



A preface to the special issue of optimization and engineering dedicated to SDEWES 2020 conferences

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Abstract

Global warming and climate change call for urgent minimization of the impact of human activities on the environment. There is a great need for the improvement of resource efficiencies by integrating various life-supporting systems. The challenge is on the energy, water and environment systems to integrate and become more sustainable. This research field has received increased attention over the past years with studies across the energy, water and environment systems that optimized different engineering problems. The present Special Issue stems from four Conferences on Sustainable Development of Energy, Water and Environment Systems held in 2020, in four countries of three continents. This review introduction article intends to introduce the topical field and the articles included in this Special Issue of Optimization and Engineering.

Keywords Optimization · Energy · Water · Environment · Engineering

1 Introduction

Sustainable development is a highly interdisciplinary concept that involves the interaction of various systems, such as energy, water, and environment, by using waste from one, as a resource in another, and in the exact moment when it is beneficial to all (Mikulčić et al. 2017). In 2002, Sustainable Development of Energy, Water

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and Environment Systems (SDEWES) Conferences started to address this issue. In 2020, four SDEWES conferences were held—due to the COVID 19 pandemic, all of them as online events:

- In February, the 2nd Latin America SDEWES Conference (LA SDEWES 2020) in Buenos Aires, Argentina;
- In April, the 1st Asia Pacific SDEWES Conference (AP SDEWES 2020) in Gold Coast, Australia;
- On 28 June–2 July, 4th South-East European SDEWES Conference (SEE SDEWES 2020) in Sarajevo, Bosnia and Herzegovina;
- Finally, in September, 15th SDEWES Conference (SDEWES 2020) was held in Cologne, Germany.

Overall, SDEWES 2020 conferences created a temporally distributed forum for researchers worldwide to exchange and discuss their ideas and findings, thus demonstrating the sciences' responsivity to emerging international, European, regional and national challenges. The research topics ranged from technical, economic, environmental, and social studies to the studies investigating the sustainability of energy, transport, water, environment and food production systems and their interconnection and integration. From around 700 accepted manuscripts presented at 2020 SDEWES Conferences, ten constitute the central part of this Special Issue of Optimization and Engineering.

2 Background

The content of this section is based on articles published in special issues of other journals dedicated to the SDEWES conference series. The articles covered in this section are divided into several research areas: energy issues, water issues, environmental engineering and management, sustainable engineering solutions, and development.

Many articles have used advanced numerical methods and mathematical modeling techniques to study energy engineering problems of differentiated complexity. The topics ranged from the optimization of a microchannel ceramic heat exchanger (Shi et al. 2017), geometry determination for oscillating water-column wave-energy converters (Ulazia et al. 2020) to studying the impact of district energy share in cities on the optimal sizing of energy storage (Dominković and Krajačić 2019). In the same category of decision-making problems, steam system optimization in an industrial combined heat and power (CHP) plant (Filkoski et al. 2020) and energy recovery by retarded osmosis in a sugar plant (Safder et al. 2020) was studied. Multi-objective optimization and other advanced decision-making approaches were adopted in studying a factory acting as a prosumer on the electricity market (Perković et al. 2017), selecting working fluids for geothermal plants (Martínez-Gomez et al. 2017), and designing equipment units or components for a CHP unit (Costa et al. 2020) and aspirating smoke detection system (Višak et al. 2021). High-tech applications included metaheuristic optimization methods for grid-edge

technology (Schellenberg et al. 2020), as well as optimization and optimal control of HVAC systems for an electric vehicle (Cvok et al. 2021) and manufacturing environments (Mawson and Hughes, 2021).

