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Editorial

Sustainable Development of Energy, Water and Environment Systems (SDEWES)

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Earth's natural systems provide essential resources such as water, food, energy, and materials that we all are dependent upon. These resources would be depleted if they are consumed at a faster rate than their replacement. Overpopulation, overconsumption, deforestation, mining of minerals, erosion, pollution, and contaminations are the main causes of the depletion of natural resources.

Additionally, the planet is more than just a source of fundamentals: we also rely on Earth's systems to assimilate our waste, cycle nutrients, and provide a climate and conditions favorable for our survival. Inefficient use of materials usually results in considerable waste generation. Once generated, waste should be handled by utilizing a range of methods including recycling, reuse, treatment, energy recovery and storage.

Importantly, our activities are connected to environmental effects such as air and water pollution, climate change, and declining biodiversity. In particular, human actions on water, food, energy, waste, and urbanization have significant impacts on the environment. Such impacts both raise concerns about the future and set the stage for understanding how our own behaviors and practices can reduce such effects. As highlighted by UNEP [1], if we continue consuming our resources in the same way as today, 180 billion tons of material would be needed to meet the global demand by 2050. Consequently, this ever-increasing demand for natural resources would potentially escalate local conflicts such as those observed in areas where mining competes with farming and urban development. Our individual and collective choices that affect the environment determine whether our future will be sustainable. Decisions such as where we live, how we live, how we power our cities and industries, how we dispose of our waste, and how we use our limited water resources will play important roles in building a sustainable future.

Sustainable development has been defined by the UN [2] as "*developments that meet the needs of the present without compromising the ability of future generations to meet their own needs*." That is, the management of natural resources in ways that do not diminish or degrade our planet's ability to provide them in the future. Although the definition is short, it is not simple. It requires that we select and think ahead to a specific goal (what we aim to sustain) and also consider the factors that will affect our ability to achieve that goal. To make decisions that will help us meet our goal, we will need to answer questions such as: What kind of uses and benefits are we trying to sustain? What sorts of factors affect the continuation of those uses and benefits?

Engaging deeply with sustainability also takes us beyond environmental science, into other fields of inquiry. Science alone cannot tell us what kind of future we ought to work toward, what ought to be sustained, or how environmental benefits and harms ought to be distributed in society. Questions like these, and the decisions and actions that stem from them, invoke values. Therefore, in this Special Issue, several articles present relevant tools and concepts from a range of different perspectives.

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In 2002, the first Sustainable Development of Energy, Water, and Environment Systems (SDEWES) Conference was held in Dubrovnik, Croatia. Since then, a total of 21 conferences around the world have been organized to address the above-mentioned issues. In 2021, the 16th SDEWES conference was held, from October 10 to 15 in Dubrovnik, Croatia. The conference brought together around 630 scientists, researchers, and experts in the field of sustainable development from 58 countries.

The tradition of SDEWES conferences is that, after each event, the authors of the most valuable papers are invited to publish their research results in Special Issues of high-ranking journals. Seven papers presented at the conference were selected for this Special Issue of *Sustainability* as reviewed below.

The first contribution to this Special Issue was provided by Serna-Loaiza et al. [3]. They acknowledge the importance of biorefineries for future sustainable societies, and they conducted experiments and analyses to identify optimal conditions for an important pre-treatment step, namely the liquid-hot-water. After running different experiments, they found the ideal temperature and duration minimizing the degradation products and lignin hydrolysis. By applying such an inclusive approach where lignin hydrolysis is analyzed within the liquid-hot-water pre-treatment processes, this study allows for more integrated decisions that value all the different lignocellulosic components of wheat straw. The same TU Wien team, this time led by Adamcyk, conducted further experimental work on lignin in the fourth Special Issue contribution, looking at the effect of temperature on the precipitation of colloidal lignin particles [4]. The different results depending on temperature and initial concentration pave the way for future research in the optimization of lignin precipitation processes. Lignin is an abundant biopolymer, with several prospective applications as a material, such as in sunscreens, emulsifiers and food packaging, thus making it more efficient to be produced and can increase its use.

