Towards a Net-Zero Energy District Transformation in a Mono-criterion Scenario Analysis
The Case of Bo01, Malmö District

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Abstract: Transforming cities to deal with the resource scarcity and the threats of the climate change remain major challenges in the urban development. Hence, districts are already taking an active key role in European policies. Buildings are a key consumer of energy worldwide representing over than 40% of the overall energy consumption at European level. In this current context of arising interest, reducing energy consumption is an important target. During the last years, the 'zero energy idea' has been introduced in international scientific literature review aiming at a more sustainable urban and built environment focusing on individual buildings by articulating the requirements for an annual basis of an energy balance equal to zero. 'U-ZED' (Urban-Zero Energy Districts) methodological assessment tool focuses on the challenge of zero energy objective on a district scale. In this paper, the analysis emphasises the 'transformation' of Bo01 Malmö area in a mixed-use zero energy district.

1 INTRODUCTION

Modern cities deal with many challenges in regards to phenomena of climate change, greenhouse gas emissions, pollution, scarcity of renewable resources, increase in urbanisation growth forecasted to over than 75% by 2030, lead to an increased demand for infrastructure, energy consumption, etc. In this current context of the arising interest in environmental impacts, European Union proposes initiatives, directives and policy targets (i.e. EPBD recast, etc.) for reaching energy efficiency and a high level of its autarky in its Member States. Thus, there is a need to rethink the urban development strategies in holistic visions and approaches, where energy and effective building retrofitting have a key role (Becchio et al., 2016).

Already in 2008, the European Union published its 2020 climate and energy objectives, including: 20% reduction in greenhouse gas emissions, compared to '90s levels, increase in share of energy consumption from natural resources to 20% and 20% of the improvement of the European energy efficiency (Große et al., 2016). Along with this track, the concept of 'zero energy' is gaining international interest in the scientific literature review focusing more on individual autonomous buildings and aiming at long-term and concrete applications in larger territorial scales (i.e. district) (Marique and Reiter, 2014).

Notwithstanding, due to the complexity of the context, the challenge of its application in a cohesive whole is the *'district'* as a subset and micrograph of the city able to evaluate the energy patterns and identify solutions towards the sustainable strategic urban planning. 'U-ZED' (Urban-Zero Energy Districts) assessment tool deals with the challenge of the 'zero energy' objective by translating the district into a systemic approach to establishing a simplified (and simulation) methodology for the conceptualisation of the zero energy standards in a multi-criterion and parametrical context in the district scale.

In this paper, the 'zero energy' objective is fostered in a mono-criterion level (social and functional mixing) within the case-study of Bo01, Malmö district (Sweden) (as evaluated by the U-ZED tool as potential for zero-energy applications). The purpose of the paper is, therefore, to identify the principal drivers towards the 'district retrofitting'

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with zero energy targets via the formalisation of a scenario analysis and a modelling procedure according to them within the analysis in the particular case-study of Bo01, Malmö district and its conversion towards the direction of ‘zero energy standards’.

The paper is structured accordingly: Section 2 develops the principle methodological holistic approach of the U-ZED tool, Section 3 describes further the context of a ‘mixed-use’ district and its importance for its labelisation as ‘zero energy’, Section 4 outlines the three scenarios developed towards the zero energy standards and the modelling procedure in the Bo01, Malmö district, while Section 5 concludes with the main critical discussion and the further analysis towards the future conceptualisation of the net-zero energy idea in a district level.

2 ‘U-ZED’ METHODOLOGICAL ASSESSMENT TOOL

‘U-ZED’ (Urban-Zero Energy Districts) as a methodological assessment district approach contributes to the establishment of a simplified simulation tool on the basis of contextualisation of a district’s urban structure (typology and morphology) with zero energy attributes and completes the existing approaches by developing a methodological tool in diverse steps and a multi-criterion and parametrical context. The tool explores the linkage of the beneficial influence of the urban structure and the patterns of the achievement of the increase in energy efficiency and the zero energy standards in five (5) steps (Figure 1).

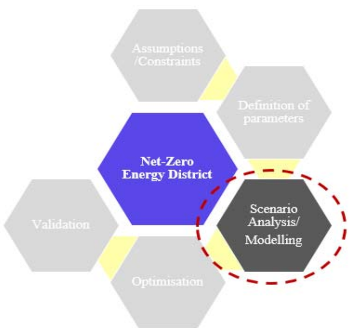

Figure 1: U-ZED methodological approach.

