International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Analysis of Stand-Alone Solar Photovoltaic for Desert in Iraq

Ali A K Al-Waeli[1], Kadhem A N Al-Asadi[2]
[1]Ibn Rushed College, Baghdad University, Baghdad, Iraq
[2]Education College for Human Science, University of Basra, Iraq

Abstract— *The demand for electricity in Iraq increased from 11,000 MW in 2007 to 16,000 MW in 2013, and is expected that this demand will be increased to more than 20000 MW in 2020. Iraq has been suffering from a shortage of processed electricity since 1991 and will increase if the current demand continues. The Iraqi government has begun to use solar energy to produce electricity as one of its future goals as part of its focus on reducing environmental damage and pollution of the country's atmosphere, soil, and water as well as working to determine the best ways to use renewable energy in the country. The Iraqi government is working with many local and international research bodies to study renewable resources to generate electricity. The availability of renewable energy sources locally and renewable, in addition to being environmentally friendly, is one of the most important factors determining the choice of new sources of energy. It can be said that solar energy in Iraq meets all these requirements. The level of solar energy density in this country is very high and among the desirable rates globally. As it is free energy for all, renewable for a long time, and does not harm the environment.*

Keywords— *Iraq, Solar Energy, Stand-Alone System, Photovoltaic, environmental variables.*

I. INTRODUCTION

The continued progress and development of societies and the need to provide conditions of comfort, both in housing and transport, have greatly increased global energy demand. Rising demand for energy caused an increase in fossil fuel consumption, which is expected to be depleted soon [1]. The trend towards renewable energies is growing around the world in an impressive way [2]. Applications of power generation from wind stations and fields have begun to spread in many countries around the world [3]. The production of electricity using solar energy has become available and an acceptable option around the world. In Iraq, solar energy can be considered the best and most logical alternative to burning fossil fuels [4]. The solar energy falling to the ground in one hour is enough for a full year of electricity to all the earth if used properly [5]. There is no denying that energy availability is of great importance in the progress and development of societies. It also provides solutions to other dilemmas such as water, food, environment, health, education, climate protection, information, communication and mobility. A sufficient amount of environmentally friendly energy that reduces high air pollution and reduces greenhouse gases is one of the biggest challenges facing the planet today [6].

Solar energy can be used in many applications rather than fossil fuels. It can be used to heat the water in the residential buildings and factories [7, 8]. This energy can also be used to heat the air for home and laboratory heating purposes [9, 10]. It is also currently used to heat the Trombe walls to store heat for ventilation and heating for the comfort purposed in houses and buildings [11, 12]. One of the most promising applications for the use of solar energy is water distillation [13, 14]. Water is the lifeblood and the provision of adequate drinking water to revive residential communities away from urbanization [15, 16]. The most important uses of solar energy today are in the production of electricity and either by concentrated heating or using photovoltaic cells. Solar heat is used to heat the air that rotates wind turbines in solar chimney systems [17, 18], as it is used in concentrated power plants to generate electricity [19, 20]. As for the solar cells, part of this fallen radiation is used in the production of electricity, while the largest part goes to heat the cell [21, 22]. Today, the use of photovoltaic thermal (PV/T) systems is an excellent, realistic, and promising alternative [23, 24]. In these systems, the photovoltaic cell is cooled using a cooling fluid, whether air, water or kinds of nanofluids, to increase its electrical output and to utilize the heat absorbed in other applications [25, 26].

The advantages of crystalline solar cells they are efficient, reliable with long lifetime and have a long record of proven durability [27]. Therefore, they are often the preferred solution for solar-based electricity production on buildings. On the other hand, thin film solar panels are less efficient and have a shorter lifetime [28]. However, thin film technology is increasingly used in small applications. It is generally expected that in the long term, thin film technology with multi-layer cells will be widely used and attain efficiencies beyond 25%. The major advantage of thin film is that they use less material and are therefore potentially less expensive than conventional PV technology [29].

The use of PV technology to produce electricity has become known and popularly accepted these days. Photovoltaic systems are used outside or connected to the electrical grid (producing electricity directly to the network system) [30]. Photovoltaic cells outside the grid are used in small power systems linked to diesel power generators as an alternative to dust storms or clouds [31]. Both these types of PV systems can be used in Iraq. Solar photovoltaic technology is suitable for generating electricity in rural desert areas away from the grid in particular [32]. Iraq is a country rich in solar resources and when using hybrid solar power plants and diesel generators in remote logic, it can reduce fossil fuel discharges to a large extent [33].

Ali A K Al-Waeli and Kadhem A N Al-Asadi, "Analysis of stand-alone solar photovoltaic for desert in Iraq," *International Research Journal of Advanced Engineering and Science*, Volume 3, Issue 2, pp. 204-209, 2018.

