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Solar energy in Iraq: potential and new technologies

Wisal Abdul Razak Ali
Chief Engineer, Head of Administration of Planning Projects - Iraqi Communication & Media Commission-Universal Service Directorate - (CMC) Regulatory Framework body
Baghdad - Iraq

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Corresponding Author

E-mail: wisalali897@gmail.com
Mobile: 07709208636

Abstract
In recent years, climate change is affecting more intensively in the form of water scarcity, desertification, and frequent droughts. In addition, Iraq is experiencing rapid population growth and urbanisation. This increases the needs of socio-economic development. One of the main ways out of the energy crisis in Iraq is solar energy. In this regard, it is of interest to investigate the potential and new technologies of this direction for Iraq.
Material and methods. The source materials are the data obtained from Global Solar Atlas. In this study, analysis and synthesis were used as methods, namely analysis of solar resources in Iraq, analysis of current new technologies in solar energy and synthesis of the results into promising options for the development of this area of energy.
Direct normal irradiation and Horizontal irradiation during the day and year are determined for Iraq in general and by areas in particular. The results are shown on a map and in the form of a histogram. The current technologies in solar energy have also been analysed with a perspective of their application in Iraq. Different designs of semiconductor materials have been analysed in terms of efficiency. Anbar, Sulaymaniyah, Dahuk, Najaf and Erbil showed the best performance under direct normal irradiation for the areas of Iraq. Accordingly, these areas have good potential for the construction of high capacity solar power plant. The analysis of modern technologies in solar energy with the prospect of their application in Iraq and the analysis of different designs of semiconductor materials in terms of efficiency showed the possibility of applying the latest technologies with high efficiency. However, Poli-Si and especially Mono-Si are not quite suitable for climatic conditions due to high sensitivity to high temperatures. Heating of the surface layer to 60-70°C, which is common in summer in hot regions including Iraq, results in a loss of 20 per cent of rated performance.

Introduction

Solar energy is currently one of the most relevant and promising areas in the field of renewable energy sources. Recently, solar energy has been actively developing. New technologies are aimed at increasing the efficiency factor. Solar energy has many advantages: inexhaustibility, noiselessness, ubiquity, that is, the possibility of using it in remote regions of any country, environmental friendliness, the possibility of use in various spheres, as well as rapid development towards increasing the efficiency factor in all climatic zones and even in space [1].

Solar energy has disadvantages, such as the need for large areas, intermittent cycle, use of rare earth materials, still high cost of solar panels, low efficiency and environmental pollution in the production of solar panels and their utilization [2, 3]. However, all these disadvantages are challenges that scientists around the world are working on and making some progress.

The utilisation of solar energy in Iraq is a very urgent task due to climate change requiring the reduction of greenhouse gas emissions. The operation of solar power plants is carbon neutral [4].

The relevance of this area is also supported by the energy crisis. In recent years, climate change is affecting more intensively in the form of water scarcity, desertification, and frequent droughts. In addition, Iraq is experiencing rapid population growth and urbanization. This increases the needs of socio-economic development [5-7].

The energy crisis in Iraq has resulted in a shortage of electricity due to a shortage of gas imported from Iran. The consequences of power outages are restrictions in the daily life of the population, such as the shutdown of air conditioners and refrigeration equipment in extreme heat, shutdown of the water supply system, etc. Electricity supply constraints negatively affect the business and economy of the country as a whole [8, 9].

Significant investments in Iraq's energy supply system have not been able to equalize the situation with a very significant difference between supply and demand [9, 10].

To overcome the energy crisis in Iraq, comprehensive measures are needed, which include the following aspects:

Diversification of energy sources: the development of renewable energy sources, including solar and wind energy, will help to reduce dependence on conventional sources such as oil and natural gas.

Modernization and expansion of infrastructure: investment in modern energy systems, construction of new power plants and transmission networks will increase electricity generation and distribution.

Energy efficiency: implementation of energy conservation technologies and measures in industry, commerce and households will help reduce energy consumption.

Energy demand management: the development and implementation of energy demand management programs, including the promotion of energy-saving technologies and consumption modes, will help optimize energy use.

Development of public policies and incentives: the creation of an effective energy policy, including financial incentives, tax breaks and development of energy legislation, will help attract investment in the sector.

Private sector development: creating a favorable investment environment and private sector development in the energy sector will help diversify and improve infrastructure and technology in this field.

The combination of these factors will help Iraq to overcome the energy crisis by ensuring stable and sustainable energy development, reducing pollution and ensuring energy security.

