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Review Article

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ABSTRACT

The Journal of Sustainable Development of Energy, Water and Environment Systems (JSDEWES) is an international journal dedicated to the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from natural resources and replacing them with knowledge based economy, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding energy, transport, water, environment and food production systems and their many combinations. In total 67 manuscripts were published in Volume XIII, all of them reviewed by at least two reviewers. The Journal of Sustainable Development of Energy, Water and Environment Systems would like to thank reviewers for their contribution to the quality of the published manuscripts.

KEYWORDS

Editorial, Equity, Renewables, Electrification, Circularity, Resilience, Decarbonization, Sustainability.

INTRODUCTION

This editorial discusses the contributions of the papers belonging to Volume XIII of the The Journal of Sustainable Development of Energy, Water and Environment Systems (JSDEWES), an international journal dedicated to the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by decoupling growth from natural resources and replacing them with knowledge based economy, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding energy, transport, water, environment and food production systems and their many combinations.

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ENERGY COMMUNITIES AND EQUITY

The ongoing transformation of energy systems is shaped not only by technological progress but also by the institutional, market, and social environments in which new solutions emerge. Economic growth and technological advance influence the environment, and to minimize environmental impact and promote sustainable development, modern technologies and human behaviors should also adapt [1]. Carbon dioxide emissions are often used as an indicator to assess the impact of economic factors on pollution at the global level [2]. To investigate how changes in financial development, energy use, and foreign direct investment affect carbon dioxide emissions, Nguyen et al. used Vietnam’s data from 1990 to 2021 [3]. They showed that, in the long run, emissions rise as finance and the economy expand, and they identified an asymmetric pattern in which decreases in energy use are linked to higher emissions, while emissions decrease when finance contracts and when foreign direct investment increases. In the short run, financial development still increases emissions, and changes in energy use may initially lower emissions and later raise them, while positive foreign direct investment effects reduce emissions. These results point to policies that stimulate investment while steering energy use toward cleaner sources and low-emission technologies [4], while climate change consequences enhance the decline in gross regional product, accompanied by an annual decline in employment [5]. In the same context, the interlinkage between Private Credit, Renewable Energy, Economic Growth, and Carbon Emissions was investigated by Prasetyo et al. with the focus on how private credit interacts with growth, renewables, trade openness, and energy use to shape CO_2 emissions. The authors found that private credit to non-financial sectors and total energy consumption increase emissions, while renewable primary energy is associated with lower CO_2. The study recommended policies that accelerate the clean-energy transition and expand green credit, since economic growth alone does not reduce emissions [6].

Likewise, the influence of fuel and technology costs, as well as policy targets, on the pace of the energy transition has been shown for the case of Croatia [7] and for CO_2 point sources and their projected development in Austria [8]. Similarly, Groppi et al. used the H2RES model for Italy to test different carbon-price paths and market setups. They found that carbon pricing increases electricity and hydrogen costs during the transition, but once renewables reach roughly 90% of the mix, system costs stabilize and become largely independent of price signals. A low-now, high-later carbon path minimizes consumer energy costs through 2035 to 2050, while power purchase agreements stabilize green hydrogen prices, yet can become more expensive than market prices after high renewable penetration [9]. Furthermore, identifying the most cost-effective pathways can support the development of a 100% renewable energy system [10], and help overcome mismatches between national planning and local development [11]. In this context, Tangi and Amaranto presented three ways to plan multi-energy systems while considering more than just cost. Tested on a synthetic case, the methods highlighted trade-offs and showed how different objective priorities change the optimal technology mix, while also comparing data needs and computational time across approaches [12]. Local governance can also be supported through indicators based on the Sustainable Development Goals, which can assess the local impacts of key European Union energy targets [13], as well as through approaches that explore solutions to strengthen the energy resilience of rural areas within renewable energy communities [14]. Along these lines, Eleksiani et al. combined global research mapping with lessons from case studies in 37 countries to show how renewable energy systems can strengthen climate resilience in off-grid communities. They found that implementation often fails because studies focus on technical and economic issues while overlooking social and cultural factors, which are addressed in only about 30% of the evidence [15]. Therefore, renewable energy assessments should make use of available tools that integrate socio-economic, environmental, and spatial evaluations [16], such as models developed to support renewable energy communities' investment decisions on generation portfolios and operational electricity-sharing management [17]. To further support the advancement of renewable energy communities, Magni et al. evaluated Italy's new incentive scheme against the previous experimental one, varying key formula parameters to assess distributional effects. They found that under higher market electricity prices, the new design can penalize communities and favor investor-type members, and that its size and geography rules risk disadvantaging southern regions relative to the north. This implies hidden barriers that could slow equitable growth [18].

Beyond the energy sector, growing pressure on decision-makers to adopt smart, circular, and green models [19] has led to the implementation of circular economy principles that seek to bridge gaps between theory and practice [20]. Loukil compared how African countries are progressing toward a circular and sustainable economy by constructing two composite indices: one scoring current performance and another tracking average yearly progress and then relating these scores to key drivers and barriers. He showed that higher overall development supports the transition, while heavy reliance on resource rents slows it. He also concluded that stronger institutions and better infrastructure can increase pressure on resources unless policies explicitly steer development toward circular practices [21]. Similarly, Jallow and Jiang constructed an inclusion index for 44 Sub-Saharan African countries and found that greater financial inclusion is associated with higher CO_2 emissions, especially in East and Southern Africa. They argued the main channel is higher consumption enabled by improved access to finance, and recommended aligning inclusion policies with climate goals by steering credit toward green investments and clean energy [22]. For successful implementation in the industrial sector, it is important to examine factors influencing market leadership in green technology adoption [23], and key parameters for digital and holistic development in Industry 4.0 [24]. In this regard, Sepúlveda et al. demonstrated how quadruple-helix collaboration between university, industry, government, and the community moved an alternative shrimp feed from early research through TRL 1 to 9 and into the market. Using local raw materials, the solution targets feed and fattening costs while reducing water and energy use, culminating in a university spin-off aimed at scaling technology transfer across the shrimp sector [25]. Improving production-process management can also reduce environmental burdens and enhance workers' well-being [26], while cost-optimal energy performance levels can be supported through ISO standards [27]. Based on qualitative interviews with eight Portuguese firms and five certification-support bodies, Pinto et al. found that adopting the environmental management system standard ISO 14001 is mainly motivated by stakeholder pressure and market differentiation, and that it tends to deliver operational gains while improving international image and competitiveness. Despite mixed evidence in the literature, these cases support the view that certification can facilitate internationalization for small and medium enterprises by signaling credibility and improving processes [28].

