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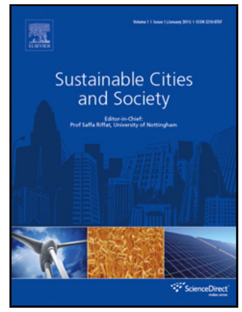

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Towards the Development of a Net-Zero Energy District Evaluation Approach

A Review of Sustainable Approaches and Assessment Tools

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HIGHLIGHTS

- The 'zero energy' objective has a rising interest in the literature and it is mostly considered on the individual building.
- Applying the 'zero energy objectives' in a district remains a challenging process for the U-ZED approach.
- The NZED or the 'smart ground' is defined as: *'The district, where the energy supply/on-site potential is equalised by the final energy demand of its users. The NZED is* ***'structured'*** *and* ***'located'*** *'smartly' to ensure its long-term concept'.*
- The paper is based on an academic overview by emphasising the multidisciplinary approaches and investigates the literature gap in the district level.

ABSTRACT: Districts have a significant role in achieving the principles of sustainability. Within the past decades, a great variety of assessment tools and methodologies has been developed in an effort to 'translate' the sustainability criteria into applied cases. There is an increasing interest in this contribution scaled up the assessment to larger territorial analysis and urban agglomerations. Notwithstanding, developing an assessment tool with sustainable standards requires strategic approaches to incorporate the theoretical framework to their implementation of city districts by measuring their performance in a consistent manner in respect of multiple criteria. Among these issues, energy efficiency and the zero energy objectives are significant for European policies. This study aims to provide an overview of the existing assessment tools and methods comparing their criteria and key parameters. As a second step, it introduces a simplified methodological assessment theoretical tool (U-ZED) by focusing on the commitment towards the zero energy targets in a future district. In a more general perspective, the study deals with the challenge of the development of a tool from building to district with the main concern to define the context of sustainable and long-term districts dealing with the challenges of 2050 horizon.

Keywords: assessment; district; energy; sustainability; tool

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NOMENCLATURE

GHG	Greenhouse Gas
EPBD	Energy Performance of Buildings Directive
BREEAM	Building Research Establishment's Environmental Assessment Method
U-ZED	Urban Zero Energy District (Tool)
NZED	Net Zero Energy District
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
LEED	Leadership in Energy and Environmental Design
HQE2R	Sustainable Renovation of Buildings for Sustainable Districts
NEST	Neighborhood Evaluation for Sustainable Territories
AEU	Environmental Approach to the Urban Planning
URGE	Development of Urban Green Spaces to improve the quality of life in cities and urban regions
INDI	Indicators Impacts
ENVI	Environmental Impacts
TRNSYS	Transient System Simulation Tool
SBToolPT	Sustainable Building Tool, Portugal
SUNtool	Sustainable Urban Neighborhood modelling Tool

BIM	Building Information Modelling
HEED	Home Energy and Efficient Design
BEE	Built Environment Efficiency
CAD	Computer Aided Design
GSBC	German Sustainable Building Council
iiSBE	international initiative for a Sustainable Built Environment
EPFL	École Politechnique Fédérale de Lausanne
PV	Photovoltaics
LCA	Life Cycle Assessment
RE-SIZED	Research Excellence for Solutions and Implementation of Net-Zero Energy City Districts project

1 INTRODUCTION

1.1 Context

In the aftermath of the first two energy crises in 1973 and 1978, Europe intensified the effort to become gradually independent of fossil fuels (Daniels, K., Hammann, R., 2008). The problem of future availability of fossil fuels is currently being overshadowed by the discussion of how their use contributes to the climate change. The rapidly growing world energy use has already raised concerns over supply difficulties; exhaustion of energy resources; heavy environmental impacts; climate change; etc. (Lomard-Pérez, L., Ortiz, J., Pout, C., 2008). On the other hand, buildings occupy a key role among the major contributors to energy consumption and GHG emissions. In 2016's report of the IEA (International Energy Agency (IEA), 2016) regarding the key indicators of the trends of energy consumption, during the last two decades (1984-2004), the primary energy has grown by 49%.

Studies argue that urban and built environment in contemporary cities contribute substantially to climate change - principally on the ecological footprint and the great reliance on natural resources (Aelenei et al., 2013). Existing literature review highlights the results of these policies applied in the EU States and investigate their role in the adaptation of innovative energy concepts, such as the 'net-zero energy' (Annunziata, Frey, & Rizzi, 2013). Indeed, there is a rising interest for assessment tools and (rating) methodologies to demonstrate the energy performance in buildings and urban agglomerations (Saunders, 2008). An increasing awareness of the climate change and its impacts are generating the demand for tools and systems towards the commitment in a more transparent and sustainable manner through more tangible means. The design and operation of urban systems and buildings require new generation evaluation tools, methods and approaches. Various countries have already introduced such tools in this direction (Reed, 2011). Notwithstanding, the process of conception, implementation, optimisation and monitoring of a sustainable urban project (i.e. eco-district, net-zero energy district, etc.) demands a well-structured approach. Finding the appropriate tool/or method is critical for remarkable outcomes in social, environmental, economic or spatial dimensions.

Already since 2000, the early tools have been developed around the world. BREEAM – one of the first approaches - was launched in the 90s to offer an environmental label and sustainable design patterns for ***buildings***. Diverse methods and tools have been based and adapted by their developers, urban planners, architects, engineers, city stakeholders, etc. to reflect the problematic of environmental impacts in cities (Saunders, 2008). New movements recognise the context of sustainable development and encourage the reinforcement of more liveable and healthy city districts with a high environmental and societal quality of life (Ayyoob, 2013).

1.2 Scope and limitations

The purpose of this review paper is to give an overview of existing models and modelling approaches for sustainable development in districts and introduce an approach for conceiving a district with zero energy attributes. At the same time, because of the focus of this works is on 'design patterns' towards the zero energy objectives, it makes sense for the authors to address the simulation, optimisation and modelling approaches that the sustainable planning is hold.

Given the challenges regarding the maximisation of the energy efficiency and the district evaluation with zero energy objectives, a critical view at the existing literature review indicates restrictions:

- Limited existence of tools and approaches in individual buildings with zero energy attributes and restricted literature in districts and urban agglomerations' experiences
- Limits on the existing reviews and lack of informative support for district evaluation
- Limitations of tools in individual buildings neglecting phenomena on urban agglomerations (i.e. mobility; etc.)

The scope does not include detailed building-level modelling and it is limited to the district level design problematic with the focus on the interaction between city districts and energy. The work is based on an academic overview by emphasising the multidisciplinary approaches and completes the previous studies on the assessment tools. In terms of types of tools; approaches; etc., the authors propose a classification by criterion that address the specific aspects. This covers from general tools to specific packages (i.e.'CitySim'; etc.) in diverse territorial levels. The extensive field of the 'optimisation' and related approaches is beyond the scope of the current research. Notwithstanding, a reference of the most interesting tools is presented accordingly.

1.3 Overview of the paper

The paper is structured accordingly. The first section introduces the problematic of the research study including the previous work and the main findings of the literature review. Section 2 overviews the methodological approach of the study and the criteria for the tools' selection to be analysed including the analytical description of the tools and modelling approaches. Section 3 describes in a summary the existing tools and approaches in buildings; districts and cities; the criteria and particular case studies. Section 4 discusses the concept of the proposed U-ZED approach and the preliminary findings, while Section 5 summarises the conclusions of the work by encompassing limitations, opportunities and future directions perspectives.

1.4 Previous Works

Managing the challenges of the climate change with its impacts in a district or a larger urban agglomeration is an evolving area. Up to now, the available tools, methodologies, etc. for this complex context are rather limited in the scientific literature. Generally speaking, these approaches focus on only one or two aspects of the urban energy flows and deal with difficulties of the lack of data regarding the energy consumption, etc. Notwithstanding, typical tools in the review (A2PBEER Consortium, 2013):

- Investigate only the external environment of the buildings attributes, etc. (i.e. ENVI-met, etc.)
- Simulations on individual buildings' energy consumption with the possibility to be extended in a district usually based on three-dimensional model (i.e.CitySim, etc.)
- Combined loads of buildings in regards to the climate impacts to analyse the energy supplies, etc. (i.e. SimStadt, etc.)

Robinson (Robinson, D., 2011) focuses on modelling and simulation approaches for the sustainable urban design emphasising the building energy modelling and related to it issues including the urban climate; temperature; etc. Pol and Robinson (Pol, O., Robinson, 2011) summarise the results of modelling work in regards to the impact of the urban morphology on building energy demand. Jebaraj and Inivan (Jebaraj, S., Iniyan, S., 2006) reviewed 252 works focusing on the conception phase and the use of integrated energy models. Other reviews covered particular issues relevant to the field of energy in a district level. Vreenegoor et al. (Vreenegoor, R., Hensen, J., De Vries, B., 2003) summarise the advantages and drawbacks of simulation tools (i.e. SUNTool, etc.) and certifications (i.e. LEED; CASBEE; etc.) in district level with a highlight on residential building stock in Germany.

1.5 From an eco-district to a zero energy district

As globalisation intensifies, cities are increasingly adopting endeavours towards the sustainable development. European Union releases already policies and recasts to strength the economic prosperity and attractiveness in contemporary cities; promote equality; social cohesion and regeneration in urban agglomerations; enhance the sustainability and increase the quality of life (Flurin, 2016). EU promotes the legislative framework and the disciplines through the establishment of the 'eco-districts' and the 'zero energy objectives' (EPBD; etc.).