Although solar energy is currently not as widespread in Iraq due to various challenges including lack of sufficient financing and infrastructure, the country has a huge potential to develop this field and benefit from clean and renewable energy [11, 12].

Therefore, it is of interest to investigate the potential and prospects of this field for Iraq.

Materials and methods of research

The input materials are data obtained from Global Solar Atlas [13]. Direct normal irradiation and Horizontal irradiation during a day and a year are determined for Iraq as a whole and by regions in particular. The results are summarized in a map and as a histogram. In this study, analysis and synthesis were used as methods, namely analysing solar resources in Iraq, analysing modern new technologies in solar energy and synthesising the results obtained into promising options for the development of this area of energy. The efficiency of different semiconductor materials, the influence of external factors (light level, temperature fluctuations, precipitation) on the efficiency were analysed. Also, the plans for the development of solar energy in Iraq and approved projects for the construction of power plants, and the latest world developments with an analysis of the possibility of their use in Iraq are given. Also analyzed modern technologies in solar energy with the prospect of their application in Iraq.

Research results

Neighbourhood-specific solar power generation estimates from the Global Solar Atlas are suitable for preliminary studies because they take into account default values for many factors that are important for PV system design. For more detailed assessments, one should work with PV power plant project configuration tools and use solar and weather data as inputs for modelling.

However, a preliminary assessment of the insolation level of the proposed area and the potential energy yield is necessary before the investment phase of a solar power plant. The direct normal exposure within Iraq is shown in **Fig. 1**.

Iraq has a huge amount of unused solar resources; hence, the direct normal irradiation per day for Iraq is 5.25-7.85 kWh/m^2, Global horizontal irradiation per day for Iraq is 5.52-6.71 kWh/m^2.

In some parts of the country, the irradiation level exceeds 1900 kWh/m^2. In addition, the lifetime cost of solar energy, even taking into account the cost of solar panels, is lower than fossil fuel power generation.

In the deserts of Iraq, the average solar energy density is 3140-3373 MJ/m^2. The Syrian Desert in western Iraq has the highest solar electricity generation capacity potential of 1776 MJ/m^2 among all regional deserts.

Desert areas in Iraq cover about 220000 km^2 [14, 15]. Accordingly, one of the main disadvantages of solar energy, namely the need for large areas, which is a limitation for many countries, is not a problem for Iraq.