The space available for the installation of photovoltaic cells controls the technical possibilities of generating electricity with grid-connected PV systems (for example, buildings, parking spaces, etc.). Assuming that 80 percent of Iraq's homes are flat-topped, the installation of photovoltaic cells is relatively simple. The roofs of the houses are at least 20 square meters in size, so the total potential space available is around 1588 megawatts and a potential annual electricity production capacity of 5180 GWh. The typical photovoltaic capacity per square meter of land is about 30 Wp (Watt peak) corresponding to 30 MWp per square kilometer [34].

The efficiency of photovoltaic cells is affected by different weather conditions such as air temperature [35], solar radiation [36], relative humidity [37, 38], and dust pollution [39, 40]. Various weather conditions have reduced the efficiency of photovoltaic cells in Iraq, and the Iraqi researcher has focused on these conditions and studied them with great concentration. The Iraqi researcher studied the effect of air humidity on the cells and sites where the effect of this moisture affects productivity. They also studied the effect of the intensity of solar radiation in the atmosphere of the city and the desert. The high temperature of the photovoltaic cell reduces its efficiency so this subject has been studied extensively. Treatment with PV/T systems, using nanoparticles, or PCM substances has been reported to reduce this effect [41]. The effect of the accumulation of dust on the surfaces of solar applications in general has taken a considerable amount of study and review [42]. The physical and chemical properties of dust, the type of contaminants and the have a significant role in the rate of low productivity of the solar application whether it is a solar chimney, a concentrated solar power station, or a solar cell [43, 44]. Ref. [45] indicated that periodic cleaning every two weeks maintains a high productivity of the cell provided. Also, the use of specified cleaning materials has a competent. In addition, modeling is important for accurately predicting the annual performance of the PV system for any given geographical location, directing the building, and the type of photovoltaic technology. Models can be used to accurately predict the response of photovoltaic systems to a wide range of operating conditions encountered [46, 47]. Modeling software requires specifying different operational and environmental conditions, which the unit's performance depend on. These inputs can be obtained using a solar simulator or measured natural outdoors conditions [48, 49].

The PV system contains beside PV arrays, various wiring, battery charge controller, inverters, and batteries, mounting hardware, combiner boxes and monitoring equipment [50]. In this paper, we will try to review various articles to evaluate wither the use of standalone PV systems in desert of Iraq is valuable or not.

II. Solar Energy in Iraq

Several valuable scientific studies have shown that total solar energy reaching the Earth's surface is 10,000 times the world's total installed energy reserves per year [51]. Iraq is a region rich in solar energy, where the sun's brightness increases more than 3,300 hours a year. The solar radiation falling in the desert areas of Iraq, which currently accounts for more than 60% of the country's area, is equivalent to hundreds of thousands of times the total energy generated in this country [34]. PV electricity can be considered the main alternative and the most feasible application of solar energy. That solar energy is energy available everywhere and free of pollutants and a true friend of the environment, as the end is not subject to geographical or political restrictions and does not cause consumption of any fuel. At the same time, building the photovoltaic system requires short construction periods, small or medium size design systems can also be provided, so the design size of the PV plant is flexible and can be used directly and can be easily stored or redeployed in other areas. Photovoltaic systems can be combined with buildings. The study of the feasibility of solar energy in Iraq (current and future situation) requires us to discuss the following points: the status of energy in Iraq, the solar density in Iraq; the benefits of using solar energy in Iraq; and the future of solar energy in Iraq.

III. Electrical Energy Status in Iraq

Over the past 60 years, Iraq has suffered from political instability, with many military coups and many government changes that have caused deterioration in services and infrastructure in the country in general. Since 1980 until today, Iraq has been in a constant war and has eaten green and land. In 1980, the Iran-Iraq war sparked, which lasted for eight years. This war caused an increase in government spending on war and reduced spending on infrastructure, especially electricity [52]. In 1991, the first Gulf War broke out when the US-British-French coalition launched the worst campaign in human history to destroy all infrastructures. This brutal aggression targeted all the country's power plants indiscriminately and caused over 95% destruction at all stations. If there is something the Americans can be proud of, it is that they have destroyed infrastructure for a country that is basically weakly built, and they have done something unprecedented even to Genghis Khan [53]. After this war and the destruction of this country, the United States and its allies from the coalition countries imposed resolutions through the United Nations to ease the siege of Iraq and expose its citizens of starvation and causing severe shortages of food and medicine and continued this siege until the invasion of Iraq in 2003 and occupation by the aggressor countries headed by United State.

All these unjust acts of aggression have destroyed the infrastructure of Iraq's power plants. Today, in 2018, Iraq still suffers from a severe shortage in the processing of electricity to citizens, noting that 90% of the factories and government buildings are still out of work [54]. The Iraqi Ministry of Electricity has identified the shortfall in the production of electricity up to 6000 megawatts currently increasing during the summer because of the need to use air conditioners in this hot season of the year, which runs from May until the end of September [34].

