A Review of Solar Energy Applications in Baghdad-Iraq

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Abstract-Baghdad, the capital of Iraq, is a densely populated city and suffers from significant air pollution as a result of energy production by dilapidated power stations, in addition to the use of thousands of diesel generators for this purpose. Tomorrow is characterized by a high intensity of solar radiation and a long period of brightness for most of the year. This makes the use of solar energy applications possible and desirable. The study reviews solar applications for heat and electricity production and the possibility of using them in the city of Baghdad - Iraq.

In the review, references were used by several aunts in this research field, and all studies confirmed Baghdad's willingness to use solar applications such as heating water for home use. Air heating in winter which reduces the electricity consumed on this application in winter. The use of thermal storage, whether in the Trombe wall or in a solar salt gradient pond is a very successful solar application. As for the production of electricity, either through the concentrated power station (CPS) or using solar cells, studies have proven successful, with the need for further research to increase the productivity of photovoltaic cells through the use of photovoltaic systems (PVT).

Keywords: *Baghdad-Iraq, Solar Applications, Solar Pond; PV; PV/T.*

I. INTRODUCTION

Iraq forms the eastern frontier of the Arab countries that lies in southwest Asia between latitudes 29° 5' and 37° 22' N and longitudes 38° 45' and 48° 45' E (Figure 1). Iraq has an area of 438 320 km2, bordered by Turkey on the north, Saudi Arabia and Kuwait to the south, the Arabian Gulf to the southeast, Iran from the east, and Syria and Jordan to the west [1]. The Iraqi estimated population in 2015 was 34 589 572 persons with a growth rate of 2.4%. The capital city is Baghdad with a population of 5.751 million persons [2].

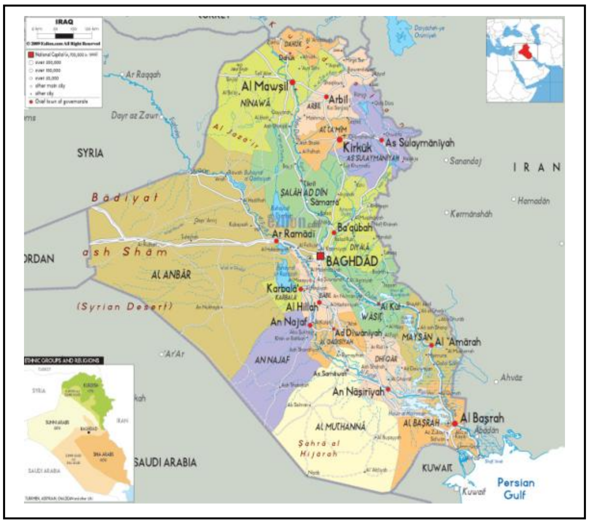

Fig. 1, Iraq map

The area of Iraq can be divided into four major geographic regions: the Upper Tigris and the Euphrates, the highlands to the southeast, and the Dibba is plain exclusively with scrub plants that extend eastward to Kuwait and south to Saudi Arabia. Also, the island plateau (although this arid region is flat in the first place, it contains deep river valleys, watersheds in the two rivers), and there are some highlands scattered here and there [3]. The climate of Iraq is characterized by being mainly continental climate. It is very hot and very dry most days of the year. The desert climate is moderate, cold, dry, and hot. Climate hazards such as drought, sandstorms and floods are possible in this atmosphere.

Iraq climate characterized by high temperatures in the summer and moderate in winter, the highest temperatures value are in June, July and August between 43°C and 50°C at mid-day. In January the temperatures range between 1°C to 8°C [4 & 5]. Northern Winds cause hazards of dust storms especially at spring and autumn. Iraq is located near the solar belt, which receives a quantity of solar radiation with an average of (6.5-7) kilowatt-hours per square meter. The periods of sun brightness range from 2800 to 3300 hours per year. This gives Iraq the necessary qualifications for the exploitation of solar energy [6]. The highest actual brightness of the sun is in June at an average of 11.4 hours/day, and the lowest in January by 6.3 hours/day. 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].

