International Journal of Sustainable Energy Planning and Management Vol. 47 2025 1–6

International Journal of
Sustainable Energy Planning and Management

Sustainable energy planning with storage, photovoltaics, biomass co-firing forecasting and heat planning

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ABSTRACT

This 47th volume of the International Journal of Sustainable Energy Planning and Management presents the most recent work on energy planning with a focus on storage in energy systems, cofiring of biomass in coal-fired power stations and forecasting of electricity demand for better planning practise. Analyses also demonstrate the potential for photovoltaics (PV) in Iraq, and barriers for its implementation in Indonesia, where perceived cost is a dominant barrier. Heat planning is a long-standing focus area of the journal – in this volume with a focus on stakeholder interests and the organisation of the heat planning process. Lastly, this volume presents analyses of links between energy and development in Africa.

Keywords

Rooftop PV;
Energy transition;
Renewable energy adoption;
Forecasting;
Solar resources

http://doi.org/10.54337/ijsepm.11164

1. Issue Contents

In this 47th volume of the IJSEPM, Abdelhamied and coauthors [1] present work on the integration of electricity storage in national electricity systems. They develop a planning framework and address both techno-economic and policy considerations. Early policy measures will enable a higher introduction of electricity storage and thus provide better potential for high penetration of renewable energy sources. At the same time, curtailment can be decreased.

In a previous issue of this journal, Buss, Wrobel & Doetsch gave an overview of global grid-connected storage systems [2], Jeannin investigated the electricity storage potential in electric vehicles [3], Perinhas and coauthors as well as Tomc and Vassallo looked at electricity storage in renewable energy communities [4–6]. In the latter, Tomc and Vassallo found that a combination of PV and storage could decrease grid imports by 93-96% in different Australian locations. Wider works based on the smart energy concept (see [7–9]) have, however, shown that drawing on cheaper storage options elsewhere in the wider energy system should be addressed [10]. With thermal energy demands, heat storage has benefits in terms of low cost and high efficiency, and with electrification of heating demand or the exploitation of the cogeneration of heating and power (CHP) synergy [11], dispatchable loads combined with heat storage can provide flexibility to the electricity system as well as to the heating system [12].

District heating and thermal storage are thus established as pivotal to the energy system transition and are also recurring topics in the IJSEPM journal [13]. In the present volume, Persson et al. [14] explore the potential for seasonal thermal storage in Sweden by conducting a spatial analysis, assessing the availability of suitable land area in proximity of significant district heating demand. For Sweden this is a novel and timely study, since despite the vast district heating build-out, limited applications of seasonal thermal storage exist, in contrast to Denmark with a comparable district heating share. The authors find extensive potential in terms of suitable land area for seasonal storage, though the

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Received 25.11.2025 | Accepted 26.11.2025 | Published 10.12.2025
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southern parts of Sweden in general display more promising results. Persson was previously involved in an analysis of district heating length in Italy in the IJSEPM [15], based on Minimum Spanning Tree.

Sugiyono and coauthors [16] investigate the prospects for cofiring biomass in coal-based power stations in Indonesia, taking into consideration the separation of Indonesia into many islands with different characteristics both in terms of biomass availability and in terms of power generation capacity. Using LEAP, the authors model scenarios for business as usual and biomass co-firing. For Indonesia to rely adequately on such resources, analyses across regions with surplus and regions with deficits are required.

In this journal, Irsyad [17] previously looked at the phasing out of coal in the South Kalimantan Province, and Volkova investigated different replacement rates of coal with renewables in the Estonian district heating system [18]. In China, biomass has also been investigated with a perspective of replacing coal in district heating [19].

