Evaluating Positive Energy Districts: A Literature Review

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Abstract. To achieve the climate goals in the Paris Agreement and clean energy transition, positive energy districts must be promoted. A positive energy district is focused on increasing the efficiency of the buildings within it, using the renewable energy it produces, favouring electric and hybrid cars, and storing all the energy produced, in order to make clean energy for the whole city. Positive energy is a concept that takes into account not only the energy aspect, but also the environmental, social, and economic sphere. In order to be effective, this transformation requires the intervention of the community and the local decision-makers. The aim of the paper is to investigate the scientific literature, through the scientific dataset SCOPUS, in order to develop an evaluation framework for energy transition to support the decision-makers. Since the positive energy district is a recent paradigm, the investigation is extended to consider energy fields and takes into account different levels of urban scale. Specific keywords are used in order to find different economic methods in the literature, which can be used to support positive energy transition.

Keywords: Energy districts · Positive energy district · Economic evaluation · Economic valuation · Economic assessment · Economic analysis

1 Introduction

The concept of a positive energy district (PED) is becoming a possible solution for clean energy and meeting the climate goals set by Agenda 2030 and the Paris Agreement [1–3]. Given that 70% of people are expected to be living in cities by 2050, it is fundamental to find a sustainable solution at the urban level in order to create a healthy habitat for citizens. This concept is underlined by the United Nations in the definition of the 17 sustainable development goals (SDGs) within the 2030 Agenda, in particular by SDG 11, which aims to make cities inclusive, safe, resilient and sustainable [2].

In the last few years PEDs have received much attention as a possible solution for the global situation [3–5]. A PED could be defined as an energy-efficient and energy-flexible urban area aimed at creating a surplus of clean energy for the city by using renewable energy, producing an annual net-zero energy import and net-zero CO2 emissions in a certain time frame [3].

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To increase PEDs it is important to involve the local decision-makers and the community. In order to support this complex decision, evaluation methodology can help to quantify the benefit derived from the application of positive energy districts. Until now, the main evaluation methods used to monetize the environmental impact in the field of energy decision-making problems have been life cycle cost (LCC) [6], and cost-benefit analysis (CBA) [7]. In recent years, the analysis of multi-criteria decisions (MCDA) [8] has also been used to support decisions-makers. MCDA has the aim to involve decisions-makers in focusing not only on the energy aspect but also taking a wide range of perspectives into account. There are already various evaluation methods in use for PEDs, but to support the decision-maker more of them need to be identified in the literature. The aim of this research is to conduct a literature review to find more evaluation methods, in this way the concept of the PED is not confined to academic areas but can be put into practice. The literature review was carried out by using the scientific database SCOPUS.

The concept of the PED is new in literature. In fact, the period of publication regarding this concept only started in 2018 and by the end of 2021 there were fewer than 100 documents which mentioned it. In detail, the economic evaluation methods applied for PEDs are life cycle costs (LCC) [9, 10], cost-benefit analysis (CBA) [11], multi-criteria decision analysis (MCDA) [12, 13], and life cycle assessment (LCA) [14, 15]. More recently, also other approaches have been considered, such as the estimation of environmental and social impacts or the sensitivity analysis.

The rest of the paper is structured as follows: the Sect. 2 regards the research methodology, aiming to show the steps used for the literature review analysis. The third part is dedicated to the results, the outcome of the analysis. The last part is the conclusion, summarizing the overall research and pointing out a future perspective on this topic.

2 Research Methodology

The literature bibliography analysis was conducted by using the SCOPUS database.

All the periods present in the literature, from 1975 to 2021, were taken into consideration. The analysis was conducted by using a multistep research approach (see Fig. 1). In detail, it was developed in three steps. The first step was the general analysis, using the keywords *("economic evaluation" OR "economic valuation" OR "economic assessment") AND ("energy"). "All fields*" gave a result equal to 85′043, instead of with the selection "*title, abstract, keyword*" 7′633 results.

