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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 56 manuscripts were published in Volume XII, 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, Sustainable Energy Governance, Renewable Energy Systems, Advances In System Flexibility, Biomass Potential, Alternative Fuel Conversion, Water Management, Local Cooperation

INTRODUCTION

This editorial discusses the contributions of the papers belonging to Volume XII 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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SUSTAINABLE ENERGY GOVERNANCE

The global shift towards a decarbonized and sustainable future involves not only technological change but also shift of energy governance and socio-political structures. Regional organizations and partnerships have emerged as mechanisms to address challenges related to energy management and the promotion of new energy technologies, particularly to reduce fossil fuel dependence and mitigate climate change. Since the adoption of Sustainable Development Goals (SDG), global partnership has been on the front lines of tackling climate change and energy transition goals. Countries have developed their own national pathways to reduce global greenhouse emissions [1], with the strong electrification incentives, which will require new capacities of renewable energy and interconnectedness of energy sectors [2]. However, areas such as Africa face significant challenges, including a lack of energy infrastructure, reliance on fossil fuels, and inadequate access to clean energy, despite its vast renewable energy potential. Access to electrical energy is crucial for the development of rural areas, as it is pointed out in the case of Niger [3]. But without the sufficient conventional infrastructure in those areas, solutions like microgrids are needed to achieve renewable and safe supply of electrical energy [4], while interregional partnerships, in terms of technical and financial support, are fundamental in boosting global energy transition and climate goals. For that reason, the Africa-EU Energy Partnership was launched to enhance energy governance in Africa, particularly in Sub-Saharan Africa, with a focus on achieving universal access to sustainable and affordable energy. To explore the impact of such partnership, Adiatu [5] employed a thematic analysis focusing on capacity building, private-public cooperation, and technical support to strengthen political dialogue, data-driven energy policies, and sustainable development goals, particularly in renewable energy. It is shown that such cooperation has revolutionized the energy sector in Africa, providing energy governance and capacity to meet global carbon reduction targets. The importance of local authorities to support and mobilize energy transition actions is crucial in mitigating the effects of climate change [6]. However, local authorities must consider the balance between socio-economic development and environmental protection in planning future development [7]. To assess government capacity, Raupp et al. [8] presented an Indigenous Adaptive Capacity Index to evaluate climate change vulnerability in Indigenous Lands, focusing on their autonomy, organizational skills, and environmental protection. Index was applied on the river basin with the Belo Monte hydropower plant in the Amazon, assessing varying degrees of adaptive capacity and different degrees of engagement and environmental protection, which can help in the proposition of adaptation actions. It is shown that socio-economic attributes correlate with the level of carbon emissions in particular countries [9] and willingness to pay for renewable energy [10] with a high correlation between economic, environmental, and social characteristics. By the use of correlation and regression analysis, Georgieva [11] showed the relationship between economic development, environmental investments, and greenhouse gas emissions in the EU from 2008 to 2022. The analysis reveals that increased environmental spending, particularly in recent years, correlates with a decline in emissions, where environmental investments grow faster than GDP, indicating a strong commitment to sustainability. The study suggests that "green" spending and innovative technologies can mitigate the negative effects of economic growth on emissions. Therefore, environmental goals should be integrated into economic policies and enhance international cooperation.

Sustainable development is emerging at the front line of recent academic and global discourse with new topics and areas of research [12] and is entering diverse aspects of our society. Climate mitigation is also included in the transformation of urban areas, but implementation of sustainable solutions should be accelerated [13]. Previously, SDEWES Index has been utilized to evaluate urban scenarios and measure their sustainability [14]. Kılkış [15] has extended the analysis on 11 coastal and island cities in the Mediterranean Sea Basin, providing detailed sustainability evaluation using SDEWES Index. This index measures sustainability across seven dimensions: energy usage, renewable energy potential, CO_2 emissions, water usage, environmental quality, urban planning, and innovation. The study benchmarks current performance and projects future improvements under a scenario of 100% renewable energy. Based on the analysis, the top-performing cities in the analysis are Messina, Siracusa, and Palermo, but all cities face challenges in reaching top global benchmarks. Potential creation of local jobs through renewable energy projects was also considered, emphasizing the need for integrated approaches to urban planning and decarbonization to meet climate change goals. Similarly, industrial ecosystems are shown to be environmentally and economically beneficial [16], where a holistic industrial approach leads to technical and economic advantages supported by cultural, organizational, social, and behavioral factors [17]. To further improve sustainable development of the industry sector, Bellini et al. [18] reviewed Italy's digitalization progress in Industry 4.0 and compared it to Germany's with the support of survey data from 238 companies. They identified Italy's main challenge as a lack of a holistic digital approach across the entire value chain of the product. The study highlights a lack of understanding about the potential benefits of digital transformation across industries in Italy and emphasizes the beneficial effect of digital measures to improve energy efficiency and sustainability. Furthermore, local industry can benefit from supply chains reinvention by using low-cost raw materials or energy fuel from waste sorting plants [19]. Sustainable practices of waste management in future smart cities will be led by digital technologies [20]. Lasch et al. [21] focused on characterizing shredders in waste treatment plants, addressing fluctuations in material throughput caused by inconsistent mass and volume flow rates. They studied dynamic control solutions to stabilize output, proposing a control loop for real-time adjustments. Their initial attempts did not fully resolve throughput inconsistencies, but the research shows assurance for future improvements in shredder performance through advanced control systems. Continuing with sustainable practices, eco-friendly product design has also been shown to have significant environmental benefits [22]. But with the inclination of aligning with the sustainable development and energy transition goals, it is important to avoid misleading acts leading to greenwashing [23]. In the study by Alam et al. [24], impact of green marketing practices was explored, namely eco-friendly products, ethical pricing, eco-friendly locations, and sustainable marketing, on the business performance of Indian electronics manufacturers. With the implementation of smart partial least square model and through a survey of 160 industry executives, the research finds that sustainable marketing significantly enhances business success. The results provided valuable insights for companies aiming to remain competitive while improving sustainability efforts in a challenging market environment.

