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Scopus-Based Analysis of Peer-Reviewed Literature Related to Solar Energy in GCC Countries

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Abstract

This paper analyzes and presents the solar energy research status in the GCC countries using Scopus-database. Its findings may be valuable for researchers, politicians, industry, or decision makers to see how much the participation of the GCC countries in the field of solar energy and how it compares to other countries. The data gathered from Scopus database aided in outlining and identifying the active institutions and researchers in the field of solar energy in the GCC. In terms of the largest contribution, Saudi Arabia has the highest research output (with more than 60% of the published articles in the GCC), followed by the UAE (about 17%) and the remaining percentage is the contribution of the other GCC countries.

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Keywords: Solar Energy; Bahrain; Kuwait; Oman; Qatar; Saudi Arabia; United Arab Emirates; GCC Countries; Scopus Database

1. Introduction

With the depletion of oil and gas resources, the GCC countries realized that they have to depend less on oil and gas and must start relaying on other sources of energy such as solar energy. Electricity consumption is as high as 1.15 kW/person, especially, due to the large growth rate in demand at about 9.5%[1]. In a recent study, the possibility of replacing gas-based heaters with parabolic trough concentrated solar power plants in conjunction of thermal energy storage system was conducted, to investigate overcoming the daily fluctuations in availability of solar

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radiation in the UAE[2]. In another study, an extensive review of literature on solar energy and its application in the UAE was presented[3]. The environmental aspects were shown to pinpoint the performance of different technologies. It is well known that the solar energy system applications are not all the same for any location on Earth. Each site has its own special condition. Like in other GCC countries, the electricity production has increased from 39.9 TWhr per year to 110 TWhr per year in the last fifteen years in the UAE, which places the country in the group of the highest electricity consuming countries worldwide. In 2012, UAE was ranked tenth in electrical energy consumption with 10.13 MWhr per person. However, with the presence and abundance of solar energy, UAE and other the GCC countries have to find ways to utilize such vast clean/renewable source of solar energy[4]. An example of PV/thermal collector used to produce electricity to run HVAC cooling system with a conversion efficiency of less than 50%. However, a more efficient system was introduced by Al-Alili et al[5] which uses concentrating PV/thermal collectors to utilize solar energy into air conditioning systems. The study considered GCC environmental conditions. In another recent study it was found that applying sustainable aspects in the architectural design processes that interact with environmental and sever climatic conditions[6]. There is a lot of published work in literature on applications of solar energy systems[7,8] ranging from solar water heating[9,10] to solar desalination[11,12,13,14]. Other types of systems on renewable energy application can also be found[15,16,17,18].

2. Methodology

In this work, Scopus-database was utilized to analyze and investigate the status of solar energy research in the GCC countries. Scopus-database provides a huge source of information that can be used for many purposes. One purpose is to analyze and track the history and range of peer-reviewed published articles and their citations of an author, affiliation, or a country[19]. It is a large abstract and citation database of peer-reviewed literature: scientific journals, book chapters, and conference proceedings. The study will lead to a better understanding of the current and future status of research in the field of solar energy in GCC countries. Hopefully, the results of this study will be of benefit to energy policy makers and those active in research improve solar energy in the GCC countries. Scopus data were used in number of publications in literature[20,21,22].

Scopus allows different search parameters such as “Document search”, “Author search”, “Affiliation search”, and “Advanced search” for many fields such as “Article Title, Abstract, Keywords”, “Source Title”, “Year of Publication”, etc. Keyword used in this study is simply “solar” in document search for the various GCC countries, i.e., Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, and United Arab Emirates. The data collated were used to gather the following facts: (a) Publication activities of GCC and the World, (b) Top cited solar energy-related articles in GCC, (c) Solar energy related publication distribution in GCC, (d) Top journal titles with solar energy publications with GCC institutions, and (e) Top productive authors in GCC. The data were collected during the first week of January of 2016.

