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RESEARCH ARTICLE

Empowering cities through Positive Energy Districts: Strategies and implementations from PED projects of EU climate neutral and smart cities

[version 1; peer review: 2 approved with reservations]

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Abstract

Background

Positive Energy Districts, which incorporate energy planning at the district level, are a pioneering concept for sustainable, smart and climate-neutral urban development. This concept supports creating communities that generate more annual energy than they consume. To this end, integrative innovative solutions for Positive Energy Blocks/Districts and Positive and Clean Energy Districts have been, are being, and will continue to be devised, tested, and monitored for their performance in the “Lighthouse” cities of various EU research and innovation initiatives. This review paper showcases a range of EU

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Any reports and responses or comments on the

projects that were brought together through panel discussions and workshops during two key events: the MAKING-CITY final event (June 13, 2024) at the Innovation Camp in Groningen, and the Sustainable Places 2024 Conference (September 25, 2024) in Luxembourg.

Methodology

11 invited projects on Positive Energy Districts and Positive and Clean Energy Districts, and their corresponding case studies aim at exploring innovative strategies and practical approaches to accelerate the transformation of cities towards sustainability and resilience. Participants of the two events have gained insights into cutting-edge initiatives, exchanged best practices, and discussed actionable steps to foster the development and implementation of PEDs/PCEDs in diverse urban contexts.

Results and Discussion

These projects collectively serve as a portfolio of related initiatives derived from Smart Cities and Communities, the Climate Neutral Cities Mission, and the Driving Urban Transitions funding programs—each targeting different stages in the planning, design, implementation, or operation of PEDs/PCEDs.

Conclusion

This study primarily highlights how the eleven projects and their case studies collaborate and cooperate by discussing policy recommendations, technological innovations, economic frameworks, and the role of social and local communities. Through these explorations, it seeks to offer insight into the complex and varied domain of PEDs/PCEDs in terms of replication and future steps.

Keywords
Positive Energy Districts, Replication, Community Engagement, Climate-neutral cities, Positive and Clean Energy Districts, Energy Communities, Energy sharing, Energy transition

article can be found at the end of the article.

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Introduction

Positive Energy Districts (PEDs) are a transformative approach to achieving sustainable urban development by enabling districts to generate more energy than they consume on an annual basis. This concept is pivotal in addressing the global challenges of climate change, energy security, and urban resilience. By integrating advanced energy technologies, innovative governance structures, and community-driven initiatives, PEDs provide a replicable framework for cities to transition towards climate neutrality. The European Union (EU) has positioned PEDs as a cornerstone of its Climate Neutral and Smart Cities Mission, emphasizing their potential to create interconnected, energy-positive urban systems European Commission, Directorate-General for Research and Innovation (2018).

According to Olgyay (2019), no building is an island, and optimizing an individual building may be detrimental to its neighbours. In some locations, zero energy buildings have disrupted utility loads causing increasing amounts of carbon intensive energy to be on the electricity grid. This points out to environmental opportunities that can best be addressed at the district to urban scale. Locality, in terms of technical solutions, new business models, individuals and communities and regulations, is very compatible to the scalable logic from Positive Energy Blocks (PEBs) to PEDs.

The significance of PEDs lies not only in their technical capabilities but also in their socio-economic impact. By fostering community engagement, enhancing local economies, and supporting the adoption of renewable energy technologies, PEDs contribute to sustainable growth and improved quality of life. The development of PEDs requires an interdisciplinary approach that integrates urban planning, energy system optimization, stakeholder collaboration, and innovative policy frameworks. Besides, the idea of scale and representativeness of the various socio-economic contexts/groups of citizens is of utmost importance for effective and impactful urban transformation, taking into account cross-sectoral impacts, interdependencies, and co-benefits, as Positive Clean Energy Districts (PCED) European Commission (2022) are also an essential component of the future climate-neutral cities.

This paper brings together insights from eleven diverse EU-funded projects that have explored various aspects of PEB/PED/PCED development. These projects were discussed during the MAKING-CITY final event in Groningen (June 2024) and the Sustainable Places 2024 Conference in Luxembourg (September 2024). The insights gained highlight innovative strategies, best practices, and actionable steps to foster PED implementation across different urban contexts (Sustainable Places Conference. (2024). Workshop on Empowering Cities Through Positive Energy Districts: Strategies and Implementation. https://www.sustainableplaces.eu/previous/sp2024/empowering-cities-through-positive-energy-districts-strategies-and-implementation/). This comprehensive review aims to provide cities with practical tools and knowledge to replicate successful PED initiatives and accelerate their journey towards sustainability and resilience.

The invited eleven projects mention their PED journeys, best practices, and challenges and how to develop strategies to overcome the barriers and implementation processes. The projects represent different stages of PED development, design, implementation, or operation stages. They recount plan, design, and implementation stories to encourage other cities to participate in PED developments. This paper aims to learn from each other and transfer knowledge and experience between EU PED research and innovation projects.

During both events, firstly, the project's objectives, key innovations, value propositions, and potential challenges or best practices were discussed. Based on the initial presentations, participants took the opportunity to show the strongest and weakest points in their projects. Afterwards, four questions were directed to all PED sister projects, and they prioritized one or two questions based on their most successful solutions or biggest failures.

Positive energy districts: state of the art in EU

The state of the art in PED development across the EU showcases a wide range of innovative methodologies and pilot projects, each contributing unique perspectives and solutions to this evolving field. PEDs embody a vision of energy autonomy and climate neutrality that aligns with the EU's long-term environmental goals.

PEDs are defined as urban districts that achieve a net annual surplus of renewable energy while maintaining net-zero carbon emissions. This entails integrating various energy solutions, including renewable energy sources, energy storage, and demand-side management, within a district-wide framework. PEDs also focus on creating synergies between different sectors such as mobility, housing, and energy.

EU-funded projects have demonstrated the practical applications of PED concepts. These projects vary in their scale, focus, and implementation strategies, ranging from retrofitting existing neighbourhoods to designing new urban areas with integrated renewable energy systems. Each project contributes valuable lessons on addressing technical, economic, and social challenges.

The technological backbone of PEDs includes advanced renewable energy systems, such as solar photovoltaics, wind turbines, and geothermal energy, combined with energy storage solutions like batteries and thermal storage. Smart grids, energy management systems, and AI-driven optimization tools enable efficient energy use and integration. Additionally, PEDs leverage digital platforms for real-time monitoring and community engagement.

Effective policy frameworks and governance models are critical to PED success. EU projects have explored innovative approaches, such as public-private partnerships, citizen-driven energy communities, and integrated urban planning. These models ensure that PEDs are not only technically feasible but also socially inclusive and economically viable.

The goal of PED projects is to provide replicable and scalable solutions that can be adapted to diverse urban contexts. Lessons learned from pilot projects inform strategies for broader adoption, addressing challenges related to funding, stakeholder engagement, and regulatory barriers. Collaboration between cities and knowledge-sharing platforms are essential for accelerating PED development across the EU.

Overview of EU Research and innovation projects on Positive Energy Blocks and Districts

Prioritized eleven projects that were invited to the two panels organized represent a variety of different targets, scales, and concepts on PEBs, PEDs, or PCEDs. Their PED journeys, best practices, and challenges and developed strategies to overcome the barriers and implementation processes are summarized in this section. The planning, design, and implementation stories are presented to encourage other cities for PED developments. The projects are representing different stages of PED developments, such as design, implementation, or operation stages. The aim of this overview is to learn from each other and transfer knowledge and experience between EU PED R&I projects. The discussion points are based on each project's objectives, key innovations, and value propositions and their potential challenges or best practices.

MAKING-CITY

Launched in December 2018, MAKING-CITY www.makingcity.eu, over its 72 months, has demonstrated advanced methodologies based on PEDs. Defined as "districts with annual net zero energy import and net zero carbon emissions, working towards an annual local surplus of renewable energy," PEDs and their integration into urban planning have been the project's main focus.

To ensure successful PED implementation, MAKING-CITY has addressed key sectors supporting long-term energy transition. This involves shifting from finite energy sources like fossil fuels to renewable energy, improving energy efficiency, and better managing demand. While current city energy plans target 2030 as a mid-term goal (aligned with Europe's 2030 Climate & Energy Framework), MAKING-CITY emphasizes a longer vision. The City Vision 2050 proposes tools and strategies for transforming urban energy systems, including low-carbon solutions and creating City Planning Offices to enhance municipal planning.

