Journal of Sustainability for Energy
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Special Issue: Renewable Energy Communities and Thermal Energy Storage for Sustainable Energy Transition

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Received: 12-02-2024 **Revised:** 12-02-2024 **Accepted:** 12-02-2024

Citation: A. Franco, G. Mutani, S. Nardini, and E. Lorenzini, "Special issue: Renewable Energy Communities and thermal energy storage for sustainable energy transition," *J. Sustain. Energy*, vol. 3, no. 4, pp. 222–223, 2024. https://doi.org/10.56578/jse030401.

Editorial

The special issue of this journal features selected contributions from the two roundtables held during the **9th AIGE-IIETA Conference**, which took place in **Caserta (Italy) from June 3 to 5, 2024**. These contributions reflect the discussions and findings presented during the roundtables. These roundtables focused on two pivotal themes in the context of the ongoing energy transition exploring two interconnected pillars of the energy transition: **Renewable Energy Communities (RECs)** and **Energy Storage**. While RECs focus on electrical energy, thermal storage extends renewables into the thermal sector—the largest energy consumption area—meeting heating, cooling demands, and amplifying their role in decarbonization.

The first roundtable on Renewable Energy Communities highlighted the transformative potential of these community-driven energy models in promoting sustainable territorial development, enhancing energy efficiency, and reducing carbon emissions. Key themes included the importance of local energy autonomy, the integration of IoT technologies, and the need for a favorable regulatory framework. Concrete examples demonstrated how RECs can bring tangible economic and environmental benefits. Moreover, a key aspect of these communities is their ability to foster social inclusion, engage citizens actively, and encourage public participation in energy matters. This roundtable offered an insightful perspective on the potential of RECs, highlighting the role they play in driving local and national energy transitions. However, one limitation identified was the tendency to focus primarily on electrical energy, with thermal energy uses often underexplored.

The second roundtable on Energy Storage provided a comprehensive overview of various technologies and strategies aimed at improving energy efficiency and supporting the transition to renewable energy. A key focus was the development of an international heat market to reduce energy waste and enhance overall efficiency, with discussions on the potential of cross-border thermal resource sharing to lower CO_2 emissions. Energy storage was highlighted as a critical element for optimizing grid management, particularly in managing excess renewable energy. Pilot projects highlighted the tangible benefits of storage technologies, including cost reductions and improved energy performance. The roundtable also explored emerging research trends, such as phase-change materials, molten salt systems, and the role of thermal storage in enhancing building energy flexibility. Hydrogen has been identified as a promising storage option, with applications spanning both stationery and mobile systems. Advanced strategies, including the use of data analysis and AI to optimize energy storage materials, were discussed, with a focus on designing more efficient and sustainable storage technologies.

Together, these two roundtables provided valuable insights into the synergies between renewable energy generation and energy storage solutions, each of which plays a critical role in the broader context of energy transition.

This special issue compiles the most significant contributions emerging from the roundtable discussions, focusing on six key articles.

The first one, **"ENEA's Approach and Technologies for the Development of Smart Energy Communities in**

Italy" by Gilda Massa et al., presents a model developed by ENEA for energy communities, with a particular focus on the use of IoT technologies to optimize the management of energy resources. This approach not only improves efficiency but also promotes active citizen participation, fostering a decentralized management model that integrates social, environmental, and technical aspects.

The paper **"Fundamental Challenges in the Implementation of Positive Energy Districts: Definitions, Design, Technologies, and Sustainability"** authored by Maurizio Cellura et al., analyses the challenges related to the implementation of Positive Energy Districts (PEDs), which represent an advanced form of energy community. The paper explores how the integrated design of energy systems, sustainable mobility, and low-emission generation can support the transition to zero-emission cities. It also emphasizes the critical role of local stakeholders' involvement and the co-creation of solutions that address the specific needs of communities.

The third paper **"An Italian Geoportal for Renewable Energy Communities"** by Guglielmina Mutani et al., proposes a practical tool for the planning and optimization of renewable resources within RECs, through a national geoportal. This tool enables the identification of optimal configurations for the production and distribution of renewable energy, considering economic, social, and environmental variables. The paper demonstrates how optimizing energy self-sufficiency through energy sharing can lead to significant economic and environmental benefits.

In the paper **"Towards the Implementation of Renewable Energy Communities in Various Application Fields in Italy"**, Maurizio Sasso et al. present case studies exploring the implementation of RECs in various application contexts, such as residential and industrial areas. The results show how the creation of energy communities, both in urban and rural settings, can bring tangible benefits in economic, environmental, and social terms, improving energy efficiency and addressing challenges like energy poverty.

Regarding energy storage, Kamel Hooman's contribution, **"Heat Commodification for a Sustainable Energy Future"**, presents an innovative vision on treating heat as a commercially tradable resource, suggesting the creation of an international heat market. Hooman's paper discusses the potential for heat storage systems, such as solid-state salt-based technologies, to facilitate cross-continental heat exchange, contributing to a more efficient global energy system. This idea could revolutionize the management of thermal resources, making the global sharing of low-cost heat possible and enhancing the overall efficiency of energy systems without the need to convert heat into electricity.

The last paper of the special issue **"Integration of Groundwater Storage and Heat Pumps in Second-Generation District Heating Systems"** by Martina Capone and Vittorio Verda explores the integration of geothermal heat pumps into district heating systems, proposing solutions for the efficient seasonal storage of heat. This approach improves the efficiency of heating systems, reduces costs, and allows for more sustainable management of thermal resources, aligning with the needs of energy transition.

All the contributions featured in this special issue underscore the growing recognition that the integration of renewable energy sources with advanced energy storage technologies is essential for achieving the goals of the energy transition. The articles explore various technological, social, and economic aspects of both Renewable Energy Communities and Energy Storage solutions, offering valuable insights into their potential to reshape the future of energy systems. Furthermore, the strong connection between electrical and thermal energy management is a key takeaway from the roundtables, as it highlights the need for an integrated approach to energy planning and policy. By combining innovative technologies, effective stakeholder engagement, and supportive regulatory frameworks, these solutions have the potential to accelerate the shift toward a more sustainable, low-carbon energy future.

For editorial reasons, the contents of this special issue have been distributed across two journals: five articles are published here, in the Journal of Sustainability for Energy (JSE), while one article from the series is published separately in the journal of Power Engineering and Engineering Thermophysics (PEET), "Heat Commodification for a Sustainable Energy Future" by Kamel Hooman, volume 3, issue 3. Readers are encouraged to also consult the contribution in PEET for a comprehensive understanding of the topic.