To achieve mentioned ambitious goals, education and promotion of social responsibility, circular economy, ecology, environmental protection, and greening are of the upmost importance for future generations of leaders, scientists, and members of society [25]. For this reason, massive open online courses were conducted for education of sustainable development, where challenge-based learning activities were efficient for developing skills that can be transferred to real-world scenarios [26]. However, based on the study by Pambudi et al. [27], the readability of educational material should be improved. They investigated the readability of 3 texts on geothermal renewable energy material in vocational high school textbooks in Indonesia using the descriptive quantitative method. The sample size was 340 respondents in 19 schools. According to the research method, the texts scored a low readability level, where over 50% of students found two of the three selected texts relatively easy to understand, while one was more challenging. These findings highlight the need for reevaluating the readability of educational materials when designing curriculums and educational strategies. From all of the above, it is shown that climate change mitigation involves an integrated approach motivated by cutting-edge scientific research and innovative solutions to ensure a healthy and accessible environment for all people [28]. Greening strategies based on health indicator patterns in urban areas can contribute to the minimization of climate change effects [29]. Health co-benefits of climate change mitigation policies are shown by Gjorgievska et al. [30] for North Macedonia. Using the Carbon Reduction Benefits on Health tool and MARket ALlocation model, authors estimated that reducing air pollution could prevent 629 bronchitis cases, 2788 asthma symptom days in children, and 143 deaths. Furthermore, 6,973 work-lost days among the adult employed population and the prevention of 182,320 restricted activity days can be achieved. In conclusion, this study highlights the benefits of public health improvements alongside economic, social, and environmental benefits, providing a strong incentive for reduction of greenhouse emissions.

RENEWABLE ENERGY SYSTEMS

A number of energy planning models have been developed with the recent deployment of variable renewable energy to analyze supply and demand in energy systems and avoid large curtailments [31]. Such tools are usually represented as top-down models and are sensitive in the analysis of RES integration. Linkage of hourly energy models and yearly integrated assessment models can be utilized to provide more accurate studies [32]. Therefore, Parrado-Hernando et al. [33] introduced a model that integrates hourly variability of renewable energy sources into integrated assessment models to improve accuracy in energy planning. The study focuses on the Spanish energy system, calibrating the model with historical data from 2017-2020. The results show that incorporating hourly resolution provides a more accurate representation of the power system and reveals the challenges in reaching Spain's 2030 renewable energy goals. The model can enhance policy assessments and energy system design under varying renewable energy conditions. It is known that future renewable energy systems will have high penetration of solar energy [34]. However, as geometrical, thermophysical, and optical parameters impact the solar energy performance under different weather conditions [35], novel concepts to optimize energy performance are developed. Mohammad et al. [36] discussed solar photovoltaics optimization using response surface methodology, focusing on three key variables: solar irradiance, module temperature, and wind speed. A dataset of 328 readings was analyzed, revealing that module temperature negatively impacts generated power. The study achieved a maximum power output of 128.883 W under optimal operating conditions, which closely matched experimental results. With 98.45% accuracy, the model demonstrated a precise relationship between the associated variables. Depending on solar irradiance, ambient air temperature, and PV system load, generation and operational lifetime vary depending on solar panel temperature [37]. Therefore, different concepts have been developed to estimate the temperature distribution and to show variations of annual energy yield for different temperatures [38]. Adamu et al. [39] investigated the impact of high temperatures on the performance of two market maximum power point tracking charge controllers (MPPT) in photovoltaic systems in comparison with pulse width modulation (PWM) charge controllers. Conducted in Nairobi, Kenya, the study shows that at temperatures below 50°C, MPPT controllers offer a 24%–29% energy gain over the other, while at high cell temperatures, the advantage diminishes, with performance gains dropping to 0.2%. This suggests that a more cost-effective option, PWM controllers, perform comparably in high-temperature conditions. As it is shown, utilization of solar energy can vary across different applications even for the same weather conditions. For that reason, innovative concepts such as novel air-based photovoltaic thermal collectors are proposed to achieve energy efficient and economical systems [40]. To improve absorption of solar radiation for solar collectors, magnetic nanofluids are proposed as thermal mediums [41]. Similarly, to enhance light management in photovoltaic performance, Hayat et al. [42] used dye-sensitized solar cells with scattering layers. Authors compared two semiconductors, titanium dioxide and tin dioxide, with pandan leaf dye as the natural sensitizer. Results showed that scattering layers improve light absorption and increase the photo-conversion efficiency, utilizing natural dyes and optimized light pathways, thus offering a potential solution for improving efficiency and consequently solar cell cost reduction.

