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The Role of Positive Energy Districts through the Lens of Urban Sustainability Protocols in the Case Studies of Salzburg and Tampere

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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. Indeed, 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, even better, 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. However, 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 Urban Sustainability protocols for PEDs, which can effectively assess the complexity of the impacts a PED 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. These certification protocols were established before the concept of PEDs and, therefore, are not considered. However, they exhibit some shared characteristics which permit the evaluation of PEDs' sustainability. In fact, through this research, an attempt is made to analyze how the implementation of sustainability protocols in existing PED projects can improve sustainability, but also how PED projects can improve evaluation systems through interventions that have not been considered so far. To test a methodology that could be extended in future case studies, an analysis of three of the world's best-known certification systems, LEED-ND, BREEAM-CM, and CASBEE-UD, was conducted on two completed PEDs case studies, Tampere and Salzburg.

Keywords: neighborhood assessment tools; LEED-ND; BREEAM-CM; CASBEE-UD; urban sustainability; positive energy district

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1. Introduction

The International Energy Agency has placed great emphasis on reducing CO_2 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 [1–3].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, resulting in massive growth in demand for urban energy infrastructure [2,4,5]. 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 [6]. Climate action in cities, districts, and neighborhoods is essential to achieve the ambitious net-zero emissions goals. 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 has set for themselves in the areas of energy and climate change [7]. With the new perspective indicated at the World Economic Forum in 2015, research and innovation plans for cities aim to vigorously address several global challenges that affect our cities and society: health and safety, digitization, energy, and climate change as the priority [4,5,8]. The area of Smart Cities and Communities was already defined as a priority and strategic direction by both the previous European Horizon 2020 program [4,9] and the 17 Sustainable Development Goals established by the UN and the 2030 Agenda [10]. 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 [11]. For this reason, the European community wanted to focus efforts on smaller urban areas, such as blocks, pilot districts, and neighborhoods [12–14], towards a widespread and capillary smart land concept to initiate a more functional awareness of the topic by exploiting and incentivizing local co-design according to location [4]. Therefore, as highlighted in the Horizon 2020 projects that initially focused on the energy efficiency of buildings and local production of renewable energy on-site, there has been a broadening of interest in the urban district [9]. Indeed, in recent years, to support the urban energy transition, the concept has become even more ambitious, moving from highly efficient buildings close to energy neutrality (nZEB) to zero-emission buildings (ZEB) [15]. As a result of this process of reducing CO_2 emissions, the various anthropological actions with the greatest impact have been included, supporting and promoting energy sharing, waste heat recovery, electric mobility, and energy storage, and the scope has been broadened to include the implementation of zero-emission districts or, better still, positive energy district (PEDs) under this heading [12,16–19]. Suppose a zero-emission district combines the built environment and its associated services to reduce harmful emissions as much as possible. In that case, a PED combines the built environment, mobility, and sustainable production and consumption to increase energy efficiency, make the district energy self-sufficient by exploiting energy surpluses, reduce greenhouse gas emissions to zero from its inception, and create added value for the citizens who use, work, and live in these spaces [12,16,18]. PEDs also require integration between buildings, users, energy networks, mobility services, and information systems. 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 [7,20–23]. The concept of sustainability concerns the continuity of economic, social, and environmental aspects of human society and the non-human environment, without compromising these aspects for future generations [24]. Starting from the outlined context, there are currently no sustainability assessment systems inherent to PEDs, as they are also newly created, and thus cannot even be compared to each other, except about PED characteristics alone. Knowing that several international assessment protocols at the neighborhood or urban scale deal with sustainability in general, one assumes that they could help in this regard. In general, the role of these green assessment tools is the development of a system of measurement for all the sustainability goals in a district, which are more easily compared with current and past urban practices and other green districts [25,26]. The main thematic areas are energy, water, material use, and 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 [27]. Certification protocols have been introduced to give an evaluation based on a common set of criteria [24]. As PEDs are relatively young compared to the latest updates of the different certification protocols, a lack of criteria that enhance the added value of positive energy districts is known in the literature [23,25,26,28–31]. The authors consider a certification protocol that enhances their potential and could be essential for their development, which, however, is not considered to the same extent in current protocols. In fact, through this research, an attempt is made to analyze how the implementation of sustainability protocols in existing PED projects can improve the concept of sustainability, but also how PED projects can improve evaluation systems through interventions that have not been considered so far. To test a methodology that could be extended in future case studies, an analysis of three of the world's best-known certification systems was conducted on two completed PED case studies, which are available on the PED-EU-NET website and will be carried out in Section 1.1. The research topic is innovative both because no protocols have been found for PEDs and because there are no publications on the application of these protocols to PEDs.

1.1. Certification Protocols in the World for Urban Districts

Over the years, many certification protocols have been developed and constructed to assess the sustainability of neighborhoods. Overall, their common goal is to establish distinct procedures, standards, and metrics to direct sustainability-related aspects of urban development schemes during the planning and execution stages [32]. In addition, certification systems create a voluntary market engine, with the possibility of evaluating and marketing development projects as 'sustainable' [24]. 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 [32]. The certificate, label, and/or grade function serve 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 [27]. Previous studies [24,27,32] have reported several shortcomings of certification systems for neighborhoods and have 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, to extend the analysis to PEDs and the type of structure of the certification protocol and indicators, in this research, an analysis of three of the world's best-known certification systems was undertaken: LEED for Neighborhood 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, as well as about how sustainable development is defined in them, through the evaluation of certification protocols and completed PED case studies. The aim is to evaluate possible improvements for existing certification protocols and future PEDs projects. Infact, the paper consists of four sections. The first section describes the current certification protocols and provides a description based on the most up-to-date literature of the definition of a positive energy district, describing the complexity it brings within a multi-stakeholder urban context.

The second section identifies and describes the proposed methodology for identifying possible improvements between current urban ratings and case studies by presenting a flow chart of the algorithm devised by the authors. Immediately afterward, the sustainability certificates chosen to conduct the study and the case studies selected to apply the methodology are presented.

In the third section, the methodology is applied by identifying possible criteria similar to the characteristics of the PEDs and re-evaluating the values of the selected criteria. In the fourth section, the results are analyzed with the different configurations formed and their descriptions. Finally, the conclusions of the study and future developments are presented.

1.2. Features and Application of PED: A Complex Urban District

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 [12,13]. However, widening the perspective, it is expected that PEDs will increase the quality of life in cities, help achieve the COP21 goals, and improve European capabilities and knowledge, becoming a global model [16]. Moreover, considering the keen interest of the European Commission to deliver at least 100 PEDs by 2050 and the current situation of European cities [13], 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 [16]. 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 [7]. In an attempt at 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 [12]. For PEDs, several stakeholders such as cities and public bodies, industry and business, research and academia, citizens and civic society, and private and professional stakeholders 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 [33]. PEDs are part of complex systems [34] precisely because people, buildings, cities, and mobility are all very complicated [9] systems that, if intertwined, give rise to combinations of large [8] and uncontrollable situations that would lead the district to be the danger itself [35]; this is one of the many reasons why it is complex to evaluate PEDs with current certificate protocols. These protocols unfortunately do not evaluate the positive benefits of making such an improvement in an urban district. Table 1 lists the main characteristics describing PEDs in the first column. The authors present definitions of the characteristics in column 2 based on the International Energy Agency—ANNEX 83 group [17], COST ACTION [15], and the PED-EU-NET [13]—and as identified in the reference literature listed in column 3. In column 4, the parameters and values are identified using the same methodology as introduced above, and qualitative–quantitative modalities for the evaluation of these characteristics have been selected from the reference literature in column 3.