3. Results and Discussion

The Gulf Cooperation Council (GCC) is a regional intergovernmental political and economic union consisting of Arab countries of the Arabian Gulf and was established on 25 May 1981. Its member states are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates[23]. The goals of this union are establishing similar regulations in different fields such as administration, legislation, religion, finance, trade, customs, and tourism, encouraging scientific and technical developments in different areas, forming scientific research centers, create joint projects, establishing cooperation among the private sector, and reinforcing ties between their people. The GCC launched several initiatives within the member states to enhance social, economic and political integration between them; common market to ease the movement of goods and services, allowing full equality among GCC citizens to work in the government and private sector, social security, capital movement, real estate ownership and access to education, health and other social benefits in all member states, single currency and the creation of central bank would also position the GCC as a single entity with greater influence on the international financial system, power grid connection, inter-regional railways, water connection and common air transport are among the major infrastructure projects that would promote and facilitate integration among member states. Very recently, GCC countries agreed on introducing and implementation of Value Added Tax (VAT) in the member states. Unifying regulations in the area

of standardization is achieved by establishing GCC Standardization Organization, this will help in developing the production and service sectors, enhance the inter-GCC trade and protect consumer, environment and public health.

This region's economy is of the fastest growing economies in the world, mostly due to the boom in oil and gas. These profits are coupled with a construction and investment flourishing supported by many years of saved petroleum revenues. Data were collected on solar energy related publication distribution in GCC countries, which are presented in Fig. 1. It illustrates the amount of published articles that have any of the GCC countries as country of affiliation. Saudi Arabia has the largest volume of publications. For example, in 2014 a total of 561 documents related to solar energy were published in GCC, of which 396 documents in Saudi Arabia, and 90 in UAE.

Table 1 presents the total published articles of GCC countries, as compared to each other and some selected major World countries and the World. The table also presents the h-index of each country. It is obvious that USA has the highest h-index with more than 100,000 documents (representing third of word's output). It is followed by China and Germany. If we consider the GCC as one entity, then it produced more than 3,400 documents (which represents about 1% of the world's output). The GCC h-index is 67. However, within the GCC, Saudi Arabia is the largest contributor with more than 2,000 publications (about 60% of GCC), with h-index of 61.

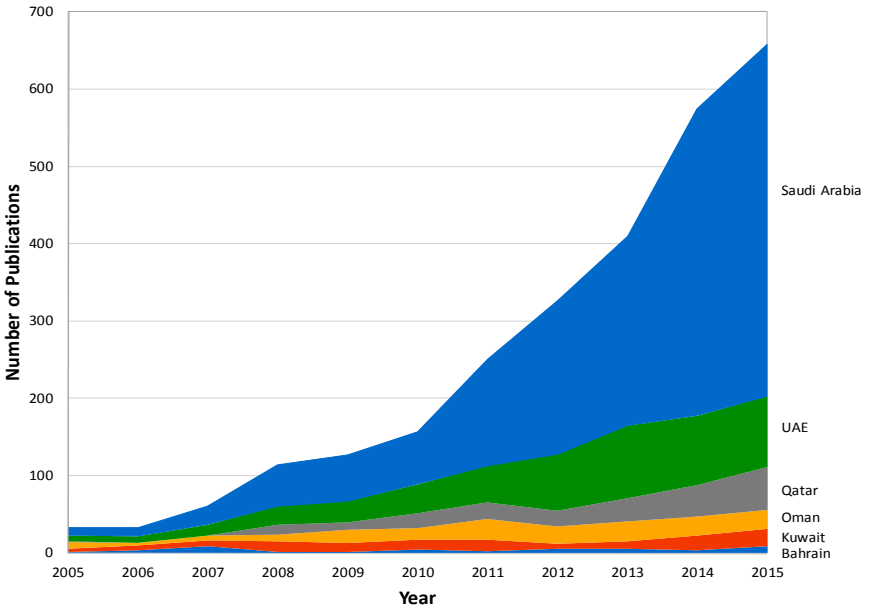

Fig. 1. Solar Energy Related Publication Distribution for GCC Countries during 2005 – 2015

Table 1. Publication Activities of GCC and the World

Country	Number of Publications	h-Index
Bahrain	105	17
Kuwait	264	25
Qatar	231	18
Oman	232	29
Saudi Arabia	2,066	61
United Arab Emirates	575	28
GCC	3,405	67
USA	103,972	425
China	39,833	187
Germany	28,779	248
World	378,322	466

Fig. 2 presents the top 15 productive GCC institutions in solar energy related publication contributions. King Abdulaziz University is the top institution in GCC with 462 publications, followed by King Saud University with 393 published documents, and then KFUPM with 331 documents. The top scientists that have a GCC affiliations in the published articles are presented in Fig. 3.

