

Article

A Qualitative Methodology for Identifying Governance Challenges and Advancements in Positive Energy District Labs

Silvia Soutullo ^{1,*}, Oscar Seco ^{1,*}, María Nuria Sánchez ¹, Ricardo Lima ², Fabio Maria Montagnino ³, Gloria Pignatta ⁴, Ghazal Etminan ⁵, Viktor Bukovszki ^{6,7}, Touraj Ashrafian ⁸, Maria Beatrice Andreucci ⁹, and Daniele Vettorato ¹⁰

¹ Renewable Energy Division, CIEMAT, 28040 Madrid, Spain; nuria.sanchez@ciemat.es

² Laboratory for Energy Systems, IMPACT, HEPIA, University of Applied Sciences and Arts of Western Switzerland, 1202 Genève, Switzerland; ricardo.lima@hesge.ch

³ STeDI—Research Centre, The Cyprus Institute, 2121 Nicosia, Cyprus; f.montagnino@cyi.ac.cy

⁴ School of Built Environment, University of New South Wales (UNSW), Sydney 2052, Australia; g.pignatta@gmail.com

⁵ Austrian Institute of Technology (AIT), 1210 Vienna, Austria; ghazal.etminan@ait.ac.at

⁶ Advanced Building and Urban Design Ltd., 1139 Budapest, Hungary; bukovszki.viktor@abud.hu

⁷ School of Life Sciences, Technical University of Munich, 85354 Munich, Germany

⁸ Department of Architecture and Built Environment, Faculty of Engineering and Environment, Northumbria University, Newcastle Upon Tyne, Newcastle NE1 8ST, UK; touraj.ashrafian@northumbria.ac.uk

⁹ Department of Planning, Design, Technology of Architecture, Sapienza University of Rome, 00196 Rome, Italy; mbeatrice.andreucci@uniroma1.it

¹⁰ EURAC Research, Institute for Renewable Energy, 39100 Bolzano, Italy; daniele.vettorato@eurac.edu

* Correspondence: silvia.soutullo@ciemat.es (S.S.); oscar.seco@ciemat.es (O.S.)

Abstract

Governance challenges, success factors, and stakeholder dynamics are central to the implementation of Positive Energy District (PED) Labs, which aim to develop energy-positive and sustainable urban areas. In this paper, a qualitative analysis combining expert surveys, participatory workshops with practitioners from the COST Action PED-EU-NET network, and comparative case studies across Europe identifies key barriers, drivers, and stakeholder roles throughout the implementation process. Findings reveal that fragmented regulations, social inertia, and limited financial mechanisms are the main barriers to PED Lab development, while climate change mitigation goals, strong local networks, and supportive policy frameworks are critical drivers. The analysis maps stakeholder engagement across six development phases, showing how leadership shifts between governments, industry, planners, and local communities. PED Labs require intangible assets such as inclusive governance frameworks, education, and trust-building in the early phases, while tangible infrastructures become more relevant in later stages. The conclusions emphasize that robust, inclusive governance is not merely supportive but a key driver of PED Lab success. Adaptive planning, participatory decision-making, and digital coordination tools are essential for overcoming systemic barriers. Scaling PED Labs effectively requires regulatory harmonization and the integration of social and technological innovation to accelerate the transition toward energy-positive, climate-resilient cities.

Keywords: positive energy districts (PEDs); urban living laboratories (ULLs); urban energy transition; sustainable urban development; renewable energy integration



Academic Editor: Jianming Cai

Received: 28 May 2025

Revised: 9 July 2025

Accepted: 18 July 2025

Published: 23 July 2025

Citation: Soutullo, S.; Seco, O.; Sánchez, M.N.; Lima, R.; Montagnino, F.M.; Pignatta, G.; Etminan, G.; Bukovszki, V.; Ashrafian, T.; Andreucci, M.B.; et al. A Qualitative Methodology for Identifying Governance Challenges and Advancements in Positive Energy District Labs. *Urban Sci.* **2025**, *9*, 288. <https://doi.org/10.3390/urbansci9080288>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

To address the challenges generated by climate change and the rapid urbanization in densely populated regions, it is necessary to develop urban frameworks that allow reversing energy and environmental trends while reducing existing inequalities. A growing body of evidence indicates that even the most celebrated “frontrunner” cities are struggling to meet their own targets, revealing a persistent implementation deficit [1]. New urban models oriented toward a successful energy, economic, social, and environmental transition are needed [2–4]. Under this context, different governance initiatives are being proposed, mainly under two dominant theoretical paradigms of Transition Management and Polycentric Governance, which offer distinct yet complementary perspectives on how to conceptualize and organize the complex process of governing systemic change. The Transition Management approach provides a prescriptive, goal-oriented roadmap and governance frameworks such as the Climate City Contracts and local experimental governance setups [5]. On the other side Polycentric Governance offers a descriptive lens for understanding the multi-actor, multi-level reality in which any such roadmap must be navigated, as well as a way to address the key challenges in its implementation at the different scales: (i) stewarding capacity, (ii) unlocking capacity, (iii) transformative capacity, and (iv) orchestrating capacity [6].

Urban Living Laboratories (ULLs) represent one of the most interesting initiatives in the context of Polycentric Governance of urban climate transitions, which focuses on co-developing urban solutions in a multi-stakeholder dialog and under real conditions of use [7]. These labs represent a crucial step in learning how to design inclusive, sustainable, and climate-resilient urban environments [8], and embody an experimental governance model that facilitates the evaluation of different solutions in a real life, user centric setting, and the co-development of enhancements. Ultimately, they are designed to create a collaborative environment where various stakeholders can explore, develop, and experiment with solutions to urban challenges, all while involving local communities [9].

Their innovative approach to urban development and public–private partnerships steps beyond the traditional approach of implementing sandboxes and testbeds for innovative technologies in the urban fabric. It substantially underscores the need for adaptability, transparency, and informality in their processes, as well as the central role of citizens from the design to the uptake and evaluation phase. As a result of an appropriate setup, they can generate highly valuable insights that would inform decision making for city stakeholders. The innovation drivers in these projects stem from agglomeration effects and multi-actor engagement, where innovation activities cluster around living urban initiatives. However, these effects might not be evenly distributed, nor consistently beneficial for all participants [10]. The innovation process within ULLs is typically iterative, involving cyclical stages of development, testing, and refinement based on ongoing feedback and evaluation. There is a strong focus on learning and experimentation, with ULLs intentionally integrating processes of both research and innovation to generate new knowledge and effective solutions. Ultimately, urban living labs are designed to address a wide range of urban challenges, encompassing social, economic, and environmental issues that cities face on their path towards sustainable development. Authors explore the application of living labs to foster gendered energy technology innovation in impoverished urban settings [11], the establishment of new welfare spaces, and other social challenges [12,13].

Challenges and dilemmas associated with strategic urban experimentation have been assessed through a review of the literature on socio-technical systems, alongside insights from transdisciplinary research on living labs [14]. It has been envisaged the opportunity of combining the ULL approach with comprehensive urban transitional strategies, with the aim of functionalizing the ULL approach towards the achievement of specific socio-

technical transitions in the urban environment, specifically supporting zero emission targets [15].

While much of the current literature and practical application of ULL originates from Europe, emerging experiences in Asia, the Americas, and Oceania demonstrate how these frameworks are adapted to these local socio-economic, climatic, and technological contexts. Initiatives such as the Urban Living Lab Center support low-carbon development by fostering capacity building and scaling urban innovations across sectors like energy, mobility, and digitalization. Through regional hubs in Asia, Africa, and Latin America, they promote collaborative urban transformation, linking training, research, and practical implementation [16].

In Asia, Japan's SolarEV City [17] integrates solar energy and electric vehicle infrastructures in dense urban areas, enhancing distributed energy storage and grid interaction [18]. Taiwan's initiatives in 'Smart Taipei' show the development of PED site-selection criteria tailored to local urban morphology and energy consumption patterns [19]. In South Korea, the Seongdaegol living lab, EnergyX DY-Building, and the Ulsan Hydrogen Town showcase different energy carriers (electric and hydrogen) within PED-like frameworks [20,21]. In China, smart city pilot policies have demonstrated significant progress in fostering green urban development through the deployment of digital infrastructures, industrial upgrading, and innovation-driven agglomeration effects, although regional heterogeneity persists due to variations in economic and technological capacity [22].

In the Americas, Canada offers well-documented cases such as the Drake Landing Solar Community, a district that achieves 100% solar space heating through seasonal thermal storage [23]. Montreal's Positive Energy District synergizes with Urban-Industrial Symbiosis principles [24], creating integrated energy flows between residential and industrial buildings [25]. West Five, an energy-positive community in Ontario, Canada, is designed to achieve net-zero energy by integrating residential, office, and retail spaces with renewable energy systems, including a micro-utility and solar PV installations. EVE Park initiative features 84 all-electric homes powered by solar energy and supported by battery storage systems, serving as a Canadian pilot for sustainable energy communities and innovative regulatory frameworks [26]. In Latin America, key examples of urban laboratories include Mexico City's Laboratorio para la Ciudad [27], which focuses on mobility and urban sustainability, and Chile's Laboratorio de Gobierno [28], dedicated to transforming public services through design thinking. Grassroots initiatives such as Arquitectura Expandida in Bogotá [29], community-led renewable energy projects like Argentina's Cauchari-Olaroz solar complex and Amazonian indigenous solar cooperatives [30], as well as Laboratorio Procomum in Brazil and Casa Gallina in Mexico City, add a cultural and environmental dimension to urban lab practices [31]. Together, these initiatives illustrate diverse approaches, ranging from government-led innovation to citizen-driven social experimentation.

Oceania hosts a growing number of urban living labs where innovative solutions for sustainable energy, mobility, and urban development are tested in real-world settings. These collaborative environments bring together government, academia, industry, and local communities to co-create and implement low-carbon urban systems. Projects such as CSIRO's Urban Living Labs [32], Monash University's Net Zero Precinct Living Lab [33], and the Lot Fourteen Innovation Hub [34] demonstrate the potential of precinct-scale innovation, integrating renewable energy, smart mobility, and circular economy principles, fostering partnerships between start-ups, research institutions, and public agencies to advance smart city technologies. Complementing these efforts, Australia's Regional Australia Microgrid Pilot Program (RAMPP) and Byron Bay's community microgrids reflect a resilience-driven approach, combining solar generation, energy storage, and community

ownership in remote and regional areas [35]. Collectively, these living labs contribute to the region's transition towards energy-positive, climate-resilient urban environments.

Several urban strategies tailored to the local context can be assessed, creating a comprehensive map of solutions to tackle the climatic and energy challenges facing cities. Current literature presents various concepts related to climate-friendly neighborhoods, including Zero Emission Neighborhood [36], Nearly Zero Carbon Neighborhood [37], Net Zero Energy districts [38], Zero Energy District, Smart Energy Community, and Positive Energy District (PEDs) [39,40]. The latter concept, introduced by Set Plan Action 3.2 [41], encompasses three topics related to energy: flexibility, efficiency, and production [42]. The implementation, analysis, and optimization of innovative urban solutions in PEDs can highly benefit of the availability of flexible living laboratories, equipped to monitor and quantify urban fluxes, that would facilitate synergies among different urban factors such as energy, social, economic or governance [43], thus resulting into effective Positive Energy District Labs (PED Labs).