Climate change represents a great threat to the world, it starts to show its intensity in many parts of the world, perhaps the Gulf Cooperation Council and Iraq are from the most important affected countries [8, 9]. The most important threats of climate change and daily stress in Iraq is increasing the salinity of river water, drought, decrease of agricultural areas, and the increase of dust storms [10, 11].

Iraq totally dependent on the export of oil that makes its economy week in addition to its dilapidated infrastructure due to wars and its woes [12]. Iraq now is facing a great danger, which is the fluctuation of oil prices and their decline in continuous fall, causing pressure on the state budget and preventing the improvement of services [13]. Polluted air represents another great threat to the Iraqi citizen because of the emissions resulting from the use of poor types of fuel. The Iraqi gasoline is full of lead compounds while the diesel fuel has high sulfur content [14, 15]. Besides the exploration of oil and gas represents another dilemma faces Iraq because of its dangerous environmental impacts [16].

The electrical grid and lack of equipment is one of the worst of the legacy of Iraq from previous decades; until 2017 the electricity supply did not exceed 12 hours per day in most parts of the country [17]. This acute shortage in the processing of electric power caused the adoption of the Iraqi citizen on the personal and joint generators, which fueled with diesel and gasoline [18]. The excessive use of bad fuel has been reflected in air quality and the Iraqi environment. The environmental risks associated with pollutants from motor vehicles and generators are large and harmful to humans as well [19]. Hence the biggest challenge is to reduce air pollution by switching to the use of renewable energies in generating electricity. Iraq can follow the example of the GCC countries and their pioneering experiences in this field [20].

Solar energy represents one of the most important sources of renewable energies in Iraq [21]. This energy is available almost permanently, free of charge, and has a high power output to be used in CPS stations and by photovoltaic cells [22]. Thermal energy can also be produced to heat air and water for domestic uses. The photovoltaic cells can be used in remote areas away from network connections to generate electricity [23, 24]. It can be used for outdoor street lighting [25], and can operate communications towers in remote locations [26]. In the case of the remote residential communities, in such areas more than one method can be integrated to generate electricity, such as using wind power with diesel generators in addition to photovoltaic cells to equip residential complexes with electricity [27 & 28]. Even in cities where electricity grid is available, load can be reduced by converting part of the required energy, such as parking lights, health clinic to the use of PV modules [29, 30]. Many of the more remote and well-used farms are now using solar energy to rotate working pumps [31, 32]. Solar energy can also be used directly to produce potable water [33, 34].

Despite the enormous potential of Iraq in the field of solar applications but to date it is backward and rare use. The shift to solar energy needs a lot of attention and educating the public on its importance. To date, electricity has not been regulated and rationalized in homes and government departments, and the use of electricity has continued to affect its limited potential. This article reviews many of the research efforts that have been made to verify the possibility of using solar energy applications in Iraq and their use. In this study, we will focus on reviewing the published scientific researches related to Iraq or neighboring countries with the same solar conditions.

II. THE WATER HEATING

Perhaps the simplest application of solar energy is to heat water for domestic or industrial purposes. This application is widespread around the world and reduces the use of fossil fuels. Unfortunately, this application is lagging behind in Iraq, despite the right weather conditions. The solar radiation in Iraq is not less than 265 W/m2 in winter, which is a high intensity that gives high heating temperatures and suitable for this application [35].

Ref. [36] investigated the possibility of increasing the thermal storage time of a solar heater after sunset by using pipes filled with two materials: first Pebbles as a sensible heat storage media, and secondly the paraffin wax as a phase change material (PCM) that represents the latent heat storage media. The study showed that the use of latent heat storage media is better than using the sensible heat storage media. The weight of the added substances to the water tank is also less in the case of PCM. The used water heater works for longer periods so that the water stays hot inside the tank until the next morning.

