooms or homes. These heaters have many designs and different competencies. However, most researchers gave promising results in their experience in the winter climate of Iraq, as shown in Table 3.

Table 3, solar air heater studies

Ref. No.	Location	year	The study aim	Critical findings
[39]	Iraq	2013	Evaluation the performance of a solar air heater using concrete and PCM as basic parts of the heater.	The addition of PCM to the concrete has significantly increased the air temperature outside the heater, which means improved system efficiency. The increase in air temperature outside the wax condition with concrete increased by 54.97% compared to the case of concrete alone. Highest storage efficiency reached 54.13% for wax condition with concrete compared to using concrete alone.
[40]	Iraq	2016	Study of the performance of a transparent collector solar air heater had an area of 1 m^2 using aluminum plate as a direct solar heating media.	The results confirmed that this heater is suitable for the atmosphere of Iraq. The increase in air temperatures was 101% higher than ambient air temperature.
[41]	India	2014	The study of the possibility of storing excess solar energy using a phase change material, which was lauric acid. The advantage from storing and heat release when the solar energy is insufficient or not available to heat the air.	The results showed that the degree of hot air outside the heater depends on the speed of air circulation inside the heater, and both determine the time required to charge the PCM. During the discharge period the internal air velocity is the only effect.
[42]	Iraq	2017	Design and construction of an equivalent solar collector for condensing and assembling solar radiation using soft steel with copper tube fixed on flat absorption plate. The study aims to assess the potential of this model in the Iraqi climate.	The highest air temperature exited from the heater was 120°C in August while the reflective plate temperature was 69°C and the glass cover temperature was 43°C.
[43]	India	2017	Analysis of the performance of a new solar air heater with three absorption plates to increase the heat transfer and study the optimal performance thermal and hydraulically.	The results on the solar collector showed a boost in the performance range of 18 to 31% compared with one rough side and the hot temperatures rose to 51-60% compared to the conventional solar air heater.
[44]	India	2017	Evaluation of a novel solar air heater with arched absorber plate using tabulator.	The arched tabular design increased the air turbulence causing high improvement in Nusselt No. at high Re No.. The overall performance of the studied type was increased.
[45]	Turky	2017	Study of the effect of the solar collector fish of three experimental solar heaters. The three heaters were made of thickness (7 cm, 5 cm, 3 cm) using multiple glass panels.	The results showed that for low airflow rates with large gaps with a thickness of 3 cm heater the best performance was achieved compared with others.

The solar thermal storage wall (Trombe wall)

Trombe wall is built from variable and available materials such as water, construction materials, and stones. This wall is used to warm the air for comfort conditions in winter. This technology is a solar collector that acts as heat storage media in buildings [46]. The technology of translucent insulation has developed and the possibility of adding it to the wall structure gives a promising prospect. This wall is characterized by a large storage capacity and positive energy balance during the period of heating the required space [47]. Like all solar applications, weather conditions affect the output of this wall. The intensity of solar radiation is the most important weather variables and can be considered ideal for the wall in the circumstances of Iraq. As the clouds reduce the solar radiation reaching the wall due to its low performance, thanks to the atmosphere of Iraq, which has few periods of clouds in general and their impact is limited. Wind has a cooling effect on the wall's thermal storage abilities. In Iraq, the wind has limited speed throughout the year, which means that wind will not have this cooling effect on the wall. Dust creates a barrier between the falling radiation and the wall, and it represents a negative effect when using a transparent surfaces. The winter season in Iraq is a rainy season that causes soil cohesion and reduces dust storms. Table 4 listed the Trombe wall studies.