PED Labs are collaborative spaces where people work together to create neighborhoods that produce more renewable energy than they use over a year. These labs bring together researchers, city planners, businesses, and residents to test new ideas and technologies in real cities. Instead of focusing on traditional lab equipment, they prioritize teamwork and real-world experiments, like trying out solar energy systems or smart grids in actual urban areas. They also share lessons learned and help shape policies to make it easier for other cities to adopt similar solutions [44]. PED Labs use digital tools, like computer simulations or virtual models, to plan and test ideas before implementing them. While some PED Labs have physical locations, their main goal is to connect people and ideas, not just buildings. Virtual PED Labs [45] take this further by allowing remote collaboration and digital experiments, making it easier for experts worldwide to participate [46]. This virtual PED concept allows for expanding the area of energy generation and storage, as it is not subject to geographical boundaries, increasing its flexibility and autonomy through a greater number of energy market players involved [47].

Within this study framework, this paper tackles the lack of a consolidated definition of PED Labs and improves, through the reasoned selection of key practices, the overall approach to their adoption as a strategic tool to accelerate the deployment of effective PEDs. This work falls within the activities of Working Group 3 (WG3)—‘PED Labs, Monitoring and Replication’ of the COST Action CA19126 or Positive Energy Districts European Network (PED-EU-NET) [48]. Specifically, the process of reviewing existing concepts, projects, and facilities relevant to PED Labs, as well as mapping their current landscape, has been carried out in Task 3.1, resulting in the ability to position this concept in the international debate and generating key research questions related to its development and implementation across Europe and beyond.

Although the literature on PEDs and ULLs has expanded, significant gaps remain. Most research focuses on conceptual frameworks, technical definitions, and normative goals, while empirical insights on the specific implementation of PED Labs are limited. Existing case studies are scarce and often highlight best-case scenarios without critically analyzing their limitations, failures, or contextual challenges. As a result, how experimental, real-world PED Lab settings help overcome implementation barriers, and how these models can be transferred across diverse socio-economic, climatic, and regulatory contexts remains underexplored. The literature lacks comparative empirical studies, critical assessments of failures, detailed analysis of governance dynamics, and a consolidated definition or operational framework for PED Labs.

The main objective of this article is to identify the key aspects (challenges, barriers, stakeholders, and driving factors) that must be considered in the implementation process

of PED Labs. To this end, a qualitative analysis based on surveys and subsequent analyses was conducted, addressing the following research questions:

- What are the current barriers to the implementation of PED-Labs?
- What are the drivers and incentive factors (‘unlocking factors’) that determine the “fertility of the soil” for PED-Lab initiatives?
- What processes and actors define the steps, power relationships, and subsidiarity in responsibilities and decisions within PED Lab initiatives?

The methodology applied in this study enables the identification of the main elements that define a PED Lab, the conditions for successful implementation, existing gaps, and the key actors involved at each stage of the process. The study also proposes a consolidated definition of PED Labs, maps their current landscape, and highlights key barriers, drivers, and stakeholder roles. By positioning PED Labs as strategic tools for energy transitions, the research addresses gaps in empirical evidence and governance analysis. This work contributes to the standardization of PED Lab models and offers practical guidance for cities, researchers, and practitioners aiming to implement or replicate such initiatives. Through a critical evaluation of existing efforts, it advances the understanding of PED Labs as catalysts for positive energy transitions in diverse urban contexts.

2. Methods

The qualitative analysis employed in this study aims to understand certain phenomena and characteristics related to PED Labs. A dynamic and flexible methodology was applied in phases: survey preparation, data collection, analysis, and interpretation of findings. The first step involved designing and administering structured questionnaires to expert focus groups. Data collection methods were subsequently defined through online questionnaires and group discussions, enabling the gathering of subjective and detailed insights through collective reflection on the topics discussed. Once the databases were created, the information was coded and processed, providing results on barriers, incentive factors, key stakeholders, and the characteristic facilities of these laboratories. This analysis allowed the current state of PED Labs to be mapped, identifying their strengths and weaknesses through a SWOT matrix, and addressing the proposed research questions. As a final outcome, a series of recommendations has been proposed to guide the development and future replication of PED Labs. These steps were essential to gather and synthesize practical knowledge, draw on diverse stakeholder experiences, and contribute to the conceptual development of the PED Lab model.

In parallel, a review of existing literature, EU-funded projects, and case studies was conducted to frame the PED Lab concept in a broader international and academic context. This ensured that findings from focus groups could be cross-referenced and validated against existing knowledge.

The entire methodology reflects an overview of an evolving field, where limitations relate mainly to the terminological ambiguity around PEDs and PED Labs across regions and disciplines, and the early-stage development of many initiatives. Additionally, participation in focus groups was voluntary, which may have introduced selection bias or incomplete coverage in the data collection. All participants are members of the COST Action CA19126 working groups.

Figure 1 presents a schematic representation of the participatory methodology implemented in this study, with each of the three main steps detailed in the subsequent subsections. The following sections of this article present the main results, answer the research questions posed in the introduction, propose recommendations, and outline the study’s limitations.

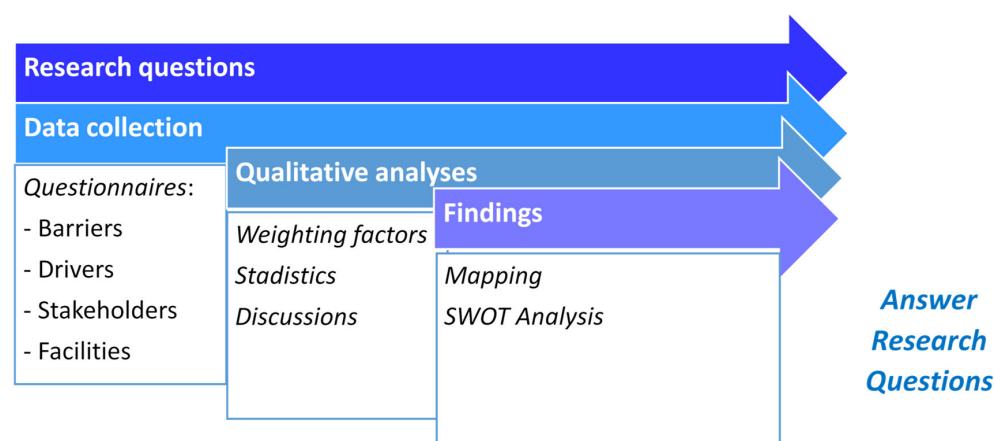


Figure 1. Diagram of the methodology implemented in this research.

2.1. Questionnaire Development and Data Collection

The generation of these questionnaires followed an iterative process based on literature and active participation of the WG3 expert group. The first step consisted of analyzing the experiences and outputs generated by different European projects on Smart Cities and Climate Neutral Cities, such as SINFONIA [49] or Cities4PEDs [50], and European initiatives like the CONCERTO Program [51] or the DUT partnership [52]. This process allowed for the development of several sets of questions about barriers, incentives, and stakeholders. Subsequently, several workshops were held within the activities of WG3 to update, adapt, and classify the questions proposed to the PED Lab concept. Numerous international initiatives have been working on Positive Energy Districts for years, although only recently has a database been developed to compile information on both PEDs and PED Labs [53]. This new PED database was created thanks to the collaboration between COST Action CA19126 [48], JPI Urban Europe [54], and Annex 83 of the EBC of the IEA [55]. Once the questions were adapted to the PED Lab environment, the questionnaires were presented to the WG3 expert group, gathering the necessary data to conduct this qualitative study.

The 30 PED laboratories registered in the Cost Action Database, located throughout Europe, were used as case studies for this research. (see Figure 2). This sample covers a wide range of European climates, encompassing regions from the south (Spain and Italy), the center (Netherlands and Belgium), and the north of Europe (Finland and Estonia). It also encompasses different contexts, such as social housing blocks, energy districts, and virtual laboratories. Identifying the main characteristics of these laboratories and evaluating the existing literature on these emerging urban concepts enabled the development of a series of questions for the questionnaires. These questions were selected to identify the key positive and negative factors influencing the implementation of PED Labs, according to the experience and opinions of the participants. More information about the questionnaires can be found in deliverable T3.1 of WG3 of Action Cost CA19126 [56].

The questions were initially coded around three thematic areas: (i) barriers to PED Lab implementation; (ii) drivers and unlocking factors enabling their success; and (iii) key stakeholders involved in their development and operation. Subsequently, another set of questions was designed and implemented, coded as facilities, with the objective of gathering information on the facility assets required for the operation of these laboratories.

To gather information on existing PED and PED Lab initiatives, several online workshops and interactive sessions were held with an average of twenty expert participants from the WG3—Task 3.1 network. The process was divided into two phases: (i) completion of online questionnaires using collaborative tools such as MURAL, and (ii) follow-up group discussions to validate and refine questionnaire results and build consensus.



Figure 2. Map of PED Labs and PED Relevant Case Study distributed in Europe available in the Cost Action CA19126 Database [53].

To obtain relevance-weighted responses on these issues, participants were asked to:

- Approve and refine a proposed list of items in each of the three proposed thematic areas, suggesting groupings and modifications where necessary.
- Rate each item using a Likert scale from 1 (low relevance) to 5 (high relevance).
- Participate in facilitated discussions to interpret questionnaire results collectively and identify key learnings.

The qualitative analysis was structured around four main topics: barriers, drivers, stakeholders, and facilities, which were further divided into more specific categories. This coding of the questionnaire data allowed, on the one hand, the grouping of information to identify patterns or trends, and on the other, the development of a holistic understanding of these laboratories. Figure 3 shows the four topics coded in the questionnaires, schematically highlighting the key aspects to be considered within each.

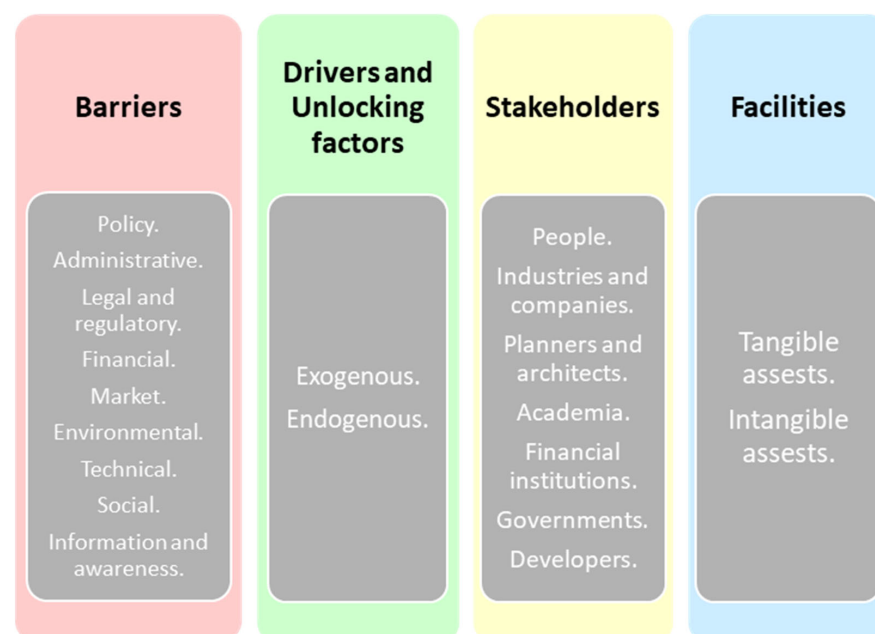


Figure 3. Scheme of the key aspects considered in the four thematic areas coded for the questionnaires.

