Chapter 44
Towards Climate Neutrality: Progressing Key Actions for Positive Energy Districts Implementation

Rosa Romano, Maria Beatrice Andreucci, and Emanuela Giancola

Abstract Positive Energy Districts (PEDs) represent an emerging urban transition paradigm, an advanced framework to effectively attain decarbonization targets, as well as a holistic approach to foster more resilient and livable cities. However, implementing PEDs is challenging, demanding substantial planning, design, and operations changes. Mainstreaming PEDs calls for innovative legal, institutional, business, and organizational frameworks, as well as an active involvement of the main actors (i.e., cities, municipalities, communities, investors, industry players, and service providers), to co-design and jointly progress ambitious agendas, multiscale plans, flexible instruments, and adaptive structures. Benefitting from the authors' cooperation within the Horizon 2020 project, Cooperation in Science and Technology COST Action 'Positive Energy Districts European Network' (PED-EU-NET in PED-EU-NET | COST ACTION CA19126, 2020), the proposed contribution addresses relevant issues and opportunities characterizing the development of PEDs in Europe, relating attention to effective implementation, context-specificity, replicability, and upscaling. Among the results achieved in the first year of the COST research activities, the authors present an understanding of the PEDs policy landscape in Europe, and a catalogue of the key lessons learned from PEDs in progress. In detail, some comprehensive and interrelated aspects (stakeholder-oriented strategies and technological and system innovation) that have emerged towards enabling conditions for upscaling PEDs structure are analyzed. Through the investigation of existing framework conditions, barriers, and enablers of piloting projects, as well as emerging impacts at international level, the authors provide original insights, and formulate key recommendations for take-up and advancement towards climate neutrality, making a timely and original input to enhanced scholarly understanding of PEDs.

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44.1 Introduction

This document The European Union's SET-Plan Action 3.2 introduced, in 2018, the acronym PEDs, to describe 'Energy-efficient and energy-flexible urban areas, or groups of connected buildings, which emit net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy.

They require integrating different systems and infrastructures, as well as interaction between buildings, the users, and the regional energy, mobility, and ICT systems, while securing the energy supply and a good life for all, in line with social, economic, and environmental sustainability' (EU Commission 2018). Accordingly, in the last years, ongoing initiatives such as the EU's Horizon 2020 'Smart Cities and Communities (SCC) Lighthouse Projects', the Joint Programming Initiative Urban Europe (JPI UE), and the European Energy Research Alliance–Joint Program Smart Cities (EERA–JP SC) have been active to increase the knowledge about the integration of innovative solutions for the planning, deployment, and replication of PEDs. PEDs are already a common objective of ongoing EU research projects (e.g., SPARCS, POCITYF, ATELIER, +CityxChange, Making City, etc.) that have joined the discussion on key issues, such as a commonly shared definition, or the role and relevance of different stakeholders towards implementation, as recently highlighted by the Horizon 2020 project Cooperation in Science and Technology COST Action PED-EU-NET (2020–2024).

In detail, PED-EU-NET aims to drive the deployment of PEDs by harmonizing, sharing, and disseminating knowledge and breakthroughs on this innovative urban and sustainable model across different stakeholders, domains, and sectors, at national and European levels. The Action has been structured in four interlinked thematic Working Groups (WGs) around the core PED vision that are focused on: (WG1) mapping existing concepts, strategies, projects, socio-technical innovations related to PEDs in Europe; (WG2) developing guides and tools to support the implementation of PEDs; (WG3) exploring the success factors of PED Labs, working up common protocols for monitoring and evaluation of PEDs and PED Labs across Europe; (WG4) ensuring the transfer of knowledge and the translation of experience beyond the network. The goal is to establish a PED innovation ecosystem to facilitate open access of knowledge, exchange of ideas, pool resources, experimentation of new methods, and co-creation of novel solutions across Europe. Additionally, this COST Action wants to support the capacity building of new generations of PED professionals, early-career investigators, and experienced practitioners, mobilizing relevant actors from and across Europe to collectively contribute to the long-term climate-neutral target (PED-EU-NET 2020).