Rural off-grid energy systems are increasingly utilized to provide low emission electricity at reasonable cost. Compared to grid electrification, hybrid configurations of renewable resources can be seen as an economical and environmental alternative [43]. To satisfy energy demand in every period, integration of technological solutions such as batteries, hydrogen systems [44] or e-mobility [45] can be implemented to achieve good energy management in off-grid communities. Off-grid photovoltaic projects were evaluated by Mbumba et al. [46] for schools and health posts in Angola, focusing on their economic viability and environmental impact. The study uses Monte Carlo simulations and discounted cash flow analysis to identify key challenges, such as subsidized diesel prices. It is shown that expanding existing grids is costly due to dispersed rural populations and difficult terrain, and off-grid solar can support basic social services and address the low electrification rate. Hybrid solar energy systems are also developed with nuclear energy with the need for carbon neutral power generation [47]. Nuclear power plant employment involves a complex and multidimensional decision process, investigating the feasibility of replacing nuclear power with renewable energy [48]. In other instances, site assessments are carried out for installations of new nuclear power plants, as can be seen in research by Shafii et al. [49]. Authors presented a comprehensive approach to selecting the most suitable nuclear power plant site in Indonesia based on safety aspects. The study integrates fuzzy-AHP and fuzzy-TOPSIS methods to evaluate and rank potential locations. Eleven safety-related criteria were identified, including geology, seismology, population density, and environmental impact. To weigh those criteria, expert input and focus group discussions were conducted. The results showed that West Kalimantan is the most suitable location, with a preference score of 0.5675, followed by East Kalimantan with a score of 0.5469. This approach highlights the importance of using advanced decision-making tools to ensure the safety and feasibility of nuclear power sites while reducing bias in expert opinions.

Other applications are also combined with solar energy. Integration of solar energy with thermoelectric generator systems can increase efficiency and reduce specific costs [50]. However, depending on its specific applications, thermoelectric geometry should be optimized to achieve higher power output while maintaining low cost [51]. To improve energy efficiency by converting waste heat into electricity, Szramowiat-Sala and Sornek [52] explored integration of thermoelectric generators into wood-fired stoves. Experimental results show that they can achieve power generation efficiencies up to 42% in a boiler without an accumulation layer and 30% with an accumulation layer. The study concludes that thermoelectric generators can be a feasible solution for enhancing the performance and sustainability of wood-fired stoves, reducing emissions, and contributing to cleaner energy use. Moreover, water purification techniques such as boiling and reverse osmosis are starting to be coupled with renewable energy to reduce environmental impact and secure fresh water supply [53]. Energy efficiency of distillation processes is relatively low, although distillation separation is a widespread technology for processing liquids. Optimal control performance can increase energy savings leading to more efficient and sustainable processes [54]. For that reason, renewable water distillation is being investigated. Nasir et al. [55] proposed a novel hybrid solar distiller with a photovoltaic-powered thermoelectric system. This design significantly improves the productivity of distilled water by using thermoelectric modules to enhance both evaporation and condensation processes, recycling latent heat back into the system. Experimental results show a remarkable 672% increase in productivity compared to traditional solar distillers. The study also introduces mathematical models to simulate the system's performance, validating the experimental outcomes.

Furthermore, floating PV systems are also gaining more interest due to the possibility of natural cooling, evaporation reduction, avoiding land use, and they are often coupled with hydropower reservoirs [56]. Also, different floating PV configurations [57] and cooling of the photovoltaic modules [58] lead to better energy performance. The technical and economic feasibility of hybrid system operation was examined by Passos et al. [59] in the case of the installation of floating photovoltaic in hydroelectric power reservoirs in Brazil. Using the Ilha Solteira hydroelectric plant as a case study, 12 scenario simulations based on different weather conditions show that integrating a 480 MW FPV system can reduce hydroelectric power generation by 6% and 7% in the water volume consumption. The hybrid system could avoid 55,000 tons of CO_2 emissions annually, improve water reserves, and generate profits after 13 years, enhancing renewable energy capacity without needing additional land. Riely et al. [60] explored the integration of retention ponds and floating photovoltaic solar plants in Waimanalo, Hawai'i, to address flood mitigation and energy needs. By co-designing these systems, stormwater runoff can be reduced by up to 50%, and half of the local energy needs can be met. This approach combines clean energy and green infrastructure to promote environmental and social justice, particularly in disadvantaged communities. Solar energy can also be linked to hybrid systems with different configurations and layouts according to the availability of energy sources, such as a trigeneration system consisting of biomass-fired steam cycles, wind turbines, photovoltaic panels [61]. For efficient utilization of renewable energy, it is important to have an accurate energy potential assessment. A variety of wind potential assessment methods are available, including retrieving wind speeds by multisensory satellites approaches [62]. On the same line, Shame et al. [63] assessed the wind energy potential in Zanzibar's coastal region using the Weibull distribution model to analyze half-hourly data. Data from 2021 and 2022 showed that wind speeds are mostly between 5 and 13.7 m/s, indicating strong potential for sustainable wind energy. The site is classified by national standards as having high potential, with wind energy densities between 700 and 7,000 MWh/m^2 for more than 90%. Also, it is shown that the most cost-effective wind turbine is the POLARIS P62-1000 due to its high-capacity factor and power output. Due to seasonal and stochastic characteristics, prediction of short- and long-term wind speed presents a challenge of large-scale integration of wind energy. Many researchers have developed forecasting models based on deep learning [64], satellite images [65], or neural models [66]. In the same line, Martinez and Iglesias [67] analyzed the effects of climate change on wind resources in Europe and North America using CMIP6 wind speed, considering a middle-of-the-road scenario and an augmented emissions scenario. In Europe, wind power density is expected to decline by around 15%, showing consistent decreases year-round. North America, however, experiences more regional and seasonal variations, with some areas seeing wind energy increases of over 60%, while others face decreases of up to 50%. This research helps understand long-term trends of wind energy dynamics under different climate scenarios and consequently provides valuable inputs to the wind industry. Lastly, co-location of wind and wave energy can also contribute to renewable energy generation but has shown feasibility variations regarding history data [68]. The potential of wave power is also projected to change based on regional climate models for different emission scenarios [69]. Rusu [70] analyzed wind and wave climate dynamics over two periods: 1976-2005 and 2041-2070, of which first covers historical reference period. Using the Simulating Waves Nearshore model, it analyzes wind and wave power, comparing past data with future projections under climate scenario RCP 4.5. The results projected wave energy reductions of 8% in the northwest, with increases of 10% in the southeast. Furthermore, wind power density may increase by 40% in certain areas, especially in autumn.