Table 4,Trombe wall studies

Ref. No.	Location	year	The study aim	Critical findings
[48]	Iraq	2009	To test a Trombe wall designed and made using a plastic water bottles and its suitability to work in the atmosphere of Iraq, for the period 2006 and 2007.	The results showed that this wall has the potential to store solar energy from 7:00 AM to sunset and keep warm enough to heat the air until 5:30 AM of the next morning. The high solar radiation in Iraq caused a temperature of water to reach 64.6℃ while the metal wall was 74.4℃.
[49]	Iraq	2015	The fit a wall built by locally available materials with cheap prices for Iraqi homes in the winter.	The results showed that the wall examined is suitable for work in the Iraqi air space in the winter. The use of a phase change material, which is available at low prices in the local markets in the wall, gave high and suitable thermal storage.
[50]	Iraq	2016	Study of the effect of adding AL2O3 nano to paraffin wax to enhance thermal conductivity on wall loading and discharging time.	The speed of loading and discharging of paraffin wax improved by adding nanomaterials. Also, the maximum temperature of the wall rose during the wall charging period compared to a wall that uses wax only. The outside air of this wall was warmer than the wall of wax. The Trombe wall with nanoparticles and wax increased the maximum temperatures to 29.08% compared to the wax wall alone.
[51]	Iraq	2016	Study and test the performance of a new type of simple storage wall (Trombe wall) consisting of thirty-three bottles of plastic water in the front of the wall with paraffin wax behind the bottles confined to a glass panel in the winter conditions in Baghdad.	The designed wall is effectively store solar energy and can be used for heating homes after sunset.
[52]	Iran	2016	The study focuses on the comparison of energy efficiency glasshouses, tromp walls, and atrium. And among many of the most common houses such as solar provides details of the methods of using these methods to save energy and benefit from it.	The use of solar photovoltaic systems, the Trombe wall, atrium and the combination of these systems gives an improvement in energy consumption greatly. They reduce energy consumption for lighting, heating and ventilation, and can sometimes cool buildings.
[53]	Saudi Arabia	2017	The total embodied energy rating, CO emissions, and energy saved annually from casting using most of the cooling concepts such as tromp wall, orientation, cross ventilation, lighting, wind tower, wind channel, etc for SodhaBers Complex (SBC).	The SBC building is a unique and new type of building combining many concepts of thermal comfort. The time of energy recovery in the buildings of this type close to 22 and 20 years. The results show that with the integration of different ways and concepts of cooling the buildings, it can reduce the amount of the consumed energy.
[54]	Netherlands	2017	Check the performance of a new type of tromp wall It is designed during a design project called "Dual Face 2.0".	Instead of using building materials such as stone, transparent materials are used in this wall in addition to variable phase materials (PCM) and air insulation. Insulation is used to guide the thermal mass of the PCM. The

				new system is designed to be adjustable for cooling and heating purposes.

The solar pond

Solar saline ponds store heat by converting solar radiation into heat and storing it for long periods of time in pond layers contain salty water. This application benefits from high solar radiation intensity throughout the year. The heat is stored in summer and used in the winter. The rationale for benefiting from this application is all available in Iraq [55].The raw salt required in this type of ponds is available in Iraq at very low prices. The intensity of solar radiation exceeding 800 W/m^2 for more than two months in summer gives the pond the best storage solar radiation. Dust is the main obstacle to the spread of this application in Iraq, as its accumulation in the surface layer of pond water reduces the intensity of solar radiation reaching the bottom layer of the pond, thus reducing the efficiency of the system's storage of energy [56]. The sedimentary soils that spread in Iraq are an obstacle in the use of such ponds because of the ease of penetration from groundwater, which increases the cost of these ponds because of the need to isolate them in a variety of ways. Table 5 illustrates some of solar ponds studies.

