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Review

Positive Energy Districts Enabling Smart Energy Communities

Dimitrios Siakas [1], Harjinder Rahanu [2], Elli Georgiadou [2], Kerstin Siakas [3,4] and Georgios Lampropoulos [5,6,*]

[1] Sustainable Energy Systems Research Unit, Häme University of Applied Sciences, 13100 Hämeenlinna, Finland; dimi.siakas@hamk.fi
[2] Department of Computer Science, School of Science and Technology, Middlesex University, London NW4 4BT, UK; h.rahanu@mdx.ac.uk (H.R.); elli.georgiadou@gmail.com (E.G.)
[3] Department of Industrial Production, School of Technology and Innovations, University of Vaasa, 65200 Vaasa, Finland; ksiakas@gmail.com
[4] Department of Information and Electronic Engineering, School of Engineering, International Hellenic University, 57400 Thessaloniki, Greece
[5] Department of Applied Informatics, School of Information Sciences, University of Macedonia, 54636 Thessaloniki, Greece
[6] Department of Education, School of Education, University of Nicosia, 2417 Nicosia, Cyprus
* Correspondence: lamprop.geo@gmail.com

Abstract: Energy transitions concentrated on a neighborhood or district scale represent a fairly new area of focus at the European (EU) level, aiming to combat future global warming and to reduce anthropogenic greenhouse gas (GHG) emissions. In the EU energy transition policy agenda, positive energy districts (PEDs) refer to urban areas where more renewable/zero-emissions energy is produced annually than is consumed. PEDs have increasingly grown in recognition and significance, as a societal solution geared towards a low-carbon future. The relevant aims include the utilization of 100 PEDs by 2025 and alignment with the EU, which seeks to become a climate-neutral continent by 2050. However, this target raises questions regarding the means of achieving fast and consistent adoption across various socio-technical contexts. Defining the opportunities, challenges, and key issues to address short-term project timelines is vital to implementing fit-for-purpose solutions and bringing PEDs into the mainstream. Proactive knowledge sharing, adaptive learning, and collaboration across disciplines and sectors will bring know-how for understanding the requirements in different contexts. The need for practical approaches to facilitate PED implementation is crucial. This study aims to elucidate the opportunities for and barriers to successful PED design and implementation by compiling and synthesizing experiences from 61 PED projects, identifying key drivers, challenges, enablers, and ethical considerations. In addition, the authors present a framework, consisting of moral principles, which can help present the issues concerning the development and deployment of PED in an ethical context.

Keywords: positive energy districts; PED; smart communities; smart cities; PED drivers; PED challenges; technology; ethics

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1. Introduction

Global warming and the need to replace fossil fuels with renewable energy sources are bringing about a significant transformation in the energy domain. The energy transformation requires decentralized systems with small local generation units, concentrating on renewable energy production [1]. Technological advances enable small- and micro-scale residential renewable generation units to offer electricity in remote areas, meet increased

demand, and satisfy sustainability and regional self-sufficiency, as well as increasing energy awareness in society. According to this new approach, which uses small power generation units (e.g., photovoltaic (PV) units), consumers become prosumers who can generate and consume energy as a result of smart grids. By enabling peer-to-peer energy trading and sharing, prosumers can influence the peak loads, by, for example, engaging in demand-side management through load shifting and energy storage solutions. They can impact the balance between local supply and demand, which can significantly reduce PED energy costs. Additionally, it is possible to share the surplus energy with others, reducing or eliminating the need for negotiations with the grid and minimizing energy losses that are associated with long-distance transmissions.

The Sustainable Development Goals (SDGs) of the United Nations aim to address urgent environmental, social, and economic issues in a cohesive way [2]. The European Union (EU) is dedicated to achieving the SDGs through various actions and Research and Innovation (R&I) activities, with a view to attaining a sustainable future through modernizing the European economy and society. The EU Framework Program for R&I advances the transition to a sustainable future, with the goal of making Europe the first climate-neutral continent by 2050 [3]. Cities "*produce more than 60% of GHG emissions*" and "*consume 78% of the world's energy, more focus is placed on urban areas*" [4]. As a result, SDG11—"*Sustainable Cities and Communities*"—has gained increased attention through various initiatives targeted at improving sustainability at urban areas by improving social and economic conditions, upgrading urban services and infrastructure, and enhancing the appeal and competitiveness of cities and urban districts. The PED initiative also supports the Green Deal goals [5], the Renovation Wave [6], and the Mission on Carbon-Neutral and Smart Cities [7].

Several approaches and different SCC (Smart Cities and Communities) solutions, reflecting specific circumstances, exist with the aim of transforming a city into a smart city. Urban cities represent complex systems, including a multitude of interconnected dynamics, promising opportunities and complicated challenges. The use of Information and Communication Technology (ICT) infrastructure promotes an increased understanding of success factors for their deployment and roll-out. In 2016, the strategic targets of the EU commission regarding the priority "*Number 3, Create technologies and services for smart homes that provide smart solutions to energy consumers*" was signed by the EU commission with the following aims: (i) urban spaces should use secure, affordable and clean energy; (ii) smart transport services should be implemented; and (iii) low-emission and emission-free vehicles and smart tools and services should be used [8]. Smart transport services, in particular electric mobility (e-mobility), are gradually being integrated with PEDs with the aim of creating synergies that advance sustainable mobility and urban decarbonization. Electrical vehicles with vehicle-to-grid (V2G) capabilities can be used as an energy source for PEDs when needed and also help balance the grid. However, there are still challenges, such as the system's ability to recognize the vehicle users' habits and needs and adjust accordingly.

With regard to the EU 2050 aims, the concept of using positive energy districts (PED) for sustainable urban development was established in autumn 2018, including a target of 100 EU PEDs by 2025 [9]. The PED Program is a result of the European SET Plan and is being implemented by the transnational Joint Programming Initiative (JPI) Urban Europe [10]. PEDs, also known as energy-efficient neighborhoods and energy-positive neighborhoods (EPN), are system-level concepts characterized by the local management of energy sources. The PED locally stores surplus energy or exports it to the overlaid grid and buys energy from the grid when there is a shortage at the local level [11]. PEDs can be defined as "*energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus*

production of renewable energy. They require integration of different systems and infrastructures and 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" [12].

The PED *Target* is seen as the optimization of the three key functions of PEDs (energy flexibility, energy production, and energy efficiency) that aim to achieve an energy surplus and climate neutrality (see Figure 1).

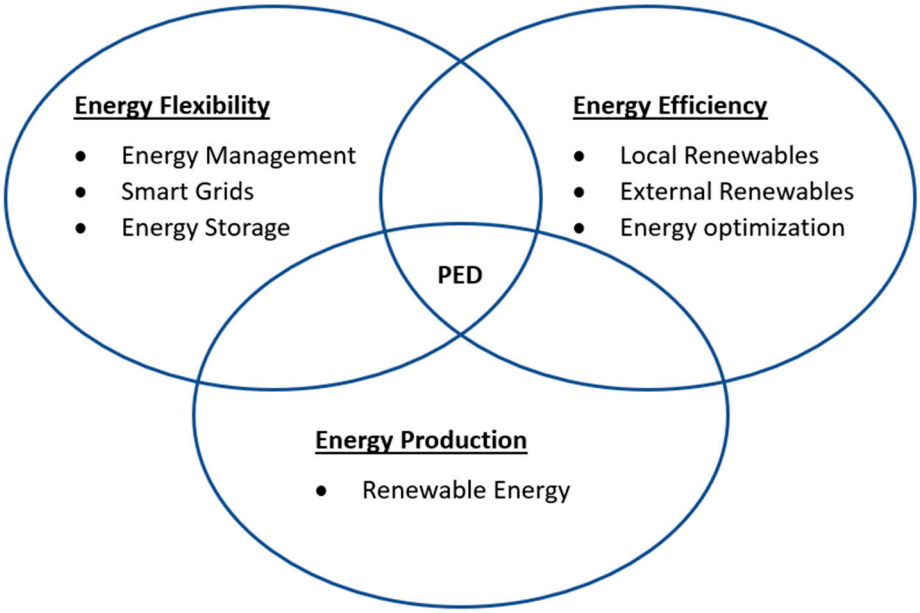

Figure 1. PED framework: three functions of a PED [8,10].

