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Special Issue 1.2024

What transition for cities?

Scientific debate, research, approaches and good practices

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Toward a certification protocol for Positive Energy Districts (PED). A methodological proposal

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Abstract
To achieve the ambitious CO_2 emission reduction targets, set by the Sustainable Development Goals, it is crucial to act on cities. Cities are responsible for 67% of the world's primary energy consumption and about 70% of energy-related CO_2 emissions. To support the urban energy transition, a broad implementation of zero-emission districts or positive energy districts (PEDs) is expected. PEDs can be defined as energy-efficient and energy-flexible urban areas that aim to provide a surplus of clean energy to the city by using renewable energies. In developing the PEDs concept, it is necessary to consider not only the technical issue of energy systems but also the environmental, social, and economic spheres. To be effective, it is important to provide decision-makers with tools such as protocol certification for PEDs, which can effectively assess the complexity of the impacts a PEDs might have on other urban transformations from a multi-stakeholder perspective. LEED for neighborhood development, BREEAM communities, and CASBEE for cities are the most widely used and known protocols in the world for the evaluation of districts. Protocol certifications today do not consider PEDs because they are outdated, but some common characteristics can already be found within them, which allows for the possibility of reformulating scores and inserting new evaluation criteria. The aim of this research, through a review of the literature, is to analyze the current protocol certificates at the district level, identifying criteria and scores within the evaluation methods, with the aim of contributing to the definition of a PED certification protocol with effective criteria and scores to support design and development of PEDs.

Keywords
Positive Energy District; LEED Neighborhoods; BREEAM communities; CASBEE Urban Districts.

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1. Introduction

The International Energy Agency has placed great emphasis on reducing CO2 emissions in cities and related systems. Cities account for more than 50% of the global population, 80% of the global GDP, two-thirds of global energy consumption and more than 70% of annual global carbon emissions (IEA, 2020). These factors are expected to increase significantly in the coming decades: it is anticipated that by 2050 more than 70% of the world's population will live in cities(Aboagye & Sharifi, 2024), resulting in massive growth in demand for urban energy infrastructure (European Commission, 2021). Climate action in cities is essential to achieve the ambitious net-zero emissions goals(Gaglione, 2023). From this perspective, it is known that urban development in the coming years will have to shift from simple building solutions to positive-energy neighborhoods and districts (Becchio et al., 2020). All of this, along with other innovative concepts developed in the past for cities of the future, will be crucial to achieving the goals the United Nations have set for themselves in the areas of energy and climate change (Gargiulo et al., 2012; Suppa et al., 2022).
With the new perspective indicated at the World Economic Forum in 2015(Yin et al., 2022), research and innovation plan for the cities, aiming to vigorously address several global challenges that affect our cities and society: health and safety, digitization, energy, and climate change in the first place (Guarino et al., 2022). PEDs fall under this heading.
The area of Smart Cities & Communities was already defined as a priority and strategic by both the previous European Horizon 2020 program and the 17 Sustainable Development Goals established by the UN and the 2030 Agenda (Kroll et al., 2019). Over time, however, it became apparent that financing large smart city projects at the urban level was a complex task, with a huge demand for resources and investment. For this reason, the authors decided to focus efforts on smaller urban areas, such as city blocks, pilot districts and neighborhoods, towards a concept of a diffused smart land focusing initially on energy efficiency in buildings and on-site local renewable energy production(Guida & Martinelli, 2023). In recent years, to sustain the urban energy transition the concept became even more ambitious, from highly efficient buildings to net-zero ones(Lwasa et al., 2022; Niu & Zhang, 2023). Later on, by including energy sharing, waste heat recovery, e-mobility, and energy storage, the scope was broadened to include the implementation of net-zero districts or even better PEDs (Guarino et al., 2022). PEDs represent a new approach towards a sustainable and efficient city and urbanization model(EBC, 2022).
An urban Positive Energy District combines the built environment, mobility, sustainable production, and consumption to increase energy efficiency decrease greenhouse gas emissions and create added value for citizens(Bisello et al., 2024). Positive Energy Districts also require integration between buildings, users, and various energy networks, mobility services, and IT systems(Albert-Seifried et al., 2022).
Although the transformation of a neighborhood is beneficial to many stakeholders involved, points of agreement are not always found that make all projects sustainable and feasible(Fistola et al., 2023; Mazzeo, 2017). The concept of sustainability concerns the continuity of economic, social, and environmental aspects of human society and non-human environment, without compromising these aspects for future generations (Boschetto et al., 2022; Mazzola et al., 2017). A green building is a practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort (*EPA Green*, 2017). The awareness of the importance of green buildings and the effects of their energy efficiency are diffused from hundreds of kinds of certification systems around the world (Wangel et al., 2016).
In general, the role of these green assessment tools is the develop a system of measure for all the sustainability goals in a buildings/districts and more easily compare with current and past buildings/districts practices and other green buildings/districts(Volpatti et al., 2024).

The main thematic areas are energy, water, material use, indoor quality, and comfort: each area is evaluated on its net use; in other words, if the building produces or reuses resources, the evaluation is about its efficiencies and its percentage of reused, recycled or virgin materials (Boschetto et al., 2022).
Certification protocols have been introduced to give an evaluation based on a common set of criteria (Mazzola et al., 2017; Volpatti et al., 2024). PEDs need a protocol certificate that can enhance their potential, which, however, is not considered in the same way in current protocols.