Starting from the results achieved in the first year of this scientific cooperation—and in particular during the 1st PED-EU-NET Urban Stakeholder Workshop held in Rome in October 2021—the paper presents some comprehensive and interrelated aspects of enabling conditions for mainstreaming and upscaling PEDs, focusing on stakeholder-oriented strategies, and technological innovations to ensure energy production, efficiency, and flexibility at the district scale. The objective is twofold, i.e., to explore existing framework conditions, barriers, and emerging impacts at international level, and provide key recommendations for uptake and advancement towards climate neutrality, making a timely and original contribution to enhanced scholarly understanding of PEDs.

44.2 Stakeholder-Oriented Strategies and Innovative Governance Model for PEDs

Among the key aspects suitable to describe the characteristics of a PED project, the implementation phase (‘PED phase’) is considered particularly relevant, as challenges and barriers for PED related projects vary from the planning stage to the implementation stage. For this reason, a ‘PED phase’ can be defined according to the ambition and the development stage it is experiencing (i.e., ‘planning’, ‘implementation’, ‘implemented/in operation’) (Zhang et al. 2021). This categorization refers to projects where the construction of the energy systems has been completed (e.g., in Drammen and Stor-Elvdal Municipality, in Norway, already in operation), or not yet commissioned (e.g., in Turku, in Finland, and Bergen in Norway, currently under planning), or integrated into existing energy networks (e.g., in Lund in Sweden, and Odense in Denmark, currently under implementation). Accordingly, previous studies have highlighted some conditions that seem to facilitate inter-organizational collaboration and presented them as critical factors to ensure the PED process a lasting commitment to collaboration and coordination between interested parties and other actors. The initiators must facilitate engagement throughout the process and be enabled by profitable and innovative business models, well-conceived governance structures, and information and communication technologies (Civiero et al. 2021).

The PED project is, in fact, a complex process that requires a high degree of coordination, considering that some actors tend to shift their positions, or rethink their involvement, when moving from one phase to another (Hamdan et al. 2021). From a governance perspective, PEDs offer an appropriate arena for collaboration between different sectors (residential, manufacturing, commercial, public, etc.) and users (owners and tenants, intervening as individuals or as members of communities) to enable a holistic and inter-sectoral approach to energy planning as a key integrative part of sustainable urban development (Bhowmik 2020). For this reason, one of the crucial challenges and barriers to implementing a PED project also depends on the engagement of the different stakeholders in its planning and implementation, and not only in the adaptation of the technical solutions (Bossi et al. 2020).

In that direction, the experiences, and cases studies on ‘PED Gaps’ presented during the recent 1st PED-EU-NET Urban Stakeholder Workshop confirmed how the implementation phase of PEDs can be envisioned as a direct function of active collaboration between cities, private actors, and citizens. Those findings suggest a potential for strengthening the levels of cooperation and mutual trust between all stakeholders, and especially the energy and buildings sectors. Shifting the focus of private stakeholders from pure profit to mutual benefits appear crucial to strengthen this inter-sectoral cooperation, even if this requires significant changes in current practice and business models, as well as the introduction of new technologies, especially the ones that would allow energy storage for a flexible energy supply and use. In addition, the PED-EU-NET Urban Stakeholder Workshop results also suggest that the technologies that target flexible energy demand in buildings are considered very important features by the stakeholders. The high costs of technologies and the weak financial incentives in today’s context were identified as the strongest barriers to the adoption of PEDs. Consequently, the introduction of new business models that reduce costs and mitigate investment risks is considered vital to support PEDs deployment.

The removal of the existing legal and regulatory barriers, which were identified to particularly impact the development of PEDs in Italy, was, also considered crucial to create stronger incentives for mainstreaming districts and neighborhoods able to produce and use energy in a more flexible and ‘smarter’ way, thus paving the way to a wide-scale adoption of PEDs in cities (Fig. 44.1).

Considering the large variety of stakeholders who are meant to participate in this process (end-users; public authorities; financial institutions, and property developers, etc.), it is also imperative to identify both the desired configuration of the energy systems, and the different roles the actors are willing to take (Ahlers et al. 2019).