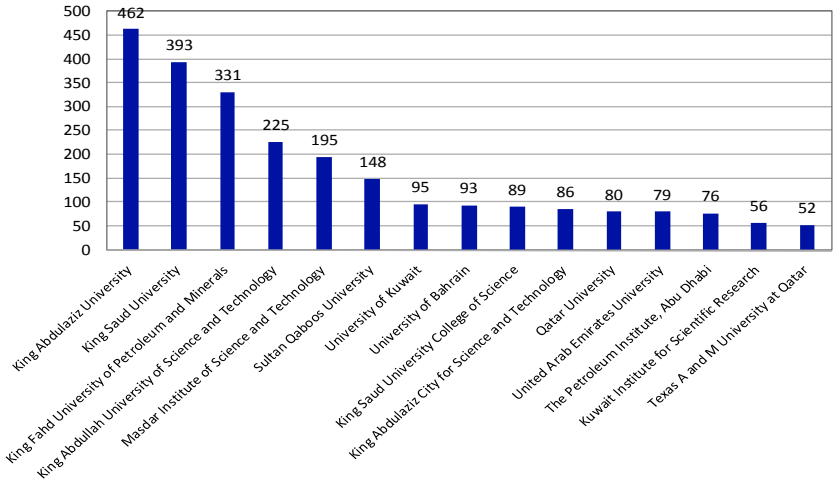

Fig. 2. Top 15 Productive GCC Institutions in Solar Energy Related Publication

The top ten journal titles with most published articles are presented in Fig. 3. The top five journals are Renewable Energy, Solar Energy, Energy Conversion and Management, Desalination, and Renewable and Sustainable Energy Reviews with a total of publications of 146, 126, 95, 93, and 81, respectively.

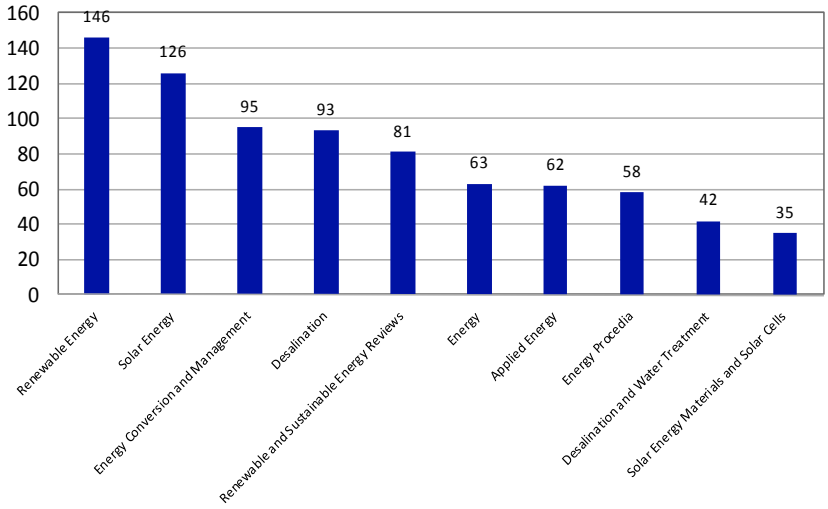

Fig. 3. Top 10 Journal Titles with Solar Energy Publications with GCC institutions

In an attempt to list the top cited papers in GCC Table 2 is presented. The table shows the most cited documents in GCC. It presents article's title, authors, GCC contributing affiliation, journal's title, and number of citations. King Abdullah University of Science & Technology (KAUST) in Saudi Arabia is the biggest contributor.