1.2 Certification Protocols in the World for urban district.

Over the years, many certification protocols have been developed and constructed to assess the sustainability of neighborhoods. In general, they are all united by the definition of specific processes, criteria, and indicators, precisely because certification schemes for sustainable neighborhoods promise to provide guidance to urban development projects on how to work with sustainability issues in planning and development activities (Wangel et al., 2016). In addition, certification systems create a voluntary market engine, with the possibility of evaluating and marketing development projects as 'sustainable'(Mazzola et al., 2017).
Unlike principles, certification systems address the sustainability of an area using a predefined set of criteria and assessable indicators. In this way, they also provide a rather precise definition of sustainable development. The criteria, or credits gained for the criteria, are then aggregated, sometimes with a weighting, to provide a certificate, label and/or communicable grade (e.g., 'gold' or 'excellent') for the project (Wangel et al., 2016). The certificate, label and/or grade function as tools for benchmarking and marketing the sustainability of a specific urban development. However, the aggregation weighting and complexity of the tools make it difficult to understand what the result (vote or label) means in terms of what has been evaluated.
Furthermore, it can obscure the extent and ways in which urban development contributes to sustainability (Boschetto et al., 2022). Previous studies (Boschetto et al., 2022; Mazzola et al., 2017; Volpatti et al., 2024; Wangel et al., 2016) have reported a number of shortcomings of certification systems for neighborhoods and proposed new methods and criteria. However, these studies have mainly focused on the content of the protocols and criteria by incorporating new methods of criteria calculation.
Along the lines of previous work, with the aim of extending the analysis to PEDs and the type of structure of the certification protocol and indicators, we analyzed three of the world's best-known certification systems: LEED for Neighborhoods Development (LEED-ND); BREEAM Communities (BREEAM-C) and CASBEE for cities (CASBEE-UD).
This study differs from previous works because it analyses and discusses the existing certification protocols for urban districts, and about how sustainable development is defined in them, it aims to select common characteristics with the PEDs to identify new indicators that can be implemented and evaluate the PED with its salient features.

1.3 Complexity and Application of PED

Research all around the world is still struggling to find a unique definition for PEDs. From an energy-focused perspective, a PED is seen as an energy-self-sufficient and carbon-neutral urban district.
Indeed, positive energy means that energy districts also play an important role in producing excess energy using renewable energy sources and feeding it back into the grid (Bossi et al., 2020; Guarino et al., 2022).
However, widening the perspective, it is expected that PEDs will increase the quality of life in the cities, help achieve the COP21 goals, and improve European capabilities and knowledge to become a global model (Derkenbaeva et al., 2022).
Moreover, considering the keen interest of the European Commission to deliver at least 100 PEDs by 2050 and the current situation of the cities (Bossi et al., 2020), it is necessary to address this concept not only for new

areas of urban development and the construction of new buildings and neighborhoods but especially for the redevelopment of the existing building stock (Derkenbaeva et al., 2022).
The discussion on how and where to define the boundaries of these entities is still open and conclusions may differ depending on whether one considers physical limits and management aspects or those related to the overall energy balance and energy carriers, ranging therefore from local to regional scale (Bossi et al., 2020; Niu & Zhang, 2023).
The discussion also often starts from the local dimension of city blocks, up to the urban dimension. In this regard, some interesting research on existing tools to support decision-making toward climate neutrality in cities and districts has been already carried out (Suppa et al., 2022).
In an attempt for extreme simplification, it can be said that PEDs must strike an optimal balance between energy efficiency, energy flexibility, and local energy production in turn also achieving integrated sustainability based on environmental, economic, and social features (Guarino et al., 2022).
For PEDs several stakeholders such as cities and public bodies, industry and business, research and academia, citizens and civic society, private and professional stakeholders, and citizens play a central role in the energy transition. Satisfying outcomes of Positive Energy Buildings/Districts requires the involvement of a wide range of different stakeholders right from the beginning.
Therefore, increasing the knowledge of PEDs, public communication, dissemination, and public engagement among the public is vital (Bisello et al., 2017).
PEDs are also a complex system because people, buildings, cities, and mobility are all complex systems (Volpatti et al., 2024). We tried to find a definition in the literature that would explain why this complexity exists, the term "complexity" used by academics is a narrower concept than is employed by practitioners; in fact, certain context-related aspects that practitioners point to as being complex are identified by academics as complicated (Baccarini, D, 1996). This is because theoretical complexity focuses on emergence, uncertainty, nonlinearity, and interdependence among the elements present in a project. Purposes of this case study, we do not distinguish between the terms "complex" and "complicated" – following the common usage employed by several authors (Angelakoglou et al., 2019; Baccarini, D, 1996; Bottero et al., 2016).
Complexity will impact project goals and objectives, project planning and organization as well as staff recruitment requirements. Indicate that complexity in the project context has become the focus of attention for several reasons: it impacts the way the project is planned, executed, and controlled; it can hinder the identification of goals and objectives; it also influences how the project is organized as well as the skills required by workers; it can impact project objectives (scope, time, cost, risks, etc.).
According to (Baccarini, D, 1996), one definition of project complexity is that it consists "of many varied interrelated parts". He advocated implementing it in terms of the differentiation and interdependency of varied elements. In their paper (Baccarini, D, 1996), identified two dimensions of project complexity: structural complexity and uncertainty. In addition, structural complexity has two sub-dimensions: the number and interdependence of project elements, such as tasks, specialists, and components. He also proposed two sub-dimensions of the uncertainty dimension: uncertainty in goals and means (Baccarini, D, 1996).
Structural complexity is the easiest for practitioners and researchers to identify and increases with size, variety, breadth of scope, level of interdependence between people or tasks, pace, or variety of work to be done. Interdependence between people or tasks, pace, or variety of work to be done, number of locations and time slots, work to be done, the number of locations and time zones.
The existence of strict deadlines, e.g., closing of a construction site, or opening of an infrastructure, is a source of complexity because it leads to an increase in the pace of work and stress of the people involved.

2 Certification protocol's analysis for PED

2.1 Methodology

The objective of this research is to adapt the current urban scale procedures to enable their use in evaluating potential Positive Energy Districts developed within the project. Comprehensive acquaintance with the internal needs of different protocols and the crucial attributes of PEDs is requisite for this analysis.