Flurin (Flurin, 2016) defines the 'eco-district' as an 'urban experiment' aiming to assess the city's ability to develop districts within sustainability criteria and in line with the recommendations of the Brundtland Report (European Union, 1987) and the broadcast at the United Nations Rio Conference (United Nations, 1992). The 'eco-district' designates an 'urban environment aiming to integrate the objectives of the **sustainable development** and focusing on the energy; the environment and the quality of users' life. To understand well the eco-district concept, a more theoretical approach, its urban model and typology, its technical characteristics and elements are important for its environmental performance. In literature review: two main definitions correspond to this approach: a) general and b) administrative. At the first approach (general), the eco-districts are described as laboratories where the sustainable city is tested. In the case of the second approach, the definition is established by the national, regional and local administrations for the implementation and production of the eco-district, meaning that the concept of an eco-district is idealistic without the obligation of realizing it (Yepez-Salmon, 2011).

Indeed the 'eco' concept added an interesting value to districts and the springboard to the 'green' page to ensure their longevity. Notwithstanding, the challenges of the climate change reinforce the cities' efforts to deal with its disastrous environmental impacts (i.e. scarcity of energy resources; etc.) and a rising interest of the zero energy concept is introduced. However, studies and reports dealing with zero energy at the district/community scales are few in number and most scientific works investigating energy issues at district scale focus either on the impact of the urban form on energy consumption in buildings (Baker, N., Steemers, K., 2000) or the potential of solar energy utilisation (Marique, A.F., Reiter, S., 2014). Jalala (Jalala, S., 2016) states that zero energy projects are more worthwhile and efficient on a district scale to provide energy techniques for renewable systems that are not available in individual buildings.

Indeed, being restricted to the building level as an autonomous entity ignores the impacts of phenomena (i.e. mobility fluids; etc.) linked to larger territorial levels (Marique, A.F., Penders, M., Reiter, S., 2013). Districts are a subset of the city and one of its constructive elements with physical and administrative boundaries structured in accordance with historical, cultural, urban or other criteria usually surrounded by the infrastructure through its expansion. This territorial level appears interesting in operational and multi-thematic context as a 'city micrograph' to identify the patterns of the zero energy concept (Riera Pérez, G., Rey, E., 2013). The term 'Net-Zero Energy **District**' is an innovative concept still in progress growing prevalent during the last years and it is still restricted to the scientific literature review. Juusela et al. (Juusela, M., Crosbie, T., Hukkalainen, M., 2016) figure the role of the urban agglomerations as widely recognised as a key role in reducing emissions and energy consumption. In line with changes in energy systems, research into the energy performance of the built sector is broadening its objectives at the district level.

Cortese and Higgins (Cortese, A., Higgins, C., 2014) state a NZED as a group of buildings with a stated goal of achieving the zero energy objectives. Carlisle et al. (Carlisle, N., Geet, O., Pless, S., 2009) define the ZEC (Zero Energy Community) as *'the community with reduced energy requirements (covered by renewable resources) by increasing energy efficiency'*. Todorovic et al. (Polly, B., Kutscher, C., Macumber, D., Schott, M., Pless, S., Livingood, B., Geet, 2016) define the ZEC as the *'community with greatly reduced energy requirements'* and includes energy not only for residential buildings but also for other infrastructure (Todorovic, 2012). Todorovic (Todorovic, 2012) states also respectively the question of the 'zero carbon city' and the role of the simulation tools towards the 'zero energy city'. In terms of renewable energies at a district level, the studies tend to include more the *solar potential* of the existing urban zones from the point of view of solar panels without including the energetic consumption of buildings (Amado, M., Poggi, F., 2012).

1.5.1 Energy supply literature

Generally, the fact of 'energy supply' involves largely the simulation and optimisation of district heating and cooling systems' installation. Liu et al. (Liu M, Shi Y, Fang F., 2014) overview combined technologies and systems at a district and their optimisation, as well. Vasebi et al. (Vasebi A, Fesanghary M, Bathaee S., 2007) examine the dispatch of a district grid powered by combined heat power plants, while Casisi et al. (Casisi M, Pinamonti P, Reini M., 2009) extend the idea to include the optimisation of location of CHP microturbines and a central power plant (case study in Italy). Nuytten et al. (Nuytten T, Claessens B, Paredis K, Van Bael J, Six D., 2013) determine a method for the theoretical maximum of the flexibility in districts' systems and various storage concepts for particular case studies.

Other studies study the planning and economics of energy systems in districts. Gustafsson and Karlsson (Gustafsson S-I, Karlsson BG., 1991) simulated district heating systems in Sweden.

Courchesne (Courchesne-Tardif A., 2011) within the use of TRNSYS simulates the district heating and solar thermal systems under a scenario analysis. Connolly et al. (Connoly D, Lund H, Mathiesen BV, Leahy M., 2009) identify 37 software tools for planning strategically the distributed energy resources in a district; CHPs and other energy systems.

1.5.2 Energy demand literature

Modelling the energy demand requires predominantly its sources. In a district, the demand is related to its users; the buildings; the transport; etc. Describing the energy demand in a district or even predict it is essential for a study to zero energy objectives to evaluate the profile and reduce the requirements. Notwithstanding, the energy demand modelling has often been related to individual buildings within the use of software tools, i.e. EnergyPlus; eQuest; etc. (Crawley DB, Hand JW, Kummert M, Griffth, 2006). Some cases have been extended to evaluate the building performance within a parametric analysis or event to optimise the building typology to reduce its environmental impacts (Basbagill JP, Flager FL, Lepech MD., 2014). Nguyen et al. (Nguyen, A., Reiter, S., Rigo, 2014) provide a comprehensive review of simulation methods applied to optimise the energy efficiency in an individual building. Yao (Yao J., 2012) studied the optimisation of the building design for diverse building types to minimise its energy requirements, while Salat (Salat,S., 2009) used a building energy modelling to emphasise the role of the buildings' morphology in energy consumption of a district.

2 METHODOLOGICAL APPROACH

The aim of the research paper is to review the existing concepts and methodologies deal with the sustainability in districts. To this end, the study proposes an approach towards the challenge of the zero energy objectives and its application.

2.1 Organisation of criteria

2.1.1 Criterion of urban (territorial) scale

The first criterion of our research included the spatial dimension. Among the selection of the existing tools, approaches and methodologies for the 'spatial' evaluation, we defined the matrix below (Table 1).

Table 1 Matrix of tools, approaches and methods related to their urban scale

City	***District***	***Building***
CASBEE for Cities	BREEAM (Communities)	BREEAM
CitySim	LEED	LEED
SimStadt	HQE2R (Suden)	NEST
	EcoCity	TRNSYS
	NEST	ENVI-met
	Eco-maires	DGNB
	AEU	SBTool
	RSP02	SUNtool
	Meeddat	SHE
	ARPE	BIM
	URGE	PLEIADES+COMFIE
	Sustainable Development Charter	EQUER
	INDI	HEED
	ENVI	e-QUEST
		ENERGY
		Vasari
		ECOTECT
		Beopt
		Ascot
		Green Star

2.1.2 Criterion of tool type

The subsequent criterion is the type of the approach and in particular: (1) Software; (2) Methodologies; (3) Certifications; (4) Zero Energy Tools. It is interesting to notice that the majority of the approaches consider simulation and software modelling for **buildings**. Shady et al. (Attia & Herde, 2011) define a number of tools focus on the concept of zero energy objectives and are included in our research study (Table 2).

Table 2 Matrix of tools, approaches and methods related to their type

Software	*Methodology*	*Certification*	*Zero Energy Tools*
CitySim	CASBEE	BREEAM	HEED
SimStadt	HQE2R	LEED	e-QUEST
INDI	EcoCity	DGNB	ENERGY
ENVI	Eco-maires	SBToolPT	Vasari
Ascot	AEU	Green Star	ECOTECT
NEST	RSP02		Beopt
TRNSYS	Meeddat		
ENVI-met	ARPE		
SUNtool	URGE		
SHE	Sustainable Development Charter		
PLEIADES+COMFIE	BIM		
EQUER	E+C-		
EnergyPro			
EnergyPlan			
Homer			
Epic-hub			

Sameti and Haghighat (Sameti, M., Haghighat, F., 2017) propose tools to optimise the district level problems including the reduction of energy demand. Most tools used in district energy optimization consist of algebraic modelling language (AML). The district 'design' strategy has a pivotal role to maximise its energy efficiency, however, it remains challenging as (Sameti, M., Haghighat, F., 2017).

Table 3 Matrix of optimisation tools and approaches

Optimisation tool	**Description**
EnergyPRO	Techno-economic optimization of poly-generation energysystem in both thermal and electrical aspects
HOMER	Modelling, optimization and parametric sensitivity grid-connected and standalone renewable energy technologies focusing on electrical energy conversion.
GAMS	Optimisation of carbon emissions; required energy and total cost of a district (built-in models)
Epic-hub	Concept of 'energy hub' for design; operation and energy consumption optimisation at site and district level
Neplan	Analysis regarding energy flows and losses and interface for GIS

2.1.3 Other criteria

In this section, we highlight the rest of the criteria taken into account at the diverse approaches (Table 3). Overviewing the selected tools, approaches and methodologies included in our research, Table 3 reveals the significance of the environmental impacts and their focus on the context of 'sustainability'. Indeed, diverse approaches include more than one parameters (i.e. environment and energy, etc.) at their context. This research interests more on the energy and environment parameters to illustrate the zero energy objectives.