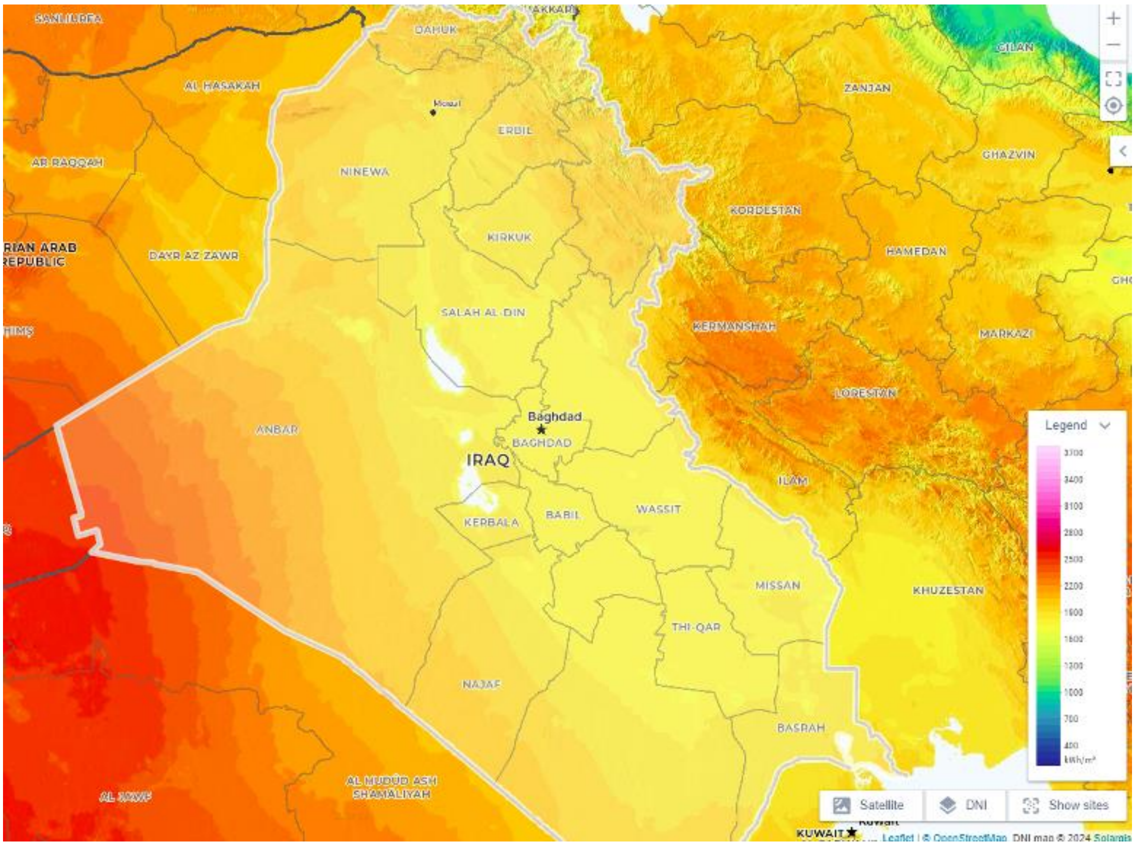


Fig. 1. ***The direct normal exposure within Iraq [13]***

Based on data from the Global Solar Atlas, **Figure 2** shows the direct normal irradiance by area in Iraq.

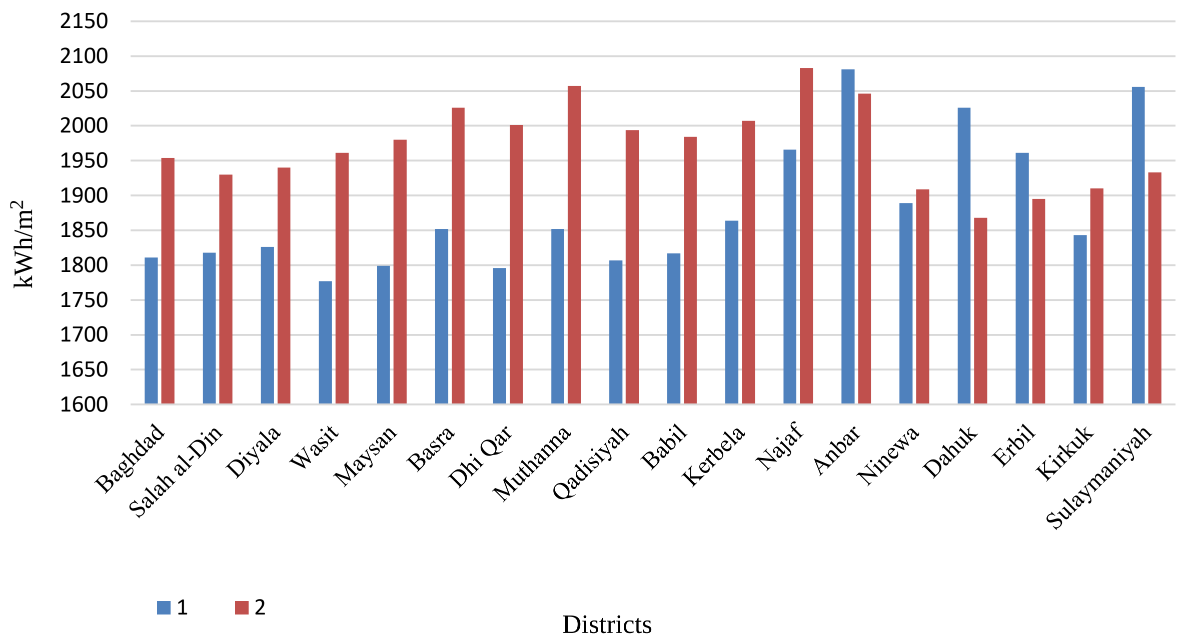


Fig. 2. ***Row 1: The direct normal irradiation by Iraq districts; Row 2: Horizontal irradiation***

Anbar, Sulaymaniyah, Dahuk, Najaf and Erbil showed the best performance at direct normal irradiation by area in Iraq. Accordingly, these areas have good potential for the construction of a large capacity solar power plant.

Solar insolation decreases strongly from north to south, and this difference increases in winter and decreases in summer. In summer, from June to August, there is a much more even distribution of solar radiation over Iraqi territories. Insolation varies slightly from east to west with some estimation errors.

Air pollution, especially in large cities, also needs to be taken into account as it affects the accuracy of the measurement.

In general, numerous studies [12, 16, and 17] have shown that due to the uniform distribution of solar irradiation throughout Iraq, solar energy in the Go area is capable of providing electricity to the entire country.

Thus, the development of a comprehensive strategy of transition to solar energy, as having the maximum potential, will solve the problem of electricity shortage, a number of economic and social problems.

