Journal of
Photonics for Energy

PhotonicsforEnergy.SPIEDigitalLibrary.org

Special Section Guest Editorial: Solar Energy Solutions for Electricity and Water Supply in Rural Areas

Kerstin Wydra
Fatima Toor
Martina Jaskolski
Nikolaos Tzoupanos

SPIE.

Kerstin Wydra, Fatima Toor, Martina Jaskolski, Nikolaos Tzoupanos, "Special Section Guest Editorial: Solar Energy Solutions for Electricity and Water Supply in Rural Areas," *J. Photon. Energy* **9**(4), 043101 (2019), doi: 10.1117/1.JPE.9.043101.

Special Section Guest Editorial: Solar Energy Solutions for Electricity and Water Supply in Rural Areas

Kerstin Wydra,[a] Fatima Toor,[b] Martina Jaskolski,[c] and Nikolaos Tzoupanos[d]
[a]Erfurt University of Applied Sciences, Germany
[b]University of Iowa, United States
[c]The American University in Cairo, Egypt
[d]Technical University of Berlin, Campus El Gouna, Egypt

Humanity is presently facing the challenges of climate change, which, when continuing on the present path, will be leading to tipping points transforming our planet into a state humankind has never experienced and is not prepared to survive in. The heating-up of our planet is primarily due to the use of fossil-fuel-based energy resources. Its geophysical and ecological consequences have a detrimental effect on our basic needs for water and food. It also threatens the ecological and socio-economic frameworks and infrastructure on which humanity relies. The seventeen Sustainable Development Goals (SDGs)[1] adopted by all United Nations member states in 2015 address these challenges, with SDG 7 "Affordable and Clean Energy" and SDG 6 "Clean Water and Sanitation" explicitly naming provisions for sustainable energy and clean water. Considering the 17 goals, solutions cannot be developed for single goals or by any single discipline; rather, interdisciplinary approaches need to synergistically link disciplines and stakeholders in order to achieve progress on a sustainable path. One such approach is the framework of the water-energy-food nexus, embedded in a socio-economic implementation framework.

This special section of the *Journal of Photonics for Energy* (JPE), on Solar Energy Solutions for Electricity and Water Supply in Rural Areas, addresses the SDG challenges, assessing technological solutions for solar energy use under conditions of limited resource access, as is often the case in rural areas of the global South. In particular, rural areas around the planet are often disadvantaged in their access to both water and energy, so the special section concentrates on the water and energy situation in rural areas. Given that many water applications rely on pumping for water supply, limited electricity supply is often inextricably linked to limited water supply. In this special section, we present a range of scientific assessments of innovative photovoltaics (PV)-based technologies for rural areas, as well as case studies from different rural areas of the planet that look into the application and success of technological innovations in place. The focus on Egypt is due to the fact that this special section was edited in concert with the Third International Conference on Solar Energy Solutions to Electricity and Water Supply in Rural Areas, hosted by The American University in Cairo in October 2018.

A review by Wydra, Jaskolski, Wagner, and Mohamed provides an introduction to the technological and socio-economic framework of sustainable energy and water supply globally, describing the current status, challenges and outlook for solar photovoltaic (PV) electricity production and water supply technologies in rural areas.[2] The water-energy-food nexus approach is presented in its relation to the Sustainable Development Goals (SDGs) globally, in the MENA region and in Egypt. Recommendations are given on institutional governance and research and development (R&D) to overcome silo thinking and enhance sector collaboration on all levels as prerequisite to achieving the SDGs. In this context, the latest developments in PV and water technologies, and their opportunities for rural development are outlined, and examples from Egypt are highlighted.

An article by Wydra, Becker, and Aulich focuses on implementation options for autonomous, solar-energy driven water supply in rural areas, with a case study of different rural settings in Nigeria.[3] Economically feasible concepts are developed for different target groups—for example, single farmers, farmer cooperatives, and communities—and for rural kiosks. In all cases, further benefits besides supply of sustainable energy and clean drinking water are achieved, providing increased food production and additional income, and thus, improving the livelihood of the rural population.

An article by Ehrmann, Fickert, and Nolz deals with PV-powered irrigation pumps in remote areas of Egypt, through optimizing azimuth and tilt angles of the PV panels in relation to the water pressure required for watering three agricultural crops: potato, tomato, and date palm.[4] For high water flow ($128\ m^3/h$) they recommend specific tilt angles for southern orientation and for east–west orientation for each crop. Farmers following these recommendations can optimize the efficiency and costs of the PV component of their irrigation system according to the specific needs of the crops.