In this paper, the analysis is restricted to the step of ‘Scenario Analysis/Modelling’ (Figure 1) in a mono-criterion context at the simplified exemplar case of Bo01, Malmö district in three interesting conceptual terms proposed by the authors: the *‘smart location’*, the *‘smart typology’* and the *‘smart morphology’* corresponding to three of our research questions:

- ‘Where are we going to *‘locate’* our district (‘smart location’)?’
- ‘What is the the *‘optimal type’* of the district (‘smart typology’)?’
- ‘What is the *‘optimal urban structure’* of the district (‘smart morphology’)?’

2.1 The Role of the ‘District’

A comprehensive problematic and challenge that the study had to deal with, has been the ‘territorial scale’ to apply zero energy solutions. The strategy of the identification of the territorial scale for an effective energy planning takes into account the strategic decisions in a ‘city level’ to ensure a more integral diagnosis (Barbano and Egusquiza, 2015).

For this study, the district is understood as an ‘urban block’ and a complicated system with diverse key parameters of its ‘internal’ and ‘external’ environment as presented below (Figure 2).

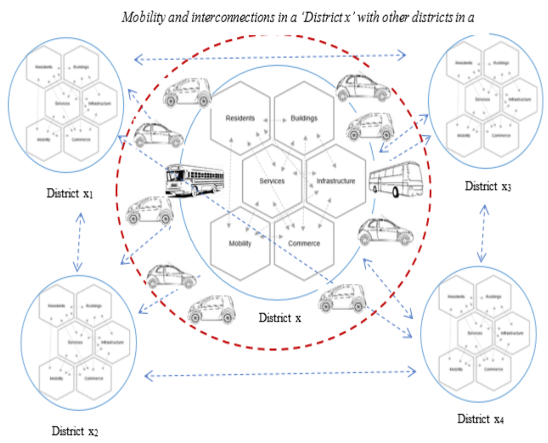

Figure 2: District approach, interconnections with ‘internal’ and ‘external’ environment.

2.2 Diagnosis of Ten European Cases

The analysis focuses on representative European case studies (Figure 3) selected with an ‘eco’ character for the following reasons:

- More than 50% of the cases are implemented.
- The availability of the information.
- The geographical criterion of their localisation in Europe.

Figure 3: State-of-the-art-analysis. diagnosis & review of ten European case studies.

2.3 Definition of Key Parameters

A compilation of criteria and key parameters strategically significant for the urban structure of the NZED (Net Zero Energy Districts) synthesis is the subsequent step divided into two groups (qualitative and quantitative) described and analysed in three axes: *(1) the 'smart' location, (2) the 'smart' typology* and *(3) the 'smart' morphology*.

2.3.1 'Smart Location'

Key parameters in regards to the 'smart location':

- Geographical site/Topography: proximity to the city centre and neighbouring districts.
- Connectivity/Accessibility: emphasis on the physical connectivity (boundaries).

2.3.2 'Smart Typology'

Key parameters in regards with the 'smart typology':

- Buildings: physical composition and attributes (i.e. geometrical dimensions, etc.)
- Mixed-use land uses 'optimal' combination of residential and non-residential land-uses by promoting a variety of dwelling typology and resulting in more efficient urban environments.
- Density: highly-dense districts are effective tools related to mobility and transport issues.
- Household synthesis: a typology of household (number of persons per household).

2.3.3 'Smart Morphology'

Key parameters in regards with the 'smart morphology':

- Compactness: dense structures for lower energy use and carbon emissions per capita, less air, water and lower resource (Fertner and Große, 2016).
- Geometry: geometry of the building (i.e. dimensions, etc.) to determine the building's energy use (Masmoudi, 2004)
- Orientation: spatial parameter to analyse the accessibility of (Dujardin, Marique and Teller 2014).