Table 4 Matrix of tools, approaches and methods related to other criteria

Environment	*Architecture*	*Transport*	*Society*	*Economy*	*Energy*	*Other*
CASBEE	BIM	BREEAM	BREEAM	BREEAM	CitySim	SUNtool

Environment	*Architecture*	*Transport*	*Society*	*Economy*	*Energy*	*Other*
BREEAM	Vasari	EcoCity	ENVI	Ascot	SimStadt	
LEED	HEED		EcoCity	NEST	LEED	
HQE2R	ENERGY		NEST	RSP02	Sustainable Development Charter	
INDI			RSP02	DGNB	TRNSYS	
ENVI			Meeddat		PLEIADES+COMFIE	
Ascot			ARPE		HEED	
EcoCity			DGNB		e-QUEST	
NEST					ENERGY	
Eco-maires					Vasari	
AEU					ECOTECT	
RSP02					Beopt	
Meeddat					E+C-	
ARPE						
URGE						
Sustainable Development Charter						
ENVI-met						
Green Star						
DGNB						
SHE						
EQUER						

Summarising the main conclusions of the analysis, the Figures 1 to 3 present the matrixes of the tools, approaches and methods related to their territorial scale, their type and other criteria as studied at the literature review. Among the 36 tools, the majority focus on individual buildings and are connected to software to mainly model the buildings with particular attributes. Regarding the other criteria, Figures highlight the focus on the environmental impacts and the energy as well. Indeed, diverse are the approaches to combine assessment factors to retrieve modern agglomerations by challenges of climate change, etc.

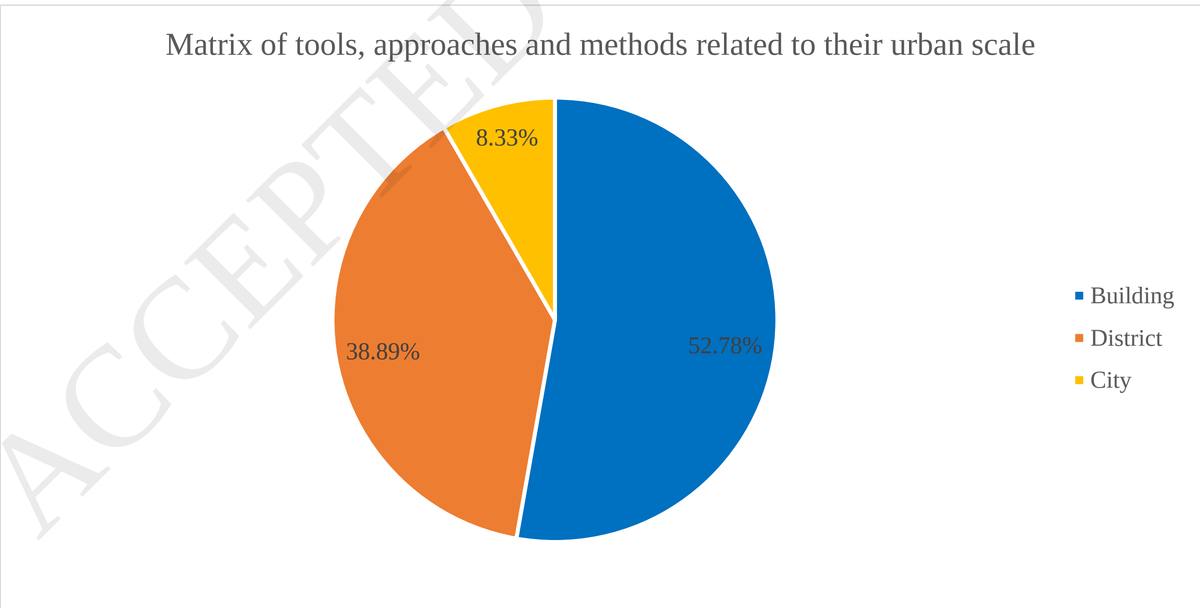

Figure 1 Matrix of tools, approaches and methods related to their urban scale

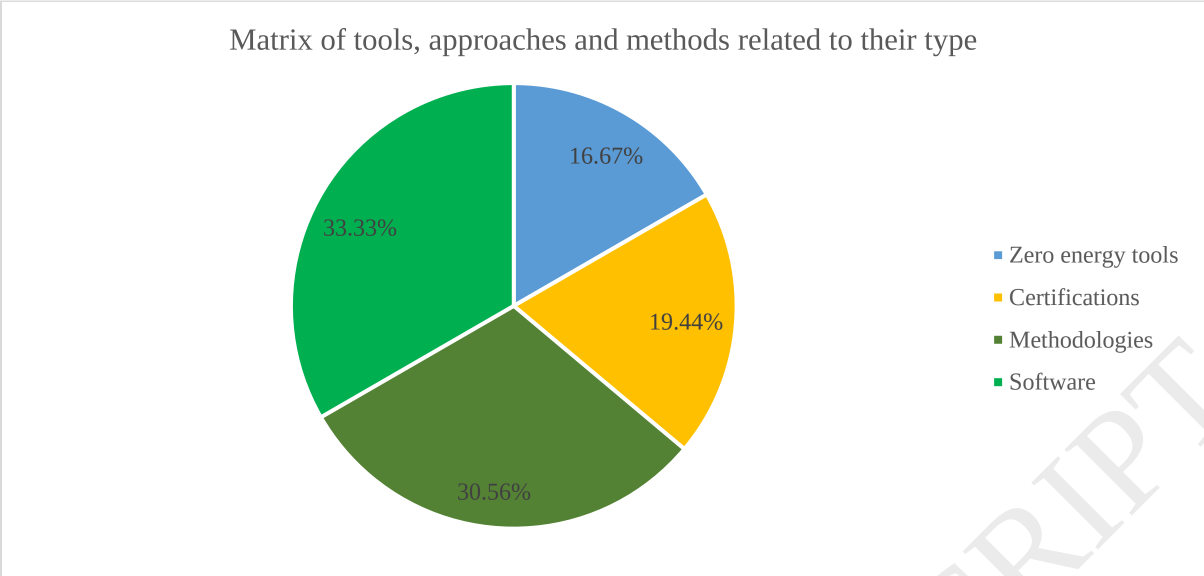

Figure 2 Matrix of tools, approaches and methods related to their type

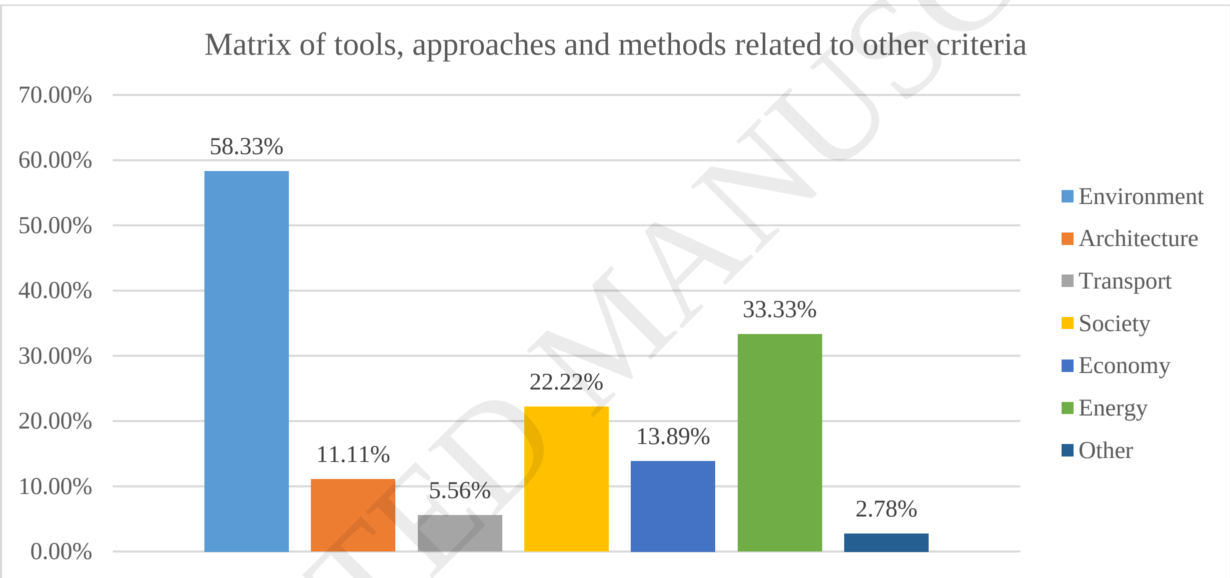

Figure 3 Matrix of tools, approaches and methods related to other criteria

3 DESCRIPTION OF THE TOOLS AND ASSESSMENT APPROACHES

3.1 Methodological approaches in cities, districts and buildings

Compared with the building and district levels, sustainability assessment approaches for the city level are underdeveloped. Notwithstanding, sustainability indicators are increasingly used for guiding development plans at the city level, but, unlike the building or the district level not particular interest is given to a comprehensive approach (Ayyoob, S., 2013). The performance assessment of buildings has a long history. Interesting findings in the literature review of the 'sustainable approaches' in cities; districts and buildings are presented below:

3.1.1 CASBEE for Cities

'CASBEE' for Cities is an assessment **approach** for the environmental effects on the **cities** through the triple approach of the sustainability (environment, society and economy). The tool includes a twofold aspect: (1) to improve the environmental quality, the activities and the quality of life ('Environmental Quality') of the city and (2) to decrease the negative environmental impacts ('Environmental Load') outside of the city. Evaluating a city with CASBEE approach initially is to set a hypothetical boundary to enclose the city by evaluating the BEE (Fig. 4) (Mukarami, et. al., 2011):

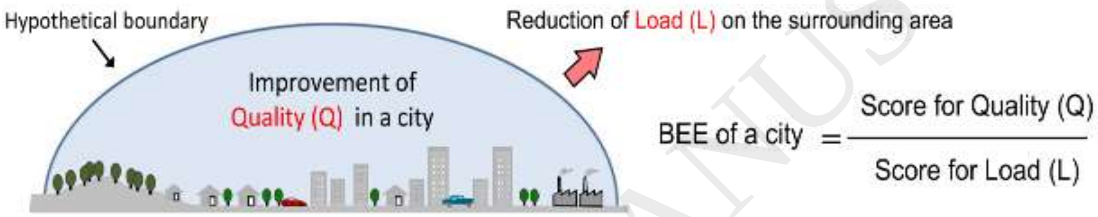

Figure 4 The hypothetical boundary implemented in CASBEE-City

CASBEE estimates the index (BEE) after the implementation of policies. By comparing the two values, CASBEE City quantitatively evaluates by estimation the effectiveness of the different policies in order to share a common understanding of the current state and cooperate together in setting goals and pursuing them in order to create futuristic cities in terms of environmental respect (Mukarami, et. al., 2011).