2.1.1. Barriers

A series of questions was developed to identify the key aspects that hinder or block the implementation and development of PED Labs. These questions were formulated based on the existing literature on Smart Energy Cities projects [57–59] and were subsequently adapted, updated, and ranked based on feedback from a WG3 workshop involving eighteen experts from COST Action PED-EU-NET. In this workshop, it was assumed that the barriers to implementing a Smart Energy City are similar and scalable to those encountered in the PED Lab context. Nine categories of barriers (i.e., policy, administrative, legal and regulatory, financial, market, environmental, technical, social, and information and awareness) were proposed to the WG3 participants, resulting in fifty-one targeted questions.

2.1.2. Drivers and Unlocking Factors

Additional questions were designed to identify the key factors that drive the adoption of PED Lab initiatives or establish favorable conditions for their implementation and development. These questions were derived from the literature on Smart Cities and Urban Laboratories [60–62]. For analytical clarity and based on the area of action, the factors were classified into two categories, which are drivers and unlocking factors. Drivers are the key elements that motivate the initiation and execution of a laboratory, while unlocking factors are conditions that enhance or improve the initial environment, thereby facilitating the deployment of these urban laboratories.

2.1.3. Stakeholders and Processes

The successful implementation of PEDs requires the collaboration of diverse stakeholders, necessitating systematic methods for identifying and engaging these groups throughout different development phases. Cheng et al. [63] proposed a stakeholder mapping framework that addresses dynamic roles at the building, district, and city levels and suggests incorporating managerial tools into the PED development toolbox. Other interview-based studies have assessed stakeholders' perceptions regarding energy vulnerability mitigation through PEDs, thereby promoting a more inclusive transition in urban areas [64]. However, harmonizing design phases, stakeholder interests, and scales can be challenging due to their frequent intersections. In practice, these elements are interconnected at critical decision-making moments, known as “intervention points”, where it is essential to identify the key stakeholders and the appropriate tools for engagement [65].

Similarly, further questions were sought to identify the main actors and processes involved at each stage of deploying PED Labs. In these questionnaires, six subsequent phases were identified: vision, decision, planning, execution, evaluation (check/act), and scaling and replication. Additionally, seven stakeholder groups were considered: people, industries and companies, planners and architects, academia, financial institutions, governments, and developers. The classification of stakeholders was built on the types of stakeholders commonly discussed in the PED literature. This follows either a taxonomical or functional approach. Taxonomical approaches identify stakeholder sectors, usually including community, market/private, policy/public sectors [66], in many cases supplemented by the research/academic sector [4]. The market sector can be broken down to energy providers, technology developers, while the community sector may include a citizen and an NGO subgroup [67]. The functional approach specifies roles justifying stakeholder engagement [68]. Property owners, energy system operators, potential local energy producers, and potential flexibility providers as key target groups to engage early on [69,70]; urban planners, representatives from different levels and departments of governments can act as important catalysts, and residents, researchers and technical experts are important to consult to ensure best fit and legitimacy in local contexts [71,72]. As the specific list

of stakeholder types will vary from project to project [66], we opted for a taxonomical approach, using a functional approach to identify categories that will likely show different required levels of engagement, with the categories shown in Table 1.

Table 1. Stakeholder categories and actor types involved in the PED Lab implementation process.

Stakeholder Category	Stakeholder Type
Community	Residents, citizens, property owners, energy communities, and neighborhood organizations
Financial	Investors, banks, funding providers, and financial institutions
Industry	Technology providers, grid operators, energy providers, and private companies
Planning	Urban planners, architects, and consultants
Research	Universities, research institutions, and research-performing private companies
Policy	Local and national authorities, public administrations, and local and national governments
Developer	Real estate, asset, and portfolio developers and managers

2.1.4. Facilities

The design or replication of a PED Lab requires identifying the types of facilities necessary for its proper operation. Based on existing literature and the expertise of the participating professional group, this question was addressed by categorizing facilities into two groups: tangible and intangible assets. Tangible assets refer to elements that enable the physical transformation of a district (i.e., structures and infrastructure), while intangible assets relate to the transformation of non-physical components (i.e., society, knowledge, behavior, economy, or skills). Based on this, the questionnaire focused on three key aspects:

- The specific role of these facilities in the development of a PED Lab.
- Identification of tangible (hardware) and intangible (software) assets.
- Creation of a comprehensive list of facilities.

2.2. Qualitative Analysis

The second step involved a comprehensive qualitative analysis of the responses obtained from the questionnaires. Once the response database was generated, the data were systematically coded to identify convergence or divergence in expert opinion and to map the interconnections among barriers, drivers, and stakeholder roles. This process resulted in a classification of these laboratories' facilities based on tangible and intangible assets and stakeholder roles, as well as a SWOT matrix identifying the most positive and negative aspects of the implementation process. Other previous studies, also based on an approach using SWOT matrices, delve into identifying the key contextual factors for transforming districts in Latin America and the Caribbean [73].

These analyses were enriched by collaborative discussions held during multiple WG3 meetings under COST Action PED-EU-NET [48], ensuring that diverse perspectives were represented. This qualitative approach facilitated the identification of primary challenges faced by PED Labs and informed the subsequent development of targeted research questions.

2.3. Findings

The starting point for this methodology was the 30 relevant cases and laboratories from the Cost Action database [53], classified into four categories according to their implementation phase. An evaluation of their characteristics made it possible to identify the most relevant topics to be addressed in the questionnaires. Table 2 shows the classification of these laboratories and highlights some of their key characteristics.

Table 2. Classification of PED Labs and PED relevant cases from the Action Cost PED Database, indicating some of their peculiarities [53].

Phase	Number	Characteristics
Planning	12	Many of the PED Labs are planned within the framework of European projects targeting energy goals, climate neutrality, or inequality reduction. They leverage public–private partnerships and require more tailored regulations, broader stakeholder involvement and dissemination, and the simplification of certain administrative procedures.
Implementation	12	Several have been developed within European projects aimed at increasing energy efficiency and sustainability while reducing vulnerabilities. They leverage reduced material and technology costs and greater short-term stakeholder engagement. They require simpler, better-coordinated administrative procedures, more robust medium and long-term plans, and well-developed economic models.
Completed	1	Rehabilitated suburban area in Trento (Stardust project), which leveraged existing financing and economic models to improve energy efficiency and sustainability. It requires ongoing funding and stakeholder involvement to ensure the proper maintenance of the facilities in the future.
In Operation	5	Real, virtual, and semi-virtual laboratories (some also developed within European projects) operate through various funding sources. Require effective coordination, greater stakeholder engagement, and sustained funding to operate with updated facilities.

Once the surveys were developed, conducted, and processed, the final step of this methodology was to identify the main findings. To this end, the results were initially mapped to detect trends, peaks, or gaps, enabling the creation of categorized lists. The findings were then structured to highlight existing problems and challenges, as well as available resources and the essential requirements for the successful operation or replication of a PED lab. These aspects were organized using a SWOT matrix, which identifies strengths, weaknesses, opportunities, and threats. To develop this matrix, participants analyzed different laboratories listed in the COST Action CA19126 PED database [53], drawing on the collective experience and knowledge of professionals highly committed to PED initiatives across Europe. This database was specifically designed and developed to map PEDs, PED Cases, and PED Labs, supporting the identification of the most relevant characteristics of these urban structures and enhancing understanding of their development and operation.

3. Results

This section presents the outcomes obtained from the questionnaires, qualitative discussions, and WG3 workshops held in the framework of COST Action PED-EU-NET [49].

The first four Sections 3.1–3.4, present the details of the analysis performed on the identified barriers, drivers, unlocking factors, stakeholders, and facilities, respectively. The following Section 3.5 presents a SWOT analysis that synthesizes the internal strengths and weaknesses, as well as external opportunities and threats, associated with PED Lab development. Once all the information generated has been processed, and after a process of discussion and analysis, the research questions proposed are answered. These questions capture the main identified challenges and gaps and serve as a roadmap for future research on the implementation, evaluation, and replication of PED Labs.

3.1. Analysis of Barriers

Drawing on the survey data and collaborative discussions, the analysis categorizes the barriers that impede the successful implementation and development of PED Labs into distinct domains, offering an understanding of the challenges that must be overcome. In particular, nine categories are proposed within the group of blocking factors, such as

- Policy: Energy plans, governance body visions, or political commitment.
- Administrative: Coordination, public participation, dissemination, ownership or authorization procedures.
- Legal and regulatory: Regulations, instability, building codes, incentives or privacy protection.
- Financial: Cost, financial support, access to capital, economic crisis or risks and uncertainty.
- Market: Split incentives, energy price distortion, or energy market actors.
- Environmental: Lack of information or negative effects on the natural environment.
- Technical: Tested solutions, technical commitments, qualified personnel, computational scalability, grid instability or accurate urban models.
- Social: Inertia, interest, acceptance, engagement, rebound effect, attitudes, exclusion or lack of trust.
- Information and awareness: Insufficient information, awareness, perceptions or information asymmetry.

Analysis of these data reveals that administrative, legal, financial and some social factors pose significant challenges. Conversely, environmental factors, along with many technical and market factors, are perceived as less obstructive to the implementation of these laboratories. A more detailed analysis of the barrier code database highlights widespread concerns across almost all categories, identifying factors that delay or block implementation. Except for the Environmental topic, the other eight categories achieve average scores above 3 (on a scale from 1 and 5).

Figure 4 presents the questionnaire results on barriers, shown in a radar graph. On average, the highest-scoring category is Information and Awareness, followed by Financial and Social, with values above 3.6. The highest-scoring subcategory or question is 'Inertia' from the Social category, followed by 'Limited access to capital and cost disincentives' from the Financial category, both with values above 4. Conversely, the lowest-scoring subcategory or question is 'Negative effects of project intervention on the natural environment' from the Environmental category, followed by 'Hostile or passive attitude towards environmentalism' from the Social category, both scoring below 3.

To overcome the two main obstacles identified, a series of measures are proposed, recognizing that the contextual factors of each laboratory are key elements when selecting appropriate solutions. The barrier related to inertia can be reduced by increasing the engagement and active participation of technicians, citizens, and policymakers in laboratory activities through communication, information sharing, and capacity-building initiatives. Limited access to capital and financial instruments can be mitigated through new flexible economic models that combine public and private sponsorship to secure the necessary resources. Overcoming both barriers requires a shift in mindset to recognize and emphasize the benefits of integrated, efficient, and sustainable urban solutions that have already been successfully tested.