Table 1. This table shows all the characteristics common to PEDs. Columns 2 and 4 present a proposed definition and reference parameters and values taken from the literature.

PED Characteristic	Definition	Ref.	Parameters and Value
Energy			
Energy efficiency	Energy efficiency in PED is the quantitative and measurable relationship between a result achieved with a machine or process using renewable energy and the energy used to achieve it.	[6,14,16,18]	The system's yields are well within international benchmarks
Energy flexibility	Energy flexibility in PED is a concept based on the generation of (local) energy from renewable sources, which is distributed in a region-wide network where, thanks to the use of computer optimization systems, it is redistributed according to where it is most needed.	[12,16,18,36]	kWh consumed $\leq$ kWh produced
		[12,36–38]	Energy surplus transfer contract
Energy surplus	The PED has as its basic principle the production of energy from renewable sources. Where possible, and respecting the other indicators, it aims to pursue an energy surplus to make energy production profitable for the district.	[12,36,38,39]	With energy surplus kWh consumed < kWh produced
		[12,14,36,40]	Balanced—without energy surplus kWh consumed = kWh produced

Table 1. *Cont.*

PED Characteristic	Definition	Ref.	Parameters and Value
Nearly zero-energy buildings and net-zero-energy districts	NZEBs and NZEDs are very high-performance buildings/neighborhoods, aiming for high sustainability and energy savings. They aim to produce very low carbon emissions and to be powered by renewable energy sources. One method of analysis is Life Cycle Assessment.	[6,12,16,36,41]	Life Cycle Assessment—Material recycling and re-use
Renewable energy production	Renewable energy is energy from renewable resources naturally replenished on a human time scale. Renewable resources include sunlight, wind, water movement, and geothermal heat. In PEDs, both individual technological solutions joined by the grid and concentrated local production that is subsequently redistributed into the grid following the rule of the greatest efficiency and least waste of energy is envisaged.	[31,42,43]	kWh consumed $\leq$ kWh produced
Energy Community	Energy communities are a particular form of organization based on the production and self-consumption of electricity. They are systems that allow an entire community to benefit from renewable energy produced locally, either by individual citizens or by local businesses involved in the initiative.	[10,12,44,45]	Renewable Energy Communities contract
Urban and local development, real estate			
Technological solutions	Three of the most important real estate revolutions will condition and enhance the technological solutions of a PED, aiming for good financial returns, and will be able to stimulate the development of this concept of living in quality spaces.	[41,46,47]	1. AIoT—integration into measurement and reporting
		[2,45,47,48]	2. Abatement intelligence—predictive analytics to simulate emissions over time
		[5,6,31,49]	3. Carbon offsetting and offset integration
Sector coupling and cross-sectorial integration	Varies from state to state and from sector to sector. In particular, it must be emphasized that the European Union will give an update on how this mechanism will work.	[4,21,26]	Increased quality of work and life—sensitivity analysis and survey
New business models, the future role of "citizen energy communities" (CEC) and "renewable energy communities" (REC)	A financial model involving the operation of RECs and CECs. CECs are united with RECs by geographical proximity: citizens connected under the same medium-voltage station can be members of a REC and share the renewable energy produced by the REC's installations.	[39,41–45]	Renewable Energy Communities contract.
Active involvement of problem owners and citizens	Co-active participation with owners, citizens, and others in the changes in and transformations of urban districts and cities.	[25,30,49]	Sensitivity analysis and survey
Urban areas or groups of connected buildings	Develop zones and small neighborhoods with small functions to optimize consumption and networks.	[7,9,11,12]	Urban instruments—Regulatory plan
Existing building stock is main challenge to achieving climate neutrality	Urban development models that integrate existing and new buildings, not just urban transformations.	[9,36,39,41]	Urban instruments—Regulatory plan

Table 1. *Cont.*

PED Characteristic	Definition	Ref.	Parameters and Value
Resilience and security of energy supply	I am designing for special and complicated contexts considering the development of energy security solutions such as hacker attacks on the district's energy management system.	[17,18,37,50]	Administrative and political action plan
Infrastructure			
Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels	Urban design for maintaining or improving the climate context, making it energy-positive to harness renewable energy from blue corridors and to regulate the microclimate and environmental quality with green lungs in the district.	[42,51–53]	kWh of geothermal water consumed $\leq$ kWh of geothermal water produced
		[25,51,54,55]	CO_2 produced in the district $\leq$ CO_2 absorbed by natural green lungs in the district
Developing the role of mobility in the PED Reference Framework	Intelligent design of urban mobility, exploiting where possible the district's energy surplus for the transport service system.	[2–4,56]	kWh consumed $\leq$ kWh produced by surplus of the districts
People			
Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	Socio-economic systems to reduce poverty and re-integrate groups of people who are unable to access services into the economic system.	[9,20,26,33]	Urban instruments—Regulatory plan
		[5,9,21]	Administrative and political action plan
Quality of life	Income and work, housing, health, education, quality of the environment, personal safety, civic engagement, work–life, balance, infrastructure and services, mobility, culture and leisure, economic context, demographic context.	[16,20,27,33]	OCSE indicator—Political action plan
Regulatory sandboxes, living labs, and testing environments	A living lab is an infrastructure for the experimentation of new technologies under real conditions in a limited geographical context and over a limited period, to test their feasibility and degree of usefulness for end users (citizens, businesses, beneficiaries, etc.). Interaction with users enables continuous improvement of the technology to improve its characteristics with a view to its application on a larger scale.	[25,57]	Social and Inclusive Action
			Administrative and political action plan

2. Materials and Methods

This paper aims to analyze the intrinsic characteristics of urban PED certification protocols and compare them with the aspects that characterize some of the case studies, to identify possible elements for improvement both for the protocols and for future PED projects. To achieve this, a methodology has been developed, as illustrated in the Figure 1. Specifically, in Figure 1 it is proposed, on the one hand, to analyze the protocols by selecting all the criteria on which PED aspects are included and, on the other hand, to compare these project proposals with the aspects of the PED projects implemented. Three different scenarios can be derived from this comparison:

- The protocol's internal values related to a particular issue (e.g., presence of photovoltaics or community involvement) are addressed in the same way by requiring the same quantitative level, so no further improvement measures are required.

- The internal features of the protocol are better than the case studies, so improvements can be made to the case studies and possible future projects.
- The internal aspects of the case studies are better than what is recommended in the certification schemes, so possible additions to the latter can be considered for PED projects.