Masaki et al. (Masaki, T., Toshiharu, I., Shuzo, M., Shun, K., 2014) highlight the originality of the approach to be designed for assessing municipalities in Japan in terms of environmental; social and economic aspects. Typical case study of the CASBEE application presented at their works the region of Putrajaya city (located south of Kuala Lumpur), a rapidly developing municipality in Malaysia assessed to validate the tool's indexes (see Fig. 5&6):

Figure 5. Geographical location of Putrajaja city

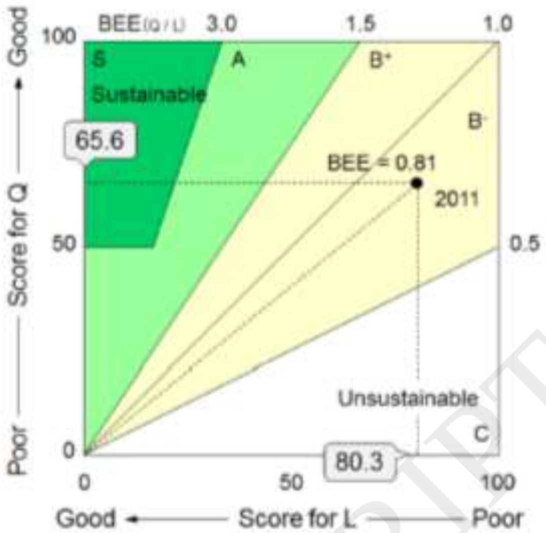

Figure 6. Assessment results of CASBEE Tool

3.1.2 'Sustainable Renovation of Buildings for Sustainable Districts' or HQE2R approach

'Sustainable Renovation of Buildings for Sustainable Districts' or HQE2R has as the objective of developing a **methodological approach** to promoting the sustainable development and the quality of life at the **district** scale and it focuses on the (Valdieu, & Outrequin, 2003):

- Quality of **buildings** and non-built components (i.e. energy performance, optimised use of construction materials, etc.)
- Quality of urban environment in respect of the urban sprawl, the public spaces, and the mobility

Generally speaking, the HQE2R approach is a decision aid tool for local communities. Thus, the method encompasses three phases: (a) inventory, (b) diagnosis and (c) evaluation (Fig. 7) (Valdieu, & Outrequin, 2003). However, the 'heart' of the HQE2R methodological framework is the role of ***'participation'***. The conduct of an urban planning or neighbourhood regeneration project consists of 4 phases. The HQE2R approach offers operational methods and tools for taking a coherent sustainable development approach in each phase (Suden.org, 2004).

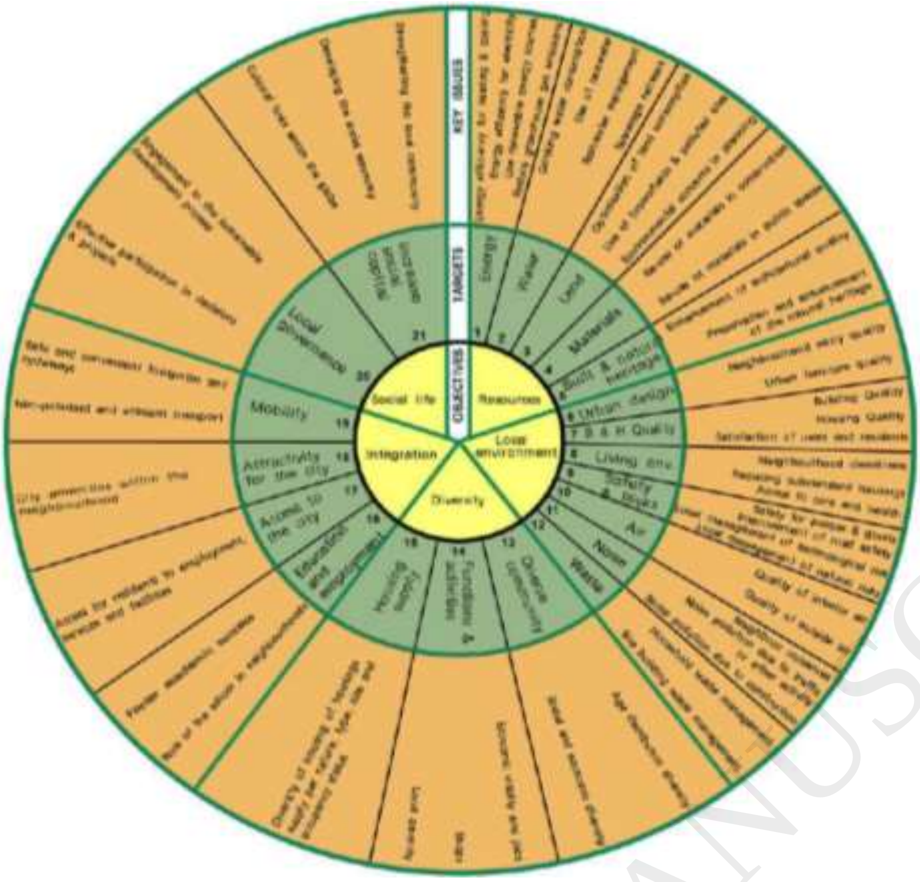

Figure 7 The HQE2R sustainability circles

3.1.3 EcoCity assessment tool

EcoCity tool promoted to highlight innovative concepts at **districts** (i.e. urban structure, transport, energy, etc.) with the goal to develop a common concept and design in various socio-cultural, economic and climatic conditions in participant countries. The approach was practice principally during 2002-2005 in European districts (Rakšányi & Coplak, 2003).

3.1.4 Eco-maires

Eco-maires approach for the encouragement of the ‘sustainable development’ in the scale of district presented in 4 phases: (1) project conception with environmental criteria, (2) social development with urban balance in favour of residents and users, (3) the creation of activities, (4) governance principles with emphasis on transparency, solidarity and participation.

3.1.5 AEU (Approche Environnementale de l’Urbanisme)

Method developed for the integration of the environmental aspects of urban projects including energetic issues, environmental, waste and water management, etc.

3.1.6 RSP02

Multi-criteria approach oriented on the objectives of sustainable development in a multi-thematic context: governance and participation, social, economic and environmental dimension, etc.

3.1.7 (Grid) Meeddat

Grid analysis by Ministry of Energy and Environment to frame the projects of eco-districts proposing 4 problematics: governance and pilot projects, economic development in combination with a social dimension, performance, and environment, urban and architectural quality.

3.1.8 ARPE

The approach aims to control the environmental impacts of the urban development to enhance their overall quality in the perspective of the sustainable development. The levers of its action are respected for the ecological balance, social development, economic development and governance.

3.1.9 URGE

The method scopes to improve the capacity of the green spaces in the city in qualitative and quantitative terms for the improvement of the quality of life. One of its principle objectives is the increase in knowledge of the interactions of systems: nature-economy-society in the urban environment. URGE consists of 4 thematic axes: use, development, planning and management of green spaces.

3.1.10 The Sustainable Development Charter (‘La Charte de développement durable)

The goal to define the options that render a **district** livable and sustainable. It is a reference throughout the realisation of the project (mainly on conception, realisation, and its exploitation). This approach includes all the essential issues of the sustainable development: energy, water, materials, nature, landscape, housing quality, hygiene, security, air quality, waste, diversity, accessibility, participation, solidarity.

3.1.11 BIM

BIM is a project management **methodology** that governs the materialisation of the information system through the use of particular software (Di Guida, Villa, & Piantanida, 2015). The existing model is based on decision-support methods to evaluate multiple metrics and visualise alternative plans prior to actual construction. It focused on building design and construction phase and it is limited in its ability to provide an appropriate methodology for large-scale development projects (Kim, Fischer, & Orr, 2015). Application of BIM for most aspects of building design has been explored for the data processing of a **building** description even in early stages. Its definition is described via a systemic process throughout the building development. BIM is translated as an exchange, interpretation and utilisation of ‘meta-data’ of a CAD model (Gerrish, Ruikar, Cook, Johson, Philip, & Lowry, 2017).

