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Critical review of solar thermal resources in GCC and application of nanofluids for development of efficient and cost effective CSP technologies

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ABSTRACT

Utilization of solar energy for multiple applications is an integral part of sustainable development primarily due to its abundance and potential to offset fossil fuel consumption. The booming field of solar energy enables the solar energy utilization, and open new opportunities within commercial and research development programs. Emphasis has been given to the new development of novel technologies that are more efficient for capturing, storing and utilizing solar energy that can store thermal energy at high temperature and across a wide temperature range. Also, the coupling of Concentrated Solar Power (CSP) and storage systems presents a significant potential to improve the capture, utilization and storage of solar energy which enhances the reliability of alternative energy options and diversifying away from fossil fuels to mitigate environmental impacts while ensuring the continuous provision of power to meet the growing demand. This paper gives an insight into the recent progress (within the last few years) in the research and development of integrated solar energy systems and their potential to improve the efficiency of integrated solar systems through the utilization of nanotechnologies. This review provides an update on integrated solar energy systems for scientists, students and industrial organizations working in the field.

1. Introduction

The incoming solar radiation in the upper atmosphere is 174,000 terawatts (TW), in which approximately 70% is absorbed by the atmosphere, lands and ocean encompassing the Earth. Considering solar fluxes in the form of incoming and reflected radiation, a total of 122,000 terawatts (TW) of energy is available in the atmosphere for energy production, while the total world energy demand during the fiscal 2016 year was 21.73 TW and which is expected to increase to 26.78 TW by 2040 [1,2]. Considering the above facts, the Desertec foundation stated that “Within six hours deserts receive more energy from the sun than humankind consumes within a year” [3].

Evidently, there is an urgency to develop efficient and economically viable solar technologies, in which widespread deployment can contribute to a cleaner energy future. However, the solar industry currently utilizes traditional technologies of heat transfer, electricity generation and power transmission which all need to be integrated with present modern techniques. Recent technical advancements such as nanotechnology, HVDC (High Voltage Direct Current), smart grids and improved solar specific power generation turbines are some of the improvements which can contribute to efficient energy conversion and transmission systems.

While the countries in the Gulf Cooperation Council (GCC) are blessed with significant fossil fuel reserves, they are also situated in a region with a large annual availability of solar radiation. However, the necessary deployment mechanisms in the form of policy and technology development have not yet been fully realised thus impeding the widespread deployment of solar technologies. In this regard, the abundance of low-cost fossil fuels will challenge the widespread implementation of solar technologies. However, considering commitments by nation-states in COP 21 to combat climate change, the opportunity to maximize solar radiation has become a global objective. For Qatar, it is reflected in the Qatar National Vision 2030 which encourages both sustainable development and innovation to progress environmentally, economically and socially.

Germany has set an unprecedented example by integrating renewable energy into their national energy mix. As per the German Agora Energiewende, on May 8, 2016, Germany observed negative PPAs for few hours as renewable sources generated 87% of energy consumed [4]. Unfortunately, Germany lacks the appropriate DNI levels (Direct