Hakim and Septama [20] present a multivariate forecasting model to anticipate the evolution of electricity demand in the province of Lampung, Indonesia, with the aim of strengthening evidence-based regional energy planning. The study applies a VAR (Vector Autoregressive) model to historical series of electricity consumption, population and Gross Regional Domestic Product from 2010 to 2023. This quantitative approach aligns with research demonstrating the value of advanced regression and predictive methods for understanding complex systems and supporting energy-related decision-making [21]. The model performs very well, achieving a MAPE (Mean Absolute Percentage Error) of 0.57 percent and a coefficient of determination R^2 of 0.998, confirming its reliability for medium-term projections. The results indicate a steady increase in electricity demand through 2030, driven by demographic and economic growth. The study also highlights Lampung's strong dependence on the Sumatra grid and the need to reinforce local generation capacity, an issue noted in regional assessments of Indonesia's energy sustainability [22]. In a context where PLN (Perusahaan Listrik Negara) and regional authorities are advancing policies to transition towards lower-emission energy systems, the authors underscore the strategic role of hydropower, geothermal energy and other renewables in reducing the dominance of fossil fuels. The methodological contribution of this work resonates with the emphasis in this journal on robust analytical tools for sustainable energy system planning design [23] and connects with the broader literature calling for models capable of handling complexity and uncertainty in energy systems [24,25].

Iraq holds good potential for PV as established by Nassif and coauthors [26]. Using geographical information system (GIS)-based analyses, they analyse Iraq factoring in various determinants, finding that 6.3% of Iraq's surface area is appropriate for PV. Depending on utilisation, this translates into potential production in the TWh/yr range. If 5% is used, 3.4 TWh can be produced. With increasing temperatures, cooling is an important feature in maintaining efficiency in future Iraqi PV installations. In the context of the IJSEPM, this is the first work on Iraq presented here. Previous work with Iraqi ties has focused more on oil price impacts in a geopolitical context [27,28]. PV as a technology in the energy transition is well-addressed in, e.g., Leuven's article on energy districts [29] and Viesi's work on energy transition in the Alps [30] – but also in work focusing more on resource assessment in different locations including Colombia [31], India [32] and the Arctic area [33].

Eliwa et al. [34] analyse Indonesian consumers' intention to adopt residential PV systems using an extended version of the UTAUT (Unified Theory of Acceptance and Use of Technology) model, identifying Perceived Cost as the dominant barrier, followed by Knowledge, Facilitating Conditions, and Ease of Use. The study is particularly relevant in a country where solar deployment progresses slowly despite its substantial technical potential, a situation already documented by Gunawan et al. [35], who show that Indonesia is advancing well below its national targets and regional peers. These findings align with research emphasising the need for regulatory stability and reduced user-side uncertainty to accelerate adoption, consistent with decarbonisation pathways towards NZE (Net Zero Emissions) in which solar plays a central role [36]. Likewise, the strong global technical and economic competitiveness of PV, as demonstrated by Korfiati et al. [37], reinforces the relevance of addressing the social barriers identified.

In line with recent perspectives on user mobilisation and engagement in flexibility-related services [38], the work of Eliwa et al. underscores that unlocking residential solar adoption in Indonesia depends simultaneously on alleviating perceived economic burdens, improving public information, and consolidating effective institutional support for households. Reindl and Palm [39] , Ugulu [40,41] and Gunawan and coauthors have previously also explored adoption in different settings [42].

In [43], Kaiser and coauthors approach the energy transition from a municipal heat planning perspective using a Multi-Criteria Decision Analysis (MCDA) approach. In their work, they factor in stakeholder priorities, and conflicting interests, and develop a six-step decision-making model drawing on twelve quantitative and qualitative criteria. The approach is tested on a Northern German city case. While implementation remains context-dependent, the structured approach lays a foundation for informed and socially accepted planning decisions.

The IJSEPM has presented extensive work within the field of heat planning, with a particular focus on spatial analyses. Möller and Nielsen presented their heat atlas [44], and Nielsen focused on the validity of heat atlases over measured data, finding that for individual houses, heat atlases are adequate but not for other building types [45]. Csontos and coauthors presented the Hotmaps Online Heat Atlas for heat planning purposes [46]. Some areas lack good data, thus Moreno presented an open data tool [47]. Wider spatial considerations were considered by Knies [48] and Kuriyan & Shah also went further in the integration of technological models with spatial analyses [49]. Other research has focused more on the organisational processes and stakeholders, e.g., Krogh investigating stakeholder engagement in the transition to 4th generation district heating [50]. Also, Divkovic addressed the wider planning frame for transitioning heating systems [51].