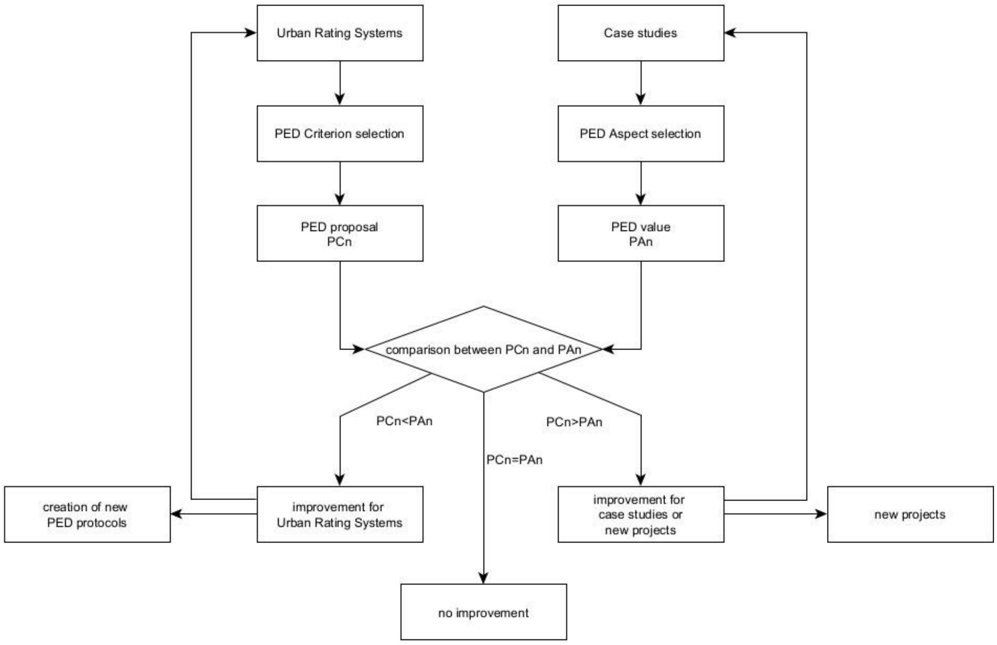

Figure 1. Flowchart of the methodology used, where PCn is the n-th PED criterion selected in an urban rating system and PAn is the n-th PED aspect selected from a case study. Produced by the authors.

2.1. Characteristics of the Certification Protocols Chosen

2.1.1. LEED for Neighborhoods Development (LEED-ND)

Starting with one of the most widely used certification systems in the world for its simplicity of understanding, the U.S. Green Building Council (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 [28]. This tool promotes sustainable building and development practices through a suite of reporting and recognizes projects that are committed to better environmental and health performance [20]. LEED intends to encourage all cities to measure and improve performance, focusing on outcomes from ongoing sustainability efforts [37]. To leverage a globally consistent method of performance measurement for a streamlined and data-based pathway to LEED certification for cities [58]. For these reasons, 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 [24]. The goal of the partnership of NRDC and USGBC was 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 [58]. The LEED-ND criteria for sustainable neighborhoods [28] in cities are cited in Table 2. This table presents the LEED-ND criteria [14], which, following the methodology outlined above, are generally acknowledged as PED characteristics [5] by the scientific community involved [12].

Table 2. This table shows all criteria with their scores within the LEED-ND certification protocol; the criteria in grey were selected as common concerning the characteristics of PEDs.

Smart Location and Linkage		**28**
Credit	Preferred Locations	10
Credit	Brownfield Remediation	2
Credit	Access to Quality Transit	7
Credit	Bicycle Facilities	2
Credit	Housing and Jobs Proximity	3
Credit	Steep Slope Protection	1
Credit	Site Design for Habitat or Wetland and Water Body Conservation	1
Credit	Restoration of Habitat or Wetlands and Water Bodies	1
Credit	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1
Neighborhood Pattern and Design		**41**
Credit	Walkable Streets	9
Credit	Compact Development	6
Credit	Mixed-Use Neighborhoods	4
Credit	Housing Types and Affordability	7
Credit	Reduced Parking Footprint	1
Credit	Connected and Open Community	2
Credit	Transit Facilities	1
Credit	Transportation Demand Management	2
Credit	Access to Civic and Public Space	1
Credit	Access to Recreation Facilities	1
Credit	Visitability and Universal Design	1
Credit	Community Outreach and Involvement	2
Credit	Local Food Production	1
Credit	Tree-lined and Shaded Streetscapes	2
Credit	Neighborhood Schools	1
Green Infrastructure and Buildings		**31**
Credit	Certified Green Buildings	5
Credit	Optimize Building Energy Performance	2
Credit	Indoor Water Use Reduction	1
Credit	Outdoor Water Use Reduction	2
Credit	Building Reuse	1
Credit	Historic Resource Preservation and Adaptive Reuse	2
Credit	Minimized Site Disturbance	1
Credit	Rainwater Management	4
Credit	Heat Island Reduction	1
Credit	Solar Orientation	1
Credit	Renewable Energy Production	3
Credit	District Heating and Cooling	2
Credit	Infrastructure Energy Efficiency	1
Credit	Wastewater Management	2
Credit	Recycled and Reused Infrastructure	1
Credit	Solid Waste Management	1
Credit	Light Pollution Reduction	1
PROJECT PED TOTALS (Certification estimates)		**80**
PROJECT TOTALS (Certification estimates)		**100**

2.1.2. BREEAM Communities

The second important certification protocol is BREEAM, introduced in 1990; it was the world's first environmental assessment method for new building designs [58]. 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 come a long way, and it is now employed on a global scale. The subjects in this rating system fall into five assessment categories, which are evaluated through suitable criteria: Governance, Social and Economic well-being, Resources and Energy, Land use and Ecology, and Transport and Movement [29]. As sustainability problems frequently impact all three dimensions of sustainability—social, environmental, and economic—it is difficult to classify them. Therefore, BREEAM aims to evaluate each problem's intent by assessing the above five categories, shedding light on the issue. A sixth category promotes innovation, which demonstrates the importance of finding innovative solutions to solve the problem.

The categories are as follows, with a brief description of their overall goals [29]:

- Governance (GO) promotes the involvement of the community in decision-making regarding the development outcomes under the influence of the design, construction, and operation.
- Social and Economic well-being (SE) contemplates societal and economic factors influencing health and well-being such as sufficient housing and availability of employment.
- Resources and Energy (RE) addresses the sustainable use of natural resources and the reduction in carbon emissions.
- Land use and Ecology (LE) encourages sustainable land use and ecological enhancement.
- Transport and Movement (TM) addresses the design and provision of transportation and movement infrastructure to promote the use of sustainable means of transportation.
- Innovation (Inn) promotes employing innovative solutions in the rating where they help obtain environmental, social, and/or economic benefits in a way that is not looked at elsewhere in the scheme.

This sustainability standard originated in the UK in 1990, created by the governmental Building Research Establishment (BRE). According to data published on its official website, BREEAM is the most widely used building sustainability certification standard in the world, boasting more than 16,000 certified projects in more than 50 countries, totaling, according to the governing body, more than 40 million square meters certified, including offices, retail buildings, schools, industrial buildings, and more.

BREEAM aims to ensure that its standards provide social and economic benefits whilst ameliorating the environmental impacts of the built environment [29]. As a result, BREEAM is especially likely to put a value on developments according to their sustainability benefits [32]. 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 [24]. Overviews of the assessment items are displayed in Table 3. Table 3 also shows the selection of BREEAM Communities criteria [29] considered by the authors, after careful study, to be common to the PED characteristics agreed upon by the scientific community involved [12].