An article by Fouad, Moataz, Kandil, Shihata, and Morgan describes the optimization of PV systems and thermal insulation layers in a zero energy building under Egyptian climate conditions.[5] The optimal position and tilt angle for PV modules serving for energy generation and as shading elements for energy savings in combination with insulation options were studied. Additionally, the resulting monetary savings of up to 235% for the optimal combination are presented.

Harrag presents a neural network maximum power point tracking (MPPT) controller, in order to improve the performance of a PV-driven water pumping system.[6] The proposed neural network MPPT controller has been trained using inputs and output data collected using the conventional P&O algorithm. The efficiency of the proposed algorithm has been studied successfully using a DC motor-pump powered by 36 PV modules via a DC-DC boost converter controller using the proposed neural network MPPT algorithm. Experimental study results using the STM32F4 board in the hardware in the loop mode prove that the efficiency of the proposed controller reduces the response time and eliminates the steady-state oscillation, leading to an improvement of the entire system performance.

Ullah presents optical modeling of a concentrator photovoltaic (CPV) system, which consists of a primary parabolic trough and a secondary nonimaging reflector.[7] The proposed system is capable of providing high concentration and greater reliability than traditional trough-based designs. The proposed design sets the solar cell at the center of a trough in a square shape, which achieves a geometrical concentration of 285, an acceptance angle of ± 1.1 deg, and an optical efficiency of 72%. The detailed architecture design and optical ray-tracing simulation are presented to show the innovative idea for harnessing solar energy using the parabolic trough concentrator.

Jaskolski, Schmitz, Otter, and Pellegrino investigate the success of solar driven water filtration technologies based on a 14-month applied study carried out in 16 oasis villages across Egypt's Western Desert.[8] The article assesses the feasibility of running anodic oxidation and greensand filtration for drinking water purification solely based on solar PV energy input. The study analyzes the ability of the solar PV-driven solution to generate water that adheres to international and national drinking water standards, focusing particularly on iron removal and chlorine generation. The authors conclude that the system was successfully run by local operators in this remote desert area for several years, and proved to be a relatively maintenance-free solution. While the technology efficiently removed iron from the water, small system improvements were needed in order to permanently guarantee safe chlorine levels in the water. The article makes a contribution to assessing the performance of innovative off-grid PV solutions for the supply of safe drinking water in rural areas, as required by SDG 6, and emphasizes the high potential of small-scale solar PV technology innovations in this area.

Yu Jeco, Larroder, and Oguma examine the technical and social feasibility of using a solar powered ultraviolet light-emitting diode (UV-LED) module for microbial water treatment in Panobolon Island in the Central Philippines.[9] Using a laboratory-scale prototype, the authors tested the system's efficiency in treating water sampled from deep wells on the island. A survey conducted with local residents assessed the social response to the tested technology. On the laboratory scale, the system successfully removed *Escherichia coli* bacteria from the water, which were found to contaminate most water samples. Turbidity tests peformed on the water samples revealed the feasibility of using UV-LED technology for *E. coli* inactivation. In the social study, local residents confirmed that they were in need of water treatment and related positively to the solar-powered solution, confirming readiness to receive training on the building, operation, and maintenance of the suggested system.

References

1. United Nations, "Sustainable development goals," 2015, https://www.un.org/sustainabledevelopment/sustainable-development-goals.
2. K. Wydra et al., "Nexus approach to solar technology for energy and water supply for sustainable rural development in Egypt: a review," *J. Photonics Energy* **9**(4), 043108 (2019).
3. K. Wydra, P. Becker and H. A. Aulich, "Sustainable solutions for solar energy driven drinking water supply for rural settings in Sub-Saharan Africa: a case study of Nigeria," *J. Photonics Energy* **9**(4), 043106 (2019).
4. S. Ehrmann, L. Fickert and R. Nolz, "Optimizing the setup of a photovoltaic pumping system for irrigation considering different crop water requirements," *J. Photonics Energy* **9**(4), 043104 (2019).
5. M. M. Fouad et al., "Simulation of a zero energy office building in Egypt with a photovoltaic integrated shading system," *J. Photonics Energy* **9**(4), 043103 (2019).
6. A. Harrag, "Neural network maximum power point tracking for performance improvement of solar PV water pumping system," *J. Photonics Energy* **9**(4), 043109 (2019).
7. I. Ullah, "Optical modeling of two-stage concentrator photovoltaic system using parabolic trough," *J. Photonics Energy* **9**(4), 043102 (2019).
8. M. Jaskolski et al., "Solar-powered drinking water purification in the oases of Egypt's Western Desert," *J. Photonics Energy* **9**(4), 043107 (2019).
9. B. M. Yu Jeco et al., "Technosocial feasibility analysis of solar-powered UV-LED water treatment system in a remote island of Guimaras, Philippines," *J. Photonics Energy* **9**(4), 043105 (2019).