The PED *Guiding Principles* focus on quality of life, inclusivity, affordability, the eradication of energy poverty, resilience, sustainability, and energy supply security. Inclusivity and the eradication of energy poverty within PEDs are operationalized through stakeholder participation and engagement in design and practical interventions from the beginning. The explicit goals of PEDs are to improve affordability and prevent energy poverty by focusing on vulnerable groups and integrating energy justice frameworks. Practical measures include building retrofits, renewable energy integration, and the redistribution of surplus energy toward low-income households. Energy models with community ownership and new types of energy ownership within PEDs can empower vulnerable groups by decreasing energy expenses and promoting adequate energy behaviors. However, challenges such as lack of trust and awareness need to be addressed through community engagement and energy poverty minimization policy measures.

A number of PED *Enablers* can be identified, including governance frameworks and political vision, the integration of energy in urban planning, data management, information and communication technologies (ICT), and the active involvement of energy communities and governance, including citizens and other stakeholders; city administrations, real estate developers, and energy suppliers constitute potential enablers.

A smart energy management system (EMS) dynamically switches between local energy management and the energy imbalance market (a dynamic real-time energy supply market) so that the customer always has the most suitable energy options [13]. Energy flexibility refers to the capacity of a system to modify the production and/or the consumption of distributed energy [13]. A building's energy flexibility is its capacity to "*support the operation of the entire building energy system by adjusting the relationship between its energy demand and generation through specific operation strategies in accordance with local environmental conditions*

and user requirements" [13]. Similarly, when compared to fossil fuel vehicles, e-mobility reduces the carbon footprint of the PED. Studies have shown that, by using e-mobility, there is a potential 71% saving in carbon emissions [14]. An important aim of the PED approach is to increase energy flexibility. This can be achieved by maximizing self-consumption, as well as by reducing peak power demand through the use of energy management, smart micro grids, and battery storage. Local stakeholders, including citizens and residents, are motivated to engage in governance processes to contribute to the broader achievement of societal goals, such as encouraging collective responsibility and active involvement in sustainable initiatives. Energy efficiency includes renewable energy sources and energy optimization, with the aim of reducing energy consumption without negatively impacting the performance of a system.

The PED concept was based on earlier ideas of single nearly-zero-energy buildings (NZEB), extended with urban decarbonization and building energy sharing [9]. The primary aim of a PED is to ensure a dignified and high quality life for citizens by providing safety and security, while ensuring that the individual citizen feels free and satisfied as a member of a larger community [15]. The key aspects of successful PEDs involve energy generation, efficiency, and flexibility, and they require active and mutual interactions between energy generation and storage systems, as well as consumers.

The program regarding "*Positive Energy Districts and Neighborhoods*" was established in 2018 by "*Action 3.2 on Smart Cities and Communities of the European Strategic Energy Technology Plan*" [16]. Data regarding the success and challenges of existing PED have been collected by "JPI Urban Europe" [17].

Systems, infrastructures, and ICT systems, i.e., the technologies that underpin PEDs, have the potential for social impact. The creation of PED solutions has changed the environment in which such technologies are used. However, the design and utilization of these technologies raise questions about wrong and right. Hence, an analysis of the nature and social impact of technologies is required to rationally justify the formulation of policies for the ethical use of such technologies, as in PED solutions. A concrete example concerns data privacy and surveillance concerns due to the increased use of ICT and cyber/physical systems in PED energy management. Another example concerns unintentionally increased living costs due to expensive improvements in energy infrastructure, which may displace low-income residents. The fast deployment of PEDs, if not managed in a transparent and inclusive way, may jeopardize the marginalization of certain groups or the intensification of social inequalities. All these examples raise questions about social justice and fair access to benefits.

Based on the ethical study of the social impact of technologies, we can increase our understanding of the nature of the problems and suggest adequate solutions [18]. Through this process, justifiable policies can be developed to allow for the ethical development and deployment of PED solutions that are socially beneficial. This process enables the development of policies that are justifiable and promote the ethical development and deployment of PED solutions for the greater social good.

Although PED reviews studies can be found in the existing literature, most of them concentrate on specific PED characteristics. A research gap exists regarding a wide-ranging overview of opportunities and challenges. The focus of this study is to add a comprehensive broadened view on the concept of PEDs to the existing PED literature. Thus, this study contributes to the understanding of PEDs, as well as their success factors, barriers and interdependencies. Ethical considerations, an important factor often overlooked in existing PED literature, were identified as a significant research gap that this study also aims to address.

We examine the concept of PEDs and discuss the associated opportunities and challenges, drivers, success factors, and barriers in the utilization of a PED. We identify the

ethical concerns in their design, implementation, and exploitation and integrate a novel ethical framework.

2. Method

This critical literature review on PEDs' drivers, characteristics, success factors, and barriers involves exploring scientific publications in a systematic way, including conference proceedings and relevant, recent, credible and high-level academic journals.

Because of the broad and wide-ranging subject of this study, which affects a great variety of things, a critical literature review was conducted by carefully searching for suitable scientific articles in highly-regarded library repositories. The aims were to categorize, assess, and capture earlier research findings without bias. A systematic literature review is generally thought to be an accurate approach for gathering articles. However, it is not a suitable method for addressing broad subjects that require the wide-ranging collection of data [19]. This study aims to present an overview of the topic in order to increase comprehension of diverse aspects of PEDs. For this reason, a critical literature review/integrative literature review was adopted.

Following the guiding principles of Jesson and Lacey [20], specific keywords, such as "*characteristics*", "*drivers*", "*success factors*", "*barriers*", "*challenges*", were used in combination with "*positive energy district*" or "*PED*", revealing significant advancements such as "*smart communities*", "*smart cities*", "*renewable surplus energy*" and challenges including participation, commitment, operation, interoperability and security. The carefully chosen keywords directed the identification of suitable and noteworthy articles that are important for the aims of the article. For example, the theme of ethical considerations and challenges was noticed and identified, despite the importance of the subject, to be overlooked in technical PED literature. Hence, this research gap is addressed in this study by integrating an ethical framework.

This comprehensive critical literature review was carried out through a detailed exploration of scientific databases and library repositories, such as "*Web of Science*", "*Scopus*", "*ACM*", "*IEEE*", and "*Google Scholar*". This study strives to expand the current understanding of PEDs and the potential difficulties that may be a barrier for their successful implementation. It aims to contribute to future development and research in this important domain.

3. Experiences from 61 PED Projects

PEDs can positively influence the realization of sustainability in urban areas; hence, the number of PED-related developments is increasing. It should be noted that understanding strategies, experiences, and project features is pivotal to designing and developing effective PED programs.

The PED cases collected by JPI Urban Europe are summarized and presented in a PED booklet [21]. In this study, all the projects included in the JPI Urban Europe booklet were analyzed. Moreover, extensive scientific literature has been published on diverse PED experiences (see, e.g., [13,19,20,22–25]). However, since the concept of PED is relatively new, innovative, complex, and context specific, reflections on the past and future of urban sustainable development, including PED opportunities and PED challenges, are likely to provide incentives for supporting urban transition.

Experiences, thoughts, problem statements, worries and concerns faced by the 61 PED cases and summarized in the PED booklet [21] are uncovered, extracted, processed and grouped into 10 categories for easier perception and comprehension, as shown in Tables 1–10. The inclusion criteria for projects in this study were that the fields of success factors and challenges/barriers were completed. All other fields were examined, since

characteristics, drivers, success factors, challenges, and barriers were sometimes hidden within other text fields.