2.1.3. CASBEE for Cities

The last certification system analyzed is the most widely used throughout Asia and is the CASBEE; this acronym means Comprehensive Assessment System for Built Environment Efficiency (CASBEE) [24]. This is a method for assessing and scoring the environmental performance of buildings and the built environment.

Table 3. This table shows all criteria with their scores within the BREEAM Communities certification protocol. The criteria in grey were selected as common concerning the characteristics of PEDs.

	Governance	**9.3**
Credit	Consultation plan	2.3
Credit	Consultation and engagement	3.5
Credit	Design review	2.3
Credit	Community management of facilities	1.2
	Social and economic well-being	**42.7**
Credit	Economic impact	8.9
Credit	Demographic needs and priorities	2.7
Credit	Flood risk assessment	1.8
Credit	Noise pollution	1.8
Credit	Housing provision	2.7
Credit	Delivery of services, facilities, and amenities	2.7
Credit	Public realm	2.7
Credit	Microclimate	1.8
Credit	Utilities	0.9
Credit	Adapting to climate change	2.7
Credit	Green infrastructure	1.8
Credit	Local parking	0.9
Credit	Flood risk management	1.8
Credit	Local vernacular	0.9
Credit	Inclusive design	1.8
Credit	Light pollution	0.9
Credit	Training and skills	5.9
	Resources and ecology	**21.7**
Credit	Energy strategy	4.1
Credit	Existing buildings and infrastructure	2.7
Credit	Water strategy	2.7
Credit	Sustainable buildings	4.1
Credit	Low-impact materials	2.7
Credit	Resource efficiency	2.7
Credit	Transport carbon emissions	2.7
	Land use and ecology	**12.8**
Credit	Ecology strategy	3.2
Credit	Land use	2.1
Credit	Water pollution	1.1
Credit	Enhancement of ecological value	3.2
Credit	Landscape	2.1
Credit	Rainwater harvesting	1.1
	Transport and movement	**13.8**
Credit	Transport assessment	3.2
Credit	Safe and appealing streets	3.2
Credit	Cycling network	2.1
Credit	Access to public transport	2.1
Credit	Cycling facilities	1.1
Credit	Public transport facilities	2.1
PROJECT PED TOTALS (Certification estimates)		**82.1**
PROJECT TOTALS (Certification estimates)		**100.3**

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) [58]. CASBEE for Cities is a tool for the assessment of comprehensive area development projects including a group of buildings [30].

Compared to other tools available worldwide, CASBEE for Cities has a unique and simple structure. It follows the triple bottom line concept, which is one of the important frameworks for the assessment and identification of sustainability through the three classifications of the environment, society, and the economy. In each sub-category, are three different categories are omitted for the sake of brevity because they are not integral to the salient features of CASBEE but are described below; overviews of the assessment items are displayed in Table 4. As we can see, Table 4 also shows the selection of CASBEE criteria [30] considered by the authors, after careful study, to be common to the PED characteristics agreed upon by the scientific community involved [12].

Table 4. This table shows all criteria with their scores within the CASBEE for Cities certification protocol. The criteria in grey are considered to be common with the characteristics of PEDs that have been selected.

Q1—Environment		**33.36**
Credit	Rainwater utilization	1.39
Credit	Treated water	1.39
Credit	Reduction in the amount of sewage discharge	1.39
Credit	Reduction in the amount of rainwater discharge: Capacity of detention ponds	0.7
Credit	Reduction in amount of rainwater discharge: Rainwater-permeable surfaces and equipment	0.7
Credit	Wood material	1.39
Credit	Recycled material	1.39
Credit	Garbage separation	1.39
Credit	In-area resource circulation	1.39
Credit	Ground greening	2.78
Credit	Rooftop greening	1.39
Credit	Wall greening	1.39
Credit	Natural resources	1.39
Credit	Landform	1.39
Credit	Patch (planar) quality: Habitat space of species	0.7
Credit	Patch (planar) quality: Consideration for regionality	0.7
Credit	Corridor (network) quality	1.39
Credit	Environmentally considerate buildings	11.1
Q2—Society		**33.3**
Credit	Compliance	5.56
Credit	Area management	5.56
Credit	Understanding of hazard map	0.92
Credit	Disaster prevention of various infrastructures	0.92
Credit	Disaster prevention: vacant space and evacuation route	0.92
Credit	Continuity of business and life in the block	0.92
Credit	Traffic safety	3.7
Credit	Crime prevention	3.7
Credit	Convenience	2.78
Credit	Distance to medical, health/welfare facilities	0.92
Credit	Distance to educational facilities	0.92
Credit	Distance to cultural facilities	0.92

Table 4. *Cont.*

Credit	History and Culture	2.78
Credit	Consideration for the formation of townscape and landscape	1.39
Credit	Harmonization with the periphery	1.39
Q3—Economy		**33.36**
Credit	The development of traffic facilities: level of roads, etc.	1.39
Credit	Usability of public transportation	1.39
Credit	Logistics management	2.78
Credit	Consistency with and complementing upper-level planning	2.78
Credit	Utilization level of standard floor area ratio	2.78
Credit	Handling of brownfield sites	0
Credit	Inhabitant population	2.78
Credit	Staying population	2.78
Credit	Housing	0
Credit	Non-housing	5.56
Credit	Information service performance	2.78
Credit	Block management	2.78
Credit	Possibility to make demand/supply system smart	2.78
Credit	Updatability and expandability	2.78
PROJECT PED TOTALS (Certification estimates)		**74.78**
PROJECT TOTALS (Certification estimates)		**100.02**

2.2. Completed PED Case Study: Features and Strengths

According to the methodology outlined above, to understand the shortcomings of the current certification protocols, or to identify new evaluation criteria to be added to the current certification protocols, it is necessary to identify representative PED projects. For this study, through the analysis of the site set up for the dissemination of PED projects worldwide, only two projects currently completed were identified as usable. Information on this aspect was taken from the European PEDs monitoring portal of the PED-EU-NET project [13,17]. The reason why these 2 case studies were chosen is simply because they are considered finished and operational. This makes it possible to identify the strengths and weaknesses of both the protocols and the projects analyzed. To compare the 2 case studies, some parameters and characteristics were taken from the PED-EU-NET portal and are reported below.

The first case study is Salzburg Geneis district, Mozart's birthplace, in an Austrian town on the border with Germany, surrounded by the Eastern Alps and bisected by the Salzach River. How is possible to see in the Figure 2a,b there are a small group of house with the strategy of this PED case study was to create a dynamic district and building-scale energy modeling, including microclimate modeling, a Klimaaktiv certification system, an energy community, and flexibility with shared heating and electricity systems.

The second case study is Tampere, Ilokkaanpuisto district. This Finnish town is situated between the Näsijärvi and Pyhäjärvi lakes. The difference in altitude of the two lakes, about 18 m, gives rise to the Tammerkoski rapids which are about 945 m long and are used as a source of hydroelectric power. Infact, how is possible to see in Figure 2c,d, the strategy of this PED case study was to create energy efficiency—A-class buildings, heating via GSHP energy production, installation of photovoltaics (PVs); employ digital technologies—smart control and monitoring of HVAC and indoor circumstances; and promote E-mobility—installation of charging stations for electric vehicles.