ASCEND

The ASCEND project https://www.ascend-project.eu/, focuses on accelerating the development of PCEDs to advance the EU's Climate-Neutral and Smart Cities Mission. It aims to create two demonstrative PCEDs in Lyon and Munich, designed to be inclusive, affordable, and scalable. These solution packages integrate technical, social, and governance innovations to provide replicable models for cities across Europe. The project also supports "Multiplier Cities" to ensure broader replication and adoption.

As of 2024, ASCEND is implementing its six solution packages, including digital infrastructures, energy-efficient buildings, decarbonized mobility, and citizen-centric solutions. These packages are tested in lighthouse and multiplier cities, with feedback loops ensuring continual improvement. The ultimate goal is to scale these solutions for wider adoption by cities and investors through well-fitted financial plans, fostering healthier and more climate-neutral urban environments.

PED-ACT

The PED-ACT project https://ped-act.com/ aims to optimise the PED process (mainly on design and planning stages) in an iterative way. It characterises the existing PEDs, using artificial intelligence (AI) approaches, to generate digital models for feasibility study through improved common database development, co-learning/co-creation, and replication modelling. There are four specific tasks: 1- to contribute to the standardization of the PED common database for information integration; 2- to investigate a co-design matrix for multi-criteria characterization of PEDs and generate digital models; 3- to enhance co-learning and co-creation strategies with an iterative process; 4- to propose a replication plan for PEDs to contribute to a climate-neutral city.

The PED-ACT project focuses on five demo cases, respectively, in Sweden, Turkey, and Austria, and all these five demo cases have been registered in the common PED database www.pedeu.net/map. In addition, the PED-ACT team also contributes significantly to the visualisation of information sets in such a database. Five digital models have been fully developed with extensive sensitivity analysis of various technological-economic combinations for achieving PEDs. The first PED manifesto has been announced with many signatures from individuals to committee themselves to co-develop PEDs.

NEUTRALPATH

NEUTRALPATH https://neutralpath.eu/ aims to support cities in their transition to climate neutrality by designing a collaborative plan for a more sustainable future for all. To enable the transformation of cities towards climate neutrality, the project partners will establish innovative governance strategies. Furthermore, the project partner will define metrics for evaluating PCED so that annual energy and CO2 balances can be monitored. NEUTRALPATH also contributes to scale-up and replication by promoting PCEDs and fosters collaboration between cities to build on existing knowledge, technology, and funding and, in turn, make an actual contribution to climate goals.

PCEDs are crucial elements of the urban transformation process towards climate neutrality and must be at the core of cities' decarbonisation plans. In the role of lighthouse cities, Dresden and Zaragoza will demonstrate two PCEDs through the design, implementation, and evaluation phases. To this end, both have established CN-Labs to design participative and human-centred solutions and promote faster dissemination and replicability at the EU level. In addition, through their respective CN-Labs, three fellow cities (Istanbul, Ghent, and Vantaa) will become direct participants in the processes and later actors in the design of their own PCED.

ATELIER

ATELIER https://smartcity-atelier.eu focuses on developing and implementing PEDs, focusing on Amsterdam and Bilbao as Lighthouse Cities. The project aims to develop citizen-driven PEDs, targeting a reduction of 1.7 kilotons of CO2 emissions. Successful strategies are intended for replication in six Fellow Cities (Bratislava, Budapest, Copenhagen, Krakow, Matosinhos, and Riga), promoting widespread adoption. Within the lighthouse cities, the focus is on revitalizing old industrial sites with completely new mixed-use developments in the Buiksloterham area of Amsterdam and a mix of new built and refurbishment projects in Zorrotzaurrre island in Bilbao.

Apart from testing various technological innovations such as next-generation low-temperature district heating and cooling and energy storage and management systems, ATELIER has placed a great emphasis on engaging stakeholders to address the challenges posed during the development of the project. By deploying the so-called Innovation Atelier framework, topics related to four tracks, i.e., integrated smart energy systems and electromobility; governance; integrated planning and law; new financial instruments; and data, privacy, and data platforms, are addressed. Additionally, a strong focus has been placed on capacity building in the cities with the development of bold city visions for each city and replication plans. The project is entering the monitoring and evaluation phase, with the expected finalizing in April 2026.

SPARCs

As part of the H2020 project SPARCS (Sustainable Energy Positive & Zero Carbon Communities) https://sparcs.info, the two lighthouse cities of Espoo and Leipzig and the five fellow cities of Kifissia, Kladno, Lviv, Maia, and Reykjavik addressed issues relating to the future climate-neutral energy supply and the climate-neutral and social transformation of entire neighbourhoods from 2019-2024. The cities tested innovative smart city solutions in the area of PEDs and focused specifically on the benefits of digitalisation. In order to gather and share information with local citizens and thus raise public awareness of the need for sustainability in cities, SPARCS tested and implemented in Leipzig advanced technologies for a positive energy balance in buildings and neighbourhoods, flexible grid management, storage options for renewable energies, and e-mobility solutions. The aim was to lay the foundations for sustainable and integrated urban development and management strategies.

The City of Leipzig developed and tested measures and prototypes on the topics of energy and heat supply and the climate-neutral design of urban neighbourhoods in two model districts and in a virtual energy district. In cooperation with urban research and industry partners, the partners involved were able to successfully implement several project activities, including the operation of a virtual power plant as part of the energy district, which is based on the integration of a large number of decentralised systems and devices that provide automated data. The use of AI allows predicting energy flows and optimising them with foresight. In addition, PV systems and electricity storage systems were installed in the model districts, which will make a significant contribution to reducing greenhouse gas emissions in the future. An optimisation model for the strategic planning of climate-neutral district heating systems was developed, and options for reducing the charging load when charging e-buses were implemented. As part of the project, it was also decided to build Germany's largest solar thermal plant, which is scheduled to go into operation at the end of 2025. The project has resulted in several prototypes whose further development will continue beyond the end of the project, including the 'Energy Twin'—a' digital energy map for the city of Leipzig. In order to tackle the massive task of the energy transition, the City of Leipzig has also developed a standard model for climate-friendly neighbourhood development that can serve as a basis for the further development of existing neighbourhoods in Leipzig and other municipalities in order to transform neighbourhoods in a socially just and climate-friendly way.

POCityF

The POCITYF https://pocityf.eu/ project focuses on transforming historic cities into smart, sustainable hubs by implementing PEDs while preserving their cultural heritage. Its main objectives are to accelerate the energy transition, reduce carbon emissions, and improve the quality of life for citizens. Key innovations include advanced energy solutions like smart grids, renewable energy systems, and energy storage, combined with digital platforms for urban mobility and citizen engagement. The project's value proposition lies in creating replicable PED frameworks that balance sustainability with historical preservation, benefiting both local communities and future urban planning initiatives.

As of 2024, POCITYF is in the implementation and replication phase. Lighthouse Cities, such as Alkmaar and Évora, have successfully deployed and tested several innovative solutions, while Fellow Cities are beginning to adapt these practices to their local contexts. The project is focused on scaling its outcomes, sharing knowledge, and fine-tuning strategies to maximize the impact of PEDs across Europe

RENplusHOMES

RENplusHOMES (Renewable Energy-based Positive Homes) https://renplushomes.eu/aims to address critical challenges in energy consumption, carbon emissions, and resource scarcity within the EU building sector. The project develops 23 innovative solutions encompassing hardware, software, and methodologies tailored for Circular Plus Energy Homes (CPEH). These solutions include prefabricated Building-Integrated Photovoltaics (BIPV) with recycled materials, hydrogen storage, wireless IoT, and advanced digital tools for energy optimization. Demonstrated across four large-scale pilot sites in Austria, Spain, Estonia, and Romania, RENplusHOMES integrates cost-effective deep retrofitting, demand response, and energy communities, enhancing energy efficiency and sustainability.

Key innovations involve over 50% recycled content in building materials, co-design methodologies promoting stakeholder engagement, and systems delivering excess energy to the grid (195 MWh annually). By 2050, the project aspires to renovate over 50 million m² to CPEH standards, saving 1.56 MtCO2-eq and utilizing 39,226 tons of recycled materials.

As of 2024, RENplusHOMES is in the implementation phase, actively testing its solutions at demonstration sites while refining business models and scaling methodologies. Its holistic approach aligns with EU Green Deal objectives, promoting climate-neutral, resource-efficient, and socially inclusive energy systems.

LEGOFIT

The LEGOFIT project https://www.legofit.eu/, funded under the Horizon-CL5-2022-D4-01 call, began in May 2023 and will continue until 2027. This project aims to design and validate advanced, scalable solutions to achieve Energy Positive Homes (EPHs) and enable the transition to PEDs. It focuses on both new constructions and retrofitting existing buildings by integrating passive and active technologies. The core innovation of LEGOFIT is its comprehensive design platform, which leverages Building Information Modelling (BIM) to ensure seamless information exchange and system interoperability.