Expanded demand for clean and environmentally friendly production of goods in industrialized countries increases the need for cleaner power generation, including that from Renewable Energy Sources (RES). Seljak et al. (2016) studied micro gas turbines supplied with alternative fuels, including tire pyrolysis oil and liquefied wood. A novel system for waste heat recovery and water saving in coal-fired power plants was proposed by Tan et al. (2021). Novosel et al. (2021) considered combined energy conversion and hydrogen generation in thermal power plants. Concentrated solar power plants with energy storage were studied by Ortiz et al. (2017). The application of photovoltaics (PV) in domestic hot water systems was investigated by Casaleiro et al. (2018) and in floating power plants—by Tina et al. (2021). The potential of PV and wind power in the respective countries' energy systems was studied in Brazil by Schmidt et al. (2016) and in Russia by Ermolenko et al. (2017). Hydropower generation and its links with urban water management and flood risk mitigation were considered by Sahin et al. (2017). The concept of osmotic power plant driven by the salinity gradient between seawater and river water in the mouth of Magdalena River in Colombia was presented by Salamanca et al. (2019).

Safe and accessible sources of energy have become an important goal of all modern societies. Many published studies consider the integration of renewable sources in energy systems, using the least-cost optimization models as a planning tool for long-term generation expansion. A study by Fedak et al. (2017) presents the development of the Autonomous Power Supply (APS) system based on the energy mix. Such a system works in an isolated arrangement and reliably supplies electricity from renewable sources for small residential or public utility devices in an urban area. The paper by Dorotić et al. (2019) proposes a novel approach for defining the energy system of a carbon-neutral island that relies on intermittent renewable energy sources in combination with the vehicle-to-grid concept as a demand response technology taking also marine transportation into account. In work by Šare et al. (2015), three scenarios for the years 2020, 2030 and 2050 are presented, highlighting the influence of electric vehicles on both the hourly distribution demand curve and electricity production from renewable energy sources in Dubrovnik region. This work aims to achieve a 100% renewable and sustainable region's power system up to 2050. In a similar paper by Vidal-Amaro and Sheinbaum-Pardo (2018), the Minimum Total Mix Capacity (MTMC) method enables establishing and evaluating different high-RES scenarios for transitioning the Mexican electricity system to a system where RES cover 75% of the electricity demand. Bačeković and Østergaard (2018) compare two possible ways to develop a 100% renewable energy system using the example of Zagreb, the capital of Croatia. The first is the traditional non-integrated renewable energy system, where each energy sector is developed independently. In contrast, the second employs the concept of an intelligent energy system where different sectors are linked together to exploit synergies and increase the system's efficiency. Thellufsen et al. (2020) present a methodology to design Smart Energy Cities within the context of 100% renewable energy at a national level. This approach is adopted in transitioning the municipality of Aalborg

to a 100% renewable smart energy system within Danish and European energy systems. Supplementary to the above analyses, Taseska-Gjorgievska et al. (2019) focus on the transmission network capacity to accept variable renewable energy.

Biomass as a renewable energy source that could efficiently replace fossil fuels has been investigated widely. Biomass availability for energy production on a national or regional scale was studied in Sweden by Kjärstad and Johnsson (2016), in Japan by Ooba et al. (2016), and in Italy by Caputo et al. (2019). The energy potential of biomass-derived by-products or waste generated in agriculture was investigated by Knápek et al. (2020). On the level of specific countries or regions, the same issue was studied in Croatia by Pfeifer et al. (2016), in Austria by Maier et al. (2017), in Italy by Milani and Montorsi (2018), and in Taiwan by Chang et al. (2019). San Juan and Sy (2021) developed a multi-objective target-oriented robust optimization model to design biomass co-firing networks integrating uncertainty in biomass properties with investment and operations planning. Ozgen et al. (2021) presented an overview of nitrogen oxides emissions from biomass combustion for domestic heat production.

Researchers paid much attention to the strategies and technologies for the sustainable use of biomass. Tabata et al. (2021) investigated interactions between woody biomass energy systems and natural ecosystem. Policy impact on the economic viability of biomass gasification systems in Indonesia was discussed by Sriwannawit et al. (2016). Mikulandrić et al. (2020) modelled temperature distribution and syngas composition in a fixed bed biomass gasifier using advanced mathematical tools. A graphical method based on the break-even concept to determine the sustainable use of biomass was proposed by Fan et al. (2020). Budzianowski and Postawa (2017) reviewed and synthesized the knowledge available in the scientific literature about the carbon footprint of renewable energy from biogas. They highlighted that biogas could decarbonize energy systems only when its life-cycle CO₂ footprint is lower than that of displaced conventional technologies. Ajanovic and Haas (2014) studied economic prospects of advanced biomass-based energy carriers in EU countries up to 2050. Graciano et al. (2018) analyzed novel conceptual routes for thermochemical conversion of microalgal biomass into marketable products.

