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Editorial

Energy Systems and Applications in Agriculture

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Agriculture and agro-based industries consume more energy, mainly derived from fossil fuels. The extensive use of fossil fuels results in greater greenhouse gas emissions, ultimately triggering climate change. For example, Pakistan is an agricultural country and, per capita, emissions are considered extremely low compared to the rest of the world. However, it has been globally ranked at the seventh most to be affected by climate change. Unexpected heavy rainfalls recently caused flooding in Pakistan, evidencing global climate change, and resulting in huge agricultural losses in addition to human life and infrastructures. It is difficult to achieve the UN SDGs under such devasting scenarios in developing countries such as Pakistan. Therefore, the deployment of mostly energy-efficient and renewable energy resources in agriculture and associated sectors seems crucial. MDPI's journal *Energies* realized this burning problem, and offered a Special Issue with themes surrounding, but not limited to, energy-efficient agriculture, robotics and farm mechanization, food processing and storage, renewable energy for agriculture, temperature and humidity control systems for agriculture, sustainable energy and clean fuel for farmers; biomass, biogas and bioenergy; next-generation greenhouses; aquaponics, hydroponic and aeroponic farming; sprinkler and drip irrigation systems, solar dryers and solar pumping, livestock and poultry barns, agricultural built environments, modeling and simulation and modern water/wastewater treatment. The journal published eleven high-quality articles in this Special Issue entitled "Energy Systems and Applications in Agriculture", mainly focusing on various agricultural applications powered by energy-efficient and/or nonconventional energy resources, including renewable energy. A short review of the published articles is defined below for the readers to easily chose the topic of interest accordingly.

The postharvest storage of agricultural products is crucial for the minimization of postharvest losses, which, throughout the supply chain, are controlled through the provision of optimum temperature and relative humidity conditions. The vapor compression refrigeration system operated using the grid electricity is generally used for providing such optimal conditions, resulting in a higher energy consumption and carbon footprint. However, a cooling-pad-assisted solar hybrid system that consumes 30% grid electricity and 70% from solar PV modules was used for tomatoes storage [1]. Physicochemical (total weight loss, total soluble solids, titratable acidity, pH, etc.) analyses showed the efficient storage of tomatoes under the studied system [1].

The postharvest storage life of agricultural products can be enhanced through drying, which can be performed with dryers that use fossil fuel, electric or solar energy. Microwave drying has advantages of product quality preservation and being time saving [2]. An experiment performed on cantaloupe slices revealed that thinner samples under a higher microwave power resulted in better thermodynamic performance [2]. Moreover, energy and exergy parameters modeled using the adaptive neurofuzzy inference system (ANFIS) predicted results more accurately than an artificial neural network (ANN) [2] did.

Agricultural production requires energy for processes ranging from sowing to harvesting and/or processing until consumed by the end user. The investigation of the energy consumption of major food crops (wheat–rice) in Pakistan was conducted to ascertain the total energy consumed by these crops [3]. The study results revealed that the total energy consumption of rice was twice that of wheat production [3]. The associated CO_2 emissions were also higher in rice production.

Irrigation pumping systems (IRSs) are mostly employed in irrigating crops to fulfill water requirements and can be powered through conventional and nonconventional energy resources. Energy utilization in agriculture can be optimized by operating IRSs with solar and/or wind energy [4,5]. A technoeconomic assessment of nonconventional energy resources (solar, wind and hybrid) in Sudan revealed that solar PV was more suitable in most studied sites for irrigation water pumping, as compared to wind and wind–solar hybrid energy systems [4].

The uncontrolled burning of agricultural wastes/residues is one of the major causes of environmental pollution. Thermochemical processes used to extract useful energy from agricultural waste include carbonization, gasification and pyrolysis [6]. The biofuel can be generated from date palm waste through the pyrolysis technique [6]. Technoeconomic analyses of date palm pyrolysis revealed that Saudi Arabia earned approximately USD 44.77 million annually by processing date palm waste (only 50%) through pyrolysis with a 2.57 year payback period [6].

Greenhouse production in cold regions is badly affected by very low outdoor temperatures, with most greenhouses in Canada shutting down in colder months, particularly from November to February. This is due to the high costs involved in heating and dehumidification to maintain the greenhouse's environment. However, Chinese solar greenhouses with south monoslopes (CSGs) are the way forward to avoid expensive heating in winter [7]. The CSGs, in comparison to traditional greenhouses, could save 55% on annual heating for vegetable production in the Canadian environment [7]. In another study, an air-to-water heat pump (AWHP) was developed for greenhouse heating in Daegu, Korea [8]. The COP of the system was calculated to be 2.2, even at lower outside temperatures ($-13°$) [8].

