From the ‘smart ground’ to the ‘smart city’:
An analysis of ten European case-studies

First Author Name\textsuperscript{1}, Second Author Name\textsuperscript{1} and Third Author Name\textsuperscript{2}
\textsuperscript{1}Institute of Problem Solving, XYZ University, My Street, MyTown, MyCountry
\textsuperscript{2}Department of Computing, Main University, MySecondTown, MyCountry
{f\_author, s\_author}@ips.xyz.edu, t\_author@xy.mu.edu

Keywords: Case-study, City, District, Energy, Smart

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 European Climate and Energy package foresees a substantial reduction of energy consumptions in buildings by 2020. The implementation of net Zero Energy Buildings (nZEBs) as the building target from 2018 onwards represents one of the biggest challenges to increase energy savings and minimize greenhouse gas emissions. The aim of this paper is the development of a methodological systemic approach about energy management in a district scale 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 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 to creating 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’, ‘digital’, ‘intelligent’, ‘smart’ and even combinations (De Jong, Joss, Schraven, Zhan, Weijnen, 2015). Despite the various descriptions and debates about what is ‘smart’ or ‘intelligent’ can be found in literature (Angelidou, 2015; Hollands, 2008; Komminos, 2011), there is no agreed definition of a ‘smart city’ and its strategic planning is still largely unexplored (Angelidou, 2015).

Calvillo et al. propose that a ‘smart city’ is a sustainable and efficient urban centre that provides a high quality of life to its inhabitants through the optimal management of is natural resources (Calvillo, Sanchez-Miralles, Villar, 2016), while Angelidou outlines the complexity of the system by diverging interests made up by: the use of ‘smart energy’ towards intelligent ways for the energy reduction (e.g. ‘smart buildings’, ‘smart transportation’, ‘Intelligent Transport Systems’, etc.) using innovative technologies (Angelidou, 2015). In ‘smart cities’, governments and businesses invest in Information Computer Technologies (ICT) to improve sustainable development and quality of life, by providing smart urban infrastructures that will inform residents about the desired environmental agenda. In fact, a ‘smart city’ provides the required infrastructure for citizens and officials to make more ‘intelligent’ decisions (Khansari, Mostashari, Mansouri, 2014). The Smart City concept operates in a complex urban environment, incorporating several complex systems of infrastructure, human behaviour, technology, social and political structures and the economy. It provides an intelligent way to manage components, such as transport, health, energy, homes and buildings and the environment (Gaur, Scotney, Parr, McClean, 2015). What is certain, though, is that the ‘intelligent (smart)’ city represents a multi-disciplinary and dynamic field that is being shaped by the urban metabolism of the contemporary life.

Energy management is one of the most demanding issues within the complexity of the ‘smart city’. Therefore, significant attention is dedicated to ass the impacts of the ‘smart solutions’ towards the planning for shifting from conventional to ‘smart’
city (Calvillo, Sanchez-Miralles, Villar, 2016). Cities are the centre of economic activities, development and research, therefore, they are the key for the ‘smart’ growth of the European Community (Vollaro, Evangelisti, Carnielo, Gori, Guattari, Fanchiotti, 2014). In this framework, the European ‘Smart Cities & Communities Initiative’ encourages cities to ambitious measures to progress by 2020 towards a 40% reduction of greenhouse gas emissions through sustainable use and energy production. In this effort, the concept of ‘zero (or nearly zero)’ is expected to play a crucial role and it is anticipated to contribute significantly at the achievement of the future ‘smart cities’ envisioned by the European Union and promoted through its regulatory framework (Kyllili & 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. Today, the problematic of ‘Zero Energy Buildings (ZEBs)’ has aroused increasing interest in an international level in the scientific literature review towards solutions for a more sustainable urban and built environment focusing on the building scale (Marique & Reiter, 2014). Although this approach is now relatively common in individual building, the need for investigation in larger scales to meet the environmental expectations is more imperative than ever. Sustainability of the built environment is by no means restricted to questions regarding the location of buildings and urban densification. In this context, the district level appears to be particularly interesting in operational terms for modelling and exemplify it as a first step towards the understanding and the realisation of the ‘smart city’ as it consists its micrograph and one of its constructive elements. The district is an autonomous and coherent system, socially and functionally mixed with symbols, features and morphology. By addressing targeted issues, this approach results in innovative solutions (Pérez & Rey, 2013) with the introduction of modern technologies and multi-energy applications.