Key innovations within LEGOFIT include:

- Integrated Design Platform: This user-friendly BIM-based platform enables streamlined pre-construction processes, reducing the design phase duration while improving accuracy.
- AI-Driven Optimization: Advanced AI and machine learning technologies are employed to optimize energy performance, predict energy demand, and support smart decision-making.
- Sustainability Strategies: LEGOFIT promotes circular economy practices by incorporating residues and recycled materials from the building lifecycle, reducing environmental impact.
- Urban-Scale Model Integration: The project employs Urban-Scale Model Integrated Digital Twins (USEM-DTs) to simulate energy outcomes at the district level, enhancing scalability and replication potential.

As of 2024, LEGOFIT has established the foundational elements of its design platform, nearing completion of BIM and Virtual Energy (VE) models for its pilot projects. The project has also successfully developed the LEGOFIT Stakeholders' Community, which includes policymakers, technology providers, and building sector professionals, fostering collaboration and knowledge exchange. Moving forward, LEGOFIT aims to ensure that its solutions are scalable and replicable across diverse European contexts, ultimately contributing to climate-neutral, energy-efficient building stocks and districts by 2027.

InterPED

InterPED https://interped.eu/ aims to demonstrate the potential of PEDs by integrating local excess/waste heat (E/WH) and renewable energy sources (RES) with the local energy systems. To this end, InterPED will develop a cloud-based solution focused on enhancing sector coupling and demand flexibility. This solution will be validated in four large-scale pilots distributed across Europe in Spain, the United Kingdom, Switzerland, and Romania. In order to increase its impact, InterPED will carry out a post-project replication strategy with four additional follower districts.

The InterPED cloud-based platform will be composed of advanced management tools for planning, supervision, and control of PEDs (including power, heating and cooling, and mobility). These tools will include the integration of analytical services (predictive, modelling, and optimisation) to achieve a more efficient operation and improve the interoperability of PEDs. This toolbox will be incorporated under the life-cycle assessment (LCA) methodology and will provide multi-criteria decision analysis (MCDA) support for urban planners and suppliers. In addition, to empower consumers through remuneration, InterPED will develop a peer-to-peer trading platform using blockchain technology, which will serve as an open energy marketplace. The key strategy to ensure solutions work in the everyday context of citizens is that InterPED will involve both the community and service providers in the design of the solutions through participatory co-design processes.

InterPED is a three-year project that started in January 2024. Approaching the end of its first year, it has set up the specifications for the demo scenarios in the pilots, and it is currently shaping its engagement strategy with users.

TIPS4PED

The TIPS4PED project aims to design, develop, and test a digital twin-based platform to support municipalities in implementing PEDs. The project focuses on enhancing the environmental sustainability of cities and reducing operational costs by providing evidence-based results for decision-making. The TIPS4PED Platform will offer various modules to support municipalities from technical, social, financial, regulatory, and administrative perspectives. The project adopts a people-centric approach, engaging, training, and empowering citizens and stakeholders through a co-design methodology.

As of 2024, the TIPS4PED project is in its initial phases. The focus is on planning and preparation, including laying the groundwork for creating Digital Twins for the Lighthouse City (Turin) and three Follower Cities (Cork, Kozani, and Budapest). These efforts aim to establish a strong foundation for developing decarbonization roadmaps. The project aspires to propose scalable and reproducible technologies and digital optimization strategies to support the achievement of the EU's 2030 goals, taking into account diverse market circumstances and regulatory frameworks.

Table 1 in underlying data (Alpagut *et al.*, 2025) presents the comparison of the project ambitions and targets, outcomes, outputs and the lessons learned of the 11 PED/PCED projects.

Table 2 shows the comparison of the 11 PED/PCED projects in terms of project stages whether they are feasibility, planning/ design, implementation or operation stages.

Comparison of project stages

Key Questions towards PED Developments:

Four questions were directed to the 11 projects during the two events. These questions are referring to the identified challenges and best practices that are listed in Section 2. The questions focus on social, economic, technical, and political aspects of PED developments. The questions are as follows:

- Q1. How have you engaged local communities in your PED project, and what strategies have been most effective in gaining their support?
- Q2. What economic models or funding mechanisms have proven successful in making your PED project financially sustainable?
- Q3. What technological innovation from your project has had the most impact on achieving positive energy balance?
- Q4. Could you generate any policy recommendations based on the design/implementation of PEDs in your project? How should be the optimum political and legal environment for encouraging PED developments?

The projects are requested to identify two questions based on their experience and challenges. Table 3 summarized the prioritized questions according to the 11 projects.

As seen in Table 3, Q1 on engaging local communities is preferred the most, whereas Q3 on economic models developed in the projects is the least identified question. A few projects focus on developing policy recommendations as the main outcome of the projects, while most of the projects emphasize the technological innovations developed, as all of the EU R&I projects provide a real setting for testing technologies.

Q1: Starting with Q1 focusing on engaging local communities, according to MAKING-CITY, engaging local communities has been essential to successfully implementing our PEDs, as they encompass various urban aspects. In MAKING-CITY, the approach has varied between the two lighthouse cities due to the diverse groups involved and their roles. In Groningen, local ambassadors have facilitated homeowner participation in transforming their single-family houses. The energy cooperative leading the transformation includes engaged neighbours who encourage broader community involvement. In Oulu, the school within the PED serves as an example through interactive tools, engaging not only students but also numerous visitors. By educating children, the future generation is being prepared to actively participate in sustainable community initiatives.

On the other hand, in the PED-ACT project, we have engaged five communities, respectively in Sweden, Turkey, and Austria. The strategies are different. For instance, in Sweden and Turkey, we use a top-down approach by engaging mostly municipalities or municipality-owned utility companies and real estate companies, since most of the targeted communities are owned or significantly influenced by these parties. While in Austria, the engaging strategy is from the bottom up, by showing direct economic return and environmental benefits to the local stakeholders. In NEUTRALPATH, a climate-neutral lab has been set up in two lighthouse cities and three fellow cities to involve residents and local associations in

Table 2. Comparative Project phases of PED Projects.

Project Name	Feasibility	Planning/ Design	Implementation	Operation
MAKING-CITY				x
ASCEND	x	x		
PED-ACT	x	x		
NEUTRALPATH	x	x		
ATELIER				x
SPARCs				x
POCityF				x
RENplusHOMES		x	x	
LEGOFIT		x	x	
InterPED		x	x	
Tips4PED	x			

Table 3. Questions Prioritized by Projects.

Project Name	Q1: Local Communities	Q2: Economic Models	Q3: Technological Innovations	Q4: Policy Recommendations
MAKING-CITY	x		x	
ASCEND		x		x
PED-ACT	x			x
NEUTRALPATH	x		x	
ATELIER		x	x	
SPARCs		x		x
POCityF	x		x	
RENplusHOMES	x	x	x	x
LEGOFIT	x		x	
InterPED	x			x
Tips4PED	x		x	

co-design activities. These CN-labs will act as innovation hubs to coordinate and facilitate co-creation processes. The CN lab in Ghent brings together citizens, associations, private organizations, research institutions, and the local government to develop breakthrough projects. These projects serve as a catalyst to create involvement and support. To devise a portfolio of projects and shape a local energy action plan, a neighbourhood energy coalition is being built in Ghent. This coalition puts citizens in the driver's seat to shape projects and plans that benefit the neighbourhood. To also hear the voices of non-dominant groups in this process, we collaborate with the social organization Saamo. They apply participatory strategies to involve less vocal and less wealthy neighbourhood residents through door-to-door conversations, collective street activities, and group discussions in reference groups.

Moreover, local communities in the POCITYF project have been actively engaged through strategies that prioritize collaboration, co-creation, and education. In both Lighthouse Cities, Alkmaar and Évora, a strong focus has been placed on involving citizens in the planning and implementation of PED solutions, ensuring that their needs and feedback are integrated into the project's innovations. In Alkmaar, the community engagement strategy included workshops and open consultations to inform and involve residents about the benefits of renewable energy systems, such as solar PV installations and smart grids. For instance, at the De Meent sports complex, local residents were invited to learn about the innovative energy solutions being implemented, creating awareness and enthusiasm for sustainable practices.