Starting from the general analysis, the second step was to reduce the research area by adding specific words and creating two groups. For the first analysis, the words related the scale of application were added, creating the group B; in detail:

- *(("economic evaluation" OR "economic valuation" OR "economic assessment") AND ("energy") AND ("Urban"))* = 215 results
- *(("economic evaluation" OR "economic valuation" OR "economic assessment") AND ("energy") AND ("District"))* = 211 results
- *(("economic evaluation" OR "economic valuation" OR "economic assessment") AND ("energy") AND ("Neighborhood"))* = 14 results

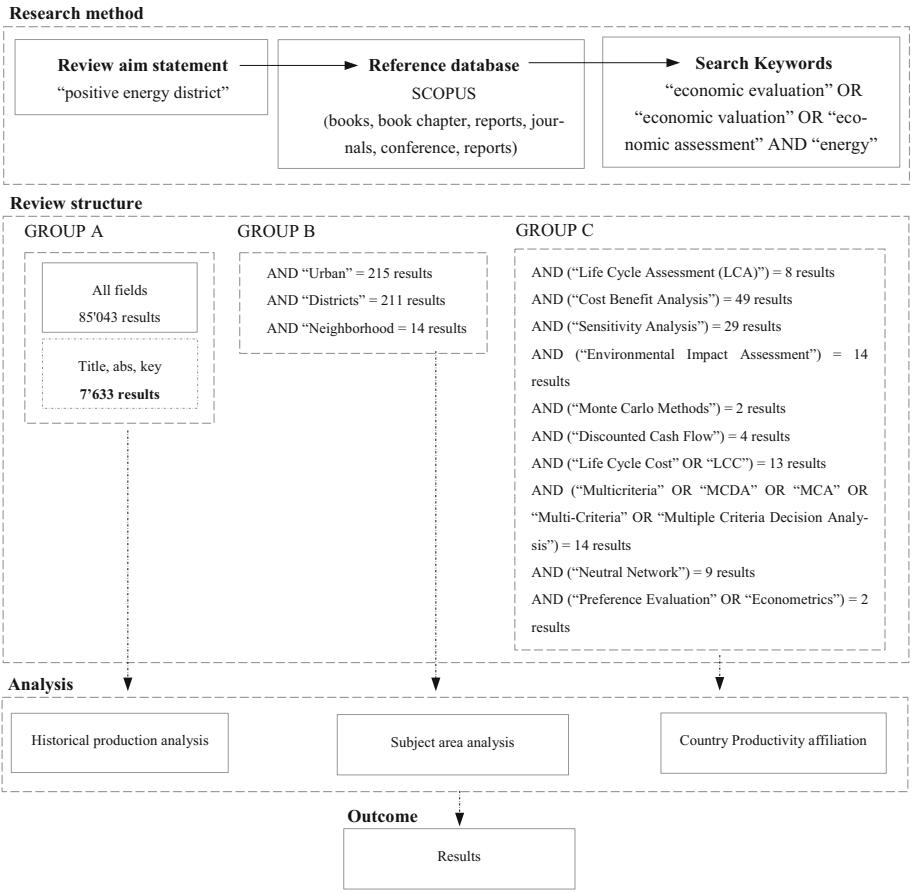

Fig. 1. Literature review framework

For the second analysis, specific keywords regarding the evaluation methods were added, creating group C; in detail:

- *AND ("Life Cycle Assessment (LCA)")* = 8 results
- *AND ("Cost Benefit Analysis")* = 49 results
- *AND ("Sensitivity Analysis")* = 29 results
- *AND ("Environmental Impact Assessment")* = 14 results
- *AND ("Monte Carlo Methods")* = 2 results
- *AND ("Discounted Cash Flow")* = 4 results
- *AND ("Life Cycle Cost" OR "LCC")* = 13 results
- *AND ("Multicriteria" OR "MCDA" OR "MCA" OR "Multi-Criteria" OR "Multiple Criteria Decision Analysis")* = 12 results
- *AND ("SROI" OR "Social Return on Investment")* = 0 results
- *AND ("Preference Evaluation" OR "Econometrics")* = 2 results
- *AND ("Quantitative Analysis")* = 4 results

The last step was the analysis of the groups created. Specifically, the analysis was conducted in: *Historical production, Subject area analysis* and *Country productivity affiliation.* The *historical production* allowed the production activity regarding the research analysis created during the time to be understood. The second analysis, *country productivity affiliation,* showed the geographical area where the documents were published. The last analysis, *subject area analysis*, according to the SCOPUS database, show the area of publication, for example, energy, environmental sciences, and social area.

