From the ‘Smart Ground’ to the ‘Smart City’
An Analysis of Ten European Case-studies

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Abstract: During the last two centuries, the urban percentage of the world's population, combined with the overall growth phenomenon, has deeply increased and it is projected to reach 60% by 2030. In this current context linked to environmental issues managing to plan sustainable cities appears a main policy target. The implementation of Zero Energy Buildings as a European target becomes a challenge for the energy savings with the significant commitment for larger urban scales. The aim of this paper is the development of a methodological systemic approach about energy management in a ‘district scale’ with zero energy context within the analysis of ten European case-studies to the potential of a ‘smart ground’ towards the development of a ‘smart city’. This work opens and addresses numerous future research perspectives that should be investigated widely to develop districts with an operational, sustainable and long-term context.

1 INTRODUCTION

The future of the majority of citizens’ is undeniable urban. Fascinating the urban development is already taken place in the notion of ‘smart city’ (Angelidou, 2015). Metropolitan areas around the world aimed at upgrading urban infrastructure and services with a view of better environmental, social and economic conditions and enhancing cities’ attractiveness. Reflecting these developments, many new ‘categories’ of the contemporary city have been entered: ‘sustainable’, ‘green’, ‘intelligent’, ‘smart’, etc. (De Jong et al., 2015). Despite the various debates about what is ‘smart’ in literature (Angelidou, 2015; Hollands, 2008; Komninos, 2011), there is no agreed definition of a ‘smart city’ and its strategic planning is still largely unexplored (Angelidou, 2015).

Calvillo et al., (2016) propose a ‘smart city’ as a sustainable and efficient urban centre with high quality of life through the optimal management of its natural resources, while Angelidou highlights the complexity of the system by diverging interests: the use of ‘smart energy’ towards ‘intelligent’ ways for the energy reduction (i.e. ‘smart buildings’, ‘smart transportation’, ‘Intelligent Transport Systems’, etc.) using innovative technologies (Angelidou, 2015). In ‘smart cities’, governments invest in Information Communication Technologies (ICT) to improve sustainable development by providing ‘smart urban infrastructures’ that inform end-users about the desired environmental agenda. In fact, a ‘smart city’ provides the required infrastructure for citizens for more ‘intelligent’ decisions (Khansari et al., 2014), while its concept operates in a complex urban and built environment incorporating several systems of technology, social and political structures, economy and human behaviour as well.

Energy management is one of the most demanding issues within this complexity. Therefore, significant attention is dedicated to assess the impacts of the ‘smart solutions’ towards the planning from ‘conventional’ to the ‘smart’ city (Calvillo et al., 2016). Cities are the core of economic activities, development and research and the key for 'smart growth’ (Vollaro et al., 2014). In this framework, the European ‘Smart Cities and Communities Initiative’ encourages cities to ambitious measures to progress by 2020 towards a 40% reduction of greenhouse gas emissions. ‘Energy 2020’ European strategy affirms that *‘the well-being of people, industry and economy depends on safe, secure, sustainable and affordable energy’* and confirms the targets ’20-20-20’ defined in 2007 aimed at reducing greenhouse gases by 20%, increasing renewable energy to 20% and achieving a 20% improvement in energy efficiency (Eurostat, 2014). In this effort, the concept of 'zero' is expected to have a crucial role and anticipated to contribute significantly at the achievement of 'smart cities' envisioned by the European Union (European Directives, etc.) (Kylili and Fokaides, 2015).

The major challenge, therefore, is the adaptation and retrofitting of the existing building stock in order to reach the annual zero-energy balance. The problematic of 'Zero Energy Buildings (ZEBs)' has aroused increasing interest in international level towards solutions focusing on the individual building (Marique and Reiter, 2014). District level appears to be particularly interesting in operational terms for modelling and exemplifying as a first step towards the realisation of the 'smart city'. It consists the city's micrograph and a constructive element. By addressing targeted issues, this approach results in innovative solutions (Pérez and Rey, 2013) with the introduction of modern technologies and multi-energy applications.

The paper focuses on the solutions for districts' transformation into more sustainable with the introduction of the 'smart ground'. The hybridization of the 'smart' location and morphology with the alternative use of multi-energy systems is the key factor. Two additional levers complete this approach: (1) optimization of occupants' actual needs and (2) organization of storage (energy, water, etc.). The paper is structured accordingly. Section 2 includes the methodological approach and proceeds to explore the evaluation tool developed and the description of the 'smart ground', Section 3 illustrates ten European exemplar case-studies highlighting their principles and the main findings of their comparative analysis, while Section 4 summarizes and discusses the most interesting points that emerged from the previous review.