The bulk of the country's citizens rely on small or medium-sized generators (not more than one megawatts) to compensate for the lack of government processing [55]. These generators

Ali A K Al-Waeli and Kadhem A N Al-Asadi, "Analysis of stand-alone solar photovoltaic for desert in Iraq," *International Research Journal of Advanced Engineering and Science*, Volume 3, Issue 2, pp. 204-209, 2018.

work with Iraqi gasoline and diesel, which both represent the worst fuels in the world because they contain large amounts of sulfur [56-58]. The operation of these generators causes high noise in addition to the emission of millions of tons of air pollutants and greenhouse gases [59]. The operation of these generators caused additional problems for the environment of Iraq, which is heavily contaminated with the depleted uranium launched by the American warplanes, which has caused contamination of irrigation, water and air for billions of years [42, 60]. It is believed that the number of generators operating in Iraq exceeded two million generators of all sizes.

The use of renewable energies in Iraq is still very late and does not exceed some of the dams that produce hydroelectric power and some shy projects to use PV systems whose capacity does not exceed 10 kilowatts [34].

IV. Solar Density in Iraq

Iraq has a high-density solar card available across the country from north to south. The occurrence of this country in the Middle East, on the north-eastern edge of the Arabian Peninsula, is adjoining the region of the solar system. The climate in this country is very hot, with temperatures reaching 56 degrees Celsius during the hot summer season from the beginning of May to the end of September [61]. The climate in Iraq is generally dry (the rainfall is very small and in small amounts) and the atmosphere is very high. But the weather is humid in the southern coastal area of Basra province, the most popular days of the year [62]. Air conditions such as the heat of the atmosphere associated with high solar radiation, humidity and dust, as well as lack of rain, can be considered as barriers to reducing the use of photovoltaic systems [63]. Desert areas in Iraq, especially near the Saudi Arabian Empty Quarter, are areas of high solar density. The entire area of Iraq can be considered to have a suitable solar intensity for the operation of photovoltaic stations [64]. The solar density of Iraq is approaching the density of the solar belt states, which are considered one of the highest solar densities in the world. According to the Iraqi studies, solar energy in Iraq has the ability to provide enough electricity to meet all the needs of local electricity in addition to the provision of significant quantities of electricity for export [65].

V. Benefits of Using Solar Energy in Iraq

The use of solar energy in Iraq to generate electricity offers many benefits. Solar energy is an environmentally friendly energy: it is clean and sustainable and helps to protect its environment and reduce the damage caused by the production of electricity from fossil fuels [66]. The use of solar energy will certainly reduce air pollution, as it will reduce the emissions of sulfur oxides, nitrogen oxides, carbon monoxide and partially burned hydrocarbons and reduce the emission of the first greenhouse gas (carbon dioxide) in the atmosphere [67]. Solar energy is free energy, which gives it economic advantages; there is no need to spend money to buy fuel or to reduce the damage produced from using it [68]. The reliance on solar energy to produce electricity will reduce the dependence of the Iraqi state on non-renewable sources [69]. Solar systems do not require much maintenance and the highest costs are spent on the installation costs, so there are no recurring costs at all [70].

Going forward with the use of solar energy to produce electricity in Iraq faces two major problems [71]:

First: Electricity is considered subsidized goods in the Republic of Iraq; it is sold at prices below the actual cost. On average, the Iraqi government supports at least 28%, and the amount of support is greater than that up to 50% in some areas of Iraq. Iraq (the rich country in oil and gas) relies on electricity production through generators using black oil or diesel, as well as many natural gas generators [34]. The actual cost of oil production and decontamination or production and transportation of natural gas for the current generation is already low, because these materials are produced domestically [72, 73]. A liter of diesel fuel is sold for $ 0.20 while natural gas is sold at $ 1.50 per million British thermal units (approximately the same as 1,000 cubic feet of gas). The Iraqi government pays more than this value and can sell this gas at much higher prices and export it to the world as liquefied natural gas at a price of around $ 4/MCF, and natural gas prices in Europe and the USA have recently raised to $ 8. Oil has risen recently to exceed the $ 60 a barrier.

Secondly: Theoretically, if the Iraqi government partially subsidizes solar through carbon trading, unfortunately till today the government has not established the internationally recognized resolutions and laws to promote and allow trading in carbon offsets under the Kyotot Protocol (with a current value of at least $ 20 per ton) of CO. The presence of such regulations, which have the force of law, can be used to reduce the effective "gas price equivalent" by more than $ 1.20 per MCF [74].

VI. Future of Solar Energy in Iraq

Why is the current focus on renewable energy and solar energy in Iraq these days? The correct answer is that this concentration is due to the lack of energy in exchange for the rising demand for it, and the fluctuation of oil prices rapidly and largely, causing a global economic recession, in addition to the rising prices of natural gas and the environmental hazards resulting from pollution from the burning of fossil fuels such as coal, oil and natural gas [75]. The available resources of solar energy in Iraq can be considered in addition to the availability of sites necessary to build such stations [76]. As Iraq is a country rich in oil and gas reservoirs, the availability of government incentives and increased funding and investment options are reasons to focus on solar power generation [34].