RENEWABLES, GRIDS AND ELECTRIFICATION

The global shift towards low-carbon energy systems is accelerating the deployment of renewable generation, electrification technologies, and advanced grid solutions. Integrating variable renewable power at both small and large scales introduces technical, economic, and operational challenges. To achieve economy-wide net-negative emissions scenarios, it is common to investigate the effects and required levels of investment in renewable energy and the decarbonization of end-use sectors [29]. Adoption of the water-energy-food nexus can improve social-ecological system resilience, as shown at the Victoria and Alfred Waterfront in South Africa [30]. Similarly, Imasiku et al. studied least-cost electrification pathways for Zambia. By improving and benchmarking spatial inputs, such as population clusters and the grid network, using open datasets and utility feedback, they showed that investing in new grid lines shifts the least-cost mix toward standalone solar, reducing grid-extension investments by about 10% and yielding roughly USD 33 million in savings [31]. Renewable energy integration stimulates the decarbonization and electrification of interconnected sectors, supported by policies and the Sustainable Development Goals [32]. Off-grid photovoltaic projects, such as ones in Sub-Saharan Africa, show that electricity supply for schools and health posts can be covered by renewables [33]. Imasiku and Saunyama also showed, using the example of health-facility electrification in Kenya, Ghana, and Rwanda, that unreliable or absent electricity undermines essential services and correlates with poorer outcomes, including higher child mortality. They argue that decentralized renewables, especially solar PV, paired with tailored investment and financing models, can rapidly improve reliability and help deliver United Nations Sustainable Development Goals 3 and 7 [34]. However, to ensure the security of electric power systems, it is necessary to account for local needs and resources and to carefully plan autonomous, secure, and low-carbon systems [35], as shown in decarbonization analyses of cost-optimal pathways for the Italian energy system [36]. Achieving demand and supply balance in the case of the Tomini Bay area in Gorontalo is shown by Salim et al. with projected demand rising sharply to about 1,425 MWh by 2050, they found that shifting toward local renewable sources, especially river and solar resources, could enable the region to supply roughly 1,490 MWh in 2050, ensuring regional energy security [37]. Therefore, integrating solar and wind into the electricity mix is often studied to support government targets of reaching 100% renewable energy sources [38], leading to a need for easy-to-replicate methods for spatial, energy, and economic solarization analysis [39]. For this reason, Hida et al. simulated how increasing small-scale solar PV generation affects a radial distribution feeder in Albania, testing different connection points and load conditions to determine the maximum capacity the feeder can host without breaching limits on voltage, line loading, and transformer loading. They concluded that solar installations improve the voltage profile but can overload transformers and increase losses if poorly sited [40]. Similarly, Kamberi et al. studied a closed-loop distribution feeder in Albania with added PV plants and showed that, across several connection strategies and load levels, photovoltaics reduces network losses, eases transformer overloading, and raises node voltages without breaching voltage limits. The remaining issue is total harmonic distortion of voltage, which exceeds allowable limits in all scenarios but remains close enough to be mitigated with targeted filters, improved sitting, and better operational management [41]. With rapid growth in solar energy deployment, there is also increasing interest in understanding key elements of PV systems, such as power-converter efficiency [42] and the impact of red-soil albedo on the energy yield of bifacial PV systems [43]. Accordingly, Peter et al. combined simulations and field tests in Kenya to identify the best fixed tilt and mounting height for bifacial solar panels on concrete, sand, and grass. They showed that a very low tilt of about 5 degrees maximizes energy by balancing increased rear-side reflection against front-side losses, and that raising panels to about 2 m delivers the highest yield, with concrete producing the strongest rear reflection among the tested surfaces [44]. This expansion of solar energy has also inspired a number of studies on coupling PV with other technologies, such as modelling a solar-hybrid pilot plant based on photovoltaic-thermal collectors with an air-to-water reversible heat pump [45] and optimizing the energy performance of an integrated collector-storage solar water-heater prototype [46]. Likewise, Pambudi et al. experimentally evaluated a serpentine flat-plate solar water heater in Solo, Indonesia, and found an optimal flow rate of 180 L/h, yielding 57% thermal efficiency, nearly 82% heat-absorption efficiency, and close to 70% collector efficiency. They also conducted a life-cycle assessment, showing that the use phase dominates energy savings and CO_2 reductions, whereas materials and manufacturing drive most costs and embodied impacts [47]. Renewable energy can also be coupled with alkaline electrolysis to produce green hydrogen [48], or configured as a standalone solar PV-electrolyzer-fuel cell power-supply system [49]. Feitosa and Costa simulated 1 MW PV-powered electrolysis stations at ten cities along a 3,187 km highway corridor connecting Brazil's North and Northeast, projecting a levelized cost of 3-4 USD/kg at 30-35 t H_2/year. They suggested that distributed highway refueling is technically feasible, although still above today's grey-hydrogen costs [50]. Similarly, electric vehicles also provide flexibility to distributed energy resources, such as PV generators [51], therefore, their accompanying infrastructure should be optimized for best performance [52]. Syafii et al. designed and tested an internet-connected control and monitoring system for a building-level EV charging station integrating rooftop PV and battery storage, using a Raspberry Pi controller, calibrated sensors, and a web dashboard to supervise voltage, current, power, energy, and costs. They showed that rule-based logic prioritizes solar electricity and switches to the grid based on solar irradiance and the battery state of charge [53]. Accordingly, solutions such as mechanisms for controlling low-speed panel orientation [54] contribute to the adoption of decentralized renewable energy technologies, which is crucial for transitioning toward a renewable energy-driven economy [55]. Ashraf et al. modelled a solar-PV-powered system that prioritizes a constant-speed induction motor while sending surplus power to heating and lighting loads, using a pulse-width-modulation inverter and a boost converter governed by maximum power-point tracking. They showed that, between two control strategies, changing the modulation index yields a much faster response than changing the reference frequency, with settling times of about 0.2 s for speed and 0.12 s for torque, versus slightly over 0.5 s for the frequency-based method. Even under partial shading, the design keeps the motor close to its target of about 1,700 revolutions per minute while maintaining operation at the PV maximum power point [56]. When integrating up to 100% inverter-based resources, special attention should be paid to power-system stability challenges [57]. Wanjekeche et al. compared harmonic problems and mitigation options across three real distribution-network settings in Namibia, a university campus with a 100 kW PV plant, a utility feeder with very low power factor, and a residential area, assessing voltage and current distortion and frequency components against standards. They evaluated mitigation options and provided scenario-specific guidance to restore power quality and reliability [58]. Taken together, these studies demonstrate how important it is to provide more sustainable means of power transmission and to enhance stability. This has prompted the development of robust secondary controllers for voltage control and power-oscillation damping [59], as well as models of transmission-grid faults in electrical communities using stochastic distributions to enable outage prediction and improve planning and dispatch, as shown by Barate et al. for Benin [60]. They proposed using the Kolmogorov-Smirnov test alongside error estimation using Akaike's information criterion and Bayesian information criterion, as well as the Chi-square test with error estimation using the root mean square error. The approach aims to help operators anticipate blackouts and prioritize lines and resources in the Togo-Benin network. As is well known, remote island renewable energy communities are often disconnected from the national grid and face strongly seasonal energy loads and water demand [61]. They can operate off-grid with battery or hydrogen energy storage systems and power supply from a 220 kW small-scale hydropower plant [62]. To design and operate remote microgrids for isolated areas, generation, storage, load management, substations, and controllers should be considered to maintain stable and efficient operation. For this reason, Ngoc-Hung tested feeder switching and islanded operation at low demand using detailed simulations, showing improved energy management, fewer disruptions, and reliable service. He also stressed the importance of following established international standards and offered practical guidance for resilient deployments, illustrated with a case from Vietnam [63].