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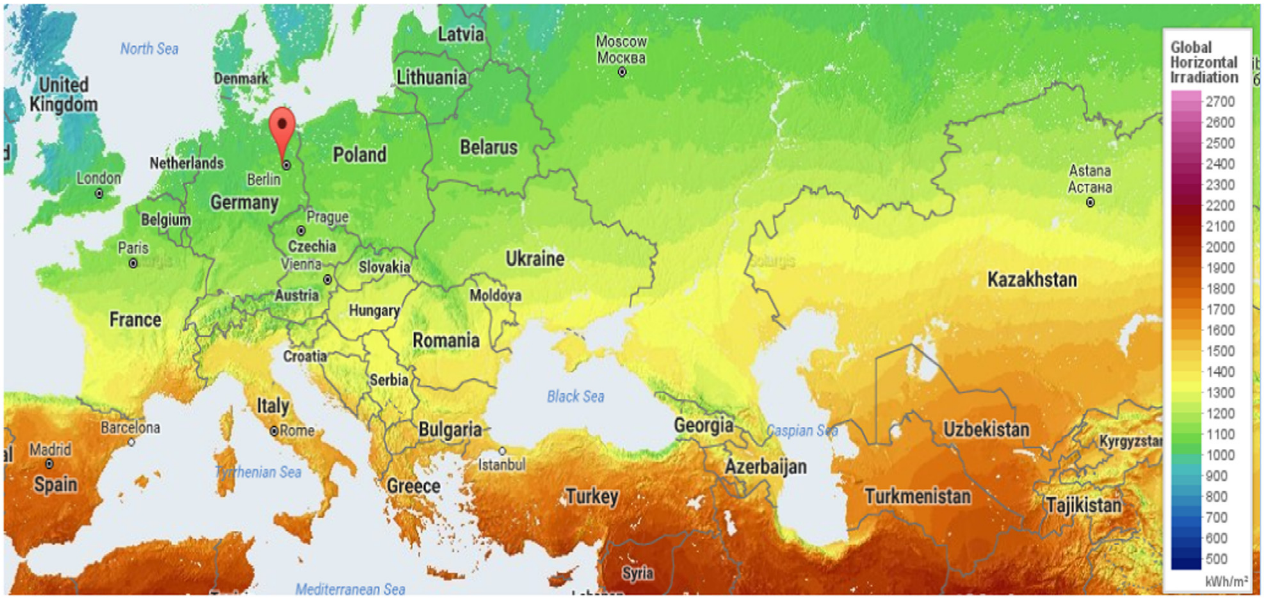
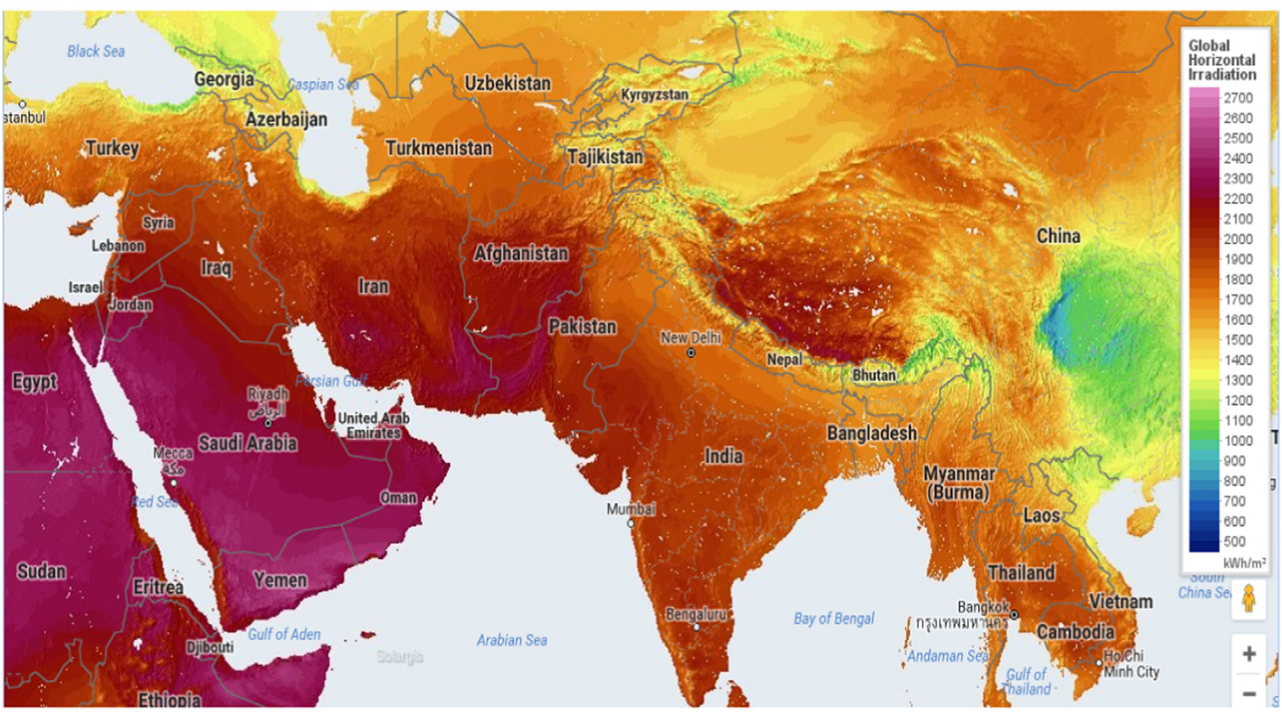


(a)



(b)

Fig. 1. (a) GHI potential in Germany [5] (Solar resource map © 2018 Solargis).(b) GHI potential in Qatar and China [5] (Solar resource map © 2018 Solargis).

Normal Irradiance) which hinder the development of CSP technologies in their territory. Due to which they could not sustain this development for longer durations continuously. However, Qatar and other Gulf countries are blessed with higher DNI radiation levels.

Furthermore, China has achieved the leading position in solar PV installation worldwide. The GHI (Global Horizontal Irradiance) maps are given below for both the countries along with GHI potential map for Qatar. It is evident from the Fig. 1(a & b), the GHI levels in Germany are in the range of 1000 kWh/m^2/year which are half of the levels available in Qatar. The GHI levels in China and Qatar are in the almost similar domain (1900–2000 kWh/ m^2/year).

The shaded sections in Fig. 1(a & b) above explicitly show that there is a vast solar energy potential in Qatar and the nearby Gulf Cooperation Countries (GCC) which is presently untapped. There is a need for shifting policies from fossil-based energy generation and consumption to renewable or specifically solar-based energy systems. Further, shifting focus on advanced solar technology (Solar thermal) and its availability all over the world, it can be concluded that there lies a tremendous opportunity for cooperation amongst different nations. Fig. 2(a & b) give an insight of DNI levels in the mentioned regions of the world [5].

Fig. 2(a) shows the DNI ranges in the USA, where the concentration is 2712 kWh/m^2/year, which is followed by Spain and the countries in the MENA region (Fig. 2(b)). The DNI for Spain is 2075 kWh/m^2/year,