This focus is one of the future objectives of the Iraqi government and as part of the focus on improving the environment and reducing pollution. In addition to the required work needed to develop the citizens' awareness about the benefits of using renewable energy such as solar energy in the country. So far, the Iraqi Ministry of Electricity has not worked out a plan to deploy renewable energies to generate electricity [34]. Practical and theoretical studies of solar energy have shown that Iraq has the potential to create solar power systems. Authors of the book found that the large-scale commercial solar project is applicable in the country. The

Ali A K Al-Waeli and Kadhem A N Al-Asadi, "Analysis of stand-alone solar photovoltaic for desert in Iraq," *International Research Journal of Advanced Engineering and Science*, Volume 3, Issue 2, pp. 204-209, 2018.

possibility of establishing a photoelectric system in Iraq was also discussed with the impact of weather variables on the efficiency and performance of PV systems.

The Iraqi Ministry of Electricity has confirmed that it will list several renewable energy pilot projects. Of these projects the project to establish a power plant using 100 kW of solar PV, and another project with a capacity of 10 MW. These pilot projects, if implemented, will contribute electricity to the rural areas and the marshes of Iraq and provide more than 30 gigawatt hours of annual diesel generation with renewable electricity [34]. As a result, diesel consumption will be reduced by more than 11.5 million liters annually and avoided over 18735 metric tons of carbon dioxide per year.

Ref. [77] studied the different performance parameters of the photovoltaic systems and the atmospheric effects of Iraq. The results of the study gave a clear idea and solid information about the feasibility of PV systems for independent work in the Iraqi desert. The information available from manufacturers is usually limited to temperature coefficients, such as the current short circuit current, the open circuit power of the Voc, and the maximum Pmax capacity, in the classification conditions. This information, although useful in comparing the performance of photovoltaic units in classification conditions, is not sufficient to predict performance under uncharacteristic operating conditions, especially in extreme conditions that apply during the summer periods of Iraq.

In addition, the numerous studies conducted by the Refs. [78, 79] on the effect of dust on the performance of the solar cell and how to reduce the damage resulting from it, either by periodic cleaning or other cleaning methods have laid an acceptable basis to move forward in the projects of power production using safe systems and provide stable electricity.

VII. Conclusion

Iraq can be considered one of the most feasible and preferred areas for the implementation of photovoltaic solar systems in the world. The reliance on electricity produced by the PV system provides many immediate benefits to the lives of people in the deserts of Iraq. These systems can also be used in small towns and villages or in Iraq's vast marshes. The stations must be constructed with efficient load characteristics and maintain the necessary energy supply used by the Iraqis.

Numerous studies by Iraqi and non-Iraqi researchers have shown that the performance of photovoltaic systems to be installed in different parts of Iraq can work at almost the best performance. Also, these systems will produce enough energy that will meet the requirements of pregnancy for the Iraqi citizen in the desert and the marshes and remote areas. Many studies of the life cycle cost of the system have been considered, with the appropriate design of course, it is possible to extend the life span of all parts of the system, which will reduce the cost of replacing these parts to a large extent and reduce the cost of the system in view of its operating life.

References

[1] M. T. Chaichan and K. A. H. Al-Asadi, "Environmental impact assessment of traffic in Oman," *International Journal of Scientific & Engineering Research*, vol. 6, no. 7, pp. 493-496, 2015

[2] M. T. Chaichan, S. H. Kamel & A. N. M. Al-Ajeely, "Thermal conductivity enhancement by using nano-material in phase change material for latent heat thermal energy storage systems," *SAUSSUREA*, vol. 5, no. 6, pp. 48-55, 2015.

[3] H. A. Kazem and M. T. Chaichan, "Wind resource assessment for nine locations in Oman," *International Journal of Computation and Applied Sciences IJOCAAS*, vol. 3, no. 1, pp. 185-191, 2017.

[4] A. H. A. Al-Waeli, K. Sopian, H. A. Kazem and M. T. Chaichan, "PV/T (photovoltaic/thermal): Status and future prospects," *Renewable and Sustainable Energy Review*, vol. 77, pp. 109-130, 2017.

[5] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Renewable energy and GCC States energy challenges in the 21st century: A review," *International Journal of Computation and Applied Sciences IJOCAAS*, vol. 2, No. 1, pp. 11-18, 2017.

[6] A. H. A. Al-Waeli, K. Sopian, H. A. Kazem and M. T. Chaichan, "Photovoltaic solar thermal (PV/T) collectors past, present and future: A review," *International Journal of Applied Engineering Research*, vol. 11, no. 22, pp. 1075-10765, 2016.

[7] H. A. Kazem, H. S. Aljibori, F. N. Hasoon and M. T. Chaichan, "Design and testing of solar water heaters with its calculation of energy," *Int. J. of Mechanical Computational and Manufacturing Research*, vol. 1. No. 2, pp. 62-66, 2012.