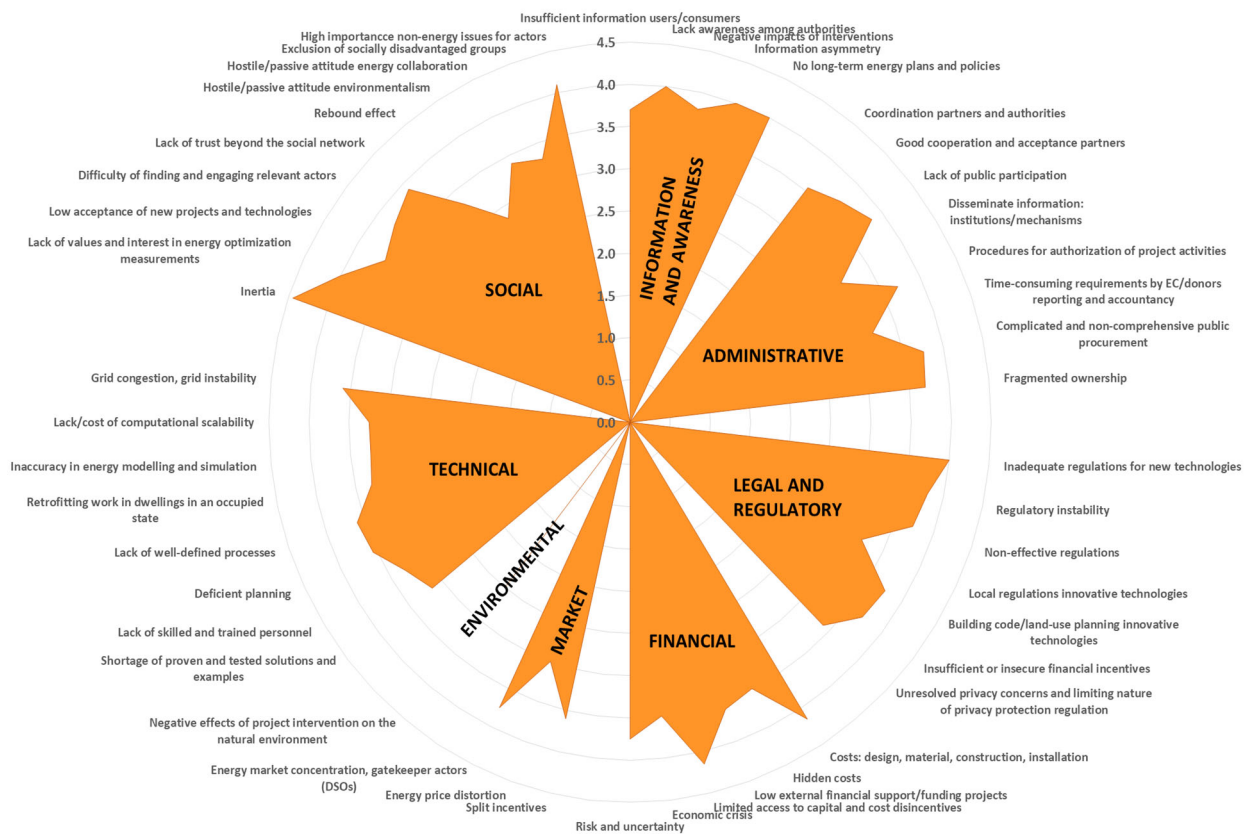


Figure 4. Radar graph showing the blocking factors weighted on a 1 to 5 Likert scale by the questionnaire participants.

3.2. Analysis of Drivers and Unlocking Factors

Two categories are defined for the group of driver factors, considering aspects such as

- **Drivers:** Climate change, urbanization trends, urban redevelopment, economic growth, market attractiveness, environmental quality, or energy autonomy.
- **Unlocking factors:** Technological improvements, innovative solutions, prefabricated packages, energy communities, prosumers, storage systems, decreasing cost, benefits, awareness, engagement, social acceptance, policy frameworks, funding, or multidisciplinary approaches.

Figure 5 presents the results of the questionnaires regarding driving factors. The statistical data for this code indicate that both Drivers and Unlocking Factors categories received averaged scores above 3, with values of 3.45 and 3.3, respectively, on a scale from 1 to 5. As illustrated in the radar graph the factors that most enhance the implementation of a PED Lab, according to respondents, include 'Climate change mitigation', 'Energy autonomy and independence', 'Economic growth', 'Financial mechanisms', 'Strong existing local networks and associations', 'Improved local and national policy frameworks', 'Technological improvements for renewable energy systems (RES) production', and 'Energy efficiency and prefabricated packages for buildings', all scoring above 4.

Conversely, the aspects that contribute least to the implementation of these urban laboratories include: 'Rapid urbanization trend and need of urban expansions', 'Ability to predict benefits', 'Ability to predict the distribution of benefits and impacts', 'Social acceptance', and 'Dedicated change-agents among citizens', all scoring less than or equal to 3.5. To further incentivize these less influential aspects, a series of measures is proposed, recognizing that the contextual factors of each laboratory are key when selecting appropriate solutions. Controlled and efficient urban expansion is necessary, characterized by the

rational use of resources and a sustainable land use index. Improving social acceptance requires involving citizens in the development of new urban models, fostering a sense of pride and ownership in these laboratories. The development of digital citizen platforms allows for the evaluation of different integrated urban scenarios, helping to highlight the associated benefits and predict potential negative impacts that can be avoided.

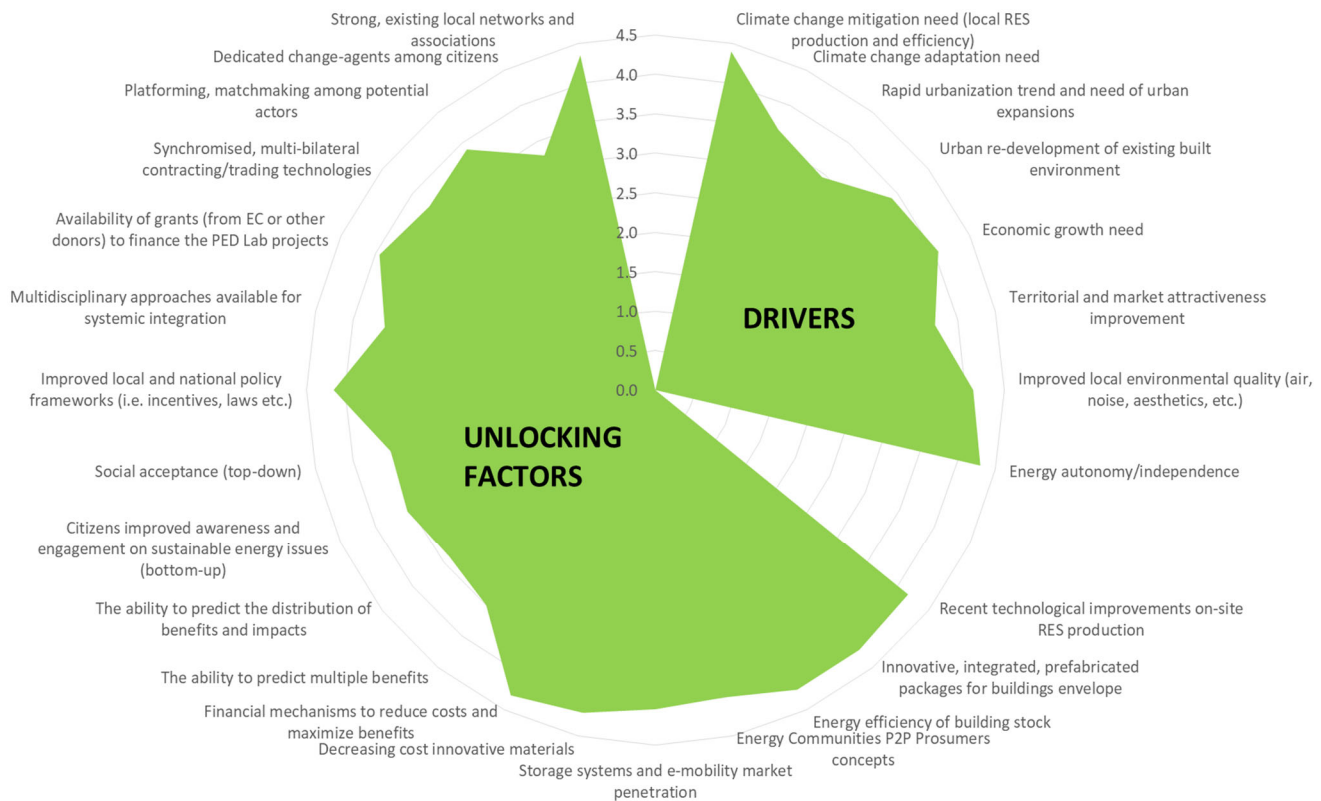


Figure 5. Radar graph showing the unlocking factors and drivers from 1 to 5 Likert scale by the questionnaire participants.

3.3. Analysis of Stakeholders and Process Mapping

The correct mapping of stakeholders requires identifying who will participate in each of the processes of these laboratories. Six phases are considered in the life cycle of a PED Lab: vision, decision, planning, implementation, check/act and upscale and replicate. Seven groups of stakeholders are proposed: people, industries and companies, planners and architects, academia, financial institutions, governments, and developers.

Figure 6 shows the influence of each stakeholder in the six proposed phases. As shown, the influence of each stakeholder varies throughout the implementation process, and it is important to note that some stakeholders may change their positions or reconsider their participation as they move from one phase to another. Analysis of the statistical values generated in this code shows average scores above 3 for both the phases and the stakeholder categories. In the phase category, average scores for all actors range between 3.6 and 3.8, with the highest values in the Vision phase and the lowest in the Plan and Check/Act phases. In the actor category, average scores throughout the process range between 3.3 and 4, with maximum values for Governments and minimum for Financial Institutions.

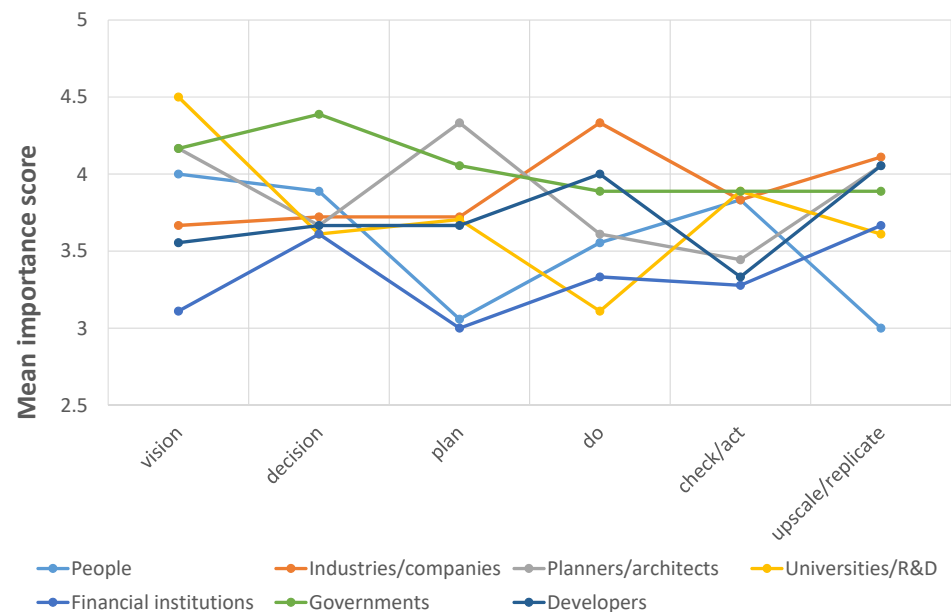


Figure 6. Line graph showing the stakeholders involved in each of the proposed processes, weighted from 1 to 5 by the questionnaire participants.

The distribution of stakeholder roles in each phase is as follows:

- *Vision phase:* The participation of universities and the R&D sector is determinant, along with that of the government and planners. Consulting with citizens is also a high priority.
- *Decision phase:* The government is the main actor, supported by citizens.
- *Plan phase:* In this phase, planners manage the process with support from the government, assisted by industry, universities, and developers.
- *Do phase:* Industry and developers are the primary actors operating within a framework promoted by the government. The role of financial institutions as investors also becomes prominent.
- *Check/Act phase:* All stakeholders must be involved in this phase in various capacities.
- *Upscale/Replicate phase:* This phase is linked to the ‘do phase’ and features a similar distribution of roles. Notably, the lack of citizen involvement in this phase is surprising.

