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How Positive Energy Districts in European Cities Affect City Design

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***Abstract*— Positive Energy Districts (PEDs) are a relatively new concept aimed at advancing the main goals of the Energy Union strategy. They rely on an integrated, multi-sectoral approach to tackle Europe's most complex challenges. PEDs combine energy efficiency, renewable energy production, and energy flexibility at the city level.**

The fundamental idea behind PEDs is to create urban areas capable of generating more energy than they consume while remaining adaptable to shifts in the energy market. This adaptability is crucial because PEDs aim not only to achieve an annual surplus of net energy but also to alleviate strain on centralized energy networks. They achieve this by enhancing on-site load matching and self-consumption, employing technologies for energy storage, and utilizing smart control for energy flexibility.

So, how do PEDs influence city design? What types of programs and strategies must local authorities have in place to support the transition to PEDs? Do PEDs encompass all building types in urban environments? And what is the added value of incorporating green buildings into PEDs?

This paper will conduct a systematic literature review to address these questions: (RQ1) the current status of PED implementation in Europe; (RQ2) the impact of PEDs on city design; and (RQ3) the inclusion of all building types in PEDs.

The methodological approach involves a comprehensive study of bibliographic sources following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), supplemented by data analysis, mapping, and text mining using VOS viewer.

The primary contribution of this research will be a cognitive framework for Positive Energy Districts in Europe and a selection of case studies demonstrating how PEDs have influenced city design and how green buildings have supported the transition to PEDs in these cases.

Index Terms - City design, City programs and strategies, Energy Flexibility, Energy Efficiency, Positive Energy District, Renewables Energy production.

I. INTRODUCTION

The Positive Energy District (PED) is a relatively recent concept that exemplifies the main goals identified by the European Energy Union Strategy. Indeed, the PED integrates energy efficiency, renewable energy production, and energy flexibility through a logic of integrated and multisectoral approach that reflects at the local level (urban dimension), yet realizing, in energy terms, an interdependence and exchange with the higher regional and national levels. This introduction outlines the political and regulatory framework that has supported the development of the PED concept and the funding programs that contribute to its dissemination in Europe. The aim of the paper is to help disseminate the concept of PED to a wider audience [1] by identifying to what extent PEDs can influence city design.

Today, cities, acting as communication hubs, are responsible for over two-thirds of global energy consumption and are the primary drivers of climate change. Therefore, it is necessary to make every possible effort to mitigate the potentially severe consequences of climate change, which represents, in fact, the most ambitious human challenge [2]. On one hand, cities represent the main source of global pollution, with about 75 percent of global CO_2 emissions, with transportation and buildings emerging as major contributors. On the other hand, however, it is undeniable that cities also serve as engines for national economic development and global progress, contributing to over 80 percent of global Gross Domestic Product (GDP).

So, what has Europe done to address the challenge? On one hand, it has implemented and funded transformative roadmaps, while on the other hand, it has launched the Energy Union to consolidate energy policy under a unified framework.

A. Transformative Roadmap

The urban agendas (Agenda 2030, the New Urban Agenda, the Addis Ababa Agenda on Financing for Development) and European agreements on climate change (Paris Agreement) serve as transformative roadmaps for addressing climate change, alongside the "2020 Climate and Energy Package", the "2030 Climate & Energy Framework", the "2050 long-term strategy for a climate-neutral EU", the European Green Deal, and the "Renovation Wave Strategy". They all highlight the need for district and community-level approaches and the integration of renewable solutions to create zero-energy districts, recognizing that aggregating projects at this level can lead to zero or even positive energy outcomes [3].

These transformative roadmaps have subsequently materialized into a series of regulatory packages and policies, establishing a legislative framework that empowers individual European member states and collectively the entire Europe in achieving the outlined objectives [4].

B. Energy policy under a unified framework

The European Energy Union Strategy focuses on three objectives across five dimensions, namely: energy security, internal energy market, energy efficiency, decarbonization, and research and innovation. The Commission's response included fifteen action points, among which the fourteenth emphasized the need for a forward-looking EU strategy for energy and climate research and innovation (R&I). This led to a specific approach for R&I that developed a Strategic Energy Technology Plan and a Research and Innovation Agenda with clear priorities and objectives.

The SET Plan identified ten priority actions to accelerate the transformation of the energy system through coordinated or joint investments among European countries, private stakeholders (including research and industry), and the European Commission itself. Action Number 3 of the SET Plan (out of ten priority actions), namely, "Create technologies and services for smart homes that provide smart solutions to energy consumers," was divided into two Sub-Actions: 3.1 "Smart Solutions for Energy Consumers" and 3.2 "Smart Cities and Communities", which was ultimately reformulated into "Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of Positive Energy Districts". Thus, for the first time, the concept of Positive Energy Districts (PEDs) was defined (2018) and subsequently included in the "Renovation Wave Strategy" (2020) and - through the Driving Urban Transition Partnership - in the Horizon Europe Framework Program.

Finally, to complete the regulatory and policy framework supporting the decarbonization of the building stock, it is encompassed in the "Clean Energy for All Europeans Package" (European Commission, 2019) [5], while "Fit for 55" is the legislative package to achieve the EU's climate target for 2030 - including at the urban level - along with the RE-Power EU Plan, which introduces energy efficiency as the fastest and most cost-effective way to address the current energy crisis, reducing bills and increasing the binding Energy Efficiency target from 9% to 13%.

C. SET Plan e R&I programs

The new strategic target of SET Plan Sub-Action 3.2 was inspired by discussions within the European Innovation Partnership on Smart Cities and Communities, particularly by the Initiative on Positive Energy Blocks and "Zero Energy/Emission Districts", aiming to address the ambitious climate goals of the COP21 agreement and align with the increasingly progressive objectives set by the Energy Efficiency Directives (EED) and the recently adopted new Directive on the Energy Performance of Buildings (EPBD).

Moreover, these same roadmaps have influenced the creation of dedicated actions and funding programs aimed at unlocking the potential of cities, facilitating the achievement of sustainable urban development goals and strengthening financial aspects by empowering cities to accelerate actions towards the Sustainable Development Goals (SDGg). The concept of Positive Energy Districts (PEDs) is based on an integrated multisectoral approach that combines the integration of renewable energy production, energy flexibility, and energy efficiency within the local urban dimension, expanding even to the regional or national level regarding energy supply networks. The goal of PEDs allows for the aggregation and integration of many projects related to buildings and the citizens who inhabit or use them (energy consumers and producers), as well as aggregating mobility systems through ICT and IoT, from the local to the regional level. Therefore, the PED was developed as a supportive framework capable of integrating the mentioned objectives into a holistic perspective.