DISTRICT HEATING AND COOLING

Thermal networks and building-level heating and cooling systems are central to achieving deep decarbonization in cities and regions. Because heat demand, building characteristics, and local infrastructure vary widely, effective solutions increasingly combine energy-efficiency measures, advanced control strategies, renewable-based technologies, and next-generation district heating and cooling concepts. Optimizing fifth-generation district heating and cooling systems can yield primary energy savings [64] and integrating model predictive control with thermochemical energy storage can enable stored heat to meet demand more effectively [65]. In this context, Dell'Isola developed a nonlinear model predictive control approach for a fifth-generation district heating and cooling network with directional medium flow and benchmarked it against a non-directional flow controller in a virtual district. Over an eight-month simulation, directional flow reduced total heat-pump electricity use to 38 MWh (versus 41 MWh under non-directional flow) while maintaining thermal comfort, and it also clarified how building performance, pumping energy, and floor-temperature constraints affect optimal operation [66]. Furthermore, machine learning methods can further support operational optimization by predicting energy savings and thermal comfort improvements from optimized HVAC systems [67]. In addition, convolutional and recurrent neural networks have been used to compare fault detection and diagnosis performance for heating, ventilation, and air-conditioning systems [68]. To reduce costs while maintaining comfort, Zulkafli et al. modelled a building's air-conditioning and mechanical-ventilation power consumption based on five air-side factors and applied linear programming to select temperature set-points for morning, midday, and late afternoon that minimize energy use. They identified robust, near-optimal settings of approximately 17-18 °C for supply air and around 21 °C for return air, achieving about 4.26% lower daily energy consumption than current operation [69]. However, a just transition also requires targeted support for retrofitting energy-poor dwellings [70] which can deliver meaningful heating-energy savings through energy-efficiency measures [71]. Accordingly, Sharma et al. applied ISO frameworks and life-cycle assessment to three conventional houses in Jammu, India, quantifying embodied impacts through a water-energy nexus lens and showing that the dominant material drivers differ for embodied water and embodied energy. Using a stakeholder scenario manager, they proposed pro-local design and regulatory measures capable of reducing both indicators by around 30%, offering flexible, income-sensitive pathways that may be replicable beyond India [72]. To fully understand the cost and primary energy savings of deep retrofits, all life-cycle phases, including construction, operation, maintenance, and end-of-life, should be considered [73]. This is particularly important for heritage buildings, where retrofit choices must preserve historic value while meeting current energy-efficiency and decarbonization requirements [74]. Addressing this challenge, Almås et al. ranked retrofit measures for older detached houses by energy savings, greenhouse-gas impacts, and cost, concluding that current policy underperforms. They recommended promoting low-cost, high-return measures; strongly subsidizing geothermal heat pumps, new windows, and external wall insulation; and deprioritizing PV, basement-floor or roof insulation, and balanced ventilation due to high embodied global-warming potential and long payback periods under Norway's low-carbon electricity mix. Overall, their results point to the need for policy redesign that prioritizes the best combined outcomes [75].