2.3.4 Introduction of 'Smart Ground'

Along with the axes analysed previously, the study carries out the introduction of the 'smart ground' implying that the development of a NZED demands the analysis of the 'optimal' and 'intelligent' location, typology and morphology before the application and/or installation of any technological realisation. To the above principles and prerequisites of significance importance is the role of residents' *participation* to maintain a fully engaged sustainability, collaborative and strategic planning from the conception till the implementation of the urban project (Figure 4):

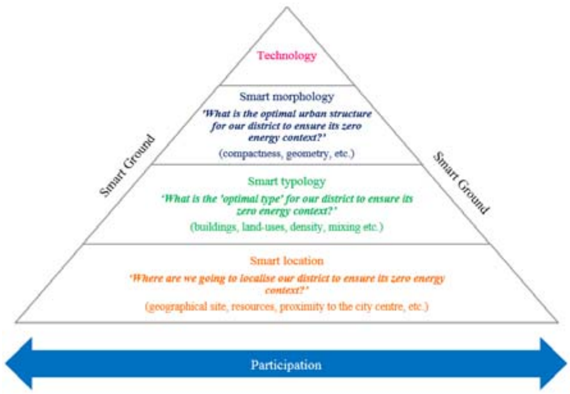

Figure 4: Introduction of the notion of 'smart ground' for the description of a NZED.

2.4 District Evaluation

Within the past decades, an arising interest in diverse assessment tools around the world has been developed to evaluate the energy performance and efficiency of the built and urban environment in a district (Ayyoob, 2013). Already since 2000, the development of the early approaches has been launched with the certification and labelisation tools (Yepez-Salmon, 2011).

In this context of district evaluation, U-ZED tool assesses the potential of zero energy retrofitting via three pillars to reach a high level of energy autarky by introducing (Figure 5):

- Pillar 1. Optimisation of residents' energy requirements
- Pillar 2. Energetic hybridisation: Combination of the capacity of the renewable resources and the energy systems installed at the district.
- Pillar 3. Organisation of energy storage: Demand for energetically efficient systems in function with the peak periods of consumption to achieve an optimal balance.

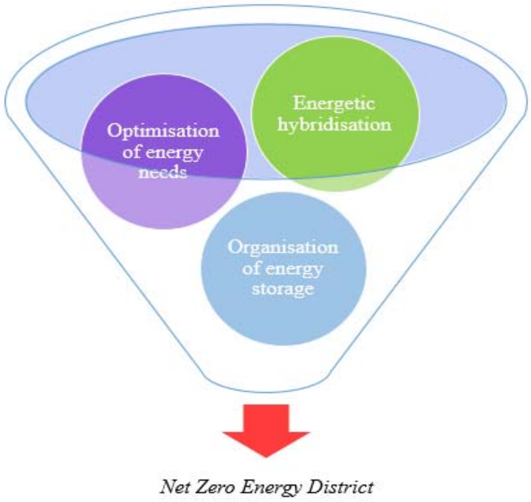

Figure 5: Pillars of NZED Evaluation (U-ZED tool).

3 THE CRITERION OF 'MIXED-USE' DISTRICT

In a broad sense, the 'mixed-use' context in a district is the combination of residential and non-residential activities and functions on the basis of a multi-functional and efficient territory. As a goal, the 'mixed-use' district aims at promoting the economic growth in relation to the sustainable development to achieve uniform distribution of the population and the residential development in spatial conditions (Vorontsovab and Salimgareevc, 2016). 'Mixed-use' (or heterogeneous) areas enhance the compatible land-uses to be located in proximity and decrease the car dependency (Arroyo Group, 2009)

4 CASE OF BO01, MALMO

Malmö is the third largest city in Sweden by population after Stockholm and Gothenburg divided into ten (10) districts (Anderson, 2014). Western Harbour is located in the northwest of the city center of Malmö (318,000 inhabitants in 2014 and center of a metropolitan area with approximately 700,000 inhabitants). The 175ha area consists of a peninsula stretching out into the Öresund Straight and Universitet Sholmen located between the peninsula and the old city center of Malmö (Figure 6) (Anderberg and Foletta, 2015):

Figure 6: Geographical site of Bo01, Malmö district.

For the last 15 years, Western Harbour has been the major flagship of the Swedish international eco-city ambitions. These city projects are presented both as leading examples of the conversion of former industrial harbor areas and of environmental adaptation of densely built urban environments. Western Harbour is a centrally-located former shipyard area developed into a mixed area for housing, schools, offices, shops and other workplaces as well as for recreational areas with public spaces, etc. By 2031, when the area has been completed, it is expected to accommodate more than 25,000 residents (Anderberg, 2015).