The mapping of residual performances provides the basis to proceed within the evaluations of the interventions to realign the building to current rules and the planning of its operations. In the building, the structural, architectural and system models allow for instance dynamic analysis, energy or noise analysis and encourage to design targeted interventions. The goal is to assess in advance the investment impact in terms of benefits, costs and implementation timing. The procedure of the implementation of BIM method includes (1) documentary survey and model structure, (2) architectural mapping, (3) 3D modelling (4) evaluation (Fig. 8) (Di Guida, Villa, & Piantanida, 2015):

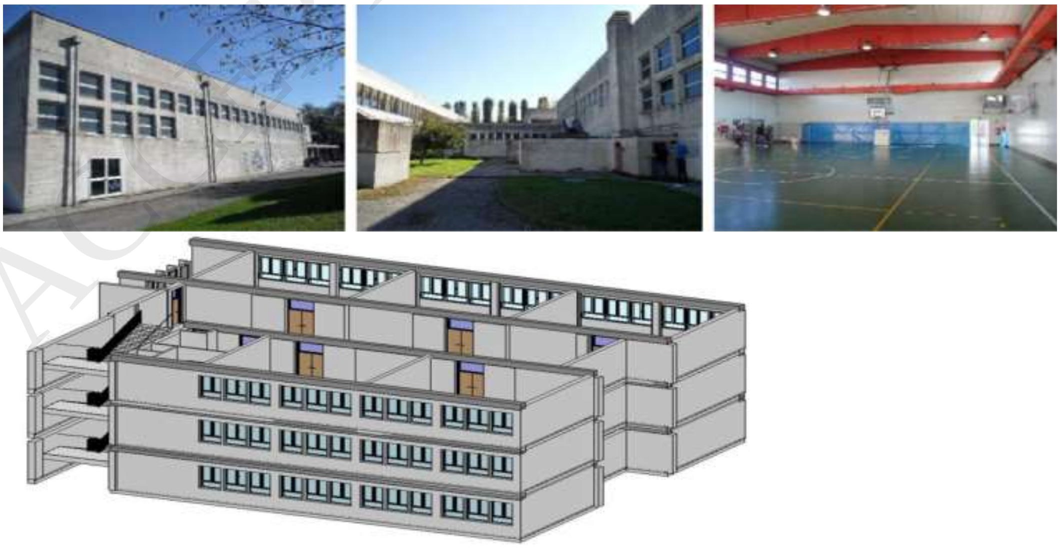

Figure 8 Typical example of BIM application. Mascagni' secondary school in Melzo (BIM)

3.2 Certifications

3.2.1 BREEAM

BREEAM is the world's first **method** and rating system to assess and measure the sustainability of the **built** environment and provides an environmental label (Khezri, 2011), while at the same time it improves, measures and certifies the social environmental and economic dimensions. BREEAM has a long track record in the United Kingdom and it is considered as the first assessment tool for **'green buildings'** and it was widely expanded in European countries and Brazil (Fig. 9) (BRE Global Limited, 2013).

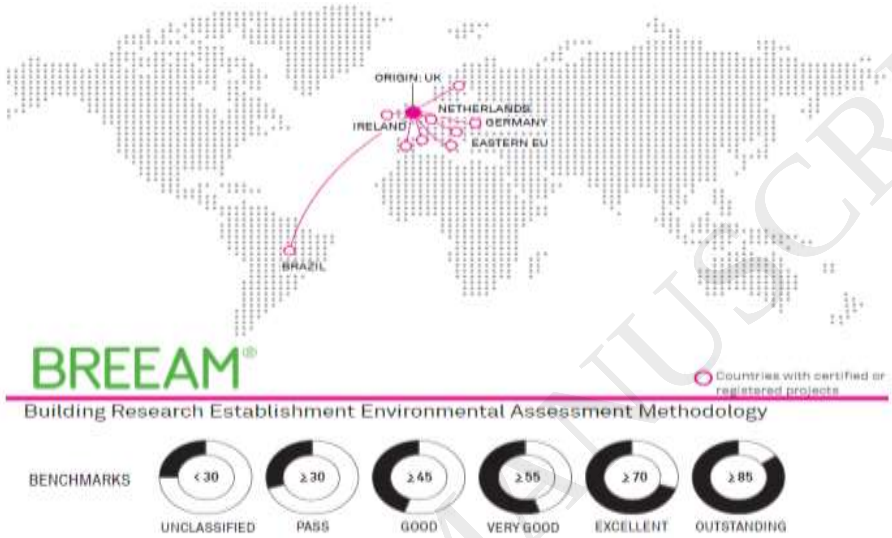

Figure 9 Expansion of BREEAM tool (Europe & Brazil)

The **method** integrates the sustainable building design and the construction techniques into the holistic urban strategic procedure (BRE Global Limited, 2013) aiming at mitigating the environmental impacts of the buildings, to stimulate the demand for sustainable buildings in districts (Miranda, 2013). The main objective of the method is to: *'Provide authoritative guidance on ways of minimising the adverse effects of buildings on the global and local environments while promoting a healthy and comfortable indoor environment'*. The main criteria of the BREEAM context are *energy, transport, water, waste, materials, innovation, etc.* (Banani, Vahdati, & Elmualim, 2013).

By analogy, the certification is expanded in larger territorial agglomerations and in particular to districts (BREEAM Communities) (BRE Global Limited, 2013). It was established in the UK in 1990 as a first environmental **certification for buildings** – initially for offices – and afterwards for a **district/community**. The certification divides its assessment **environmental** criteria into: *'climate and energy', 'resources', 'transport', 'ecology and biodiversity', 'buildings' and 'innovation'* (BRE, 2012);(Banani, Vahdati, & Elmualim, 2013);(Chakarova, 2011)) (Fig. 11). A typical paradigm of a case study application of BREEAM communities is the district of Masthusen, Malmö (Sweden). This mixed-use agglomeration (located in the Western Harbour of Malmo) has been certificated with the rating of 'Excellent' for its masterplan and it consists the **first certified project**) outside the UK (BRE Global Limited, 2013).

Figure 10 BREEAM assessment method categories

3.2.2 LEED

LEED was developed by the US Green Building Council. There are LEED rating systems that can be applied to commercial or residential situations, new or existing **buildings**, interior or exterior, and generic or specific programs (King, 2011). In the United States, the LEED system is currently the most widely utilised method for rating a building's **environmental performance**, divided into six categories: *sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, public transport and less car dependency and design innovation* (Azhar, 2011);(Caron, & Blais, 2009). Unlike other assessment district methods, LEED focuses on green building practices and construction and relates the district with its landscape as well as its local and regional context (Ayyoob, 2013). LEED commits for prosperous and sustainable districts within effectively 'green' buildings and it was expanded from the US around the whole world (Fig. 12) (Khezri, 2011).

Azhar (Azhar, 2011) proposes a two-step methodology for the application of LEED approach to the buildings:

- Development of a conceptual framework to establish the relationship between BIM and LEED rating processes.
- Validation of the developed framework via a case study.

LEED scopes of categorisation of the buildings' types are considered according to: (1) the construction of new buildings, (2) the existing buildings (Hamedani, 2014), while its main objectives are: the increase of the buildings' value, the waste, water and energy management, the reduction of greenhouse emissions, etc. (Chakarova, 2011).

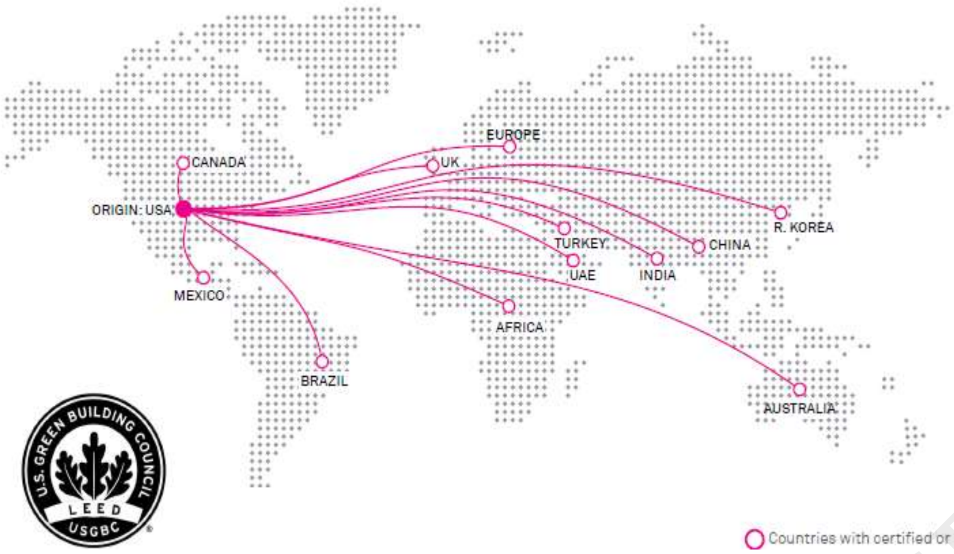

Figure 11 Expansion of LEED tool

3.2.3 Green Star

Green Star is a rating tool for the assessment of environmental parameters related to buildings' design and it was launched in 2003 to be expanded later in other neighbouring countries (Fig. 12) (Banani, Vahdati, & Elmualim, 2013). Green Star has similar attributes to BREEAM and LEED certifications and it assesses the environmental performance of newly constructed or renovated buildings focusing on the subsequent fields: *energy, transport, water, environmental quality, materials, innovation, etc.* (Mitchell, & McKenzie, 2009).