Table 2. Top 25 Cited Solar Energy-Related Articles Based on Scopus Database in GCC

Authors	Publication	Journal Title (Year)	Affiliation	Cited
Beaujuge, P.M., Fréchet, J.M.J.	Molecular design and ordering effects in p-functional materials for transistor and solar cell applications	Journal of American Chemical Society (2011)	KAUST, Saudi Arabia	627
Wang, F., Deng, R., et al.	Tuning up conversion through energy migration in core-shell nanoparticles	Nature Materials (2011)	KAUST, Saudi Arabia	522
Tang, J., Kemp, K.W., et al.	Colloidal-quantum-dot photovoltaics using atomic-ligand passivation	Nature Materials (2011)	KAUST, Saudi Arabia	484
Hasnain, S.M.	Review on sustainable thermal energy storage technologies, part I: Heat storage materials and techniques	Energy Conversion and Management (1998)	KACST, Saudi Arabia	418
Ip, A.H., Thon, S.M., et al.	Hybrid passivated colloidal quantum dot solids	Nature Nanotechnology (2012)	KAUST, Saudi Arabia	408
Cabanetos, C., El Labban, A. et al.	Linear side chains in benzo[1,2-b:4,5-b']dithiophene-thieno[3,4-c] pyrrole-4,6-dione polymers direct self-assembly and solar cell performance	Journal of the American Chemical Society	KAUST, Saudi Arabia	308
Jokiel, P.L., Coles, S.L.	Response of Hawaiian and other Indo-Pacific reef corals to elevated temperature	Coral Reefs (1990)	KFUPM, Saudi Arabia	299
Khawaji, A.D., Kutubkhanah, I.K., Wie, J.M.	Advances in seawater desalination technologies	Desalination (2008)	Royal Commission, Saudi Arabia	284
Kraemer, D., Poudel, B., et al.	High-performance flat-panel solar thermoelectric generators with high thermal concentration	Nature Materials (2011)	Masdar Institute, UAE	248
Yiu, A.T., Beaujuge, P., et al.	Side-chain tunability of furan-containing low-band-gap polymers provides control of structural order in efficient solar cells	Journal of the American Chemical Society (2012)	KAUST, Saudi Arabia	239
Garnett, E., Cai, W., et al.	Self-limited plasmonic welding of silver nanowire junctions	Nature Materials (2012)	KAUST, Saudi Arabia	223
Abdelsalam, A.K., Massoud, A., et al.	High-performance adaptive Perturb and observe MPPT technique for photovoltaic-based microgrids	IEEE Transactions on Power Electronics (2011)	Texas A&M, Qatar, Qatar Univ.	203
Mohandes, M., Rehman, S., Halawani, T.O.	Estimation of global solar radiation using artificial neural networks	Renewable Energy (1998)	KFUPM, Saudi Arabia	190
Lee, O.P., Yiu, A.T., et al.	Efficient small molecule bulk heterojunction solar cells with high fill factors via pyrene-directed molecular self-assembly	Advanced Materials (2011)	KAUST, Saudi Arabia	181
Gao, P., Grätzel, M., Nazeeruddin, M.K.	Organohalide lead perovskites for photovoltaic applications	Energy and Environmental Science (2014)	King Abdulaziz Univ., Saudi Arabia	167
Abdul Wahab, S.A., Bakheit, C., AlAlawi, S.M.	Principal component and multiple regression analysis in modelling of ground-level ozone and factors affecting its concentrations	Environmental Modelling and Software (2005)	Sultan Qaboos Univ., Oman	154
Raut, H.K., Ganesh, V., et al.	Anti-reflective coatings: A critical, in-depth review	Energy and Environmental Science (2011)	King Saud Univ., Saudi Arabia	151
Yoong, L.S., Chong, F.K., Dutta, B.K.	Development of copper-doped TiO2 photocatalyst for hydrogen production under visible light	Energy (2009)	Petroleum Institute, UAE	149
Al Qaradawi, S., Salman, S.R.	Photocatalytic degradation of methyl orange as a model compound	J. Photochemistry & Photo-biology A: Chemistry (2002)	Qatar Univ., Qatar	143
Bartelt, J.A., Beiley, Z., et al.	The importance of fullerene percolation in the mixed regions of polymer-fullerene bulk heterojunction solar cells	Advanced Energy Materials (2013)	KAUST, Saudi Arabia	142
Elhadidy, M.A., Shaahid, S.M.	Parametric study of hybrid (wind + solar + diesel) power generating systems	Renewable Energy (2000)	KFUPM, Saudi Arabia	129
Andrady, A.L., Hamid, S.H., et al.	Effects of increased solar ultraviolet radiation on materials	J. Photochemistry & Photo-biology B: Biology (1998)	KFUPM, Saudi Arabia	122
Vandewal, K., Albrecht, S., et al.	Efficient charge generation by relaxed charge-transfer states at organic interfaces	Nature Materials (2014)	KAUST, Saudi Arabia	120
Abdul Wahab, S., Al Alawi, S.M.	Assessment and prediction of tropospheric ozone concentration levels using artificial neural networks	Environmental Modelling and Software (2002)	Sultan Qaboos Univ., Oman	119
Gao, H., Liu, C., et al.	Plasmon-enhanced photocatalytic activity of iron oxide on gold nanopillars	ACS Nano (2012)	King Abdulaziz Univ., Saudi Arabia	118