[8] M. T. Chaichan, K. I. Abass & H. M. Salih, "Practical investigation for water solar thermal storage system enhancement using sensible and latent heats in Baghdad-Iraq weathers," *Journal of Al-Rafidain University Collage for Science*, issue 33, pp. 158-182, 2014.

[9] M. T. Chaichan, K. I. Abass, D. S. M. Al-Zubidi, H. A. Kazem, "Practical investigation of effectiveness of direct solar-powered air heater," *International Journal of Advanced Engineering, Management and Science (IJAEMS)*, vol. 2, no. 7, pp.1047-1053, 2016.

[10] M. T. Chaichan, A. J. Ali, K. I. Abass, "Experimental study on solar air heating," *Al-Khawarizmi Eng. Journal*, vol. 14, No. 1, pp. 1-9, 2018.

[11] M. T. Chaichan, K. I. Abass, "Performance amelioration of a Trombe wall by using phase change material (PCM)," *International Advanced Research Journal in Science, Engineering and Technology*, vol. 2, no. 4, pp. 1-6, 2015.

[12] M. T. Chaichan, K. I. Abass, D. S. M. Al-Zubidi, "A study of a hybrid solar heat storage wall (Trombe wall) utilizing paraffin wax and water," *Journal of Research in Mechanical Engineering*, vol. 2, No. 11, pp. 1-7, 2016.

[13] M. T. Chaichan, H. A. Kazem, "Single slope solar distillator productivity improvement using phase change material and Al2O3 nanoparticle," *Solar Energy*, vol. 164, pp. 370-381, 2018.

[14] M. T. Chaichan, H. A. Kazem, K. I. Abass, A. A. Al- Waeli, "Homemade solar desalination system for Omani families," *International Journal of Scientific & Engineering Research*, vol. 7, no. 5, pp.1499-1504, 2016.

[15] M. T. Chaichan, "Enhancing productivity of concentrating solar distillating system accompanied with PCM at hot climate," *Wulevina*, vol. 23, no. 5, pp. 1-18, 2016.

[16] M. T. Chaichan & H. A. Kazem, "Water solar distiller productivity enhancement using concentrating solar water heater and phase change material (PCM)," *Case Studies in Thermal Engineering, Elsevier*, vol. 5, pp. 151-159, 2015.

[17] S. T. Ahmed & M. T. Chaichan, "A study of free convection in a solar chimney sample," *Engineering and Technology J*, vol. 29, no. 14, pp. 2986-2997, 2011.

[18] M. T. Chaichan, "Practical study of basement kind effect on solar chimney air temperature in Baghdad-Iraq weather," *Al Khwarizmi Eng. Journal*, vol. 7, No. 1, pp. 30-38, 2011.

[19] M. T. Chaichan & K. I. Abass, "Practical investigation for improving concentrating solar power stations efficiency in Iraqi weathers," *Anbar J for Engineering Science*, vol. 5, no. 1, pp. 76-87, 2012.

[20] M. T. Chaichan, K. I. Abass, H. A. Kazem, "Energy yield loss caused by dust and pollutants deposition on concentrated solar power plants in Iraq weathers," *International Research Journal of Advanced Engineering and Science*, vol. 3, no. 1, pp. 160-169, 2018.

[21] H. A. Kazem, M. T. Chaichan, "Effect of environmental variables on photovoltaic performance-based on experimental studies,"

International Journal of Civil, Mechanical and Energy Science (IJCMES), vol. 2, no. 4, pp. 1-8, 2016.

[22] H. A. Kazem and M. T. Chaichan, "The impact of using solar colored filters to cover the PV panel on its outcomes," *Bulletin Journal*, vol. 2, no. 7, pp. 464-469, 2016.

[23] M. T. Chaichan, H. A. Kazem, A. M. J. Mahdy & A. A. Al-Waeely, "Optimal sizing of a hybrid system of renewable energy for lighting street in Salalah-Oman using Homer software," *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, vol. 2, no. 5, pp. 157-164, 2016

[24] M. T. Chaichan, H. A. Kazem, A. M. J. Mahdy & A. A. Al-Waeely, "Optimization of hybrid solar PV/ diesel system for powering telecommunication tower," *IJESET*, vol. 8, no. 6, pp. 1-10, 2016.

[25] A. H. A. Al-Waeli, K. Sopian, M. T. Chaichan and H. A. Kazem, H. A. Hasan, A. N. Al-Shamani, "An experimental investigation on using of nano-SiC-water as base-fluid for photovoltaic thermal system," *Energy Conservation and Management*, vol. 142, pp. 547-558, 2017.

[26] A. H. A. Al-Waeli, M. T. Chaichan, H. A. Kazem, K. Sopian, "Comparative study to use nano-(Al2O3, CuO, and SiC) with water to enhance photovoltaic thermal PV/T collectors," *Energy Conversion and Management*, vol. 148, no. 15, pp. 963-973, 2017.