Regarding Research & Development programs, on one hand, the Horizon Europe program, through its five missions, has launched funding programs for research and innovation aimed at improving the effectiveness of funding itself, pursuing clearly identified objectives, and addressing some of the greatest challenges of our time - such as the Mission 100 Climate and Neutral Cities [6-12]; on the other hand, through Partnerships, it has promoted the establishment of initiatives where the European Union, national authorities, and/or the private sector jointly commit to supporting the development and implementation of research and innovation programs in response to Europe's most complex challenges, including specifically two Partnerships: the CET (Clean Energy Transition) and the DUT (Driving Urban Transition). It is within the latter (DUT) that, through co-financing action between the European Union and Member States, the aim is to accelerate the transformation of the energy system by developing and implementing 100 Positive Energy Districts contributing to overall sustainability and clean energy goals by 2030 [13-15].

D. Aims of our study

This study aims to provide a critical overview of the implementation status of PEDs in relation to the specific theme of city design through a scientific literature review integrated using open-access bibliometric software with content analysis conducted by the authors.

Our review article highlights an original contribution to the current state of the research field by providing insights on the evolution of the PED [16-18] and the related topic of city design to verify if it is already embedded in the PED concept, or alternatively, extraneous to it.

The literature review analyzed in the paper [19] is the result of meticulous analysis conducted on a list of articles finalized by the end of October 2023. Starting from this list, the authors first created a repository of articles and then proceeded to collect, analyze, and visualize the data and indicators of interest, also using open-access bibliometric software, as indicated in the methodological section. In particular, to facilitate a critical evaluation of the data, Scopus archive and the VOS viewer tool (version 1.6.20, released on October 31, 2023) were used to examine and compare co-occurrence data among various publications.

Paper “How Positive Energy Districts in European cities affect city design” is structured as follows: Section 2 describes the general methodology related to the analysis of scientific literature; Section 3 presents the main results; Section 4 provides a discussion of the results and Section 5 conclusions and next steps.

Thus, based on results the analysis has taken place which results are here presented in the paper to provide answers to following research question:

- RQ1 Is city design already embedded in the PED concept?
- RQ2 or alternatively, is extraneous to it?

II. GENERAL METHODOLOGY REGARDING THE ANALYSIS OF SCIENTIFIC LITERATURE

To conduct a bibliometric analysis of the scientific literature on Positive Energy Districts (PED), we followed the PRISMA-ScR protocol, a systematic mapping method. Using Scopus and Web of Science. We undertook six methodological steps: defining study objectives (I), creating search queries (II), selecting relevant documents (III), creating a database (IV), and conducting analyses (V), results and discussion (VI) (Figure 1a, 1b).

Firstly, we defined study objectives to structure subsequent steps effectively (I). Then, on October 27, 2023, we queried Scopus and Web of Science using the search string "positive energy district(s)" (II). We selected 140 articles meeting predefined eligibility criteria, focusing on PEDs in titles, abstracts, or keywords, and written in English (III). Next, we created a database in Excel format, extracting metadata from Scopus and including attributes such as title, DOI, year, journal, authors, affiliation, keywords, and funding information. Articles were categorized as review, article, or conference paper (IV). The analysis phase (V) involved bibliometric and content analyses. The bibliometric analysis utilized data from Scopus supplemented by information from Web of Science. Additionally, VOSviewer was used for further detailed analysis. Content analysis involved reading all 140 articles. Articles were classified based on whether they focused on methodological aspects or applied research to real case studies at district or city levels. Finally, (VI) the results and discussion sections addressed findings derived from bibliometric and content analyses, providing insights into the state of research on PEDs.

Then the study proceeds to a bibliometric analysis of scientific literature using VOS viewer.

This study employed bibliometrics [20], a subset of scientometrics, to statistically analyze scientific literature, aiming to assess research performance. We utilized VOS viewer [21], developed by CWTS at Leiden University, known for its robust data mapping capabilities. The methodological steps involved:

- Conducting a data search and comparison using the search string "positive energy district(s)" in Scopus.
- Exporting the resulting file.
- Performing bibliometric analysis with VOS viewer, generating co-occurrence networks of words from literature. VOS viewer provides the option to build co-occurrence networks of words extracted from the scientific literature, including journal types, researcher or organization names, country of publication, and author-chosen keywords, using text mining. The software can extract bibliographic networks from data files downloaded from various databases such as WoS, Scopus, Dimension, PubMed, and RIS. Keyword co-occurrence network analysis is among the most effective approaches for presenting scientific trends and the evolution of issues over time, creating concise and consistent maps [22]. The objective of co-occurrence analysis is to establish a framework for a bibliographic set by clustering terms extracted from the keywords [23].
- Analyzing results and discussing sub-questions regarding city design in PED concepts and relatives connection.. Results and discussion of the sub-questions. Through the analysis, the software helped us to take a holistic approach to define, develop, model, and validate the presence of city design into the PED concept. The data analysis and selection process are represented in Figure 2.

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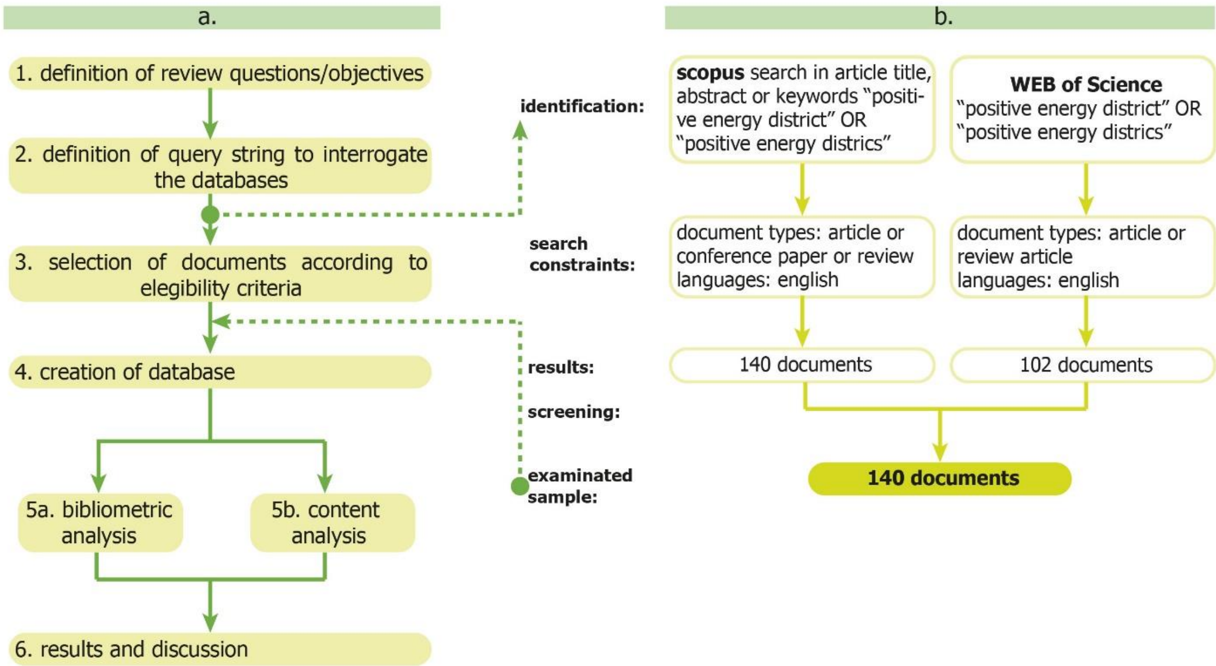