4.1 Scenario Analysis

The paper analyses the criterion of functional and social mixing in the Bo01, Malmö district in regards with three scenarios: motivations and reasons for its realisation (scenario 0), current situation and achievements (scenario 1) and potential to a NZED transformation (scenario 2):

4.1.1 Scenario 0. First Phase: Bo01 Malmö District Housing Exposition

Scenario 0 includes the early first approach of the urban initiative of the Bo01, Malmö district realised as a redevelopment of the post-industrial Western Harbour area of Malmö (Figure 7) for the international housing exhibition (Bo01) and the subject of the ‘City of Tomorrow’ (Austin, 2009) as a result of public and private entities (Klas, 2004).

Figure 7: Western Harbour area before 1998.

The vision for Bo01 was to create a modern mixed-use district committed to sustainable principles. The 350 residential dwellings exposed at the Housing Expo (2001) comprised a mixing of tenures with particular architectural design, patterns and construction materials to minimise the energy consumption and promote the sustainable mobility. Bo01 Housing Expo served as a model for the successive urban development of the Västra Hamnen area (Anderson, 2014).

Designed by Klas Tham, the ambition for the Bo01 district has been to create a compact, mixed-use and lively district with reduced mobility requirements by favoring environmentally friendly transport and a self-energy (autonomous) community based on 100% local renewable resources.

4.1.2 Scenario 1. Second Phase: Completion of the Bo01, Malmö District, and Current Approach

After Bo01 housing exposition, the area was completed and expanded as a second phase with the goal to create an attractive district in terms of (Anderberg, 2015):

Energy

An important part of the energy concept of the district is the low energy use in buildings. Each unit is only allowed to use 105kWh/m^2/year including electricity. A system for a district energetically autonomous is installed for Bo01 (Sydkraft) (Figure 8) powered by the wind, solar, biogas and heat pumps (production of 6,200MWh of heating, 3,000MWh of cooling and 6,300MWh of electricity) including heat recovery from ventilation systems, triple-glazed windows and energy-efficient appliances and equipment.

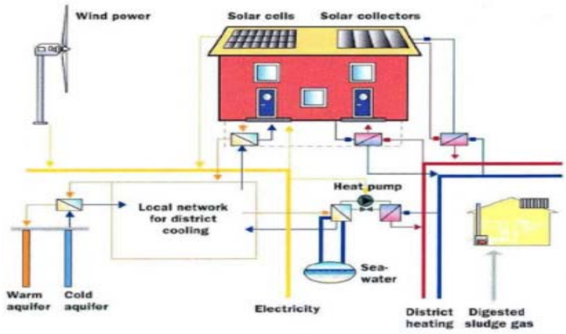

Figure 8: Description of the energy system in Bo01, Malmö district.

Transport

Stakeholders in Bo01 Malmö planned to minimise the future mobility requirements by emphasising the cycle paths (8,185m). The district is well-served by mild public transport and by interesting mobility concepts, i.e. car sharing supported and introduced by the CIVITAS Initiative (Figure 9), etc. At least one bus stop is located within 300m of every dwelling and buses pass at seven-minute intervals throughout the day. Additionally, from the southern border of the district, the Malmö Central Station abstains 1km (Foletta, 2015). The study analyses in detail the transportation system in the Bo01 district (almost 50% of the road network, more than 20% of cycle paths and 20% of pedestrian routes).

Building Housing

The city focuses on the demonstration of innovative green solutions with interesting building typology including almost 60 different housing patterns (CMHC, 2005) and more than 1,000 dwellings covering an area of 30ha. Most of the buildings cover residential requirements (3-4 storeys) combined with several commercial and community amenities (Fais, 2009; NK Architects Sustainability Archives, 2015). Among the existing buildings, the remarkable case remains the ‘Turning Torso’ tower (2005) of 190m (the tallest residential building in Scandinavia) and 54 storey designed by S. Calatrava consisted of 147 apartments and conference facilities (Figure 10). However, the high construction costs and the weak interest about condominiums lead the tower to an economic failure (Anderberg, 2015).

Figure 9: Diverse Building Typology in Bo01, Malmö district.

Figure 10: Building Typology and 'Turning Torso' Tower in Bo01, Malmö district.