CIRCULAR MATERIALS IN THE BUILT ENVIRONMENT

Advancing sustainability in the built environment and related material cycles increasingly relies on innovations that reduce embodied impacts, valorize waste streams, and integrate renewable or bio-based resources. Recent research demonstrates a broad spectrum of approaches, ranging from low-carbon building materials and optimized recycled aggregates to functional textiles, biogenic insulation, and circular resource pathways. For example, natural waste such as seaweed can be valorized for insulation and building materials [76]. Such solutions may support environmentally oriented certification schemes and, in turn, contribute to the development of positive energy districts [77]. To assess sustainable building materials, Rosa et al. proposed a data-augmented deep-learning workflow that predicts thermal conductivity and compressive strength of cementitious composites containing phase change materials based on mix-design features. Trained on combined real and synthetic data, the model achieved high predictive accuracy and can accelerate screening and optimization of phase-change-material-enhanced concretes with substantially reduced laboratory testing [78]. In addition, ceramic waste such as washbasins, toilet bowls, urinals, bidets, and bathtubs can be recycled as alternative aggregates in concrete mixtures [79]. Conversely, ash and slag waste from thermal power plants can be utilized to produce earthquake-resistant non-autoclaved aerated concrete [80]. Using recycled construction and demolition aggregates, Vazquez et al. produced permeable concrete paving slabs and compared five mixes against a natural-aggregate permeable control. The mixes exhibited air contents of approximately 1.6-2.2% and slumps of 12-19.8 cm, while hardened properties remained within typical ranges for permeable concrete: compressive strength 7.0-10.7 MPa, split tensile strength 1.76-1.79 MPa, flexural strength 1.79-2.44 MPa, and modulus of elasticity 9.5-12.6 GPa. Overall, the study indicates that construction and demolition waste coarse aggregates can feasibly replace natural aggregates in non-structural permeable pavements [81]. So, because cement production accounts for roughly 5-8% of global carbon dioxide emissions [82], technical solutions aimed at reducing energy-related emissions through efficiency improvements are being actively investigated, including innovative composite concrete masonry units [83]. Similarly, Szép et al. tested concrete mixes incorporating different cement substitutes and evaluated them against two criteria: retention of mechanical performance after high-temperature exposure and environmental footprint. Laboratory tests on standard specimens showed that some mixes retained acceptable compressive and flexural strength after heating while reducing the footprint by approximately a factor of ten compared with a reference mix [84]. More broadly, within contemporary work on sustainable textiles and fashion, advances are also being made in modified fibers [85], including studies on how pretreatment of cotton/polyester blend fabrics influences chitosan functionalization [86]. In this area, Melati et al. developed a cotton-dyeing process that replaces synthetic dyes with a plant extract from banana floral stems, combining microwave heating with chitosan treatment to achieve deeper color and improved fastness while reducing processing time and energy use. A response-surface optimization using a Box-Behnken experimental design identified near-optimal conditions that yield strong color and good-to-excellent fastness to washing, light, and perspiration, indicating a practical pathway toward more sustainable textile dyeing [87].

WATER SYSTEMS AND THE ENERGY NEXUS

Water systems face mounting pressures from climate change, urbanization, pollution, and intensifying resource demands. Recent research reflects the breadth of challenges and solutions shaping modern water management, spanning global assessments of water resilience, advances in drinking-water treatment, and the growing importance of the energy-water nexus in power-sector planning. Enhancing water resilience to climate change requires addressing key challenges and opportunities, evaluating policies and strategies across countries, presenting best management practices [88] and deploying green technologies to maintain the microbiological stability of drinking water [89]. Kerrouche and Zehri applied a quarterly Autoregressive Distributed Lag approach for Saudi Arabia and found that spending on potable water and food production significantly improves social welfare and public health, while investment in renewable energy drives economic growth, public health, and environmental sustainability. They reported synergistic benefits when investments in water or food are combined with renewables and therefore recommend prioritizing potable-water and renewable-energy investment, complemented by targeted social programs [90]. Likewise, agriculture industry should integrate sustainability concepts, economic, socioenvironmental [91], and technological to improve efficiency and ensure food safety while minimizing environmental impact [92]. For this reason, Olmos-Cruz et al. studied solar dehydration of tomatoes as a food-preservation strategy in Mexico, motivated by high food insecurity and substantial tomato losses in the supply chain. The authors analyzed how ambient temperature, relative humidity, wind speed, and solar irradiance affect drying performance across four seasons. The results suggest that relative humidity is the dominant driver of drying, enabling up to 40% shorter drying times and up to 32% higher diffusion coefficients, showing that local conditions can help maximize dehydrated-tomato production and support food security [93].

In areas with limited access to clean water, low-cost household treatment solutions such as activated-sand-based systems for rural and informal settlements [94] can provide safe water even during extreme hydrological events, when raw-water quality parameters change rapidly [95]. To investigate this, Alshutairi et al. tested six point-of-use drinking-water systems commonly used in Saudi Arabia, namely polypropylene cotton prefilters, granular and block activated carbon, and reverse osmosis. They measured sensory and physicochemical parameters against World Health Organization guidelines. Purified water typically showed pH 7.24-7.84, very low conductivity and total dissolved solids, and hardness of 0.45-2.84 mg/L, with overall removal efficiencies of approximately 92-99%. Activated carbon removed free chlorine by 94-100%. The authors concluded that these systems can substantially improve household water quality, with the optimal selection depending on local contaminants and user needs [96].