For these reasons, the methodology shown in Figure 1 is introduced. The diagram illustrates how the internal criteria of various urban rating systems are analyzed and strategies and scores concerning PEDs are incorporated. This results in a modified protocol that takes PEDs into account.

In particular, the proposed methodology for revising sustainability certification protocols on an urban scale comprises five steps:

- Conduct an internal analysis of the existing protocols to identify the PED strategies already in place.
- Definition of a new criterion to include within the protocol, based on the strategies previously outlined. This will ensure that the criterion meets diverse protocol requirements, as different systems have varying internal strategies.
- Definition of the internal scores within each protocol that are related to PEDs or not, thus obtaining the division between PED scores (p_{PED}) and non-PED scores (p_{nPED}).
- Creation of the new credit score, now referred to as P_{nc}. The narrative can be constructed in two different ways:
  - Reducing the p_{PED} score by a fixed $\%_{nc}$ percentage to maintain balance in the protocol's evaluation. The $\%_{nc}$ varies for each protocol depending on the total credits of p_{tot} and the p_{PED} score. It will use the next formula to determine the erosion of the points from p_{PED}:

    $$P_{nc} = p_{PED} \times \%_{nc}$$

  - reducing the p_{nPED} score by a fixed percentage, to increase the value of the new protocol's PED score:

    $$P_{nc} = p_{nPED} \times \%_{nc}$$

- Redefine the new scores of the other internal criterion according to the formulas below in the order previously used, while ensuring that the new criterion will not alter the total score of the entire protocol:

$$P_{ic} = p_{iPED} \times (1 - \%_{nc})$$
$$P_{ic} = p_{inPED} \times (1 - \%_{nc})$$

2.2 Methodology application

In this paper, the methodology outlined above is applied to three distinct protocols at the urban level: LEED for Neighborhood Development, BREEAM Communities and CASBEE Communities.

Starting with one of the most widely used certification systems in the world for its simplicity of understanding, USGBC launched LEED in 2000. Since its inception, LEED has grown to encompass more than 16,000 projects in the USA and more than 30 countries (*LEED. "Checklist: LEED Neighborhood Development.,"* 2023).

This tool promotes sustainable building and development practices through a suite of reporting and recognizes projects which are committed to better environmental and health performance (Bisello et al., 2020). LEED intends to encourage all cities to measure and improve performance, focusing on outcomes from ongoing sustainability efforts (Karner et al., 2017).

To leverage a globally consistent method of performance measurement for a streamlined and data-based pathway to LEED certification for cities (Arabi et al., 2018). The U.S. Green Building Council (USGBC), the Congress for the New Urbanism (CNU), and the Natural Resources Defense Council (NRDC)—organizations that represent leading design professionals, progressive builders and developers, and the environmental community—have collaborated to design a rating system for neighborhood planning and development based

on the combined principles of smart growth, New Urbanism, and green infrastructure and building. The goal of this partnership is to establish a national leadership standard for assessing and rewarding environmentally superior green neighborhood development practices within the framework of the LEED® Green Building Rating System™. The result of their effort was named LEED-ND (Arabi et al., 2018).
The LEED-ND criteria for sustainable neighborhoods in cities are cited in (*LEED. "Checklist: LEED Neighborhood Development.,"* 2023).
The second important certification protocol is BREEAM. Was initially introduced in 1990; BREEAM was the world's first environmental assessment method for new building designs (Arabi et al., 2018). It uses a balanced scorecard approach with tradable credits to enable the market to decide how to achieve optimum environmental performance for the project. BREEAM has now come a long and it is now employed on a global scale. The subjects in this manual fall into five assessment categories which are contemplated through suitable criteria (BREEAM, 2014). Classifying sustainability issues is hard to come by, as they often influence all three aspects of sustainability (social, environmental, and economic). The goal of BREEAM is to shed light on the intention of each issue by evaluating categories. A sixth category promotes innovation which shows the importance of it. The categories are as follows with a brief description of their overall goals: Governance (GO): Promotes the involvement of the community in decision-making regarding the development comes under the influence of the design, construction, and operation. Social and economic well-being (SE): Contemplates societal and economic factors that influence health and well-being such as sufficient housing and availability of employment. Resources and energy (RE): Address the sustainable use of natural resources and the reduction of carbon emissions. Land use and ecology (LE): Encourages sustainable land use and ecological enhancement. Transport and movement (TM): Address the design and provision of transportation and movement infrastructure to promote the use of sustainable means of transportation.