Table 1. Drivers of PED planning.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Drivers of PED planning	• "*Rapid growth of cities including demographic changes*"; • "*Changes in the business environment challenge the city development*"; • "*Limited existing local renewable energy resources*"; • "*Extending urban development (living environment, comfort, health) within qualitative housing*"; • "*Increased demands on resources and infrastructure, to be simultaneously developed toward sustainable and carbon neutral solutions*"; • "*Wide network of different stakeholders with different viewpoints and goals, conflicting stakeholder goals*"; • "*Cultural differences of partnering cities, replication difficulties*".	In addition to the EU and national incentives that have created an urge to develop PEDs, a significant trigger is the creation of smart ecosystems for utilizing renewable energy sources, reducing energy consumption, and improving the urban environment in cities and other urban environments. However, the concept of a PED is multidisciplinary, novel and contemporary, and the context and culture are different in every district, making replicability a challenge. This study aims to increase understanding of potential difficulties that may be a barrier for successful PED implementation.

Table 2. Stakeholder engagement.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Stakeholder engagement	• "Agreement needed by majority of residents in multi property private residential about" ○ "*The need of building retrofit intervention*"; ○ "*Which kind of energy efficiency interventions have to be implemented*". • "*Encouragement of local stakeholder, residents, citizens and other stakeholders (e.g., housing associations) businesses, Non-Governmental Organizations (NGO) participation, engagement and involvement*"; • "*Making citizens problem owners so that they can see the benefits instead of only looking at the direct costs*"; • "*Citizen engagement and promotion of the prosumer concept*"; • "*Empowerment of project partners*"; • "*Development of a joint mission*"; • "*Active, new and innovative co-creation and co-design models for stakeholder collaboration*"; • "*Choosing and co-designing the interventions involving the residents from the very beginning of the planning process by public measures*"; • "*Participation of the residents is central to active coexistence instead of an anonymous neighborhood*". • "*Incentives for combining living and working, attracting business, participatory processes and a variety of living realities, a socially sustainable and lively district*"; • "*Utilizing numerous public ground floors and open spaces for use by citizens for social engagement, workshops and urban gardening*".	The PED approach is end-user-oriented, meaning that the PED operations need to consider the needs and requirements of all the stakeholders. The main stakeholders are building occupants, building owners and citizens, because they either represent the main users of the premises and e-mobility or pay a considerable part of the investments in innovative and contemporary technologies. The agreement of all stakeholders, who usually have different experiences, viewpoints and incentives, may be quite difficult to achieve. The involvement and active engagement of stakeholders from the very beginning is of utmost importance for the success of a PED. In addition to the aim of being a community with positive renewable energy, a PED also aims to combine living and working by including social engagement to attain health, sustainability, inclusivity, quality of life, and the security of the energy supply. To attain the active engagement of stakeholders, it is vital to create a common PED vision and mission statement between all stakeholders.

Table 3. Governance.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Governance	• "*Advisory services to support residents' energy renovations and increased use of renewable energy*"; • "Legal and business consulting when needed"; • "*Environmental, Economic, Societal, Social, Community participation—behavioral influence*"; • "*Open governance structure and national and international communication*"; ○ "*Public commitment at government level*"; ○ "*Local administration commitment*"; ○ "*Stakeholders' involvement*". • "*Ownership at political level and top-level administration, key departments within municipality, project coordination/management*".	The prototyping, application, governance and management of energy communities within PEDs are challenging [26]. These communities, initiated by the EU, need to be transposed into member states' regulatory frameworks. The aims are to encourage authorized and legitimate collaboration between all stakeholders involved in the production, sharing, and use of locally produced renewable energy.

Table 4. Business models.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Business models	• "*Integrated planning from the beginning on urban planning, mobility, energy, environment*"; • "*Good understanding of the financial models necessary for the project*"; • "*Focus on cost efficiency and affordability of the implemented technologies*"; • "*Costs of PEDs: more than 70% of the costs of private residential buildings have been covered by residents (with the help of different financial mechanisms: tax credit, transfer of tax credit, loans, etc.)*". • "*Viable business models, investment, and risk sharing models that focus on adequate Return on Investment (ROI) for the private stakeholders involved*"; • "*Realization of collective self-consumption projects*"; • "*Reducing energy demand by optimized use of energy on the site, quality equipment related to energy consumption (office automation, household appliances, efficient kitchen appliances, central freezers and laundry rooms etc.) to limit consumption*"; • "*Buildings instrumented with digital energy meters allowing a good interpretation of the consumption by the users and encouraging the control of these*". • "*Creation of a roadmap*".	In order to carry out business, a successful, cost-effective and profitably business model based on the core strategy is needed. Adequate business models for developing successful PEDs are significant, but there is an absence of unified and consistent business models covering the needs of PEDs [23]. Regarding PEDs, the business model needs to include the set-up of renewable energy and energy storage [27]. The PEB business models differ depending on geographical conditions, which influence both technology choices and energy needs. Moreover, building traditions, socioeconomic conditions, legislation and building regulations vary in different countries. Based on the business model, a roadmap guiding the implementation process is fundamental.

Table 5. Identified barriers.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Identified challenges	• "*Political and financial*"; • "*Effective and innovative management of smart grids*"; • "*Physical/spatial constraints of continuity between adjacent buildings and Distributed Energy Resources (DER) available within the local energy system*"; • "*Regulative framework, regulatory barriers for test bed/piloting experimentation, necessary dispensations from national energy/grid/concession legislation*"; • "*Limited knowledge and understanding about ZEB ambitions, and embedded requirements are a low priority on the executing level (construction side)*"; • "*Time pressure, ongoing construction around the area, requires a decision about the connection of the PED to the technical infrastructure*"; • "*Uncertainty about the acceptance of the project by the authorities, the time pressure, and the assumed cost increases, heighten the risk for hindering project implementation*"; • "*Disagreement among the involved partners e.g., between the local and regional authorities on the evaluation of the project with regard to planning regulations could jeopardize the implementation of the project*"; • "*Knowledge transfer: The planning and design of a micro energy system requires a fast and up-to-date knowledge transfer within the field of legal/juridical questions and the application of an integrated planning approach that connects the different technological solutions*".	The PED reference framework [28] grouped the PED factors according to importance for the success of a PED [11,22]. According to the study, governance and social are the most important issues for successful PED implementation, followed by markets and technology. This study indicates that adequate governance is extremely important and that stakeholder engagement is of similar importance for the success of a PED; clearly, it is a social issue or maybe even a sociocultural issue. So, in this sense, the authors agree with the ranking of importance presented in the PED reference framework. External partners can be compared to market and technological solutions to technology. Enablers of PEDs, according to the PED reference framework [28], are: "*Political vision and governance framework, active involvement of problem owners and citizens, integration of energy and urban planning, ICT and data management*".

Table 6. External partners.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
External partners	• "*PED platform for innovation and opportunity to develop new business ideas, new business ventures*"; • "*New companies are created with the development of new products and solutions for energy distribution*"; • "*Initiatives for active, new and innovative co-creation models for stakeholder collaboration*"; • "*Pro-active and innovative external partners covering all crucial topics to realize PEDs*"; • "*Political level integrated planning (urban planning, planning of energy and mobility infrastructure)*"; • "*Initiatives for biodiversity, water and landscape*".	The PED stakeholders include representatives (in addition to end-users) from the state, prefecture, municipality, city, and other urban stakeholders, as well as innovative businesses with an interest in the PED process.

Table 7. Investment.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
Investment	• "*Feasibility studies*"; • "*Investment cost of buildings by typology*"; • "*Willingness from building/asset owners to invest*"; • "*Willingness of the investors to accept longer payback times for their investment and put additional effort into the planning and innovation process*". • "*Investments in renewable energy generation capacity*"; • "*Investigation of financial support from national innovation agencies and international funding bodies*"; • "*Implementation of a compatible economic model, limiting the use of public funding*"; • "*Integration of future users (tenants, owners, employees) needs to be developed. The aim is to optimize the user behavior respectively to minimize potential negative effects on the energy system. Future non-residential users are not yet known and their energy behavior (demand, synergy effects etc.) is difficult to plan*"; • "*The cooling of buildings through automation is a measure for climate adaptation creating long-term attractiveness for buyers and renters of the building*".	The concept of PEDs is gaining traction across Europe, with many projects underway to investigate their potential and challenges. PEDs are developing as an essential strategy in the transition toward sustainable urban energy systems. Diverse EU support programs have been developed based on a dedicated innovation strategy. Similarly, a number of EU countries already carry out research and innovation programs that focus on addressing PED-related challenges [28]. Adequate financial support is needed to overcome the initial challenges and to maintain long-term operations. In addition to EU, national and regional support, private homeowners and housing corporations need to invest considerably in order to reap the benefits of the investment; hence, good PED understanding is imperative.