Carbon dioxide emissions are statistically significantly associated with gross domestic product per capita, energy intensity, and renewable energy consumption [97]. At the same time, events such as flooding can generate severe social and economic consequences and, in extreme cases, catastrophic impacts [97]. In this context, Gotal Dmitrović and Čerepinko showed that changes in farming practices, demographic shifts, and the influence of the European Union Nitrates Directive coincide with declining pollutant levels and clear improvements in surface-water quality. They linked these trends to the expansion of sewerage systems, improved municipal wastewater treatment, and reduced agricultural pollution [98] Reliability under severe water scarcity should also be evaluated from an energy-water nexus perspective on a per-power-plant basis [99], and multi-level decision-making processes can support adoption of water-reuse technologies from a value-chain perspective [100]. Along these lines, Álamos et al. introduced a Territorial Water Vulnerability Index that combines technical and socio-cultural factors using fuzzy logic. They found that 4,841 of 10,042 census blocks exceed a vulnerability threshold of 0.5, driven by water-supply constraints, limited coverage in informal settlements, and frequent unscheduled outages, alongside very low response capacity. Their method provides an actionable framework for targeting interventions in areas where vulnerability clusters are highest [101]. Moreover, green roofs also offer a promising option to mitigate urban heat-island effects, reduce stormwater runoff, lower energy consumption, improve air quality, and enhance biodiversity, thereby contributing to urban sustainability and livability [102]. In a related application, Yang How et al. measured the quality of roof-harvested rainwater in southern Malaysia and purified it using progressive freeze concentration. They showed that higher rainfall correlates with lower total dissolved solids, that the number of dry days before a storm is not a significant factor, and that no supercooling occurs in the falling-film set-up. An energy analysis indicated that the freeze process requires about one-tenth the energy of distillation, suggesting a practical, low-energy route for producing drinking water from rooftop runoff [103]. Furthermore, modern irrigation techniques can significantly reduce water consumption, improve soil quality, and protect water resources from contamination [104]. To prevent landslides in steep citrus orchards after intense rainfall, Izumi et al. tested mixing clay into topsoil to slow infiltration. In laboratory soil-tank experiments representing a 30-degree orchard slope, higher clay content reduced infiltration and limited stability loss, indicating improved protection against slope failure. They noted an operational trade-off, namely that permeability must be low enough to stabilize the slope, yet high enough to supply water for trees [105]. Reliability in severe water-scarcity conditions should also be evaluated from an energy-water nexus perspective on a per-power-plant basis [106]. This is relevant for emerging options such as floating solar PV, which can be feasible and economically competitive with other power sources in suitable contexts [107]. In a related line of work, Fares et al. experimentally upgraded a single-slope solar still by adding recycled ground-tire rubber to the basin and a PV-powered paddle wheel to agitate the water. Compared with the conventional still, productivity rose by approximately 95% with rubber alone and by about 172% when combined with the paddle wheel. Average energy efficiency increased from 17% to as high as 46% at 90 rpm, indicating a low-cost pathway to higher freshwater yield in harsh climates [108].

In addition, Wastewater treatment, particularly in oil exploration and production, is among the most expensive processes in the petroleum sector [109]. Accordingly, water demand should be considered when optimizing the layout and sizing of water-injection pipeline networks in oilfields [110]. Meixner et al. developed a practical treatment model for wastewater contaminated with hydrocarbons at the Sovjak hazardous-waste site, with the goal of achieving discharge-quality water for natural streams. The design links two subsystems, one conditioning floating oils and soft tar and another treating accumulated water and uses simulation and systems thinking to tune overall performance so that quality targets are met with acceptable treatment rates [111]. Machine-learning techniques are increasingly applied to predict river flow, groundwater levels, and other hydrological variables [112]. In parallel, physicochemical parameters and biological indicators, including birds, are used to evaluate water quality[113]. For example, Gauto et al. combined laboratory measurements from a water-treatment plant in north-eastern Argentina with spectral data from the European Space Agency's Sentinel-2 satellite to predict turbidity at the plant intake. Among several regression methods, a random-forest model performed best, achieving a coefficient of determination of about 0.91 and a root-mean-squared error of roughly 144 nephelometric turbidity units. They also mapped turbidity spatially and identified the most influential satellite bands, providing a practical approach to support plant operations without continuous field sampling [114].

FLOOD RISK AND BLUE-GREEN INFRASTRUCTURE

Cities are increasingly exposed to climate-driven hydrological extremes, making flood-risk management and resilient urban planning central to sustainable development. Recent research highlights that conventional drainage systems alone can no longer address intensifying flood hazards, especially in environmentally and socio-economically sensitive areas. Emerging approaches therefore combine geospatial risk assessment, nature-based solutions, and blue-green infrastructure to reduce vulnerability while enhancing livability and ecological function. Accordingly, it is important to assess the potential consequences of flooding in areas of significant environmental and socio-economic importance [115]. In vulnerable but economically and socially active coastal-riverine settings, there is also potential for waterfront zones that may be suitable for floating urban development [116]. In this context, Gomes et al. proposed using Hydrological Interest Areas and functional spatial "arches" (upstream-midstream-downstream) to support flood-resilient urban planning that integrates nature-based solutions with land-use rules. Applied to the Bambu River watershed, they compared scenarios and showed that a realistic open-space intervention plan can protect 2,243 lots in a 25-year flood event, whereas the current layout leaves about 21% of properties in flood-prone areas [117]. Urban land-use efficiency can also contribute to limiting increases in global warming [118]. Relatedly, Amback et al. simulated five urban-growth scenarios in a sprawling area and showed that when open spaces are lost, or are not designed to temporarily store stormwater, flooding becomes significantly worse. They argued that cities must plan early by treating open spaces as functional components of drainage systems and by integrating drainage, open-space planning, and land-use rules so that future neighborhoods can be safely occupied. Overall, preserving and purpose-designing open spaces is essential to prevent higher flood peaks and wider damages [119]. Similarly, Annadi et al. combined the Analytic Hierarchy Process with high-resolution GIS mapping to identify areas of highest flood risk in Auckland, using seven factors including slope, land use, rainfall intensity, and drainage density. They estimated that 16% of the city is highly susceptible, 63% moderately susceptible, and 21% at low risk, and validated the map against historical flood events with about 83% accuracy. This provides planners with a practical basis for dynamic floodplain management and real-time decision support [120] In addition, identifying adaptation indicators can support decision-making and improve risk management by embedding climate resilience into urban policy design [121]. This can be complemented by analyzing the interplay between ground-temperature variation, vegetation cover, and building thermal demand in order to better understand the implications of urban growth [122]. Building on these points, de Mello Neto et al. proposed a two-step framework to evaluate whether establishing urban-fluvial (blue-green) parks is socio-economically viable when land expropriation and compensation are required. They first compared avoided flood damages with investment costs and then, where net benefits were positive, designed a local "win-win" business model integrating parks with new subdivisions. In the Maricá case, over a 50-year horizon the benefits exceed implementation and operation and maintenance costs, and local land values increase by approximately 40%, supporting a functional network of blue-green open spaces for flood resilience and urban value creation [123].