Aromasodun, Biala and Shitu [52] examine the relationship between total, renewable and non-renewable energy consumption and economic growth across the eight official regional economic blocs of Africa from 1996 to 2022, offering a comparative perspective that highlights how structural differences shape the continent's energy transition. The study employs panel data and the MG (Mean Group) and PMG (Pooled Mean Group) estimators, selected through the Hausman test, confirming the presence of long-run relationships between energy and growth. The authors show that total energy consumption has heterogeneous effects: negative in AMU (Arab Maghreb Union) and CEN-SAD (Community of Sahel-Saharan States), positive in ECOWAS (Economic Community of West African States), IGAD (Intergovernmental Authority on Development) and SADC (Southern African Development Community), and insignificant in COMESA (Common Market for Eastern and Southern Africa), EAC (East African Community) and ECCAS (Economic Community of Central African States).

These patterns are consistent with analyses that emphasize the need for modelling frameworks sensitive to the structural diversity of African economies, such as the work of Khaleel and Chakrabarti on discrepancies in energy demand modelling in Nigeria [53]. Similarly, the positive contribution of renewable energy in several blocs aligns with literature underscoring the importance of sociotechnical factors, including energy literacy, efficiency and consumer behaviour, themes extensively reviewed by Umoha and Bande in their assessment of energy conservation in African contexts [54]. Finally, the authors' recommendation to design strategies tailored to each bloc resonates with broader perspectives calling for balanced and socially responsive energy policies, such as the proposals for fiscal reform to alleviate energy poverty discussed by Borge-Diez et al. in the European context [55]. Lastly in this issue Ashgar [56], develop and test an energy management guideline for sustainable educational institutions in Malaysia.

References

[1] Abdelhamied MM, Yazawa N, Cong R. Scenario-based framework for national energy storage integration in decarbonization pathways. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10125.

[2] Buß K, Wrobel P, Doetsch C. Global distribution of grid-connected electrical energy storage systems. International Journal of Sustainable Energy Planning and Management 2016;9:31–56. https://doi.org/10.5278/ijsepm.2016.9.4.

[3] Jeannin N, Dumoulin J, Pena-Bello A, Wannier D. A spatiotemporal analysis of photovoltaic electricity storage potential in electric vehicles. International Journal of Sustainable Energy Planning and Management 2025;44. https://doi.org/10.54337/ijsepm.9825.

[4] Perinhas SM de O, Sousa JAM de, Viveiros CSPC, Barata FA de SF. Techno-economic Assessment of Battery Energy Storage Systems in Renewable Energy Communities. International Journal of Sustainable Energy Planning and Management 2025;44. https://doi.org/10.54337/ijsepm.9290.

[5] Tomc E, Vassallo AM. Community electricity and storage central management for multi-dwelling developments: an analysis of operating options. International Journal of Sustainable Energy Planning and Management 2018;17. https://doi.org/10.5278/ijsepm.2018.17.3.

[6] Tomc E, Vassallo AM. The effect of individual and communal electricity generation, consumption and storage on urban Community Renewable Energy Networks (CREN): an Australian case. International Journal of Sustainable Energy

Planning and Management 2016;11. https://doi.org/10.5278/ijsepm.2016.11.3.

[7] Lund H, Østergaard PA, Connolly D, Mathiesen BV. Smart energy and smart energy systems. Energy 2017;137. https://doi.org/10.1016/j.energy.2017.05.123.

[8] Lund H, Andersen AN, Østergaard PA, Mathiesen BV, Connolly D. From electricity smart grids to smart energy systems - A market operation based approach and understanding. Energy 2012;42:96–102. https://doi.org/10.1016/j.energy.2012.04.003.