Ref. [37] studied the solar collector's performance using a water-based evacuation tube containing single-walled carbon nanotubes. The results showed that higher efficiencies were achieved for concentrations higher than one of carbon nanotubes walls. The energy efficiency of the collector increased with the value of solar radiation. Ref. [38] examined the use of Al2O3-water nanofluid in a flat plate solar collector to evaluate its impact on the collector performance. The results showed that energy efficiency increased when using nanofluid by 83.5% for 0.3% v / v and 1.5 kg/min flow rate, and the thermal efficiency of the system increased by more than 50% compared with the system used without nanofluid.

III. THE SOLAR AIR HEATERS

Ref. [39] studied practically the use of concrete as a major part of the air heater, and in the second case the authors studied the use of paraffin wax as a phase change material (PCM) added to the concrete as a basic part of the air heater. Field experiments took place in the climate conditions of the city of Baghdad-Iraq in January and February 2012. The practical measurements showed that the outside air temperatures increase significantly for the second case compared to the first case and the efficiency of the system improves. The highest storage efficiency was 54.13% for the wax condition compared to the concrete. The increase in heat obtained for the second case (with wax) was higher by 54.97% compared to the first case.

Ref. [40] designed and manufactured a transparent collector solar air heater had an area of 1 m2. The heating source in this design was an aluminum plate that was heated by the solar radiation directly. The experimental tests results showed that this solar air heater was suitable for Iraq weathers. The tested air heater increased the heated air by about 101% more than the ambient air.

Ref. [41] research the feasibility of storing excess solar energy using lauric acid as phase change materials (PCM) and release it when energy is insufficient or not available for solar drying. The results showed that the temperature of the hot air and the inside air speeds set the charge time, while during the discharge period only affect the speed of the inside air. The researchers in Ref. [42] have created a parabolic concentrator collector to condense and assemble the solar rays using mild steel with a fixed copper serpent tube on the plate of a flat absorption, this collector has been designed to work in the Iraqi climates. The results of the study showed that the highest temperature was recorded in August and was 120°C with a reflective temperature of 69°C and aperture of the lens and the glass temperature cover is 43°C.

IV. THE SOLAR THERMAL STORAGE WALL (TROMBE WALL)

This wall is a wall built of materials available such as water and stones. This wall is called the Trombe system and is used to heat the air in winter. This technology can be summed as the Trump wall system is a solar collector that acts as a heat storage device in buildings [43]. This application has promising prospects, especially with the development of transparent insulation technology and the possibility of adding it in the structure of the wall. This wall has huge storage capacity with a positive energy balance during the heating period, thus contributing to heating the building [44]. Weather conditions affect the performance of this wall and the most important conditions are the intensity of solar radiation, which can be considered ideal for the wall. Clouds reduce the solar radiation intensity, and then it reduces the performance of the Trombe wall, but the period of clouds is little in the atmosphere of Iraq in general, which makes their impact during the winter season is limited.

The wind speed, the faster the speed the less thermal storage of the wall. Iraq is characterized by low wind throughout the year especially winter and therefore wind speed will not be an obstacle to the use of the wall. Dust can be a problem in the case of a transparent surface on the wall; this is a bit of a consequence, if we know that the dust storms decrease significantly during the winter of Iraq.

Ref. [45] designed and tested a wall manufactured with a number of water bottles in the atmosphere of the winter of Baghdad city for the period 2006 and 2007. The results showed a high capacity for this wall to store the sun's energy for a period of time from 7:00 AM to 5:30 AM of the next day. The designed wall reached a maximum water temperature of 64.6°C, while the highest temperature of the metal wall was 74.4°C. Ref. [46] built a heat storage wall from simple building materials, available locally and cheap. The appropriateness of this wall to Iraqi homes was examined in the winter of Baghdad-Iraq (December 2014 and January 2015). The results of the study proved that the designed wall is suitable for use in Iraqi winter. The use of PCM in such a wall gave promising and good results as it gave a high and sufficient thermal storage, in addition to its availability at low prices in local markets.