Today, the creation of efficient photovoltaic systems is one of the main directions of alternative energy. The main engineering problem of this industry is the search for methods and materials that increase the efficiency factor of solar cells. It is assumed that the theoretically possible limit of efficiency factor for semiconductor technology is 85-88%. The current efficiency is 15-30 % [18].

Depending on the semiconductor materials used in the design (Fig. 3), the nominal efficiency of solar panels is [19]:

- Amorphous silicon, A-Si. For a long time, the conversion efficiency did not exceed 5-7%, but with the transition to thin-film technologies, it has risen to 14-16%. The efficiency is quite stable because the "loose" in shape surface of the cells absorbs well even weak or scattered light [20].

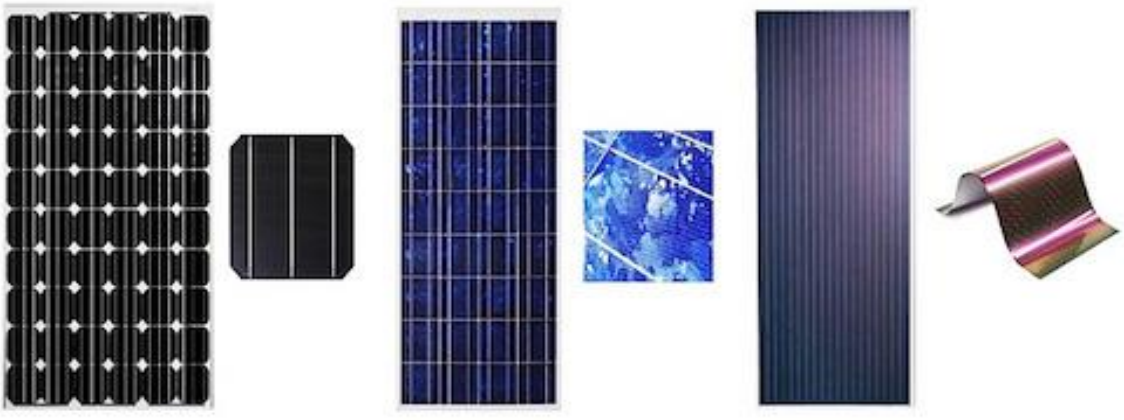
• Polycrystalline silicon, Poli-Si. Nominal performance is in the range of 19-21%. The drop in performance under unfavorable light conditions is medium, due to the multidirectional arrangement of the crystals of the absorbing layer [21].

• Monocrystalline silicon, Mono-Si, provides the highest energy yield under ideal light conditions, up to 24%. When the position relative to the sun changes and temperatures are high, the efficiency of such solar cells decreases significantly [22].

• Cadmium telluride (Cd-Te) photovoltaic cells are rapidly gaining popularity due to their combination of high average efficiency and low price. More stable performance than pure crystalline silicon modules is achieved by the ideal bandgap width of the p/n junction. The efficiency is slightly lower than polycrystals, but the average annual efficiency is higher [23].

• Rare earth copper/indium/ gallium sulfide, CIGS. Capable of maximizing absorption up to 40% or higher due to the possibility of multilayer cell layout. Widely used in the aerospace industry, but "on the ground" is almost not used due to the high price [24].

• Third generation photovoltaics. Uses organics, complex polymers or materials on quantum dots as semiconductors. Cheap, easy to manufacture and have fantastic absorption capabilities. Despite relatively low efficiencies in the range of 6-15%, these solar cells could already be in widespread use today if it weren't for their short lifetime. The current sustainability record is less than 2000 hours, or less than 3 months, which is insufficient for mass production and application [25].



a b c

Fig. 3. ***Types of solar batteries: a - monocrystalline, b - polycrystalline, c - thin-film batteries [26]***

The performance of the panels after assembly, due to their design features, remains unchanged. This is not the case with constantly changing external influences. The maximum impact on all photovoltaic systems is the level of light. In the complete absence of light, most modern photovoltaics do not function except for exotic variants with an additional layer of phosphor of long-lasting luminescence [27].

The next influential factors are direction to the sun and diffuse light. At large tilt angles, the largest drop in real efficiency occurs for monocrystalline solar panels. Rare-earth thin-film batteries are minimally affected by deteriorating light conditions.

The drop in shade has a particularly unfavourable effect on crystalline modules, up to the possibility of their failure. Film structures are less affected.