The analysis of these aspects enables the formulation of practical recommendations to define a phase-based engagement strategy. The visioning phase is an open-ended discovery process where the PED Lab resembles a conventional laboratory, focused on research and innovation activities. The decision phase functions more as a participatory democratic process, emphasizing the involvement of public institutions and citizens, with activities focusing on deliberation and maximizing legitimacy. The planning phase is driven by planners, transforming the PED Lab into a participatory design/planning process, where the key activity is the synthesis of formal (expert) and tacit (citizen) knowledge strategies to frame and solve the PED challenge. The do phase is when technology developers take the lead, and the PED Lab becomes a sandbox to test, simulate or play out different PED configurations, identifying what works best in the local context. The check phase has no clear frontrunner; instead, co-leadership between research, policy, and private actors suggests a focus on sense making and translating previous findings into concrete actions across different domains such as new policies, installed technologies, and knowledge. Finally, the upscaling phase shows higher scores for the actors most involved in applying these findings to other projects. At this stage, the PED Lab consists of a series of strategizing activities, each leveraging the diverse stakeholder group and insights from earlier phases,

focused on specific aspects of replication or upscaling. Citizens focus on expanding the PED's geographical or technical scope, technology developers on rolling out their products, developers on creating new PEDs elsewhere, and governments on establishing enabling frameworks to accelerate PED adoption.

3.4. Facilities Classification

Based on the responses from the expert panel, the facilities were classified according to tangible and intangible assets and the role of stakeholders in each phase. The following figure shows the classification of the facilities, highlighting when and where they are relevant in the implementation process.

Figure 7 effectively categorizes facilities into tangible and intangible assets, reflecting a holistic view of what is required to implement PED Labs. This dual categorization acknowledges that successful PED implementation relies not only on infrastructure and technology, but also on human, social, and institutional factors. The mapping of each facility across six implementation phases: Vision, Decision, Plan, Do, Check/Act, Upscale/Replicate, provides insight into the dynamic relevance of each asset type over time. For instance, intangible assets dominate the early stages, emphasizing the need for public awareness, fostering trust, and establishing robust legal frameworks. Conversely, technical systems become more critical in later action-oriented stages, during implementation and monitoring phases, ensuring that the necessary infrastructure is in place.

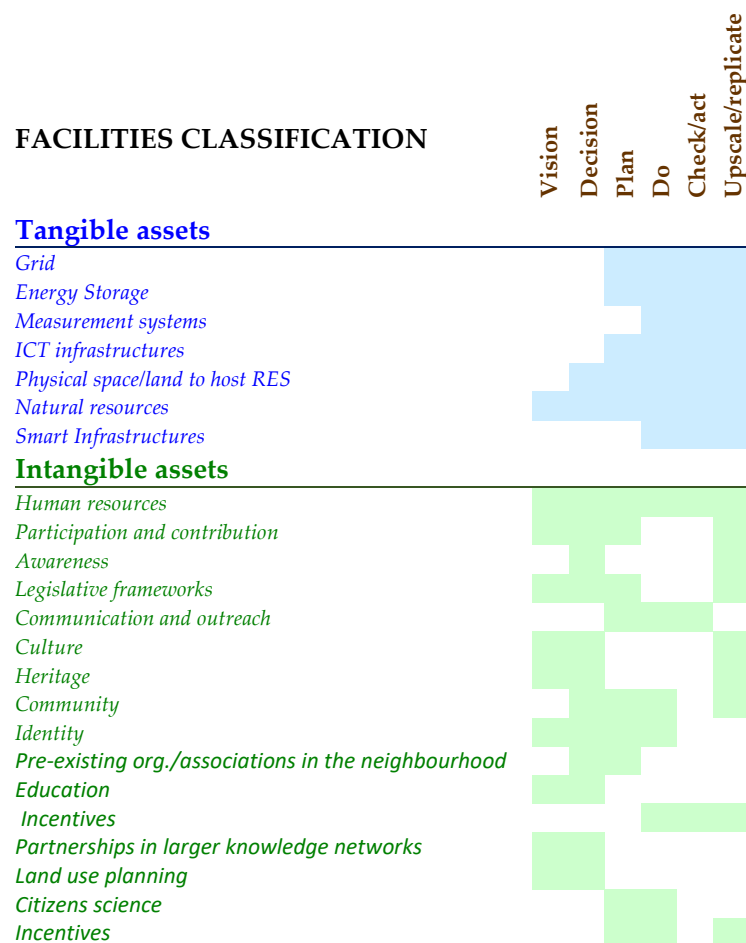


Figure 7. Classification of facilities to identify when and where they are relevant in the PED Lab implementation process.

The figure highlights the importance of intangible assets such as legislative frameworks, culture, education, and identity that are often underrepresented in technical planning. Their consistent presence across multiple stages suggests their foundational role in ensuring long-term behavioral change, social acceptance, and institutional resilience. This challenges traditional infrastructure-focused models by placing equal importance on intangible assets.

The matrix serves as a strategic planning tool, helping project teams and policymakers identify which facilities to prioritize at each stage and assess readiness and identify potential gaps. The early identification of gaps, such as weak community participation or insufficient legislative support, can inform corrective action before implementation begins.

The presence of certain assets in the final stage (Upscale/Replicate) reveals which elements are essential for expanding PED Labs beyond pilot projects. This includes assets such as participation, culture, community, and incentive mechanisms. Their enduring relevance suggests that sustainable upscaling depends on long-term investments in capacity building and institutional frameworks.

The diverse nature of the assets implies that PED Labs cannot be realized through isolated efforts. Successful implementation requires coordinated input from engineers, urban planners, social scientists, policymakers, educators, and citizens, encouraging collaborative governance models. Finally, the figure provides actionable insights for policymakers and funding bodies. It highlights critical leverage points, assets that support multiple phases, and thus offers guidance on where to prioritize investment. For example, strengthening education, legal frameworks, and community networks may yield system-wide benefits throughout the PED lifecycle. This enables more efficient resource allocation, better stakeholder coordination, and improved readiness for future scaling or replication.

3.5. SWOT Analysis

Once the key features, facilities, and main actors are identified, it is necessary to structure the results to highlight the available resources and necessary requirements for the successful operation or replication of a PED Lab. These aspects are structured in a SWOT matrix expressing the Strengths, Weaknesses, Opportunities, and Threats identified by the focus group. This analysis reflects the collective expertise and experience of practitioners actively and deeply engaged in PED initiatives across Europe. Figure 8 summarizes the main key elements of this SWOT matrix.

A major **strength** lies in the foundation of expertise many PED initiatives are built. Several teams already have extensive backgrounds in sustainability and smart energy systems, which naturally lends credibility and depth to PED-related projects. PED Labs also offers something cities rarely obtain: a chance to test strategies before fully committing to them. This ability to trial and adjust in real urban settings is crucial for reducing risk and improving outcomes. Another asset is the experience on the results of tested solutions, in other words, the availability of insights from earlier efforts, lessons learned, data collected, and relationships built, which accelerates future implementation. The practice of co-design, where solutions are shaped in collaboration with stakeholders, also stands out. It ensures that interventions resonate with those directly affected. Additionally, these labs serve as a platform for learning across projects and cities, encouraging replication and refinement.

Regarding the **weaknesses**, perhaps the most fundamental is the ongoing lack of a shared understanding of what exactly constitutes a PED Lab. This conceptual ambiguity can slow down coordination and dilute impact. Moreover, many projects suffer from limited or inconsistent engagement from key players. Without sustained buy-in from stakeholders, long-term implementation falters. In some cases, energy transition strategies are not aligned with urban planning processes, creating barriers to integrated solutions. Regulatory support

is often vague or missing entirely, especially at the district scale, where governance tends to be fragmented or absent. Time and resource constraints mean that many PED Labs are rushed into action without the chance to fully refine or tailor their interventions. Resource scarcity also extends to limited space, which constrains the development of renewable energy facilities. There is also the issue of insufficient communication between the many actors involved, with technical and social dimensions frequently handled in isolation rather than through a unified approach.

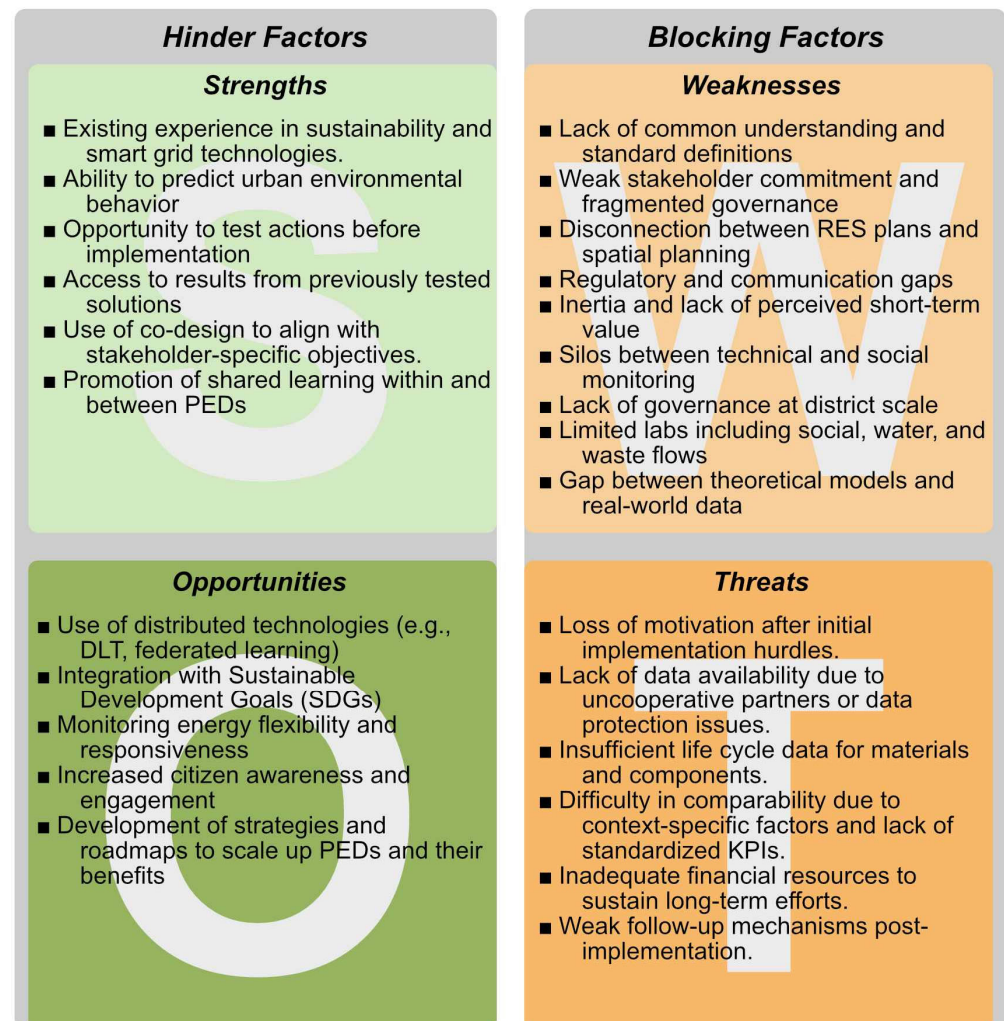


Figure 8. SWOT analysis summary based on the results obtained from the COST PED WG3 focus group.

Supporting the PED development, **opportunities** related to technological advancements, especially in decentralized systems, think block chain, edge computing, or federated data models, are becoming increasingly accessible. These can support the kind of distributed, flexible infrastructure PEDs require. At the same time, public awareness around energy and climate issues is rising. Citizens are more informed and, when engaged meaningfully, more willing to participate in transformative projects. This opens the door for labs to serve not only as technical platforms but also as civic spaces for dialog and innovation. The group also pointed to the opportunity to develop clear strategies and roadmaps to increase PED numbers and benefits.