3 Results and Discussions

3.1 Group A: Analysis About Search Fields

The first analysis was the general research in the energy area in the framework of economic methods. The outcome shows a total of 85′043 documents for "*all field*", and 7′633 documents for the limited research to "*title, abstract, keywords*". The documents start to be published in 1951 (see Fig. 2). The most intense period of production for the area "*all fields*" is between the 2008 and 2021, with 77′171 documents, equal to 91%. In particular, the last four years produced 34,196 documents, equal to 40% of the total production.

For the area referred to "*title, abstract and keywords*", the most intense periods of production were the last 15 years, with a production of 6′040 documents, equal to 79% of total. Especially, the last four years have produced 2′349 documents, which represent the 31% of total. Figure 2 reports the *historical production analysis* comparing the two areas, "*all fields*" and the limited area "*title, abstract, and keywords*".

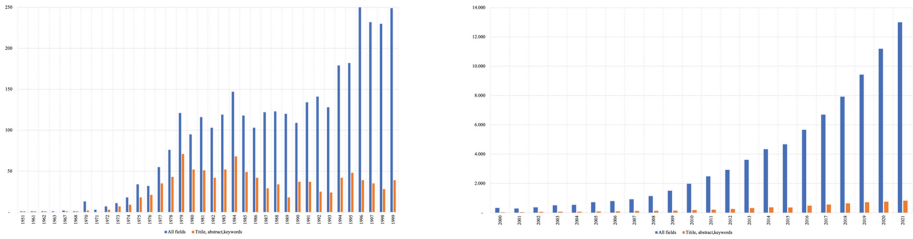

Fig. 2. *Historical production* for "*all fields*" and research limited "*title, abs and key*".

The second analysis regards the examination of the *subject areas* (see Fig. 3). The database SCOPUS identify 27 subject areas for the field "*all fields*" and the limited research "*title, abstract and keywords*". In particular, for both the fields the main subject areas are energy, environmental sciences, engineering and chemical engineering. In detail for "*all fields*," 60% of all documents are produced in the four subject areas identified, instead of the "*title, abstract, and keywords*" research limitation 71% of documents are produced from the four-subject area.

The last analysis regards the country of production. For the research "*all fields*" it emerges that there are 160 countries which produced documents, instead of for the limit research "*title, abstract and keywords*" there are 132. From the dataset SCOPUS, the countries which have mostly produced documents are China, United States, United Kingdom and Italy.

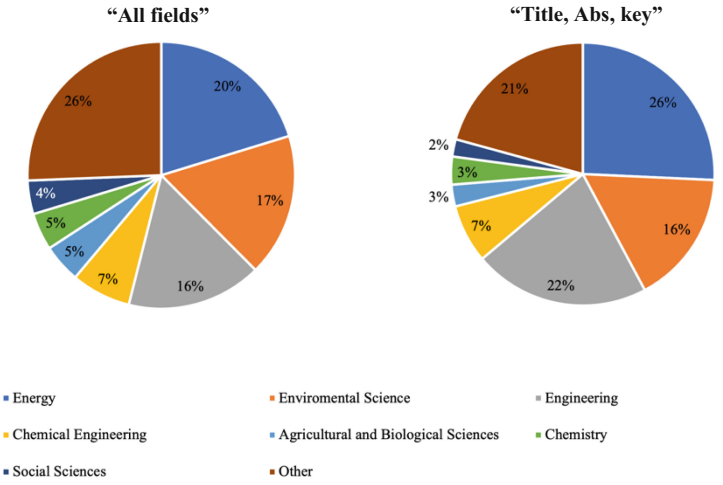

Fig. 3. *Subject area analysis* for "*all fields*" research on the left and "*title, abstract and keywords"* on the right.

3.2 Group B: Economic Method and Energy View at Territorial Scale

The second analysis focused on the territorial scale. In detail, the research was conducted in "*title, abstract, keywords*" research limitation, adding new keywords related to the territorial scale. Specifically, the words used were *urban*, *district* and *neighbourhood.* The results shows that the keyword *urban* has produced 215 documents, instead *neighborhood* has produced 14 documents. From the *historical production analysis*, the word *urban* was present since 1972, instead, the word *neighborhood* has appeared just since 2013 (see Fig. 4).