In the second contribution, Papapolymerou and colleagues tackle existing issues with respect to microalgae and anaerobic digestate [5]. For a sustainable society, founded on principles of the circular economy, new further applications and uses of the nutrient-rich anaerobic digestate, produced by biogas plants, should be explored. While studies already exist, assessing the economic feasibility of using anaerobically digested sludge as fertilizer, their results are usually conditions- and location-dependent [6], in turn implying that more potential uses may provide effective, suitable alternatives when/where appropriate. As such, this study assesses the effect of adding the digestate to the growth medium of a specific microalgae species and checks how its growth rate is affected. Results were promising towards future higher uptake of anaerobic digestate as a raw material for microalgae growth media formulation, thus potentially leading to higher biomass production.

Another advancement in relation to waste minimization associated with novel products is presented in the third Special Issue contribution, by Daza-Serna and colleagues [7]. Acknowledging the increasing demand for erythritol as a sugar substitute, they assess through experiments the potential of electrodialysis as a more efficient method for ions removal and recovery, in order to develop a cleaner, optimized industrial process for erythritol production. Although with relatively low efficiency values, implying the need for more research into improved energy utilization, desalination of 96% was achieved, making electrodialysis an attractive process for this application, worth future investigation. With the three pillars of sustainability (environmental, economic, and social) typically interconnected, here the authors show the importance of public awareness to increase the uptake of new technologies and ideas.

A very different, but nonetheless intriguing, research work linking current biotechnologies and future sustainable societies was provided in the fifth contribution, by You et al. [8]. With cities and communities becoming increasingly reliant on digital tools and technologies, the related power consumption is nothing but negligible. In the study, a “bio-digital” interface powered by microbial fuel cells was developed and continuously operated over one year, producing enough power to be self-sufficient in relation to data logging, transmission, LED and more.

Arguably the greatest opportunities for energy efficiency benefits still pertain to the building sector, due to their large share of total energy consumption. As such, this was the focus of Novelli et al. in the sixth contribution to this Special Issue [9]. More specifically, they simulated a medium-scale commercial office building according to the Quality-Matched Energy Flows framework, with positive implications for lighting demands, cooling, and heating loads, peak demands, net energy use, operational costs, and design considerations. Significant energy and cost reduction were modelled, though remained considerable, thus highlighting an opportunity for further research. Overall, buildings will remain a central focus of sustainability research, due to not only their high energy footprint, but also their related construction and demolition waste, which has prompted research into potential waste trading schemes and a more sustainable project/construction management process [10]. In addition, less commonly used materials will need to be considered more often as an alternative to concrete and steel, which are linked to significant embodied energy, water and carbon. For instance, recent studies have analyzed the footprint of wooden houses in relation to indoor environment quality risks and life cycle assessment [11].

The Special Issue concludes with its seventh contribution, by He and all, which mainly deals with economic aspects of sustainability [12]. Specifically, a novel mathematical modelling approach was developed and applied to assess African countries' petroleum investment environment. A similar study, though utilizing a more traditional multi-criteria decision approach, recently assessed the merits of different electricity generation technologies for Niger [13]. Applying credible, reliable, and robust modelling approaches, especially those that can deal with and quantify uncertainty, together with effective data collection methods [14], will be increasingly crucial for future studies in all of the several interconnected fields of research related to the "Sustainable Development of Energy, Water and Environment Systems". It is argued that more systematically applying a system thinking approach, could help researchers and the society as a whole to understand the interactions among sustainable development goals, and thus their synergies and tradeoffs [15,16], in turn facilitating the achievement of the ambitious, but crucial, global targets.

This Special Issue of *Sustainability* overviews the selected papers submitted to the SDEWES Conferences in 2020 and 2021. These papers address the issues in the fields of sustainable development, energy, water, buildings, infrastructure, and waste management. Translating the contributions of these papers into impacts is highly important for developing policies and strategies for a sustainable future through gaining knowledge and further increasing public awareness. The editors of this Special Issue believe that the papers published here will be of interest to the readership of *Sustainability*. Future SDEWES conferences will maintain the tradition of disseminating new research methods and findings on sustainability. Readers are referred to the International Centre for Sustainable Development of Energy, Water, and Environment Systems (SDEWES) for information on the upcoming events [17].

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