Finally, several external **threats** were also pointed out. Starting is hard enough, but sustaining momentum is even harder. Many initiatives lose steam after the initial pilot phase, particularly when funding ends or partners drift away. Data privacy regulations

and a lack of collaboration can limit access to the very information needed to evaluate and improve PED systems. Meanwhile, the variability in local conditions and the absence of standard performance metrics make it difficult to compare or benchmark results across contexts. This hinders the ability to build a robust evidence base. Finally, financial uncertainty remains a constant concern. Without long-term support and clear mechanisms for follow-up, even the most promising labs can stagnate or be dismantled before they reach maturity.

The four categories that make up this SWOT matrix allow highlighting the most general aspects to be considered in the implementation of a PED Lab. These elements complement other enquiries as that of Soutullo et al., 2020 [43]. However, it is important to keep in mind that these factors depend largely on the specific characteristics of each laboratory. While they provide useful insights, these factors should be carefully assessed against the specific context of the PED Lab to effectively support its successful deployment.

4. Discussion and Conclusions

Comparative international experiences show that PED Labs adapt their objectives and implementation strategies to reflect regional priorities and capacities. In Europe, they are primarily driven by policy frameworks and aligned with smart city and climate neutrality goals. In Asia, PED Labs often emerge from technology-driven urban experiments, integrating energy, mobility, and digital systems to foster innovation-led growth, with smart city initiatives supporting green urban development through digital infrastructure and industrial modernization. Across the Americas, PED-related efforts focus on combining renewable energy systems with innovative governance models and urban-industrial synergies. In Latin America, many initiatives arise from grassroots movements, blending social innovation with environmental sustainability and often emphasizing participatory approaches to urban development and energy transitions. In Oceania, PED Labs contribute to strengthening resilience in regional and remote communities by integrating renewable energy, energy storage, and community engagement. Despite these contextual differences, PED Labs face common challenges related to governance complexity, stakeholder coordination, and long-term sustainability, yet develop solutions shaped by local climate conditions, socio-economic realities, and technological readiness.

This study addresses a fundamental gap in the literature by clarifying the conceptual and operational contours of PED Labs, offering an empirically grounded framework to guide their implementation, evaluation, and replication. Through qualitative methodologies, stakeholder engagement, and cross-referencing with current European initiatives, the study identifies and analyzes the critical barriers, enablers, actors, and facilities critical to their deployment. Further analysis of the collected data highlights social and financial aspects as the most blocking factors. Nevertheless, climate change mitigation measures, strong local networks, and improvements in local and national policy frameworks are identified as the main drivers.

The implementation of PED Labs represents a significant step forward in the pursuit of sustainable, climate-resilient urban environments. Unlike traditional testbeds focused on isolated technology demonstrations, PED Labs operate as dynamic socio-technical systems. They integrate technological innovation with institutional, cultural, and community processes. This integrated perspective is reflected in the facility classification (Figure 7), where intangible assets, such as legislative frameworks, education, identity, and awareness, emerge as essential in early phases (e.g., Vision and Decision), while tangible infrastructures (i.e., ICT systems, energy storage, grid infrastructure) dominate implementation and upscaling phases. This finding underscores the need for holistic planning that incorporates both human and technical dimensions from the outset. PED Labs are not simply sites of

technical innovation but key vehicles for co-producing knowledge, policy, and behavior change toward energy-positive urban futures.

Another key contribution of this research lies in its detailed mapping of stakeholder influence across the six phases of the PED Lab lifecycle. The stakeholder importance survey reinforces the importance of all the stakeholder groups, since neither received a score below 3. Interestingly, it shows different dominant actors in different phases. The mapping of stakeholders reveals the pivotal role of government actors and the importance of citizen involvement, particularly during the vision and decision phases. The analysis generated through this matrix supports the definition of a phase-based engagement strategy and, thus, the design concept of the PED Lab for each phase. Table 3 shows the dominant actors, the main facilities assets, and phase-based suggestions that outline engagement concepts at each phase of PED Labs.

Table 3. Specific roles of key Stakeholders, main facilities assets, and phase-based suggestions of PED Labs.

Phase	Dominant Actor	Main Facilities Assets	Engagement Concept
Vision	Research	Intangible	Citizen science, co-discovery
Decision	Policy and community	Intangible	Participatory democracy
Plan	Planning	Tangible and Intangible	Participatory planning and design
Do	Industry	Tangible	Citizen science, field testing
Check/Act	Industry, policy, research	Tangible	Sense making, site policy, and design recommendations
Upscale/Replicate	Industry, policy, planners, developers	Tangible and Intangible	Strategizing, general policy, market rollout recommendations

The participatory design of this study, leveraging input from the COST Action PED-EU-NET community, allows for a detailed exploration of these issues. Notably, the SWOT analysis reveals that while PED Labs benefit from accumulated technical expertise and increasing public interest in energy transition, they remain vulnerable to several risks. These include conceptual ambiguity, inconsistent stakeholder commitment, and funding discontinuity, factors that can undermine long-term impact if not addressed strategically.

Opportunities for the expansion and institutionalization of PED Labs are tied to the rapid evolution of decentralized energy technologies, increased digitalization, and the growing acceptance of collaborative governance models. Public awareness, growing civic interest, and emerging digital tools such as federated data platforms and smart simulations provide fertile ground for replication and upscaling. However, realizing this potential will require addressing structural weaknesses, particularly the absence of standardized frameworks and evaluation metrics.

The analysis of the data and the engagement concepts generated after the implementation of this methodology allows answering the three proposed research questions.

What are the current barriers to the implementation of PED-Labs?

This research identifies nine categories of factors that hinder the development of a PED Lab, including social, administrative, legal-regulatory, financial, and information-related factors. The qualitative analysis reveals that social and financial factors emerged as particularly obstructive, followed by administrative, regulatory, and legal, and information and awareness aspects. These findings reflect broader challenges in urban innovation, where multi-level governance and divergent stakeholder interests can create friction in implementation.

What are the drivers and incentive factors (unlocking) that determine the “fertility of the soil” for PED-Lab initiatives?

This research formulates forty-two questions related to unlocking and driving factors. The qualitative analysis identifies the need for climate change mitigation measures, the presence of strong local networks, and the improvement of local and national political frameworks as the primary aspects that most encourage the development of a PED Lab. Technological advancements and cost reductions in renewable systems also enhance the feasibility of PED Lab deployment. However, the absence of standardized governance models and common evaluation metrics continues to constrain the replicability and scalability of these initiatives across different urban contexts.

What processes and actors define the steps, power relationships, and subsidiarity in responsibilities and decisions within PED Lab initiatives?

In this work, seven groups of stakeholders have been identified that influence the achievement of urban laboratory objectives across the six proposed phases, depending on the activities required at each phase. Governments stand out as one of the main actors throughout the process.

The importance of collaborative governance is further reinforced by the classification of facilities and the interdependence of actors. While PED Labs thrive on cross-sectoral synergies, these are often undermined by fragmented practices and insufficient coordination. The classification framework developed in this research offers a practical tool to manage this complexity and ensure the timely mobilization of critical assets and actors.

Finally, this research affirms the pressing need for a shared conceptual and operational framework for PED Labs. The current diversity in definitions, approaches, and scopes across Europe and beyond creates barriers to comparison and replication. By distilling findings from focus groups, the literature review, and existing cases, this study contributes concrete parameters for future standardization, particularly in relation to stakeholder engagement, asset planning, and governance design.

PED Labs hold significant promise as instruments for achieving zero-emission targets and advancing broader urban sustainability agendas. Realizing this potential will depend on consolidating their conceptual foundations, embedding them within robust governance systems, and securing the long-term policy and financial commitments needed for impact.

5. Recommendations and Limitations

PED Labs emerge as viable platforms for conducting a variety of experiments towards PEDs, allowing for the analysis and validation of integrated solutions across similar or diverse urban contexts.

When implementing a PED Lab, the first recommendation is to establish a clear definition of what this type of urban laboratory is and what it entails. The initial concept is rooted in the Urban Living Lab concept combined with the Smart Energy City and Near Zero Energy Buildings frameworks, with a focus on the district scale and a robust monitoring component within controlled environments. This approach merges the capabilities of a living lab with sustainability and energy positivity objectives, enabling experiments to be conducted in real urban settings, and with a citizens' centric perspective, to validate innovative solutions on small and medium scales. However, stakeholder mapping is essential, as it reveals the dynamic roles of various groups throughout the six phases of a PED Lab's life cycle.

As a result of the application of this methodology, it was possible to answer the research questions formulated at the beginning of the study and to develop a series of recommendations for establishing effective PED Labs. These recommendations, along with suggested implementation mechanisms and expected outcomes, are listed in Table 4.

Table 4. Reasoned list of recommendations supporting the establishment of PED Labs.

Recommendation	Implementation Mechanism	Expected Effects
Prioritize stakeholder commitment and participation.	Develop tailored communication strategies for each stakeholder category, highlighting their specific value propositions	Balanced participation across stakeholder categories, embedding inclusion principles in PED Labs operations, and enhancing representativeness
Build coherent and inclusive governance at the district level, promoting citizen involvement in leadership wherever possible.	Design appropriate governance mechanisms through multi-stakeholder dialog. Identify and engage vulnerable and marginalized groups. Establish rules with PED Lab promoters to empower citizens.	More effective and impactful PED Labs, with inclusive governance and extended user-centered validation processes.
Focus on integrated, holistic district planning, incorporating other dimensions into the energy approach.	Establish a common planning tool at the district level as a PED Lab asset. Integrate energy dimension with mobility, services, zoning, and green infrastructure. Prioritize open source and open data systems to reduce barriers.	Consistent data collection, integration, and management. Holistic view of energy in district master planning. Open access to data and services.
Capitalize on favorable regulations through communication and action plans.	Map the existing regulatory landscape and promote strategies to activate supportive regulations via PED Lab governance.	Integration of the PED Lab into multilevel governance, accelerating the adoption of relevant energy and climate regulations.
Identify quick wins and short-term added value to motivate stakeholders.	Map project outputs and assets and identify those most suitable to deliver immediate value to stakeholders. Implement scaling-up actions on selected bundles.	Increased stakeholder engagement, reduced skepticism and disillusionment, and improved communication and dissemination through success stories.
Break down silos between technical, social, environmental, and political approaches	Provide tools for balanced dialog among stakeholders, introduce citizen science approaches and science-policy focus groups, and establish challenge-driven cross-disciplinary teams.	PED Labs are positioned as place-based open innovation platforms where diverse disciplines contribute to urban problem solving.
Leverage all available data providers, including citizen science, to bridge modeling with real-world applications.	Map data providers and develop value propositions to engage them in data sharing. Engage citizen science NGOs and pursue funding to increase high-quality citizen-sourced data generation.	Broader data sources, improved model validation, and enhanced citizens' involvement and awareness.
Further develop Information and Communication Technologies (ICT) in laboratory facilities.	Expand district ICT infrastructure through targeted projects, partnerships with technology providers, and the activation of underutilized assets (e.g., smart meters, home automation) with smart software solutions.	Improved data collection processes, greater data volume and coverage, and expanded opportunities for experimentation in PEDs.
Define reliable business models to test different scenarios, combining technologies and innovations	Integrate systemic business modeling as a core component of PED Labs. Engage stakeholders to align diverse interests and desired impacts in business model design.	Increased private sector interest, fairness embedded in co-designed models with vulnerable groups representatives, and greater acceptance and scalability.
Integrate PED Labs into urban strategies for achieving the UN SDGs	Develop a tool linking PED Lab outcomes to UN SDGs targets, demonstrating the contribution of PED solutions when fully deployed.	Enhanced contribution of PED Labs to local SDG agendas, and greater community mobilization toward sustainability goals