The top collaborative countries are shown in Figure 4. The USA has the highest score with a total of 486, followed by Egypt with a total of 284, then Malaysia with 168 publications. The reason is that these countries are active in solar energy research and the GCC countries benefit from working jointly with them and various projects. The top ten foreign collaborative institutions with GCC are presented in Fig. 5, they are Massachusetts Institute of Technology (MIT), Universiti Kebangsaan Malaysia (UKM), and University of Malaya, with a total of 59, 56, and 49, respectively.

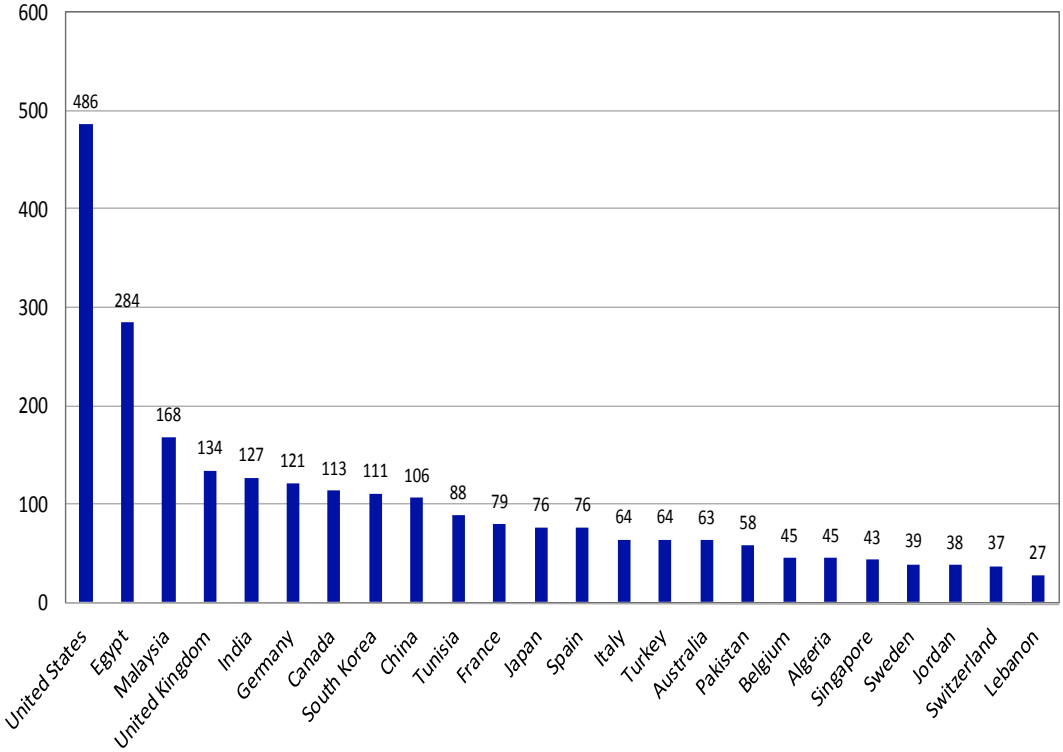

Fig. 4. Top 24 Collaborative Other Countries with GCC

4. Conclusion

The GCC countries recognize that they need to be less dependent on oil and gas as sources of energy and economy. Also, they have to consider other sources of energy for power generation. During the past couple of decades, the GCC countries began supporting scientific research to be conducted in more sustainable energy resources such as solar energy. However, more solar energy research was conducted at somewhat larger scale during the past ten years. Many researchers worked on various applications of solar energy for electricity production, water desalination, space cooling, etc. This work can be used by researchers, politicians, industry, or decision makers to see how much the participation of the GCC countries in the field of solar energy