The paper focuses on the challenge of districts’ transformation into ‘smart’ grounds towards the development of ‘smart city’. The paper is structured accordingly. Section 2 includes the methodological systemic district approach and proceeds to explore the evaluation tool developed for this purpose, Section 3 illustrates ten European exemplar case-studies highlighting their principles and main findings, Section 4 summarizes and discusses the most interesting points that emerged from the previous review.

2. METHODOLOGY

2.1 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) aiming at articulating the main energy uses: building energy consumption, production of on-site renewable energy and transportation energy consumption (Marique & Reiter, 2014) and it is consisted by components with interesting interactions and interconnections (Figure 1). 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 & Marique, 2014).

![Figure 1: Systemic approach of NZED](image)

The balance is annual but monthly balances are also studied to capture the gaps between energy consumption and production by renewable sources. Transportation-related fuel consumption is also minimized. Production potential area of energy is developed to a maximum offset, at a minimum, all the primary energy consumption due to the operation and use of buildings and daily passenger transportation. As far as the metric of the system is concerned, the balances are proposed in terms of primary energy. Note also that a net zero-energy district connects interactions among the buildings inside the system and its surroundings (Teller & Marique, 2014).

At a ‘district scale’, there are few cases including the ‘zero’ concept and they mainly focused on zero carbon emissions without the use of fossil fuels (e.g. the case of the eco-district BedZED, Sutton, UK, etc.). Most of them are called ‘sustainable districts’ or ‘eco-districts’ but in their initial targets a balance of ‘zero energy’ does not exist. With a view to the overall quality of living conditions, the promotion of the return to the city raises multi-dimensional questions that must be incorporated into the processes of their urban transformation (Pérez & Rey, 2013).
2.2 Development of ‘NZED’ evaluation tool

The process of optimization, evaluation and monitoring of urban projects (as well as for a NZED) requires a defined framework and methodology. A certain number of approaches for assessing the sustainability at the district scale has been developed in institutional and academic world. These can be grouped into four main categories: (i) certifications, based on an evaluation of the results, regardless of the process; (ii) modelling: concepts that incorporate all of the parameters on a quantitative basis; (iii) targeted assessment tools: evaluation of a specific phase of the project and finally, (iv) decision-making tools: strengths and weaknesses of a project as a whole (Martínez-Pérez, De La Torre-Díez, Candelas-Plasencia, & López-Coronado, 2013).

The scope of the NZED is to define and optimize the energy needs as a first step, which are parameters of different variables in the district system and depend on: the population, the household synthesis, the building envelope but also on the systems used for domestic hot water, heating, electricity and cooling needs. Three parameters in terms of the system analysis are defined concerning: the energy, the water and the waste. The systemic approach is a general perspective for a better integration of the individual building into its context in policies dealing with energy efficiency. Promoting building and retrofitting of energy efficient buildings is a fundamental step towards NZED but it is not sufficient. A compilation of these criteria that synthesize three pillars of the NZED and evaluate the feasibility of an urban area to achieve the net-zero energy concept is realized (Figure 2):

1. **Optimization of needs** by analysing the key factors for a district (location, morphology, organization, etc.) comparing the initial goals with the real consumptions and achievements. This pillar is concentrated on the way to an energetically autonomous district with the control and optimization of the occupants’ actual needs (energy, transport, etc.).

2. **Use of energetic hybridization** by analysing the possibility to combine the potential, the energy systems and the technologies used for the energy needs.

3. **Organization of storage by analysing the energy performance** of the technologies and systems installed. In the framework of a net-zero energy project of an energetically autonomous district, the parameter of storage allows the energy distribution during all the seasons and optimize its consumption regarding the needs.

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. The eco-districts are often absorbed by the pillars of the sustainable development, essentially under the environmental angle. The economic and social preoccupations are less developed compared with the environmental problematic. This means that the actions concerning the pillar ‘environment’ can sometimes have social impacts (e.g. the actions effectuated for the energy reduction, etc.). However, the fact that the districts are a priori oriented towards the environmental aspect, can explain the tendency of the European stakeholders towards the energy question and the climatic change. The majority of the eco-districts selected absorb at the same time a multi-themed approach, meaning:

- **Energy**: use of renewable energy (photovoltaic, aeolian, geothermal, etc.), energy autarky, reduction of the consumption, etc.
- **Water**: recuperation and valorisation of the storm water, green roofs, etc.
- **Waste**: recycling, compost, etc.
- **Materials**: ecological materials preferably of local production, interdiction of certain types (PVC, etc.), construction types that favour the cycle of life
Transport: encouragement of public transport and green mobility, parking policies, etc.