The Water engineering problems have been discussed and analyzed by many articles, where the water-energy nexus has been most significantly studied (Urbaniec et al. 2016). Technology-oriented studies investigated, among others, the performance of a direct contact membrane distillation (DCMD) system driven by salt-gradient solar ponds (Suárez and Urtubia 2016), and water-energy-GHG nexus of alternative heat recovery options in the industry (Chinese et al. 2018). Large-scale thinking was represented by Sankey-diagram application in the studies on China's energy-water nexus performed by Hu et al. (2013) and later also Ou et al. (2014), analysis of the water and renewable energy nexus in Sub-Saharan Africa (Brandoni and Bošnjaković 2017), cross-sectoral integration of the water and energy issues in Brazil (Semertzidis et al. 2018), and the integrated assessment of the German food-energy-water nexus sector (Schlör et al. 2018a, b). The importance of climate change was visible in the studies on combining the net-zero targets for a hydrogen community with an energy/exergy-water nexus perspective (Kilkış and Kilkış 2018)

and the implications of national climate targets on the energy-water nexus in Germany (Sehn and Blesl 2021).

The reviewed articles are only a part of the SDEWES papers that highlight the successful applicability of optimization in engineering developments related to energy, water and the environment. The papers from previous SDEWES conferences confirm that there is still a lack of further research within all of the reviewed thematic areas.

3 Overview of the special issue articles

This OPTE SI dedicated to the SDEWES 2020 Conferences includes ten papers concerned with data collection and engineering decision making related to Energy and Environment problem types.

Industrial building design (IBD) is an engineering activity whose main goals are minimum investment costs, maximum flexibility and expandability of production systems. As it involves knowledge of architecture, structural design, energy and production planning, there is a need for multidisciplinary and multi-objective optimization (MOO) methods for supporting engineering decisions. Reisinger et al. (2021) observed that most research on and tools for optimal design solutions and decision-making focus either on a production system or building optimization. Therefore, holistic approaches, efficient design exploration schemes, and complete data availability are lacking. After performing state-of-the-art analysis and fifteen expert interviews, the authors used the acquired information for developing a design space for efficient use of MOO in IBD to integrate flexibility trade-off besides traditional economic and environmental exchanges. A digital parametric model implementing the design space was developed and tested on a pilot project from the food and hygiene products sector. Results validated the efficiency of both design space representation and flexibility rating. There is a need for developing an interactive MOO algorithm that could guide decision-making towards economic, environment-friendly and flexible design solutions.

Šramková et al. (2021) studied collecting reliable waste composition data needed for the planning, on the level of territorial units, of future waste management, including the potential for sorting and recycling, and waste treatment infrastructure. In principle, it is possible to determine waste composition based on constantly updated mixed municipal waste analyzes. However, as only a limited number of analyzes could be available, arriving at reliable results presents a complicated statistical problem. For each area under consideration, one has to decide where to sample the waste (which sub-areas are representative in the sense of waste composition) and how many representative samples are sufficient for the reliable description of waste composition. The authors tested the described approach to acquiring waste data in a case study for the Czech Republic at the micro-regional level. After stratifying the investigated territory into five clusters of sub-areas, they applied the model for the representatives' choice. The interpretation of acquired results led to the conclusion that one has to select appropriate statistical methods for calculating confidence intervals of the estimates of waste fractions.