Water management is also required for power-plant cooling, gasification, carbon capture, hydroelectricity, and emission control [124], contributing to emerging interdependencies between the water and wastewater sector and the hydrogen sector [125]. In this regard, Nachchach et al. monitored water quality in the El Oulfa urban wetland in Casablanca over one year and assessed it using the Water Quality Index and the Trophic State Index. The water was consistently classified as non-potable and predominantly eutrophic, with the downstream station reaching a Trophic State Index value of 83.49 in April 2024. The authors identified runoff, wastewater inputs, and seasonality as key drivers and recommended targeted controls and natural filtration measures [126]. As cities become increasingly central to climate governance, particularly in regions already experiencing severe climate impacts, the rise of climate-emergency declarations illustrates how local governments are integrating climate planning processes in response to frequent extreme events [127]. At the national scale, energy-sufficiency measures can reduce demand through behavioral and structural changes and may significantly improve EU countries' sustainability performance and energy resilience [128]. Nevertheless, urban climate resilience varies widely. Pécsinger et al. demonstrated this using a multidimensional index for nineteen Hungarian cities based on forty-one environmental, social, and infrastructure indicators. Their analysis ranked Békéscsaba highest due to strong green infrastructure and renewable-energy uptake, while Budapest ranked among the lowest due to high density and limited green space. They also identified eight city clusters and highlighted targeted actions, including expanding green infrastructure and improving energy efficiency [129].

CIRCULAR ECONOMY AND WASTE VALORISATION

The transition toward a circular economy increasingly depends on the ability to recover value from waste streams, redesign material flows, and integrate industrial by-products into sustainable production systems. Research across diverse sectors shows how organic residues, plastics, agricultural by-products, food-system losses, industrial slags, and wastewater solids can be transformed into usable materials, energy carriers, or inputs for new value chains. These advances reduce environmental burdens and reliance on landfilling, while strengthening resource security, lowering greenhouse-gas emissions, and supporting economic resilience. To adequately integrate waste-to-energy technologies, it is necessary not only to optimize the mix ratios of waste sources [130], but also to increase public awareness and acceptance [131]. To identify where food waste mainly occurs, Zseni et al. compared European Union countries using multivariate statistics, including principal component analysis. They identified three profiles: countries with high waste in farming, manufacturing, and distribution; countries with lower waste early in the chain but higher waste in restaurants and households; and countries with overall average or below-average waste. They concluded that linear links to socio-economic indicators are weak, although patterns emerge, such as flatter-terrain populations and higher meat or fish supply in the first group, and a concentration of former Eastern Bloc countries in the third group [132]. Research on circular resource pathways increasingly focuses on converting organic residues into valuable products, helping ensure that food systems remain productive, accessible, and nutritious while lowering their carbon footprint and protecting ecosystems [133]. Examples include investigations of hydrothermal carbonization of hemp cake and pumpkin cake [134]. Similarly, Kuvendziev et al. valorized European carp viscera by extracting omega-3- and omega-6-rich fatty acids using supercritical CO_2 and modelled polyunsaturated fatty-acid solubility using a feed-forward artificial neural network with high accuracy ($r \approx 0.9905$). Experiments across 20-40 MPa, 313-333 K, and 3.23-5.9 g CO_2/min achieved a maximum extract of 0.52 g per g of freeze-dried input at 40 MPa and 333 K, highlighting a low-solvent, "green" route to upcycle fish-processing by-products [135]. More broadly, integrating resource flows across sectors is central to strengthening sustainability outcomes. In particular, social-ecological resilience can be improved through governance approaches that address the whole water-energy-food nexus [136]. At the technological level, key operating parameters, including temperature, equivalence ratio, steam-to-fuel ratio, and the gasification medium, strongly influence waste-management performance [137]. Complementing these perspectives, Khune et al. reviewed how co-digesting waste-activated sludge with food waste can address nutrient-balance limitations and high solids content, increase biogas yields, and enable nutrient recovery for fertilizer and compost. They also showed that the resulting energy can offset electricity use at wastewater treatment plants, drawing on South African waste streams and outlining practical constraints and options for converting biogas to electricity [138]. Efforts to expand circular and bio-based resource systems increasingly depend on policy change [139] and integrated modelling and regional assessments, such as linking biomass-potential modelling with the need to balance non-productive land functions while ensuring the economic viability of energy-crop biomass [140]. Building on these themes, Mihajloska et al. provided a detailed case study of North Macedonia's Strumica region, mapping primary, secondary, and municipal biowaste resources through a combination of policy review and stakeholder surveys. Their findings highlighted composting and a potential mycelium-based value chain as promising avenues for residue valorization, while underscoring regulatory gaps and weak waste-separation practices that divert roughly 22,000 t/yr of biodegradables to landfills [141].

