energies

Editorial

Advanced Energy Systems in Energy-Resilient and Zero/Positive Energy Buildings, Communities, and Districts

Hassam ur Rehman [1,*] and Ala Hasan [2]

[1] VTT Technical Research Centre of Finland Ltd., P.O. Box 1000, FI-02044 Espoo, Finland
[2] Independent Researcher, Hai Al-Mustansiriya, Baghdad 02044, Iraq
* Correspondence: hassam.rehman@vtt.fi; Tel.: +358-40-621-5917

The pursuit of sustainable energy solutions has become a critical focus in addressing the challenges of climate change and urbanization. This Special Issue provides a comprehensive overview of recent research in the field of energy and sustainability, encompassing diverse topics such as urban energy planning, short-term electrical load forecasting, energy resilience, energy flexibility, energy efficiency, nearly zero-energy buildings and districts, and the development of Positive Energy Districts (PEDs). The studies included in this Special Issue demonstrate the importance of combining innovative technologies, community engagement, and policy support to achieve energy efficiency and sustainability goals. By exploring the practical applications and impacts of these advancements, this Special Issue fosters a holistic understanding of the current state of energy research and its potential to drive positive change in urban environments. This Special Issue includes a total of 16 papers covering different aspects of building and district planning, technologies and their economics, building design and retrofitting, citizen engagement and the collection of energy data, energy resilience, and energy flexibility.

Multiple studies discuss the development and benefits of Positive Energy Districts (PEDs), which aim to achieve net-zero energy imports and CO_2 emissions while producing surplus renewable energy [1]. PEDs, defined as urban areas that produce more renewable energy than they consume, are explored through various case studies [2]. This Special Issue highlights the importance of building renovations, renewable energy integration, and community engagement in achieving sustainable urban development. PEDs have the potential to support energy accessibility, alleviate energy poverty, and contribute to carbon reduction [3]. Key sustainable development goals can be achieved through PEDs, such as energy accessibility, sustainable cities, and climate action [4]. Different methodologies to evaluate the multiple benefits of PEDs are developed with the use of stakeholder engagement to align project strategies with broader perspectives [5]. The advancements in energy and sustainability research presented in this Special Issue underscore the critical role of innovative technologies, predictive modeling, and community engagement in achieving sustainable urban development. The integration of automated data collection, energy demand prediction, and renewable energy sources into urban energy planning and retrofitting frameworks has demonstrated significant potential in reducing energy consumption and emissions and enhancing efficiency. Positive Energy Districts (PEDs) have emerged as a promising solution to urban sustainability challenges, offering benefits such as energy self-sufficiency, energy resilience, energy flexibility, reduced carbon emissions, and improved social equity and energy resilience [6]. Therefore, future cities and districts require planning that can accommodate such innovative districts and buildings based on local conditions in order to provide carbon-neutral, sustainable, and resilient districts that are socially acceptable and economically feasible.

Received: 6 February 2025
Revised: 24 February 2025
Accepted: 25 February 2025
Published: 2 March 2025

Citation: Rehman, H.u.; Hasan, A. Advanced Energy Systems in Energy-Resilient and Zero/Positive Energy Buildings, Communities, and Districts. *Energies* **2025**, *18*, 1218. https://doi.org/10.3390/en18051218

Evaluations of green building technologies and post-evaluation studies underscore the need for continuous improvement in energy efficiency and occupant satisfaction [7]. While green buildings generally meet energy performance standards, the effectiveness of certain technologies, particularly energy-saving ones, can be improved. Research on novel technologies such as wireless power transfer for battery-charging smart controls, glazing, and the reuse of advanced building materials demonstrates their potential to contribute to sustainability. In addition, producing energy through waste (using heat recovery) is another method that can support sustainability goals [8]. Hence, further research is needed to introduce these innovative solutions to society in a way that is economical, scalable, and can be replicated.

The benefits of district-level energy strategies over individual building retrofits are highlighted in this Special Issue, including significant reductions in CO_2 emissions and energy use. Effective stakeholder engagement can lead to new, more effective solutions; however, new methods are needed to achieve this [9] in order to provide feasible solutions. Advances in machine learning and data analysis are highlighted for improving the accuracy of energy demand predictions [10]. Various machine learning models for short-term load forecasting in buildings are discussed, with the most accurate methods identified based on different data resolutions and time steps. The Special Issue highlights the importance of data preparation in model accuracy, error calculations, forecasting, and performance analysis [10].