Waste-to-energy (WTE) treatment is an efficient approach to waste utilization and an essential countermeasure against global warming. Among various WTE methods, the steam supply from waste treatment plants to industrial sectors stands out due to its high energy recovery efficiency. However, as Maki et al. (2021) observed, the WTE transition is not spreading in Japan because Japanese policymakers do not fully understand its economic benefits. They tend to focus on single facility performance improvement, neglecting the importance of the WTE to regional development and its effects on land use. Selecting the highly industrialized Aichi prefecture as the case study area, the authors estimated the potential of steam supply and demand from waste treatment plants to the industrial sector and evaluated possible economic benefits. After assessing the spatial distribution of the industries' heat demand and economical steam transport distance, they evaluated the steam supply potential from waste treatment plants to industrial sectors. Undoubtedly, such potential exists in Aichi prefecture as a territory of steelworks, machine building, and car factories. However, there is no heat supply capability of the waste treatment plant currently. Although it is profitable to supply heat within a 1 km range, the profitability will decrease with the extending heat supply distance. One can improve the efficiency of energy recovery from waste by changing the location of the waste treatment plant and increasing heat transport efficiency on both the supply and demand side.

Waste collection and treatment systems and various industrial facilities and transport systems are significant contributors to air pollution. To control and enable air pollution mitigation, systematic collection of necessary data through measurements of air quality parameters is essential. Pochwała et al. (2021) discussed applying a low-cost measurement system for Particulate Matter pollution mounted on Unmanned Aerial Vehicles. The aim was to develop cheap, small, and lightweight devices for use in creating atmosphere quality surveys, especially in cities and heavily urbanized spaces. The authors tested a prototype UAV-mounted measurement system over a burial area close to a medium-sized town in Poland, thus avoiding inconvenience to the local population. They analyzed obtained data on PM₁, PM_{2.5} and PM₁₀ concentration at different altitudes through an inductive knowledge management system for classification analysis of air pollution. Answers were sought using the decision tree method to the questions on which PM indicators to measure and at which altitude to ensure completeness of measurement results for a particular survey area. The optimized measurement plans would enable systematic air pollution measurements employing cheap sensors mounted on drones.

As renewable energies are essential sources for supplying electric power demand and a fundamental entity of future energy markets, wind power producers (WPPs) in most of the world's power systems have a crucial role. On the other hand, the wind speed uncertainty makes WPPs deferent power generators, which causes adequate bidding strategies, leading to market rules, and the turbines' functional abilities to penetrate the market. The paper by Heydari et al. (2021) proposed a new bidding strategy based on optimal scenario making for WPPs in a competitive power market. As WPP generation is uncertain, the producers must create different plans for wind power production. In this vein, the authors improved the prediction intervals method to make scenarios and increase the accuracy of the presence of WPPs in the

balancing market. Besides, they proposed a new algorithm called the grasshopper optimization algorithm (GOA) to simulate the optimal bidding problem of WPPs. A set of numerical examples and a case study based on real-world data illustrated the proposed method's properties.

Kraft processes constitute adaptation options to biorefineries for producing biofuels and other high-value products from wood biomass. Biorefineries enable opportunities to increase the process's revenue, reduce fossil fuels usage and greenhouse gas emissions. However, to ensure an effective Kraft process transformation, the existing mill infrastructure needs to be consolidated. In this sense, simultaneous optimization of the water system, the heat exchanger network and the utility system is necessary. The literature review by Ahmetović et al. (2021) identifies a series of systematic methods (process integration conceptual and mathematical programming) along with the results of several case studies that reduce water and energy consumption in Kraft processes. Initial studies in this field considered and solved separate water and energy integration problems. Recent works have focused on developing combined water and energy integration methods and their application to various process options. Typical savings lead to freshwater consumption decreases between 20 and 80% and energy consumption reductions between 15 and 40%.

Ibrić et al. (2021) addressed the synthesis of combined evaporation-crystallization energy systems for recovering valuable materials from waste in line with sustainable development and circular economy concepts. The authors considered the utilization of distiller waste from the Solvay process, which comprises sodium chloride (NaCl), calcium chloride (CaCl₂), and water. The superstructure optimization of a heat-and-power-integrated evaporation-crystallization system employed solving the proposed mixed-integer nonlinear programming model (MINLP). The developed thermodynamic model for multi-component electrolytic systems enabled to include the partial crystallization of NaCl and production of concentrated CaCl₂ solution in addressing the considered case study. A three-step solution strategy helped to circumvent a problem with added nonlinearities and solve the overall MINLP model. The authors presented the optimal design of a heat-integrated evaporation-crystallization system with mechanical vapour compression. Applying the model to solving a range of decision-making problems such as increasing the product value or reducing equipment and utility costs should be possible.