Table 8. Technological solutions.

Entity	Extracted Texts from Report on 61 PEDs	Explanation

Technological solutions	• "*Decarbonizing the building heating/cooling and transportation system for reducing emissions*";
	• "*Different renewable energy facilities*";
	  ○ "*Solar thermal energy*";
	  ○ "*Local photovoltaics*";
	  ○ "*Geothermal energy*";
	  ○ "*Ground source heat utilization*";
	  ○ "*District heating and cooling (DHC)*";
	  ○ "*Heat pump systems*";
	  ○ "*Waste heat utilization*".
	  ○ "*Seasonal underground thermal energy storage*";
	  ○ "*Renewable materials*".
	• "*Technology piloting with focus on storage technologies and new digital services*";
	• "*Smart energy solutions*";
	• "*Technology integration*";
	• "*Energy demand side management, optimized self-consumption, energy storage and load management*";
	• "*Predictive and self-optimized energy use*".
		The integration of various energy systems and the deployment of smart technologies are essential for efficient energy management [29]. Effective energy management strategies are also needed to enhance renewable energy dispersion and cycling aging of battery storages [30]. Interdependencies between governance, technology, and market dynamics characterize PEDs. A holistic, cross-disciplinary and systematic understanding is crucial for managing complexities and urban challenges including microclimates and resource availability [31]. The replication and scalability of successful PED models across different urban contexts is challenging.

Table 9. PED creation process.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
PED creation process	• "*Activities in the area of energy, buildings, mobility, digitalization, communication, circular and sharing economy*"; • "*Slow procurement procedures*"; • "*Jobs creation during the construction of new facilities*"; • "*Deregulation of monopolies*"; • "*Possibilities for Person to Person (P2P) trading*"; • "*Regulatory, technical, energy related, upscaling and replication long planning processes (input on an early planning phase necessary)*"; • "*Investigation of energy legislation and for adapting to innovative market concepts, changes in regulation*"; • "*Living lab, exhibition, pilots and sandbox experimentation and testing (developed, demonstrated, evaluated and optimized), new PEB prototypes, setting up local regulatory sandboxes with some-several dispensations from national regulator*";	PED creation includes several challenges, such as governance, market dynamics, incentives, and social acceptance. These diverse factors should be addressed collectively to ensure successful PEDs [24]. The development of a comprehensive and consistent view among stakeholders is important for avoiding misunderstandings. PEDs support e-mobility, which is an integral part of renewable energy utilization and GHG emission reduction. PEDs necessitate cutting-edge energy flexibility technologies to manage mismatches between renewable energy generation and consumption. This comprises addressing reverse power flows and ensuring grid stability [32].

Table 10. PED results.

Entity	Extracted Texts from Report on 61 PEDs	Explanation
PED results	• "*High visibility of results*"; • "*Coordinating communication and dialogue with the international funding institutions; informing the government, parliament, local public administration, businesses and citizens on a regular basis*". • "*Scarce historic data and track records for PED cases*"; • "*Socio-economic research regarding acceptance and stakeholder participation*"; • "*Focus on utilizing all types of data (energy, weather, traffic etc.) for new applications and services and on making the PED real-time monitorable*"; • "*Advanced monitoring and control systems at building and at DHC level*"; • "*Impact of innovative interventions difficult to quantify*"; • "*Particularities of passive housing (building standard that is energy-efficient, comfortable, cost-efficient and environmentally friendly), associated measures and optimum comfort*".	Improving the buildings' energy efficiency is significant. Highly energy-efficient buildings are essential for PEDs to maintain a positive energy balance and support e-mobility. The integration of renewable energy systems in building renovations is tailored to address unique challenges in PEDs [33]. Smart cities and PEDs aim to improve urban sustainability and livability by combining data and sensors in the design of comprehensive governance scenarios [34]. The initial focus on buildings and energy grids now includes multiple urban sectors. Smart energy cities have developed to denote digitally mediated low-carbon cities. An integrated, holistic and multi-stakeholder perspective dominates recent debates [35].

A thematic analysis was used to categorize, extract and synthesize the texts from the JPI Urban Europe booklet. The data were thoroughly examined to identify common themes, common topics, ideas and patterns of meaning that came up repeatedly. The header "*Entity*" in the 10 tables describes the categorization of themes, including characteristics pivotal for the design and creation of a PED. It is followed by the "*extracted texts from report on*

61 PEDs". The texts are within quotes because they are given in [21] in the words of the project partners themselves. They were selected because of their representative expression regarding the entity. The third column, "*Explanation*", synthesizes the meaning of that particular entity.

All the entities relate to the long-term mission of the EU to become climate-neutral by 2050 [6], with the target of the creation of 100 PEDs by 2025 [9]. PEDs are a novel concept and their implementation is challenging [24]. This study tries to reveal opportunities and barriers for successful PED design and implementation by investigating the report on 61 existing PED projects [21] and taking into consideration the different development phases of a PED (energy planning, PED implementation, monitoring, strategic capacity-building, and stakeholder involvement) [25].

3.1. PED Opportunities

Studies have suggested that PEDs offer opportunities for decarbonization, energy poverty reduction, and urban energy system transformation through renewable energy integration, community energy control, and innovative financial and governance models. For example, it is suggested that the main drivers of energy flexibility are [13]:

(i) "The strategic and commercial interests of private sector parties for developing flexibility technologies for local grids";
(ii) "The urgency of congestion management in the city, and the project";
(iii) "Financing available for measures".

PEDs offer innovative models of energy ownership and generation that aim to reduce energy poverty (which impacts a substantial portion of the population), because households can improve their energy behavior and with increased awareness and the application of smart solutions reduces their energy cost. PEDs provide [36]:

- Environmental opportunities, presenting significant potential for reducing GHG emissions.
- Technological opportunities in the form of more resilient, adaptable and efficient energy system due to locally distributed power generation.
- Financial opportunities, including contemporary decentralized energy systems, benefits being shared between stakeholders, new job creation.
- Social opportunities, including enhanced social equity, reciprocity, and added collaborative efforts. Citizen participation is considered an opportunity; however, involving a third party to assist or take control may be easier for residents but may include other challenges.
- Political and legislative opportunities, in new forms of shared energy ownership.

3.2. PED Challenges

Studies have suggested that PEDs face challenges including the need for clear definitions, stakeholder engagement, and a lack of practical implementation experiences [37]. The PED concept is a complex phenomenon that, for its design and its implementation, requires a systemic, holistic, and integrated approach addressing technological complexity, environmental questions, socioeconomic issues, financial and regulatory aspects, governance and legal restrictions, difficulties in upscaling, and replicating successful models [13,38,39].

The obstacles for replicating successful PED models originate mainly in cultural differences among the different stakeholders/actors. Culture related to the various approaches to addressing common human challenges and can be broadly understood as the values, practices, and behaviors that emerge within national, organizational, team, and professional contexts [40–42]. Today, stakeholders/actors are becoming more team oriented and apparently culturally more convergent, due to increased reliance on ICTs and a mutually

established way of conducting business. However, the core values and interests of different societies often show significant divergence. Hence, business models and governance structures tend to be different in different countries, and even in different municipalities. Incentives for social acceptance are understood and applied differently. Even knowledge sharing and decision-making take place in a different manner in hierarchical top-down societies compared to flattered democratic countries. These obstacles are all context-specific, making standardized solutions difficult to apply across different cities or districts.