Much of the information that was used for the analysis was retrieved from the PED-EU-NET website; in Table 5, the most important properties for each of the 2 demo cases have been compiled and included in the PED characteristics column. Table 5 consists of the characteristics of the PEDs introduced in Tables 1 and 2, with the columns representing the values or parameters of the 2 houses concerning the presence or absence of these characteristics. Parameters and qualitative–quantitative values of the 2 demo sites were entered based on the information contained on the PED-EU-NET website.

(**a**)

(**b**)

(**c**)

(**d**)

Figure 2. (**a**) Plan of Salzburg Geneis district; (**b**) photo of Salzburg Geneis district; (**c**) plan of Tampere, Ilokkaanpuisto district; (**d**) render of Tampere, Ilokkaanpuisto district.

Table 5. This table shows all the characteristics of the PEDs introduced in Table 1 common to PEDs. In the 2 columns on the right-hand side, parameters and qualitative–quantitative values of the 2 demo sites considered important have been inserted. Compiled by the authors based on the information on the PED-EU-NET website.

PED Characteristics, Specific Aspects of PED Framework		**01—Salzburg Geneis District**	**02—Tampere, Ilokkaanpuisto**
Analysis by Literature	**Parameters and Values**	**Presence**	**Presence**
General information	A1P012: Country	Austria	Finland
	A1P013: City	Salzburg	Tampere
	A1P016: Ownership of the case study/PED Lab:	Mixed	Mixed
	A1P017: Ownership of the land/physical infrastructure:	Single Owner	Multiple Owners
	A1P018: Number of buildings in PED	17	6
	A1P019: Conditioned space [m^2]	199,762	9
	A1P022a: Financing—PRIVATE—Real estate	No	Yes
	A1P022c: Financing—PRIVATE—Other	No	Yes
	A1P022e: Financing—PUBLIC—National funding	No	Yes
	A1P022i: Financing—RESEARCH FUNDING—EU	Yes	Yes
	A2P008: Annual energy demand in buildings/electricity demand (GWh/annum)		Yes
Energy			
Energy efficiency	A2P028: Energy efficiency certificates	Klimaaktiv certificate, Greenpass certificate	Yes

Table 5. *Cont.*

PED Characteristics, Specific Aspects of PED Framework		01—Salzburg Geneis District	02—Tampere, Ilokkaanpuisto
Analysis by Literature	**Parameters and Values**	**Presence**	**Presence**
Energy flexibility	A2P024: Smart electricity grid	Yes	No
	A2P024: Smart metering and demand-responsive control systems	No	Yes
Energy surplus	Annual energy surplus	Yes	No
	Annual energy surplus (GWh/annum)	−0.0419496	0.05
	A2P016: Annual non-renewable electricity production on-site (GWh/annum)	−1	0
Nearly zero-energy buildings and net-zero-energy districts	Net-zero emission	No	Yes
	Self-sufficiency (energy autonomous)	No	Yes
	Climate neutrality	Yes	Yes
Renewable energy production	A2P011: PV—specify production in GWh/annum	0.7770664	0.75
	A2P014: Annual energy use (GWh/annum)	0.819016	0.7
Energy Community	Energy Community	Yes	Yes
Urban and local development, real estate			
Technological solutions	Circularity	No	No
	Air quality and urban comfort	Yes	No
	A2P023: Photovoltaics	Yes	Yes
	A2P023: Heat Pump	No	Yes
	A2P023: Geothermal energy system	Yes	Yes
	A2P023: Waste heat recovery	No	Yes
	A2P024: A2P024: Information and Communication Technologies (ICT)	No	Yes
	A2P024: Energy management system	Yes	Yes
	A2P024: Demand-side management	Yes	Yes
Sector coupling and cross-sectorial integration	A3P008: Integrated Urban Strategies	Building/district certification	Strategic urban planning, digital twinning, and visual 3D models, SECAP updates
New business models, future role of CECs and RECs	A3P006: Economic strategies	Innovative business models, local trading	Open data business models, circular economy models
Active involvement of problem owners and citizens	A3P007: Social models	Yes	Yes
Urban areas or groups of connected buildings	A2P025: New high-performance buildings	Yes	Yes
	A2P025: Mobile applications for citizens	No	Yes
	A2P025: Building services (HVAC and lighting)	Yes	Yes
	B1P013: Natural areas	Yes	Yes
	B1P014: Residential	Yes	Yes

Table 5. *Cont.*

PED Characteristics, Specific Aspects of PED Framework		01—Salzburg Geneis District	02—Tampere, Ilokkaanpuisto
Analysis by Literature	**Parameters and Values**	**Presence**	**Presence**
Existing building stock is main challenge to achieving climate neutrality	A2P025: Energy efficiency measures in historic buildings	No	No
Resilience and security of energy supply	A3P009: Environmental strategies	Yes	Yes
Infrastructure			
Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels	A3P009: Environmental strategies	Energy-neutral, low-emission zone	Energy neutral, net zero carbon footprint, carbon-free, greening strategies, sustainable urban drainage systems (SUDSs), nature-based solutions (NBSs)
Developing the role of mobility in the PED Reference Framework	A2P026: Measures to reduce traffic volume (e.g., measure to support public transportation, shared mobility, measure to reduce journeys and distances)	Yes	No
	A2P026: e-Mobility	Yes	No
People			
Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	A3P007: Social models	Strategies towards (local) community-building, behavioral change/end-user engagement, social incentives, quality of life, strategies towards social mixing, affordability, citizen/owner involvement in planning and maintenance	Co-creation/citizen engagement strategies, behavioral change/end-user engagement, digital inclusion, citizen/owner involvement in planning and maintenance
Quality of life	A3P007: Social models	Yes	Yes
Regulatory sandboxes, living labs, and testing environments	A3P007: Social models	Yes	Yes

3. Results

Through the identification of the internal PED characteristics of the urban-scale sustainability protocols listed above and the evaluation of the PED characteristics of the case studies analyzed, it is possible to compare and evaluate possible improvements to both systems.

At the operational level, as can be seen in Figure 3, each relating to a single protocol, the relevant criteria were initially assigned to each aspect of the PED projects for subsequent comparison. In this way, it was possible to note not only the expected comparison during the presentation of the methodology but also whether, quantitatively, some of the criteria were slightly or much better or worse than the respective aspects of the case studies to be evaluated. Tables 6–8 compare all the criteria selected for the PEDs from the LEED—ND certification protocol with the characteristics of the two selected case studies: in the first column, the criteria selected from the certification protocols are shown (Table 6—LEED—ND; Table 7—BREEAM—CM; Table 8—CASBEE—UD); in the second column, in white, the Salzburg Geneis case study and its essential strategies and characteristics are presented; and in the last column, in white, the Tampere, Ilokkaanpuisto, case study is presented. The criteria in grey correspond to the characteristics. The best solutions are presented in dark green and light green, the good solutions.