Furthermore, recovery of plastic waste has also been widely analyzed using both physical and chemical characterization [142] and techno-economic assessment [143]. In this context, Vadiraj et al. reviewed plastic-waste pyrolysis to produce liquid plastic oil, arguing that it can complement mechanical recycling by converting mixed plastics into a high-calorific fuel, with reported liquid yields of up to 80 wt% at 300-500 °C. They synthesized how temperature, residence time, pressure, reactor design, carrier-gas flow, and catalysts influence product yield and quality, and they positioned plastic-to-liquid conversion as a promising route for difficult-to-recycle plastics while outlining the parameters that most improve outcomes [144]. Similarly, advancing biodiesel utilization likewise requires addressing both fuel-quality constraints and emissions challenges. Biodiesel blending strategies and a range of NOx-reduction techniques can help meet biodiesel standards while lowering nitrogen-oxide emissions in internal-combustion engines [145]. Complementing this, Sulistyo et al. evaluated waste cooking oil as a biodiesel feedstock within a Green Technical Vocational Education and Training setting, analyzing parameters such as spray angle, injection pressure, viscosity, and preheating temperature to assess combustibility and recyclability. Their work framed waste-to-biodiesel conversion as a practical educational tool aligned with Sustainable Development Goals 7 and 12, showing how culinary-school waste oil can be transformed into renewable fuel while fostering green skills and supporting sustainable waste management [146]. Also, decarbonizing cement manufacturing increasingly involves integrating alternative fuels and advanced combustion strategies, including the potential of oxy-fuel combustion combined with biomass co-firing to reduce both pollutant and carbon emissions in cement production [147]. From an operational perspective, Borsuk et al. applied computational fluid dynamics to model the co-firing of solid recovered fuel in an air-through precalciner at a cement plant. Their simulations identified operating conditions, including a 150 mm fuel-inlet nozzle, a 1,000 kg/h feed rate, and a 1,000 Nm^3/h transport-air flow, which maintain process stability and preserve clinker quality [148]. Overall, efforts to strengthen circularity and reduce industrial emissions increasingly link material recovery with low-carbon production pathways. In particular, renewable-electricity-based hydrogen direct reduction of iron is emerging as a promising route for low-carbon steelmaking [149]. Along similar lines, Watjanatepin et al. evaluated mineral carbonation options for steel slags using life-cycle assessment, life-cycle costing, and the Analytic Hierarchy Process to rank scenarios across environmental and economic criteria. Their analysis identified one basic oxygen furnace treatment route as the most favorable under equal weighting, while noting that results are sensitive to how decision-makers prioritize the criteria [150].

INDUSTRY AND TRANSPORT DECARBONIZATION

System decarbonization increasingly depends on hybrid energy systems that combine renewable electricity, hydrogen production, and coordinated optimization across scales. For example, producing hydrogen from landfill gas through a combined power-to-gas and biogas-reforming configuration highlights the potential role of waste-derived fuels in low-carbon pathways [151]. At the system level, multi-scale optimization methods can link long-term design with short-term dispatch in nuclear-renewable hybrid systems, strengthening planning coherence and operational performance [152]. Extending similar ideas to the household scale, Diaz-Bello et al. showed that genetic-algorithm-based control of PV-battery-EV hybrid systems can reduce electricity costs and grid dependence under volatile price conditions. Collectively, these studies illustrate how optimization, from hydrogen production chains to system-level hybrids to individual prosumers, can support more flexible and economically robust decarbonization trajectories [153]. Industrial fuel transitions are also explored through biochemical and thermochemical routes. Research has examined the synthesis of bio-hydrogen, bio-syngas, acrolein, propylene glycol, epichlorohydrin, bio-methanol, and bioethanol [154], along with techno-economic evaluations of synthetic natural gas and methanol production from renewable hydrogen and captured CO_2 [155]. Similarly, Mecséri et al. provided a life-cycle assessment comparing hydrogen, compressed natural gas, methanol, ethanol, and Fischer-Tropsch fuels with conventional gasoline, diesel, and grid electricity for 2025 and 2050. They found compressed natural gas to have the lowest near-term climate impact, while in 2050, decarbonized production routes make gaseous hydrogen the leading option on both climate and acidification metrics, with methanol remaining comparatively unfavorable [156]. Hydrogen technologies are also demonstrated in practice, including assessments of hybrid hydrogen-based systems in an outdoor test facility [157] and a standalone solar PV-electrolyzer-fuel-cell system for a case study in Niamey, Niger [158]. Tamtam et al. developed an AI-supported hyperfuzzy decision framework to evaluate hydrogen fuel-cell options for Morocco's smart-city mobility. Using criteria including power density, fuel consumption, electrochemical performance, thermal management, response time, hydrogen purity, and efficiency, they showed that hydrogen-powered public transport ranks as the most attractive option, followed by stationary fuel cells and refueling infrastructure [159].

At the building scale, studies have shown how physiological thermal-comfort models can capture dynamic human thermal responses [160]. In the industrial sector, Lee et al. used grey relational analysis on responses from 214 companies to rank carbon-reduction measures. They identified resource recovery and reuse as the most impactful category, followed by efficient lighting, equipment upgrades, behavioral measures, and energy-efficiency optimization. They also emphasized that policies and management systems function as enabling frameworks, and they proposed a knowledge-based management system supported by training and targeted investments [161]. Integrated modelling approaches likewise play a crucial role in planning decarbonized systems, including coupled energy-system and grid-planning models that enable more consistent infrastructure assessments [153], as well as new aggregation criteria for optimizing energy-community configurations in real-world cases [154]. Within hybrid microgrid operation, Hasan et al. presented the "Dual Predator Optimization" algorithm, inspired by whale and grey-wolf hunting strategies. Compared with other optimization approaches, it reduces electricity costs by around 20%. In a fully renewable configuration, it eliminates load shedding and increases hydrogen production by roughly 18-21% [162].