ADVANCES IN SYSTEM FLEXIBILITY

With the penetration of variable renewable energy sources, existing power grid operators are challenged with ensuring stability and security of supply [71]. Technical concerns such as reduction of system inertia and short circuit levels can be addressed with flexibilization technologies to maintain dynamic stability [72]. Oni and Longe [73] focused on this issue by enhancing the stability of power grids by addressing inter-area power oscillations in complex systems. They proposed a novel method for modelling a multi-terminal DC transmission link that provides resilient, flexible, and scalable oscillation damping by introduction of a supplementary controller. The results show that the implementation of a secondary controller significantly improves the damping of power oscillations, achieving up to 100% enhancement. In energy planning tools, power transmission systems are usually overly simplified and do not properly reflect integrations of variable energy sources [74], but there are multiple flow allocation methods to allocate the usage and costs of the transmission grid to market participants [75]. To address these challenges, Voshtina et al. [76] focused on improving Net Transfer Capacity calculations in Albania. They introduced a fast capacity calculation method aligned with day-ahead market principles, aiming to enhance power system stability and cross-border trade. A Python algorithm is proposed to automate calculation, increasing efficiency. The results demonstrate the bilateral method for NTC calculation yields higher values in comparison to the composite method. The study highlights the importance of coordinated approaches between Western Balkans Transmission System Operators to ensure market development, cross-border cooperation, and system security. Due to high power grid investment costs, rural areas have the highest percentage of non-electricity access. The electrification of those areas will depend on new microgrids in combination with renewable energy sources [77]. Analysis of residential microgrid projects under seven tariff designs shows that batteries can be utilized for grid stabilization by a capacity tariff scheme allowing price arbitrage [78]. Therefore, Dadjiogou et al. [79] explored the use of smart microgrids based on photovoltaic energy to supply electricity to telecommunications operator sites and local populations in rural areas of Africa. The study uses Particle Swarm Optimization for real-time intelligent management of energy flow, ensuring low electricity costs and minimizing power loss. The results show significant benefits, including a high renewable factor of 98%, a low levelized cost of electricity of US$0.0187, and improved electricity access for low-income communities.

Electrification of the transport sector, which is one of the largest energy consumers, is advantageous in terms of reducing fossil fuel use and carbon footprint but increasing electricity demand [80]. Unfortunately, electrification is challenged by a lack of available infrastructure. One of the solution is fuel stations modification in fast charging facilities for electric vehicles, with integrated onsite PV generation for grid connection cost reduction [81]. Umair et al. [82] reviewed Malaysia's electric vehicle sector, highlighting key challenges like inadequate charging infrastructure, high costs, low consumer awareness, and safety concerns. It suggests solutions such as expanding charging networks, integrating renewable energy, enhancing safety standards, and developing a battery recycling industry. The study emphasizes that addressing these issues is essential for Malaysia to align with global electric vehicle adoption trends and contribute to sustainable transportation. Furthermore, solar energy is often viewed as a support solution for battery electric vehicle charging stations. But due to the intermittency of solar energy, other energy sources, technological solutions, and energy management operations are also needed [83]. Providing assistance to users with information on the energy price, cost, and travel time of the electric vehicle to the charging station can accelerate the electric vehicle market [84]. For that reason, Syafii et al. [85] presented a simple photovoltaic electric vehicle charging management system using two commercially recognized development modules, Raspberry Pi and ESP32, and compared their efficiency and cost-effectiveness. The operation management system will regulate the operation pattern based on the availability of intermittent energy and the remaining storage capacity of the battery state of charge. Results show ESP32 offers a cheaper and simpler alternative to the Raspberry Pi for managing solar-powered EV charging and can be used for basic applications without complex computing needs. Sustainable mobility is more and more viewed in combination with electric vehicles, solar energy, and battery storage as an opponent to grid connection [86]. Moreover, the development of solar-powered autonomous vehicles is also investigated, where PVs can cover most of the vehicle load [87]. Esmaeili et al. [88] discussed the design and implementation of a solar-powered four-wheeled one-seater car. The car integrates solar power with plug-in charging, using six solar panels, each producing 135 W with an efficiency of 23% for a total power of 810 W. The vehicle is equipped with two motors and a unique aerodynamic shape for reduced air resistance, and the design focuses on enhancing energy efficiency and stability of the vehicle. Electric vehicle charging behavior can influence greenhouse gas emissions savings according to the available generation mix in the exact period **[89]**, and their environmental impact differs from region to region **[90]**. Holmgren et al. **[91]** conducted a life cycle assessment of shared stand-up e-scooters in Sweden, comparing first-generation models with newer, heavier models introduced from 2020 onwards. The study finds that the production phase contributes the most to the environmental impact for both models, while the switch to swappable batteries has converted the vehicle fleet to smaller vehicles with lower environmental impacts. The findings aim to help e-scooter providers and cities improve the resource and energy efficiency of shared e-scooter services, enhancing urban transport sustainability. Public transport is also aiming to become more sustainable by transitioning from diesel to biodiesel buses and electric buses **[92]**. Challenges of electrifying heavy transportation seek out hybrid solutions, such as battery-hybrid diesel-electric locomotives **[93]**. Krznar et al. **[94]** evaluated the feasibility of using a hybrid internal combustion engine and electric generator system as a power source for heavy lift multirotors, which currently rely on lithium polymer batteries with limited flight time. It compares three multirotor designs for both battery-powered and hybrid systems with capacities between 15-35 kg. Results show that the hybrid system significantly enhances flight endurance and operational range, enabling longer, more versatile missions for multirotors in various applications, especially after a certain critical mass threshold.

