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Editorial

Special Issue "Net-Zero/Positive Energy Buildings and Districts"

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The important goal of decarbonization of communities and cities has resulted in the emergence of new concepts and implementations of Net-Zero/Positive-Energy Buildings and Districts (NZPEBD) in recent years. Research on NZPEBD comprises all related aspects of energy in buildings and communities, from the basic definition of the concept, including the boundary and types of energy credits definitions, to the characteristics of the building envelope, onsite renewable energy system components and integration, interaction with the external grids, performance control and optimisation, etc., as well as social and economic aspects.

This Special Issue includes a total of 17 papers covering different aspects of NZPEBD planning, technologies and their economics, building design and retrofitting, citizen engagement and collection of energy data.

Under NZPEBD planning, six papers investigated different aspects of NPZEBD planning including definitions, replication methods, obstacles and international collaboration. Lindholm et al. [1] presented the essential factors that determine the planning of PEDs in the EU by studying different definitions of PEDs, features and availability of the renewable energy, consumption behaviours, populations, costs and regulations. Uspenskaia et al. [2] studied common trends in technologies and replication strategies for positive-energy buildings/districts in smart city projects. A case study was performed in Leipzig, one of the lighthouse cities in the SPARCS project, which emphasised the importance of formulation of replication modelling for the upscaling process. Tuerk et al. [3] considered the economic optimisation and market integration opportunities provided by the Clean Energy Package for Plus Energy Buildings (PEBs) and Plus Energy Districts (PEDs). They identified the regulatory limitations at the national level with regard to transposing the set of EU Clean Energy Package provisions. Different options for PEBs and PEDs were studied based on the H2020 EXCESS project. Makvandia and Safiuddin [4] studied the challenges for net-zero buildings in single-family homes in the Greater Toronto Area. The main challenges were technical obstacles, lack of governmental and institutional support, lack of standardisation and low public awareness measures. Recommendations were provided for governmental and academic support for technological uptake and financial incentives. Zhang et al. [5] analysed 60 PED projects in Europe by their main characteristics: geographical information, spatial–temporal scale, energy concepts, building archetypes, finance source, keywords, finance model and challenges/barriers. Many projects use an annual scale; about one-third of the projects have an area smaller than 0.2 km^2 and the most common renewable energy systems are solar, district heating/cooling, wind and geothermal energy. Hedman et al. [6] explained Annex 83 "Positive Energy Districts" of the International Energy Agency—Energy in Buildings and Communities Programme (IEA-EBC). The structure of Annex 83, including its four subtasks, and the working plan were described. The main topics of discussion were the definitions of PEDs, virtual and geographical boundaries, evaluation approaches, the role of different stakeholders, environmental, economic and societal implications, and learnings from realised PED projects.

Under technologies and their economics, five papers studied the technologies of fuel cell, PV, PVT and waste heat with borehole storage. Lindholm et al. [7] studied the use of electricity generated by solar photovoltaic (PV) panels to produce hydrogen gas and its seasonal storage for a reversible solid oxide cell (RSOC) operation. A case study showed that the system can achieve higher utilisation of the generated PV electricity, resulting in achieving a net-zero annual energy balance. Lovati et al. [8] proposed a peer-to-peer (P2P) business model for PV in a small community of 48 individual prosumer buildings in Sweden, considering the energy use behaviour, electricity/financial flows, ownerships and trading in a local electricity market. The results show different use of the common PV resource by the buildings and diverse self-sufficiency features. Lovati et al. [9] presented an agent-based modelling environment for shared urban photovoltaic (PV) systems between 48 households in a local grid of a positive energy district with optimised self-sufficiency. Various scenarios were explored by varying the number of owners of the PV systems and their pricing profiles. Penaka et al. [10] presented a techno-economic study of a typical PVT system for a single-family house to generate electricity and domestic hot water in 85 locations worldwide. The economic performance was assessed using net present value and payback period under two financial models. Hirvonen and Kosonen [11] studied the utilisation of excess heat from waste incineration together with borehole thermal energy storage as seasonal energy storage to supplement conventional district heating of a new residential area. A total of 36 different storage configurations were investigated to obtain the techno-economic performance. In case the district boundary is expanded to include the waste heat generation, the community as a whole can progress toward net-zero energy.

The first step towards achieving net NZPEBD is to minimise the energy demand of buildings by adapting higher energy conservation measures. There are four papers on building design and retrofitting. Hirvonen et al. [12] investigated the potential of Energy retrofitting of buildings for achieving CO_2 emissions neutrality in six Finnish building types by comparing the emissions reduction, investment and life cycle costs. The results indicate that it is possible to reduce the emissions cost-neutrally by 20 to 70% in buildings with district heating and by 70 to 95% with heat pumps. Switching single-family homes with oil or wood boilers to heat pumps produced the largest emission reduction potential. Albatayneh [13] used multi-objective optimisation with various design variables in the building's envelope to reduce the heating and cooling energy in residential buildings in the city of Ma'an, Jordan. The results indicate savings of 88.1%, 94.2% and 78.5% in the total energy consumption, cooling load and heating load, respectively, compared with a baseline building. Koke et al. [14] studied design strategies for suitable building concepts and energy systems to be used in Nearly Zero-Energy Container Buildings (NZECBs) for different climates. Container-based lightweight buildings have high ecological and economic potential. Three cases in Sweden, Germany and Ethiopia were demonstrated and compared, particularly regarding energy self-sufficiency. The influence of different climate zones on the energy efficiency of a single-family house was studied, as well as the influence of the insulation and battery size. Quintana et al. [15] presented a digital spatial map of both electricity use and district heating demand of a set of buildings in the city of Borlänge, Sweden. A toolkit for top-down data analysis was used based on an energy database of monthly consumption of the buildings, which consisted of 228 and 105 geocoded addresses. Digital mapping showed a spatial representation of hotspots of electricity use in high-occupancy/-density areas and for district heating needs. The results can provide an understanding of the existing energy distributions for stakeholders and energy advisors.

Citizen engagement is very important as it is essential to keep citizens informed and engaged with the increasing numbers of technologies and the large scale of urban development. Fatima et al. [16] examined citizen engagement in Espoo (Finland) and Leipzig (Germany) to assess readiness for developing and implementing positive energy districts (PEDs). They studied the cities' operations and methods for citizens' participation.

As lighthouse cities, findings from these two cities can be used to assist other cities in Europe and beyond to plan and operate PEDs together with citizens.

Assessing the energy performance of buildings for PEDs at the urban scale requires large amounts of data. However, these data can be challenging for communities to acquire. Han et al. [17] used a Gaussian mixture model (GMM) with an Expectation-Maximisation (EM) algorithm to produce synthetic building energy data. This method is tested on real datasets. The developed approach is useful for building simulations and optimisations with spatio-temporal mapping.

The heterogeneity of the involved research underlines the importance of following a holistic approach when undertaking NZPEBD planning and implementation. It also shows that further multi-disciplinary research is needed for the integration of advanced technology together with developed people's engagement practices and financing mechanisms on individual and community levels. The NZPEBD challenges will be greatly intensified when going from a small-scale community to a district or a city level.

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