Factors such as precipitation (rain, snow, hail) do not change the efficiency of solar energy conversion. However, mechanical damage to the protective layer is possible, which threatens loss of tightness and Potential induced degradation (PID) [28]. The degradation occurs due to the high potential difference between the cell (semiconductor) and other parts of the module such as the fixture, aluminum frame and glass. This potential difference results in current leakage causing migration of positive and negative ions. This leakage reduces the photovoltaic effect by contaminating the cell, which further results in power loss. Degradation can be as high as 30% or even 70%. The causes of degradation and failure of solar modules are summarized in **Figure 4**. As we can see, PID occurs approximately in the middle of the service life, and can lead to a 2.5-30 % reduction in solar panel power.

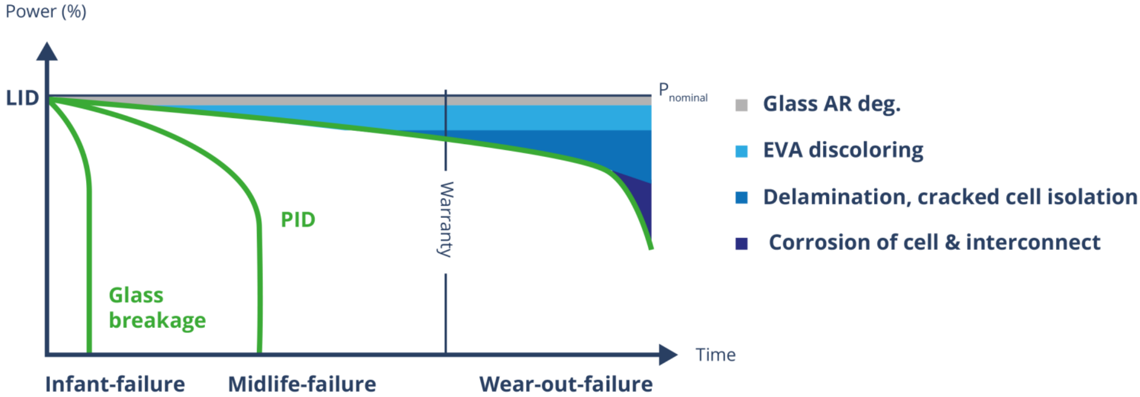


Fig 4. ***Causes of solar module failures [5, 29].***

The most well-known cause of PID was polarisation, noticed in the first high-efficiency panels produced by the American company Sun Power. Under certain conditions, the panels lost up to 30% of their rated power in a very short time. As it was found out, the cause was the potential of the panels relative to ground, and the degradation could be prevented by grounding the positive electrode of the solar panel [5, 29].

In addition, the efficiency of modules is affected by temperature fluctuations [21]. Fast changes of freeze/thaw cycles are the most dangerous for modules. Low temperatures do not cause changes in the efficiency of solar cells. However, Poli-Si and especially Mono-Si are very sensitive to high temperatures. Above +25°C, monocrystals begin to lose efficiency by about 0.5% with each degree. Heating the surface layer to 60-70°C, which is common in summer in hot regions, including Iraq, results in a 20% loss of rated performance. This problem is solved by various systems for cooling PV panels by means of air, water, nanofluids, etc.

Iraq's solar development plans, announced in November 2021, call for the introduction of 12 GW of solar capacity by 2030. About 7.5 GW of the planned solar capacity is to come from utility-scale solar power plants, and Iraq has reached agreements with developers - at various stages - on projects that will add 4.5 GW to this capacity [30].

The approved projects include a 1GW power plant in Basra to be built by TotalEnergies as part of a $27 billion mega-deal; a 750-megawatt two-stage power plant in Muthanna province to be built by Chinese state-owned PowerChina; and two projects totaling 525 megawatts to be developed by a consortium led by Iraq's Al-Bilal Group.

To reach the full target, Baghdad wants the remaining 4.5 GW to come from "embedded and distributed" solar power. This would require installing systems on the roofs of government buildings and encouraging homeowners. The latter could replace or at least reduce reliance on expensive generators that cost Iraqi households more than $4 billion a year, contribute to noise and air pollution, and have a negative impact on public finances through subsidized gasoline prices [30].

The latest developments allow expanding the possibilities of distributed and embedded solar energy. For example, "solar tile" (University of Western Sydney) - tiles made of polycarbonate and two main layers: solar panels and a thin transparent tank with a heat transfer medium **(Figure. 5)**. Such a "solar tile" generates electricity and heats water [31-32].

SolarGaps smart solar blinds can also be used in residential and industrial premises **(Figure. 5)**. Solar blinds can generate up to 100-150 W of electrical energy per 1 m^2.

a. "Solar shingles." b. "Solar shingles."

c. Sunny Block

Fig 5. ***The latest solar energy technologies [32, 33]***

There is also a revolutionary technology (University of Exeter (UoE) - building blocks with embedded solar cells **(Figure 5)**. The facades of houses built with these solar bricks (blocks), called Solar Squared, will be able to generate electricity and still have the ability to let sunlight into the building. The parameters of the nickel-manganese accumulator of such solar bricks are as follows: nominal voltage - 12 V; power consumption - 0.24-1.68 W [33].