Ref. [47] built two thermal storage walls that were designed to study the effect of enhancing the thermal conductivity of paraffin wax on the charge and discharge periods of the wall by adding nano-Al_2O_3 to paraffin wax in one wall. The improved thermal conductivity of the paraffin wax with the addition of nanomaterials has improved the speed of charging and discharging. The addition of nanoparticles to wax has also resulted in higher temperatures and less charging period of the wall compared to a wall that uses only wax. Also, the outside air of this wall is hotter than the case of wax wall only, and the stored energy loss is faster as well. The Trombe wall with nanoparticles and wax stored higher temperatures up to 29.08% compared to the wall of wax alone.Ref. [48] built a simple storage wall (Trombe wall) and tested this wall in the winter conditions of Baghdad. Thirty-three plastic water bottles placed inside the wall with paraffin wax that was confined by a glass panel. Paraffin wax used was about 10 kg. The researchers measured the distributed temperature in variable parts of the Trombe wall and evaluated the energy stored within these parts. The results showed that the studied wall is effective in storing solar energy and can be used as an auxiliary method to heat homes after sunset.

V. THE SOLAR PONDS

In solar saline ponds, solar radiation is converted into heat and stored for long periods in the salty water layers of the pond. This application needs high solar radiation intensity as well as high atmospheric temperatures, both of which are available in the atmosphere of Iraq [49]. The raw salt used in this type of ponds is available in Iraq at very low prices. Iraq's porous sedimentary soil makes it expensive to set up such ponds and isolate them in a variety of ways. The primary obstacle for such application is still the dust, as its accumulation reduces the solar radiation intensity reached to the lower layer of the pond, hence, reducing the system effectiveness and efficiency [49].

Ref. [50] connected a simple solar double sloped basin type still to a solar salt gradient pond. The solar pond heated recalculated water, and this hot water used to heat the brackish water in the distiller along daylight and night. The tests were conducted in Iraqi Autumn weathers and the results show increase in the distiller daily productivity with larger productivity increase at night. Ref. [51] tried to increase the efficiency of the solar pond system and access to optimal performance using several modifications and improvements. A small solar pond was employed for this purpose with increasing the water temperature by using reflective mirrors. The researchers used the Taguchi method to determine the best performance of the set of variables studied and they concluded the validity of this method to determine the best.

Ref. [52] worked on adding heat to a solar pond using an external source to enhance its performance. The hollow solar tube collectors were used to collect thermal energy by transferring liquids to the lower convection zone of the solar pond. The results of the study showed that in the absence of a decrease in heat extracted from the pond, the heat will lose from the pond in fact; also, adding liquid at specific periods of time may cause a significant decline in the temperature of the solar pond. Ref. [53] measured and compared the spread of salt in a salted solar pond when a transparent polyethylene film with permeability greater than 70% was added to separate the lower convection area and the non-convection zone and collect the necessary data for 15 continuous days. The results showed a mass transfer through molecular diffusion. The concentration of salt at the top increases linearly over time while it remains constant to the bottom with a polythene film but decreases in a pool without the polythene film.

VI. THE USE OF SOLAR CONCENTRATION FOR ELECTRICITY GENERATION

A. *The solar chimney*

Solar chimneys rely on heating the air under the collector and directing it upwards through the chimney. Therefore, high air temperature and high solar radiation are prerequisites for solar chimney operation and both requirements are well available in Iraqi weathers [54]. High humidity can cause a reduction in the intensity of solar radiation. However, in Iraq, many areas have relatively low humidity most days of the year; making the use of this application to generate electricity possible [55]. Also, here the dust that is abundant in Iraqi climates represents an obstacle to the use of solar chimney. This point must be studied in great detail because of its importance in determining whether this application is successful or not. The use of variable types of detergents and cleaning methods is important in this regard [56].