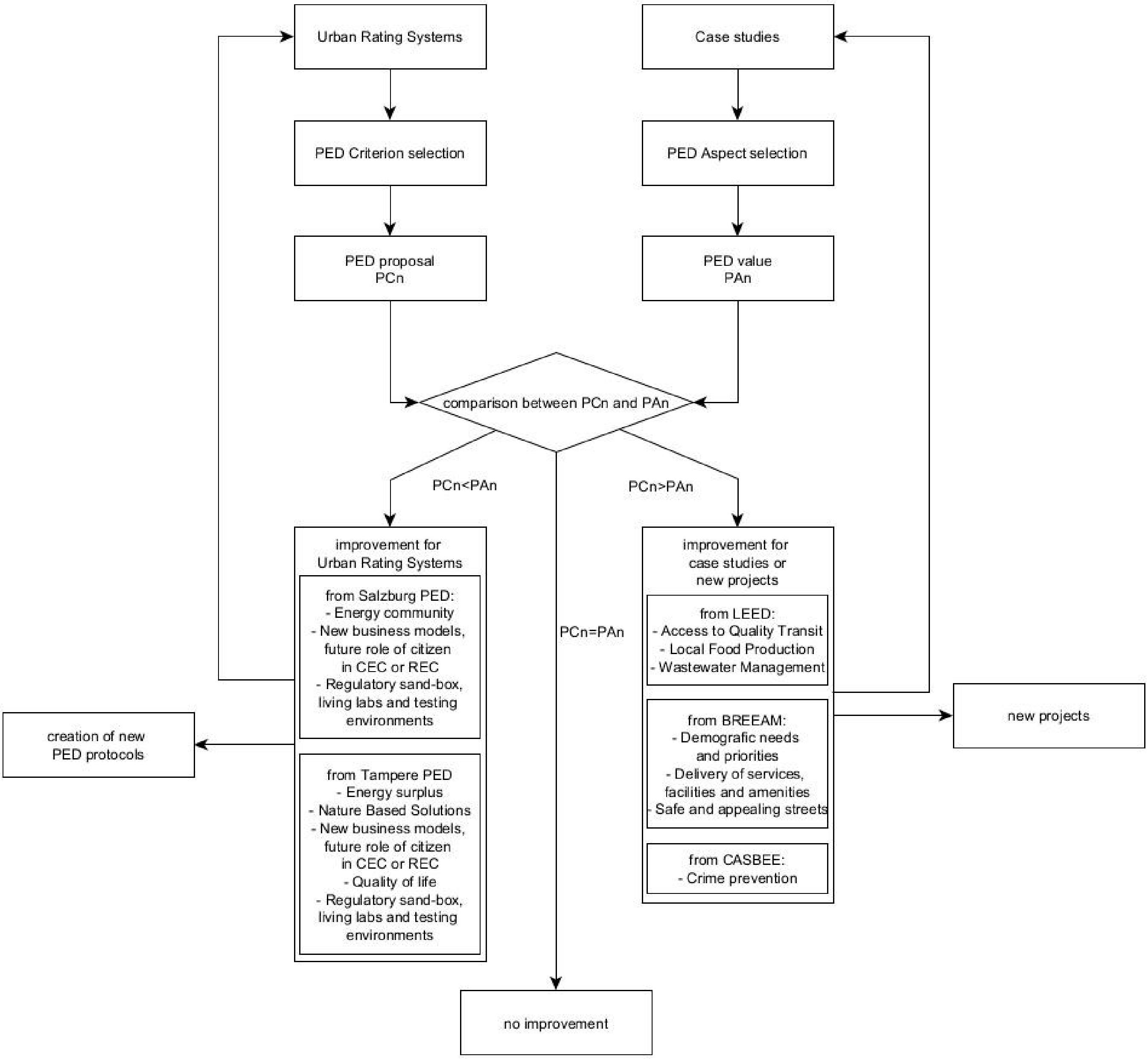

Figure 3. Flowchart of the methodology used, where PCn is the n-th PED criterion selected in an urban rating system and PAn is the n-th PED aspect selected from a case study. In this graph, there is the possible application and the consequences. Produced by the authors.

Table 6. This table shows all criteria selected for PED from the LEED-ND certification protocol with the characteristics of the two case studies selected, produced by the authors based on Tables 1–5.

N°	LEED-ND for PEDs	Corresponding Criteria	01—Salzburg Geneis District, Specific Aspects of PED Framework	Corresponding Criteria	02—Tampere, Ilokkaanpuisto, Specific Aspects of PED Framework
N°	**Smart Location and Linkage**		**Energy**		**Energy**
1	Preferred Locations	16, 17, 18, 24,26	Energy efficiency	16, 17, 18, 24,26	Energy efficiency
2	Access to Quality Transit	24, 25	Energy flexibility	24, 25	Energy flexibility
3	Bicycle Facilities		Not enough energy surplus		Energy surplus, producing more energy than consumed
4	Housing and Jobs Proximity	16, 17, 18, 24, 26	Nearly zero-energy buildings and net-zero-energy districts	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				
	Neighborhood Pattern and Design	13, 16, 17, 24, 25,	Energy production	13, 16, 17, 24, 25,	Energy production
6	Walkable Streets	17, 24, 25,	Energy Community	17, 24, 25,	Nature-Based Solutions (NBS)
7	Mixed-Use Neighborhoods				
8	Housing Types and Affordability		**Urban and local development, real estate**		**Urban and local development, real estate**
9	Connected and Open Community	3, 5, 10,	Technological solutions	3,5,10,	Technological solutions
10	Transportation Demand Management				
11	Access to Civic and Public Space	12	Sector coupling and cross-sectorial integration	12	Sector coupling and cross-sectorial integration
12	Community Outreach and Involvement		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)
13	Local Food Production				
14	Tree-lined and Shaded Streetscapes	9, 12, 15,	Active involvement of problem owners and citizens	9, 12, 15,	Active involvement of problem owners and citizens
15	Neighborhood Schools				
	Green Infrastructure and Buildings	12, 17,	Urban areas or groups of connected buildings	12, 17,	Urban areas or groups of connected buildings
16	Certified Green Buildings				
17	Optimize Building Energy Performance	18	Existing building stock is main challenge to achieving climate neutrality	18	Existing building stock is main challenge to achieving climate neutrality
18	Building Reuse				
19	Indoor Water Use Reduction	18,	Resilience and security of energy supply	18,	Resilience and security of energy supply
20	Outdoor Water Use Reduction				
21	Rainwater Management		**Infrastructure**		**Infrastructure**
22	Heat Island Reduction	5, 14, 19, 20, 21, 22	Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels	5, 14, 19, 20, 21, 22	Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels
23	Solar Orientation	2, 3, 6, 7, 10, 14	Developing the role of mobility in the PED Reference Framework	2, 3, 6, 7, 10, 14	Developing the role of mobility in the PED Reference Framework
24	Renewable Energy Production				
25	District Heating and Cooling		**People**		**People**
26	Infrastructure Energy Efficiency	8, 9,	inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	8, 9,	Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness
27	Wastewater Management				
28	Light Pollution Reduction	5	Quality of life		Quality of life
	PROJECT TOTALS (Certification estimates)	9, 12	Regulatory sandboxes, living labs, and testing environments	9, 12	Regulatory sandboxes, living labs, and testing environments

For LEED-ND, it was possible to note that, as described in Table 6, LEED-ND, compared to the characteristics of the PED case studies, values access to quality transit, local food production, and wastewater management, which are neglected by the studied PEDs. Conversely, LEED-ND neglects energy surplus, producing more energy than consumed, new business models, and the future role of "City Energy Communities" (CECs) and

"Renewable Energy Communities" (RECs) concerning both case studies and nature-based solutions (NBSs) for Tampere only.