To develop context-sensitive solutions and easily perceived and apprehended roadmaps, which consider regulatory frameworks, local conditions, and community needs, the integration of multi-disciplinary expertise with diverse perspectives is required, as well as a systemic, holistic integrated approach enabling adaptive strategies. Knowledge sharing and iterative learning need to be emphasized for increasing shared understanding across sectors and disciplines, which, together with the use of contemporary tools and data-driven processes, support decision making and enable coordinated action and the management of complexity. The coordination of actors is crucial. Knowledge sharing opportunities and listening to the voices of stakeholders/actors are imperative, together with persistence, to overcoming socio-cultural obstacles. In the long run, this approach will enable improved PED scalability, replicability, and sustainability, as well as ensuring that technical innovations are aligned with efficient governance, social acceptance, and economic viability.

PED challenges can be divided into the following categories [36]:

- *Technological challenges* surrounding the infrastructure and technology available for a PED. The PED energy system is characterized by various renewable energy provisions, flexibility, and high energy efficiency [25]. Due to the novelty of PEDs, there is limited experience regarding how to manage reciprocal energy streams from PV generation into the energy system. The availability of injection points in the electrical grid may become a barrier as the increased integration of renewables could result in grid congestion, hindering the growth of clean energy infrastructure [13].
- *Financial challenges* associated with the establishment of PEDs include the initial investment required for setup and the potential for rising grid costs due to the increasing number of both individual and collective prosumers. The sustainability and viability of the business model behind PEDs can be hindered by high upfront costs, a lack of available capital financing, and insufficient expertise, which, in turn, could prevent homeowners from investing in these systems. A significant barrier for fully utilizing PEDs is the low compensation offered for surplus energy sold back to the grid from diverse forms of prosumer relationships. Peak consumption and energy storage solutions managed by smart devices are at the core of PEDs. By definition, PED design focuses on generating excess energy. The PED built environment includes a network of related buildings, energy facilities, power plants, and energy and mobility infrastructure, as well as storage facilities with high capital expenditure (CapEx). The governance structure and stakeholder engagement also add to the financial burden.
- *Social challenges* include stakeholder opinions, social inclusivity and affordability for residents, opportunities for social participation, employment, and opportunities for business, as well as the issue of energy poverty [37,43]. Change agents, opinion leaders, citizens and local stakeholders are key elements in creating a successful PED. The foundation of common and shared vision and values is a critical step for ensuring stakeholder engagement [25]. There is a lack of knowledge and awareness regarding PED opportunities connected to the creation of PEDs. Establishing trust through early and ongoing engagement and ensuring open and transparent communication with citizens are essential for equal participation and changing deep-rooted patterns of energy consumption behaviors. Common shared values, visions, and goals, compre-

hensive definitions, and well-articulated and communicated roadmaps are important for avoiding ambiguity and promoting a feeling of shared purpose. Frequent updates and open forums for knowledge sharing enable mutual understanding and diminish change resistance. Targeted training and easily accessible platforms for knowledge sharing and co-creation enable stakeholders to learn and adopt best practices. Trust can be further strengthened by addressing barriers including a lack of awareness, energy vulnerability, and administrative complexity through visible commitment and support from policymakers.

- *Political, legislative and regulatory challenges*. Legislative challenges exist and there is a clear need for a supportive legal framework. Low-carbon energy systems utilized by smart technology and innovations are considered to be people-centered because they account for energy poverty and other fairness-related matters [44]. However, the costs of implementing renewable-energy technology that is energy efficient is likely to lead to new energy systems that eliminate people who are faced with energy poverty [45]. Legal frameworks and national laws are significant in either enabling or hindering PED development. The alignment of national legal frameworks with European and international sustainability goals is a cornerstone in the successful utilization of PEDs. For example, Italy is a pioneering country in terms of embedding the European Directives regarding renewable energy communities in its regulatory framework [26]. A governance model has been formalized to empower energy community members by outlining a framework that allows organizations and citizens to collaborate in producing, sharing, and managing locally generated energy, thus supporting energy transition goals and climate neutrality. The framework can be used to plan the adequate implementation of a renewable energy community according to Italian regulations. This has allowed Italy to insert this type of innovative model into its national law, enabling new prospects for sustainable urban development and social inclusion. On the contrary, in countries with national laws that have not yet adapted to supporting energy sharing, community participation, or decentralized energy management, PED development may be significantly hindered by regulatory uncertainty, administrative barriers, and a lack of incentives.
- *Environmental challenges*. The evaluation of environmental impacts at the district level requires a standardized, reproducible, and transparent method [43]. The absence of a common assessment methodology has given rise to attempts using multiple resilience indicators [46].
- *Business model challenges*. Economically viable business models. The European Commission introduced two new legal concepts, "*citizen energy communities (CEC)*" and the "*renewable energy communities (REC)*" [28]. The CEC can become a distribution system where no operator network charges or tariffs need to be added to shared electricity flows. In order to utilize such possibilities, the concepts of CEC and REC need to be implemented into national legislations.

A holistic perspective is needed to create successful PED projects, because they integrate a variety of diverse entities as described in Tables 1–10. These entities are intertwined with each other, creating a complexity that may hamper successful PED implementation. For example, PED governance challenges, such as a lack of practical experience and established protocols (due to the novelty of the concept), unclear roles and responsibilities, administrative complexity, and the miscoordination of stakeholders, create difficulties in the decision-making process and the coordination of the wide range of involved actors, undermining the development of viable business models. Managing a wide network of diverse stakeholders (public, private, citizens, research) requires a clear understanding of the positions and goals of each party. Misaligned interests can lead to conflicts and

project setbacks. Moreover, the insufficient involvement of policymakers, local communities, and industry result in lack of shared vision and a shared culture, which leads to limited knowledge sharing, little generation of intensives for the engagement of citizens and occupants, and potential resistance to change. These gaps in engagement intensify uncertainties regarding business models, limitations regarding financing, and vague value propositions. Without a shared vision, the priorities of different stakeholders will create challenges for designing sustainable and viable business models. A combination of socio-cultural, technical, economic, environmental, political, legal, ethical and demographic considerations [39] is needed to address all challenges. Additionally, tailored strategies that consider local preconditions and contexts are needed.

Effective PED governance requires integrated, cross-disciplinary, and cross-sectoral collaboration, political commitment, and clear roadmaps and platforms for stakeholder engagement and knowledge sharing.

4. PEDs and Ethical Concerns

For individuals to become responsible computer professionals, they need to be consciously aware of their broader societal responsibilities in their everyday practice. Six traditional moral and ethical concepts are presented to permit computer professionals to be aware of the ethical and moral concerns over the design, implementation, and deployment of ICT systems [47]: "*Quality of Life, Use of Power, Risks and Reliability, Property Rights, Privacy, and Equity and Access*", as analyzed in Table 11.

Table 11. Traditional moral and ethical concepts.

Concept	Commentary
Quality of Life	In the development and implementation of technology, stakeholders must assess the societal impact of the deployment of a technology on the quality of life for each citizen. Pertinent questions need to be asked, such as "*Is faster, better, more, always an increase in quality of life for users of technology?*" and "*Do designers', decision makers', users' conceptions of quality of life correspond?*" [44].
Use of Power	Power is endowed to decision makers by the esoteric knowledge and skills they possess. Therefore, each decision concerning design and deployment for that technology is an exercise of power. It must be understood that, in the context of any design and implementation, there is a power dynamic between the powerful and the less powerful, which must be understood.
Risks and Reliability	Technology has become ubiquitous and spread its tentacles to every part of our personal lives. The reliability of all technologies, which are used by consumers, users, and the public is of the utmost importance. Stakeholders must be informed about the foreseeable risks, which are associated with the use of technology. Ethical choices will always be invoked in the compromises in design and implementation for life-critical systems.
Property Rights	In the development and deployment of technology, it is important to understand both intellectual and physical property rights. Ideas of ownership must be carefully considered to ensure that other traditional moral and ethical concerns, such as the use of power and equity and access, are not compromised.
Privacy	Privacy expectations differ among stakeholders and need to be considered in the design of technologies and systems. Likewise, the converse principle of the right to know is of paramount importance in stakeholders' opinions, enabling public dialogue, in the process of development and deployment of technologies.
Equity and Access	Modern technology has created a divide between those who have access to it and those who do not. Decision making concerning the development and deployment of technologies must be built around painstaking ethical reasoning about issues of equity and access in contemporary society.