District heating networks play a crucial role in the transition towards sustainable cities, thanks to their ability to efficiently provide space heating and domestic hot water to buildings using renewable sources, waste heat sources, and cogeneration plants. The paper by Quaggiotto et al. (2021) focused on the optimized generation of the district heating networks' heat supply units. The optimization problem relying on a Mixed-Integer Linear Programming formulation and a detailed district heating network model based on finite difference methods enabled the simulation of a model predictive control strategy. The proposed control strategy aims to minimize the district heating operator's operational costs by using two flexibility sources: the thermal inertia of the heat carrier fluid in the network pipelines and an additional centralized thermal storage tank. Computer simulations of Verona's (Italy) district heating network were carried out to schedule, over two typical weeks, the heat supplies of the cogeneration units, heat pumps and gas boilers as functions of heat load,

waste heat production and electricity price forecasts. Results show that the cost savings obtained using the network as thermal buffer compared to the current control reach 14.4 and 3.1% in a middle-season and winter week. The thermal storage tank determines a significant further cost reduction in the winter week only. In conclusion, the article shows the potential of the considered model predictive control strategy with different flexibility sources.

Public transport services in Europe rely to 60% on buses, and most vehicles are diesel-fueled. In response to the governments' pressure to introduce zero-emission buses, regional transport administrators attempt to apply analytical tools for identifying optimal solutions. However, only a few of the published models combine least-cost planning with the assessment of emissions, taking into account multiple technologies which might achieve these aims. Chinese et al. (2021) adapted an existing optimal location model for urban electric transport to match regional transport needs, aiming to evaluate well-to-wheel carbon emissions along with airborne emissions of NO_x and PM10. Model application to a real case study of a regional bus transport service in North-Eastern Italy resulted in identifying electric buses with relatively small (60 kWh) batteries as the best compromise for reducing carbon equivalent emissions. Even though Italy's current economic conditions, such vehicles' life cycle cost is still much higher than those of Euro VI diesel buses. The case study indicates that the proposed model is a valuable tool for studying ways to minimize infrastructure costs while allocating low- or zero-emission buses to the most suitable routes maximizes the environmental benefit.

Plug-in hybrid electric vehicles (PHEVs) typically combine several power sources, coordinated through an optimal energy management strategy. When considering the so-called blended mode, in which the engine regularly operates over a trip, the shape of battery state-of-charge (SoC) trajectory over travelled distance is crucial for achieving minimum fuel consumption. The paper by Soldo et al. (2021) deals with an in-depth analysis of optimal SoC trajectories obtained by off-line control variable optimization of a PHEV-type city bus given in parallel (P2) powertrain configuration. The authors conducted optimization using dynamic programming based optimization algorithm for a wide range of driving cycles and operating scenarios. Unlike usually assumed linear-like near-optimal shape, the SoC vs travelled distance trajectory can take on significantly different optimal shapes for non-zero road grade profiles or driving cycle with a relatively long distance. The emphasis is on analyzing the root causes for such behaviour and its implications for fuel consumption.

4 Conclusions

This article reviews ten recent research papers devoted to optimizing engineering problems related to the sustainable development of Energy, Water and Environmental Systems. Written by author teams representing more than a dozen countries of Asia, Europe and North America, the contributions illustrate global research efforts that topical area is attracting. The Guest Editors believe that the selected papers and the addressed issues expand the knowledge body published in the Optimization and

Engineering journal and will be of interest to its readers. The Guest Editors also hope that after the inaugural SI published in January 2021 (see editorial by Mikulčić et al. 2021), this second special issue will strengthen the collaboration between the SDEWES Conference series and the OPTe journal.

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