In conditions with high solar radiation intensity, it is expedient to fulfil the thermal energy requirements for heating and hot water supply with the help of solar plants. In this direction, work is also underway to improve the efficiency of the plants. In Eleiwi [34] presents the results of an experimental study on the performance of an integrated solar air heater system under Iraqi climatic conditions. The comparison was made between using a flat plate and a metal fibre air heater as an absorbing surface. The efficiency of the latter was 88.5 %, which is twice that of the flat plate. The temperature difference between the absorption surface and the exhaust air in the case of the metal fibre heater is less than that of the flat plate.

Improving the performance of thermal energy storage of solar water heater in Iraq weather conditions is addressed in [35]. The test results showed that the overall thermal efficiency of the system with storage medium as porous medium and crude paraffin wax as phase change material was 6.35 % higher than without them. In another paper [36] were investigated to improve the performance of a hybrid photovoltaic system by using reflectors and cooling with water jet. The maximum overall instantaneous efficiency was 64 % and the largest percentage improvement in electrical performance of PVT with reflectors was 42.6 %.

The application of modern solar energy technologies will expand the possibilities of its development in Iraq and thus solve energy, social, economic problems.

The World Bank stressed that while Iraq does not lack decarbonization solutions in its national contribution document, its objectives nevertheless remain broad and lack "any analytical assessment of investment costs and impacts".

In comparison, Turkey has a well-developed production in this area. CW Energy engineering, in addition to industrial installations, offers rooftop solutions and services in grid-connected systems, stand-alone battery-powered systems, solar irrigation systems, LED lighting, solar camera systems, etc. And the Ministry of Environment, Urbanisation and Climate Change is working to provide public buildings across Turkey with small and medium-sized PV installations for self-consumption [Turkish government to green its roofs with solar panels. https://balkangreenenergynews.com/turkish-government-to-green-its-roofs-with-solar-panels/].

Renewable energy is not developing fast enough in Iran. The total renewable energy capacity by 2024 is 879 MW, less than 1% of the total nominal power generation capacity of the country [37].

Currently, renewable energy sources (solar, wind, biomass, geothermal) and hydropower account for about 59% of Turkey's nominal generating capacity, while in Iran this figure is about 15%.

Further development of solar energy is linked to increasing the efficiency of solar panels, reducing the cost of production and increasing the scale of production. In addition, the development of efficient energy storage systems is becoming increasingly important to ensure that energy is always available to consumers even when the sun is not shining. In Iraq, solar energy can be considered the best and most logical alternative to burning fossil fuels.

Conclusion

One of the main ways out of the energy crisis in Iraq is the development of solar energy. This will be in line with the main trends in the development of the global energy sector and preserve the environmental situation in the country, as well as ensure its economic security.

In order to develop a state program for the development of Iraq's electric power industry focused on the use of environmentally friendly RES, it is necessary to carry out additional research aimed at clarifying regional energy potentials and the needs of local, non-system consumers. In addition to the construction of industrial solar power plants, off-grid plants should also be developed, as analysis has shown the possibility of covering the electrical load of individual farms or remote villages with off-grid power plants.

The solar energy density in Iraq is one of the highest in the world, as it is located near the equatorial belt, which gives it the necessary natural conditions for utilizing solar energy.

The duration of sunshine is between 2,800 and 3,000 hours per year with a daily horizontal radiation of more than 5.52-6.71 kWh/m^2. This makes the region extremely favorable for investment in the construction of solar power plants.

Anbar, Sulaymaniyah, Dahuk, Najaf, and Erbil showed the best performance in direct normal irradiation for Iraqi districts. Accordingly, these areas have good potential for the construction of high capacity solar power plant.

The analysis of modern technologies in solar energy with the prospect of their application in Iraq and the analysis of different designs of semiconductor materials in terms of efficiency showed the possibility of applying the latest technologies with high efficiency. However, Poli-Si and especially Mono-Si are not quite suitable for climatic conditions due to high sensitivity to high temperatures. Heating the surface layer to 60-70°C, which is common in summer in hot regions including Iraq, results in a loss of 20 per cent of rated performance. Nevertheless, this problem can be solved by using different systems for cooling PV panels through air, water, nanofluids, etc., which, however, leads to higher installation costs.