The membrane energy recovery ventilator (ERV) can be used to recover energy from the exhaust of air-conditioned buildings. The study investigated the energy saving potential and CO_2 emissions along with other thermal comfort parameters by employing the ERV [9]. It was determined that the hybrid system consisting of the Maisotsenko cycle evaporative cooling (MEC), vapor compression air-conditioning (VAC) and ERV (i.e., MEC-VAC-ERV) achieved thermal comfort with a higher energy-saving potential (49%), and lower CO_2 emissions (499.2 kg CO_2/kWh) as compared to other studied systems in building air-conditioning [9].

The rotating biological contactor (RBC) can be used for the treatment of different wastewaters with a lower carbon footprint. The energy-efficient RBC could be easily operated with renewable energy sources, such as solar or wind, saving approximately 90% in energy costs. The studied RBC only consumed 0.14 kWh/m^3 [10], which was reasonably less than conventional treatment options. On the other hand, the average removal efficiency of COD, TN, ammonium, and turbidity was reported to be approximately 73.9%, 38.3%, 95.6% and 78.9%, respectively [10]. Mercury removal from wastewater using modified corn-cob-activated carbon was investigated in another study [11].

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References

1. Munir, A.; Ashraf, T.; Amjad, W.; Ghafoor, A.; Rehman, S.; Malik, A.U.; Hensel, O.; Sultan, M.; Morosuk, T. Solar-Hybrid Cold Energy Storage System Coupled with Cooling Pads Backup: A Step towards Decentralized Storage of Perishables. *Energies* **2021**, *14*, 7633. [CrossRef]
2. Zadhossein, S.; Abbaspour-Gilandeh, Y.; Kaveh, M.; Szymanek, M.; Khalife, E.; Samuel, O.D.; Amiri, M.; Dziwulski, J. Exergy and Energy Analyses of Microwave Dryer for Cantaloupe Slice and Prediction of Thermodynamic Parameters Using ANN and ANFIS Algorithms. *Energies* **2021**, *14*, 4838. [CrossRef]
3. Ashraf, M.N.; Mahmood, M.H.; Sultan, M.; Shamshiri, R.R.; Ibrahim, S.M. Investigation of Energy Consumption and Associated CO_2 Emissions for Wheat–Rice Crop Rotation Farming. *Energies* **2021**, *14*, 5094. [CrossRef]
4. Khan, Z.A.; Imran, M.; Altamimi, A.; Diemuodeke, O.E.; Abdelatif, A.O. Assessment of Wind and Solar Hybrid Energy for Agricultural Applications in Sudan. *Energies* **2021**, *15*, 5. [CrossRef] [PubMed]
5. Khan, Z.A.; Imran, M.; Umer, J.; Ahmed, S.; Diemuodeke, O.E.; Abdelatif, A.O. Assessing Crop Water Requirements and a Case for Renewable-Energy-Powered Pumping System for Wheat, Cotton, and Sorghum Crops in Sudan. *Energies* **2021**, *14*, 8133. [CrossRef]
6. Al Yahya, S.; Iqbal, T.; Omar, M.M.; Ahmad, M. Techno-Economic Analysis of Fast Pyrolysis of Date Palm Waste for Adoption in Saudi Arabia. *Energies* **2021**, *14*, 6048. [CrossRef]
7. Dong, S.; Ahamed, S.; Ma, C.; Guo, H. A Time-Dependent Model for Predicting Thermal Environment of Mono-Slope Solar Greenhouses in Cold Regions. *Energies* **2021**, *14*, 5956. [CrossRef]
8. Rasheed, A.; Na, W.H.; Lee, J.W.; Kim, H.; Lee, H.T. Development and Validation of Air-to-Water Heat Pump Model for Greenhouse Heating. *Energies* **2021**, *14*, 4714. [CrossRef]
9. Ashraf, H.; Sultan, M.; Sajjad, U.; Shahzad, M.W.; Farooq, M.; Ibrahim, S.M.; Khan, M.U.; Jamil, M.A. Potential Investigation of Membrane Energy Recovery Ventilators for the Management of Building Air-Conditioning Loads. *Energies* **2022**, *15*, 2139. [CrossRef]
10. Irfan, M.; Waqas, S.; Khan, J.A.; Rahman, S.; Kruszelnicka, I.; Ginter-Kramarczyk, D.; Legutko, S.; Ochowiak, M.; Włodarczak, S.; Czernek, K. Effect of Operating Parameters and Energy Expenditure on the Biological Performance of Rotating Biological Contactor for Wastewater Treatment. *Energies* **2022**, *15*, 3523. [CrossRef]
11. Liu, Y.; Xu, X.; Qu, B.; Liu, X.; Yi, W.; Zhang, H. Study on Adsorption Properties of Modified Corn Cob Activated Carbon for Mercury Ion. *Energies* **2021**, *14*, 4483. [CrossRef]