Figure 1. Methodological steps of the research (a) with a zoom on the article selection process (b)

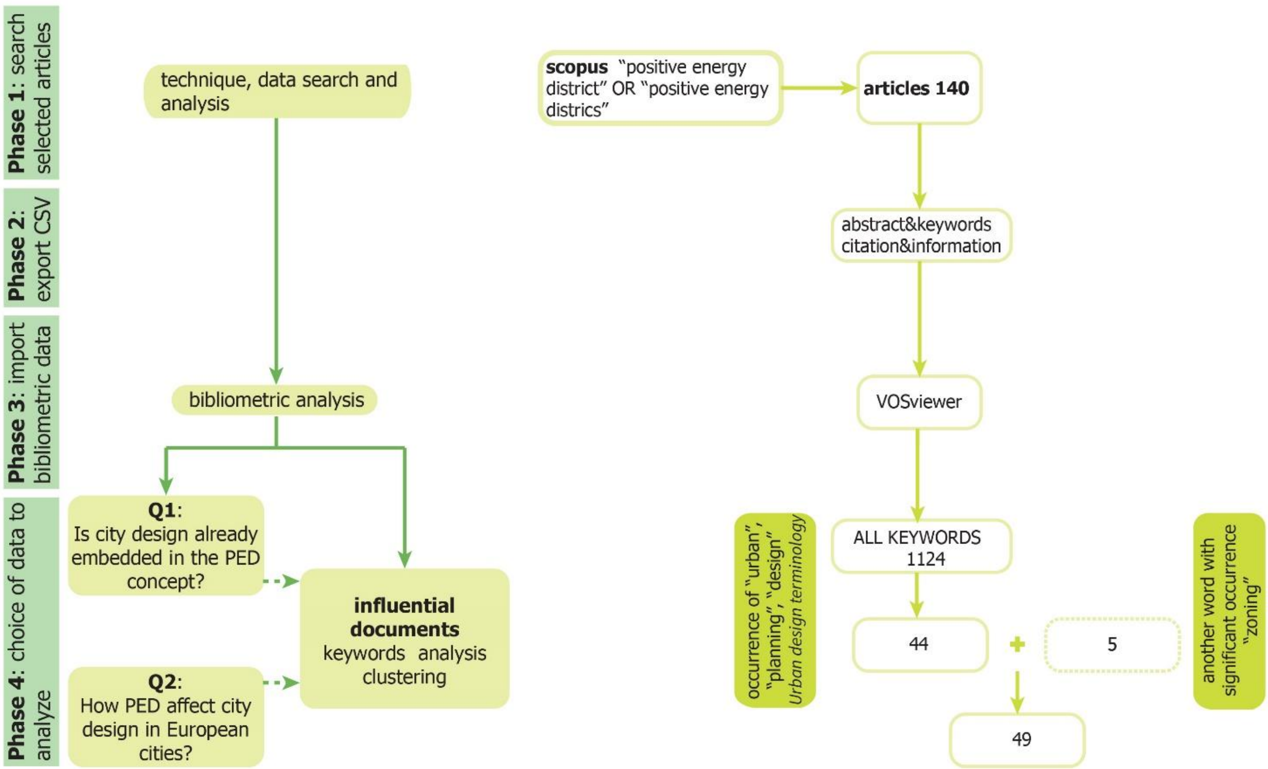

Figure 2. The VOS viewer-based data analysis and selection process

III. RESULTS

This section presents the findings obtained from the bibliometric analysis conducted using Scopus and Web of Science databases, followed by a discussion on the outcomes derived from the VOS viewer tool.

In accordance with the article selection methodology outlined in Section II, our search yielded 140 documents from Scopus and 102 from Web of Science, with the latter identified as a subset of the Scopus sample.

The data were downloaded in CSV format (comma-separated values; CSV file stores tabular data in

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plain text, where each line of the file typically represents one data record), which is a suitable format to be processed by VOS viewer.

In all articles, VOS viewer identified a total of 1124 keywords, but for our study purpose we decide to limit the process analysis only to the words "positive energy district", "city design", "planning", "urban", "design" and the urban design terminology [24] in two categories: all text and authors' keywords.

In our we deemed it more pertinent to concentrate co-occurrence analyses on bibliometric maps derived from all text. This category, in our opinion, more accurately reflects the topics stated in the publications [25]. This decision has led to a selection of 44 keywords.

Among all potential VOS viewer visualization, we decided to present the results obtained from this bibliometric analysis in terms of network visualization (Figure 3). In this visualization, each point is assigned a color indicating the density of items at that specific point.

In all text, VOS viewer identified the keywords associated with "positive energy district" and no one to the "city design". The results obtained (Table 1) show that among the keywords, the most frequent term is "positive energy district" with a total link strength of 1094 and 68 occurrences. It is closely followed by "zoning" with a total link strength of 242 and 14 occurrences. While the term "urban planning" is noteworthy, the keyword "architectural design" has a link strength of 86 and shows only 4 occurrences.

The software categorizes the keywords into 14 clusters. These clusters, distinguished by different colors, clarify the relationships between the various topics. The lines connecting the different items indicate the strength of the links (i.e., the number of publications in which two terms recur together), whereas thicker lines indicate a stronger link. Additionally, a strong link is observed when multiple clusters share the same color. Keywords are represented in nodes, and the size of the nodes corresponds to the frequency of occurrence of the keyword.