This Special Issue highlights the importance of energy-efficient technologies, renewable integration, the circular economy, and advanced data-driven prediction models in creating sustainable and resilient urban environments. From Positive Energy Districts (PEDs) to waste heat recovery and building retrofitting, these approaches are paving the way for the achievement of net-zero and positive energy goals. Technologies such as machine learning and energy simulation tools can enhance the accuracy of energy predictions and the optimization of resources.

We would like to thank the authors of the papers for their valuable contributions to this Special Issue. We also wish to express our gratitude to the reviewers of the papers for their time and effort.

Funding: This Special Issue was supported and funded by the Research Council of Finland, "Energy Resilience in Buildings in Extreme Cold Weather Conditions in Finland 2022–2025 (FinERB), grant number 348060" and "Integration of Building Flexibility into Future Energy Systems 2020–2024 (FlexiB), grant number 333364" and by the European Union's Horizon 2020 research and innovation program [H2020-LC-EEB-03-2019] and the Euratom research and training program 2014–2018 under the project 'EXCESS (FleXible user-CEntric Energy poSitive houseS)' grant agreement No [870157].

Acknowledgments: IEA EBC Annex 93 Energy Resilience of the Buildings in Remote Cold Regions and IEA EBC Annex 83 Positive Energy Districts.

Conflicts of Interest: Author Hassam ur Rehman is employed by the VTT Technical Research Centre of Finland Ltd. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Gondeck, M.; Triebel, M.A.; Steingrube, A.; Albert-Seifried, V.; Stryi-Hipp, G. Recommendations for a Positive Energy District Framework—Application and Evaluation of Different Energetic Assessment Methodologies. *Smart Energy* **2024**, *15*, 100147. [CrossRef]
2. Healey Trulsrud, T.; van der Leer, J. Towards a Positive Energy Balance: A Comparative Analysis of the Planning and Design of Four Positive Energy Districts and Neighbourhoods in Norway and Sweden. *Energy Build.* **2024**, *318*, 114429. [CrossRef]
3. Bruckner, H.; Alyokhina, S.; Schneider, S.; Binder, M.; Abdin, Z.U.; Santbergen, R.; Verkou, M.; Zeman, M.; Isabella, O.; Pagliarini, M.; et al. Lessons Learned from Four Real-Life Case Studies: Energy Balance Calculations for Implementing Positive Energy Districts. *Energies* **2025**, *18*, 560. [CrossRef]
4. Schreiber, F. The Long Road from Urban Experimentation to the Transformation of Urban Planning Practice: The Case of Tactical Urbanism in the City of Barcelona. *J. Urban Mobil.* **2025**, *7*, 100100. [CrossRef]
5. Mueller, L.; Marcroft, T.P.; von Beck, C.; Zeiss, J.P.; Schwanitz, V.J.; Wierling, A.; Holstenkamp, L. "First Come, First Served" or "the More, the Merrier"? Organizational Dynamics of Citizen-Led Solar Initiatives and the Presence of Photovoltaic Installations in Germany. *J. Clean. Prod.* **2024**, *449*, 141861. [CrossRef]
6. Ur Rehman, H.; Nik, V.M.; Ramesh, R.; Ala-Juusela, M. Quantifying and Rating the Energy Resilience Performance of Buildings Integrated with Renewables in the Nordics under Typical and Extreme Climatic Conditions. *Buildings* **2024**, *14*, 2821. [CrossRef]
7. Yue, N.; Li, L.; Caini, M.; Xie, X. Occupant Information Computer Vision Sensing-Based Displacement Ventilation in Large Space Building for Improving Indoor Environment and Energy Efficiency. *Build. Environ.* **2025**, *269*, 112364. [CrossRef]
8. Miškić, J.; Dorotić, H.; Pukšec, T.; Schneider, D.R.; Duić, N. Holistic Method for Determining the Techno-Economic Feasibility of Waste Heat for the Planning of the Low-Temperature District Heating Systems. *Energy* **2024**, *313*, 133968. [CrossRef]
9. Bertolami, I.; Bisello, A.; Volpatti, M.; Bottero, M.C. Exploring Multiple Benefits of Urban and Energy Regeneration Projects: A Stakeholder-Centred Methodological Approach. *Energies* **2024**, *17*, 2862. [CrossRef]
10. Purna Prakash, K.; Pavan Kumar, Y.V.; Reddy, C.P.; Pradeep, D.J.; Flah, A.; Alzaed, A.N.; Al Ahamdi, A.A.; Ghoneim, S.S.M. A Comprehensive Analytical Exploration and Customer Behaviour Analysis of Smart Home Energy Consumption Data with a Practical Case Study. *Energy Rep.* **2022**, *8*, 9081–9093. [CrossRef]