[9] Lund H, Mathiesen BV, Connolly D, Østergaard PA. Renewable Energy Systems - A Smart Energy Systems Approach to the Choice and Modelling of 100 % Renewable Solutions. Chem Eng Trans 2014;39:1–6. https://doi.org/10.3303/CET1439001.

[10] Lund H, Østergaard PA, Connolly D, Ridjan I, Mathiesen BV, Hvelplund F, et al. Energy Storage and Smart Energy Systems. International Journal of Sustainable Energy Planning and Management 2016;11:3–14. https://doi.org/10.5278/ijsepm.2016.11.2.

[11] Lund H, Østergaard PA, Sorknæs P, Nielsen S, Skov IR, Yuan M, et al. District heating in clean energy systems. Nature Reviews Clean Technology 2025. https://doi.org/10.1038/s44359-025-00076-8.

[12] Johannsen RM, Arberg E, Sorknæs P. Incentivising flexible power-to-heat operation in district heating by redesigning electricity grid tariffs. Smart Energy 2021;2:100013. https://doi.org/10.1016/j.segy.2021.100013.

[13] Nielsen S, Sorknæs P, Vad Mathiesen B, Lund H, Moreno Saltos DC, Zinck Thellufsen J. Heating Sector Strategies in Climate-Neutral Societies. International Journal of Sustainable Energy Planning and Management 2024;43:101–22. https://doi.org/10.54337/IJSEPM.8554.

[14] Persson U, Et al. National spatio-technical potential for PTES in Sweden: A first-order assessment by criteria screening. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10123.

[15] Dénarié A, Macchi S, Fattori F, Spirito G, Motta M, Persson U. A validated method to assess the network length and the heat distribution costs of potential district heating systems in Italy. International Journal of Sustainable Energy Planning and Managemen 2021;31. https://doi.org/10.5278/ijsepm.6322.

[16] Sugiyono A, Kuncoro AH, Fitriana I. Strategies Toward Energy Transition in Indonesia: An Assessment of Multi-Regional Biomass Supply for Coal Co-Firing Power Plants. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10514.

[17] al Irsyad MI, Et al. A Strategic Plan for Renewable Energy Transition in a Coal Dependent Region using Participatory Backcasting: The Case of South Kalimantan Province in Indonesia. International Journal of Sustainable Energy Planning and Management 2025. https://doi.org/10.54337/ijsepm.9826.

[18] Volkova A, Lat\~{o}šov E, Lepiksaar K, Siirde A. Planning of district heating regions in Estonia. International Journal of Sustainable Energy Planning and Management 2020;27. https://doi.org/10.5278/ijsepm.3490.

[19] Zhang J, Lucia L Di. A transition perspective on alternatives to coal in Chinese district heating. International Journal of Sustainable Energy Planning and Management 2015;6:49–69. https://doi.org/10.5278/ijsepm.2015.6.5.

[20] Hakim L, Septama HD. Multivariate Forecasting of Electricity Consumption for Sustainable Energy Planning. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10040.

[21] Lozano A, Cabrera P, Blanco-Marigorta AM. Non-linear regression modelling to estimate the global warming potential of a newspaper. Entropy 2020;22:590. https://doi.org/10.3390/E22050590.

[22] Siregar YI. Ranking of energy sources for sustainable electricity generation in Indonesia: A participatory multi-criteria analysis. International Journal of Sustainable Energy Planning and Management 2022;35:45–64. https://doi.org/10.54337/IJSEPM.7241.

[23] Østergaard PA, Maestosi PC. Tools, technologies and systems integration for the Smart and Sustainable Cities to come. International Journal of Sustainable Energy Planning and Management 2019;24. https://doi.org/10.5278/ijsepm.3405.

[24] Cabrera P, Carta JA. Computational Intelligence in the Desalination Industry. Springer Optimization and Its Applications 2019;150:105–31. https://doi.org/10.1007/978-3-030-25446-9_5.

[25] Prina MG, Johannsen RM, Sparber W, Østergaard PA. Evaluating near-optimal scenarios with EnergyPLAN to support policy makers. Smart Energy 2023;10:100100. https://doi.org/10.1016/j.segy.2023.100100.