2 METHODOLOGY

2.1 The Systemic Approach

The goal of this study is the development of an initial scripting tool on the basis of urban contextualisation of the 'smart ground' adapted to the systemic approach. For this study, the district is understood as an 'urban block' and a complicated system with various parameters, while the Net-Zero Energy District (NZED) aims at articulating the primary energy uses: building energy consumption, production of on-site renewable energy and transportation energy consumption (Marique and Reiter, 2014) (Figure 1).

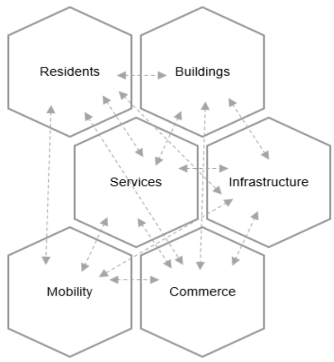

Figure 1: District components and interconnections.

Teller and Marique underline that the 'Net-Zero Energy District' concept is described, by analogy with the Net-Zero Energy Building, as a *'district in which annual energy consumption for buildings and transportation of inhabitants are balanced by the local production of renewable energy'* (Teller and Marique, 2014) (Figure 2):

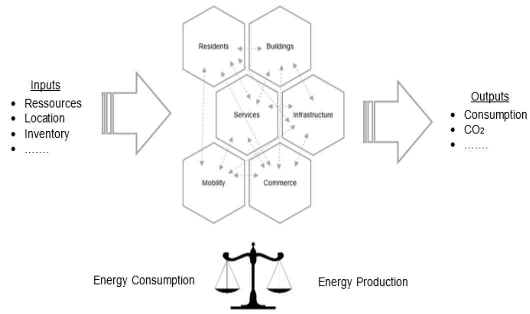

Figure 2: Systemic approach of NZED.

However, moving from buildings to districts with a net zero energy concept requires holistic integrated approaches, in which all the aspects of 'green' are considered (i.e. mobility, 'smart technologies', etc.) (Kolokotsa, 2015). 'Smart ground' could be the basis of a 'smart grid' and 'smart city' as part of an efficient energy management system in a district in conjunction with power generation and energy demand. However, the achievement of NZED demands significant effort at operational characteristics (Kolokotsa, 2015).

2.2 The Notion of 'Smart Ground'

The innovative notion of 'smart ground' is defined in accordance with the development of effectively performed districts towards the 'smart city' and symbolizes the hybridization of technologies, multi-energy systems and renewable energy produced on-site introducing the urban reflection and importance at its planning and design. A compilation of qualitative and quantitative criteria (and sub-criteria) is acquainted by the authors in accordance with two strategic axes:

2.2.1 The Smart 'Location'

Four (4) essential criteria synthesize this axis (in a non-exhaustive way):

a) *Climate (and Micro-climate)*: the weather conditions (temperature, daylight, wind, etc.) influence the occupants' actual requirements in energy and policies pursued (i.e. impediments for mild modes of transport- in cold climates, etc.).
b) *Potential of Natural Resources*: constitutive key factor for the 'smart location'.
c) *Proximity*: proximity of services and facilities for the site (i.e. the presence of an existing transportation network enables savings and ensures the connections to the city and encouragement of 'green' mobility, less dependency on car use, etc.).
d) *Functional Mixing*: 'functional autonomy' of the district within its economic centre and diversified services.

The 'smart location 'emphasises the geographical site of a NZED. However, the goal of the study remains the urban analysis and the identification of the 'ground' (needs, potential, etc.) as a preliminary step of any technological installation or achievement to enhance its character as NZED in maximum.

2.2.2 The Smart 'Morphology'

The 'smart morphology' is associated with the reflection of the district's urban structure:

a) *Density (Residential and Population)*: central to the urban planning of a district: a) limit displacements and car dependency, b) economise land use.
b) *Orientation:* spatial district's urban pattern that reflects the integration of benefits of solar gain and natural lighting in NZED within its architectural and planning composition. Marique and Teller (Teller, Marique, 2014) consider an angle of 25° measured horizontally at a central point of each façade of the NZED to maximise the solar gain.
c) Compactness: crucial to reduce energy consumption. Maignant (Maignant, 2005) underlines the optimum compactness with spherical geometrical shape, while simultaneously public transport are more cost-effective, accessible and effective in a more dense urban tissue.