BIOMASS POTENTIAL

The role of biomass in future energy mix should be developed with respect to economic, ecological, and sustainable land use requirements, ensuring balanced allocation for conventional and energy crops **[95]**. Long-term utilization of available biomass should be carefully investigated to ensure sufficient and reliable supply **[96]**. In that line, Nedić et al. explored **[97]** the transition from a wood-based community to a circular, carbon-neutral, and sustainable bioeconomy in Vukovar-Srijem County, Croatia. It highlights the region's forestry potential and the need for value-chain strengthening and innovation in wood biomass management to produce high-value-added wood products. The study shows that sawdust, predominantly used for heating, can be optimized to better align with bioeconomic goals, offering recommendations for improving efficiency and environmental outcomes. Combustion of biomass products entails strict requirements on fuel quality, particle size, and ash content while simultaneously achieving high energy density. Therefore, a large number of thermal pretreatment and preparation methods are developed to ensure satisfying performance **[98]**. After, the devolatilization process of releasing volatile gases is usually performed, where it is important to determine the content of devolatilization products from biomass feedstock **[99]**. Atamanyuk et al. **[100]** evaluated the potential of apple pomace, a byproduct of the juice industry, as a raw material for alternative solid fuel. Due to its high initial moisture content, the study proposes using filtration drying, which reduces the moisture to 14% with an energy consumption of 6.11 kWh per kilogram of water removed. The dried pomace is then briquetted, producing solid fuel with a calorific value of approximately 19,438 kJ/kg, low moisture content (<1%), and ash content (~0.55%), meeting European standards for solid fuels. While the energy required for drying exceeds the combustion energy from the resulting fuel, the process's efficiency can be improved through secondary heat use. The study highlights the environmental benefits of using plant-based waste as a renewable energy source, addressing both waste management and sustainability. Biomass in the form of pellets can also be used to convert it into more valuable products, such as synthesis gas **[101]** or further processed by torrefaction to achieve different mechanical and energy parameters [102]. Dethan and Lalel [103] investigated particle size and adhesive quantities of torrefied kesambi leaf biobriquettes. The results show that the optimal conditions are a particle size of 60 mesh and 5% adhesive, producing briquettes with low moisture and ash content, a high calorific value (15.91 MJ/kg), and 79.53% fixed carbon. This research suggests that using torrefied kesambi leaves with a binder produces less energy than using kesambi wood to produce se'i (smoked) meat.

Agricultural and zootechnical communities are aiming to achieve global sustainable goals by increasing their energy, environmental, and economic performance [104]. For analysis of available agricultural land for food production, energy crops, or livestock feed, GIS-based models are used to investigate a number of key parameters when estimating possible changes in biomass potential [105]. Carrión et al. [106] analyzed the relationship between biomass and grazing potential in the high Andean grasslands of the Ampay National Sanctuary in Peru. It assesses vegetation cover, forage productivity, soil erosion, and species used for livestock in three study areas. Uspacocha showed the highest productivity and minimal overgrazing, while Yanacocha was the least productive. Vegetative structures vary widely in terms of their composition and organization. The composition and structure of vegetative formations are heterogeneous, predominantly Rosaceae, Poaceae, and Asteraceae. The natural pasture cover corresponded to the average of 75.7%. The findings emphasize that it is necessary to promote self-sustainable development to preserve natural grassland vegetation. However, agriculture and land use sectors are often overlooked in energy system models. Reforestation can play an important role in carbon sequestration, leading to lower carbon capture and storage technology investments [107], but irresponsible agriculture practices lead to soil carbon loss and higher carbon dioxide emissions [108]. Putra et al. [109] used machine learning to estimate soil infiltration based on land use changes in the sub-watersheds in Indonesia. A scenario analysis of business-as-usual, regional spatial planning, and land capability cases was made to understand the effects of deforestation and urbanization on infiltration. The research shows that natural forests support higher infiltration rates, while deforestation significantly reduces them. The findings can be used in planning sustainable land use. Lastly, aquaculture is one of the fastest-growing food industries with rising environmental impact, but sustainable farming and a healthy ecosystem can be achieved with careful spatial planning [110]. On the other hand, mangroves are essential for coastal systems as they serve as natural barriers against extreme weather conditions [111]. For that reason, it is important to ensure a balance between aquaculture production and the mangrove ecosystem. Ha Anh et al. [112] investigated relationships between mangrove ecosystems and shrimp aquaculture, evaluating environmental and economic impacts in Ca Mau, Vietnam. It compares two scenarios: business as usual (increasing shrimp farming while reducing mangroves) and a policy scenario (limiting expansion). It is shown that first scenario can boost the economy and local jobs, but with the mangrove reduction, it will impact carbon storage potential. The latter results in better environmental outcomes but slower economic growth. The findings recommend land use management and economic diversification to balance development with ecological sustainability.