[27] Z. A. Darwish, H. A. Kazem, K. Sopian, M. A. Alghoul and M. T. Chaichan, "Impact of some environmental variables with dust on solar photovoltaic (PV) performance: review and research status," *International J of Energy and Environment*, vol. 7, no. 4, pp. 152-159, 2013.

[28] H. A. Kazem, A. H. A. Al-Waeli, A. S. A. Al-Mamari, A. H. K. Al-Kabi, M. T. Chaichan, "A photovoltaic application in car parking lights with recycled batteries: A techno-economic study," *Australian Journal of Basic and Applied Science*, vol. 9, no. 36, pp. 43-49, 2015.

[29] M. T. Chaichan, H. A. Kazem, "Experimental analysis of solar intensity on photovoltaic in hot and humid weather conditions," *International Journal of Scientific & Engineering Research*, vol. 7, no. 3, pp. 91-96, 2016.

[30] H. A. Kazem, A. H. A. Al-Waeli, M. T. Chaichan, A. S. Al-Mamari, A. H. Al-Kabi, "Design, measurement and evaluation of photovoltaic pumping system for rural areas in Oman," *Environment Development and Sustainability*, 2016

[31] H. A. Kazem, S. Q. Ali, A. H. A. Al-Waeli, K. Mani and M. T. Chaichan, "Life-cycle cost analysis and optimization of health clinic PV system for a rural area in Oman," *Proceedings of the World Congress on Engineering 2013*, vol. II, WCE 2013, London, U.K., July 3 - 5, 2013.

[32] H. A. Kazem, F. Hasson and M. T. Chaichan, "Design and analysis of stand-alone solar photovoltaic for desert in Oman," *The 3rd Scientific International Conference, Technical College, Najaf*, Iraq, 2013.

[33] A. H. A. Al-Waeli, A. S. A. Al-Mamari, A. H. K. Al-Kabi, M. T. Chaichan, H. A. Kazem, "Evaluation of the economic and environmental aspects of using photovoltaic water pumping system," *9th International Conference on Robotic, Vision, Signal Processing & Power Applications, Malaysia*, 2016.

[34] M. T. Chaichan, H. A. Kazem, "Generating Electricity Using Photovoltaic Solar Plants in Iraq," Springer, ISBN: 978-3-319-75030-9.

[35] M. T. Chaichan, H. A. Kazem, A. A. Kazem, K. I. Abass, K. A. H. Al-Asadi, "The effect of environmental conditions on concentrated solar system in desertec weathers," *International Journal of Scientific and Engineering Research*, vol. 6, no. 5, pp. 850-856, 2015.

[36] H. A. Kazem and M. T. Chaichan, "Design and analysis of standalone solar cells in the desert of Oman," *Journal of Scientific and Engineering Research*, vol. 3, No. 4, pp. 62-72, 2016.

[37] H. A. Kazem and M. T. Chaichan, "Effect of humidity on photovoltaic performance based on experimental study," *International Journal of Applied Engineering Research (IJAER)*, vol. 10, no. 23, pp. 43572-43577, 2015.

[38] H. A. Kazem, M. T. Chaichan, I. M. Al-Shezawi, H. S. Al-Saidi, H. S. Al-Rubkhi, J. K. Al-Sinani and A. H. A. Al-Waeli, "Effect of humidity on the PV performance in Oman," *Asian Transactions on Engineering* , vol. 2, no. 4, pp. 29-32, 2012.

[39] M. T. Chaichan, K. I. Abass, H. A. Kazem, "Dust and pollution deposition impact on a solar chimney performance," *International Research Journal of Advanced Engineering and Science*, vol. 3, no. 1, pp. 127-132, 2018.

[40] M. T. Chaichan, H. A. Kazem, "Effect of sand, ash and soil on photovoltaic performance: An experimental study," *International Journal of Scientific Engineering and Science*, vol. 1, no. 2, pp. 27-32, 2017.

[41] A. H. A. Al-Waeli, M. T. Chaichan, K. Sopian, H. A. Kazem, "Energy storage: CFD modeling of thermal energy storage for a phase change materials (PCM) added to a PV/T using nanofluid as a coolant," *Journal of Scientific and Engineering Research*, vol. 4, no. 12, pp. 193-202, 2017.

[42] A. A. Kazem, M. T. Chaichan & H. A. Kazem, "Effect of dust on photovoltaic utilization in Iraq: Review article," *Renewable and Sustainable Energy Reviews*, vol. 37, pp. 734-749, 2014.

[43] H. A. Kazem, M. T. Chaichan, S. A. Saif, A. A. Dawood, S. A. Salim, A. A. Rashid, A. A. Alwaeli, "Experimental investigation of dust type effect on photovoltaic systems in north region, Oman," *International Journal of Scientific & Engineering Research*, vol. 6, no. 7, pp. 293-298, 2015.