and how it compares to other countries. This study utilized Scopus Database to review research studies conducted on solar energy throughout the GCC. It was found that GCC countries have a combined total of 3,405 published articles (as compared to worldwide output of 378,322). Saudi Arabia has the highest publication records and h-index followed by UAE, with total numbers of scientific publications of 2,066 and 575, respectively. The most collaborative country with the GCC countries in the solar energy research world-wide is USA with more than 480 publications (equivalent to 14%). The most collaborative country in the Arab World is Egypt with more than 280 publications. The six GCC counties have

set ambitious targets for the near future in the renewable energy sector, solar energy research will surely contribute in meeting these targets by enhancing renewable energy technologies to adapt in the harsh and unique environmental conditions in the GCC countries region, it is clearly observed that much work is still needed, especially with the research resources available in the GCC. This work can be updated annually or once every two years in order to further monitor and give recommendations regarding the situation of the solar energy in the GCC countries.

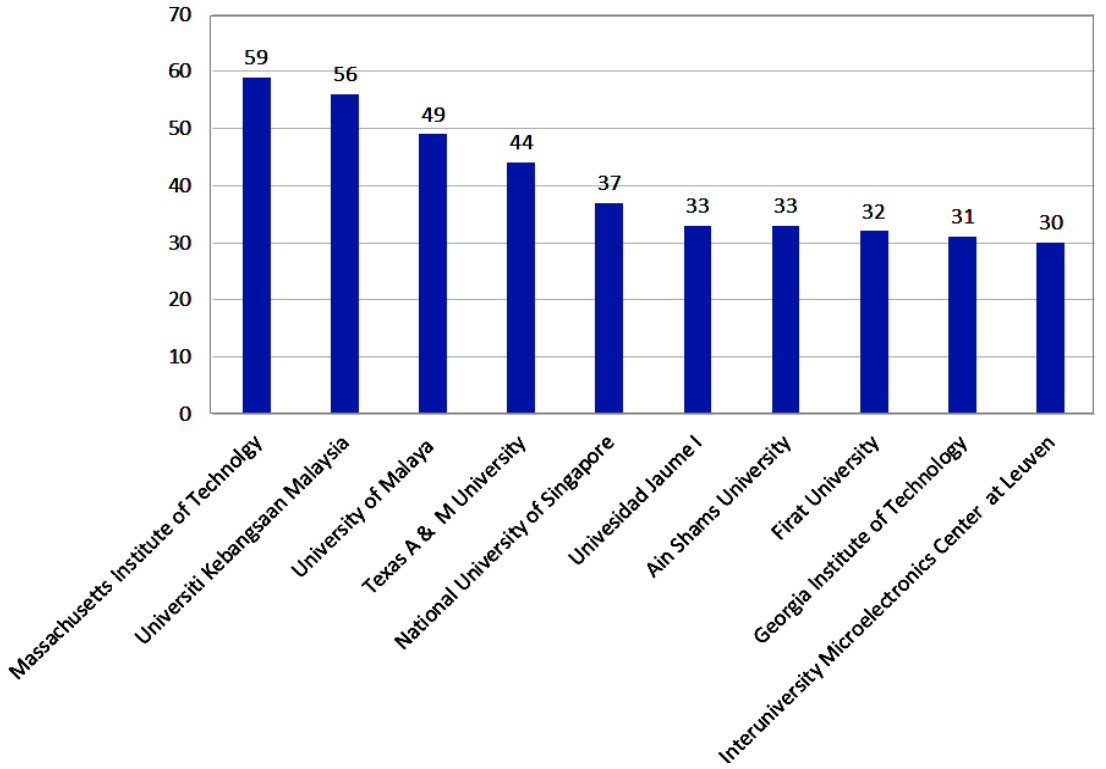

Fig. 5. Top 10 Collaborative Institutions in Other Countries with GCC

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