Ref. [57] has conducted a numerical study of heat transfer and fluid flow in the solar chimney. Different surface sites were used to test the most suitable solar chimney. The results showed that the best ventilation can be obtained when the absorbent surface of the solar chimney is in the middle of the air gap. Ref. [58] used the solar simulator system and the temperature controller system with the setting up and preparation of a solar chimney with a collector diameter of 1.22 m and a 1 m high chimney in the laboratory to study the performance of the solar chimney with environmental variables. The results showed that the experimental work of the study helped in preparing the chimney and in understanding the thermal properties of solar energy.

B. *The concentrated power stations (CPS)*

Solar stations that need to focus solar radiation on a particular target to heat it to high temperatures are called CPS. These stations are better for them to work in Iraq's hot air in general, which is clear sky by 334 days a year [59]. The intensity of solar radiation in Iraq, whether in summer or winter is high intensity and suitable for such applications [60]. The high humidity in certain areas of Iraq affect relatively the efficiency of the work of such stations, and to date no field study about this subject has been conducted in Iraq. Perhaps the most dangerous thing to do with CPS in Iraq is the dust accumulated on the reflectors or mirrors of the system. The accumulation of dust reduces the solar radiation intensity reaching the reflector or the mirror and thus reduces the reflected radiation, and then reduces the temperature of the target [61].

Ref. [62] studied the possibility of improving the efficiency of a concentrated solar power plant. The researchers studied three cases: dye the central target in black, put a reflector behind the target, and use the two variables together. The results of the study showed a clear improvement in the efficiency of thermal storage for the third case, and this efficiency varies from month to month. The highest value of thermal storage was obtained in August.Ref. [63] confirmed experimentally that the Iraqi climate is suitable for this system. The study revealed that it is possible to attain high target temperatures that can operate a power station. Besides, the study concluded that coloring the target with a selective black color increased the target absorption that increases its temperatures and stored energy.Ref. [64] suggested adding a thermal energy storage system to concentrated solar plants to avoid interruption of power supplies. The results indicated that the solar radiation intensity plays an important role in thermal storage capacity. The properties of the material used and the specifications of the capsule have a significant role in influencing the thermal performance of the system.

The researchers in Ref. [65] studied the solar thermal power generation systems that operate at temperatures higher than 400°C and the usefulness of using salt as a variable phase change material. The study showed that the thermal properties such as the melting point and the latent heat vary from one type of salt to another and the radiation characteristics of each salt. Inorganic salts can be used in CPS systems and are promising in this application. Nitrate salts are currently widely used in this field. That chloride salts did not take their role of interest. The researchers suggested several systems using chloride salt can be used in high-temperature solar plants (400 degrees Celsius).

C. The PV Modules

Iraq as a one of the third world countries needs to use renewable energy technologies such as solar energy, as it is an appropriate and viable option. In the same time, the entire area of Iraq receives huge amounts of solar radiation throughout the year [66]. The solar cell is influenced by many weather factors such as temperature, humidity and air mass. It is also affected by its location and the intensity of its shadow on the cell [67].

The high temperatures that characterize Iraq's atmosphere are beneficial and negative at the same time. On the one hand, it is useful when using solar concentrated power station (SCPS) as these stations need very high temperatures to generate electricity [68]. On the other hand, high temperatures cause lower productivity of PV cells most of the year, as the increase in temperature affects the PV voltage, as a result, reduces the generated power [69, 70]. Ref. [71] studied the effect of temperature, solar radiation, and wind speed on optical system performance (PV) in the climatic conditions of Iraq due to its changing and sharp environment. The results of the study showed that temperature plays an important role in the PV system performance (PV). The high intensity of solar radiation in Iraq has a good effect on the performance of PV, but the effect of wind has been limited as well as rain effect. The effect of dust accumulation and pollution is evident on PV performance. The researchers concluded that the widespread use of PV systems in Iraq depends on the extent of reducing the impact of the studied weather variables.

