

Water Footprint and Energy Sustainability

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1. Introduction

In many basins worldwide, high-quality freshwater is becoming increasingly scarce, while energy production increasingly requires freshwater. The rising demand for freshwater is linked to energy use. The supply of more water requires energy for pumping, e.g., for groundwater pumping and distribution. Also, pumping surface water from the source to the point of use requires energy. Moreover, irrigation and wastewater cleaning also require the use of freshwater, e.g., in industry. Rising demand for water, therefore, often goes along with larger energy demand. On the other hand, energy also requires water, e.g., for the cooling of power plants, the irrigation of energy crops, or hydropower. Hydropower might have a relatively large water footprint per unit of electricity when hydropower stations are located in areas with large water evaporation. This also means that if water levels in hydropower reservoirs are low, electricity generation decreases. This Special Issue includes five papers advancing the knowledge on water and energy relationships, showing innovative applications. These five papers present case studies from Sudan, China, Ecuador, Greece, and Spain, focusing on the improvement of water use efficiency in agriculture to increase crop yields with less water and higher efficiency in industry.

2. Main Contributions of This Special Issue

Gavilánez Luna and Rodríguez Jarama [Contribution 1] present a case study for banana export systems in Ecuador. The contribution applies the water footprint (WF) method to calculate water use for banana in Guayas, an important banana-cultivating region in Ecuador. This contribution not only includes water use in agriculture, but also in the post-harvest stage for packaging. It shows that, especially for grey WFs, it is important to take the whole production chain into account. The findings show that 75% of the grey WF can be attributed to agriculture, and 25% to the packaging stage.

Pujol et al. [Contribution 2] show the impact of filtration cycle patterns on both the water and energy footprints in drip irrigation systems. Drip irrigation is a very promising way to decrease blue WFs, but it requires energy. It is therefore important to develop irrigation systems that increase water and energy use efficiency at the same time. [Contribution 2] aims to determine the optimal balance between water filtration and filter backwashing in the system to reduce both water and energy consumption.

Nydrioti and Grigoropoulou [Contribution 3] present a decision support framework for industrial wastewater treatment and reuse. The framework is applied to a brewery in Greece. This contribution shows the benefits of proper wastewater treatment: because it can be reused, so that the blue WF decreases. Moreover, treatment also causes a smaller grey WF. However, there is a trade-off in energy use: more treatment leads to higher energy use.



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Lin et al. [Contribution 4] present the spatial and temporal distribution characteristics of the water footprint and water-saving potential of fruit trees in the Tarim River basin in China. In general, trees need more water than crops. The Tarim basin is an important growing area for fruit, but it encounters water scarcity. This contribution uses the WF method to quantify irrigation needs. It proposes an improved irrigation method that is far more efficient than traditional drip irrigation. Drip irrigation might save around 39 to 56% of water.

Al-Taher et al. [Contribution 5] make an assessment of the green water footprints (WFs) of sugar cane under climate change conditions in Sudan. Climate variability, possibly enhanced by increased atmospheric CO₂ levels due to, among other things, emissions from fossil energy use, affects the evapotranspiration of sugar cane in Sudan. The green WF is mainly determined by effective precipitation, which, due to variability, can differ by a factor of four among years. [Contribution 5] provides guidelines to improve the sustainable use of irrigation water, enabling agricultural area expansion and increased sugar cane yields in Sudan.

Common patterns of the Contributions are as follows: (i) the use of the Water Footprint proposed by the Water Footprint Network as a tool to quantify water use and water pollution; (ii) two Contributions take a life cycle approach, not only including the main water use in agriculture, but also in the packaging stage and in the food industry; and (iii) four Contributions show ways to improve water use efficiency, i.e., produce more with less water. Although the call for the Special Issue was focused on water and energy sustainability, only Contribution 2 focused directly on this relationship, while Contribution 5 analysed climate change caused mainly by fossil energy use.

3. Conclusions and Way Forward

Water availability and sustainable water management are relevant for Sustainable Development Goal (SDG) 6. All contributions aim to improve the sustainable use and management of freshwater. Agriculture is a major water user, so optimising agricultural water use and improving efficiency are important. [Contributions 2, 4, and 5] indicate that more efficiency is needed in irrigation to save water. Options could include the use of drip irrigation, although this comes with higher energy use. One solution could be to apply renewable energy, e.g., solar pumps for irrigation. In this way, carbon dioxide emissions related to fossil energy use can also be avoided.

[Contribution 1] takes whole production chains into account, both the agricultural stage as well as the packaging stage (industry), while [Contribution 3] focuses on industry alone. Both contributions show the importance of wastewater and its treatment. The packaging industry accounts for 25% of grey WF, while the brewery has a wastewater treatment plant to decrease grey WFs.

All contributions show the importance of holistic assessment methods for efficient resource management. The industry needs holistic methods to decrease its water and energy use per unit of product. For this, two approaches are shown in the contributions. On one hand, [Contribution 5] proposes machine learning to predict crop yields. Especially given the current increased climate variability, it is important to have a tool to show variations in agricultural evapotranspiration. This knowledge makes it possible to use water more efficiently. On the other hand, [Contribution 2] demonstrates the relevance of supply-chain thinking. Technical solutions are promising for increasing efficiency, as the results obtained in [Contribution 2] have shown.

There is a strong link between sustainable water and sustainable energy use. The transition towards a more sustainable energy system in order to decrease CO₂ emissions in an attempt to avoid further global warming is ongoing. Some of the renewables require

more water, e.g., hydropower, while others require far less water than traditional energy generating systems. For example, electricity generated from wind requires less water than electricity from fossil fuels generated by thermal power plants. Also, the cooling systems have differences in the volumes of water used per unit of electricity generated. Future research using case studies is promising for identifying options to further improve efficiency, not only in water management but also in energy management.

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List of Contributions

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