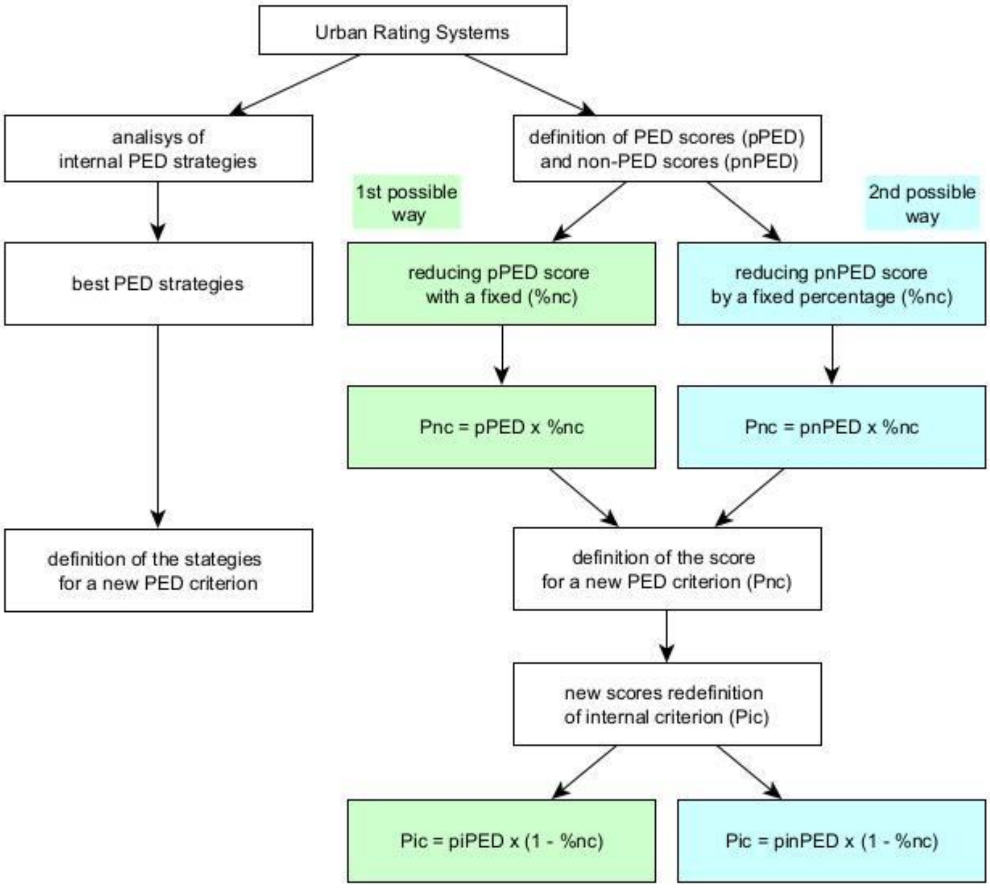

Fig.1 Proposed methodology scheme. In green and sky blue the two possible ways

Innovation (Inn): Promotes employing innovative solutions in the rating where they help obtain environmental, social, and/or economic benefit in a way that is not looked at elsewhere in the scheme. BREEAM aims to ensure that its standards provide social and economic benefits whilst ameliorating the environmental impacts of the built environment (BREEAM, 2014). As a result, BREEAM is especially likely to put a value on developments according to their sustainability benefits (Wangel et al., 2016).
BREEAM highlights the issues and opportunities that bring about a revolution in development at the earliest stage of the design process.
The rating system addresses major environmental, social, and economic sustainability objectives that have an impact on large-scale development projects (Mazzola et al., 2017).
The latest certification system studied is the most widely used throughout Asia and is the CASBEE, this acronymous means Comprehensive Assessment System for Built Environment Efficiency. Is a method for assessing and scoring the environmental performance of buildings and the built environment. CASBEE was introduced by a research committee established in 2001 through the collaboration of academia, industry, and national and local governments, which established the Japan Sustainable Building Consortium (JSBC) under the auspice of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (Arabi et al., 2018). CASBEE for urban development is a tool for assessment of comprehensive area development projects including a group of buildings (*CASBEE for Cities v.2015*, n.d.). CASBEE follows the triple bottom lines concept, which is one of the important frameworks for the assessment and identification of sustainability through the three classifications of environment, society, and economy.
Following the points of the methodology seen above, the results obtained are presented.
All strategies outlined in the protocols concerning Positive Energy Districts (PEDs) were initially identified. This enabled us to ascertain their respective strengths and weaknesses. The ensuing picture presents a comparison between the internal demands of the protocols and the core characteristics of the PEDs. The right-hand column details which parts are absent from each protocol and therefore require implementation through the definition of new criteria. In this way, it is possible to define the new adapted criterion for each protocol that is analyzed. Consequently, the scores for PED (p_{PED}) and non-PED (p_{nPED}) were determined by segregating criteria that involved PEDs from those that did not. Table 4 below reveals the outcomes.

3. Results

Before revising the protocols according to the characteristics of PEDs, by modifying their internal scores and inserting the new criterion, it was necessary to assume for p_{nc} a target weight of the latter, considered in this case to be 5 points. The two methods defined in the previous paragraph were then used, to obtain those 5 points, taking the percentage $\%_{nc}$ as 6 for the first method and 30 for the second. The following tables show the new scores calculated in this way, comparing the two methods. Note that in the first case, only the scores of the criterion that already contain PED characteristics are modified, unlike in the second case, where the criterion that does not concern PEDs are modified.
Method 1: $P_{nc} = p_{PED} \times \%_{nc}$ percentage I want to reserve for the new credit equal to 7%
Method 2: $P_{nc} = p_{nPED} \times \%_{nc}$ percentage I want to reserve for the new credit equal to 30%

$$P_{ic} = p_{iPED} \times (1 - \%_{nc})$$
$$P_{ic} = p_{inPED} \times (1 - \%_{nc})$$

In Table 5, we can see the results with method 1 and 2 for the LEED ND protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before. As we can see from the percentage values of the breakdown of the different selected criteria that correspond with the characteristics of the PEDs, it can be seen that the Neighborhood Pattern & Design section has been largely downgraded, but despite this