Table 7. This table shows all criteria selected for PEDs from the BREEAM Communities certification protocol with the characteristics of the two case studies selected.

	BREEAMS-CM for PEDs	Corresponding Criteria	01—Salzburg Geneis District, Specific Aspects of PED Framework	Corresponding Criteria	02—Tampere, Ilokkaanpuisto, Specific Aspects of PED Framework
N°	**Governance**	**N°**	**Energy**	**N°**	**Energy**
1	Consultation and engagement	3, 17, 20, 21, 22, 24	Energy efficiency	3, 17, 20, 21, 22, 24	Energy efficiency
2	Design review	13, 17	Energy flexibility	13, 17	Energy flexibility
3	Community management of facilities	17	Not enough energy surplus	17	Energy surplus, producing more energy than consumed
	Social and economic well-being	13, 17, 20, 22	Nearly zero-energy buildings and net-zero-energy districts	13, 17, 20, 22	Nearly zero-energy buildings and net-zero-energy districts
4	Economic impact				
5	Demographic needs and priorities	13, 16, 17, 24, 25,	Energy production	13, 16, 17, 24, 25,	Energy production
6	Flood risk assessment		Energy Community		Nature Based Solutions (NBS)
7	Noise pollution				
8	Housing provision		**Urban and local development, real estate**		**Urban and local development, real estate**
9	Delivery of services, facilities, and amenities	12, 15, 17, 20	Technological solutions	12, 15, 17, 20	Technological solutions
10	Public realm		Sector coupling and cross-sectorial integration		Sector coupling and cross-sectorial integration
11	Microclimate	3, 12, 15, 27		3, 12, 15, 27	
12	Utilities		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)
13	Adapting to climate change				
14	Green infrastructure	8, 10,	Active involvement of problem owners and citizens	8, 10,	Active involvement of problem owners and citizens
15	Inclusive design				
16	Light pollution	10, 18, 20,	urban areas or groups of connected buildings	10, 18, 20,	urban areas or groups of connected buildings
	Resources and ecology				
17	Energy strategy				
18	Existing buildings and infrastructure	18, 20, 22,	Existing building stock is main challenge to achieving climate neutrality	18, 20, 22,	Existing building stock is main challenge to achieving climate neutrality
19	Water strategy				
20	Sustainable buildings				
21	Low impact materials	22	Resilience and security of energy supply	22	Resilience and security of energy supply
22	Resource efficiency				
23	Transport carbon emissions		**Infrastructure**		**Infrastructure**
	Land use and ecology		Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels		Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels
24	Ecology strategy	6, 11, 13, 14, 17, 18, 19, 20, 22, 24, 25, 26,		6, 11, 13, 14, 17, 18, 19, 20, 22, 24, 25, 26,	
25	Land use				
26	Rainwater harvesting	7, 17, 23, 27, 28, 29, 30, 31	Developing the role of mobility in the PED Reference Framework	7, 17, 23, 27, 28, 29, 30, 31	Developing the role of mobility in the PED Reference Framework
	Transport and movement				
27	Transport assessment		**People**		**People**
28	Safe and appealing streets	1, 2, 3, 4, 5,	Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness	1, 2, 3, 4, 5,	Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness
29	Cycling network				
30	Access to public transport		quality of life		quality of life
31	Cycling facilities		Regulatory sandboxes, living labs, and testing environments		Regulatory sandboxes, living labs, and testing environments
	PROJECT TOTALS (Certification estimates)				

Table 8. This table shows all criteria selected for PEDs from CASBEE for Cities certification protocol with the characteristics of the two case studies selected. Produced by the authors.

	CASBEE for Cities for PEDs	Corresponding Criteria	01—Salzburg Geneis District, Specific Aspects of PED Framework	Corresponding Criteria	02—Tampere, Ilokkaanpuisto, Specific Aspects of PED Framework
N°	**Q1—Environment**		**Energy**		**Energy**
1	Rainwater utilization	1, 4, 5, 6, 7, 9	Energy efficiency	1, 4, 5, 6, 7, 9	Energy efficiency
2	Reduction in amount of rainwater discharge: Rainwater-permeable surfaces and equipment	27	Energy flexibility	27	Energy flexibility
3	In-area resource circulation		Not enough energy surplus		Energy surplus, producing more energy than consumed
4	Ground greening	4, 5, 6, 7, 9	Nearly zero-energy buildings and net-zero-energy districts	4, 5, 6, 7, 9	Nearly zero-energy buildings and net-zero-energy districts
5	Rooftop greening				
6	Wall greening	7	Energy production	7	Energy production
7	Natural resources		Energy Community		Nature Based Solutions (NBS)
8	Landform				
9	Environmentally considerate buildings		**Urban and local development, real estate**		**Urban and local development, real estate**
	Q2—Society				
10	Compliance		Technological solutions		Technological solutions
11	Area management	9, 27	Sector coupling and cross-sectorial integration	9, 27	Sector coupling and cross-sectorial integration
12	Disaster prevention of various infrastructures		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)		New business models, future role of "citizen energy communities" (CECs) and "renewable energy communities" (RECs)
13	Disaster prevention vacant space and evacuation route				
14	Continuity of business and life in the block	11, 27	Active involvement of problem owners and citizens	11, 27	Active involvement of problem owners and citizens
15	Traffic safety				
16	Crime prevention	12, 17	Urban areas or groups of connected buildings	12, 17	Urban areas or groups of connected buildings
17	Convenience				
18	History and Culture	18	Existing building stock is main challenge to achieving climate neutrality	18	Existing building stock is main challenge to achieving climate neutrality
19	Consideration for the formation of townscape and landscape				
20	Harmonization with the periphery	18	Resilience and security of energy supply	18	Resilience and security of energy supply
	Q3—Economy				
21	The development of traffic facilities: level of roads, etc.		**Infrastructure**		**Infrastructure**
22	Usability of public transportation	1, 2, 3, 4, 5, 6, 7	Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels	1, 2, 3, 4, 5, 6, 7	Green and blue infrastructures are important building blocks for climate change adaptation strategies on the district and neighborhood levels
23	Logistics management	21, 22, 23, 28		21, 22, 23, 28	
24	Consistency with and complementing upper-level planning		Developing the role of mobility in the PED Reference Framework		Developing the role of mobility in the PED Reference Framework
25	Non-housing		**People**		**People**
26	Block management	11, 20, 25, 27, 28	Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness quality of life	11, 20, 25, 27, 28	Inclusiveness, tackling the affordability of housing, and fighting energy poverty as the main aspects of inclusiveness quality of life
27	Possibility to make demand/supply system smart				
28	Updatability and expandability				
	PROJECT TOTALS (Certification estimates)	18, 19, 20	Regulatory sandboxes, living labs, and testing environments	18, 19, 20	Regulatory sandboxes, living labs, and testing environments

For BREEAM-CM, it was possible to note that, as described in Table 7, BREEAM Communities, concerning the characteristics of the two PED case studies, values demographic needs and priorities; delivery of services, facilities, and amenities; and safe and appealing streets, which are neglected by the PEDs. Conversely, BREEAM Communities neglects energy surplus; energy communities; producing more energy than is consumed; new business models; the future role of "city energy communities" (CECs) and "renewable energy communities" (RECs); and regulatory sandboxes, living labs, and testing environment from both case studies and nature-based solutions (NBSs) for Tampere only.