ALTERNATIVE FUEL CONVERSION

Carbon dioxide management is an emerging field with the request for stopping global warming. A new framework was developed to evaluate exergy efficiency of different chemical processes, where it was shown that CO_2 hydrogenation is more sustainable than syngas conversion and CCS [113]. But production of synthetic methane by hydrogenation of carbon dioxide from direct air capture still exceeds the current price of conventional methane [114]. Berahim et al. [115] explored the optimization of carbon dioxide hydrogenation to methanol using a copper/zinc oxide/alumina catalyst. Through the Response Surface Methodology, it identifies optimal conditions for pressure (31 bar), temperature (300°C), and hydrogen/CO_2 ratio (10:1), achieving a carbon dioxide conversion of 28.6%, methanol selectivity of 59.2%, and methanol yield of 16.4%. At higher pressures up to 80 bar, conversion and selectivity rose, reaching 68.35% carbon dioxide conversion, 93% methanol selectivity, and a 63.57% yield. Furthermore, packed-bed reactors are widely used for chemical reaction engineering, such as methane steam reforming reactions. For that purpose, different configurations of packed beds were developed and compared [116]. To avoid high costs, power consumption, and environmental impact due to CO_2 emissions and energy-intensive separation processes of steam methane reforming, natural gas chemical looping reforming is introduced, using metal oxides for combustion to convert natural gas to hydrogen and CO_2 [117]. Hydrogen production was discussed by Stevanovic et al. [118] through allothermal steam reforming using biomass. The process, tested in a pilot facility, uses excess chemical energy to superheat steam up to 1,200 °C. Produced synthesis gas contains up to 60% of hydrogen. The system effectively handles tars and removes impurities, achieving up to 70% energy efficiency. It highlights the benefits of high-quality hydrogen production, minimal CO_2 emissions, and lower production costs compared to electrolysis-based methods. Green hydrogen is established as a promising energy carrier to provide sustainable energy use through water electrolysis coupled with renewable power generation. But solar radiation, outdoor air temperatures, and wind speeds influence the solar-driven green hydrogen production system [119]. The cost of a hybrid wind turbine-photovoltaic hydrogen system is based on balanced supply from wind and solar energy [120], as well as system size of the plant and the number of separated groups of electrolysis system configurations based on wind-based green hydrogen [121]. Iileka et al. also evaluated the potential for green hydrogen production at the Benguela Wind Energy Community Project in Lüderitz, Namibia, by comparing different sizes of PME-based electrolysers. The results indicate that using excess wind-generated electricity, a 7 kW electrolyser can produce up to 235 kg of hydrogen annually without affecting the system's power needs. Produced hydrogen can help meet unmet energy demands to fuel direct combustion cookstoves or electric stoves via fuel cells in off-grid systems, supporting a sustainable community without needing to increase system capacity.

It is shown that the cost of biomass highly influences the feasibility of biogas and biomethane production [122]. To lower the cost of biomethane production, a hybrid solar system from an organic fraction of municipal solid waste is introduced, that can be both, economically and environmentally justified [123]. Similarly, Radosits et al. [124] explored the production of synthetic methane and methanol using CO_2 from biomass-based processes to reduce reliance on fossil fuels. It assesses various scenarios, highlighting the economic and technical challenges of electrolysis, methanation, and methanol synthesis processes. Despite potential cost reductions through technological advances, the high production costs remain a barrier. Low electricity prices and a high number of full-load hours are essential for making these fuels economically viable. Animal waste is also often used as a feedstock for pyrolysis processes to produce higher-value products. Poultry manure is usually preprocessed, and pyrolysis is supported by catalysts to achieve efficient bio-oil production [125]. For biochar production from poultry manure, conversion efficiency depends on pyrolysis temperature [126]. Similarly, Siswantara et al. [127] analyzed the pyrolysis of sheep manure using thermogravimetric analysis to explore its kinetic and thermodynamic parameters. The process shows two major stages of mass degradation: dehydration (30°C–140°C) and devolatilization (210°C–900°C), where most volatile matter degrades by 500°C. The activation energy was calculated using Friedman and Coast-Redfern methods, yielding values of 21.32 kJ/mol and 26.20 kJ/mol, respectively. Findings suggest the sheep manure has a good potential to use as pyrolysis feedstock, but further studies should be made to investigate decomposition shares of different heating rates.