[26] Nassif WG, Al-Timimi YK, Elhmaidi D. GIS-AHP for Optimal Solar Site Selection: A Case Study of Iraq and Its Implications for Climate Change. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10646.

[27] Verbruggen A. The geopolitics of trillion US oil & gas rents. International Journal of Sustainable Energy Planning and Management 2022;36. https://doi.org/10.54337/ijsepm.7395.

[28] Østergaard PA, Sperling K. Towards Sustainable Energy Planning and Management. International Journal of Sustainable Energy Planning and Management 2014;1:1–5. https://doi.org/10.5278/ijsepm.2014.1.1.

[29] van Leeuwen RP, de Wit JB, Smit GJM. Energy scheduling model to optimize transition routes towards 100% renewable urban districts. International Journal of Sustainable Energy

Planning and Management 2017;13. https://doi.org/10.5278/ijsepm.2017.13.3.

[30] Viesi D, Mahbub MS, Brandi A, Thellufsen JZ, Østergaard PA, Lund H, et al. Multi-objective optimization of an energy community: an integrated and dynamic approach for full decarbonisation in the European Alps. International Journal of Sustainable Energy Planning and Management 2023;38:8–29. https://doi.org/10.54337/ijsepm.7607.

[31] Martínez-Ruiz Y, Micán CA, Manotas-Duque DF. LCOE at Risk in Different Locations in Colombia. International Journal of Sustainable Energy Planning and Management 2025;44. https://doi.org/10.54337/ijsepm.9745.

[32] Akilesh A, Damodaran K. Accelerating Solar Power Generation to Achieve India's Net-Zero Goals: A Factor-Based Study. International Journal of Sustainable Energy Planning and Management 2025;44. https://doi.org/10.54337/ijsepm.9787.

[33] Asplund A, Nilsson LJ. Perspective on Industrial Electrification and Utility Scale PV in the Arctic Region. International Journal of Sustainable Energy Planning and Management 2024;41. https://doi.org/10.54337/ijsepm.8180.

[34] Eliwa N, et al. Consumers' Behavioral Intention on Rooftop PV Adoption to Promote Renewable Energy using Extended UTAUT Model in Indonesia . International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.9992.

[35] Gunawan J, Alifia T, Fraser K. Achieving renewable energy targets: The impact of residential solar PV prosumers in Indonesia. International Journal of Sustainable Energy Planning and Management 2021;32:111–24. https://doi.org/10.5278/IJSEPM.6314.

[36] Fitriana I, Hadiyanto, Warsito B, Hilmawan E, Santosa J. The Optimization of Power Generation Mix To Achieve Net Zero Emission Pathway in Indonesia Without Specific Time Target. International Journal of Sustainable Energy Planning and Management 2024;41:5–19. https://doi.org/10.54337/IJSEPM.8263.

[37] Korfiati A, Gkonos C, Veronesi F, Gaki A, Grassi S, Schenkel R, et al. Estimation of the Global Solar Energy Potential and Photovoltaic Cost with the use of Open Data. International Journal of Sustainable Energy Planning and Management 2016;9:17–30. https://doi.org/10.5278/IJSEPM.2016.9.3.

[38] Østergaard PA, Johannsen RM, Cabrera P. Sustainable Energy Planning and Management with PV, batteries, energy management, and user engagement. International Journal of Sustainable Energy Planning and Management 2025;44:1–4. https://doi.org/10.54337/IJSEPM.10239.

[39] Reindl K, Palm J. Exploring PV Adoption by Non-Residential Property Owners: Applying Social Practice Theory. International Journal of Sustainable Energy Planning and Management 2024;41. https://doi.org/10.54337/ijsepm.8265.

[40] Ugulu AI. Barriers and motivations for solar photovoltaic (PV) adoption in urban Nigeria. International Journal of Sustainable Energy Planning and Management 2019;21. https://doi.org/10.5278/ijsepm.2019.21.3.