VOS viewer establishes the closeness of items by calculating the strength of association between them. This strength of association is defined as "a proportion of the total co-occurrences between items compared to the total expected co-occurrences between those items, assuming they are statistically independent" [26].

While examining the network visualization map (Figure 3), it becomes clear that the predominant topics in the selected scientific literature are "positive energy district", "zoning" and "urban planning".

The analysis of keyword co-occurrence networks stands out as one of the most effective approaches to illustrate the evolution of scientific trends and issues over time. It is particularly interesting to isolate clusters in which "positive energy district" demonstrates greater linking strength. For further insights into this phenomenon, refer to Figure 4, which illustrates the keywords most frequently associated with "positive energy district":

- "Urban planning";
- "Zoning";
- "Architectural design";
- "Resilience".

We did the same isolating clusters with "urban planning", thus in Figure 5 there is possible to see which keywords are most frequently associated with it.

Vos viewer's approach to interpreting co-occurrence maps therefore serves as an initial step in the analysis process rather than a unique method of interpretation. Co-occurrence maps provide a valuable starting point for recognizing meaningful relationships between elements, such as keywords. These visualizations were useful in this study to identify relevant themes and clusters within the dataset, thus providing a high-level overview of the interconnections between elements.

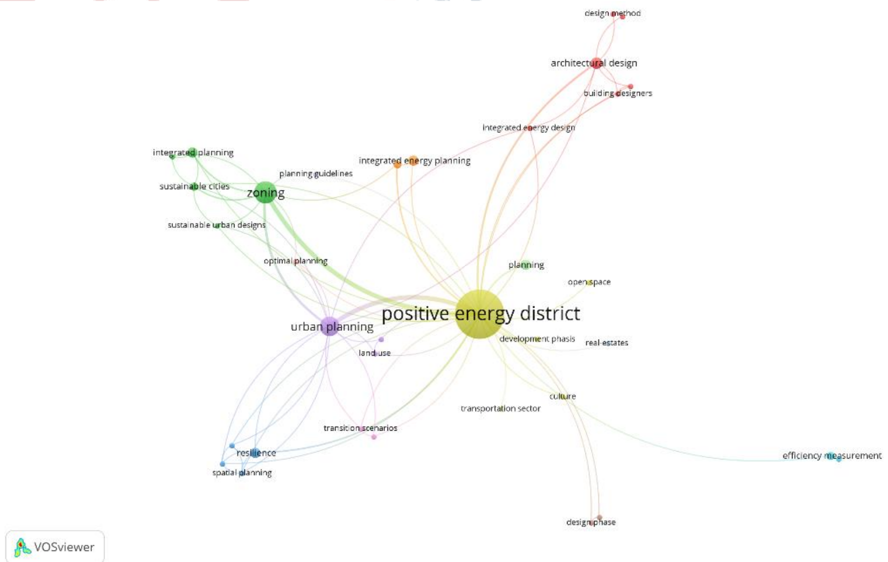

Figure 3. The network visualization map obtained with VOSviewer.

Table 1. The top 10 keywords with strong occurrences and links.

Key Words	Occurrence	Total Link Strenght
positive energy district	68	1094
architectural design	4	86
zoning	14	242
urban planning	11	238
planning	3	49
integrated planning	3	50
resilience	3	40
integrated energy planning	3	22
urban regeneration	2	20
sustainable city	2	43

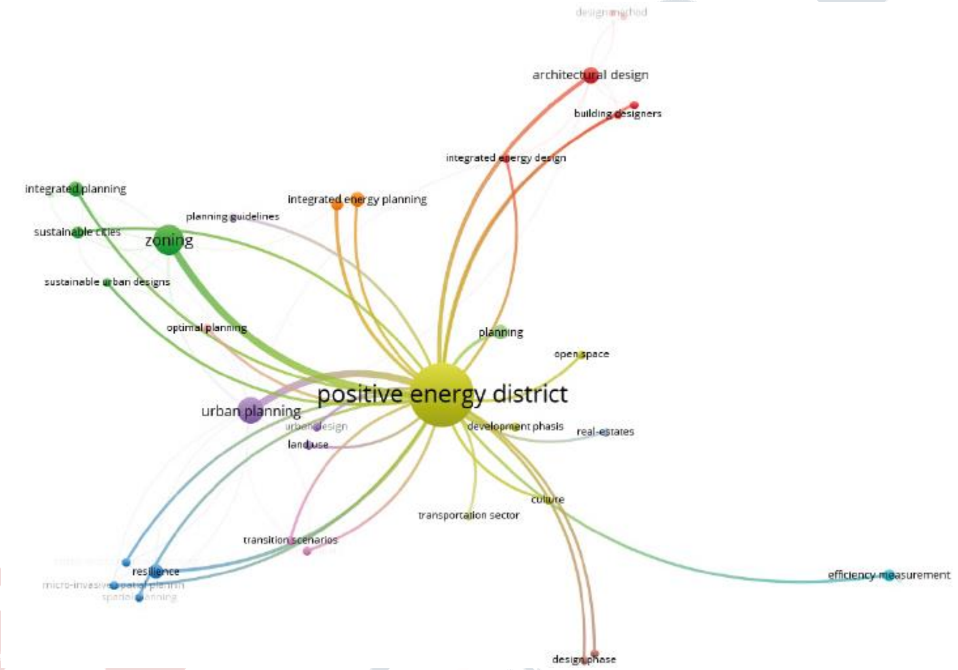

Figure 4. Most relevant associations with "positive energy district".

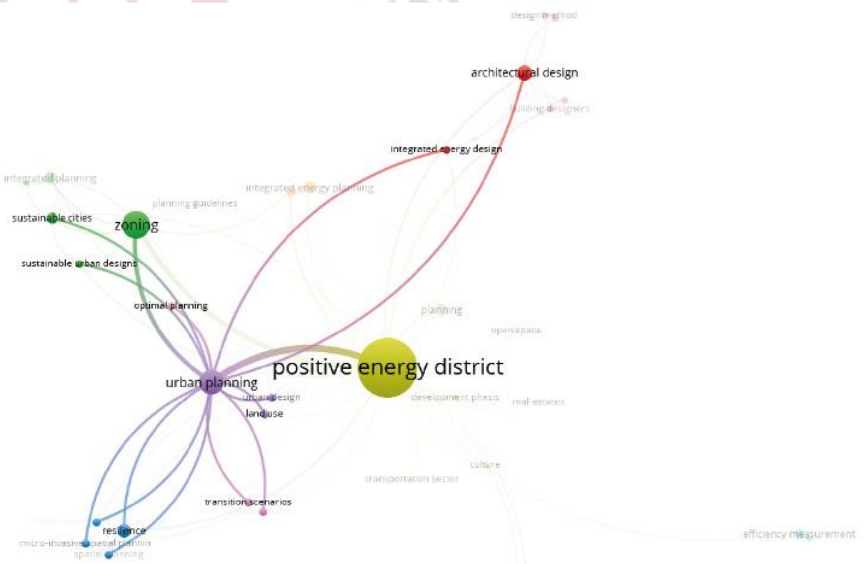

Figure 5. Most relevant associations with "urban planning"

IV. DISCUSSION

This paper provides a scientific review analysis of Positive Energy Districts (PEDs), aiming to answer specific question related to city design. The results of the bibliometric analysis reveal interesting trends.