Table 5, the solar pond studies

Ref. No.	Location	year	The study aim	Critical findings
[57]	Iraq	2009	The effectiveness of using double slope solar still connected to a solar pond	Hot water in the last layer of the solar pond used to heat the dirty water in the distilled extended work of the distilled solar to be the length of the day and night. The distillate efficiency was not affected by changing weather conditions and the daily productivity of distillation was especially high at night.
[58]	Iraq	2012	Testing the impact of several modifications on the efficiency of simple solar distiller connected to solar pond	The use of reflective mirrors to increase the concentration of solar radiation falling on the pond water increased the thermal storage of the solar pond and caused increased distilled productivity.
[59]	Saudi Arabia	2016	Study the effect of using a new pattern of heat extracted from the pond.	The lower layer temperature was increased after 75 days to 73°C. The temperature distribution revealed constant distribution in the lower layer while in the middle one it reduced linearly.
[60]	India	2017	The efficiency of a solar pond using an external source to enhance its performance by using the collectors of hollow solar tubes conveying liquids to the lower convection area of the solar pond.	The study depended on the Taguchi method to evaluate the optimum performance between several sets of studied variables. The study concluded that the use of such method to determine the best set was validated.
[61]	Jordan	2017	Study of the effect of temperature and salinity concentration on the performance of the solar pond over time.	The experimental results showed that the temperature of the bottom layer of pond after three months of thermal storage reached 85.. It is possible to extract heat energy stored in the lower area even during the day or continuously while maintaining the stable temperature of the solar pond.
[62]	India	2017	Study of the solar storage in the lower saline pond used for sodium chloride salt and gravel.	The results showed that the heat absorption of salt is more than the gravel by comparing the distribution of temperature between salt and gravel, although the gravel has a cheaper cost of salt. However, it is preferable to use salt for thermal storage rather than gravel.
[63]	Pakistan	2017	Performing a digital efficiency analysis using MATLAB, when the temperature difference kept constant at 30, 28, and 20°C across the gradient layers. The depth of the pond was varied of 1.5, 1.0, 0.5 m.	Thermal efficiency of the first pond with a depth of 1.5 m was about 21% in summer, and in winter 11%. The average annual efficiency was 21%, 19%, and 9.5% for three deep pools of 1.5 meters, 1.0 inches and 0.5 inches respectively.

The solar chimney

Solar chimneys has a solar collector is used to heat the air and direct it higher through the chimney, so high solar radiation and high-temperature air must be available to run the solar chimneys. Both conditions are available in Iraq [64]. The transparency of the solar collector is affected by dust (which is rising dramatically in Iraq during the spring and autumn) and presents a challenge to the use of a solar chimney. This point should be studied in great detail in order to determine whether this application will succeed in Iraq or not. The use of different types of cleaning detergents and their success in reducing the accumulation of dust should be studied [65]. High humidity causes a decrease in solar radiation intensity. Iraq has a relatively low humidity in most of its regions most days of the year. The effect of this factor is therefore limited to this application [66]. Table 6 represents some of the studies on solar chimney.

Table 5, the solar chimney studies

Ref. No.	Location	year	The study aim	Critical findings
[66]	Iraq	2011	A numerical study to evaluate the heat transfer and fluid flow in the solar chimney when variable basement kinds were used.	The results showed that the air movement improved when the absorbent surface of the solar chimney is in the middle of the air gap.
[67]	China	2016	Simulate the environmental variables in laboratory and evaluate their impact on a solar chimney performance.	Using a laboratory experimental model helped to better understand the chimney's preparation and thermal properties.
[68]	Algeria	2017	Study the turbulent flow by natural convection effect within a solar chimney power plant using numerical simulations to analyze the effect of the total solar gradient on the performance of the chimney.	Results The positive effect of the storage system on the performance and duration of operation of the chimney after sunset. The use of additional storage media improves the air speed of the chimney.
[69]	China	2017	Numerical study of the effect of thermal storage capacity and airflow rate of solar chimney at night when using PCMs having different melting temperatures (38°C, 44°C, 50°C and 63°C).	Results showed that the highest ventilation and thermal storage is achieved when the used PCM was with a phase temperature change of 38°C. The ventilation was stopped at night when using PCM with a melting point of 63°C. The results confirm that the minimum phase change temperature can increase the chargeability and discharge of a solar chimney.
[70]	Egypt	2017	Propose a numerical approach to study the effect of solar radiation and pressure on turbine capacity and air flow rate	The experimental and numerical results showed that the air velocity has an impact on performance and efficiency.
[71]	China	2017	Numerical study of the performance of divergent chimney with two shapes controlling parameters.	The divergent chimney power plant can achieve higher power than the cylindrical chimney. This enhancement reduces with increasing the area of the collector or the divergence angle.
[72]	India	2017	Conduct a transitional analysis of the fully developed solar power plant from Manzanares.	The results of the study showed that differences in temperature in the collector, ground, and air speed at the level of turbines can give details of airflow in the collector.