[41] Ugulu AI, Aigbavboa C. Assessing Urban Households' Willingness to Pay for Standalone Solar Photovoltaic Systems: A Case Study of Lagos, Nigeria. Journal of Sustainable Development of Energy, Water and Environment Systems 2019;7:553–66. https://doi.org/10.13044/j.sdewes.d7.0274.

[42] Gunawan J, Alifia T, Fraser K. AChieving renewable energy targets: The impact of residential solar PV prosumers in Indonesia. International Journal of Sustainable Energy Planning and Management 2021;32. https://doi.org/10.5278/ijsepm.6314.

[43] Kaiser A, Cadenbach AM, Krebs F. Stakeholder-informed multi-criteria decision-making for sustainable heat supply. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.9698.

[44] Möller B, Nielsen S. High resolution heat atlases for demand and supply mapping. International Journal of Sustainable Energy Planning and Management 2014;1:41–58. https://doi.org/10.5278/ijsepm.2014.1.4.

[45] Grundahl L, Nielsen S. Heat atlas accuracy compared to metered data. International Journal of Sustainable Energy Planning and Management 2019;23. https://doi.org/10.5278/ijsepm.3174.

[46] Csontos C, Harmat Á, Campos J, Munkácsy B. Using Hotmaps online heat atlas for energy planning in a rural area and the influence of spatial aspects on the energy mix – a case study of a geographically mixed rural area in Hungary. International Journal of Sustainable Energy Planning and Management 2024;43. https://doi.org/10.54337/ijsepm.8602.

[47] Moreno D, Nielsen S, Yuan M, Nielsen FD. The ODHeatMap tool: Open data district heating tool for sustainable energy planning. International Journal of Sustainable Energy Planning and Management 2024;42. https://doi.org/10.54337/ijsepm.8812.

[48] Knies J. A spatial approach for future-oriented heat planning in urban areas. International Journal of Sustainable Energy Planning and Management 2018. https://doi.org/10.5278/ijsepm.2018.16.2.

[49] Kuriyan K, Shah N. A combined spatial and technological model for the planning of district energy systems. International Journal of Sustainable Energy Planning and Management 2019;21. https://doi.org/10.5278/ijsepm.2019.21.8.

[50] Krog L, Sperling K, Svangren MK, Hvelplund F. Consumer involvement in the transition to 4th generation district heating. International Journal of Sustainable Energy Planning and Management 2020;29. https://doi.org/10.5278/ijsepm.4627.

[51] Divkovic D, Knorr L, Meschede H. Design approach to extend and decarbonise existing district heating systems - case study for German cities. International Journal of Sustainable Energy Planning and Management 2023;38. https://doi.org/10.54337/ijsepm.7655.

[52] Aromasodun OM, Biala MI, Shitu AM. Renewable and Non-Renewable Energy Consumption and Economic Growth in Africa: Regional Insights for Sustainable Energy Planning. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10101.

[53] Khaleel AG, Chakrabarti M. Energy modelling as a tool for curbing energy crisis and enhancing transition to sustainable energy system in Nigeria. International Journal of Sustainable Energy Planning and Management 2019;21:3–18. https://doi.org/10.5278/IJSEPM.2019.21.2.

[54] Umoh EA, Bande YM. A template for promoting energy conservation in Nigeria's residential sector. International Journal of Sustainable Energy Planning and Management 2021;32:125–38. https://doi.org/10.5278/IJSEPM.6524.

[55] Borge-Diez D, Silva S, Cabrera P, Sarmento P, Rosales-Asensio E. Energy taxes recycling as an instrument for the mitigation of the expenditure on energy products of vulnerable households in the European Union. Energy Res Soc Sci 2024;118:103787. https://doi.org/10.1016/J.ERSS.2024.103787.

[56] Ashgar SKA. Establishing Critical Elements of Energy Management for Sustainable Campus Development. International Journal of Sustainable Energy Planning and Management 2025;47. https://doi.org/10.54337/ijsepm.10169.