The section III highlights that:

- The term PED and terms related to urban design are present in 49 papers;
- Other terms - closely related to city design - although not widely included in the scientific literature analyzed in association with the term PED are nonetheless present in limited numbers anyway presenting a stronger link between PED and urban planning then between PED and zoning;
- Considering the term PED and the link with terms related to urban design there is one paper which refers to "city design", twelve papers which refers to "urban design", thirty to "planning" and five to "zoning" (Table 2).

To provide answer to the questions (RQ1) if city design is already embedded in the PED concept or (RQ2) is extraneous to it, research deep dive in the text of 49 selected papers to analyze the context in which the words "city design", "urban design" "planning" and "zoning" have been used (Figure 6).

Results are listed below:

- There's only one paper n°1 (Tab. 2) which include the words "city design". The paper present a GIS-based tool designed to delineate boundaries from an energy perspective, harmonizing with urban design and land-use planning. The paper affirm that the initial selection of appropriate areas is crucial for the successful planning and implementation of Positive Energy Districts (PEDs), which aim is to assist cities in integrating energy planning within urban design. The paper affirms that PED design and development projects lack of a structured process for identifying and selecting areas with the potential to become energy-positive. To address this gap the paper focus on GIS-based tool which utilizes a flexible multicriteria assessment method to identify suitable areas for achieving an annual positive non-renewable energy balance. Thus, the paper underscores the need for deep integration of energy sustainability within urban planning, extending to neighborhood, district, and building levels.
- Among papers which include words "urban design" the analysis has individuated twelve papers, but due to the deep dive in the text of each paper we assume that only two highlight nexus between PEDs and urban design. Namely:
  - Paper n° 3 (Table 2) emphasizes the analysis of urban districts as cohesive urban design units where optimal configurations for buildings, street lighting, vehicles, and other elements are established. The methodology developed by PathPED project defines a Positive Energy District (PED) as a primary functional unit for urban design. It considers its main components - buildings, streetlights, vehicles, photovoltaic systems, etc. - as dynamic agents capable of evolving and making decisions about their future based on a fuzzy logic engine. Thus, this paper highlights the importance of integrating various urban elements to achieve optimal energy performance and sustainability within urban design. Moreover, the paper presents Bilbao case study as the city planned the energy profiles for a district of around 23,000 s. f.
  - Paper n°7 (Table 2) present case study of City of Brno, which represents a significant step in the city's ongoing efforts to develop a smart city concept initiated in 2014. To facilitate this development, the City of Brno established a dedicated post of a development site manager within the Department of Data, Analysis, and Evaluation, part of the Strategic Development and Cooperation Department. An international one-phase urban design idea competition was organized by the City Chief Architect's Office in collaboration with the Department of Data, Analysis, and Evaluation to gather innovative concepts for the project. The Heating Plant of Brno has also played a crucial role in negotiations concerning the future of the smart district Špitálka.
- Among papers which include word "planning" the analysis has individuated thirty papers, but due to the deep dive in the text of each paper we assume that only eight highlight the nexus between PEDs and planning. Namely:
  - Paper n° 15 (Table 2) highlights the need to pass "from impact assessment to impact design: understanding co-benefit assessments as strategic planning instruments for progressive climate and renewable energy policies [or projects] to pro-actively seize the social and economic opportunities".
  - Paper n° 20 (Table 2) presents a model for the carbon-neutral and sustainable energy transition toward PEDs, targeted for the definition of strategic urban planning. Thus, the paper taking inspiration from the existing literature on the field of energy modeling and bearing in mind the guidelines of the SET-Plan Action 3.2, propose a methodology which includes the energy sharing among buildings and the presence of local storage as characterizing features of urban energy modeling. The paper presents also the Catania case study.
  - The paper n° 21 (Table 2) highlights the approaches of selected municipalities, (i.e.: Valencia), with the objectives of energy demand reduction and implementation of renewables at a local level, combining energy objectives with sustainability criteria related and urban planning. Thus, the paper

present Valencia case study where a method based on data gathering, demand analysis, study of the feasible renewable energy capacity, and techno-economic simulation of the different scenarios support urban planning.

- Paper n° 24 (Table 2) highlight Oulu case study where was created an initial plan for the optimal path of planning and implementing PEDs aiming to harmonize cities' spatial planning with energy planning.
- Paper n° 27 (Table 2) highlights how organization of an energy infrastructure based on a new generation of buildings requires profound innovations from architectural, planning and construction points of view. The case study in Roma proposes an approach to identify a sequence of phases that provide a concise and quantitative pre-assessment of the theoretical flexibility of a building block to act as an energy net component. These phases are planned to be managed within an optimization procedure, which quantifies various flexibility metrics, such as energy consumption and production targets, energy balance constraints at the building level and positive energy block scenarios, considering different levels of information and detail. Thus, a multi-criteria decision-making optimization framework for PED Blocks for cities is offered as a contribution to operationalize PED Blocks according to a new generation of urban planning practices and buildings. It invites scholars to think about a new set of criteria that can drive the innovation in planning practices and approval processes, promoting PED blocks as a common practice.
- Paper n° 33 (Table 2) focuses on PED definition which is encapsulated into the climate neutrality requirements of the built environment through the means of a positive energy balance. Thus, the paper point out that what is missing in the PED definition is criteria and specifications for the district development and planning process, due to the fact that different stakeholders and ownership structures and spatial and urban planning organizations, require different planning processes.
- Paper n° 35 (Table 2) highlights the concept that PEDs are an inherently scalable concept that can grow locally and include a mix of new and old buildings. Thus, PEDs are not merely energy projects; they require the combination of many relevant city functions, such as energy planning, (electric) mobility planning, urban planning, (open) information and communication technology (ICT), sustainability plans, etc.
- Paper n°38 (Table 2) highlights the need for information and guidance to plan and implement PEDs, including both technical planning and urban planning. Morevoer, the paper affirms than in the near future, climate adaptation will become more important, which will bring new challenges to the planning of the urban environment and PEDs.
- Paper n° 39 (Table 2) highlights how usual practice in urban planning has frequently considered energy performance of buildings individually, irrespective of the surrounding buildings. PED breaks this habit by applying integrated strategies for building renovation, energy efficiency, and local energy production from renewable energy sources (RES) in a locally interconnected and holistic way.
- Paper n° 40 (Table 2) highlights that cities are dynamic ecosystems with evolving needs and continuous development. Thus, PEDs as well smart city should aim towards developing bold city visions covering urban planning, technical, financial and social aspects.