being its impact in percentage terms the most important, in the redistribution of percentage points for its credits, both the M1 and M2 allocation methods take on great importance as an evaluation section.
With regard to the macro-criterion Smart location and linkage and green infrastructures and buildings remained virtually unchanged in numerical terms despite the subtraction of some criteria that were found to be inappropriate in the analysis of the PED characteristics. The new credit in this case would be 5.6% under the M1 method and 6% under the M2 method.
The difference would be 0.4%, which allows us to say at first glance that it would still be a difference of half a point at the overall level of the valuation but would have a significant impact.
In Table 6, we can see the results with method 1 and 2 for the BREEAM communities protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before. As can be seen from the percentage values of the distribution of the various selected criteria corresponding to the PEDs characteristics, it can be seen that with the M1 method, the macro-criteria were all lowered almost uniformly and despite this, the impact in percentage point redistribution assumes great importance as an evaluation section. With the M2 method, the macro-criteria were lowered unevenly, and despite this, the difference with respect to M2 deviates in favour of existing credits by 0.3%. At the macro level, the difference is negligible, but if one analyses the values of the criteria, one realizes how the percentage composition changes. In fact, looking at the values using the M2 method, the criteria resources and ecology, and transport and movement, both increase by almost 1.5%, but all the other macro-criteria fall. The new credit in this case would be 5.75% with the M1 method and 5.46% with the M2 method.
In Table 7, we can see the results with method 1 and 2 for the CASBEE for cities protocol certificate for PED with the inclusion of a new criterion encompassing all criteria identified before.
As can be seen from the percentage values of the distribution of the various selected criteria corresponding to the characteristics of the DPEs, it can be seen that with the M1 method, the macro-criteria were all equalised at 31% for all three macro-criteria. With the M2 method, the macrocriteria were lowered almost uniformly and the difference to M1 is almost 2 % points in its favour. The new credit in this case would be 5.23% with the M1 method and 7.57% with the M2 method. It can be seen that it is an emblematic case in this protocol to use the M2 method, as it differs from LEED-ND by 2.10 % and from BREEAM CM by 1.5 %.
As far as the method 1 and 2 is concerned, we can start from the limits of the calculation where a further analysis should be to obtain whole numbers for LEED credits; however, it remains necessary to pay attention to the rounding that is done.

4. Conclusion and future developments

Cities and new districts must be sustainable, especially in economic, environmental, and social aspects. In view of the latest data on climate change and emissions in the urban environment, the IEA and the EU have developed the concept of positive energy districts (PEDs), defined as urban districts with zero net annual energy imports and zero net CO2 emissions that produce an excess of renewable energy production integrated into an urban energy system. Being a new concept, the first projects and realizations are emerging but cannot be evaluated through defined parameters and/or current certification systems. In this context, urban rating systems can help due to their internal quantitative structures (criteria and parameters) despite the fact that they do not consider the added value of PEDs. Therefore, in this research, an attempt was made to identify PED-like parameters and criteria within the three main protocols (LEED-ND; BREEAM-CM; CASBEE-UD). The assimilation of these new criteria to be implemented collected into a single criterion allowed us to identify a score that could ensure that these urban districts could be evaluated taking into account the added value of being PED. The proposed methodology in fact has the peculiarity of being able to be implemented by variables and constants regardless of the numerical value.

This allowed us to choose constant values and to make a comparison between the different certification systems by normalizing the values of all the systems to 100, reshaping the partial value of each criterion as a percentage.

A conclusion we can make about the two methods is that both allow them to be modified, to be replicated and adapted to the context according to the weight the evaluator deems appropriate. On the other hand, being a methodology based on formulas that require a consequentiality, it allows us to compare both the three certification models with each other by seeing which fields of interest are most analyzed, and with respect to projects that are evaluated using only one methodology.

Furthermore, it makes it possible to identify the weights that the different certification protocols give to the different fields of application. In this sense, compared to the criteria contained in the original protocols, compared to the criteria selected and considered similar to the PEDs criteria, a change in these weights can be seen in all three methods. It is noticeable that in the BREEAM communities the social-economic part is sacrificed a great deal in the reassignment of the criteria for the PED egg credit, whereas we find a slight alignment with the original value for the other two protocol certificates.

The analysis carried out revealed that they could be implemented with criteria that would bring out the additional qualities of PEDs.

However, some limitations of the methodology encountered are noted below:

- When reducing initial scores to obtain space for new criteria, it is necessary to use percentages and define new scores with at least one decimal point. This applies even to protocols such as LEED, which typically only use whole values for internal credits.
- It may be possible to address the aforementioned issue by implementing a rounding factor. However, this would result in fluctuations of the total score of the protocol, as the approximations can be either higher or lower.
- The methodology used could also be valid for other protocol variations, not necessarily only for PED. The methodology used could also be valid for other urban-scale protocols. Only three protocols were used in the application but could be extended to others.

Another possible direction of research could be not to insert a new criterion, but to evaluate the individual PED-defined criterion at the beginning of the methodology and force their PED characteristics or add new requirements to them (e.g., for the credit of renewables, insert that these are connected in a CER, and so on). Alternatively, I could also have evaluated the inclusion of a PED prerequisite, without which it is not possible to gain access to certification, or, without which it will also not be possible to obtain the PED label when obtaining certification, as is already the case, for example, for energy certifications in Italy, which can have a classification up to A4, but only with certain characteristics do they obtain the definition of NZEB. Possibility of giving a higher score to the new PED credit (we assumed 5, but it is possible to give a higher or lower amount. As far as the PEDs certification protocol is concerned, we can consider it a valid system that would give value to the quality of PEDs. Surely further studies on this subject could help the scientific community to solve this lack of tools in this regard.

A future development would certainly be the inclusion of partial criteria values and a redistribution of values in order to truly value a PED over other types of urban districts.