The Concentrated Power Station

Solar stations focus solar radiation on a specific target to heat it up to high temperatures. Such stations require high solar radiation and high brightness time, in addition to high air temperatures, and there is no better place than Iraq that meets all these requirements [73]. In Iraq, the solar intensity in summer and winter is high and suitable for this application [74]. The accumulation of dust on reflectors or system mirrors can be considered as a major determinant for the use of this type of application. When the accumulation of dust reduces the intensity of solar radiation reaching the reflector or mirror, it reduces the intensity of the reflected radiation on the target and as a result reduces the temperature of the target [75]. Till today, this impact is lacks for serious and extensive studies. The high humidity in some areas of Iraq has a negative impact on the efficiency of the work of these stations did not study this subject on the ground so far and is expected to have a very limited impact. Table 6 represents some of the studies in the CPS field.

Table 6, the solar CPS studies

Ref. No.	Location	year	The study aim	Critical findings

[76]	Iraq	2012	Improve the efficiency of the concentrated solar power plant by using a reflector behind the target or by painting the central target in .black and using the two variables together	The third case gave the best thermal storage efficiency, although this efficiency varies from month to month. The highest value of thermal storage was obtained in August.
[77]	Iraq	2012	Experimentally evaluation of the suitability of .Iraqi climate for such application	The study found that the highest temperature of the target can be achieved, which enables the operation of the power plant. The coloration of the target in black causes increased temperatures and energy stored in the target.
[78]	Italy	2015	Study the possibility of benefiting from the addition of a thermal energy storage media on the performance of the concentrated solar plant and the effectiveness of the proposed system in avoiding interruption of power supply.	The results showed that the intensity of solar radiation affects thermal storage capacity as the properties of the materials used in the capsule affect the thermal performance of the system clearly.
[79]	USA	2015	The study of the use of salt as a phase change material in a solar thermal power plant .operated at temperatures higher than 400°C	The study found that the melting point of the salt and its latent heat varies from one type to the other in addition to the radiation characteristics of each species. Inorganic salts can be used in this application. Nitrate salts are currently widely used. Chloride salts do not take their role in this field. The researchers recommended using chloride salt in concentrated solar plants operating at high temperatures (400°C).
[80]	Senegal	2017	Work on the identification of suitable sites for the establishment of hybrid stations of CPS and the bio-component in the Sahel region, Senegal.	Hybrid biomass plants can be established to allow the development of organic fertilizer production and to combat the invasion of agricultural land.
[81]	France	2017	The article provides technical data for the activated solar plants (SP) Construction and project all over the world.	The tables include information such as: plant name, construction country, factory owner, target of construction. The technical characteristics of plants such as concentrated solar technology, solar energy, station space, presence and type of hybridization system, cost of electricity, power cycle liquid, liquid heat transfer, operating temperature, operating pressure, type of turbine, type of duration of storage, etc.
[82]	India	2017	The study of the design of a 100 MW solar thermal power station uses a small trough equivalent with 6 hours of thermal energy storage and work on the thermal performance .assessment of the design	The results of the study showed that the annual electricity generation can be generated by 285,288,352 kWh with the station efficiency of 21%. The proposed design of the solar thermal power plant provides analysis and performance that encourage the development and development of solar thermal power plants .in India