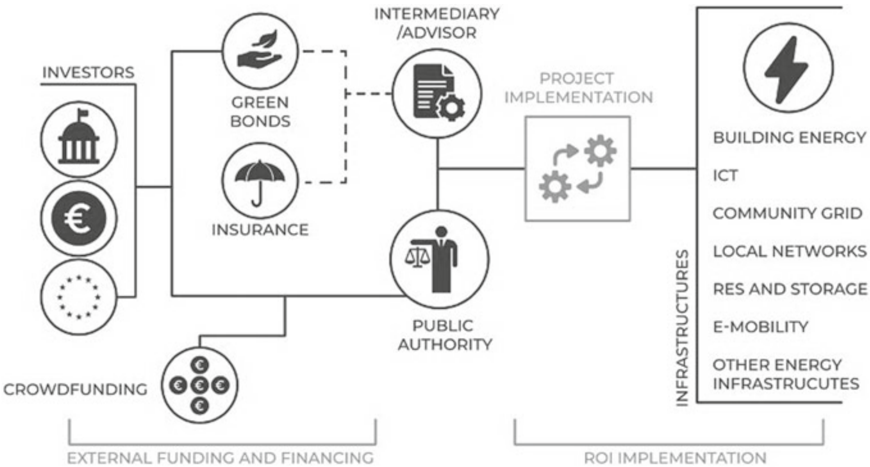

Fig. 44.1 Power distribution of channel at 1555 nm along the link of 383 km (Ahlers et al. 2020)

The different roles of the various stakeholders in all phases of PEDs implementation may be attributed to factors such as the challenges of building refurbishment, the integration of new energy systems, and the surrounding regionals and urban energy infrastructures. However, with the development of PED projects, the stakeholder constellation has been changing according to the different interests, with a consequent transfer of the responsibilities. This point is critical since users need to become more involved in the management of neighborhood systems and may also be exposed to technical challenges. All this requires a major global planning exercise from a technical and spatial planning point of view, a well-conceived governance structure, as well as solid stakeholder engagement strategies (Cheng et al. 2022).

In that direction, the project Sustainable energy Positive and zero cARbon CommunitieS (SPARCS) demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen-centered zero carbon and resource efficient economy. Among the examples currently in progress, SPARCS is developing and piloting new models for co-creation, energy communities and stakeholder engagement to bring residents in the new Kera district in Espoo (Finland), to the center of the energy ecosystem, maximizing local production and encouraging prosumer models to enhance the utilization of distributed power generation (Hukkalainen et al. 2020).

Another interesting example is the project +CityxChange (Fig. 44.2) that is finalized towards the co-created Europe-wide deployment of PEDs through integrated planning and design, creation of a common energy market, and community exchange with all urban stakeholders. In detail, this experimental approach establishes mechanisms that need to be followed up to better understand local needs and develop tailored actions to engage citizens and stakeholders in an open innovation process finalized to optimize the energy consumption of the urban district (Ahlers et al. 2019).

44.3 Technological Innovation to Ensure PEDs Energy Self-sufficiency

PEDs can generally be defined as parts of a city that generate more energy than they consume annually and that promote higher self-consumption and self-sufficiency (Hedman et al. 2021).

This increased dependence on intermittent RES intensifies the need for flexible options to ensure reliable power system operations via integrated solutions consisting of energy storage, smart urban energy networks, ICT, and e-mobility (European Commission 2018). Consequently, it is necessary to optimize the building integration within the district, local, and distant renewable and low carbon energy sources into a resilient energy system, moving beyond nZEBs. Therefore, in the framework of PEDs, the building systems should be specifically designed and should present tailored load profiles (e.g., the long-term load forecast cannot be based on its