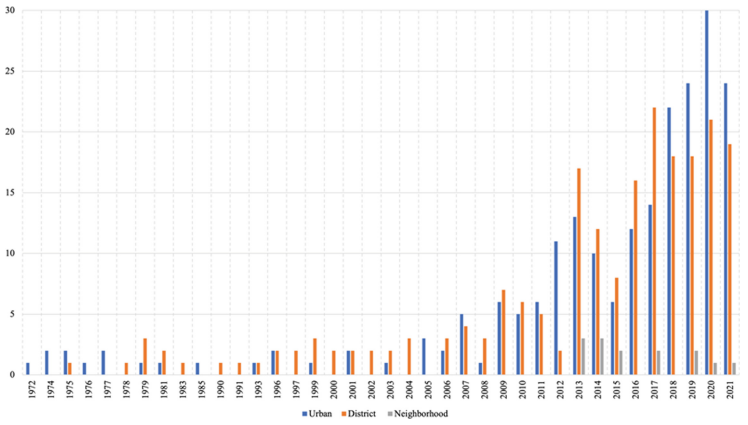

Fig. 4. *Historical production* adding keywords, *urban, district* and *neighborhood.*

For the analysis of the *subject area* specific keywords have been added related to the territorial scale. The areas with the highest number of documents were the same as the previous group in detail: *energy* with 201 documents, *engineering* with 189 and *environmental sciences* with 180.

The third analysis regards the country which produced documents. The SCOUP dataset shows that 64 countries have published documents. From the results it emerges that Italy is the country that has been producing the most part of documents. In detail, the keyword "*urban*" appears in 35 documents and for "*district*" 34 documents have been produced. Instead, Germany is the country that has produced the most part of documents with the keyword "*neighbourhood*", 14 documents (see Fig. 5). Also, the analysis shows that countries of Northern Europe use more the keyword "*district*" such as the United Kingdom with 21 documents, Sweden with 18 documents and Germany with 12 documents. Figure 5 reports the countries which have the keywords mentioned with a minimum of 2 documents.

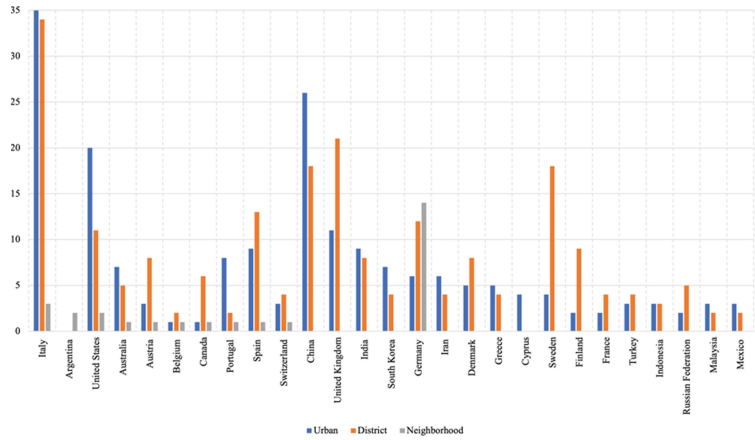

Fig. 5. Country of production focused on the keywords, *urban, district* and *neighborhood.*

3.3 Group C: Evaluation Approach

The last analysis, the most interesting, focused on the evaluation approach. The keywords added to Group B are related to different evaluation economic methods. Some words were suggested by the SCOPUS dataset, as Cost-benefit analysis (CBA) (49 documents), but others were added in order to find different evaluation economic methods, from the most common methods to monetize the energy as the Life Cycle Cost (LCC) to the methods used to estimate the social or environmental impact such as the Multicriteria analysis (MCA). Figure 6 reports all the economic methods added to the research.

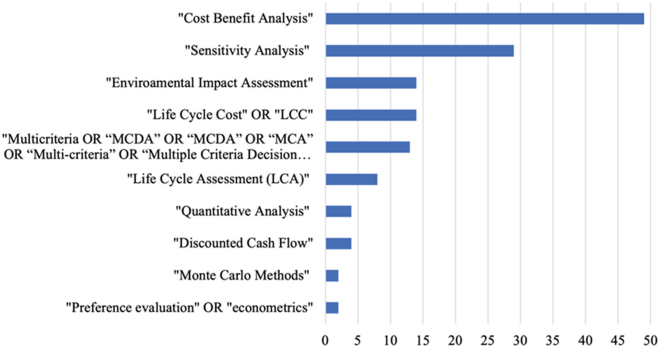

Fig. 6. Number of documents related to evaluations approaches.