Additionally, gamification initiatives, such as energy-saving challenges, encouraged active participation and behaviour changes among citizens, fostering a sense of ownership and pride in the city's energy transition. In Évora, community engagement centred around digital tools and local partnerships to educate and empower citizens. Interactive platforms were introduced to share data on energy usage and renewable production in real-time, helping residents understand the impact of PED solutions on their daily lives. Furthermore, cultural events and neighbourhood discussions were organized to bridge the gap between modern energy innovations and the city's historical heritage, ensuring alignment with local values, almost in a door-to-door approach for some solutions. Constant communication (both digital and in person) took place to inform them about the solutions, to engage them in active participation, and for constant feedback on the status of the implementations. This helped secure broad community support, even in a city deeply tied to its cultural roots. By combining tailored communication, hands-on involvement, and innovative tools, POCITYF successfully gained community buy-in in both cities, which has been crucial for the successful implementation of its energy solutions.

Furthermore, RENplusHOMES prioritizes community involvement through co-design methodologies, engaging over 70 residents per demonstration site to enhance awareness and satisfaction. This participatory approach includes workshops, educational sessions, and feedback loops, ensuring that local needs and preferences are reflected in the solutions. Strategies like leveraging local energy communities and fostering collaboration between stakeholders have proven effective in gaining trust and support. For the sister project of RENplusHOMES, in the LEGOFIT project, local communities have been actively engaged through the creation of a stakeholder community that includes key players from the building sector, such as policymakers, designers, contractors, and technology providers. This community will be involved

in the project through various activities, including roundtables, workshops, and living lab visits, which facilitate direct interaction and feedback.

These strategies will affect ensuring local needs are addressed, fostering a sense of ownership and involvement. By tailoring solutions to regional contexts and involving stakeholders in the development of the LEGOFIT platform and marketplace, the project ensures broad support and encourages local adoption of PEDs. Continuous communication and collaboration with local actors have been key to building trust and securing their support for the project's goals.

Though InterPED is still in an early stage of development, one of the strategies used to engage with local communities has been the organisation of workshops in the pilot sites tailored to their social context needs. Due to their different nature, each pilot has been assessed individually to study the technical deployments that could be carried out. After this initial characterisation phase, different workshops have taken place in the pilots involving diverse groups of residents and representatives from stakeholder organisations. In this way, both sides have provided their insights with regard to topics such as the installation of EV charging infrastructure, demand response integration, or the interaction with the InterPED platform, ensuring that these elements are helpful for the community and aligned with their values. The feedback from these sessions has been very positive so far, increasing the sense of community and collaboration among users.

Finally, in the TIPS4PED project, local communities will be actively engaged through a co-design approach, ensuring their input shapes the development of PEDs. Our strategy will include stakeholder mapping to identify and involve residents, businesses, and local authorities, alongside collaborative workshops that will allow participants to contribute to the design and validation of solutions. Transparent communication will be critical, with project goals, progress, and benefits shared through public events and accessible materials to foster trust and understanding.

Additionally, training sessions and capacity-building programs will empower citizens with knowledge about energy efficiency and renewable technologies. We expect that the most effective strategies will be the co-design workshops, which will aim to create tailored solutions addressing local challenges, and consistent communication, which will build trust and sustain engagement. These efforts will strengthen community support and ensure the solutions are both impactful and scalable.

Q2: Continuing with Q2, although ASCEND is in its early stages, several promising economic models and funding mechanisms have been identified, drawing on lessons from similar EU-funded projects. Blended financing, which combines public grants (e.g., Horizon Europe) with private capital, shows early potential for reducing risks and boosting investor confidence. The project is also leveraging EU grants and exploring green bonds, proven effective in financing climate-related infrastructure, particularly for renewable energy. Public-Private Partnerships (PPPs) are planned to mobilize resources from the public and private sectors, and Special Purpose Vehicles (SPVs), though not yet tested in ASCEND, have successfully pooled PCED initiatives in other European projects, enhancing their financial viability. These strategies aim to create a sustainable funding framework for PCEDs, ensuring their scalability and bankability while fostering widespread replication across Europe.

For ATELIER, in both demo sites, public and private funding has been used. The developments are privately funded, with the developers bringing in their own financing for the construction. Some elements of the infrastructure needed for the PED have been funded by additional project funds. In Bilbao, the Energy Performance Contract (EPC) was tested out for the renovation of some buildings. In Amsterdam, business models for multi-market energy trading are being tried to strengthen the energy community's business model. Financing schemes and business cases are also being investigated for replication in the fellow cities. Co-benefits-based business models and blended financing schemes are being evaluated for this purpose. An investment platform is also being considered.

Additionally, the aspect of citizen engagement was implemented in SPARCS, particularly in the Dunckerviertel model district in the west of Leipzig. The district is characterised by social housing and has a heterogeneous neighbourhood. While many older people have often lived in the neighbourhood for a long time, Dunckerviertel is also home to young families who are new to the area, people with a migration background, and refugees, some of whom are awaiting confirmation of their residence permit. Due to the predominantly older target group, a participation strategy focusing exclusively on digital means was not possible. Instead, a distinct analogue offer and a direct, low-threshold approach were necessary due to the complex subject matter and the different individual backgrounds instead of a general treatment of the topic of the energy transition or climate protection in order to demonstrate the individual added value of the project measures and create awareness of the necessity of the project. This was achieved through individual energy consultation hours and advice services, a regular neighbourhood meeting, cinema series for children, and several street festivals. Connecting the neighbourhood and strengthening the sense of community has contributed to a lively exchange on project-specific topics among residents and raised awareness of sustainable living. Explanatory, illustrated videos in simple language have proven to be particularly suitable as an introduction to topics such as the energy transition.

Lastly, RENplusHOMES integrates innovative business models that combine cost-effective deep retrofitting, demand-response mechanisms, and the creation of energy communities. It emphasizes maximizing value from renewable energy surplus and recycled materials. Leveraging public-private partnerships and EU funding has also played a crucial role in ensuring financial viability while reducing upfront costs for stakeholders.

Q3: The technical purpose of PEDs focuses on technologies for achieving annual positive energy balance, and for

MAKING-CITY, the use of heat pumps fed by solar PV and combined with district heating systems has been crucial for achieving the positive energy balance. Due to the singularities of our cities, the main contributor to this balance is different. In the case of Groningen, PV energy plays a fundamental role and captures the main innovations tested in our project; a solar footpath with recycled plastic integrated in the street of Europapark, the BIPV incorporated into the retrofitted high-rise building, or the bifacial PV canopy in one of the single-family houses are the most relevant ones. On the other hand, in the case of Oulu, the use of district heating return water and exhaust air heat pumps jointly with the building-integrated PVs has opened new possibilities to new low-temperature DH networks or increased the efficiency of the existing ones.

Furthermore, in Ghent (the lighthouse city of NEUTRALPATH), the aim is to reach a positive energy balance through the construction of a district heating grid, among other measures. In this manner, an entire existing building block can shift to renewable energy sources for heating and cooling at once. Further, this also allows to combine several heating and cooling sources, connected into one integrated system. The combination of different sources ensures that the most efficient source at a certain time can be used. E.g., research will be done on combining geothermal boreholes with PV-T panels (photovoltaic thermal) in a 4th and/or 5th generation district heating network. These kinds of optimisations can lead to increased efficiencies that would be hard to achieve on an individual basis. By scaling up to a district heating grid, multiple technologies can be combined to achieve the most optimal solution. Working in an existing district with a diverse building stock and private homeowners also presents some technological challenges. The renovation rate of the houses differs a lot, which makes is harder to estimate the heat demand for the district heating. Further, it is also hard to determine how many people will participate at what time. In Ghent, we are therefore trying to lower these uncertainties as much as possible by collecting information about the heat demands of the houses and the willingness to participate.

On the other hand, in ATELIER there has been a complimentary focus on heating and electricity within the two demo sites. In Amsterdam PED, high-efficiency solar PV has been integrated along with a large 1 MW battery. The battery is also being utilized for trading on the imbalance and FCR markets, thus strengthening the business model but also providing support to the wider energy system. A microgrid connects the users and is managed by the energy community. The heating system utilizes heat pumps and an Aqua Thermal Energy Storage (ATES) system in addition to the district heating. An advanced energy management system (EMS) ensures optimizing the loads and provides additional flexibility in the system. In Amsterdam, grid congestion has been a key issue for the implementation of the project, and due to the innovative systems installed as well as much higher energy efficiency, the demo site was able to stay below the substantially reduced grid capacity. A local energy market is also envisioned in the project. Whereas, in Bilbao, apart from extensive PV integration, a fifth-generation low-temperature district heating and cooling system has been implemented. Heat is supplied through geothermal boreholes, and the system is designed to supply heating and cooling demand beyond the PED area, thus supporting the neighbouring areas with surplus energy.