The Photovoltaic (PV) Modules

The use of renewable energy technologies such as solar energy in Iraq can be considered an appropriate and viable option for all scales. Iraq receives massive amounts of solar radiation throughout the year [83]. Photovoltaics may be one of the best solar technologies that have become cheap solar electricity at the individual level and stable electricity at the grid level. What is wrong with the use of these cells is affected by many of the design conditions such as location, shadows and tilt angle that vary according to seasons. The cell is also affected by weather conditions such as temperature, humidity and air mass [84]. The high temperatures that characterize Iraq's climate that is usefulness for concentrated power stations are negative when using photovoltaic cells [85]. The high temperatures of PV panels' causes low productivity, as the high temperatures reduce the voltage of the photovoltaic cell, causing a decrease in energy generated [86, 87]. The Iraqi researcher studied the effect of weather conditions on the performance of PV cell at large and identified areas of bug and ways of reducing damage. Table 7 shows the most important results of some of these studies.

Table 7, the studies of the impact of Iraqi climate variables on PV performance

Ref. No.	Location	year	The study aim	Critical findings
[88]	Iraq	2016	Study practically the effect of solar radiation intensity, temperature, and wind on the outcomes of the PV system in the Iraqi climate.	The results showed that the temperature of the PV panel has a role in improving or reducing the resulting power of the PV system. The high solar radiation intensity in Iraq has a good effect on the cell performance. Wind and rain had a limited effect on the resulting power. The accumulation of dust and dirt had a clear effect on the ability of the generated cell. The research summary pointed to the need to limit the impact of weather variables so that solar cells can be used extensively in Iraq.
[89]	Oman	2016	Look for the effective wavelength/color that causes the maximum outcome of the PV panel and the best electricity conversion using seven colored filters.	The results revealed that the natural spectrum gives the highest generated power compared to other wavelengths. The use of a blue screen produced the lowest power compared to the rest of the filters. Therefore, the visible spectrum of solar radiation is the first influence on the power produced by solar panels.
[90]	Oman	2012	Study of the effect of high relative humidity weather on the PV output.	The increase in relative humidity causes a decrease in the intensity of the solar radiation received by the PV panel, causing a decrease in the temperature of the solar air and as a result of the improved production of solar cells.
[91]	Oman	2015	Practical study of the impact of high humidity weathers on the PV arrays outcomes.	The results of the study show that the resulting solar cell is affected by the increase in relative humidity. High relative humidity affects the cell's current and voltage, causing low PV efficiency in days of high relative humidity.
[92]	Iraq	2016	Study the impact of air mass on a PV panel outcome.	The study showed a significant effect of the air mass on the electricity produced by the photo-voltaic cell. The effect of air mass on a single cell was clear and affecting the short circuit current of the cell.
[93]	Iraq	2016	Using Homer software to propose a low cost effective solution to reduce electricity consumption and reduce pollutants emitted by burning fossil fuels. The proposed system uses a hybrid system consisting of photovoltaic cells and diesel generators.	The results showed that the proposed system could be applied in practice, and that it could be a real option to solve the problem of electricity lack in Iraq.
[94]	Iraq	2017	Study the impact of all solar cell parameters that affect the PV operation like temperature, wind speed, humidity lighting, etc.	The results showed that using PC abilities like curves, Digital numbers and Analog gauge pointers to measure the effectiveness of the PV cells are affected by the environmental parameters as dust, humidity, temperature, and settlement of the PV panel's surface. The rate of efficiency drop varies from one variable to another depending on its reaction with other variables.

As with all the solar applications mentioned above, photovoltaic cells are highly affected by the accumulation of dust and dirt on their surfaces. The layers of dust and dirt prevent the arrival of solar radiation or a large part of it onto the cell, which reduces its performance. The Iraqi researcher has been very interested in studying the impact of dust, its accumulation, its type and confiscation, its effects and how to reduce it. Table 8 shows the results of some of the most important studies.