Figure 12 Expansion of Green Star tool

3.2.4 DGNB

The DGNB certification is developed by the GSBC based on 63 criteria distributed into six (6) categories weighted in an overall score of the **building** (Khezri, 2011). The tool provides a description and assessment of the buildings' sustainability with an outstanding fulfilment of up to 50 criteria from the environmental quality of ecology, economy, technology, socio-cultural aspects, etc. The sustainability concept of DGNB is broadly based on the three pillars of sustainability giving much importance to the economic aspect of the sustainable building during its entire life cycle (Fig. 13) (DGNB GmbH, 2016):

Figure 13 DGNB system

3.2.5 SBToolPT

The SBTool is a **building** certification promoted since 1996 by the iiSBE designed to reflect diverse priorities (i.e. environmental, socio-cultural, technological, etc.) within a totality of 9 sustainability categories and 25 indicators of the dimension of 'sustainability'. The approach includes the subsequent methodological path (Fig. 14) (Bragança, & Mateus, 2011):

- Quantification of the performance of the evaluated building for each indicator presented in an evaluation guide. The tool summarises the building performance on the criteria: energy efficiency, climate change, materials, waste management, health, etc. (Miranda, 2013)
- Normalisation and aggregation of diverse factors
- Calculation and global assessment

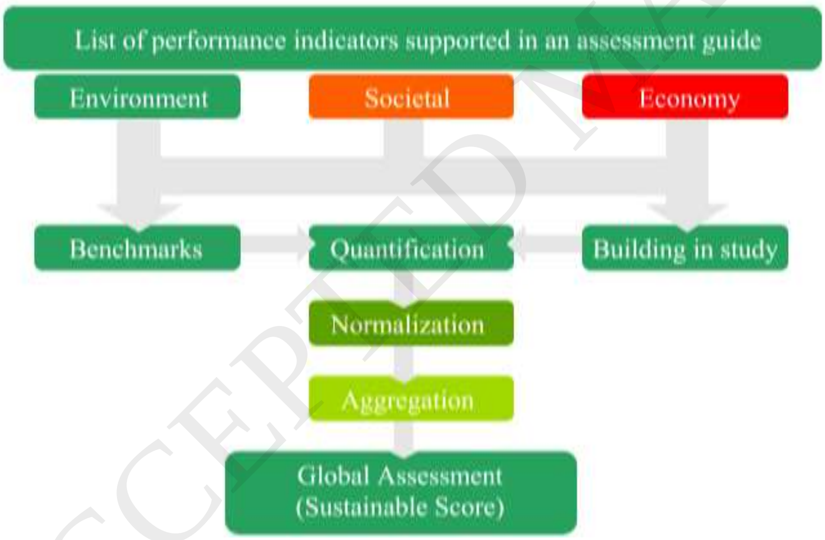

Figure 14 SBTool methodological approach

3.3 Simulation tools

3.3.1 CitySim

CitySim is a three-dimensional Java-based platform, developed at the EPFL for analysing the thermo-physical properties of **buildings** on an urban scale. The program simulates the **energy** demand of buildings regarding heating, cooling and ventilation with the consideration of climate conditions and the occupants' behaviour as well in a city level. The **tool** analyses the possibility of energy supply from renewable energy sources. The scope is to generate the additional data with special regard to water flows, waste and transport at a city level. It supports the decision-making process for sustainable urban planning by modelling the resource flows for urban configurations and simulates the energy performance of the building stock in a city and it integrates the energy system models, i.e. heat pump, cogeneration plant, PV systems, etc. An interesting point of the tool is the involvement of a stochastic occupant behaviour model to represent uncertainties of buildings' users (Valdieu, & Outrequin, 2005).

3.3.2 SimStadt

SimStadt is an urban simulation (modelling) platform photovoltaic potential to define low carbon energy strategies. The analysis examines the heating demands, the PV potential and models the renewable energy supply in 3D modelling within realistic data and inputs in a scenario analysis. The analysis is based on an enhanced 3D city modelling and contains geometric and graphical data (Valdieu,& Outrequin, 2005).

3.3.3 INDI model

Model to assess and integrate the long-term impacts of the **district**. The model expands critical questions about the district development setting its 'sustainable' profile during the diagnostic phase (Valdieu,& Outrequin, 2005).

3.3.4 ENVI model

Model to define the environmental impacts of the actions in a **district** in two parts: (a) environmental description and (b) analysis of environmental impacts. Some of its assessment criteria: energy, water and waste management, buildings, etc. (Outrequin, 2000).

3.3.5 Ascot model

Economic and environmental assessment model for renovation or **building** construction. Ascot evaluates and optimises the costs taking into consideration the cycle of life, the reduction of environmental impacts to energy reduction, etc. (Cherqui, 2005).

3.3.6 NEST assessment tool

NEST (Neighbourhood Evaluation for Sustainable Territories)1 is a LCA tool for the built environment on a district scale, developed by Salmon (Yepez-Salmon, 2011) performed directly a 3D district masterplan to assess indicators related to operational urban planning objectives. NEST assesses both environmental and socio-economic indicators. The tool relies on a database estimating the embodied energy of diverse building typology and assumes an average rate per m2 and calculates the indicators to provide a broad and qualitative assessment of the environmental performance of the neighbourhood (Lotteau, Yepez-Salmon, & Salmon, 2015). It considers the district within the systemic approach responsible related to its location; construction and operation. Thus, the tool accounts for buildings, spaces, daily mobility but also to other indicators related to energy, CO2, biodiversity, water, etc.

Case-study

NEST has already been applied on various applications and projects in France and proved its ability to enhance the design process with a life cycle perspective. Lotteau et al. (Lotteau et al., 2015) outline a case-study in the French peri-urban area of 'Pyrénées Atlantiques' (Fig. 15). The aim of the study is to investigate the degree of the environmental impacts of the newly installed project. In this case, NEST proposes a scenario analysis: sc. 0 (project environmental friendly) and sc. 1 (usual scenario of business installation) 2 and compares them to improve the proposal for the city stakeholders and the 'optimal' alternative of the strategic planning.

[1] http://www.nobatek-nest.com/en/
[2] From right to the left (Fig. 15)

Figure 15 Typical example of case-study of NEST methodological approach

3.3.7 TRNSYS

'TRNSYS' is designed for the simulation of solar water heating systems but it has become a standard choice for the simulation of thermal and electrical energy systems. Via its modular architecture, it implements components and mathematical models and it is used for thermal modelling approaches in a detailed view as well as electrical modelling (i.e. PVs, wind turbine, etc.). The software analyses in detail the energy system simulations. However, it is not available for further modelling in terms of energy flows in a district or a city level (Allegrini, Orehounig, Mavromatidis, Ruesch, Dorer, & Evins, 2015).

3.3.8 ENVI-met

ENVI-met is a three-dimensional, dynamic microclimate-analysing model developed to simulate the interactions between the built and the urban environment. The program supports the construction of a simplified 3D model of *smaller urban areas* (i.e. districts) with a simple user interface, where special data regarding surface materials and plant-types can be defined. Climate data is partially generated by the tool based on the given geographic location. The program lacks the examination of the buildings themselves and it only provides information on the outdoor surroundings (Allegrini, Orehounig, Mavromatidis, Ruesch, Dorer, & Evins, 2015).

3.3.9 SUNtool

The tool scopes to develop a software of modelling accompanying the user for the optimisation of the district planning. It calculates the energy flows, the water, and the waste consumption by concerning principally the following aspects: *irradiation, natural lighting, microclimate* and *human behaviour*. The tool assists users to obtain an assessment of the performance for diverse spatial levels and sets a parametric analysis to optimise the urban planning strategies (Cherqui, 2005). The purpose of the tool is to define various typologies and urban structures and forms in function with the perspectives of planning, microclimate, etc. with the objective of reducing the CO_2 emissions (Yepez-Salmon, 2011).

3.3.10 SHE

The project aims to (Cherqui, 2005):

- Evaluate the feasibility of the 'sustainable' dwelling through the construction of 600 houses in four European Member States (Denmark, France, Italy and Portugal)
- Integrate the sustainable development and the participation of the future inhabitants at all the phases of the process of decision for the construction
- Develop 'good practices' replicable in Europe and formulate new qualitative evaluation procedures
- Evaluate the satisfaction level of inhabitants and users

3.3.11 PLEIADES+COMFIE

PLEIADES & COMFIE is a simulation model imported to use building data and achieve a simulation analysis by using weather data (Yepez-Salmon, 2011). It is a platform oriented to the *energetic conception* procedure by calculating the energy requirements in heating, cooling and lighting and the hourly temperatures for the different thermal zones of the buildings (Weissenstein, 2012).

3.3.12 EQUER

It is a model imported by PLEIADES+COMFIE completed by data related to waste, water consumption, transport within the goal to identify the environmental profile of the buildings (Yepez-Salmon, 2011). EQUER considers twelve (12) environmental parameters in four phases of the buildings (i.e. CO_2 emissions, waste, etc.) and it is oriented to the measurement of the quantitative impacts of the architectural choices and techniques. The outputs of PLEIADES+COMFIE and the simulation results (quantity of materials, heating needs, etc.) are the basis for the EQUER model (Weissenstein, 2012).

3.4 Zero energy tools

3.4.1 HEED

HEED is a design (architectural) modelling tool for energy efficient residential buildings. It contains an application related to zero energy objectives that enable 'zero energy' balance metrics including the total energy consumption, the CO_2 emissions, the cost savings, etc. Its use requires minimal time to perform design evaluations, however, due to the nature of this data and the lack of it in terms of the building area. The tool is appropriate only for early design construction phases (Attia, 2011).