The most impactful technological innovation at the De Meent sports complex in Alkmaar within the POCITYF project is the integration of a **thermal energy storage system combined with a smart energy management system**. This system efficiently captures and stores surplus heat generated during the operation of the ice rink and reuses it for other energy needs within the facility, such as heating spaces and water. By optimizing energy flows and reducing energy waste, the complex has significantly improved its energy efficiency. This innovation not only reduces dependency on external energy sources but also aligns with the PED concept by contributing to a net-positive energy balance. The thermal storage system showcases how advanced energy technologies, paired with smart management, can transform energy-intensive facilities into sustainable and energy-positive assets for the community. Regarding Évora, the installation of Building-Integrated Photovoltaics (BIPV) on municipal buildings, as well as contributing to the positiveness of the district, allows Évora and other heritage cities to embrace this technological solution that, at the same time, increases the production of energy from renewable sources (in the case of Évora, via shingles and glass that produces electricity from sunlight) and maintains the aesthetics of the city, preserving its architecture and historical features. Also, the formation of Renewable Energy Communities, in line with the European goal to foster this association of buildings—a collective action of building users and owners to produce, consume, share, and sell energy generated from renewable sources.

In RENplusHOMES, the innovative technologies are the prefabricated BIPV-insulated façades with over 50% recycled materials, and hydrogen storage systems have been transformative. These technologies ensure high energy efficiency and enable the project to achieve surplus energy generation, supplying 195 MWh annually to the grid or neighbouring buildings. Digital tools like the Building Digital Energy Assistant (BDEA) optimize energy use, further enhancing the positive energy balance.

Moreover, the LEGOFIT project's greatest technological innovation in achieving a positive energy balance is the LEGOFIT platform, an integrated design platform that blends passive and active technologies utilizing Building Information Modelling (BIM). Thanks to the LEGOFIT platform and the modelling of high-performance and cost-effective active and passive technologies, the LEGOFIT marketplace offers to the users an extensive range of commercially available solutions, specifically chosen by the LEGOFIT technical experts. This platform provides smooth information sharing and system compatibility, giving users simple access to technical and non-technical solutions for improving building energy

efficiency. By providing decision-support tools, the platform reduces the pre-construction process and ensures a smoother transition through each project phase. Furthermore, the platform's agile development methodology enables constant contact with stakeholders, allowing for incremental solution enhancements. Additionally, the use of Urban-Scale Model Integrated Digital Twins (USEM-DTs) ensures scalability and the ability to simulate potential energy outcomes at a district level, supporting the development of PEDs. This combination of advanced tools and smart management solutions has been critical in optimizing energy performance and driving the transition to energy-positive buildings and districts.

Finally, the most impactful technological innovation in the TIPS4PED project for achieving a positive energy balance will be the digital twin-based platform. This innovative technology will enable real-time monitoring and optimization of energy flows within the PEDs. By integrating data from various sources, including energy consumption, production, and storage, the platform will allow municipalities to make informed, evidence-based decisions for energy management. It will help optimize energy use, increase efficiency, and prioritize the deployment of renewable energy solutions such as solar photovoltaics. Additionally, the platform will support the development of decarbonization roadmaps, providing cities with tailored strategies to reduce emissions and enhance energy independence. This technology will be critical in improving the overall energy balance, ensuring that energy production exceeds consumption, and contributing to the sustainability of the districts while aligning with the EU's decarbonization goals.

Q4: Closing up with policy recommendations, in ASCEND, to encourage financing for sustainable urban development, including PCEDs, several policy recommendations have been proposed. These include offering tax credits to banks supporting Environmental, Social, and Governance (ESG) projects and reducing capital requirements to lower lending risks. Issuing public institution-backed green bonds and creating new financial instruments, such as sustainability-linked and social impact bonds, aim to align financial returns with sustainability objectives. Additionally, standardising ESG ratings across Europe can enhance transparency, improve risk assessment, and foster greater investment. The recommendations also propose establishing co-investment funds involving governments, banks, and private investors to share risks and drive significant social and environmental impacts. Together, these measures aim to create a political and legal environment conducive to scaling PCEDs, reducing risks for stakeholders, and aligning financial incentives with environmental goals.

However, for PED-ACT, it lacks the design guidance or standard to regulate the development of PED. Similar to the building or transportation sectors, it is necessary to have such standards ready soon. Another suggestion is to develop the assessment/rating system of PEDs if the standard is not easy to develop. For instance, Austria has developed the national rating system (klimaaktiv) for climate-neutral PEDs, which forms the framework for planning, assessment, and quality assurance.

During SPARCS' lifetime, it has become clear that the hurdles in Germany are more of a regulatory than a technical nature. This is mainly due to restrictive laws regarding energy communities: As German law currently forbids the exchange of electricity between households; it is difficult to promote PEDs. This can be circumvented—as trialled in SPARCS—with the use of virtual power plants. However, these are dependent on smart meters, which are also not yet widespread in Germany, and installation will not be mandatory until next year. At the Baumwollspinnerei in Leipzig, a former industrial site, SPARCS introduced an innovative meter model; however, current German regulations prevent mapping it. A nationwide smart meter rollout could remove this massive obstacle and encourage grid agencies to open up to innovative and complex meter models. It has also become clear that the regulatory framework for community energy models, such as the tenant electricity model in Germany, needs to be simplified and made more flexible, as the high administrative requirements, low financial incentives, and limited scalability result in elitism that excludes the majority of society and contradicts the European demand for the promotion of energy communities. It should be noted that German regulation is currently changing rapidly, which in turn can make application and development processes more difficult. It should therefore be made more flexible so that ongoing projects are not hindered by dynamic, rapid legislative changes.

Additionally, RENplusHOMES highlights the need for policies that promote innovation in energy-efficient construction and retrofitting. Recommendations include:

- **Streamlining Regulations:** simplify permitting processes for PED technologies and harmonize EU and national standards.
- **Incentives:** Offer subsidies or tax credits for using recycled materials and achieving positive energy status.
- **Support for Energy Communities:** Facilitate the establishment of energy-sharing models and local grids.

Educational Campaigns: Increase awareness among policymakers and the public about PED benefits.

An optimal environment for PEDs requires strong political commitment, transparent legislation encouraging renewable integration, and financial frameworks to de-risk investments for developers and communities.

At last, in InterPED, from the legislative point of view, PEDs are still a theoretical concept. Although several EU countries are already discussing how to elaborate primarily legislation for encouraging PED establishment in their cities, PEDs are not mentioned in the current framework. For this reason, the process of developing and operationalising a PED entail going through some preliminary stages that differ depending on the country and the specific conditions of the district. Based on the legal barriers found in the different

pilot sites of InterPED, the following policy and regulatory recommendations are provided at the EU and national level:

- To formulate and approve policy, regulation, and standards for PEDs, including legislation on building processes and certification.
- To scale up regulations from a building scale to a district scale to accommodate the complexity of PEDs.
- To regulate the interests of stakeholders and cooperative innovation mechanisms.
- To specify responsibilities and conditions for energy exchange among users transitioning to energy prosumers.
- To address the role of local energy communities in managing energy at a community level, including demand response mechanisms and other smart grid tools.
- To adapt the legal framework gradually to account for hidden aspects that may emerge during PED development.

Replication and Upscaling Potentials in PED Projects

The successful replication of PEDs across Europe relies on a combination of technological, social, and financial strategies. Digital platforms and tools such as Building Information Modelling (BIM) and Digital Twins play a fundamental role in replicating PED solutions. For instance, the LEGOFIT project integrates BIM with AI-driven energy optimization to streamline design processes and improve scalability https://www.legofit.eu/. Similarly, the TIPS4PED project employs Digital Twins to simulate real-time energy flows, providing cities with tools for evidence-based decision-making https://tips4ped.eu/. The European Commission's Digitalisation of the Energy System (2022) underscores the importance of these technologies in achieving smart, resilient, and flexible energy systems. Digital twins can help cities optimize energy use, manage renewable integration, and simulate potential outcomes before implementation European Commission, Directorate-General for Energy (2022).

Effective community engagement is another cornerstone of PED replication. Projects including MAKING-CITY and NEUTRALPATH have shown that involving residents in the planning and implementation phases ensures social acceptance and long-term success https://neutralpath.eu/, https://stad.gent/nl/muide-meulestede-morgen/deelprojecten-muide-meulestede-morgen/muide-meulestede-fossielvrij. The European Energy Poverty Observatory (EPOV) highlights that community-driven energy initiatives can reduce energy poverty and foster social inclusion https://energy-poverty.ec.europa.eu/observatory. Successful strategies include co-design workshops, participatory decision-making, and educational campaigns.