The analysis of modern technologies in solar energy with the prospect of their application in Iraq and the analysis of different designs of semiconductor materials in terms of efficiency showed the possibilities of solar energy development in Iraq in order to solve energy, social and economic problems.

References

1. Solar Energy Pros And Cons: What Are The Advantages And Disadvantages? https://www.forbes.com/home-improvement/solar/solar-energy-pros-and-cons/
2. Arsalan Muhammad Soomar, Abdul Hakeem, Mustapha Messaoudi, Piotr Musznicki, Amjad Iqbal, Stanislaw Czapp. Solar Photovoltaic Energy Optimization and Challenges. Front. Energy Res., 30 May 2022, Volume 10 – 2022. doi.org/10.3389/fenrg.2022.879985
3. Max Roser (2020) - “Why did renewables become so cheap so fast?” Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/cheap-renewables-growth' [Online Resource].
4. Wu, Xudong & Li, Chaohui & Shao, Ling & Meng, Jing & Zhang, Lixiao & Chen, Guoqian, 2021. "Is solar power renewable and carbon-neutral: Evidence from a pilot solar tower plant in China under a systems view," Renewable and Sustainable Energy Reviews, Elsevier, vol. 138(C).
5. Adamo, Nasrat & Al-Ansari, Nadhir & Sissakian, Varoujan & Knutsson, Sven & Laue, Jan. (2018). Climate Change: Consequences on Iraq's Environment. Journal of Earth Sciences and Geotechnical Engineering, vol . 8, no. 3, 2018, 43-58, 1792-9660 (online)
6. Ali, Sabah & Qubaa, Abdalrahman & Al-Khayat, Amina. (2024). Climate Change and its Potential Impacts on Iraqi Environment: Overview. IOP Conference Series: Earth and Environmental Science. 1300. 012010. doi: 10.1088/1755-1315/1300/1/012010.
7. Neira M, Erguler K, Ahmady-Birgani H, Al-Hmoud ND, Fears R, Gogos C, Hobbhahn N, Koliou M, Kostrikis LG, Lelieveld J, Majeed A, Paz S, Rudich Y, Saad-Hussein A, Shaheen M, Tobias A, Christophides G. Climate change and human health in the Eastern Mediterranean and Middle East: Literature review, research priorities and policy suggestions. Environ Res. 2023 Jan 1; 216(Pt 2):114537. doi: 10.1016/j.envres.2022.114537.
8. Istepanian, Harry. (2014). Iraq's Electricity Crisis. The Electricity Journal. 27. 10.1016/j.tej.2014.04.006.
9. Salman HM, Pasupuleti J, Sabry AH. Review on Causes of Power Outages and Their Occurrence: Mitigation Strategies. Sustainability. 2023; 15(20):15001. https://doi.org/10.3390/su152015001.
10. Manfred Hafner · Pier Paolo Raimondi · Benedetta Bonometti. The Energy Sector and Energy Geopolitics in the MENA Region at a Crossroad. Springer. 2023. p. 216.
11. Al Mashhadany, Yousif & Abbas, Ahmed & Algburi, Sameer. (2024). Global prospects, challenges, progress and environmental impact of solar energy in Iraq. 030005. doi: 10.1063/5.0190846.
12. Roman Vakulchuk, Indra Overland, Daniel Scholten, Renewable energy and geopolitics: A review, Renewable and Sustainable Energy Reviews, Volume 122, 2020, 109547, doi.org/10.1016/j.rser.2019.109547.
13. Global Solar Atlas. https://globalsolaratlas.info.
14. Abass Ahmed. Z., Pavlyuchenko.D.A. Turning Iraq into a country of energy exporter through the exploitation of solar energy and vast desert land. E3S Web of Conferences, 114, 05009 (2019). doi.org/10.1051/e3sconf/201911405009.