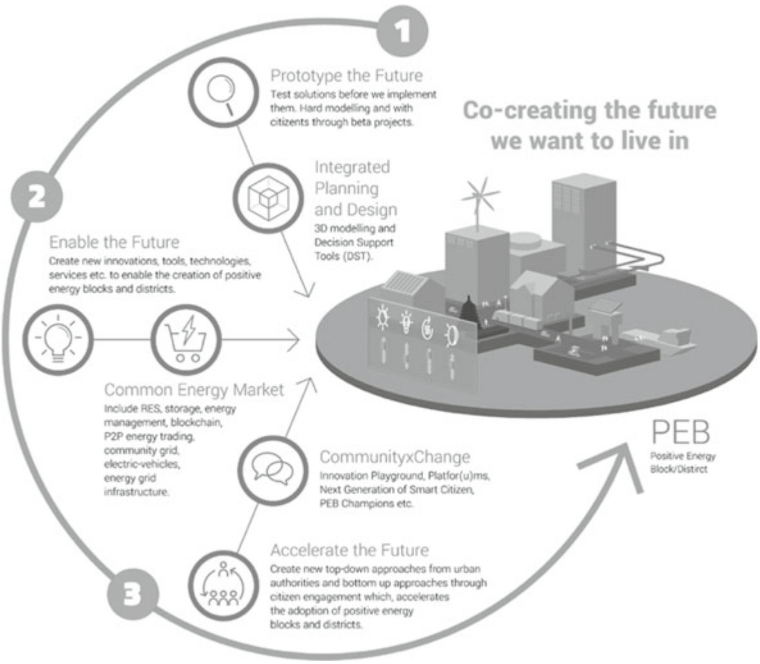

Fig. 44.2 +CityxChange integrative approach and framework for the development of positive energy blocks (Ahlers et al. 2020)

historic pattern anymore) that will enable a high penetration of carbon-free renewable sources such as wind and photovoltaics (PV) for the electricity demand as well as heat pumps, thermal waste, geothermal, solar thermal, etc. for heating and cooling. Additionally, district-scale buildings, should use 'energy cooperation' or 'energy pooling' to empower communities to own the locally produced renewable energy. Consequently, a building designed to be a functional unit of a PED must be built, or refurbished, according to the possibility of integrating a series of technical solutions, such as batteries, electric vehicles (EV), and grid-responsive control systems (Zhou et al. 2021). Equally, smart grids and digital tools for demand-side management such as smart meters, smart chargers, and Building Automation and Control Systems (BACSs) can facilitate flexibility in the PED energy system, which can help align energy demand with supply (Lyons 2019).

According to this innovative and sustainable urbanization concept (Fig. 44.3), the construction and renovation process should also be increasingly accompanied by digital solutions, such as building information modeling (BIM), 3D printing, digital twins, Internet of Things, or augmented reality. These innovative digital technologies help save costs and time and require suitable novel skills and the latest available software to be most effective.

Moreover, digitalization enables the uptake of smart energy services for building users of a PED, allowing the development of demand-side management strategies

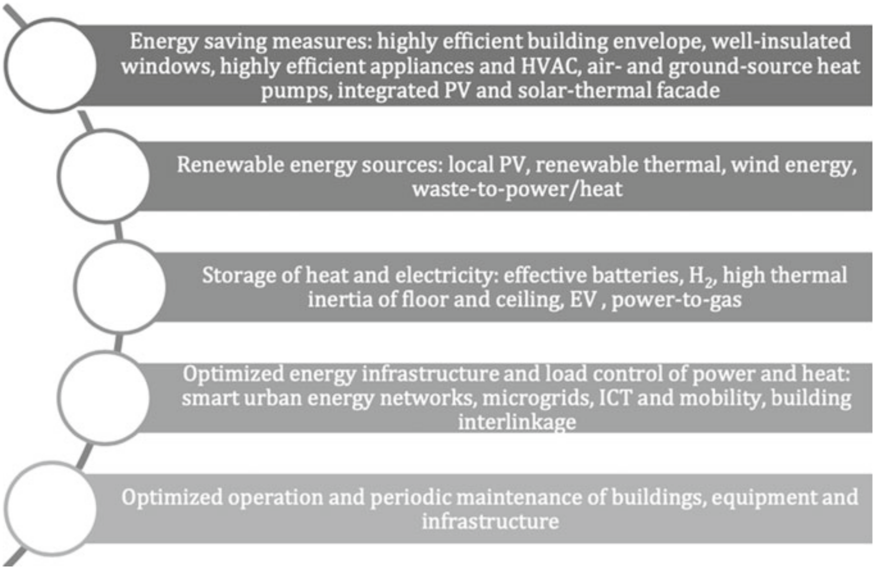

Fig. 44.3 Key research fields of technological innovations needed for deploying PED (EU Commission 2018)

to integrate flexible and decentralized renewable energy systems into its energy structure (Fig. 44.4).