3.4.2 e-QUEST

e-QUEST is a simulation tool oriented to all design phases for buildings to evaluate the energy efficiency measures including a scenario analysis (Attia, 2011).

3.4.3 ENERGY

ENERGY (10) is a conceptual tool in the context of zero energy objectives incorporating features and design parameters towards the energy efficient strategies. The input of the tool is mainly numerical by allowing alternative comparisons for diverse measures (Attia, 2011). It evaluates the integration of daylight, passive solar design, low-energy cooling, high performance in buildings, etc. for the early stages of the design processes by simulating the energy performance for 8760 hours per year (SciTech Connect).

3.4.4 Vasari

Vasari is a conceptual design (architectural) tool to produce conceptual models using geometric and parametric modelling by considering the zero energy objectives, the requirements of passive and active systems in buildings by analysing at the same time the performance of photovoltaics (Attia, 2011). Vasari performs four important capabilities: (1) design exploration, (2) 3D modelling, (3) parametric design and (4) energy modelling at the early stages of the architectural design. At the same time, Vasari constitutes a parametric connection on 2D/3D modelling (Çavuşoğlu, 2015).

3.4.5 ECOTECT

ECOTECT is primarily intended as a conceptual design tool for zero energy approach (Attia, 2011) with a wide range of simulation and analysis functionality to improve the energy performance of existing building environment.

3.4.6 BEopt

BEopt is a design tool along with the zero energy objectives in buildings. Through an optimisation procedure, the tool is developed to be used in all design stages by using a parametric analysis towards zero energy requirements. The tool includes an interactive interface through a procedure of optimisation for the building design (Attia, 2011). BEopt includes (1) main inputs to allow to users to select from many pre-defined options for the optimised one, (2) the output screen for detailed results for optimal building design in accordance with zero energy objectives and (3) the options library spreadsheet for the modification of the available options. For each building design, the tool displays detailed results regarding the energy consumption, the costs, etc. (Christensen, Horowitz & Givler, Courtney, Barker, & Anderson, 2005).

4 DEVELOPMENT OF U-ZED APPROACH

4.1 The 'zero energy' problematic

The 'zero energy' objective has a rising interest in the literature and it is mostly considered on the individual building. Existing definitions are generally concentrated on the annual balance of the (nearly) (local) energy production and consumption (Voss, K, Musall, E., Lichtme, M., 2011). Nevertheless, differences exist and several definitions co-exist depending on the country and its political targets, the local conditions; etc. (Marszal, J., Heiselberg, P., Bourrelle, J., Musall, E., Voss, K., Sartori, I., Napolitano, A., 2011). Lam et al. (Li, D., Yang, L., Lam, J., 2013) highlight the reduction of the energy demand through efficient techniques with the simultaneous adoption of the local energy inventory (renewable resources, etc.) for its production. Other derived conceptual terms in the literature are based on balance metrics. For instance, Torcellini and Crawley (Torcellini, Crawley, Torcellini, & Ph, 2006) define four ZEB balances (primary; site energy; energy cost and zero emissions).

Sartori et al. (Sartori, Napolitano, & Voss, 2012) underline the balance between the energy demand and supply over a period of time and (Sartori, Napolitano, Marszal, Pless, & Torcellini, 2010) propose a balance between the delivered and produced energy with any form of interaction within the grid, as well. Hence, the (n)ZEB is expressed by the Eq. (1) to (3).

$$\text{Import(s)} = \Sigma_i \text{ delivered\_energy(i)} \times \text{credits(i) export} \quad (1)$$

$$\text{Export(s)} = \Sigma_i \text{ feed-in\_energy(i)} \times \text{credits(i)} \quad (2)$$

where i = energy carriers

$$\text{(n)ZEB} \quad |\text{ export }| - |\text{ import }| \geq 0 \quad (3)$$

Hence, the ZEB is dependent on its system boundary and a certain load, while a crediting system converts the physical units into other metrics including the natural resources and the energy distribution to the grids and/or the city.

4.2 Zero energy district

Studies and reports dealing with zero energy at the district/community scales are few in number and most scientific works investigating energy issues at district scale focus either on the impact of the urban form on energy consumption in buildings (Baker, N., Steemers, K., 2000). From the authors point of view, the NZED is defined in respect to the: (a) Energy Demand; (b) Energy Supply and (c) Energy Storage considering the emphasis on the 'intelligent' location (Eq. 4).

Thus, the NZED or the 'smart ground' is defined as:

*'The district, where the energy supply/on-site potential is equalised by the final energy demand of its users. The NZED is **'structured'** and **'located'** 'smartly' to ensure its long-term concept'.*

$$\text{Energy Demand} \leq \text{Energy Supply} \quad (4)$$

4.2.1 Energy Demand

The energy demand in a district regards the requirements (in kWh) of the energy of users, buildings, transport, etc. and it is a function of (Equipe Reforme, 2014):

- Population/Users (P): energy requirements related to the districts' users:
    - Users' metabolic functions

- Health and comfort conditions
- Activities

– Buildings (residential) (B): energy requirements for buildings' functions (construction; heating/cooling; ventilation; lighting; appliances; etc.). The methodology assesses the building energy consumption in regards to heating/cooling (EH)/(EC); appliances (EA) and Domestic Hot Water (EDHW); thus it is calculated (for the totality of its buildings) as (Eq. 5):

EB= EH+EC+EA+EDHW (5)

– Infrastructure and services (I): energy requirements for commercial and other services in a city district
– Industrial activities (In)
– Mobility (M): the annual energy consumption for daily mobility is expressed by kWh/travel/person and represents the *mean energy consumption* for travelling for one resident/user in and outside the district. The index (Eq. 6) proposed by Boussauw and Witlox (Boussauw & Witlox, 2009) expresses the distances (Di) (in km); fm the consumption attributed by the means of transport and Ti the particular territorial unit.

Index= Di*fm/Ti (6)

– Other (O): other requirements not included in the above categories

Thus, the energy demand in a district is a function of (Eq. 7):

D=f(P,B,I,In,A,M,O) (7)

4.2.2 Energy Supply

The energy supply concerns the potential of the site in natural renewable resources. In other words, it regards the energy inventory of the city district and it is a function of:

– Geographical location (L): the energy supply for a city district is inextricably connected to the 'intelligent' location, meaning the 'smart' site planning to accommodate the zero energy objectives. The 'smart location' of a district provides the potential for the zero energy application and it is associated with:
  - Renewable energy resources (R): solar; wind; hydroelectric; geothermal; etc.
  - Climate conditions (C): related to the energy inventory (wind; solar; etc.)

Thus, the energy demand in a district is a function of Eq. (8):

S=f(L,C) (8)

The problem of matching the energy demand (by users'; buildings; etc.) with supply requires storage solutions as well. Allegrini et al. (Allegrini, J., Orehounig, K., Mavromatidis, G., Ruesch, F., Dorer, V., Evins, 2015) outline the role of the 'mixed-use' agglomerations with interconnected buildings as a viable option not only in terms of the 'smart grid' design but also by thermal networks. Overall, it is clear that buildings must be assessed as elements in the strategic design of NZEDs.

4.2.3 Energy Storage

The storage will contain the rest amount of the energy Eq. (9):

Storage(Stor)=Supply(S)-Demand(D) (9)

Three different possibilities for energy storage in a district (Equipe Reforme, 2014):

- Long-term storage corresponding to diverse energy sources: oil; carbon; gas; hydro-carbon; nuclear; etc.
- Short-term storage: synchronisation of the offer and the demand for energy.

Generally, the terminology of 'energy storage' refers in an implicit manner to resources and stocks in a long-term context.

4.3 U-ZED approach

The problematic of the U-ZED approach is twofold: (1) the theoretical approach including the description and the diagnostic phase of the problem taking into account the existing concepts. For the U-ZED tool, the 'problem' describes the 'optimal typo-morphological definition of the district with the zero energy attributes'. Through the diagnostic analysis of an on-site analysis (existing concepts), U-ZED carries out its (2) experimental approach in real followed by the typo-morphological modelling and design (Fig. 16).

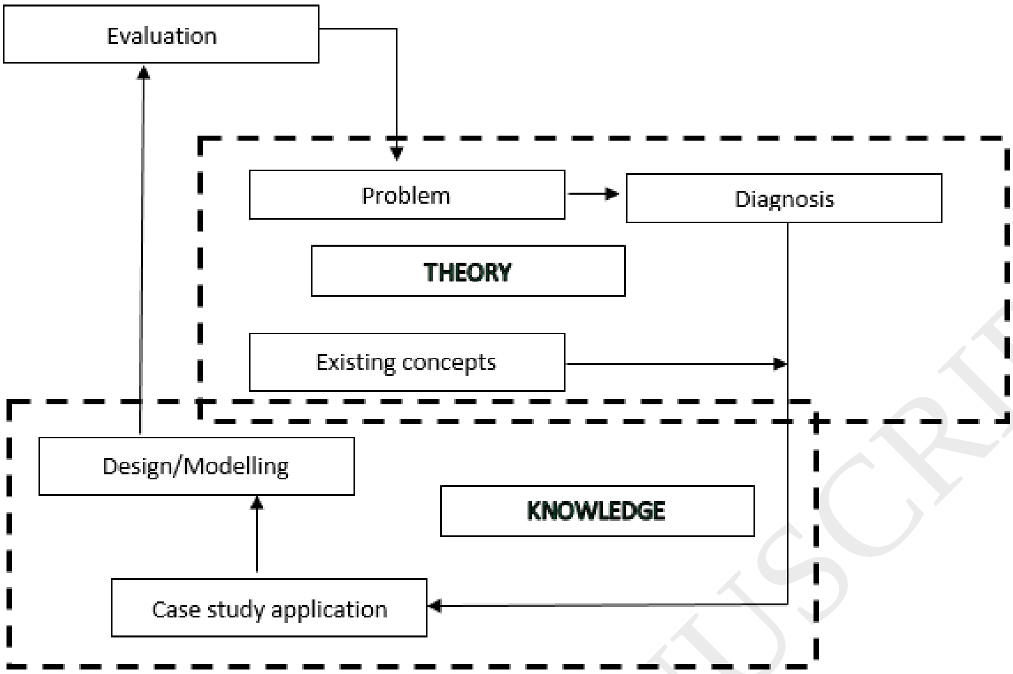

Figure 16 Steps of the U-ZED approach

Methodologically, U-ZED approach introduces three axes for NZED:

- ‘Where we are going to locate our district to ensure its zero energy context (‘smart location’)?’
- ‘What is the ‘optimal type’ of the district to ensure its zero energy context (‘smart typology’)?’
- ‘What is the ‘optimal urban structure/form’ of the district to ensure its zero energy context (‘smart morphology’)?’