WATER MANAGEMENT

Access to clean drinking water and water scarcity are one of the most critical concerns in modern society. However, water can be reused, offering a sustainable and environmentally viable water supply, but it is important that it is always adequately treated [128]. Exposure to heavy metals is still present in the wastewater even in developed countries, so treatment options for polluted water in an economic and sustainable way are still investigated [129]. Stankovic et al. [130] examined the effects of extreme hydrological events on drinking water quality in rural areas, focusing on Vlasotince in southeastern Serbia. Authors analyzed selected chemical parameters over five years to investigate the qualitative and quantitative fluctuations. Results show significant changes in turbidity, nitrates, iron, and manganese, color, and temperature during extreme events. The findings can help in managing rural water systems and highlight the crucial role of flow dynamics in water quality assessment. As water ecosystems are being threatened with socioeconomic development and human activities, screening influence of industrial, aquaculture, and domestic sector can be beneficial for decision-makers to impose sustainable regulations [131]. Industrial chemicals, pharmaceuticals, and personal care products contain micropollutants, for which efficient and economical treatment is still investigated [132]. Water sources are increasingly in danger due to contamination caused by antibiotic residues from pharmaceutical and healthcare facilities, agriculture, as well as humans and animals and several advanced treatments have been proposed to address their removal. For this reason, Rinawati et al. [133] investigated enhanced removal of antibiotic ciprofloxacin. The study discusses the removal of ciprofloxacin from an aqueous solution using graphene oxide synthesized from cassava peel waste through a modified Hummers method. Evaluation of operation variables led to the adsorption efficiency of 91.71%, achieved at pH 3, with a contact time of 20 min and 35 mg of graphene oxide adsorbent, showing that the graphene oxide material derived from cassava peel waste can be effectively used as an adsorbent for ciprofloxacin from aqueous solutions.

Water coast systems are monitored by physicochemical indicators in combination with innovative methods to assess a decrease in water quality [134]. Leachate, a wastewater stream containing microplastics disintegrated from disposed plastic materials, represents an important health and environmental concern [135]. Hence, Ali et al. [136] presented an empirical model combining on-site sampling and remote sensing techniques to evaluate microplastic pollution along the Dubai coast. Measuring indicates significant microplastic presence, ranging from 0.324 to 0.633 mg/L. Spectroscopic measurements identify distinctive spectral signatures of microplastics and use them to develop a model with high accuracy (87.30% R^2) for monitoring contamination levels. The model offers a valuable tool for long-term, large-scale environmental monitoring. Likewise, the treatment of produced water in crude oil production incurs significant costs due to the need to remove toxic compounds. Production chemicals are recognized as one of the sources causing contamination during oil and gas production processes [137]. To achieve environmental and energy benefits, reusing oil refinery effluent for cooling tower purposes is also investigated [138]. Oil-produced waters are the most abundant wastewater stream, being one of the most expensive procedures in the oil industry, To improve the wastewater treatment in the oil industry, Franchi et al. [139] assessed the potential of using salt-tolerant plants, Halocnemum strobilaceum and Suaeda fruticosa, for phytoremediation of hypersaline oil-produced water by the ability of plants to survive and tolerate the specific saline conditions. Experimental trials showed species-specific results: Halocnemum had higher salt and hydrocarbon tolerance, while Suaeda was better at degrading hydrocarbons. Therefore, phytoremediation can be employed as an appropriate and environmentally sustainable wastewater treatment solution. Similarly, Harkouss et al. [140] explored the use of membrane technologies in treating waste streams from oil and gas production. They focused on the challenges and advancements of membrane systems, such as microfiltration, ultrafiltration, nanofiltration, and reverse osmosis, in addressing pollutants like hydrocarbons, heavy metals, and suspended solids in produced water. They highlighted the importance of developing novel membrane materials and hybrid processes to enhance efficiency, mitigate fouling, and reduce environmental impact. Additionally, it emphasizes the potential for reusing treated produced water in industrial and agricultural sectors, presenting both environmental and economic benefits.

Moreover, the relationship of water and energy extends to diverse areas of sustainable development goals, leading to a need for a comprehensive and standardized framework of water-energy extended nexuses [141]. A water-energy nexus is especially important for remote communities that are vulnerable to flooding and lack access to electricity [142]. Menges and Eckenfels [143] discussed an interdisciplinary project in the Upper Harz Mountains of Germany focused on integrating energy and water management to address challenges like floods, droughts, and water shortages. The authors applied the analytical hierarchy process for decision-making, evaluating various infrastructure alternatives based on environmental, social, and economic factors. System targets were weighted based on water quality management, supply of drinking water, electrical storage, construction costs, and consumption of environmental resources. The proposed procedure can be used for social engagement and policy consultation. With significant contribution to greenhouse gas emissions and high energy intensity of wastewater treatment plants, there is an increase in conducted research and development of energy-water optimization tools for combined energy-saving and renewable integration solutions for wastewater facilities [144]. They can also contribute to electrical power grid system balancing by scheduled operation and consequently lower its energy cost [145]. Mendez-Ecoscia et al. [146] explored the optimization of wastewater treatment processes in a Finnish case study by reducing polymer and electricity consumption. Using sedimentation kinetics and advanced sensors, the researchers determined optimal polymer concentrations for wastewater containing suspended particles and phosphorous. The results suggest that dynamic adjustments based on real-time monitoring could successfully reduce unnecessary chemical use and lower environmental impacts. In addition, a new operational mode with integrated grid-scale batteries for electricity use was also proposed, offering both economic and environmental benefits. Renewable energy is also used for processes such as boiling and reverse osmosis for water purification purposes [147]. Reverse osmosis is used for desalination of seawater to reduce water scarcity, but it still has a high production cost [148]. Accordingly, Rabah et al. [149] presented a framework for evaluating the sustainability of reverse osmosis desalination plants in Gaza, integrating environmental, social, economic, technical, and institutional factors. The methodology uses multi-criteria decision analysis to find the global sustainability index for the southern Gaza desalination plant, revealing a partial sustainability score of 65%. This framework facilitates decision-making for water resource management in areas facing severe water scarcity, providing key insights into improving desalination sustainability in challenging contexts like the Gaza Strip. Unfortunately, lack of sustainability integration in water and wastewater utility companies can be seen in processes throughout the whole value chain [150], and life cycle assessments in wastewater and sludge management are often not adequately utilized due to choice of approach [151]. Life cycle assessment was conducted by Harasymchuk et al. [152], investigating the carbon footprint of the Prague water supply and sewerage system. The authors identified three key sources of emissions: process emissions, purchased energy, and services. Their recommendations include modernizing equipment, adopting renewable energy, and improving efficiency in wastewater treatment. The study concludes that continuous monitoring, organization management, and adaptation to new technologies are crucial for long-term success.