- Last, but not least, among papers which include word "zoning" there is only one paper to mention. It is paper n° 47 which points out that quantify potential energy reductions and on-site generation using currently available technologies could assist governments to develop policy, incentives, and regulations that can expedite this trend. Thus, the paper underscore that the zoning laws could be modified to facilitate the transition to PEDs for example supporting conversion of existing homes to densified counterparts, subsidies could help cover the additional cost of the most promising energy efficiency solutions and feed-in-tariffs could improve the economics for installing BIPV.

Based on the results of the analysis, authors provide the following answers to the given questions:

RQ1 Is city design already embedded in the PED concept?

Our analysis reveals that out of 140 documents referencing Positive Energy Districts (PED), only 49 establish a connection between PED and urban design terminology. This indicates that city design is not strongly embedded in the PED concept. However, a limited number of papers do highlight the importance of technical and urban planning for the development and implementation of PED. These papers emphasize the necessity of deeply integrating energy sustainability within urban planning and the importance of incorporating various urban elements to achieve optimal energy performance and sustainability. Furthermore, it appears that the selected papers suggest moving from impact assessment to what they term "impact design," which seems to be a new concept.

RQ2 or alternatively, is extraneous to it?

Our analysis found that 14 out of 140 papers clearly establish a connection between urban design terminology and PED. This suggests that urban design is not extraneous to the

Positive Energy District approach. Although the connection between PED and urban design is still developing, especially considering future research and innovation programs, it is evident that urban design plays a role in the PED concept.

Table 2. The 49 papers with the term PED and terms related to urban design.

n. article	title	doi
City Design		
1	*A GIS-based multicriteria assessment for identification of positive energy districts boundary in cities*	https://www.mdpi.com/1996-1073/14/22/7517
Urban Design		
2	*Design, Modelling and Performance Evaluation of a Positive Energy District in a Danish Island*	https://doi.org/10.5334/fce.146
3	*Holistic fuzzy logic methodology to assess positive energy district (PathPED)*	https://doi.org/10.1016/j.scs.2022.104375
4	*The opportunity for smart city projects at municipal scale: Implementing a positive energy district in Zorrozaurre*	https://dsp.tecnalia.com/handle/11556/1177
5	*Methodology for Quantifying the Energy Saving Potentials Combining Building Retrofitting, Solar Thermal Energy and Geothermal Resources*	https://doi.org/10.3390/en13225970
6	*Novel Energy System Design Workflow for Zero-Carbon Energy District Development*	http://dx.doi.org/10.3389/frsc.2021.662822
7	*Smart Districts: new phenomenon Iin sustainable urban development. Case Study of* Špitálka *in Brno, Czech Republic*	https://is.muni.cz/publication/1836842/spitalka.pdf
8	*Digital Twin for Accelerating Sustainability in Positive Energy District: A Review of Simulation Tools and Applications*	https://www.frontiersin.org/articles/10.3389/frsc.2021.663269/full
9	*Zero emission neighbourhoods and positive energy districts – A state-of-the-art review*	https://doi.org/10.1016/j.scs.2021.103013
10	*The Sense and Non-Sense of PEDs—Feeding Back Practical Experiences of Positive Energy District Demonstrators into the European PED Framework Definition Development Process*	https://doi.org/10.3390/en15124491
11	*Sustainable Urban Areas for 2030 in a Post-COVID-19 Scenario: Focus on Innovative Research and Funding Frameworks to Boost Transition towards 100 Positive Energy Districts and 100 Climate-Neutral Cities*	https://doi.org/10.3390/en14010216
12	*Environmental sustainability approaches and positive energy districts: A literature review*	https://doi.org/10.3390/su132313063
13	*Supporting Cities towards Carbon Neutral Transition through Territorial Acupuncture*	http://dx.doi.org/10.3390/su15054046
Planning		
14	*Approaches to Social Innovation in Positive Energy Districts (PEDs)—A Comparison of Norwegian Projects*	https://www.mdpi.com/2071-1050/13/13/7362
15	*Assessing multiple benefits of housing regeneration and smart city development: the European project SINFONIA*	https://www.mdpi.com/2071-1050/12/19/8038
16	*Assessing the performance of Positive Energy Districts: The need for innovative methods*	https://iopscience.iop.org/article/10.1088/1755-1315/1085/1/012014
17	*Citizens and Positive Energy Districts: Are Espoo and Leipzig Ready for PEDs?*	https://doi.org/10.3390/buildings11030102
18	*Combining Sufficiency, Efficiency and Flexibility to Achieve Positive Energy Districts Targets*	https://doi.org/10.3390/en14154697