The results of Ref. [72] study showed that the effect of wind (moderate and slow speed in Iraq) was negligible in cooling the temperature of solar cells. The high relative humidity led to a decrease in the intensity of solar radiation, which was reflected in the low temperature of the solar air and improve the output of the solar cell.Ref. [73] try to find the wavelength color that can generate the highest capacity of the PV panel and the best conversion of electricity. The results of the study found that the production of photovoltaic panels with the presence of natural spectrum is the highest compared to any other colored light. The use of a blue screen above the solar cell produced the lowest output power when compared to another color beam. The conclusion was that the visible spectrum of solar radiation directly affects the results of solar panels.

Ref. [74] investigated the effect of relative humidity on the performance of the PV system. The results show that PV cell productivity for voltage and power are increased with relative humidity decrease. The efficiency of PV goes up with low humidity. Ref. [75] indicates that relative humidity affects and is affected by other climate variables. The results of the study confirmed that relative humidity significantly affects the performance of PV power as well as the current and voltages are reduced when relative humidity is increased. The results indicated that the efficiency of the PV plate is low during the high relative humidity period.

Dust causes a reduction of solar radiation reaching the earth and thus reduces the productivity of solar cells and disrupts the work of CPS [76].

Ref. [77] investigated the concept of air mass, which describes the effect of solar radiation intensity in a bright atmosphere. The study showed that the air mass had a significant effect on the electric PV cell current. Also, the effect of the air mass on a monocrystalline cell was large and clear on the short circuit current of the cell.

Ref. [12] has extensively reviewed all the human, environmental and weather conditions that have caused the dust phenomenon to spread in Iraq. Some of the harmful effects of this dust on solar cells and cleaning techniques have also been shown to minimize its effects. Ref. [78] made a cost-effective solution using a hybrid system consisting of diesel generator and photovoltaic cells for use by civilians and the government to reduce electricity demand and reduce greenhouse gas emissions in Iraq. The researchers used the Homer software to evaluate this hybrid system for the city of Sadir and calculate the electrical demands with the initial costs. The result revealed promising calculations in this field, which made the researchers to claim that this option could be the real solution to the electricity problems in Iraq.

Ref. [79] revealed that air temperature, relative humidity, and wind speed directly affect the determination of dispersed dust and how it accumulates on the cell. On this basis, the type of cleaning required can be determined. The importance of this study is caused by the wide range of desert in the Arab countries. This area is hot and dusty most of the time. Ref. [80] investigated the impact of air pollution resulted from highways on the performance of photovoltaic cells. The results suggested that air pollution may lead to degradation of PV cells, even with a short period of two months of external exposure to pollution without cleaning. Also, the contaminated photovoltaic cells lost about 12% of its power while the naturally cleaned cells lost about 8% compared with the clean cell. The study revealed that pollutants accumulated on the PV panel surface have hydrocarbon particles resulting from traffic exhausts. The results of the study of different methods of cleaning the photovoltaic cells showed that the surface use of sodium or alcohol maintained high rates of its performance. The results of the study confirmed that the possibility of using photovoltaic cells in Iraq instead of diesel or gasoline generators is highly satisfactory.

Ref. [81] has made an assessment of the use of PV panels in five different locations around the city of Baghdad. The results showed that the systems installed in agricultural areas were less affected by the dust, while densely populated areas were more affected by this pollutant.

Ref. [82] focused on the photochemical reactions of gaseous pollutants in the atmosphere and dried droplets of seawater and their salt molecules, which cause that the most particles with a diameter smaller than 2µm. The physical properties of dust, such as gravity, particle shape, surface properties, moisture content, plastic and liquid limits, and specific grain size, vary from place to place. The reason for these differences is the topographic, geological and environmental conditions of each region. The weight and shape of dust particles also greatly affect the method of deposition and performance of PV. The author of Ref. [83] tested the effect of variable types of dust and pollutants on three types of PV panels (monocrystalline, polycrystalline, and non-crystalline). The different air pollutants studied were red soil, ash, sand, and brown sand. The results of the study showed that there is a significant reduction in the photovoltaic power produced that depends on the type of pollution and the degree of accumulation. The red soil had the highest impact on monocrystalline and polycrystalline panels. The brown sand was more efficient on the resulting power of the amorphous PV panel.