Figure 3 highlights the components that synthesize the notion of 'smart ground'.

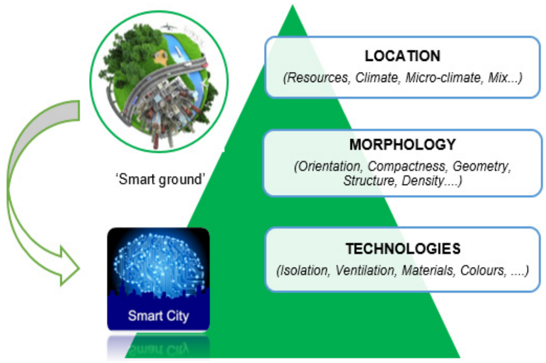

Figure 3: From the 'smart ground' to the 'smart grid'.

2.3 NZED' Evaluation Tool

The processes of optimization, evaluation and monitoring of urban projects requires a defined framework and methodology. Four main categories: (i) certifications, (ii) modelling: (quantitative basis); (iii) assessment tools, (iv) decision-making tools: (Martínez-Pérez et al., 2013). A compilation of qualitative and quantitative criteria on Figure 4:

1. *Optimization of Actual Occupants' Needs:* key indicators that frame the district's 'anatomy'
2. *Use of Energetic Hybridization*: reflects the successful incorporation of energetic systems' and technologies' variety combining with local production of renewable energy sources
3. *Organization of Storage*: energy performance of technologies, systems and techniques installed to reduce energy consumption.

3 CASE-STUDIES

A number of districts with an 'ecological' character has been developed since '90s in the North Europe supporting the idea of the urban metabolism into more 'sustainable' towards the sensitivity for the environment and the quality of life. Despite the general context of the sustainable development in urban projects, innovative realisations of the 'eco-districts' adopt an approach more sectorial and less global with specific and particular objectives. A brief review of ten (10) representative case-studies in a

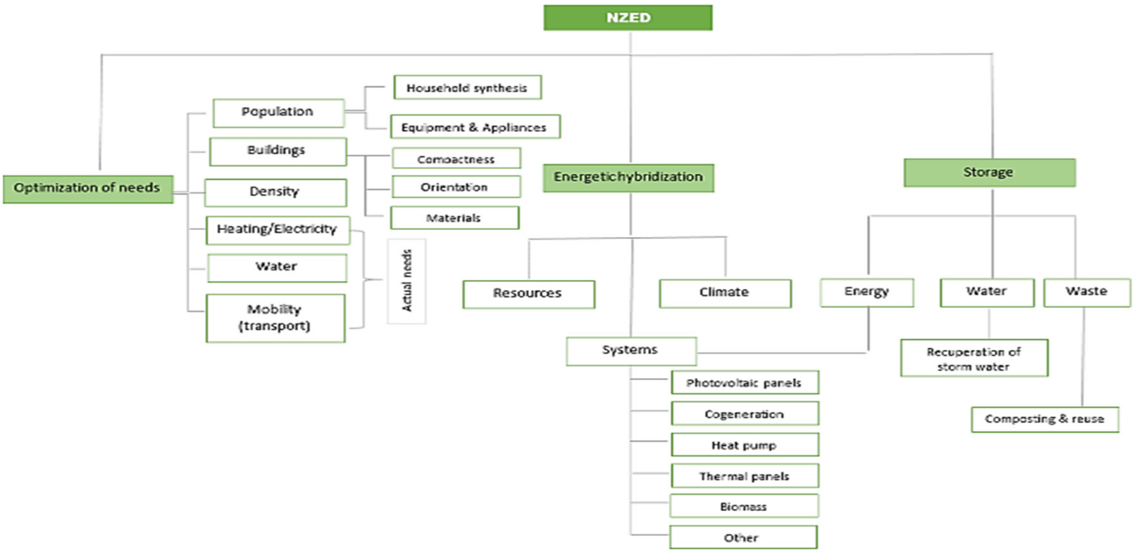

Figure 4: Analysis of the three pillars of a NZED.