Since innovative financial models are essential for scaling PEDs, the ASCEND project explores blended financing, combining public grants with private capital to mitigate risks and attract investors https://www.ascend-project.eu/. Similarly, the EU Smart Cities Marketplace promotes financing instruments such as green bonds, sustainability-linked loans, and public-private partnerships https://smart-cities-marketplace.ec.europa.eu/. The European Investment Bank (EIB) has also highlighted the role of financial instruments like the European Local Energy Assistance (ELENA) facility, which supports cities in preparing bankable energy projects https://www.eib.org/en/products/advising/elena.

As the policy frameworks and standardization are crucial for replication, the PED Framework Definition published by JPI Urban Europe emphasizes the need for consistent definitions and metrics for PEDs to guide implementation across different regions JPI Urban Europe / SET Plan Action 3.2. (2020). The EU Renovation Wave Strategy (2020) also calls for harmonized standards to facilitate deep retrofitting and energy-positive building solutions European Commission, Directorate-General for Energy (2020).

Despite the promising strategies, several challenges impede the replication of PEDs. Inconsistent or outdated regulations across EU member states can hinder PED implementation. The SPARCs project found that restrictive laws on energy sharing and smart meter adoption in Germany posed significant obstacles https://sparcs.info. The Clean Energy for All Europeans Package (2019) addresses some of these challenges by promoting energy communities and peer-to-peer trading, but full implementation remains uneven European Commission, Directorate-General for Energy (2019).

Successful PEDs rely on large-scale data collection and analysis. The InterPED project highlights the difficulties of integrating data from diverse sources due to inconsistent formats and a lack of granularity https://interped.eu/. The European Interoperability Framework (EIF) supports standardization of data protocols to address these issues https://tips4ped.eu/.

Retrofitting existing buildings to PED standards poses technical and economic challenges. The LEGOFIT project focuses on integrating passive and active technologies in retrofits, but achieving interoperability across legacy systems remains difficult https://www.legofit.eu/. The EU Green Deal Renovation Wave stresses the importance of cost-effective retrofitting solutions to overcome these challenges European Commission, Directorate-General for Energy (2020).

To support PED replication, several policy recommendations have been derived from ongoing projects and EU policy documents. First, standardizing PED definitions and metrics across Europe is crucial, with the PED Framework by JPI Urban Europe serving as a reference for certification and quality assurance standards JPI Urban Europe / SET Plan Action 3.2. (2020). Second, promoting energy communities, as outlined in the Renewable Energy Directive of EU, will empower citizens to

produce, share, and manage energy collectively https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en. Third, flexible and adaptive regulation should be encouraged to accommodate emerging technologies and dynamic project needs, as advocated by the SPARCs project (2024). Lastly, financial incentives such as green bonds, tax credits, and co-investment funds should be expanded, with support from institutions like the European Investment Bank (EIB) and programs such as ELENA https://www.eib.org/en/products/advising/elena to help municipalities invest in PEDs.

The future of PEDs in Europe lies in integrating advanced technologies like AI, digital twins, and smart energy management systems with community-driven approaches and circular economy principles. The TIPS4PED and LEGOFIT projects are at the forefront of this integration, offering scalable solutions for energy-positive urban environments https://www.legofit.eu/, https://tips4ped.eu/. Moreover, InterPED aims to create a platform suitable for efficient scaling up and replication to other districts, with four "follower" districts already joining the project for post-project replication. Once the project is completed, local energy communities and service providers will be fully trained to take full ownership of the InterPED solution and its business ecosystem. In this way, these follower districts will be able to measure the impact of the InterPED solution on wider energy infrastructure, environment, local economy, and social aspects owing to sector coupling, increased share of RES, and improved grid operation.

The EU Green Deal and the Climate Neutral Cities Mission provide strong policy support, but addressing challenges related to regulation, financing, and technology integration will be crucial. With coordinated efforts among cities, policymakers, and technology providers, PEDs can become a cornerstone of Europe's sustainable urban future, contributing to climate neutrality and energy resilience.

Towards PED developments and outlook

Looking forward, based on projects' experience and knowledge sharing, in the context of Empowering Cities Through PEDs: Strategies and Implementation, the next big opportunity or challenge for PEDs in Europe is detailed and highlighted below for the 11 projects.

According to MAKING-CITY, facing the implementation of PEDs, our cities have had the opportunity to go further in the improvements of the energy efficiency of their buildings or maximize the energy produced there, non-limiting it only to their demand but also to produce more that can be used for creating synergies with other districts exchanging the surplus with them. Now replicate and scale these concepts to other districts, and how to articulate energy exchanges into achieving a Positive Energy City would be the next big challenge for our cities.

For ASCEND, the next opportunity for PCEDs in Europe lies in scaling and replicating successful models across diverse urban settings while ensuring financial sustainability. This includes leveraging innovative funding mechanisms such as green bonds, blended financing, and co-investment funds, alongside policy frameworks that standardize ESG ratings and incentivise sustainable investments. However, a key challenge remains in harmonising regulatory environments across countries and fostering collaboration among stakeholders to integrate PCEDs into broader urban planning.

Moreover, the next big opportunity for PEDs in Europe is using advanced data analytics and AI approaches to optimise energy flows across urban districts. AI has the potential to drastically improve PEDs by enabling better prediction, real-time management, and long-term sustainability planning. Opportunities can be found in energy demand prediction, dynamic load balancing, energy storage optimization, integrative grid management, personalised energy solutions for residents, and advanced design and simulation tools. Challenges are remaining in aspects of data privacy and security, interoperability for enhanced data exchange and communication protocols, scalability and generalisation, and high computational demands.

In parallel, for NEUTRALPATH, in contrast to the current individual approach, the district approach creates new opportunities to involve all citizens in the energy transition. The challenge here is to create innovative financing models so that it becomes financially feasible for everyone to participate in these collective projects. Social innovation to involve citizens even better in the design of collective energy solutions and PCEDs is also a challenge. However, working at the district level creates new opportunities when it comes to the scale of energy-efficient solutions. Geothermal boreholes are, e.g., not possible in an existing and dense neighbourhood but applicable on a larger scale for a district heating network. These efficiency gains and other gains, such as less noise pollution from individual air-to-water heat pumps, can ensure that the district approach becomes the preferred and most feasible scenario.

ATELIER emphasizes that PEDs have a vital role in addressing many challenges of urban energy transition. This includes not only the PED areas themselves, but PEDs can be used to support neighbouring areas of the city with their energy transition challenges as well. Issues like grid congestion weren't foreseen at the beginning of the project, but the PED concept allowed sufficient flexibility to cope with it. This demonstrates that the benefits of PEDs go far beyond simply additional RES installation. Benchmarking both technologies and business models is key to further replication and scalability. Additionally, aligning stakeholders in this process can unlock the potential for future collaboration and build capacity. One key learning has been to design PEDs to align with the long-term strategic plans for the cities.

The experiences from SPARCS emphasise the growing importance of PEDS, not only for the energy transition, but also for increasing resilience. The example of the SPARCS project partner Lviv in Ukraine shows that PEDS and

decentralised energy supply from renewables increase resilience to war attacks. But PEDS also increases resilience to extreme weather events such as heavy rainfall. In Germany, regulation is currently the biggest challenge, as it makes local energy exchange more difficult and thus hinders the use of locally produced electricity.

Based on the experiences within the POCITYF project, a great opportunity for PEDs in Europe lies in scaling their implementation to address urban energy challenges while ensuring adaptability to local contexts. PEDs can play a crucial role in mitigating grid congestion, as demonstrated in Alkmaar, by employing smart energy management systems, energy storage solutions, and peer-to-peer energy trading to optimize local energy flows. Similarly, the integration of PEDs in cities with cultural heritage, like Évora, highlights the potential to blend renewable energy innovations with historic preservation, fostering sustainable urban growth without compromising cultural identity. The primary challenge will be ensuring the replication of PED concepts across diverse cities while maintaining active community involvement and equitable access to the benefits of clean energy transitions.

Looking ahead, the next big opportunity for PEDs in Europe lies in scaling up decentralized energy communities supported by AI-driven energy management systems, enabling real-time optimization of resource sharing, storage, and demand response across districts for RENplusHOMEs. Additionally, the integration of circular economy principles, such as using recycled materials in construction, presents a pathway to enhance sustainability while addressing resource scarcity. However, a critical challenge remains in harmonizing regulatory frameworks across member states, which currently hinders cross-border collaboration and innovation. The lack of standardized metrics for assessing and Certifying PED performance further complicates implementation. Addressing these barriers will require coordinated policy efforts to streamline regulations, create consistent standards, enhance funding mechanisms, and foster public-private partnerships. Empowering cities through integrated PEDs will depend on bridging technological advancements with inclusive, community-centric approaches, ensuring that all stakeholders benefit from the transition to sustainable, PEDs.