It is argued that these traditional ethical and moral aspects can act as the main principles that guide the actions/decision making of stakeholders, such as: political-level and top-level administration, key departments within municipalities, project coordination/management, external partners, businesses/companies, designers and developers, financial investors, etc. Table 11 present these six moral and ethical concepts, alongside respective commentaries. PED challenges, highlighted in Section 3.2, are understood and resolved via the consideration of these six traditional ethical and moral concepts, listed in Table 11. Then and only then can we confidently state that the resolutions that have been arrived at are morally justifiable. Table 12 shows a detailed analysis of key challenges and enablers identified through the examination of the 61 cases.

Table 12. Mapping of PED challenges and enablers to moral and ethical concepts.

Concept	PED Challenges and Enablers
Quality of Life	**Improved Comfort and Health:** designing for optimal thermal comfort, energy efficiency, and good air quality directly enhances living conditions. **Better functionality and accessibility:** planning for mixed-use districts with short distances to amenities such as schools, shops, and public spaces, together with inclusive and barrier-free design, directly improves daily convenience, quality of life and social equity for residents. The PED approach considers the well-being of both people and local ecosystems, integrating local knowledge and capabilities, and adopting degrowth policies (i.e., the idea that economies can take care of themselves, their citizens and the planet by becoming more sustainable) and circularity (a concept of resource production and consumption emphasizing sharing, recycling, reusing, repairing, and refurbishing existing products and materials as long as possible). The PED quality of life approach aims to create PEDs that are not only energy-positive but also socially just and supportive of residents' overall well-being [48]. **Community empowerment:** "*is a fundamental idea in health promotion that may assist communities in defining priorities, making choices, developing strategies and executing them to improve health and minimize inequalities in health*" [49].
Use of Power	**Energy justice:** "*all individuals, across all areas, have safe, affordable and sustainable energy that is, essentially, socially just*" [50]. The political economy of the actors involved is shaped by incumbents who stand to either benefit or be negatively affected by energy transition processes. Additionally, it involves the necessary support for communities and businesses undergoing socio-technical changes [50]. PED principles of inclusivity and affordability encourage an emphasis on justice [44]. **Inclusive governance** is promoted by the PED approach. It is a decision-making system, where all stakeholders, regardless of their identity, background, or socioeconomic status, have a saying in shaping laws, policies, and institutional practices.
Risks and Reliability	**The exclusion of low-income residents** and renters due to **green gentrification** (providing green features increases local property values and may lead to the displacement of original, usually low-income residents). **Increasing digital and energy divides:** the use of PEDs might create digital and energy divides; hence, their adoption should be carefully designed. **Reliability concerns** regarding the changeability of renewable energy sources, seasonal mismatches between energy supply and demand, and the requirements for grid integration and energy storage solutions to safeguard constant supply during periods of low energy generation or peak demand. **Outdated infrastructure, social acceptance and regulatory barriers** increase the risk of adequate coordinated governance, technological innovation, and community engagement **Regulatory and Legal Barriers:** Complex national energy/grid/concession legislation, slow public administrative procedures, and the need for regulatory dispensations can delay or impede project progress. This friction slows down the delivery of innovative solutions that enhance urban living. **Financial hurdles and unproven business models:** high financial commitments, difficulty in securing funding for innovative actions that have not demonstrated effectiveness, and challenges for building owners to find profitable investment models can stall projects. This directly impacts the feasibility of implementing energy-efficient upgrades and can increase costs for residents if not managed effectively. **Rapid scaling and replication** without careful planning may undermine intended benefits by moving environmental problems elsewhere, intensifying social inequalities and provoking community judgement.

Table 12. *Cont.*

Concept	PED Challenges and Enablers
Property Rights	PEDs utilize smart grids, shared infrastructure, and distributed energy resources, giving rise to questions about ownership, access, and benefit sharing and control, comprising a complex interaction between energy governance, technological innovation, and legal issues. The relationship between private, public, and shared infrastructures, as well as building integrated renewable energy systems, raises questions about the rights of tenants related to landlords. A tenant may not have the right to install a PV system on the roof. New business models where the city's energy company rents out solar panels to customers, and the produced energy is credited to their electricity bills, were found to enable effective participation in local power production without direct ownership of the asset. Prosumers need to have the legal right to sell energy to the grid or on a peer-to-peer basis. Local regulations, such as building codes, zoning laws (rules regulating land usage within a municipality), and environmental regulations need to enable PED technologies.
Privacy	**Privacy** in PEDs is important because of the need for numerous actors to access, manage, and share sensitive data at the PED level, often without established governance structures. There are questions regarding who owns the data collected, and who has access to data that may be decisive for system optimization, billing, and behavior change. A system where only authorized actors are allowed to read or modify data is needed to provide security and privacy protections. In this study, 1 of the 61 projects collected extensive data regarding the energy information of the buildings to be used in the open-source Energy and Climate Atlas, integrated with a 3D City Model. This may be a matter of privacy.
Equity & Access	**Equity access:** regarding social equity, PED aims to (i) safeguard affordable energy services for all, such as low-income households; (ii) include local communities, particularly underrepresented groups, in planning and decision-making for co-creation to reflect real needs; and (iii) ensure all occupants have access to PED benefits, such as energy savings, improved health outcomes, digital inclusion, green spaces, and local job creation. **Energy poverty/vulnerability and affordable energy:** when implemented in existing or historic districts, PEDs can reduce household energy needs through building retrofits and local renewable energy generation. This, in turn, can help ease energy poverty by reducing energy costs and improving living conditions for low-income occupants. **Social inclusion:** PEDs engage in distributive justice (the socially just allocation of resources, goods, and opportunity in a society) and recognition justice (social justice that emphasizes the recognition of human dignity), as well as procedural fairness, trust-building, and the integration of local capabilities and experiences throughout the PED lifecycle [48]. Effective social innovation, including stakeholder interaction, citizen involvement and capacity building, enhance the uptake and long-term success of PEDs.

5. Discussion

The aims of PEDs are to annually produce more energy than they consume by integrating renewable energy sources, energy-efficient technologies, energy storage, and smart systems. These outcomes can contribute significantly to achieving smart and sustainable development [41]. Achieving energy self-sufficiency and reducing carbon emissions through the integration of renewable energy systems, energy-efficient building and neighborhood designs, and advanced modeling techniques contribute to the EU 2050 goals [3], the United Nations SDGs [2], the EU Green Deal [5], the Mission on Carbon-Neutral and Smart Cities [6], and the Renovation Wave [7]. As a result, several recent studies have highlighted the significance of PEDs and their vital role in achieving sustainable development [23,51–55].

PEDs represent solutions for sustainable urban development and climate neutrality. PEDs enable the energy transition toward renewable energy sources and smart infrastructures by utilizing different ICT tools to analyze data to meet efficiency, sustainability, productivity and safety objectives.

The cornerstones of PEDs are energy efficiency and flexibility and the production of energy in a distributed manner from renewable sources. A high level of energy efficiency ensures that less energy is used to provide the same amount of output from a service, such as heating, cooling and, lighting. Energy flexibility aims to reduce the peak power

demand and increase self-consumption by introducing smart grids, adopting optimal energy management processes, and leveraging battery storage solutions.

PEDs offer opportunities for urban decarbonization, inclusivity and energy poverty reduction, stakeholder collaboration, innovative governance, and sustainable energy transitions through renewable energy integration. It is an innovative process that is crucial for the transition toward climate-neutral European cities.

PEDs face challenges, such as the need for clear definitions, supportive policies, viable business models, innovative technology integration, stakeholder cooperation, and practical implementation, requiring comprehensive planning, addressing socio-economic and contextual factors, and holistic approaches and innovative solutions to achieve sustainable urban environments. The challenges of replication and widespread adoption have been emphasized because every context is different, requiring fit-for-purpose solutions for mainstreaming PEDs.