Table 4. *Cont.*

Recommendation	Implementation Mechanism	Expected Effects
Offer PED Labs as a platform to strengthen and scale PEDs	Design PED Labs as experimental open innovation, demonstrating how learning-by-testing reduces costs and improves acceptance and effectiveness.	Enhanced flexibility of PEDs through innovation and the establishment of continuous learning-by-testing cycles.
Manage the motivation cycle by design, including regular revamping actions and resource allocation	Incorporate regular motivation-boosting activities in PED Lab roadmaps and action plans, tailored for each category of stakeholder. Institutionalize stakeholder consultation about the motivation to stay engaged. Implement fair resource allocation mechanisms through inclusive governance, such as participatory budgeting.	Sustained interest and participation from diverse stakeholder groups, and fair resource allocation with greater benefits for citizens and underrepresented categories
Promote data sharing and prevent conflicts and a lack of cooperation by establishing clear rules and agreements	Co-design codes of conduct, engagement rules, and MoUs to establish the PED Lab as a trusted space and prevent conflicts over data sharing.	Smooth implementation of data sharing processes and mutually beneficial deals in data sharing among key providers.
Address sustainability from the early stages.	Integrate broad sustainability goals (social, economic, and ecological) into the PED Lab's design, development roadmap, and KPIs.	Strengthened role of PEDs in sustainability agendas and multilevel action plans.
Develop climate change, energy efficiency, renewable, social, and economic measures based on proven experiments.	Establish science-policy dialogs at the local level and support them with experimental roadmaps in PED Labs. Conduct joint planning and reviews to maximize their policy relevance.	PEDs become infrastructures supporting policy-science interfaces, improving the quality of local policies through continuous data availability and validation feedback.

Nevertheless, this methodology has several limitations, as only a limited number of laboratories in Europe were studied. Therefore, further analysis of PED Labs in different locations is necessary. Increasing the sample analyzed would reduce uncertainty in the results and build greater trust among governments, property owners, and residents. Another area for further development in this methodology is the evaluation of synergies between technologies and innovations, requiring the active engagement of all stakeholders. The results of this study support the co-design, co-experimentation, and evaluation of various technological combinations. In addition, deeper exploration of co-governance strategies is needed, since these approaches promote proactive innovation while ensuring that solutions remain fit for purpose. An information, training, and capacity-building plan should also be developed to improve the use of the generated knowledge. This would enhance the capacity of governments and decision-makers to rapidly implement inclusive technological, social, and economic measures that address urgent needs in urban settlements while driving systemic change to improve quality of life and environmental performance.

The research questions initially formulated and addressed through this methodology, along with the recommendations presented, are intended to guide future research, focusing on the most relevant aspects of PED Lab implementation: barriers, drivers, facilities, and stakeholder processes. However, further research is still needed, particularly to replicate these models in different contexts. Therefore, the design, implementation, and monitoring of additional PED Labs are essential to consolidate and validate the ideas presented in this research.

Author Contributions: Conceptualization, D.V., V.B., S.S., O.S. and G.E.; methodology, D.V., V.B., S.S., M.N.S. and O.S.; validation, S.S., M.N.S., G.P., R.L., F.M.M., V.B., T.A., M.B.A. and O.S.; formal

analysis, S.S., M.N.S., G.P., R.L., F.M.M., T.A., M.B.A., V.B., D.V., G.E. and O.S.; investigation, D.V., V.B., S.S., M.N.S., G.P., R.L., F.M.M., T.A., M.B.A., G.E. and O.S.; resources, D.V., V.B., G.E., O.S., M.B.A. and S.S.; data curation, D.V., V.B. and S.S.; writing—original draft preparation, D.V., V.B., S.S., M.N.S., O.S. and G.E.; writing—review and editing, S.S., G.P., F.M.M., R.L., M.N.S., O.S., V.B., M.B.A. and T.A.; visualization, S.S., M.N.S. and O.S.; supervision, S.S., M.N.S. and O.S.; project administration, D.V., V.B., S.S., O.S. and G.E.; funding acquisition, M.B.A., O.S. and G.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by COST (European Cooperation in Science and Technology) under the Action 19126 Positive Energy Districts European Network (PED-EU-NET), CA19126.

Institutional Review Board Statement: All consultations and surveys presented in this article have been carried out with experts who are part of the COST-Action PED-EU-NET, specifically with participants of the WG3 activities of this COST-Action. Participants are subject to the conditions set out in its Memorandum of Understanding.

Informed Consent Statement: The scientific results presented in this research have been carried out within the activities developed under the framework of the COST Action CA19126 working groups, whose participants are subject to the conditions set out in its Memorandum of Understanding.

Data Availability Statement: Data are available upon request.

Acknowledgments: This article/publication is based upon work from COST Action Positive Energy Districts European Network, CA19126, supported by COST (European Cooperation in Science and Technology).

Conflicts of Interest: Author Viktor Bukovszki was employed by the company Advanced Building and Urban Design Ltd. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors are members of WG3 of the CA19126 PED-EU-NET.

References

1. Van der Heijden, J. When opportunity backfires: Exploring the implementation of urban climate governance alternatives in three major US cities. *Policy Soc.* **2021**, *40*, 116–135. [\[CrossRef\]](#)
2. Derkenbaeva, E.; Halleck Vega, S.; Hofstede, G.J.; Van Leeuwen, E. Positive energy districts: Mainstreaming energy transition in urban areas. *Renew. Sustain. Energy Rev.* **2022**, *153*, 11782. [\[CrossRef\]](#)
3. Sassenou, L.N.; Olivieri, L.; Olivieri, F. Challenges for positive energy districts deployment: A systematic review. *Renew. Sustain. Energy Rev.* **2024**, *191*, 114152. [\[CrossRef\]](#)
4. Turci, G.; Civiero, P.; Aparisi-Cerdá, I.; Marotta, I.; Massa, G. Transition Approaches towards Positive Energy Districts: A Systematic Review. *Buildings* **2024**, *14*, 3039. [\[CrossRef\]](#)
5. Doci, G.; Dorst, H.; Hillen, S.; Tjokrodikromo, T. Urban transition governance in practice: Exploring how European cities govern local transitions to achieve climate neutrality. *Front. Sustain. Cities* **2025**, *7*, 1559356. [\[CrossRef\]](#)
6. Yadav, A.; Anwer, N.; Mahapatra, K.; Shrivastava, M.K.; Khatiwada, D. Analyzing the Role of Polycentric Governance in Institutional Innovations: Insights from Urban Climate Governance in India. *Sustainability* **2024**, *16*, 10736. [\[CrossRef\]](#)
7. Voytenko, Y.; McCormick, K.; Evans, J.; Schliwa, G. Urban Living Labs for Sustainability and Low Carbon Cities in Europe: Towards a Research Agenda. *J. Clean. Prod.* **2016**, *123*, 45–54. [\[CrossRef\]](#)
8. Afacan, Y. Impacts of urban living lab (ULL) on learning to design inclusive, sustainable, and climate-resilient urban environments. *Land Use Policy* **2023**, *124*, 106443. [\[CrossRef\]](#)
9. Voorwinden, A.; Van Bueren, E.; Verhoef, L. Experimenting with collaboration in the Smart City: Legal and governance structures of Urban Living Labs. *Gov. Inf. Q.* **2023**, *40*, 101875. [\[CrossRef\]](#)
10. Bechtel, J.; Kock, A. The relevance of urban agglomeration micro-foundations for the emergence of innovation in living labs: A qualitative field study. *J. Clean. Prod.* **2023**, *427*, 139280. [\[CrossRef\]](#)
11. Mukama, M.; Kaviti Musango, J.; Smit, S.; Ceschin, F.; Petrulaityte, A. Development of living labs to support gendered energy technology innovation in poor urban environments. *Technol. Soc.* **2022**, *68*, 101850. [\[CrossRef\]](#)
12. Aernouts, N.; Maranghi, E.; Ryckewaert, M. (Eds.) *Towards a Definition of Socially-Oriented Living Labs*, 1st ed.; SoHoLab: Brussels, Belgium, 2020.