LEED v4 for Neighborhood Development Plan for PED			Criterion correspondent	Specific Aspects of the PED Framework	New criterion for LEED-ND
N°	**Smart Location & Linkage**	**23**		**Energy**	**New criterion**
1	Preferred Locations	10	16, 17, 18, 24,26	Energy efficiency	
2	Access to Quality Transit	7	24, 25	Energy flexibility	
3	Bicycle Facilities	2		Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
4	Housing and Jobs Proximity	3	16, 17, 18, 24,26	Nearly zero energy buildings and net-zero energy districts	
5	Site Design for Habitat or Wetland and Water Body Conservation	1			
	Neighborhood Pattern & Design	**31**	13, 16, 17, 24, 25,	Energy production	
6	Walkable Streets	9	17, 24, 25,	Local, regional, and european energy systems and networks	
7	Mixed-Use Neighborhoods	4			
8	Housing Types and Affordability	7		**Urban and local development, real estate**	
9	Connected and Open Community	2	3,5,10,	Technological solutions	
10	Transportation Demand Management	2			
11	Access to Civic & Public Space	1	12	Sector coupling and cross-sectorial integration	
12	Community Outreach and Involvement	2		New business models, the future role of „citizen energy communities“(CEC) and „renewable energy communities“ (REC)	New business model for PED, CEC,REC
13	Local Food Production	1			
14	Tree-lined and Shaded Streetscapes	2	9, 12, 15,	Active involvement of problem owners and citizens	
15	Neighborhood Schools	1			
	Green Infrastructure & Buildings	**26**	12, 17,	urban areas or groups of connected buildings	
16	Certified Green Buildings	5			
17	Optimize Building Energy Performance	2			
18	Building Reuse	1	18	Existing building stock is main challenge to achieving climate neutrality	
19	Indoor Water Use Reduction	1	18,	Resilience and security of energy supply	Resilience and security of energy supply
20	Outdoor Water Use Reduction	2			
21	Rainwater Management	4		**Infrastructure**	
22	Heat Island Reduction	1	5, 14, 19, 20, 21, 22	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
23	Solar Orientation	1	2, 3, 6, 7, 10, 14	Developing the role of mobility in the PED Reference Framework	
24	Renewable Energy Production	3			
25	District Heating and Cooling	2		**People**	
26	Infrastructure Energy Efficiency	1	8,9,	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
27	Wastewater Management	2			
28	Light Pollution Reduction	1		quality of life	quality of life
	PROJECT TOTALS (Certification estimates)	**80**	9, 12	Regulatory sandboxes, living labs, and testing environments	

Tab.1 Certification protocol LEED-ND with criterion selected that described PED characteristic at the left of the grey column, and the right in red new evaluation criteria that should be implemented in the overall evaluation in order to stick to the key points that represent a PED

N°	BREEAMS Communities for PED	
N°	**Governance**	**7**
1	Consultation and engagement	3.5
2	Design review	2.3
3	Community management of facilities	1.2
	Social and economic well-being	**33.2**
4	Economic impact	8.9
5	Demographic needs and priorities	2.7
6	Flood Risk Assessment	1.8
7	Noise pollution	1.8
8	Housing provision	2.7
9	Delivery of services, facilities, and amenities	2.7
10	Public realm	2.7
11	Microclimate	1.8
12	Utilities	0.9
13	Adapting to climate change	2.7
14	Green infrastructure	1.8
15	Inclusive design	1.8
16	Light pollution	0.9
	Resources and ecology	**21.7**
17	Energy strategy	4.1
18	Existing buildings and infrastructure	2.7
19	Water strategy	2.7
20	Sustainable buildings	4.1
21	Low impact materials	2.7
22	Resource efficiency	2.7
23	Transport carbon emissions	2.7
	Land use and ecology	**6.4**
24	Ecology strategy	3.2
25	Land use	2.1
26	Rainwater harvesting	1.1
	Transport and movement	**11.7**
27	Transport assessment	3.2
28	Safe and appealing streets	3.2
29	Cycling network	2.1
30	Access to public transport	2.1
31	Cycling facilities	1.1
	PROJECT TOTALS (Certification estimates)	**80**

Criterion correspondent	Specific Aspects of the PED Framework	A new criterion for BREEAMS Communities
	Energy	**New criterion**
3, 17, 20, 21, 22, 24	Energy efficiency	
13, 17	Energy flexibility	Energy flexibility
17	Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
13, 17, 20, 22	Nearly zero energy buildings and net-zero energy districts	
13, 16, 17, 24, 25,	Energy production	Energy production
17, 20, 24	Local, regional, and european energy systems and networks	
	Urban and local development, real estate	
12, 15, 17, 20	Technological solutions	
3, 12, 15, 27	Sector coupling and cross-sectorial integration	
	New business models, the future role of „citizen energy communities“ (CEC) and „renewable energy communities“ (REC)	New business model for PED, CEC,REC
8, 10,	Active involvement of problem owners and citizens	
10, 18, 20,	urban areas or groups of connected buildings	
18, 20, 22,	Existing building stock is main challenge to achieving climate neutrality	
22	Resilience and security of energy supply	Resilience and security of energy supply
	Infrastructure	
6, 11, 13, 14, 17, 18, 19, 20, 22, 24, 25, 26,	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
7, 17, 23, 27, 28, 29, 30, 31	Developing the role of mobility in the PED Reference Framework	
	People	
1, 2, 3, 4, 5,	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
5	quality of life	
1, 5	Regulatory sandboxes, living labs, and testing environments	

Tab.2 Certification protocol BREEAM for Communities with criterion selected that described PED characteristic at the left of the grey column, and at the right in red new evaluation criteria that should be implemented in the overall evaluation to stick to the key points that represent a PED