LOCAL COOPERATION

Achieving a circular and sustainable economy in the architecture, engineering, and construction industries is shown to be a complex and multidimensional procedure, and it should consider ecological, economic, and technical perspectives [153]. Growing urbanization is contributing to waste generation from the construction sector. Reusing and recycling of waste material can be achieved with the establishment of reusing and recycling marketplace, and therefore, contribute to sustainable development [154]. Sharma and Chani [155] assessed the embodied energy, water, and carbon and their relationships in the construction of conventional houses in Jammu, India, with an accompanying life cycle assessment framework. The study reveals a strong correlation between embodied energy and carbon but a weak relationship between embodied water and the other two. It is shown that cement, brick, and steel have dominant embodied energy and embodied carbon impacts. The findings suggest a need for tailored approaches to optimizing embodied water compared to energy and carbon for sustainable building practices. Recycling potential of building materials is being evaluated by obtaining information on the composition and separability of the materials and then implemented in building information models [156]. Sustainability and energy performance of buildings have also been assessed with a digital twin and an internet of things dynamic approach [157]. Schützenhofer et al. [158] proposed a "Circular Twin" framework for buildings, integrating a digital ecosystem based on the parts of algorithm design, building information modelling and virtual reality to assess design variants and their sustainability performance regarding recyclability, environmental impact, and EU taxonomy. These variants are visualized in a virtual reality environment, enabling user interaction and sustainable decision-making. The approach aims to reduce raw material extraction and waste, advancing circular building practices.

Research on reduction of energy and environmental impact extends to urban spaces, where implementation of urban energy planning tools is used to assist the optimization of related design and operation of smart cities [159]. Such cities should optimize zoning, land-use allocation, the location of new buildings, and investment decisions for efficient urban planning and infrastructure development [160]. Carrot and Villalba [161] presented a quantitative model based on the "15-minute city" concept, which assesses accessibility to resources in urban areas through 21 composite indicators. The model, applied to 70 neighborhoods in Valencia, Spain, reveals significant geographic disparities in resource access. Peripheral areas score lower in indicators related to services like education, healthcare, and leisure, while central and affluent neighborhoods show better access. The study highlights the need for targeted urban planning to ensure equitable access across all neighborhoods. Thermal conditions are also highly important when assessing the quality of urban areas. Thermal comfort zones can be classified and compared to each other based on temperature and relative humidity [162]. Affordable, accessible, and energy-efficient solutions can increase thermal comfort where needed, which is especially important in low-income housing [163]. Ospino et al. [164] examined methods to enhance living conditions in social interest housing in tropical regions, specifically focusing on Colombia's Caribbean area. The study highlights the challenges posed by high temperatures and humidity, which significantly affect thermal comfort and energy consumption in residential buildings. Using climate data, simulations were performed with tools like EnergyPlus to test passive strategies such as solar protection, cross-ventilation, and insulation. The findings show that applying these strategies can improve the comfort rate by up to 61.3% annually. The research emphasizes the importance of adapting building designs to local climatic conditions to improve energy efficiency, reduce reliance on non-renewable energy, and enhance the well-being of residents in low-income housing.

It is already mentioned that with the penetration of variable energy resources, the stability of the electricity grid can be endangered. Energy communities can participate in energy management strategies, increasing renewable energy self-consumption and providing grid balancing [165]. Not only economic benefits, but also social awareness, play a crucial role in achieving sustainable energy communities [166]. Volpe et al. [167] explored the transition of renewable energy communities into positive energy districts by proposing design and operational indicators, keeping in mind technical, economic, social, environmental, and governance dimensions. The case study was located in Catania, Sicily, constituted by 10 residential buildings. It emphasizes the need for a 20% increase in renewable energy installations to facilitate the shift. The framework requires long-term commitment, planning, and local collaboration to evaluate and guide the transformation of energy communities into more self-sustaining and energy-positive urban areas. But for successful implementation of energy communities, monitoring of electricity load profiles in an electrified environment is necessary for interpretation of behavioral impact and further research [168], leading to better energy management and system decarbonization [169]. Hilger et al. [170] developed a standardized data analysis framework using mobile measurement technology in small and medium-sized enterprises. It highlights the benefits of mobile submetering for identifying energy and load flows and thus inefficiencies in load consumption. By using disaggregation analyses and load profile characterization, the approach identifies relevant electrical consumers. However, the study emphasizes the need for tailored, detailed analysis steps beyond initial detection to achieve effective energy system optimization.

CONCLUSION

Volume XII of the Journal of Sustainable Development of Energy, Water and Environment Systems provides insights into the latest research regarding topics of Sustainable Energy Governance, Renewable Energy Systems, Advances In System Flexibility, Biomass Potential, Alternative Fuel Conversion, Water Management and Local Cooperation. 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 XII but also from special issues from the recent scientific literature and novel research from recent SDEWES Conferences.

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