Table 8, the studies of the impact of dust on PV performance

Ref. No.	Location	year	The study aim	Critical findings
[95]	Iraq	2014	Comprehensive review of the impact of human activities, geographical and weather factors on the spread and recurrence of dust	The studied variables have caused the increase in the dust storms spread in Iraq. Some of the harmful effects of this dust on

			storms in Iraq and their negative effects on the performance and efficiency of PV systems.	solar cells can be reduced by new cleaning techniques. These techniques showed its abilities to minimize the dust accumulation effects.
[96]	Iraq	2017	Study the effect of accumulated dust in different areas around the city of Baghdad, including population, including agriculture.	The results showed that residential areas in Baghdad due to high traffic caused the dust to rise and then accumulate more than the agricultural areas where the soil is adjacent and clay and dust less.
[97]	Iraq	2013	Study the effect of climate variables such as temperature, humidity and wind on the spread of dust and then accumulation on PV surfaces.	The results showed that if the main effect of the increase in dust is determined, the type of cleaning required can be evaluated.
[98]	Iraq	2015	The impact of rising dust and air pollution caused by highway traffic on photovoltaic output. Also, the study tries to find the best cleaning detergent to be used in this case.	The results indicated that air pollution helps in and further deteriorates the performance of photo-voltaic cells, even for exposure to atmospheric conditions with a short period of two months without cleaning. Contaminated photovoltaic cells lost about 12% of their strength, while cells lost their normal cleaning by about 8% compared to the clean cell during the winter months. The study found that there is a percentage of hydrocarbon particles accumulated on the surface of PV panels resulting from exhausts of cars, buses, and heavy vehicles. Cleaning the surface of PV by sodium or alcohol reduces the effect of dust accumulation and hydrocarbon pollutants at high rates. The main conclusion of the study was to emphasize the possibility of replacing diesel generators or gasoline with photovoltaic cells to generate electricity in Iraq and with high efficiency.
[99]	Oman	2015	The effect of the physical properties of sand and dust on the PV performance.	The study revealed that the physical properties have significant effect on the PV array performance.
[100]	Oman	2016	The effect of photochemical reactions of gaseous emissions in the atmosphere and the dried droplets of salt that form particles with low diameters less than 2µm.	The study showed that the physical properties of dust, such as particle shape, gravity, moisture content, surface properties, plastic and liquid boundaries, and grain size are specific, vary from place to place. The reasons for these differences were the topographic, geological and environ-mental conditions of each region. The weight and shape of the dust particles greatly affect the deposition and performance of the PV.
[101]	Iraq	2017	The effect of different types of fly dust (sand, ash and soil) on three types of PV panels (Monocrystalline, Polycrystalline, Non-Crystalline).	The results of the study showed a clear reduction in the resulting photovoltaic power, which in turn depends on the type of pollutant and the degree of its accumulation. Red soil caused the highest decrease in the performance of monocrystalline and crystalline plates. While the accumulation of brown sand has the least impact on the efficiency of the amorphous PV panel.

The Iraqi researcher studied several ways to reduce the effect of solar cell temperature and increase the efficiency of the solar panel. They proposed to take advantage of excess heat in photovoltaic panels by extracting them by different cooling fluids such as air, water and other water and to take advantage of this heat in other thermal applications [102]. Extensive studies have been undertaken by many researchers to demonstrate the importance of these systems in areas with high atmospheric temperatures such as Iraq [103]. Table 9 lists some of these studies.

Table 9, the studies of the PVT performance

Ref. No.	Location	year	The study aim	Critical findings
[104]	Oman	2017	Extensive review of published research on PVT applications around the world. Also, the technologies tested in this field.	The study showed the great interest shown by the workers in this field, due to the importance of PVT systems in increasing and spread of