The *historical analysis* shows that in 1975 the economic methods used are the preference evaluation and the costs benefits analysis. The most intense period of documents productions was in 2018. The sensitivity analysis started to be present since 2005 and it increased in the period between 2010 and 2014 (see Fig. 7). Results of the *subject area analysis* shows an important production in the fields of environmental sciences, energy and engineering, as reported in Fig. 8.

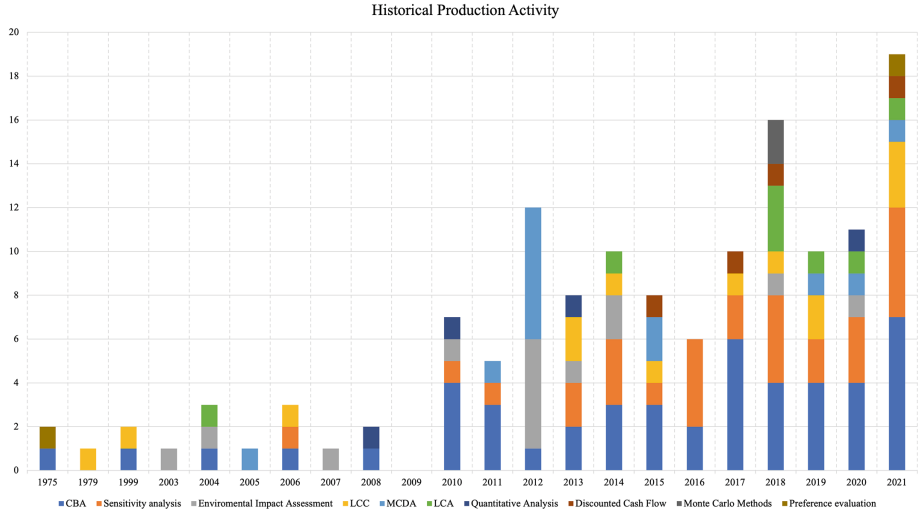

Fig. 7. Historical production activity for different evaluation approaches.

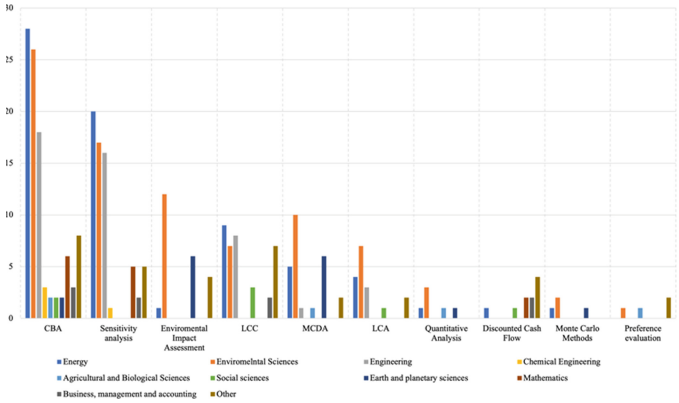

Fig. 8. *Subject areas* related to the different evaluation approaches and methods.

4 Conclusion

The present paper allowed the application of different economic methods in the field of energy at different territorial scales to be understood better, in order to support the benefits resulting from positive energy districts (PEDs).

The transformation of a city into PEDs is complex. In fact, this type of urban transformation consists in increasing the efficiency of buildings, using renewable energy, favoring the use of electric and hybrid cars and storing all the energy produced. To achieve this goal, a literature review was conducted in order to find different economic methods to support the decision-making in order to develop PEDs. The PED paradigm is new, so the literature review was extended to take into consideration energy fields in the framework of economic evaluations at different urban scales.

From the analysis it emerged that the concept of urban scale is present throughout the literature dating back to 1975, whereas the district scale started to appear from 2009. Also, it is clear from the analysis that Italy and China are the countries most interested in working on and developing research on the urban and district scale. The evaluation approach analysis shows that the economic methods mostly used are Cost of Benefits Analysis (CBA), sensitivity analysis and environmental impact.

From a future perspective, it would be interesting to investigate integrated approaches, such as the application of the evaluation methods CBA and MCA together in order to increase the creation of PEDs, since they are two approaches that complement each other. In fact, CBA is based on a detailed cost study, whereas MCA takes into account a wide range of perspectives, such as the human behaviors area.

The outcome of this study could support local decision-making in order to transform urban areas into PEDs. In this way, the concept of PED will not just be related to the academic area, but it will have a practical application.

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