15. Abass Ahmed. Z., Pavlyuchenko.D.A. The exploitation of western and southern deserts in Iraq for the production of solar energy. International Journal of Electrical and Computer Engineering (IJECE), Vol. 9, No. 6, December 2019, pp. 4617-4624. doi: 10.11591/ijece.v9i6.pp4617-4624.
16. Hamed H. Pourasl, Reza Vatankhah Barenji, Vahid M. Khojastehnezhad. Solar energy status in the world: A comprehensive review, Energy Reports, Volume 10, 2023, pp. 3474-3493. doi.org/10.1016/j.egyr.2023.10.022.
17. The Impact of Iraq Climate Condition on the Use of Solar Energy Applications in Iraq: a Review. International Journal of Science and Engineering Investigations. 6. 64-73. 2017.
18. Baiju, Adil & Yarema, Maksym. (2022). Status and challenges of multi-junction solar cell technology. Frontiers in Energy Research. 10. 10.3389/fenrg.2022.971918.
19. Chatzipanagi, A., Jaeger-Waldau, A., Cleret de Langavant, C., Letout, S., Latunussa, C., Mountraki, A., Georgakaki, A., Ince, E., Kuokkanen, A. and Shtjefni, D., Clean Energy Technology Observatory: Photovoltaics in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/812610, JRC130720.
20. Progress in Solar Energy Technologies and Applications. 2019 Scrivener Publishing LLC. DOI: 10.1002/9781119555650.
21. Gall, S. & Becker, Chaichana & Conrad, Erin & Dogan, Pinar & Fenske, F. & Gorka, B. & Lee, K.Y. & Rau, Björn & Ruske, Florian & Rech, Bernd. (2009). Polycrystalline silicon thin-film solar cells on glass. Solar Energy Materials and Solar Cells. 93. 1004-1008.
22. Guiqiang Li, Qingdong Xuan, Gang Pei, Yuehong Su, Jie Ji, Effect of non-uniform illumination and temperature distribution on concentrating solar cell - A review, Energy, Volume 144, 2018, pp. 1119-1136.
23. Rahman, Kazi Sajedur. (2022). Cadmium telluride (CdTe) thin film solar cells.
24. Olivier Fournier. Synthèse par ALD et caractérisation de couches extractrices d'électrons pour appli- cation dans les cellules solaires à base de pérovskite. Matériaux. Université Paris sciences et lettres, 2021.
25. Shah N, Shah AA, Leung PK, Khan S, Sun K, Zhu X, Liao Q. A Review of Third Generation Solar Cells. Processes. 2023; 11(6):1852. https://doi.org/10.3390/pr11061852.
26. Catherine Lane. Types of solar panels: which one is the best choice? 2024. https://www.solarreviews.com/blog/pros-and-cons-of-monocrystalline-vs-polycrystalline-solar-panels.
27. Mustafa RJ, Gomaa MR, Al-Dhaifallah M, Rezk H. Environmental Impacts on the Performance of Solar Photovoltaic Systems. Sustainability. 2020; 12(2):608. doi.org/10.3390/su12020608
28. Badran G, Dhimish M. Potential Induced Degradation in Photovoltaic Modules: A Review of the Latest Research and Developments. Solar. 2023; 3(2):322-346. doi.org/10.3390/solar3020019.
29. Al Mahdi H, Leahy PG, Alghoul M, Morrison AP. A Review of Photovoltaic Module Failure and Degradation Mechanisms: Causes and Detection Techniques. Solar. 2024; 4(1):43-82. https://doi.org/10.3390/solar4010003.
30. Yesar Al-Maleki. Urgent Reforms Needed to Unlock Iraq's Green Potential, Nov 14, 2023. https://agsiw.org/urgent-reforms-needed-to-unlock-iraqs-green-potential/
31. Adeeb J, Farhan A, Al-Salaymeh A. Temperature Effect on Performance of Different Solar Cell Technologies. Journal of Ecological Engineering. 2019;20(5):249-254. doi:10.12911/22998993/105543.
32. New technologies to harness solar energy. https://www.repsol.com/en/energy-and-the-future/future-of-the-world/solar-shingles/index.cshtml.

33. Vorobev A.E., Vorob′ev K.A. (2019). Distributed solar power. The Eurasian Scientific Journal, [online] 5(11).
34. Muhammad Asmail Eleiwi, Mohammed Fowzi Mohammed, Kamil Talib Kamil Experimental Analysis of Thermal Performance of a Solar Air Heater with a Flat Plate and Metallic Fiber. Journal of Engineering Science and Technology Vol. 17, No. 3 (2022) 2049 – 2066.
35. Eleiwi, M. A., Mokhlif, N. D., & Saleh, H. F. (2023). Improving the performance of the thermal energy storage of the solar water heater by using porous medium and phase change material. Energy Sources, Part A: Recovery, Utilisation, and Environmental Effects, 45(1), 2013-2026. https://doi.org/10.1080/15567036.2023.2185316.
36. Eleiwi, M. A., Yassen, T. A., & Khalaf, A. E. (2024). Improving the overall performance of a hybrid photovoltaic system by reflectors and cooling with water jet. International Journal of Ambient Energy, 45(1). https://doi.org/10.1080/01430750.2024.2308757.
37. Dalga *Khatzinoglu*. Iran's Renewables Ambitions Dwindle Amidst Regional Surge. Iran International. https://www.iranintl.com/en/202403208882.