The study analysed further the criterion of 'functional mixing' with regards to the land-uses and the building typology with the aid of 'Google Earth' application. Figure 11 includes the attributes of the 'functional mixing':

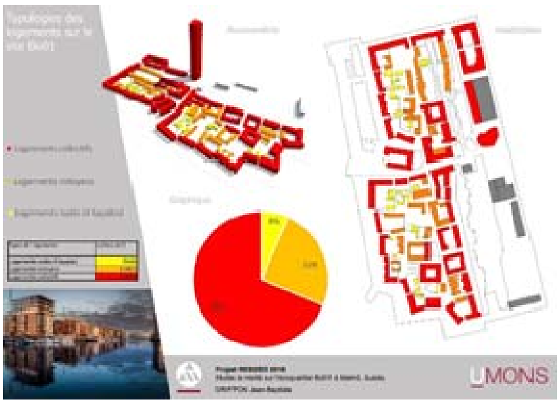

Figure 11: Functional mixing in Bo01, Malmö district.

Figure 12 illustrates the building typology with the emphasis on the residential dwellings: almost 20% of row houses, 70% of collective houses (apartments) and the rest for detached houses.

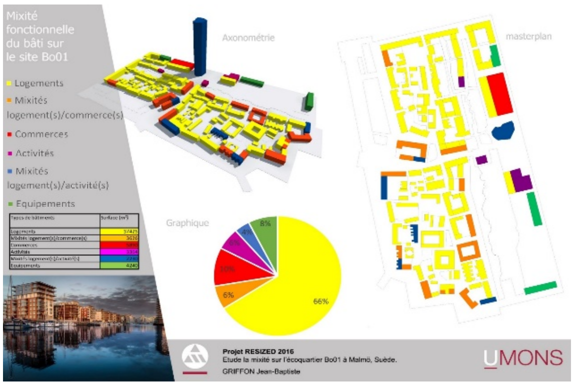

Figure 12: Building typology in Bo01, Malmö district.

Figure 13 highlights the parameter of 'number of floors' in the district: the majority of the residential dwellings include R+3 or R+4 (21% and 26% respectively).

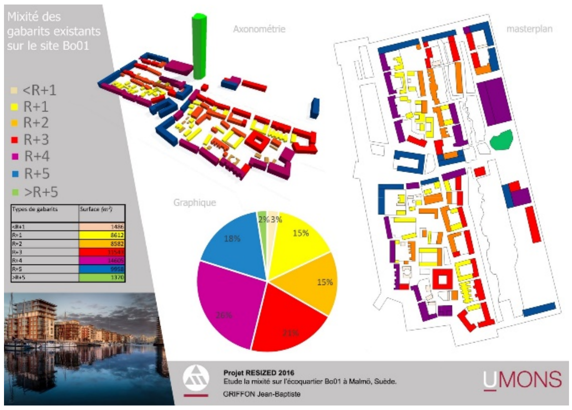

Figure 13: Number of floors in residential dwellings of Bo01, Malmö district.

4.1.3 Scenario 2. towards a NZED Bo01, Malmö District

Scenario 1 proposed an approach of the Bo01, Malmö district in terms of the 'functional' and 'social' mixing criterion. Scenario 2 completes the idea of the Bo01 Malmö district transformation via Roger's theory as a basis for the definition of the location of the new equipment and land-uses in the district in a multi-functional and mixed-use concept and the re-arrangement of the existing (Figure 14)

5 CONCLUSIONS

Bo01 district in Malmö began as an international exhibition housing in 2001 and was transformed into a viable and sustainable area. The district is the