4.4 Diagnosis/Case-studies

The U-ZED evaluation is considered with the achievement (or not) of the minimisation of the users’ energy requirements (in relation to the current inventory and the organisation of the storage) in the selected case studies[3] as:

- ❖ Positive (+): urban units/districts with potential to NZEDs
- ❖ Negative (-): urban units/districts with significant drawbacks or not achieved objectives that face difficulties for their transformation into NZEDs
- ❖ Neutral (0): urban units /districts that have the potential but their actions have not been efficient enough up to now towards the idea of zero energy.
- ❖ No data: conclusions difficult to be extrapolated for the characterisation of a district as NZED

Tables below present the most interesting findings and results of the U-ZED assessment. The problematic of the current research is twofold as reviewed previously: (1) to study the feasibility of the application of zero energy objectives to a district and therefore the prerequisite of ‘Energy

[3] Criteria for case-studies’ selection: (a) more than 50% of them have already been implemented (first experiences published); (b) representative in literature review; (c) geographical location in Europe

demand≤Energy supply' and (2) the dimension of the 'smart location' as a NZED mandatory. The lack of quantitative data regarding the energy supply at the analysed districts restricts the analysis on a theoretical approach. Nevertheless, interesting findings are presented in Tables 5 (energy demand in kWh/m^2/y) Table 6 (potential of RES) to 7 (systems of energy storage).

Table 5. Data for energy demand in ten European eco-districts

Energy demand	
District	**Total (kWh/m^2/y)**
Hammarby Sjostad	118
Bo01 Malmö	154
Eco-Viikki	78
BedZED	81
Solar Village	n/a
Vauban Freiburg	75
Kronsberg, Hannover	125
GWL Terrein	89
Eva-Lanxmeer	81
Pic Au Vent	n/a

Table 6. Data for energy supply in ten European eco-districts

District/ Type of RES	**Energy Supply**					
	Solar	**Wind**	**Hydropower**	**Bio energy**	**Geothermal**	**No resources**
Hammarby Sjostad	x	-	-	-	-	-
Bo01 Malmö	x	x	-	-	x	-
Eco-Viikki	x	-	-	-	-	-
BedZED	x	-	-	-	-	-
Solar Village	x	-	-	-	-	-
Vauban	x	-	-	-	-	-
Kronsberg	x	x	-	-	-	-
GWL Terrein	-	-	-	-	-	x
Eva-Lanxmeer	x	x	-	x	-	-
Pic Au Vent	x	-	-	-	x	-

Table 7. Data for energy storage in ten European eco-districts

Energy storage					
	Energy	**Water**	**Waste**	**Other**	
Hammarby Sjostad	x	x	x	x	-
Bo01 Malmö	x	x	x	-	-
Eco-Viikki	-	-	-	-	x
BedZED	-	x	x	-	-
Solar Village	-	-	-	-	x
Vauban Freiburg	-	x	x	-	-
Kronsberg, Hannover	x	x	-	-	-
GWL Terrein	-	x	x	-	-
Eva-Lanxmeer	x	x	x	-	-
Pic Au Vent	x	x	x	-	-

In Table 8 the initial objectives of the districts' selected towards sustainability, while in Table 9 the comparison with the achievements.

Table 8. Sustainable objectives in ten European eco-districts

Case study	**Energy**	**Water**	**Transport**	**Other**
Hammarby	- 80% re-use waste - Building consumption:	Reduced consumption	25% mobility by biogas	-

Case study	Energy	Water	Transport	Other
	60kWh/m^2 (20kWh/m^2 electricity)			
Bo01 Malmo	Based 100% on RES	-	25% of CO2 emissions	-
BedZED	- No fossil energy - 90% in heating requirements - RES	30% in water consumption Recycling	50% energy in transport	
Eco-Viikki	- 25% of heating and DHW be covered by solar - (105kWh/m2/y heating and 45kWh/m2/y electricity)	20% of waste production	20% of CO2 emissions	
Solar Village	- Improvement of heating comforts	n/a data	n/a data	n/a data
Vauban	- 65kWh/m2/y - Heating/Electricity by solar energy	-	-	-
Kronsberg	- <55kWh/m²/y (heating) - No electrical heating system	-	-	-
GWL-Terrein	-	-	Reduction on carbon footprint	
Eva-Lanxmeer	Less dependency on fossil fuel Energy production by waste	-	Reduction on car use	
Pic-Au-Vent	- Pilot application energetically autonomous - Use of RES	-	-	Eco-materials

Table 9. Achievements of sustainable objectives in ten European eco-districts

Case study	Energy	Water	Transport	Other
Hammarby	- 111 kWh/m²/y (electricity) - 46 kWh/m²/y (heating)	150lt/day/inh	- 438 kg/ household/ y - 402 kg C02 equivalent/resid ent/y	-
Bo01 Malmo	- 105 kWh/m²/y (electricity) - 47 kWh/m²/y (heating)	n/a data	0.7 parking space per household	
BedZED	- 39 kWh/m²/y (electricity) - 40 kWh/m²/y (heating)	96 lt/day/inh	n/a data /Isolated district	No fossil energy

Case study	Energy	Water	Transport	Other
Eco-Viikki	- 120kWh/m2/y (heating) - Electricity (varied)	-	Daily public transportation	
Solar Village	n/a data	n/a data	n/a data	
Vauban	n/a data	105 lt/day/inh	Adequate public transport	
Kronsberg	- 129 kWh/m²/y (electricity) - 56kWh/m2/y (heating)	n/a data	n/a data	
GWL-Terrein	n/a data	n/a data	n/a data	
Eva-Lanxmeer	n/a data	n/a data	n/a data	
Pic-Au-Vent	15kWh/m^2/y (heating per house) 42kWh/m^2/y (per household)	n/a data	n/a data	

Table 10. U-ZED (preliminary) assessment in ten European eco-districts

District	U-ZED assessment			
	Positive	***Negative***	***Neutral***	***No data***
Hammarby		√		
Bo01 Malmo	√			
BedZED		√		
Eco-Viikki		√		
Solar Village				√
Vauban	√			
Kronsberg	√			
GWL-Terrein		√		
Eva-Lanxmeer	√			
Pic-Au-Vent			√	

5 CONCLUSIONS

This study aims to demonstrate the importance of the assessment tools from buildings to districts and cities that influence the urban agglomerations and the energetic aspect in terms of sustainability. The scope of the paper is first to overview the existing approaches and as a second step to introduce the U-ZED district evaluation tool to complete this study. Notwithstanding, the scope does not include detailed building-level modelling. As a second step of the analysis, the paper introduced the U-ZED tool to identify the districts to reach a high level of energy autarky and to optimise the urban strategic planning in the future. Through an analytical scientific review of existing assessment tools and methods in the city, district and building level, the paper proposes an innovative holistic methodological approach for the district evaluation in terms of the zero energy concept in a multi-criterion base.

Thus, it is limited to district level design problematic and it focusses on the interaction between city districts and energy towards its autarky. There is not yet any single tool or method that provides the ‘optimal’ combination of the key factors expected. This work is based on an academic review by emphasising on the multidisciplinary approaches and completes the previous studies on the assessment tools at a district level. Overall, there have been great advances in recent years in the models available for district level analysis.

The paper introduces its principles and context in a multi-criterion and multi-thematic approach. A comparison among diverse assessment tools and methods in the district and building level is provided and the added value of the proposed simplified model of an assessment tool in zero energy concept is indicated. In this context, further research on the principles and criteria definition is necessary to assess the methodological approach and to integrate its holistic scheme for the city districts. Up to now, a research methodological study is developed to contribute to the establishment of a simplified, scripting and simulation and theoretical tool (U-ZED) tool for the definition of the urbanisation strategies and simplified urban models with zero energy attributes. A critical selection of key parameters that influence the structure of a district in response to the reduced energy consumption is defined as an initial step in accordance with the three prerequisites of the ‘smart ground’.

This work opens diverse perspectives to be investigated for the development of a district tool for zero energy districts to correspond to the guidelines and European directions. The tool is part of a general approach to meet the requirements for the future development of zero energy city districts. The study deals with the challenge of a tool development and an urbanisation strategy to complete the existing assessment methods and extends their boundaries from buildings to districts with the main concern to define the context of sustainable and long-term districts dealing with the challenges of the climate change in 2050 horizon.

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