City Design		
n. article	title	doi
19	*Creating Comparability among European Neighbourhoods to Enable the Transition of District Energy Infrastructures towards Positive Energy Districts*	https://doi.org/10.3390/en15134720
20	*Local Production and Storage in Positive Energy Districts: The Energy Sharing Perspective*	https://doi.org/10.3389/frsc.2021.690927
21	*Planning positive energy districts in urban water fronts: Approach to La Marina de València, Spain*	https://doi.org/10.1016/j.enconman.2022.115795
22	*Positive Energy Districts: The 10 Replicated Solutions in Maia, Reykjavik, Kifissia, Kladno and Lviv*	https://doi.org/10.3390/smartcities6010001
23	*Possibilities of Upgrading Warsaw Existing Residential Area to Status of Positive Energy Districts*	https://doi.org/10.3390/en14185984
24	*Stakeholder management in PED projects: challenges and management model*	https://journals.aau.dk/index.php/sepm/article/view/6979
25	*A Comprehensive Methodology for Assessing the Impact of Smart City Interventions: Evidence from Espoo Transformation Process*	https://doi.org/10.3390/smartcities5010006
26	*Combined effect of outdoor microclimate boundary conditions on air conditioning system's efficiency and building energy demand in net zero energy settlements,*	http://dx.doi.org/10.3390/su12156056
27	*Multi-Criteria Decision Making Optimisation Framework for Positive Energy Blocks for Cities*	https://doi.org/10.3390/su14010446
28	*Renovation assessment of building districts: Case studies and implications to the positive energy districts definition*	https://doi.org/10.1016/j.enbuild.2023.113414
29	*Technical Feasibility for the Boosting of Positive Energy Districts (PEDs) in Existing Mediterranean Districts: A Methodology and Case Study in AlcorcÃ³n, Spain,*	https://doi.org/10.3390/su151914134
30	*Technologies and Strategies to Support Energy Transition in Urban Building and Transportation Sectors*	http://dx.doi.org/10.3390/en16114317
31	*Testing Platforms as Drivers for Positive-Energy Living Laboratories*	http://dx.doi.org/10.3390/en13215621
32	*A Comprehensive PED-Database for Mapping and Comparing Positive Energy Districts Experiences at European Level*	https://www.mdpi.com/2071-1050/14/1/427
33	*A Quantitative Positive Energy District Definition with Contextual Targets*	https://www.mdpi.com/2075-5309/13/5/1210
34	*Analysis and Evaluation of the Feasibility of Positive Energy Districts in Selected Urban Typologies in Vienna Using a Bottom-Up District Energy Modelling Approach*	https://www.mdpi.com/1996-1073/14/15/4449
35	*Energy Citizenship in Positive Energy Districts—Towards a Transdisciplinary Approach to Impact Assessment*	https://doi.org/10.3390/buildings12020186
36	*Towards 100 positive energy districts in Europe: Preliminary data analysis of 61 European cases*	https://doi.org/10.3390/en13226083
37	*Positive energy districts: Identifying challenges and interdependencies*	https://doi.org/10.3390/su131910551
38	*IEA EBC Annex83 positive energy districts*	https://doi.org/10.3390/buildings11030130
39	*How to Achieve Positive Energy Districts for Sustainable Cities: A Proposed Calculation Methodology*	https://doi.org/10.3390/su13020710

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n. article	**title**	**doi**
40	*From a comprehensive pool to a project-specific list of key performance indicators for monitoring the positive energy transition of smart cities—An experience-based approach*	https://doi.org/10.3390/smartcities3030036
41	*From 'Zero' to 'Positive' Energy Concepts and from Buildings to Districts—A Portfolio of 51 European Success Stories*	https://doi.org/10.3390/su142315812
42	*European Union funding Research Development and Innovation projects on Smart Cities: The state of the art in 2019*	https://doi.org/10.5278/ijsepm.3493
43	*ChatGPT for Fast Learning of Positive Energy District (PED): A Trial Testing and Comparison with Expert Discussion Results,*	http://dx.doi.org/10.3390/buildings13061392
44	*Energy Citizenship. Tools and Technologies to enable Transition in Districts*	http://dx.doi.org/10.3390/buildings12020186
Zoning		
45	*A GIS-based multicriteria assessment for identification of positive energy districts boundary in cities*	https://www.mdpi.com/1996-1073/14/22/7517
46	*Creating Comparability among European Neighbourhoods to Enable the Transition of District Energy Infrastructures towards Positive Energy Districts*	https://doi.org/10.3390/en15134720
47	*Residential Densification for Positive Energy Districts*	https://doi.org/10.3389/frsc.2021.630973
48	*Novel Energy System Design Workflow for Zero-Carbon Energy District Development*	http://dx.doi.org/10.3389/frsc.2021.662822
49	*Smart communities in Japan: Requirements and simulation for determining index values*	https://doi.org/10.1016/j.jum.2022.09.003

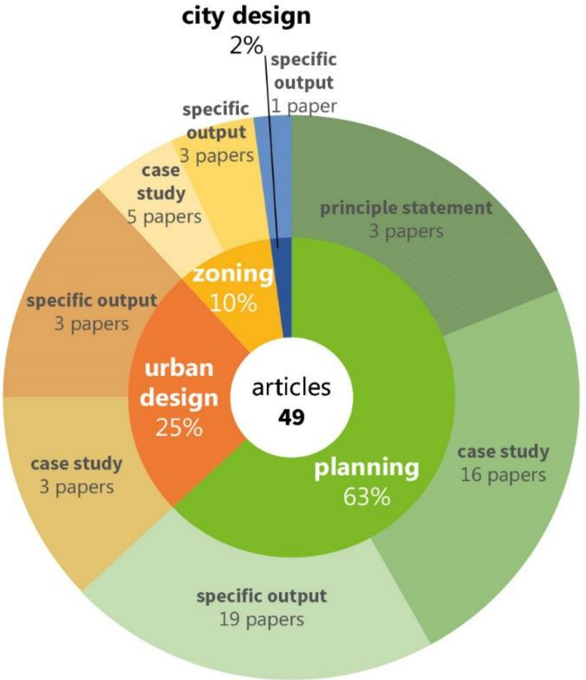

Figure 6. The selected articles to answer at RQ1 and RQ2

V. CONCLUSION

Based on the data from our research, it is evident that the implementation roadmap for Positive Energy Districts (PEDs) requires new criteria to drive innovation in planning practices and approval processes, aligning with the 2050 challenges. Among these new criteria, the nexus between PEDs and urban design must include:

- A focus on the need for deep integration of energy sustainability within urban planning.
- The integration of various urban elements to achieve optimal energy performance and sustainability within urban design.
- Innovative methods based on data gathering, demand analysis, the study of feasible renewable energy capacity, and techno-economic simulation of different scenarios to support urban planning.
- An innovative multi-criteria decision-making optimization framework for city building blocks to operationalize PEDs according to a new generation of urban planning practices.

PEDs, along with smart cities, should aim to develop bold city visions covering urban planning, technical, financial, and social aspects.

The evolution from Nearly Zero Energy Buildings (nZEBs) to Zero Energy Buildings (ZEBs) marked a significant step in enhancing energy efficiency through advanced building envelope solutions and smart sensors that reduce energy consumption and contribute to local energy production, achieving a net-positive energy balance. The concept of PEDs builds upon the foundation laid by ZEBs, epitomizing the transformative potential of smart cities. PEDs leverage integrated data, sensors, and systems to create sustainable and livable urban environments on a larger scale. This visionary approach to urban planning underscores the increasing relevance of city design and urban planning in the development of PEDs. As we move towards 2050, the role of urban planning in fostering sustainable and energy-efficient districts will become even more crucial, driving forward the agenda of sustainable urban development.