[44] H. A. Kazem and M. T. Chaichan, "Experimental effect of dust physical properties on photovoltaic module in northern Oman," *Solar Energy*, vol. 139, pp. 68-80, 2016.

[45] M. T. Chaichan, B. A. Mohammed and H. A. Kazem, "Effect of pollution and cleaning on photovoltaic performance based on experimental study," *International Journal of Scientific and Engineering Research*, vol. 6, No. 4, pp. 594-601, 2015.

[46] H. Mazin, H. A. Kazem, H. A. Fadhil, S. A. Aljunid, Q. M. Abdulmajeed, M. T. Chaichan, "Linear and nonlinear modeling for solar energy prediction for zone, region and global areas," *Chapter in Renewable Energy in the Service of Mankind, Vol. II, Springer*, pp. 21-34, 2015.

[47] H. Mazin, H. A. Kazem, H. A. Fadhil, S. Alawi and M. T. Chaichan, "Global linear, nonlinear and ANN-based modeling of monthly diffuse solar energy," *WREC XIV Proceedings, University POLITEHNICA of Bucharest, Romania, June 8 – 12*, 2015.

[48] A. H. A. Al-Waeli, K. Sopian, H. A. Kazem, J. H. Yousif, M. T. Chaichan, A. Ibrahim, S. Mat and M. H. Ruslan, "Comparison of prediction methods of PV/T nanofluid and nano-PCM system using a measured dataset and Artificial Neural Network," *Solar Energy*, vol. 162, pp. 378-396, 2018.

[49] H. A. Kazem, J. H. Yousif, M. T. Chaichan, "Modeling of daily solar energy system prediction using support vector machine for Oman," *International Journal of Applied Engineering Research*, vol. 11, no. 20, pp. 10166-10172, 2016.

[50] A. H. A. Al-Waeli, H. A. Kazem, M. T. Chaichan, "Review and design of a standalone PV system performance," *International Journal of Computation and Applied Sciences IJOCAAS*, vol. 1, no. 1, pp. 1-6, 2016.

[51] H. A. Kazem, M. T. Chaichan, A. H. A. Al-Waeli, and K. Mani, "Effect of shadow on the performance of solar photovoltaic," *WREN/WREC World Renewable Energy Congress, Rome, Italy*, 2015.

[52] A. A. Al-Waeely, S. D. Salman, W. K. Abdol-Reza, M. T. Chaichan, H. A. Kazem and H. S. S. Al-Jibori, "Evaluation of the spatial distribution of shared electrical generators and their environmental effects at Al-Sader City-Baghdad-Iraq," *International Journal of Engineering & Technology IJET-IJENS*, vol. 14, no. 2, pp. 16-23, 2014.

[53] B. R. Yaseen, K. A. Al Asaady, A. A. Kazem, M. T. Chaichan, "Environmental impacts of salt tide in Shatt al-Arab-Basra/Iraq," *IOSR Journal of Environmental Science, Toxicology and Food Technology*, vol. 10, No. 1-2, 35-43, 2016.

[54] M. T. Chaichan & H. A. Kazem, "Status and future prospects of renewable energy in Iraq," *Renewable and Sustainable Energy Reviews*, vol. 16, no. 1, pp. 6007–6012, 2012.

[55] A. A. Alwaely, H. N. Al-qaralocy, K. A. N. Al-Asadi, M. T. Chaichan, H. A. Kazem, "The environmental aftermath resulted from chemical bombardment of Halabja Territory for the period 1988-2014," *International Journal of Scientific & Engineering Research*, vol. 6, n0. 9, pp. 40-44, 2015.

[56] M. T. Chaichan, N. M. Ali, "Experimental investigation of the effect of exhausts gas recirculation (EGR) on NOx-Smoke trade-off for SIE

fueled with blends of gasoline/bioethanol," *Al-Rafidain Collage Journal*, issue 39, pp. 388-404, 2016.

[57] M. T. Chaichan, A. H. Kadhum, A. A. Al-Amiery, "Novel technique for enhancement of diesel fuel: Impact of aqueous alumina nano-fluid on engine's performance and emissions," *Case Studies in Thermal Engineering*, vol. 10, pp. 611–620, 2017.

[58] M. T. Chaichan, "Performance and emissions characteristics of CIE using hydrogen, biodiesel, and massive EGR," *International Journal of Hydrogen Energy*, vol. 43, pp. 5415-5435, 2018.

[59] M. T. Chaichan, D. S. M. Al-Zubaidi, "Operational parameters influence on resulted noise of multi-cylinders engine runs on dual fuels mode," *Journal of Al-Rafidain University Collage for Science*, vol. 35, pp. 186-204, 2014.

[60] M. T. Chaichan, H. A. Kazem, T. A. Abid, "Traffic and outdoor air pollution levels near highways in Baghdad, Iraq," *Environment, Development and Sustainability*, vol. 20, no. 2, pp. 589-603, 2018.