				photovoltaic cells in the warm areas and improving their efficiency while reducing their cost compared to energy produced, whether electric or thermal.
[105]	Iraq	2017	The effect of using nanofluid as a coolant in a PVT system.	The study showed that the stability of nanofluid used, continued at least six months after measuring the decrease in thermal conductivity achieved at intervals of 10 days, and the decrease was at a low rate not exceeding 0.003 W/m^2. Electrical efficiency increased by 24.1% compared with the PV system alone when using nanofluid. While the thermal efficiency reached its highest value by 100.19% compared to the use of water for cooling.
[106]	Malaysia	2017	Evaluate the technical and economic costs of the PVT system when nanofluid is used.	The evaluation results showed that the PVT system has an annual yield factor of 128.34-183.75 kWh / kW, while the CF was (17.82-25.52%) and the cost of energy was $ 0.196 / kWh; the recovery period was 7-8 years, the efficiency was 9.1%. The study supports that the PVT system with nanofluid improves the technical and economic performance of the system.
[107]	Iraq	2017	Investigate the possibility of determining the type of nanoparticles that have the best effect on the PVT unit.	The study showed that knowing the quality and properties of nanoparticles helps in selecting the best nanomaterials added to water. The results of the study showed that SIC-nanofluid has the highest thermal conductivity compared with Al2O3 and CuO-nanofluids.
[108]	Turkey	2016	Study of the effect of thermal energy storage using PCM and temperature on optical concentration in tropical dry climates.	The results showed that the use of a melting point in the range of 45°C to 65°C is suitable for storage of thermal energy in the studied climate. Therefore, the quality of the material should be chosen based on its melting point, which is based on the energy requirements used.
[109]	Italy	2017	Study the potential of PVT systems and the availability of heat and electricity at the same time.	The technology of hybrid bit systems represents a promising solution; especially when the roof area is limited or when heat and electricity are required at the same time. PVT systems operate more efficiently than individual PV systems.
[110]	Iraq	2014	Test the effect of different air cooling methods on the performance of solar PVT collectors using four locally made collectors.	The results showed that a double-channel and one-pass collector gave higher electrical efficiency than a single channel and double-pass model. One channel model produced the best electrical efficiency.
[111]	Italy	2017	Calculate the technical and economic performance of the PVT system to provide local hot water and space heating for comfort purposes.	The results show that the proposed PVT system provides 77% of total household thermal demand and 145% of electricity expenses during the four seasons with the export of surplus electricity to the grid, which means an increase in family income.
[112]	Malaysia	2017	The benefit of using PCM with a nanofluid cooling system to reduce PV temperatures and to maintain electrical efficiency and increase the thermal efficiency. Further, study of the effect of adding nano-SiC particles in paraffin to create higher thermal conductivity and thus higher overall efficiency.	The study showed that the use of the new system reduced the temperature of the cell by 30°C during the peak solar radiation period (12:30 Am to 1:30PM). This decrease resulted in increased open circuit voltage from 11-13 V to 20- 21 V, the output power from 61.1 W to 120.7 W, the electrical efficiency from 7.1% to 13.7%. In addition, the thermal energy gained for the system was reported to be 72%.

Solar Distillation

Water distillation and purification processes require large thermal energy consumes fossil fuels, causing significant air pollution. Solar distillation is an effective alternative that will reduce the need for fossil fuel consumption and this is reflected by improved air quality. Solar distillers can improve their productivity by increasing the surface area exposed to the sun, and thus can produce quantities of clean water for human use and suit the consumer [113]. Simple solar water distillers are characterized by low productivity and need for large areas, as well as a cold, transparent outdoor surface at a lower temperature than evaporated water from the bottom (evaporator). Moderate wind speed can be useful in cooling transparence glass and increasing distillate productivity. The accumulation of dust causes a decrease in solar radiation reaching the water in the distilled basin, resulting in a decrease in the distillate yield. Iraq's conditions can be considered suitable for solar

distillation applications because its solar radiation intensity is good throughout the year. Solar radiation in Iraq is well suited to the solar distillation process, and summer temperatures do not suit this application at all. The Iraqi researcher has worked on finding innovative, smart, and simple ways to increase distillation productivity. Table 10 represents some of these studies

