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Sustainable energy planning with district heating, PV solar and hybrid wind-solar systems

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ABSTRACT

This 50th volume of the International Journal of Sustainable Energy Planning and Management presents contemporary work from the energy planning arena with focus on the planning of renewable energy assets under grid and land constraints, and district heating decarbonisation from a hub-perspective. The two last papers in this volume address different aspects of photovoltaic development; Virtual Power Plant development in Bahrain and agrivoltaic development prospects in Indonesia.

Keywords

Grid constraints;
Hybrid wind-solar;
District heating hubs;
Agrivoltaic planning

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1. Issue Contents

In this issue, Freitas Fernandes Távora[1] address the design of wind-solar energy systems factoring in grid constraints and land availability in a purposely designed model in Excel. Testing the set-up in a Brazilian case, the model finds solutions which are financially better than wind power-only solutions while at the same time improving the utilisation of the grid. In this journal, Paliwel [2] previously addressed solar-wind hybrid systems, for isolated systems with battery.

Rieksta and coauthors [3] address district heating decarbonisation from a system dynamic approach with a view to hubs. Through scenario work, they address energy savings with shifts on the production side. Results point at that with a hub concept, external deliveries are lowered. For significant emission savings, supply-side measures are necessitated. In the words of the authors, *"energy efficiency measures in the building sector alone provide limited mitigation potential"*.

The decarbonisation of district heating is a core theme of the present journal with Saglam analysing decarbonisation of Oslo [4], Tańczuk and coauthors 'work on decarbonisation and high-temperature networks with geothermal plants [5], Nielsen and coauthors' work on the role of district heating in decarbonised societies [6], Viesi's decarbonisation effort in the Alps[7] and Balen and Maljković's work on district heating decarbonisation in Croatia with a focus on individual metering [8].

Previous work in the IJSEPM has addressed several aspects that underpin the development of distributed solar and virtual power plant concepts, including challenges related to renewable energy integration, distributed generation, storage and microgrids [9], stakeholder and business networks in photovoltaic markets [10], spatiotemporal coupling between photovoltaic generation and flexible electricity demand [11], and distributed energy trading platforms for local renewable electricity systems [12]. Building on these strands, Almoadhen and coauthors [13] address off-site solar deployment through a Virtual Power Plant framework in Bahrain, a context characterised by high solar

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potential but constrained land availability and limited private-sector participation in renewable energy development. The authors combine GIS-based site selection, PVsyst simulations and financial assessment of net metering, power purchase agreements and virtual power purchase agreements. The simulated systems range from 0.5 to 1.5 MW, with first-year electricity generation between 1.05 and 3.09 GWh. The results show that while net metering can provide high investor returns, its dependence on physical grid connections and subsidised tariffs limits scalability. Virtual power purchase agreements are therefore presented as a more balanced mechanism, broadening consumer participation while maintaining investor profitability and regulatory coordination.

The spatial dimension of renewable energy planning is also central to Putra and coauthors [14], who turn to agrivoltaic planning in semi-arid Indonesia. Their work connects to earlier IJSEPM contributions on urban-rural cooperation in fully renewable energy systems [15], location-dependent financial risk in photovoltaic projects [16], and GIS-AHP-based solar site selection [17], but shifts the emphasis towards the interaction between renewable energy deployment and rural livelihoods. The authors develop a socio-ecological suitability framework using Fuzzy-AHP and GIS-based multi-criteria analysis for Nusa Tenggara Timur, explicitly including livestock household density and participation as equity-oriented criteria. The study identifies highly suitable areas for both distributed community-scale and centralised utility-scale agrivoltaic deployment, with core suitability zones concentrated in Kupang, Rote Ndao and Sumba Timur. In doing so, the paper expands solar site-selection beyond technical and biophysical criteria, showing how spatial planning can support renewable energy deployment while reducing conflicts with rural livelihoods and food-security objectives.

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