[61] A. H. A. Al-Waeli, K. Sopian, M. T. Chaichan, H. A. Kazem, A. Ibrahim, S. Mat and M. H. Ruslan, "Evaluation of the nanofluid and nano-PCM based photovoltaic thermal (PVT) system: An experimental study," *Energy Conversion and Management*, vol. 151, pp. 693–708, 2017.

[62] A. H. A. Al-Waeli, K. Sopian, H. A. Kazem and M. T. Chaichan, "Photovoltaic thermal PV/T systems: A review," *International Journal of Computation and Applied Sciences IJOCAAS*, vol. 2, no. 2, pp. 62-67, 2017.

[63] The US PV Industry Roadmap Through 2030 and Beyond: www.seia.org

[64] H. A. Kazem, M. T. Chaichan, A. H. A. Al-Waeli, K. Mani, "Effect of shadows on the performance of solar photovoltaic," *Mediterranean Green Buildings & Renewable Energy*, pp.379-385, 2017.

[65] M. T. Chaichan & H. A. Kazem, "Thermal storage comparison for variable basement kinds of a solar chimney prototype in Baghdad - Iraq weathers," *International Journal of Applied Science (IJAS)*, vol. 2, no. 2, pp. 12-20, 2011.

[66] L. L. Kazmerski, "Photovoltaic: History, technology, markets, manufacturing, applications, and outlook", *83rd International Seminar in Brighton, Renewable Energy Policy, Security, Electricity, Sustainable Transport, Water Resources/Management and Environment, Brighton, UK*, 4-10 December 2010.

[67] A. H. A. Al-Waeli, M. T. Chaichan, K. Sopian and H. A. Kazem, "Comparison study of indoor/outdoor experiments of SiC nanofluid as a base-fluid for a photovoltaic thermal PV/T system enhancement," *Energy*, vol. 151, pp. 33-44, 2018.

[68] A. H. A. Al-Waeli, H. A. Kazem, K. Sopian and M. T. Chaichan, "Techno-economical assessment of grid connected PV/T using nanoparticles and water as base-fluid systems in Malaysia," *International Journal of Sustainable Energy*, 2017.

[69] M. T. Chaichan, K. I. Abass, H. A. Kazem, "Design and assessment of solar concentrator distillating system using phase change materials (PCM) suitable for desertec weathers," *Desalination and water treatment*, vol. 57, no. 32, pp. 14897-14907, 2016.

[70] H.A. Al-Hinai and S. M. Al-Alawi, "Typical solar radiation data for Oman," *Applied Energy*, vol. 52, pp. 153-163, 1995.

[71] Authority for Electricity Regulation in Oman, "Study on Renewable Resources", Final Report, Oman, May 2008, pp. 14.

[72] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Changing the energy profile of the GCC States: A review," *International Journal of Applied Engineering Research (IJAER)*, vol. 11, no. 3, pp. 1980-1988, 2016.

[73] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Climate change: the game changer in the GCC region," *Renewable and Sustainable Energy Reviews*, vol. 76, pp. 555-576, 2017.

[74] H. A. Kazem, M. H. Albadi, A. H. A. Al-Waeli, A. H. Al-Busaidi and M. T. Chaichan, "Techno-economic feasibility analysis of 1 MW photovoltaic grid connected system in Oman," *Case Study of Thermal Engineering*, vol. 10, pp. 131-141, 2017.

[75] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "The impact of the oil price fluctuations on common renewable energies in GCC countries," *Renewable and Sustainable Energy Reviews*, vol. 75, pp. 989-1007, 2017.

[76] M. T. Chaichan & K. I. Abass, "Practical investigation for measurement of concentrating solar power prototype for several target cases at Iraqi summertime weathers," *1st Scientific Conference for Energy & Renewable Energies Applications, UOT, Baghdad, Iraq*, 2011.

[77] H. A. Kazem, H. A. S. Al-Badi, A. S. Al Busaidi & M. T. Chaichan, "Optimum design and evaluation of hybrid solar/wind/diesel power system for Masirah Island," *Environment, Development and Sustainability*, vol. 19, no. 5, pp. 1761-1778, 2017.

[78] M. T. Chaichan, K. I. Abass, H. A. Kazem, F. Hasoon, H. S. Aljibori, A. A. Alwaeli and A. H. A. Al-Waeli, "Effect of design variation on saved energy of concentrating solar power prototype," *Proceedings of the World Congress on Engineering (WCE 2012)*, Vol. III, July 4 - 6, London, UK, 2012.

[79] H. Mazin, H. A. Kazem, H. A. Fadhil, S. Alawi, Q. Mazin and M. T. Chaichan, "Linear and nonlinear modeling for solar energy prediction on the zone, region and global," *World Renewable Energy Council/Network (WREC XIII), London, UK*, 3-8 August, 2014.