6. Conclusions

PEDs are a promising means of achieving urban decarbonization and improved quality of life. This is attempted by producing and storing an excess of renewable energy in a neighborhood through the integration of renewable energy sources and systems, enhancing energy efficiency and fostering collaboration among citizens, residents and other stakeholders, while addressing challenges such as energy flexibility, socio-economic factors, and climatic conditions to support sustainable urban development. The success factors identified include early and broad stakeholder involvement, interdisciplinary planning, and enabling policies and financing instruments to support the innovation, scaling and replication of PEDs in diverse urban settings. However, replication is found to be difficult because of different climates and technological and sociocultural stakeholder contexts.

The successful implementation of PEDs relies on early and broad stakeholder involvement, interdisciplinary collaboration, and context-sensitive planning to address local needs and avoid unintended consequences such as gentrification or inequality. Positive energy districts (PEDs) require a holistic approach integrating economic, environmental, and social aspects, with stakeholders playing a crucial role in designing and implementing them effectively. Beyond the technical systems and the performance of buildings and e-mobility, residents and citizens remain the major players. Sensitization meetings acknowledging and emphasizing good practices are crucial for building trust, achieving engagement and avoiding misconceptions.

This study aimed to reveal the opportunities and barriers for successful PED design and implementation by compiling and synthesizing experiences from 61 PED projects, identifying key drivers, challenges, enablers, and ethical considerations that were categorized according to 10 entities, which are intertwined with each other. Thus, this study contributes to the understanding of the concept of PED, as well as its success factors, barriers and interdependencies. Ethical considerations, an important factor often overlooked in existing PED literature, were identified as a significant research gap that we also aimed to address by identifying the ethical concerns in PED design, implementation and exploitation. A novel ethical framework was integrated and the key challenges and enablers identified in the 61 cases were mapped to the six ethical principles. This concretely demonstrates how ethical considerations manifest in real PED projects and how the framework can guide resolutions. The presentation of the six traditional moral and ethical concepts permits good moral practices to be developed in the design and deployment of PEDs.

This study identified PED drivers, characteristics, success factors, challenges and barriers by analyzing the JPI Urban Europe booklet [21]. Further work will include the analysis of more PED projects, using the interactive PED-EU-NET [56] database; this

database provides an overview of various PED projects. The analysis will concentrate on sociocultural, technological, economic, environmental, political, legal, ethical, and demographic (STEEPLED) factors [39], will adopt a systematic review approach, and will also involve a formal quality assessment of the related projects.

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References

1. de São José, D.; Faria, P.; Vale, Z. Smart Energy Community: A Systematic Review with Metanalysis. *Energy Strategy Rev.* **2021**, *36*, 100678. [CrossRef]
2. THE 17 GOALS | Sustainable Development. Available online: https://sdgs.un.org/goals (accessed on 3 March 2025).
3. European Commission. 2050 Long-Term Strategy. Available online: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en (accessed on 23 January 2025).
4. United Nations Generating Power. Available online: https://www.un.org/en/climatechange/climate-solutions/cities-pollution (accessed on 30 March 2025).
5. European Commission. The European Green Deal. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 1 April 2025).
6. European Commission. Climate-Neutral and Smart Cities. Available online: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en (accessed on 1 April 2025).
7. European Commision. Renovation Wave. Available online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en (accessed on 1 April 2025).
8. Gollner, C.; Europe Toward Positive Energy Districts: A Compilation of Projects Toward Sustainable Urbanization and the Energy Transition. Urban Europe. Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2020/06/PED-Booklet-Update-Feb-2020_2.pdf (accessed on 1 April 2025).
9. European Commision. Positive Energy Districts. Available online: https://setis.ec.europa.eu/working-groups/positive-energy-districts_en (accessed on 23 January 2025).
10. Transforming Citities through Positive Energy District. A Typology Framework for Positive Energy Districts. 2024. Available online: https://trans-ped.eu/wp-content/uploads/2024/01/Transped_A-Typology-Framework-for-Positive-Energy-Districts.pdf (accessed on 25 January 2025).
11. Soutullo, S.; Giancola, E.; Sanchez, M.N.; Ferrer Tevar, J.A.; García, D.; Suárez López, M.J.; Prieto, J.-I.; Antuña Yudego, E.; Carús Candás, J.; Fernández, M.Á.; et al. Methodology for Quantifying the Energy Saving Potentials Combining Building Retrofitting, Solar Thermal Energy and Geothermal Resources. *Energies* **2020**, *2020*, 5970. [CrossRef]
12. Monti, A.; Pesch, D.; Ellis, K.; Mancarella, P. (Eds.) *Energy Positive Neighborhoods and Smart Energy Districts: Methods, Tools, and Experiences from the Field*, 1st ed.; Academic Press: Cambridge, MA, USA, 2016.
13. Ntafalias, A.; Papadopoulos, P.; van Wees, M.; Šijačić, D.; Shafqat, O.; Hukkalainen, M.; Kantorovitch, J.; Lage, M. The Benefits of Positive Energy Districts: Introducing Additionality Assessment in Évora, Amsterdam and Espoo. *Designs* **2024**, *8*, 94. [CrossRef]
14. Castillo-Calzadilla, T.; Alonso-Vicario, A.; Borges, C.E.; Martin, C. E-Mobility in Positive Energy Districts. *Buildings* **2022**, *12*, 264. [CrossRef]
15. Annunziato, M.; Maestosi, P. Toward a European Vision for the Smart Cities to Come. *TECHNE-J. Technol. Archit. Environ.* **2018**, 12–15. [CrossRef]
16. Urban Europe. SET-Plan Action n3.2 Implementation Plan. Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf (accessed on 25 January 2025).