13. Mbatha, S.P.; Musango, J.K. A Systematic Review on the Application of the Living Lab Concept and Role of Stakeholders in the Energy Sector. *Sustainability* **2022**, *14*, 14009. [CrossRef]
14. Van Waes, A.; Nikolaeva, A.; Raven, R. Challenges and dilemmas in strategic urban experimentation: An analysis of four cycling innovation living labs. *Technol. Forecast. Soc. Change* **2021**, *172*, 121004. [CrossRef]
15. Martin, E.; Kodukula, S.; Rony, Y.I.; Manala, B.; Rybski, D.; Lah, O. *Urban Living Labs as Tools for Just Transition: Adapting the Living Lab Approach into the Development Cooperation Context*, 1st ed.; Wuppertal Institute for Climate, Environment and Energy: Berlin, Germany, 2023.
16. Urban Living Lab Center. Available online: <https://www.living-lab.center/> (accessed on 1 July 2025).
17. Kobashi, T.; Jittrapirom, P.; Yoshida, T.; Hirano, Y.; Yamagata, Y. SolarEV City concept: Building the next urban power and mobility systems. *Environ. Res. Lett.* **2021**, *16*, 024042. [CrossRef]
18. Kobashi, T.; Choi, Y.; Hirano, Y.; Yamagata, Y.; Say, K. Rapid rise of decarbonization potentials of photovoltaics plus electric vehicles in residential houses over commercial districts. *Appl. Energy* **2022**, *306*, 118142. [CrossRef]
19. Taipei Smart City Living Lab. Available online: <https://we-gov.org/catalog/?mod=document&uid=778> (accessed on 1 July 2025).
20. Choo, M.; Choi, Y.W.; Yoon, H.; Bae, S.B.; Yoon, D.K. Citizen Engagement in Smart City Planning: The Case of Living Labs in South Korea. *Urban Plan.* **2022**, *8*, 32–43. [CrossRef]
21. Park, J.; Fujii, S. Living Lab Participants' Knowledge Change about Inclusive Smart Cities: An Urban Living Lab in Seongdaegol, Seoul, South Korea. *Smart Cities* **2022**, *5*, 1376–1388. [CrossRef]
22. Yu, C.; Yu, J.; Gao, D. Smart Cities and Greener Futures: Evidence from a Quasi-Natural Experiment in China's Smart City Construction. *Sustainability* **2024**, *16*, 929. [CrossRef]
23. Sibbitt, B.; McClenahan, D.; Djebbar, R.; Paget, K. Drake Landing Solar Community: Groundbreaking Solar. *ASHRAE High Perform. Build.* **2015**, *8*, 36.
24. Shafiee Roudbari, E.; Kantor, I.; Menon, R.P.; Eicker, U. Optimization-based decision support for designing industrial symbiosis district energy systems under uncertainty. *Appl. Energy* **2024**, *367*, 123418. [CrossRef]
25. Shafiee Roudbari, E.; Menon, R.P.; Kantor, I.; Eicker, U. Toward Positive Energy Districts by Urban–Industrial Energy Exchange. *Designs* **2023**, *7*, 73. [CrossRef]
26. Haase, M.; Eicker, U.; Hachem-Vermette, C.; Kayo, G.; Rehman, H. Lessons learned from analyzing PED case studies. In Proceedings of the 12th International IEECB&SC'24 and European ESCO Conference 2024 “Improving Energy Efficiency in Commercial Buildings and Smart Communities”, Frankfurt, Germany, 6–7 March 2024.
27. Laboratorio Para La Ciudad (LabCDMX), Mexico City. Available online: <https://latinno.net/es/case/13232/> (accessed on 1 July 2025).
28. Laboratorio de Gobierno de Chile. Available online: <https://www.lab.gob.cl/> (accessed on 1 July 2025).
29. Arquitectura Expandida (APX). Available online: <https://arquitecturaexpandida.org/> (accessed on 1 July 2025).
30. Castro, A.; Ponce de León, A.; Cantera, A.L.; Olofsson, V.; Reina-Rozo, J.D. Energy sovereignty storytelling: Art practices, community-led transitions, and territorial futures in Latin America. *Tapuya Lat. Am. Sci. Technol. Soc.* **2024**, *7*, 2309046. [CrossRef]
31. Montero, S.; Whitney, R.; Peñaranda, I. Experimental Urban Planning: Tensions Behind the Proliferation of Urban Laboratories in Latin America. *Plan. Theory Pract.* **2023**, *24*, 473–488. [CrossRef]
32. CSIRO's Living Lab. Available online: <https://www.csiro.au/en/research/environmental-impacts/sustainability/Urban-Living-Lab> (accessed on 1 July 2025).
33. Monash University Net Zero Precincts Living Lab. Available online: <https://www.monash.edu/msdi/initiatives/project-pages/net-zero-precincts/living-lab> (accessed on 1 July 2025).
34. Lot Fourteen Innovation Hub. Available online: <https://lotfourteen.com.au/projects/innovation-hub/> (accessed on 1 July 2025).
35. Tahir, F.; Dwyer, S.; Kelly, S. Emergent opportunities and barriers on the feasibility of microgrids: Qualitative findings from an Australian funding program. *Energy Res. Soc. Sci.* **2024**, *109*, 103423. [CrossRef]
36. Hamdan, H.A.M.; de Boer, L.; Andersen, P.H. The architecture of procurement in sustainable and zero-emission neighborhood projects—Strategic challenges and new realities. *Environ. Syst. Decis.* **2023**, *43*, 472–488. [CrossRef]
37. Ekdi, F.P.; Kelly, N.; McElroy, L.B.; McQuillan, J.; Sharpe, T.; Statt, R. Zero Carbon Neighbourhoods Creating Non-Complex Information from Complex Data. In Proceedings of the 4th IBPSA-Scotland's Biennial uSIM Conference “Shaping Net Zero Policies with Building Simulation”, Edinburgh, UK, 25 November 2024.
38. Komninos, N. Net Zero Energy Districts: Connected Intelligence for Carbon-Neutral Cities. *Land* **2022**, *11*, 210. [CrossRef]
39. Cardoso, J.; Leal, V.; Azevedo, I.; Silva, M.C. Designing carbon neutral, net-zero, nearly-zero and positive energy districts or neighbourhoods: Current approaches and solutions. *Adv. Build. Energy Res.* **2024**, *18*, 602–640. [CrossRef]
40. Brozovsky, J.; Gustavsen, A.; Gaitani, N. Zero emission neighbourhoods and positive energy districts—A state-of-the-art re-view. *Sustain. Cities Soc.* **2021**, *72*, 103013. [CrossRef]

41. JPI Urban Europe/SET-Plan Action no 3.2 Implementation Plan. Europe to Become a Global Role Model in Integrated, Innovative Solutions for the Planning, Deployment, and Replication of Positive Energy Districts. 2018. Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2021/10/setplan_smartcities_implementationplan-2.pdf (accessed on 19 September 2024).
42. JPI Urban Europe/SET Plan Action 3.2. White Paper on PED Reference Framework for Positive Energy Districts and Neighbourhoods. 2020. Available online: <https://jpi-urbaneurope.eu/wp-content/uploads/2020/04/White-Paper-PED-Framework-Definition-2020323-final.pdf> (accessed on 19 September 2024).
43. Soutullo, S.; Aelenei, L.; Nielsen, P.S.; Ferrer, J.A.; Gonçalves, H. Testing Platforms as Drivers for Positive-Energy Living Laboratories. *Energies* **2020**, *13*, 5621. [CrossRef]
44. Kalms, A.; Cornago, I.; Ezquer, M.; Diaz de Garayo, S.; Arias, A.; Torres, L.; San Emeterio, D.; Irulegi, O.; Bouchotrouch, F.; De Groote, M. “oPEN Lab” project as an underpin innovation for Positive Energy District solutions in Pamplona. *J. Phys. Conf. Ser.* **2023**, *2600*, 082029. [CrossRef]
45. Utilizing Digital Twins for Urban Planning: An Integrated Approach to Sustainable and Smart City Development. 2024. Available online: https://expedite-project.eu/wp-content/uploads/2025/01/65210132-SWE-WP2-XX-T-X-0001_UrbanPlanningAndDigitalTwins.pdf (accessed on 1 July 2025).
46. Boguslawski, P. Digital Twin for Positive Energy Districts (DiGiTwins4PED). *Spectrum* **2024**, *17*, 12–14.
47. Lindholm, O.; Rehman, H.u.; Reda, F. Positioning Positive Energy Districts in European Cities. *Buildings* **2021**, *11*, 19. [CrossRef]
48. Action Cost CA19126. Positive Energy Districts European Network (PED-EU-NET). Available online: <https://www.cost.eu/actions/CA19126/> (accessed on 19 September 2024).
49. Sinfonia European Project. Available online: <http://www.sinfonia-smartcities.eu/> (accessed on 1 July 2025).
50. Cities4PEDs European Project. Available online: <https://energy-cities.eu/project/cities4peds/> (accessed on 1 July 2025).
51. CONCERTO European Commission Initiative Within the European Research Framework Programme. Available online: <https://www.concertoplus.eu> (accessed on 1 July 2025).
52. Driving Urban Transitions to a Sustainable Future. Available online: <https://dutpartnership.eu/> (accessed on 1 July 2025).
53. PED Database. Available online: https://pedeu.net/map/?ped_type=&phase=&project= (accessed on 1 July 2025).
54. JPI Urban Europe. Available online: <https://jpi-urbaneurope.eu/> (accessed on 1 July 2025).
55. IEA EBC Annex 83. Available online: <https://annex83.iea-ebc.org/> (accessed on 1 July 2025).
56. Vettorato, D.; Bukovszki, V.; Soutullo Castro, S.; Etminan, G.; Andreucci, M.B.; Pignatta, G.; Lima, R.; Ashrafian, T.; Semprini, G.; Sánchez, M.N.; et al. Review of Existing Urban Laboratories (Review Existing Concept, Projects and Facilities that are Relevant to PED Labs). Online Deliverable 3.1 Cost Action CA19126. Available online: https://pedeu.net/wp-content/uploads/2022/10/D3.1_Review_existing-urban-laboratories.pdf (accessed on 1 July 2025).
57. Mosannenzadeh, F.; Di Nucci, M.R.; Vettorato, D. Identifying and Prioritizing Barriers to Implementation of Smart Energy City Projects in Europe: An Empirical Approach. *Energy Policy* **2017**, *105*, 191–201. [CrossRef]
58. Razmjoo, A.; Østergaard, P.A.; Denai, M.; Nezhad, M.M.; Mirjalili, S. Effective Policies to Overcome Barriers in the Development of Smart Cities. *Energy Res. Soc. Sci.* **2021**, *79*, 102175. [CrossRef]
59. Bukovszki, V.; Magyari, A.; Braun, M.K.; Párdi, K.; Reith, A. Energy Modelling as a Trigger for Energy Communities: A Joint Socio-Technical Perspective. *Energies* **2020**, *13*, 2274. [CrossRef]
60. Yigitcanlar, T.; Kamruzzaman, M.; Buys, L.; Ioppolo, G.; Sabatini-Marques, J.; Moreira da Costa, E.; Yun, J.J. Understanding ‘smart cities’: Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities* **2018**, *81*, 145–160. [CrossRef]
61. Tan, S.Y.; Taeihagh, A. Smart City Governance in Developing Countries: A Systematic Literature Review. *Sustainability* **2020**, *12*, 899. [CrossRef]
62. Quadros Aniche, L.; Edelenbos, J.; Gianoli, A.; Caruso, R.; DeLosRíos-White, M.I.; Pyl Wissink-Nercua, C.; Undabeitia, A.; Enseñado, E.M.; Gharbia, S. Contextualizing and generalizing drivers and barriers of urban living labs for climate resilience. *Environ. Policy Gov.* **2024**, *34*, 490–523. [CrossRef]
63. Cheng, C.; Albert-Seifried, V.; Aelenei, L.; Vandevyvere, H.; Seco, O.; Sánchez, M.N.; Hukkalainen, M. A Systematic Approach Towards Mapping Stakeholders in Different Phases of PED Development—Extending the PED Toolbox. In *Sustainability in Energy and Buildings. Smart Innovation, Systems and Technologies*, 1st ed.; Littlewood, J.R., Howlett, R.J., Jain, L.C., Eds.; Springer: Singapore, 2021; Volume 263, pp. 447–463.
64. Hearn, A.X. Positive energy district stakeholder perceptions and measures for energy vulnerability mitigation. *Appl. Energy* **2022**, *322*, 119477. [CrossRef]
65. Natanian, J.; Magyari, A.; Brunetti, A.; Reith, A.; Guarino, F.; Manapragada, N.; Cellura, S.; de Luca, F.; Naboni, E. Ten Questions on Tools and Methods for Positive Energy Districts. *Build. Environ.* **2024**, *255*, 111429. [CrossRef]
66. 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]

67. Kozłowska, A.; Guarino, F.; Volpe, R.; Bisello, A.; Gabaldón, 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]
68. BIPED Community. Visualised Steps and Guidance in PED Stakeholder Mapping & a Framework with Tools for Engaging PED Stakeholders. Available online: <https://www.bi-ped.eu/> (accessed on 1 July 2025).
69. Rankinen, J.A.; Lakkala, S.; Haapasalo, H.; Hirvonen-Kantola, S. Stakeholder Management in PED Projects: Challenges and Management Model. *Int. J. Sustain. Energy Plan. Manag.* **2022**, *34*, 91–106. [CrossRef]
70. Bossi, S.; Gollner, C.; Theierling, S. Towards 100 Positive Energy Districts in Europe: Preliminary Data Analysis of 61 European Cases. *Energies* **2020**, *13*, 6083. [CrossRef]
71. Larsson Kolessar, L.L. Deliverable 2.2 Holistic Stakeholder Model for early PEDs. 2022. Available online: https://sustainableinnovation.se/app/uploads/2022/05/PED-ID_D2.2_StakeholderEngagementProcess_v3_220415.pdf (accessed on 1 July 2025).
72. PED-ID: Holistic Assessment and Innovative Stakeholder Involvement Process for Identification of Positive-Energy-Districts. Available online: https://jpi-urbaneurope.eu/wp-content/uploads/2021/06/PED_Pilot_Cal_FinalReportGeneralPublic_PED-ID.pdf (accessed on 1 July 2025).
73. Soutullo, S.; Ferrer, J.A.; Seco, O.; López, H.; Sánchez, M.N.; Vitale, M.J.; Reyes, A.L.; Correa, E.N.; De Diego, L. Sustainable transformation in the Latin American and Caribbean districts through the implementation of a qualitative methodology. Challenges and key aspects to be addressed. *J. Clean. Prod.* **2024**, *472*, 143336. [CrossRef]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.