Many researchers suggested using photovoltaic thermal (PVT) systems to get rid of the heat of the solar cell panel and thus increase its efficiency, and secondly to take advantage of the heat absorbed from the PV panel in other thermal applications [84].Many researchers have discussed the importance of these systems in the hot areas, especially those located in the solar belt or close to it, such as Iraq [85]. Ref. [86] reviewed the numerous research conducted on PV T systems and the methods and techniques used to increase the overall system efficiency, reduce cost and increase the life of the system. Ref [87] recirculated nanofluid (nano-SiC-water) in a PVT system and found that the stability of the nanofluid after six months after measuring the decrease in thermal conductivity was at a low rate not more than 0.003 W/m K. Electrical efficiency increased by 24.1% compared to the PV system alone when using nanofluid, thermal efficiency reached 100.19% higher than the use of water for cooling. Ref. [88] provided a technical and economic evaluation of the PVT system with nanofluid. The researchers used a theoretical and practical means in the study and analyzed the system productivity, the cost of energy, and the recovery period. Ref [89] investigated the possibility of identifying any nanomaterial that has the best effect on the PVT unit in general. The knowing the quality of the nanomaterials helps in identifying the most suitable nanoparticles of the system. The practical results showed that SiC-nanofluid gave the higher thermal conductivity compared with alumina and copper oxide.

Ref. [90] investigated the temperature effect on the optical concentration using heat energy for storage using solid and liquid phase change (PCM) under tropical dry climatic conditions. The results of the study showed that the use of PCM at melting temperature in the range of 45°C to 65°C is suitable for regulating and storing thermal energy in a tropical dry climate. The choice of melting point depends on the requirements of energy used.

Ref [91] claimed that hybrid PVT systems technology represents a promising solution especially when the roof area is limited or when heat and electricity are required at the same time. The combination of solar thermal collectors with photovoltaic modules (PV) can provide both heat and electricity simultaneously from the same installed area and with higher efficiency compared to individual solar thermal power or the PV panels are installed separately. Ref. [92] has manufactured four different PVT hybrid solar collectors and tested its air-cooling methods. Environmental variables such as temperature of the upper and lower surfaces of PV panels, air temperature along collector, air flow rate, low pressure, energy produced by solar cells, and weather conditions such as wind speed, solar radiation and the ambient temperature of Baghdad were examined. The results showed that combining the efficiency of double-channel collector and one pass is higher than the one-channel model and double-pass. The single-channel model produced the best electrical efficiency.

Ref. [93] performed a techno-economic performance calculations to evaluate the simultaneous provision of domestic hot water (DHW), space heating and power of a hybrid photovoltaic-thermal (PVT) collector. The results showed that the proposed system could provide 77% of the total household thermal demand and 145% of the average electricity over the four seasons, with the export of surplus electricity to the grid, which means an increase in the beneficiary's income.

VII. THE SOLAR DISTILLATION

Water distillation and purification processes take considerable energy from fossil fuels, causing significant air pollution. Therefore, the use of solar distillation will reduce the need for fossil fuel consumption and improve air quality. Solar distillates have the potential to increase their productivity by increasing their space to suit the consumer [94]. Iraq is an ideal country for solar water distillation applications because it enjoys a good radiant energy throughout the year. Simple solar distillates are characterized by low productivity and need for large areas exposed to solar radiation. It also requires that the transparent outer surface (condenser) to be cool and at a lower temperature than the evaporated water coming from the still bottom (evaporator). The moderate wind speed benefits the cooling of the transparent glass and thus increases the distilled productivity. As for dust, its accumulation reduces the solar radiation that reaches the distilled water and thus reduces the performance of the system. Solar radiation in Iraq is well suited to the process of solar distillation, but summer temperatures do not suit this structure at all. So the Iraqi researcher worked on finding smart and simple ways to increase distillate productivity.