	CASBEE Urban District for PED		Criterion correspondent	Specific Aspects of the PED Framework	A new Criterion for CASBEE Urban District
N°	**Q1 - Environment**	**22.92**		**Energy**	**New criterion**
1	Rainwater utilization	1.39	1, 4, 5, 6, 7, 9	Energy efficiency	
2	Reduction of rainwater discharge amount: Rainwater permeable surfaces and equipment	0.7	27	Energy flexibility	
3	In-area resource circulation	1.39		Energy surplus, producing more energy than consumed	Energy surplus, producing more energy than consumed
4	Ground greening	2.78	4, 5, 6, 7, 9	Nearly zero energy buildings and net-zero energy districts	
5	Rooftop greening	1.39			
6	Wall greening	1.39	7,	Energy production	Technological system for energy production
7	Natural resources	1.39		Local, regional, and european energy systems and networks	
8	Landform	1.39			
9	Environmentally considerate buildings	11.1		**Urban and local development, real estate**	
	Q2 - Society	**29.62**		Technological solutions	Technological solutions
10	Compliance	5.56			
11	Area management	5.56	9, 27	Sector coupling and cross-sectorial integration	
12	Disaster prevention of various infrastructures	0.92		New business models, the future role of „citizen energy communities" (CEC) and „renewable energy communities" (REC)	New business model for PED, CEC,REC
13	Disaster prevention vacant space and evacuation route	0.92			
14	Continuity of business and life in the block	0.92	11, 27,	Active involvement of problem owners and citizens	
15	Traffic safety	3.7			
16	Crime prevention	3.7	12, 17,	urban areas or groups of connected buildings	
17	Convenience	2.78			
18	History and Culture	2.78	18	Existing building stock is main challenge to achieving climate neutrality	
19	Consideration for the formation of townscape and landscape	1.39			
20	Harmonization with the periphery	1.39	18,	Resilience and security of energy supply	Resilience and security of energy supply
	Q3 - Economy	**22.24**			
21	The development of traffic facilities: level of roads etc.	1.39		**Infrastructure**	
22	Usability of public transportation	1.39	1, 2, 3, 4, 5, 6, 7	Green and blue infrastructures are important building blocks for climate change adaption strategies on the district and neighborhood level	
23	Logistics management	2.78	21, 22, 23, 28	Developing the role of mobility in the PED Reference Framework	
24	Consistency with and complementing upper-level planning	2.78			
25	Non-housing	5.56		**People**	
26	Block management	2.78	11, 20, 25, 27, 28	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	
27	Possibility to make demand/supply system smart	2.78			
28	Updatability and expandability	2.78		quality of life	quality of life
	PROJECT TOTALS (Certification estimates)	**74.78**	18, 19, 20	Regulatory sandboxes, living labs, and testing environments	

Tab.3 Certification protocol BREEAM for Communities with criteria selected that described PED characteristics at the left of the grey column, and at the right in red new evaluation criteria that should be implemented in the overall evaluation to stick to the key points that represent a PED

	LEED for Neighborhood Development Plan	BREEAM Communities	CASBEE Urban District
p_{PED}	80	82,1	74,78
p_{nPED}	20	18,2	25,24
p_{tot}	100	100,3	100,02

Tab.4 Results were obtained by differentiating internal criteria from protocols based on their involvement or non-involvement in PED strategies

LEED v4 for Neighborhood Development Plan		M1	M2
average pPED		80	80
average pnPED		20	20
new value criteria		5,6	6
Smart Location & Linkage		26,39	26,5
Credit	Preferred Locations	9,30	10,0
Credit	Brownfield Remediation	2,00	1,4
Credit	Access to Quality Transit	6,51	7,0
Credit	Bicycle Facilities	1,86	2,0
Credit	Housing and Jobs Proximity	2,79	3,0
Credit	Steep Slope Protection	1,00	0,7
Credit	Site Design for Habitat or Wetland and Water Body Conservation	0,93	1,0
Credit	Restoration of Habitat or Wetlands and Water Bodies	1,00	0,7
Credit	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1,00	0,7
Neighborhood Pattern & Design		38,83	38,0
Credit	Walkable Streets	8,37	9,0
Credit	Compact Development	6,00	4,2
Credit	Mixed-Use Neighborhoods	3,72	4,0
Credit	Housing Types and Affordability	6,51	7,0
Credit	Reduced Parking Footprint	1,00	0,7
Credit	Connected and Open Community	1,86	2,0
Credit	Transit Facilities	1,00	0,7
Credit	Transportation Demand Management	1,86	2,0
Credit	Access to Civic & Public Space	1,00	0,7
Credit	Access to Recreation Facilities	1,00	0,7
Credit	Visitability and Universal Design	0,93	1,0
Credit	Community Outreach and Involvement	1,86	2,0
Credit	Local Food Production	0,93	1,0
Credit	Tree-Lined and Shaded Streetscapes	1,86	2,0
Credit	Neighborhood Schools	0,93	1,0
Green Infrastructure & Buildings		29,18	29,5
Credit	Certified Green Buildings	4,65	5,0
Credit	Optimize Building Energy Performance	1,86	2,0
Credit	Indoor Water Use Reduction	0,93	1,0
Credit	Outdoor Water Use Reduction	1,86	2,0
Credit	Building Reuse	0,93	1,0
Credit	Historic Resource Preservation and Adaptive Reuse	2,00	1,4
Credit	Minimized Site Disturbance	1,00	0,7
Credit	Rainwater Management	3,72	4,0
Credit	Heat Island Reduction	0,93	1,0
Credit	Solar Orientation	0,93	1,0
Credit	Renewable Energy Production	2,79	3,0
Credit	District Heating and Cooling	1,86	2,0
Credit	Infrastructure Energy Efficiency	0,93	1,0
Credit	Wastewater Management	1,86	2,0
Credit	Recycled and Reused Infrastructure	1,00	0,7
Credit	Solid Waste Management	1,00	0,7
Credit	Light Pollution Reduction	0,93	1,0
Positive Energy District		5,60	6,0
Credit	Positive Energy District	5,60	6,0
PROJECT TOTALS (Certification estimates)		100,0	100,0

Tab.5 Certification protocol LEED-ND for PED with new evaluation criteria that should be implemented in the overall evaluation to represent a PED