Furthermore, for LEGOFIT, one of the most significant opportunities for PEDs in Europe will be to overcome existing knowledge gaps, particularly in the transition of existing or retrofitted buildings to PEDs, addressing technical and economic constraints, as highlighted by the LEGOFIT project. PEDs may be scaled and replicated more effectively across diverse regions by providing a comprehensive, integrated platform such as the LEGOFIT platform, which allows access to both technical and non-technical solutions, along with an agile development process and an Open Innovation Community. The next major challenges will be assuring the smooth integration of these technologies at the urban scale, addressing the difficulties of energy management at the city level, and obtaining the financial mechanisms needed to cover upfront expenses. Furthermore, PEDs' scalability will demand continuing coordination with policymakers, technology providers, and local governments to create a supportive legislative and economic environment that promotes widespread use and innovation.

In addition to the social and regulatory challenges stated above for InterPED, another great challenge that PED will have to face in Europe is data interoperability. PEDs management and their optimisation usually involve the use of smart tools that require big amounts of data for prediction and modelling. However, buildings usually either do not count on historical generation and/or consumption data, or if they have them, the granularity is not adequate for the design of these smart operation systems. Furthermore, these data from the different generation and consumption assets are also required to implement local energy trading tools, making them also necessary if market coupling is addressed, as it happens in.

Lastly, TIPS4PED, the next major opportunity for PEDs in Europe is to scale up successful models, and digital twins are set to play a pivotal role in this process. By creating digital replicas of entire districts, digital twins enable more efficient energy management and allow for better-informed decision-making. They provide real-time data that can help optimize energy use, integrate renewable energy sources, and create more sustainable, resilient urban environments. This makes it easier to adapt PED solutions to different cities with varying needs and conditions, fostering greater flexibility and scalability. However, the expansion of PEDs comes with its challenges, particularly in terms of regulatory frameworks, financial investment, and technical integration. Overcoming these barriers will require close collaboration between governments, the private sector, and local communities. Fortunately, with Europe's increasing focus on decarbonization and the EU's commitment to the Green Deal, there is strong policy support and financial backing for PEDs. In this context, digital twins represent a key technology that can drive the widespread adoption and success of PEDs across Europe, ensuring cities can meet their energy and sustainability goals.

Conclusions and next steps for collaboration

PED/PCED initiatives have emerged as a cornerstone of climate-neutral and smart urban development, tackling pressing challenges related to energy efficiency, decarbonization, and community engagement. Through a comparative analysis of 11 EU-funded projects, this paper underscores the multifaceted nature of PED implementation, from technical design to policy frameworks, and from community-lefted co-creation to innovative financing models. The 11 Eu-funded projects were brought together through panel discussions and workshops during two key events: the MAKING-CITY final event (June 13, 2024) at the Innovation Camp in Groningen, and the Sustainable Places 2024 Conference (September 25, 2024) in Luxembourg.

Despite differences in scale, geographic focus, and maturity levels, the reviewed projects converge on several critical aspects of success such as holistic integration of technologies (advanced energy solutions—ranging from district heating and cooling systems, building-integrated photovoltaics, and geothermal infrastructures to AI-enhanced digital twins and BIM platforms—have demonstrated robust potential for achieving net-positive energy balances at the district scale). Another critical aspect is community and stakeholder engagement, as meaningful citizen participation remains central to successful PED implementation. Tailored communication strategies, co-design sessions, workshops, and living labs were frequently cited as key tools for creating a sense of ownership, fostering energy literacy, and driving long-term acceptance. Flexible and Innovative Financing is discussed as a critical aspect, as well since public–private partnerships, blended financing, green bonds, and performance-based business models have proven effective. Such mechanisms mitigate risk and encourage broader participation from municipalities, private investors, and local communities alike. Regulatory alignment and policy recommendations is also commonly reported barriers—such as restrictive national laws on energy sharing, a lack of standardized PED definitions, and insufficient incentives—demonstrate the need for cohesive policy frameworks. Harmonized regulations and certification schemes at both EU and national levels would remove critical bottlenecks and accelerate wide-scale PED replication. And finally, scalability, replication, and future outlook are analysed between projects as they agree on the importance of upscaling proven solutions through digitalization, cross-border knowledge exchange, and strategic partnerships. The growing adoption of AI-driven energy systems, digital twins, and integrated urban planning tools further supports the potential for scalable replication across different European contexts.

Going forward, maximizing PED impact entails sustained collaboration among urban authorities, industry stakeholders, technology providers, and citizens themselves. Such cross-cutting partnerships will be vital in refining policy, streamlining financing mechanisms, and mainstreaming new digital technologies. Equipped with these multi-dimensional strategies and lessons learned, PEDs stand to become a fundamental vehicle for Europe's journey toward climate-neutral, resilient, and inclusive cities.

Ethics and consent

Ethical approval and consent were not required.

Data availability

ZENODO: Empowering Cities Through Positive Energy Districts: Strategies and Implementations from PED Projects of EU Climate Neutral and Smart Cities : https://doi.org/10.5281/zenodo.17497627 (Alpagut *et al.*, 2025)

DOI: 10.5281/zenodo.17497627

Underlying data

This project contains the following underlying data:

- Table 1: Comparison of Project Ambitions, Targets

Data is available under the terms of the Creative Commons Attribution 4.0 International

Acknowledgement

We hereby declare that this work has not been published elsewhere, nor is it currently under consideration for publication in any other form.

References

Alpagut B, Sirer M, Ozcan Z, *et al.*: **Empowering cities through positive energy districts: strategies and implementations from PED Projects of EU Climate Neutral and Smart Cities.** *Zenodo.* 2025.
http://www.doi.org/10.5281/zenodo.17497627

European Commission, Directorate-General for Research and Innovation: **The Strategic Energy Technology (SET) plan**. Publications Office, 2018.
Publisher Full Text

European Commission, Directorate-General for Energy: **Clean energy for all Europeans package completed: good for consumers, good for growth and jobs, and good for the planet**. 2019.
Reference Source

European Commission, Directorate-General for Energy: **A renovation wave for Europe - Greening our buildings, creating jobs, improving lives**. 2020.
Reference Source

European Commission: **Positive clean energy districts**. CORDIS-EU research results, 2022.
Reference Source

European Commission, Directorate-General for Energy: **Digitalising the energy system - EU action plan**. 2022.
Reference Source

JPI Urban Europe / SET Plan Action 3.2: **White paper on PED reference framework for positive energy districts and neighbourhoods**. 2020.
Reference Source

Olgyay V: **Designing a climate-positive future with zero-energy districts**. RMI, 2019.
Reference Source

Open Peer Review

Current Peer Review Status: ? ?

Version 1

Reviewer Report 12 March 2026

https://doi.org/10.21956/openreseurope.23005.r69409

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Summary
This paper brings together insights from eleven EU-funded projects related to Positive Energy Blocks (PEBs), Positive Energy Districts (PEDs), and Positive and Clean Energy Districts (PCEDs). The projects were presented and discussed at two events: the MAKING-CITY final event in Groningen (June 2024) and the Sustainable Places 2024 Conference in Luxembourg (September 2024). The paper is structured around four thematic questions (community engagement, economic models, technological innovation, and policy recommendations) and concludes with reflections on replication potential and future outlook. The work represents a valuable effort to consolidate cross-project experience and facilitate knowledge transfer between EU research and innovation initiatives. However, several methodological, structural, and presentational shortcomings need to be addressed before the paper can be considered fully scientifically sound.

1. Clarity and Accuracy of Presentation / Literature Citations
The paper is generally readable and the narrative descriptions of the eleven projects are informative. However, the presentation has notable weaknesses:

- The state-of-the-art section reads more as a general narrative based on the authors' own views rather than a documented, referenced overview of EU-wide PED development. It should either be rewritten as a properly referenced literature review or clearly reframed as the authors' perspective.
- The citation of references is uneven: some claims are well supported, while others (particularly in the state-of-the-art and replication sections) lack specific citations or rely on general policy documents without adequate contextualisation.
- The introduction states that this is a "comprehensive review," which overstates the scope. With only eleven projects analysed, the term "comprehensive" is misleading and should be removed or replaced with more accurate language such as "selected" or "illustrative."
- All eleven project names should be listed explicitly in the introduction, rather than requiring the reader to search through the full text to identify them.