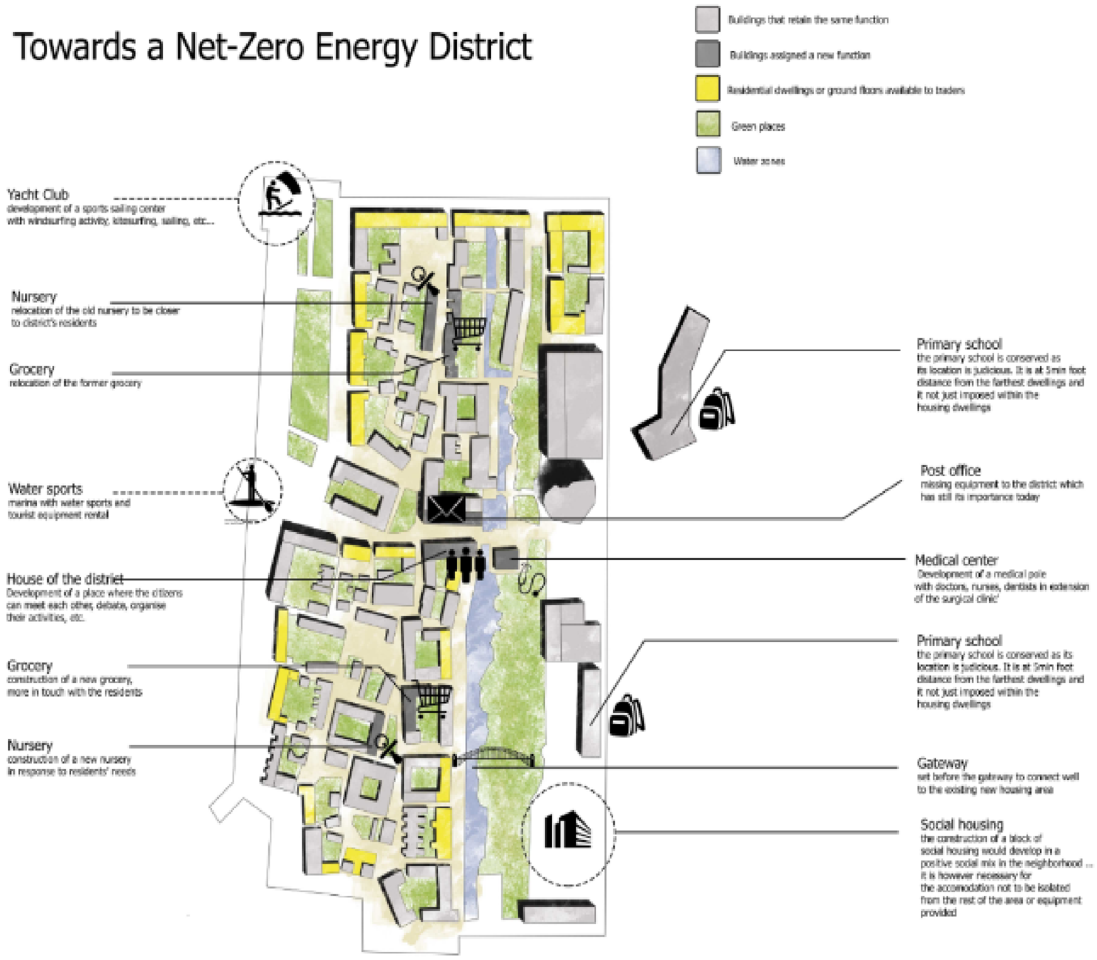

Figure 14: Proposal for Bo01 Malmö 'transformation' towards the net zero energy concept.

result of cooperation among several public and private entities in a mixed-use urban development. Much of the experience gained in the Bo01 project, both positive and negative, is being directly applied to further development in the Western Harbour area of Malmö city.

Up to now, a research methodological study has been developed to contribute to the establishment of a simplified, scripting and simulation tool (U-ZED) for the definition of the urbanisation strategies and simplified urban models with zero energy attributes. Five preliminary steps develop the constraints and the opportunities towards the feasibility of the application of zero energy idea at a district level by completing the existing approaches limited on individual autonomous buildings. An analytical literature review diagnoses ten representatives, in the scientific literature, case-studies with sustainable and ecological context and interesting accomplishments and evaluates them in regards to three pillars (optimisation of energy requirements, energetic hybridisation and organisation of energy storage).

A critical selection of key parameters and criteria (and sub-criteria) that influence the structure (typology and morphology) of a district in response to the reduced energy consumption is defined as an initial step in accordance with the prerequisites of the 'smart ground' ('smart location', 'smart typology' and 'smart morphology').

The paper contributes to the existing literature on the 'zero energy' objective via the U-ZED methodological approach towards the 'transformation' of the Bo01 Malmö district in zero energy attributes. A scenario analysis of three cases investigates the feasibility of this objective at a district scale in a mono-criterion frame ('functional and 'social' mixing). This work highlighted the opportunities to extend the boundaries of a sustainable 'eco-district' to a zero energy concept in the general perspective of the principle of 'mixing'. The methodological framework will be extended and completed, namely to take into account other parameters in a multi-criterion analysis.

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