For CASBEE-UD, it was possible to note that, as described in Table 8, the comparison of the characteristics of the two PED case studies enhances crime prevention, which is neglected by the PED. Conversely, CASBEE for Cities neglects energy surplus; producing more energy than is consumed; new business models; the future role of "city energy communities" (CECs) and "renewable energy communities" (RECs); and regulatory sandboxes, living labs, and testing environments concerning both case studies and nature-based solutions (NBSs) for Tampere only.

4. Discussion and Conclusions

Cities and new neighborhoods will increasingly have to be sustainable in all aspects (economic, social, and environmental) given the data on climate change and emissions from the urban environment. In recent years, the EEA and the EU have developed the concept of positive energy districts (PEDs), which are defined as urban districts with zero net annual energy imports and zero net CO_2 emissions working towards excess renewable energy production integrated into an urban and regional energy system. Being a new concept, the first projects and realizations are coming to life but cannot be evaluated through defined parameters and/or certification systems. In this context, urban rating systems can help through their internal quantitative structures (criteria and parameters). For this reason, in this research, an attempt was made to find similar elements or improvements that could be implemented in current protocolsthrough the implementation of an analysis methodology. Subsequently, this method was used to evaluate two case studies (Salzburg and Tampere) and analyze three protocols (LEED-ND; BREEAM-CM; CASBEE-UD).

As seen in Tables 6–8, or in Figure 4, a careful analysis of the results showed that as the survey methodology varies, so does the judgment and goodness of the assessment. This is mainly because the three studied sustainability assessment systems are based on different structures, with unequal weights for their various criteria.

The sore point of these protocols at the moment, apart from the fact that they do not have an evaluation and classification part related to the energy community and PEDs, is that they will be used for urban neighbourhoods that are difficult to compare with others because, without a certifying body to validate them, they will not have sufficient credibility and spendability in the real estate market.This causes, especially for the economic component of financing, a bottleneck that limits the expansion of this application to the advantage of other applications that do not represent the real needs and climate goals to be achieved.

In addition, this paper has brought out weaknesses but has also highlighted a possible way forward. First and foremost, having identified a methodology for identifying improvements to the certification protocols and the PED case studies concerning the starting characteristics of the PEDs, this study has made it possible to arrive at the validation of the current urban rating system as a starting point for the possible development of new set of PED criteria within the certification protocols, which could also become the basis for the development of parameters and reference values for identifying and evaluating a PED concerning an energy community, as opposed to a district that does not aim to become one. Indirectly, an avenue was opened on how to achieve this, as the comparison that was conducted in Tables 6–8 identified when the need for improvement concerned the urban rating system or the PEDs in the case studies, highlighting the weaknesses and strengths of one or the other.

Furthermore, this paper, being a pioneer in everything, could become a reference that will help the major patent-holding brands writing urban rating systems to update their current protocols concerning the evaluation and valorization of positive energy districts and, indirectly, of energy communities, or propose new urban protocols specifically designed to valorize PEDs.

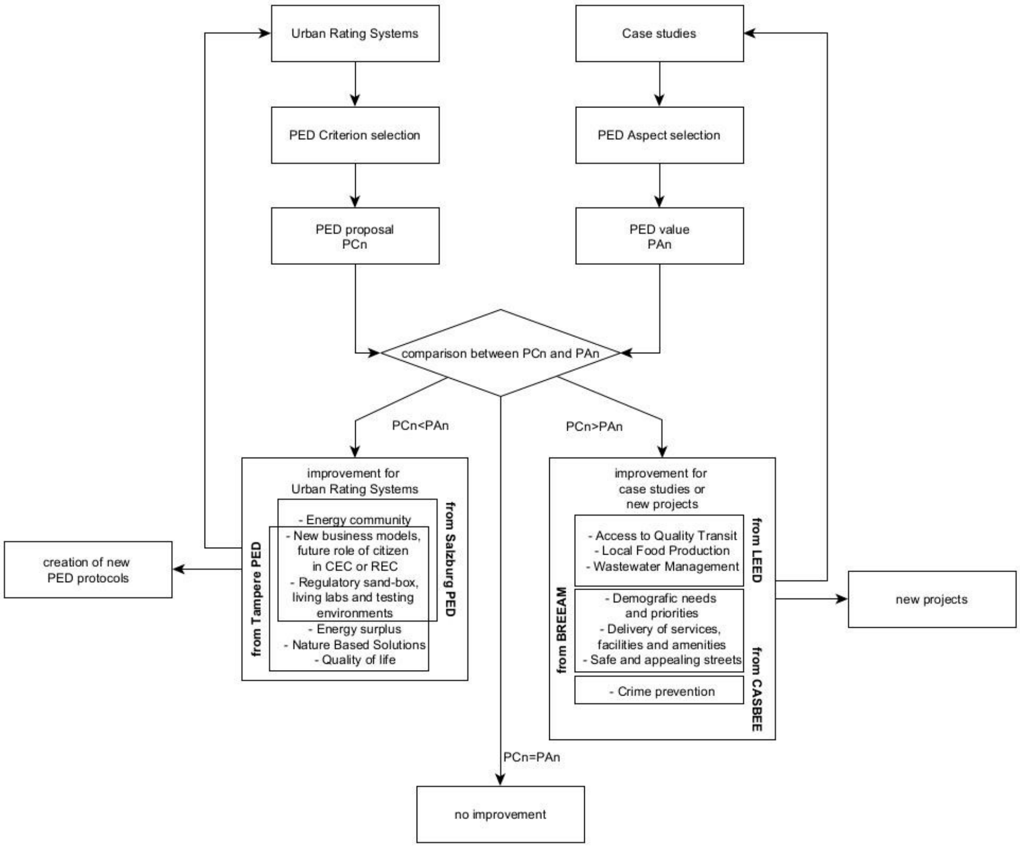

Figure 4. Flowchart of the methodology used. This graph shows the groupings of the different improvements for the case studies on the right and the certification protocols on the left. Produced by the authors.

Possible future developments, starting from the method outlined, could concern the following aspects:

- The use of the same methodology to assess and integrate further protocol systems, different from those currently used. ItIt is sufficient to analyze a rating system internally, identifying its PED characteristics and comparing these with the case studies examined. In this regard, these further analyses could feed into the possible improvements of the PED system by implementing the features absent in the protocols examined in this paper;
- The implementation of a new PED protocol, starting from the elements that define it and improved by the features highlighted in green in the previous tables and coming from the protocols;
- The improvement of the protocols taken into consideration with the addition of PED characteristics through the implementation of what is highlighted in green in the last tables concerning the case studies.

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Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs at this link: https://pedeu.net/.

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