European level is performed in this study as a first reflexion of the understanding of the sustainable context in a district scale for three principle reasons:

- More than 50% have been implemented,
- The availability of the information
- The European geographical scale

3.1 Description of Case-studies

The majority of the selected case-studies concern new-constructed projects, established mostly on urban lands with high potential of renewable resources. A number of the cases are transformations of ancient land uses or part of political initiatives. The cases-studies selected are (Figure 5):

Figure 5: Presentation of case-studies.

- *Hammarby Sjöstad (Sweden)*: new-constructed to expand the city centre of Stockholm (1994-ongoing).
- *Bo01 Malmo (Sweden)*: new-constructed district of innovative environmentally friendly technologies (1998-2002).
- *Eco-Viikki (Finland)*: testing ground construction to ecological building trends (1999-2004).
- *BedZED (Sutton, United Kingdom)*: new-constructed pilot project (1999-2005).
- *Solar Village (Greece)*: test a variety of passive and active solar systems (1984-1988).
- *Vauban (Germany)*: first district labelled as 'sustainable'and the most famous example of 'eco-projects' (1993-2006).
- *Kronsberg (Germany)*: new-constructed in the context of the Universal Exhibition in 2000 (1994-2000).

3.2 Comparative Analysis

3.2.1 Optimization of Energy Needs

Main findings:

- The majority of the projects had a *construction duration* varied from 4-6 years. Exception consists the cases of Hammarby (23 years) and the Kronsberg (11 years)
- The surface (in ha) of the 'eco-districts' varied from 1.7ha (BedZED) to 200ha (Hammarby) with an average of 35ha
- The average population density reaches the 138 inh/ha while the average residential density reaches the 48 units/ha.
- South buildings' orientation for the

maximization of natural lighting and solar gain.

3.2.2 Energetic Hybridization

Concerning the energy field and the systems used by the different cases, almost all of them use photovoltaic and solar panels. Despite the use of complicated energy systems, their energy consumption does not often achieve their initial objectives. Important reductions in water consumption in view of the recuperation of storm water and local sewage treatment in many cases (i.e. Hammarby, Malmo, etc.). The analysis of the energetic hybridization reveals that the systems mostly used are the photovoltaic panels and the co-generation. The tendency of their hybridization is obvious for the majority of the cases. Regarding the use of RES, the main statement is that the solar energy remains the first priority of the stakeholders' decisions sometimes in combination with the rest potential of each case. The use of gas and biomass seem to be less (Figure 6).

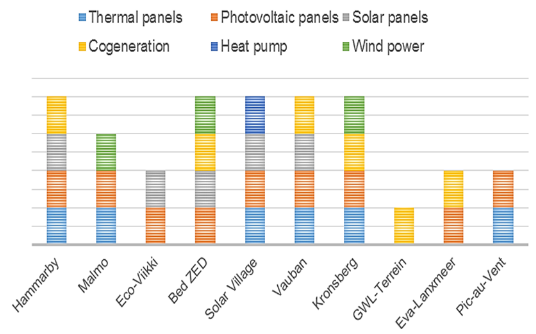

Figure 6: Energy systems and innovative technologies.

3.2.3 Organisation of Energy Storage

The organisation of energy storage remains a challenge and unexplored both in the literature review and in real life. However, the analysis of ten European 'eco-cases' reveals efforts towards mainly the recuperation of storm water (Figure 7).

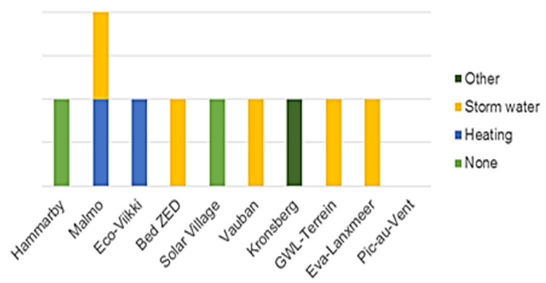

Figure 7: Organisation of energy storage.

4 DISCUSSION

This paper explores the path from the 'smart ground' to the 'smart city' as a result of the contemporary urban transformation of the modern districts. It proposes the development of a systemic methodological approach for the evaluation of a NZED within three interrelated pillars in a multi-criterion concept.

This work opens numerous future research perspectives that should be investigated widely to develop NZEDs with a concrete and operational context in real life. The proposed methodological framework (systemic approach of the district, multi-criteria approach related to three levers of evaluation, etc.) will be extended and completed as a further step in the scope of defining and transforming modern districts into sustainable, and energetically performed, validated and completed as a further step of this study within a real case-study.

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