2. Study Design and Academic Merit

The paper has clear value as a practice-oriented knowledge exchange document, and the use of structured questions across projects is a sound methodological choice. However, several issues reduce its academic rigor:

- The methodology section is brief and insufficiently detailed. The process by which projects were selected, how the panel discussions were structured, what the moderation approach was, and how responses were collected and validated are not described. This makes it impossible to assess potential biases in project selection or response interpretation.
- The responses to the four questions are presented narratively but not systematically compared. A structured thematic analysis, ideally supported by a comparison table with sub-indicators or thematic categories, would significantly strengthen the analytical contribution and make patterns across projects easier to identify.
- The paper would benefit from an early-stage clusterisation of projects based on their objectives, scale, maturity level, or thematic focus. While Table 2 addresses project phases, a more nuanced typology would help contextualise the varied responses.
- The concept of PED sister projects is introduced without prior explanation. A brief clarifying section on what this term means and how these relationships were established would improve comprehension.
- The repeated use of the phrase scalable logic is conceptually imprecise. The transition towards PEDs involves broadening stakeholder involvement and multi-level governance, not merely scaling a technical model. More appropriate terminology would be widening participation, broadening governance, or expanding stakeholder engagement.

3. Methods and Replicability
The paper does not provide sufficient methodological detail to allow the study design to be replicated. Specifically:

- The criteria and process for inviting the eleven projects are not stated.
- The format of the workshops and panel discussions is only briefly described.
- It is unclear how individual project responses to the four questions were gathered, whether through written submissions, oral presentations, or post-event synthesis by the authors.
- The roles and identities of the individual contributors to each project's responses are not specified, making it difficult to assess the representativeness of the perspectives shared.

These gaps should be addressed by expanding the methodology section with a clear description of the data collection process, participant roles, and any validation steps undertaken.

4. Source Data and Reproducibility
The underlying data are deposited on Zenodo (Table 1: Comparison of Project Ambitions, Targets), which is commendable. However, the deposited dataset appears limited to a single comparison table. The responses to the four thematic questions, which constitute the core empirical content of the paper, do not appear to be available in a structured, reproducible form. The authors should consider whether additional underlying data (e.g., anonymised workshop notes, written project contributions) can be made available or at least described more explicitly.

5. Adequacy of Conclusions
The conclusions are broadly reasonable and reflect the content of the paper, but they overreach in some areas:

- The claim that PEDs are "a cornerstone of climate-neutral and smart urban development" is an overgeneralisation. Cities may pursue climate neutrality through diverse pathways, and

PEDs represent one important approach among several. This framing should be softened accordingly.
- The conclusion that tools and knowledge lead to successful replication is too deterministic. Tools and knowledge can support and inform replication, but success depends on many contextual factors. This should be rephrased to reflect the enabling rather than deterministic role of such resources.
- Several conclusions, particularly those regarding financial models and community engagement, are well-grounded in the project narratives. The conclusions on policy recommendations are also reasonable, though they would benefit from more explicit cross-project comparison to support the generalisations made.

Summary of Required Revisions
- Expand the methodology section to allow assessment of study design and replication.
- Replace the current state-of-the-art section with a properly referenced literature review, or clearly reframe it as the authors' perspective.
- List all eleven projects explicitly in the introduction.
- Add a clusterisation or typology of projects early in the paper.
- Introduce and contextualise the concept of PED sister projects.
- Replace scalable logic with terminology reflecting broadened stakeholder engagement.
- Add a structured comparison table with thematic sub-indicators for the four key questions.
- Soften the generalisation of PEDs as the cornerstone of climate neutrality.
- Rephrase the claim that tools and knowledge directly lead to replication success.
- Clarify data availability beyond Table 1 to strengthen reproducibility.

These revisions would substantially improve the methodological rigour, conceptual accuracy, and overall scientific quality of the manuscript.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
No

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Energy modeling

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 24 December 2025

https://doi.org/10.21956/openreseurope.23005.r65152

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1. Alignment of PED/PEB/PCED Definitions
The manuscript presents a definition of **Positive Energy District (PED)** that is not aligned with standard and widely recognised definitions adopted by SET-Plan Action 3.2, DUT Partnership, JPI Urban Europe, the International Electrotechnical Commission (IEC), and the EEIBC initiative. The authors should revise the definition using official sources and provide proper references, including the date of access for any online material.
2. Incorrect Use of the Term "Scalable Logic"
The repeated use of the term "scalable logic" is conceptually inaccurate. Transitioning towards Positive Energy Districts requires widening the involvement of stakeholders and ensuring multi-level governance, rather than simply scaling up a technical or organisational model. The manuscript should replace all references to "scalable" with more appropriate terminology such as "broadening", "widening participation", or "expanding the governance framework".
3. Inconsistency Between Title and Content
The manuscript addresses three related concepts—Positive Energy Buildings (PEB), Positive Energy Districts (PED), and Positive Clean Energy Districts (PCED). For this reason, **the title should be revised to clearly reflect the scope.** The current title does not adequately match the content. Here a couple of possible options which are aligned with the text:

- “Perspectives on PEB, PED and PCED Development: Learnings from xxxxx European Projects”
- “Exploring PEB, PED and PCED Concepts: Insights from EU Research and Innovation Projects”
- “Understanding PEB, PED and PCED Pathways: A Thematic Analysis of EU Project Experiences”

4. Incorrect Claim of a "Comprehensive Review"
The review cannot be considered comprehensive due to the limited number of projects analysed. The term "comprehensive" should therefore be removed.
5. Misleading Sentence on Tools and Knowledge
The manuscript states or implies that tools and knowledge directly lead to successful replication.

This is not accurate. Tools and knowledge can inspire, inform, and support decision-making, but they do not directly guarantee successful replication of solutions. The sentence should either be removed or rephrased to reflect this nuance.

6. Incomplete List of Projects

The manuscript mentions eleven projects in the introduction, but it is necessary to read the full article to discovered which projects are considered. It must be declared in the introduction the name of the projects and not the link. Moreover just one link provided only six projects (MAKING-CITY, RENplusHOMES, PED-ACT, InterPED, SPARCS, ASCEND). Then there is not a clear indication on the type of projects in Horizon Europe as well as refence to the call for proposals which is very important information for the clusterization (anyway missing) of each project.
The authors should list all eleven projects explicitly and ensure consistency between the number reported and the number referenced.

7. Missing Clarification of Project Aims

A key missing element in the early part of the manuscript is a concise identification of the aim of each project. Although they may appear to follow a similar overarching goal, the focus areas differ significantly. A clusterization of projects based on their objectives, methodologies, or thematic areas should be introduced early in the article.

8. Lack of Reference to PED Sister Projects

The manuscript abruptly introduces the concept of PED sister projects without prior contextualisation. A short explanatory section is needed to describe what PED sister projects are and how they relate to the discussion.

9. Misleading Title and Lack of Documented State-of-the-Art

The section presented as a "state of the art" does not reflect a documented EU-wide overview of Positive Energy District development. Instead, it presents the authors' own interpretations and reflections. This must be clearly stated, or the section should be replaced with a properly referenced state-of-the-art review.

10. Insufficient Documentation and Lack of Comparative Analysis

The responses provided in the manuscript are not well documented or systematically compared. Since the participants' identities and roles are not specified, interpretation becomes unclear. A structured comparison—ideally through a table including sub-indicators or thematic categories—would significantly improve the analytical quality.

11. Inconsistent Answers and Need for Sub-Categories

The answers to the four guiding questions vary significantly between contributors. Without sub-categories or thematic groupings, the material remains anecdotal. A categorised approach is essential to give structure and meaning to the collected insights.

12. Incorrect Generalisation of PEDs as a Cornerstone of Climate-Neutrality

The manuscript incorrectly suggests that PEDs are a cornerstone of climate-neutral and smart urban development. Since cities may adopt diverse pathways towards climate neutrality, PEDs represent one possible pathway, but not a universal cornerstone. This sentence should be removed.

13. Summary of Required Revisions

- Align all definitions with recognised standards and provide full citations.
- Replace all uses of "scalable logic" with terminology that reflects widening or broadening stakeholder involvement.
- Adjust the title to reflect coverage of PEB/PED/PCED.
- Remove the term "comprehensive" when referring to the review.

- Rephrase or delete the misleading sentence regarding tools and knowledge.
- Provide all eleven project names consistently.
- Add early-stage project clusterisation.
- Introduce and explain PED sister projects.
- Replace or revise the state-of-the-art section to reflect documented EU knowledge.
- Add comparison tables with sub-indicators.
- Remove generalisations portraying PEDs as the sole cornerstone of climate-neutrality.

This set of revisions is necessary to ensure conceptual clarity, methodological rigour, and alignment with internationally recognised terminology and frameworks.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
No

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
No

Are the conclusions drawn adequately supported by the results?
No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: PED Pathway co-chair in DUT Partnership; vice-chair IWG 3.2 SET-Plan; support to IEC PED

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.