17. Positive Energy Districts (PED). Available online: https://jpi-urbaneurope.eu/ped/ (accessed on 27 January 2025).
18. Johnson, D.G.; Nissenbaum, H. *Computers, Ethics and Social Values*, 1st ed.; Pearson: Englewood Cliffs, NJ, USA, 1995; ISBN 978-0-13-103110-4.
19. Snyder, H. Literature Review as a Research Methodology: An Overview and Guidelines. *J. Bus. Res.* **2019**, *104*, 333–339. [CrossRef]
20. Jesson, J.; Lacey, F. How to Do (or Not to Do) a Critical Literature Review. *Pharm. Educ.* **2006**, *6*, 139–148. [CrossRef]
21. Gollner, C.; Hinterberger, R.; Noll, M.; Meyer, S.; Schwarz, H.-G. Booklet of Positive Energy Districts in Europe. Urban Europe: 2019. Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2019/04/Booklet-of-PEDs_JPI-UE_v5_NO-ADD.pdf (accessed on 27 January 2025).
22. Bossi, S.; Gollner, C.; Theierling, S. Toward 100 Positive Energy Districts in Europe: Preliminary Data Analysis of 61 European Cases. *Energies* **2020**, *13*, 6083. [CrossRef]
23. Zhang, X.; Penaka, S.R.; Giriraj, S.; Sánchez, M.N.; Civiero, P.; Vandevyvere, H.H.B. Characterizing Positive Energy District (Ped) through a Preliminary Review of 60 Existing Projects in Europe. *Buildings* **2021**, *11*, 318. [CrossRef]
24. Krangsås, S.G.; Steemers, K.; Konstantinou, T.; Soutullo, S.; Liu, M.; Giancola, E.; Prebreza, B.; Ashrafian, T.; Murauskaitė, L.; Maas, N. Positive Energy Districts: Identifying Challenges and Interdependencies. *Sustainability* **2021**, *13*, 10551. [CrossRef]
25. Sareen, S.; Albert-Seifried, V.; Aelenei, L.; Reda, F.; Etminan, G.; Andreucci, M.-B.; Kuzmic, M.; Maas, N.; Seco, O.; Civiero, P.; et al. Ten Questions Concerning Positive Energy Districts. *Build. Environ.* **2022**, *216*, 109017. [CrossRef]
26. Trevisan, R.; Ghiani, E.; Pilo, F. Renewable Energy Communities in Positive Energy Districts: A Governance and Realisation Framework in Compliance with the Italian Regulation. *Smart Cities* **2023**, *6*, 563–585. [CrossRef]
27. Ala-Juusela, M.; Tuerk, A. Business Models for Rolling out Positive Energy Buildings. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *1122*, 012060. [CrossRef]
28. Urban Europe. Reference Framework for Positive Energy Districts and Neighbourhoods (White Paper). Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2020/04/White-Paper-PED-Framework-Definition-2020323-final.pdf (accessed on 31 March 2025).
29. Ochs, F.; Breuss, S.; Venturi, E.; Magni, M.; Dermentzis, G. Toward Positive Energy Districts: Innsbruck, "Campagne Areal". *Int. Sustain. Energy Conf.-Proc.* **2024**, *1*. [CrossRef]
30. Zhou, Y.; Cao, S.; Hensen, J.L.M. An Energy Paradigm Transition Framework from Negative toward Positive District Energy Sharing Networks—Battery Cycling Aging, Advanced Battery Management Strategies, Flexible Vehicles-to-Buildings Interactions, Uncertainty and Sensitivity Analysis. *Appl. Energy* **2021**, *288*, 116606. [CrossRef]
31. Uspenskaia, D.; Specht, K.; Kondziella, H.; Bruckner, T. Challenges and Barriers for Net?Zero/Positive Energy Buildings and Districts—Empirical Evidence from the Smart City Project SPARCS. *Buildings* **2021**, *11*, 78. [CrossRef]
32. Sassenou, L.-N.; Olivieri, L.; Olivieri, F. Challenges for Positive Energy Districts Deployment: A Systematic Review. *Renew. Sustain. Energy Rev.* **2024**, *191*, 114152. [CrossRef]
33. 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]
34. Clerici Maestosi, P. Harmonizing Urban Innovation: Exploring the Nexus between Smart Cities and Positive Energy Districts. *Energies* **2024**, *17*, 3422. [CrossRef]
35. Clerici Maestosi, P. Smart Cities and Positive Energy Districts: Urban Perspectives in 2021. *Energies* **2022**, *15*, 2168. [CrossRef]
36. Hearn, A.X.; Castaño-Rosa, R. Toward a Just Energy Transition, Barriers and Opportunities for Positive Energy District Creation in Spain. *Sustainability* **2021**, *13*, 8698. [CrossRef]
37. Kozlowska, A.; Guarino, F.; Volpe, R.; Bisello, A.; Gabaldòn, A.; Rezaei, A.; Albert-Seifried, V.; Alpagut, B.; Vandevyvere, H.; Reda, F.; et al. Positive Energy Districts: Fundamentals, Assessment Methodologies, Modeling and Research Gaps. *Energies* **2024**, *17*, 4425. [CrossRef]
38. Guarino, F.; Bisello, A.; Frieden, D.; Bastos, J.; Brunetti, A.; Cellura, M.; Ferraro, M.; Fichera, A.; Giancola, E.; Haase, M.; et al. State of the Art on Sustainability Assessment of Positive Energy Districts: Methodologies, Indicators and Future Perspectives. In *Proceedings of the Sustainability in Energy and Buildings 2021*; Littlewood, J.R., Howlett, R.J., Jain, L.C., Eds.; Springer Nature: Singapore, 2022; pp. 479–492.
39. Siakas, D.; Lampropoulos, G.; Rahanu, H.; Siakas, K.; Georgiadou, E.; Ross, M. Improvement of Process and Outcomes Through a STEEPLED Analysis of System Failures. In *Proceedings of the Systems, Software and Services Process Improvement*; Yilmaz, M., Clarke, P., Riel, A., Messnarz, R., Eds.; Springer Nature: Cham, Switzerland, 2023; pp. 193–206.
40. Siakas, K.; Georgiadou, E.; Rahanu, H.; Siakas, E.; Meggoudis, N.; Siakas, D. Overcoming Obstacles in Global Requirements Elicitation: A Multicultural Perspective. *J. Softw. Eng. Res. Dev.* **2024**, *12*, 6:1–6:27. [CrossRef]
41. Siakas, K.; Siakas, D. Cultural and Organisational Diversity Evaluation (CODE): A Tool for Improving Global Transactions. *Strateg. Outsourcing Int. J.* **2015**, *8*, 206–228. [CrossRef]

42. Siakas, K.; Georgiadou, E.; Siakas, D. Knowledge Sharing in Distributed Teams: Influence of National and Organizational Culture. In *Entrepreneurship, Collaboration, and Innovation in the Modern Business Era*; IGI Global Scientific Publishing: Hershey, PA, USA, 2018; pp. 221–242, ISBN 978-1-5225-5015-0. [CrossRef]
43. Casamassima, L.; Bottecchia, L.; Bruck, A.; Kranzl, L.; Haas, R. Economic, social, and environmental aspects of Positive Energy Districts—A review. *Wiley Interdiscip. Rev. Energy Environ.* **2022**, *11*, e452. [CrossRef]
44. Hearn, A.X.; Sohre, A.; Burger, P. Innovative but Unjust? Analysing the Opportunities and Justice Issues within Positive Energy Districts in Europe. *Energy Res. Soc. Sci.* **2021**, *78*, 102127. [CrossRef]
45. European Commision. Energy Poverty. Available online: https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-poverty_en (accessed on 30 March 2025).
46. 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]
47. Huff, C.; Anderson, R.E.; Little, J.C.; Johnson, D.; Kling, R.; Martin, C.D.; Miller, K. Integrating the Ethical and Social Context of Computing into the Computer Science Curriculum. *Sci. Eng. Ethics* **1996**, *2*, 211–224. [CrossRef]
48. Nguyen, M.-T.; Batel, S. A critical framework to develop human-centric positive energy districts: Towards justice, inclusion, and well-being. *Front. Sustain. Cities* **2021**, *3*, 691236. [CrossRef]
49. Kruahong, S.; Tankumpuan, T.; Kelly, K.; Davidson, P.M.; Kuntajak, P. Community Empowerment: A Concept Analysis. *J. Adv. Nurs.* **2023**, *79*, 2845–2859. [CrossRef]
50. Jenkins, K.; Sovacool, B.K.; McCauley, D. Humanizing Sociotechnical Transitions through Energy Justice: An Ethical Framework for Global Transformative Change. *Energy Policy* **2018**, *117*, 66–74. [CrossRef]
51. Ghafouri, H.; Lazar, T.; Del Conte, A.; Tenorio Ku, L.G.; Tompa, P.; Tosatto, S.C.; Monzon, A.M. PED in 2024: Improving the Community Deposition of Structural Ensembles for Intrinsically Disordered Proteins. *Nucleic Acids Res.* **2024**, *52*, D536–D544. [CrossRef] [PubMed]
52. Bruck, A.; Ruano, S.D.; Auer, H. One Piece of the Puzzle Towards 100 Positive Energy Districts (PEDs) Across Europe by 2025: An Open-Source Approach to Unveil Favourable Locations of PV-Based PEDs from a Techno-Economic Perspective. *Energy* **2022**, *254*, 124152. [CrossRef]
53. Derkenbaeva, E.; Vega, S.H.; Hofstede, G.J.; Van Leeuwen, E. Positive Energy Districts: Mainstreaming Energy Transition in Urban Areas. *Renew. Sustain. Energy Rev.* **2022**, *153*, 111782. [CrossRef]
54. Brozovsky, J.; Gustavsen, A.; Gaitani, N. Zero Emission Neighbourhoods and Positive Energy Districts–A State-of-the-Art Review. *Sustain. Cities Soc.* **2021**, *72*, 103013. [CrossRef]
55. Lindholm, O.; Rehman, H.U.; Reda, F. Positioning Positive Energy Districts in European Cities. *Buildings* **2021**, *11*, 19. [CrossRef]
56. PED DB: Map—PED-EU-NET | Cost Action CA19126. Available online: https://pedeu.net/map/ (accessed on 3 April 2025).