Ref. [95] used of a solar system consisted of a concentrated solar heater linked to the solar distiller to increase the temperature of the water inside the still and storage of thermal energy extracted from it. Paraffin wax was also selected to store thermal energy in two separate isolated boxes. Paraffin wax gets the heat from the hot water coming from the concentration solar dish. This solar energy is stored in PCM as latent thermal energy. Large solar energy stored in the day is retrieved and used later after sunset. The distilled water production time of the system has increased to about 5 hours if the sun is tracked by the solar center system and wax is added to the system. The efficiency of the system has increased by 64.07%, heating efficiency about 112.87% and system productivity by 307.54%. Ref. [96] provided a simple distillation system with a low cost concentration unit that can be borne by a simple citizen. Paraffin wax was used to increase heat absorption and storage from hot water. The study showed that this system is suitable for desert areas and gives acceptable productivity compared to other systems. The addition of paraffin wax to the distillation system resulted in increased system productivity, increased concentration efficiency by 50.47%, increased heating efficiency about 157.8%, and increased system productivity by 783%.

Ref. [97] introduced a practical study to increase the heat transfer to and from paraffin wax found in the solar distillation system. In this study, aluminum powder was added to paraffin wax to enhance thermal conductivity. Practical tests conducted in Baghdad in January and February, 2013. Results showed that aluminum powder-mixed with wax increased the thermal conductivity compared with the basic materials. This addition caused better distillation efficiency and longer production time. Paraffin wax has low heat transfer rate during melting / freezing due to its low thermal conductivity. Ref. [98] studied enhancing the thermal conductivity of paraffin wax by adding alumina nanoparticles (Al_2O_3) and TiO_2 by mass percentages of 1, 2, 3, 4 and 5% to Iraqi paraffin wax. The results indicated that thermal conductivity of paraffin wax increased with the amount of added nanoparticles. The speed of thermal energy charging and discharge has greatly improved by this addition compared to net paraffin wax. Ref. [99] designed and manufactured a distillation system to solve the problem of solar distillation in hot climates, where the production of simple solar distillate stops from 12 am to 3 PM. The results showed that the proposed system increased distillate production by 120.8% without any cooling aid. With the use of air cooling after 4 PM, the productivity increased by 337.36%. When using water for cooling after 4 PM, the productivity increased by 403%. The cost of the proposed system was acceptable and within the means of people in remote areas.

Ref. [100] investigated experimentally the possibility of improving distilled solar energy through three methods working at the same time. These methods were: a) improve the conventional design and propose a design that ensures an increase in the condensation surface; b) by coupling the collector / storage of the solar water heater to the solar energy still. The water will be heated before it is sent to solar energy, and c) the use of gravel as a storage material for perceived heat which can be used when sunlight is not available.Ref. [101] made some modifications to the solar distillation and studied the distiller energy balance. The results of the study showed that the modified gradient distiller performance after improvements was better than its performance before modification.

VIII. Conclusions

The results of the published research review, which study and examine the possibilities of operating various solar systems in Iraq, give hope not only to reduce the dependence on fossil fuels in energy production, but also to produce energy that is surplus to the needs of the country and can be exported to neighboring countries. All solar applications can be implemented and presented to the consumer as soon as possible and the financial and air conditions help to spread them. The main problem in the spread of solar energy applications lies in two main points: First: low public awareness of the reduction and rational of electricity consumption. Second: low public awareness and decision-makers in the importance of using all solar applications as a renewable alternative instead of fossil fuels. The Iraqi researcher, despite the lack of fund resources available to him, studied objectively and thoroughly and scrutinized everything that helps decision-makers to get rid of the lack of clarity in the vision. The proliferation of solar energy applications today depends largely on the courage and determination of decision-makers in Iraq.

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