REFERENCES

[1] R. Oltra-Badenes, V. Guerola-Navarro, J.-A. Gil-Gómez, D. Botella-Carrubi, D. "Design and Implementation of Teaching–Learning Activities Focused on Improving the Knowledge, the Awareness and the Perception of the Relationship between the SDGs and the Future Profession of University Students". Sustainability 2023, 15, 5324. https://doi.org/10.3390/su15065324.

[2] International Energy Agency. "Global Energy Review 2021. Assessing the Effects of Economic Recoveries on Global Energy Demand and CO2 Emissions in 2021". International Energy Agency: Paris, France, 2021.

[3] European Commission. "A Renovation Wave for Europe—Greening Our Buildings, Creating Jobs, Improving Lives {SWD (2020) 550 Final}". European Commission: Brussels, Belgium, 2020.

[4] S. Koutra, J. Terés-Zubiaga, P. Bouillard, V. Becue, "'Decarbonizing Europe'. A critical review on positive energy districts approaches". Sustain. Cities Soc. 2023, 89, 104356. https://doi.org/10.1016/j.scs.2022.104356.

[5] European Commission. "Clean Energy for All Europeans Package 2019". Available online: https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en (accessed on 10 april 2024).

[6] European Commission. "EU Mission: Climate-Neutral and Smart Cities 2021". Available online: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en (accessed on 10 april 2024).

[7] CETPartnership. "Clean Energy Transition Partnership. 2023". Available online: https://cetpartnership.eu/ (accessed on 10 april 2024).

[8] DUT Partnership. "Driving Urban Transitions to a Sustainable Future. 2023". Available online: https://dutpartnership.eu/ (accessed on 10 april 2024).

[9] H. Vandevyvere, P. Cartuyvels, D. Ahlers, B. Alpagut, V. Cerna, V. Cimini, S. Haxhija, M. Hukkalainen, M. Kuzmic, K. Livik, et al. "Positive Energy Districts: An Action Cluster of the Smart Cities Marketplace". 2023. Available online: www.jpi-urbaneurope.eu/ped (accessed on 10 april 2024).

[10] European Commission. Energy Union Package. "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy". COM (2015) 80 final; European Commission: Brussels, Belgium, 2015.

[11] Temporary Working Group Set Plan 3.2. SET-Plan ACTION n°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 10 april 2024).

[12] M. Salvia, F. Pietrapertosa, V. D'Alonzo, P. Clerici Maestosi, S. G. Simoes, D. Reckien. "Key dimensions of cities' engagement in the transition to climate neutrality". J. Environ. Manag. 2023, 344, 118519. https://doi.org/10.1016/j.jenvman.2023.118519.

[13] M. Eremia, L. Toma, M. Sanduleac. "The Smart City Concept in the 21st Century". Procedia Eng. 2017, 181, 12–19. https://doi.org/10.1016/J.PROENG.2017.02.357.

[14] C. Yin, Z. Xiong, H. Chen, J. Wang, D. Cooper, B. David. "A literature survey on smart cities". Sci. China Inf. Sci.2015, 58, 1–18 .https://doi.org/10.1007/s11432-015-5397-4.

[15] I. Zubizarreta, A. Seravalli, S. Arrizabalaga. "Smart City Concept: What It I sand What It Should Be". J. Urban Plan. Dev.2016,142.https://doi.org/10.1061/(ASCE)UP.1943-5444.0000282.

[16] M.-T. Nguyen, S. Batel. "A critical Framework to Develop Human-Centric Positive Energy Districts: Towards Justice, Inclusion, and Well-Being". Front. Sustain. Cities2021, 3, 691236 .https://doi.org/10.3389/frsc.2021.691236.

[17] X. Zhang, S. Penaka, S. Giriraj, M. Sánchez, P. Civiero, H. Vandevyvere. "Characterizing Positive Energy District (PED) through a Preliminary Review of 60 Existing Projects in Europe". Buildings 2021, 11, 318. https://doi.org/10.3390/buildings11080318.

[18] I. Marotta, F. Guarino, S. Longo, M. Cellura. "Environmental Sustainability Approaches and Positive Energy Districts: A Literature Review". Sustainability2021, 13, 13063. https://doi.org/10.3390/su132313063.

[19] P. Clerici Maestosi, M. Salvia, F. Pietrapertosa, F. Romagnoli, M. Pirro. "Implementation of Positive Energy Districts in European Cities: A Systematic Literature Review to Identify the Effective Integration of the Concept into the Existing Energy Systems". Energies 2024, 17, x. https://doi.org/10.3390/

[20] P. Civiero, J. Pascual, J. A. Abella, J. Salom. "Innovative PEDRERA Model Tool Boosting Sustainable and Feasible Renovation Programs at District Scale in Spain". Special Issue: Sustainable Spatial Planning and Territorial Governance 2022. https://doi.org/10.3390/su14159672.

[21] F. Leone, F. Reda, A. Hasan, H. ur Rehman, F. C. Nigrelli, F. Nocera, V. Costanzo. "Lessons Learned from Positive Energy District (PED) Projects: Cataloguing and Analysing Technology Solutions in Different Geographical Areas in Europe". Special Issue Advanced Energy Systems in Zero/Positive Energy Buildings, Communities and Districts. 2022. https://doi.org/10.3390/en16010356.

[22] A. Bruck, S. D. Ruano, H. Auer. "One piece of the puzzle towards 100 Positive Energy Districts (PEDs) across Europe by 2025: An open-source approach to unveil favourable locations of PV-based PEDs from a techno-economic

perspective". Energy, Vol. 254. 2022. https://doi.org/10.1016/j.energy.2022.124152.

[23] R. Volpe, M. Gonzalez Alriols, N. Martelo Schmalbach, A. Fichera. "Optimal design and operation of distributed electrical generation for Italian positive energy districts with biomass district heating". Energy Conversion and Management. Vol. 267. 2022. https://doi.org/10.1016/j.enconman.2022.115937

[24] Urban Design Terminology (urbandesignlab.in)

[25] N. Comerio, F. Strozzi. "Tourism and its economic impact: A literature review using bibliometric tools". Tour. Econ.2019, *25*, 109–131.https://doi.org/10.1177/1354816618793762.

[26] O. Lindholm, H. ur Rehman, F. Reda. "Positioning positive energy districts in European cities". Special Issue Net-Zero/Positive Energy Buildings and Districts. 2021.https://doi.org/10.3390/buildings11010019