			BREEAM communities			**M1**	**M2**
			average pPED			82,1	82,1
STEP			average pnPED			18,2	18,2
1	2	3	new value criteria			5,75	5,46
1	2	1		Governance		8,81	8,61
1			GO	0,1	Consultation plan	2,30	1,61
	1		GO	0,2	Consultation and engagement	3,26	3,5
	1		GO	0,3	Design review	2,14	2,3
		1	GO	0,4	Community management of facilities	1,12	1,2
4	9	4		Social and economic wellbeing		40,38	39,85
1			SE	0,1	Economic impact	8,28	8,9
1			SE	0,2	Demographic needs and priorities	2,51	2,7
1			SE	0,3	Flood Risk Assessment	1,67	1,8
1			SE	0,4	Noise pollution	1,67	1,8
	1		SE	0,5	Housing provision	2,51	2,7
	1		SE	0,6	Delivery of services, facilities and amenities	2,51	2,7
	1		SE	0,7	Public realm	2,51	2,7
	1		SE	0,8	Microclimate	1,67	1,8
	1		SE	0,9	Utilities	0,84	0,9
	1		SE	10	Adapting to climate change	2,51	2,7
	1		SE	11	Green infrastructure	1,67	1,8
	1		SE	12	Local parking	0,90	0,63
	1		SE	13	Flood risk management	1,80	1,26
		1	SE	14	Local vernacular	0,90	0,63
		1	SE	15	Inclusive design	1,67	1,8
		1	SE	16	Light pollution	0,84	0,9
		1	SE	17	Training and skills	5,90	4,13
3	0	4		Resources and ecology		20,18	21,7
1			RE	0,1	Energy strategy	3,81	4,1
1			RE	0,2	Existing buildings and infrastructure	2,51	2,7
1			RE	0,3	Water strategy	2,51	2,7
		1	RE	0,4	Sustainable buildings	3,81	4,1
		1	RE	0,5	Low impact materials	2,51	2,7
		1	RE	0,6	Resource efficiency	2,51	2,7
		1	RE	0,7	Transport carbon emissions	2,51	2,7
2	3	1		Land use and ecology		12,35	10,88
1			LE	0,1	Ecology strategy	2,98	3,2
1			LE	0,2	Land use	1,95	2,1
	1		LE	0,3	Water pollution	1,10	0,77
	1		LE	0,4	Enhancement of ecological value	3,20	2,24
	1		LE	0,5	Landscape	2,10	1,47
		1	LE	0,6	Rainwater harvesting	1,02	1,1
1	3	2		Transport and movement		12,83	13,8
1			TM	0,1	Transport assessment	2,98	3,2
	1		TM	0,2	Safe and appealing streets	2,98	3,2
	1		TM	0,3	Cycling network	1,95	2,1
	1		TM	0,4	Access to public transport	1,95	2,1
		1	TM	0,5	Cycling facilities	1,02	1,1
		1	TM	0,6	Public transport facilities	1,95	2,1
0	0	0		Positive Energy District		5,75	5,46
					Positive Energy District	5,75	5,46
11	17	12		PROJECT TOTALS (Certification estimates)		100,3	100,3

Tab.6 Certification protocol BREEAM communities for PED with new evaluation criteria that should be implemented in the overall evaluation in order to represent a PED

CASBEE For cities		**M1**	**M2**
average pPED		74,78	74,78
average pnPED		25,24	25,24
new value criteria		5,23	7,57
Q1 - Environment		**31,7556**	**30,228**
Credit	Rain water utilization	1,29	1,39
Credit	Treated water	1,39	0,97
Credit	Reduction of sewage discharge amount	1,39	0,97
Credit	Reduction of rain water discharge amount: Capacity of detention pond	0,7	0,49
Credit	Reduction of rain water discharge amount: Rain water permeable surfaces and equipment	0,65	0,70
Credit	Wood material	1,39	0,97
Credit	Recycled material	1,39	0,97
Credit	Garbage separation	1,39	0,97
Credit	In-area resource circulation	1,29	1,39
Credit	Ground greening	2,59	2,78
Credit	Rooftop greening	1,29	1,39
Credit	Wall greening	1,29	1,39
Credit	Natural resources	1,29	1,39
Credit	Landform	1,29	1,39
Credit	Patch (planar) quality: Habitat space of species	0,7	0,49
Credit	Patch (planar) quality: Consideration for regionality	0,7	0,49
Credit	Corridor (network) quality	1,39	0,97
Credit	Environmentally considerate buildings	10,32	11,10
Q2 - Society		**31,2266**	**32,196**
Credit	Compliance	5,17	5,56
Credit	Area management	5,17	5,56
Credit	Understanding of hazard map	0,92	0,64
Credit	Disaster prevention of various infrastructures	0,86	0,92
Credit	Disaster prevention vacant space and evacuation route	0,86	0,92
Credit	Continuity of business and life in the block	0,86	0,92
Credit	Traffic safety	3,44	3,70
Credit	Crime prevention	3,44	3,70
Credit	Convenience	2,59	2,78
Credit	Distance to medical, health/welfare facilities	0,92	0,64
Credit	Distance to educational facilities	0,92	0,64
Credit	Distance to cultural facilities	0,92	0,64
Credit	History and culture	2,59	2,78
Credit	Consideration for formation of townscape and landscape	1,29	1,39
Credit	Harmonization with the periphery	1,29	1,39
Q3 - Economy		**31,8032**	**30,024**
Credit	The development of traffic facilities: level of roads etc.	1,29	1,39
Credit	Usability of public transportation	1,29	1,39
Credit	Logistics management	2,59	2,78
Credit	Consistency with and complementing upper level planning	2,59	2,78
Credit	Utilization level of standard floor area ratio	2,78	1,95
Credit	Handling of brownfield site	0	0,00
Credit	Inhabitant population	2,78	1,95
Credit	Staying population	2,78	1,95
Credit	Housing	0	0,00
Credit	Non-housing	5,17	5,56
Credit	Information service performance	2,78	1,95
Credit	Block management	2,59	2,78
Credit	Possibility to make demand/supply system smart	2,59	2,78
Credit	Updatability and expandability	2,59	2,78
Positive Energy District		**5,23**	**7,57**
	Positive Energy District	5,23	7,57
PROJECT TOTALS (Certification estimates)		**100,02**	**100,02**

Tab.7 Certification protocol CASBEE for cities for PED with new evaluation criteria that should be implemented in the overall evaluation in order to represent a PED

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