Similarly, transport decarbonization involves both technological transitions and behavioral and systemic dynamics. Motivations influencing early adoption of battery electric vehicles were investigated in surveys of 278 owners in Croatia and Slovenia [163]. High electric-vehicle penetration can also support local energy balancing within energy communities [163]. Building on this, Umair et al. synthesized technical, environmental, and economic evidence on electric vehicles, discussing how core components (batteries, chargers, motors) and coordinated vehicle-to-grid operation shape performance, comparing environmental impacts with conventional vehicles and considering the role of solar-powered charging. They also assessed regional markets and total cost of ownership, while highlighting practical barriers such as high upfront costs, charging infrastructure gaps, and challenges related to connected-vehicle integration [164], including the potential of automated trucking to reduce driver demand [165], such as and the potential of automated trucking to reduce driver demand [166]. In this context, Adam et al. systematically reviewed the implications of self-driving vehicles for traffic flow, congestion, energy use, emissions, infrastructure readiness, safety, public acceptance, and regulation. They highlighted potential efficiency gains at high adoption levels but emphasized substantial risks, including safety incidents, cybersecurity concerns, and unequal social benefits, in the absence of strong policy frameworks and infrastructure support [167].

AI AND OPTIMIZATION FOR SUSTAINABILITY

Advances in artificial intelligence, optimization, digital twins, and control-oriented modelling are playing an increasingly central role in the design, operation, and management of sustainable energy and water systems. Recent research shows how these methods can enhance system performance, reduce energy consumption, and strengthen predictive and supervisory capabilities across multiple domains. In water treatment and desalination, optimization and modelling approaches can improve both energy efficiency and operational reliability. Studies assessing the energy-saving potential of coupling a reverse osmosis plant with a cogenerative dish-Stirling unit [168], as well as identifying which parameters most strongly influence the efficiency of mechanical vapor compression desalination [169] contribute to advances in reverse osmosis technologies. Building on these modelling frameworks, Abbi et al. combined the Spiegler-Kedem transport model with particle swarm optimization and grey wolf optimization to predict salt rejection in nanofiltration and reverse osmosis systems, achieving close agreement with experimental results from Tan-Tan, Morocco. They found that grey wolf optimization performed slightly better, suggesting that lightweight bio-inspired algorithms can support rapid and reliable desalination design [170]. Digitalization also shapes organizational and behavioral dimensions of sustainability. Work in this area indicates that regulatory context, political commitment, stakeholder engagement, and the active involvement of middle managers are essential for embedding sustainable technologies in practice [171]. Complementing this, responses from 596 employees across sectors illustrate how individual sustainable lifestyle choices interact with corporate renewable-energy use and broader organizational sustainability practices [172]. A broader review by Thanh et al. further highlights that many decision-support frameworks rely on multi-criteria evaluation, and that the number and composition of criteria can strongly affect reliability when environmental, economic, and social objectives conflict [173]. AI-enabled optimization also supports power-system integration of renewables. Dilshad et al. used particle swarm optimization to determine the optimal placement and power injection levels of photovoltaic distributed generation in an IEEE 3-bus network, improving voltage profiles and power factors while illustrating broader applicability for electric-vehicle integration and demand-response strategies [174]. Beyond grid optimization, reinforcement learning is increasingly applied in building energy management. For example, recent work shows that long short-term memory networks can effectively support training of deep reinforcement learning controllers when evaluated using an EnergyPlus-based digital-twin environment [175]. Machine-learning-based monitoring tools further demonstrate how systematic procedures can yield reliable predictive models while requiring minimal user expertise [176]. Finally, methods also play an important role in the operation of distributed and off-grid systems. Bokovi et al. tested an ensemble boosting regressor to forecast microgrid loads in a solar-powered system in Togo and compared it with long short-term memory and multilayer perceptron networks. Their approach achieved high predictive accuracy ($R^2 \approx 0.83$-0.96) with less tuning effort, indicating that relatively simple architectures can perform competitively in short-term load forecasting for small-scale grids [177]. Battery modelling and predictive control remain key areas of AI-driven research. Lithium-ion battery behavior can, for example, be modelled by comparing particle swarm optimization and grey wolf optimization approaches, with attention to voltage dynamics and discharge characteristics [178]. On the other hand, experimental characterization of lithium-titanate cells likewise supports the development of control-oriented equivalent electrical-circuit models for state-of-charge estimation [179]. Carbono de la Rosa et al. demonstrated how Fourier and wavelet analyses of voltage-current signals in silicon-carbon half-cells can reveal early signs of degradation, specifically slow oscillations and loss of phase coherence, offering a computationally efficient method suitable for real-time early-warning diagnostics in battery management systems [180].

CONCLUSION

Volume XIII of the Journal of Sustainable Development of Energy, Water and Environment Systems provides insights into the latest research regarding topics of Energy Communities and Equity, Renewables, Grids and Electrification, District Heating and Cooling, Circular Materials in the Built Environment, Water Systems and the Energy Nexus, Flood Risk and Blue-Green Infrastructure, Circular Economy and Waste Valorization, Industry and Transport Decarbonization, and AI and Optimization for Sustainability. From everything mentioned, it can be seen that the research collectively highlights progress and the imperative need for transitioning towards a more sustainable, innovative, and holistic energy, water, and environment paradigm. In this work, novel methods, concepts, and solutions are presented, not only from JSDEWES Volume XIII but also from special issues from the recent scientific literature and novel research from recent SDEWES Conferences.

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