Table 10, the studies of solar distillation

Ref. No.	Location	year	The study aim	Critical findings
[114]	Iraq	2015	Study of the benefit of adding PCM to a central solar heater connected to the solar distillation system to increase the water temperature in the system as well as to store heat energy.	The results of the study showed the possibility of taking advantage of heat storage in paraffin wax, which passes hot water coming from the concen-tration plate as latent heat energy. The system can recover stored energy for later use after sunset. The distilled water production time of the system has increased by up to 5 hours if the sun is tracked by the concentrator. The increase in efficiency of the system was 64.07%, the efficiency of heating about 112.87% and the productivity of the system increased by 307.54%.
[115]	Iraq	2016	Design, manufacture, and inspection of a distillation system linked to a low-cost concentration unit that the average citizen can bear.	The use of paraffin wax in the distillate to increase the absorbed heat and water heating was found to be suitable for desert areas with acceptable produc-tivity when compared to other systems. The studied system achieved an increase in concentration efficiency by 50.47%, increased heating efficiency of about 157.8%, and increased in production by 783%.
[116]	Iraq	2016	Study of the effect of adding aluminum powder to the paraffin wax to increase heat transfer to and from the wax in the solar distillation system.	The results showed that the addition of aluminum powder to the wax caused an increase in thermal conductivity, which resulted in obtaining the best distillation efficiency and the longest production time.
[117]	Iraq	2015	Study the possibility of improving the thermal conductivity of paraffin wax by adding nanoparticles such as alumina (Al2O3) and TiO2 with increasing mass rates such as 1, 2, 3, 4 and 5%.	Thermal conductivity of paraffin wax increased by increasing the mass of added nanoparticles. The speed of thermal energy charging and discharging improved by this addition compared to pure paraffin wax.
[118]	Iraq	2016	Design and manufacture of solar distillation system to solve the problem of production of distillate solar in hot climates from 12 AM to 3 PM.	The proposed system's productivity increased by 120.8% without the addition of cooling assistance. As for the use of air cooling after 4 PM, the increase in productivity reached 337.36%. When the distiller is cooled by water after 4 PM, the productivity increases by 403%. The study showed that the cost of the designed system is low and acceptable as it is within the financial potential of people in remote areas.
[119]	Iraq	2016	The study is experimentally examining the possibility of improving solar distillation by proposing three methods: a) improving the conventional design by increasing the condensation surface; b) using a solar collector to store and heat the solar water before being sent to the distiller; c) using the gravel to store sensible heat.	The results showed that the three methods enhanced the distiller productivity. The third type (Gravel) introduced good potential compared to the other two methods.
[120]	Malaysia	2017	Study of the effect of some modifications on solar distillation and the energy balance	The results obtained showed that the performance of the graduated distillation after improvement has given better performance than before.
[121]	Algeria	2017	Checking a simple solar distiller in the same place in summer and winter	The distillate production in the winter is about 119 ml per day, while in the summer it was 1127 ml daily, the amount of increase is more than 9 times.
[122]	India	2017	The economic and practical analysis of a distillation unit equipped with an equivalent-phase solar capacitor to study real-time potentials for use in Water desalination	The results of the analysis showed that the system is suitable for overcoming the problems of corrosion, salt volume and algae. The system provides an average of 2.65 liters of distilled water per day for about 320 days a year. The system is cost-effective and economically viable.

II. Conclusions

Iraq can benefit from large solar potentials by using its various applications. The study reviewed scientific research in the field of solar energy application in Iraq and the surrounding countries and found that its field is wide and its potential is great in Iraq. Perhaps the most dangerous obstacle to the use of solar energy applications in this country is the rising dust, which is suspended in the air for long periods. This aspect still needs to be studied thoroughly. Also, the high summer air temperatures negatively affect PV systems and solar distillers. The Iraqi researcher has developed several successful practical solutions, including the use of PVT systems instead of PV. As well as, suggested several designs to increase the productivity of distillates.The trend toward solar applications to reduce dependence on the electrical grid means that Iraq gets rid of the problem of electric power. Some of the applications deployed in the neighboring countries of Iraq are easy to use and should be a priority of the attention of the government and citizens, such as solar water heaters for domestic purposes.

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