Some interesting case studies of innovative technologies and system integration have been developed in numerous European Projects such as ZenN, Syn.ikia, Sharing Cities, MAtchUP. In all these examples the energy demand in the district cluster is low

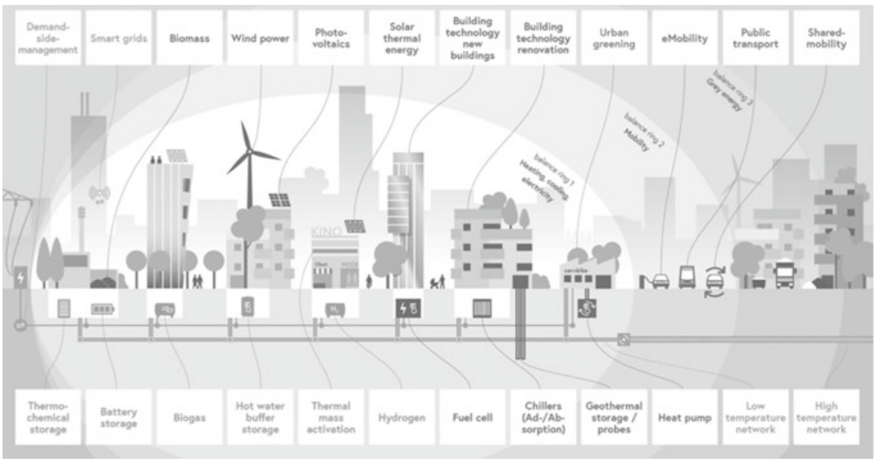

Fig. 44.4 Positive energy district model (BMVIT 2022)

and partly met by renewable energy self-produced within the neighborhood. Another measure applied to achieve the target PED is an enhanced envelope/insulation, followed by real-time measuring of consumption and heating controls reduction of the DHW supply temperature with heat recovery. Furthermore, energy management systems (Neighborhood/Building) and boiler upgrades are widely utilized. Regarding the RES, the technologies most utilized are Heat Pumps and PV. Finally, concerning the Energy storage solutions, EV, Vehicle to Grid (V2G), and Vehicle to Building (V2B) concepts, including smart charging stations implementation, are the major solution employed, followed by batteries and thermal storage (Castellanos and Oregi 2021).

44.4 Conclusion

Increasing evidence from science, governance, and practice show that climate change adaptation and mitigation and the decarbonization of our environment are of greatest urgency and should be targeted at the macro, urban, and district levels. Cities are consequently required to take an active role in adopting sustainable energy production and use for people and the environment (Saheb et al. 2018). It is now stepping up efforts towards city-wide transformation with the pioneering concept of PEDs, which builds on the paradigm of smart cities, supporting municipalities that make energy savings and provide it with a good and sustainable metabolism (Ruhlandt 2018). For achieving this relevant goal PEDs design should equally be considered powerful opportunities for users and stakeholders to promote equity and inclusion, favoring vulnerable communities where far too many people still struggle facing energy poverty (Jessel et al. 2019). At the same time, it will be necessary to develop innovative envelope and plant technologies capable of transforming existing urban districts into efficient and low-impact energy ecosystems.

Finally, the PED model requires a synergy between the management of social, economic, and technological aspects related to urban planning and building design.

Accordingly, among the next steps of the PED-EU-NET research, will be defining PED specific KPIs to develop effective integrated frameworks and guidelines for European Public Administrations, with the aim of implementing and realizing 100 PEDs in different European geographical and social contexts by 2025.

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