Despite the general context of the sustainable development in urban projects, these innovative realisations of the ‘eco-districts’ adopt an approach more sectorial and less global with specific and particular objectives - often focused on the environmental and energy performances. A brief review of the principle of sustainable development of ten (10) representative case-studies in a European level as well as an analytical comparison of their basic parameters regarding their context is performed.

The analysis focuses on the specific case-studies with an ‘eco’ character for three principle reasons:
- More than 50% of the cases have already been implemented
- The projects selected have already published their results and returned their first experiences
- The availability of the information
- The European geographical scale

Each selected study is organized in a systemic approach examining various fields as inputs and outputs analysing the initial goals and achievements and consist a progress in the field of the research plan, an intermediate plan to its concept and realization independently of their success or not. The state-of-the-art analysis, their goals and methodologies are created in the framework of approaching the net-zero energy concept of urban planning. The inefficiencies and lack of literature review limit the analysis in districts with an ‘ecological’.

### 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 (regarding the natural resources, the connectivity with the city centre, etc.) with the purpose of creating exemplar districts of sustainable urbanism attractive and operational. Most of the cases are transformations of ancient land uses or part of political (or other) initiatives in an effort to give them added value and interesting context. The cases-studies selected are (Figure 3):

- **Hammarby Sjöstad (Sweden)**: new-constructed district to expand the city centre of Stockholm.
- **Bo01 Malmö (Sweden)**: new-constructed district - example of innovative environmentally friendly technologies.
- **Eco-Viikki (Finland)**: district chosen as a testing ground construction according to ecological building trends.
- **BedZED (England)**: new-constructed district, realization as a pilot project.
- **Solar Village (Greece)**: constructed to test a variety of passive and active solar systems for heating and for supplying hot water.
- **Vauban (Germany)**: one of the first districts labelled as ‘sustainable’, a precursor and the most famous example.
- **Kronsberg (Germany)**: new-constructed district built in the context of the Universal Exhibition in 2000.
- **GWL-Terrein (Netherlands)**: district constructed to cope with the housing shortage in Amsterdam.
- **Eva-Lanxmeer (Netherlands)**: new-constructed project to promote sustainable development.
- **Pic-Au-Vent (Belgium)**: pilot project, which in progress, considered as an example of passive houses.

![Figure 3. Presentation of case-studies](image)

### 3.2 Comparative analysis

The comparative analysis outlines the general comparative results regarding the three pillars of the evaluation tool and synthesise their criteria accordingly.

#### 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) (Figure 4).

- The surface (in ha) of the ‘eco-districts’ varied from 1.7ha (BedZED) to 200ha (Hammarby) with an average of 35ha (Figure 5).

- The average population density reaches the 138 inh/ha (Figure 6), while the average residential density reaches the 48 units/ha (Figure 7).

- A typical eco-district includes apartments of terraced type and multi-family from two (2) to four (4) stores and between 2-4 rooms.

- 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 for the energy production. Despite the use of complicated energy systems, their energy consumption does not often achieve their initial objectives. The potential of energy inventory is related to the total exploitation of its alternative forms and the achievement of their initial goals. Important reductions in water consumption thanks to the recuperation of storm water and local sewage treatment in many cases (e.g. Hammarby, Malmo, etc.). Focus on waste management by improving recycling procedures with the goal of reducing the waste production through the encouragement of green plans.

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. The use of heat pumps seems to be less popular for the eco-districts (Figure 8). Regarding the use of renewable energy resources, 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 9).
3.2.3 Organisation of energy storage

The third pillar includes the characteristics of the organisation of the energy storage. This field still remains a challenge and remains quite unexplored. However, the analysis of the ten European ‘eco-cases’ reveals the efforts towards mainly the recuperation of storm water (Figure 10). The integration of this parameter is crucial for the characterisation of a district as ‘net-zero’.

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 aims at completing the existing review to ‘zero energy’ concept by investigating its feasibility at a district scale. The paper proposes the development of a systemic methodological approach for the evaluation of a NZED.

Few are the cases focused on pioneering initiatives as the ‘net-zero energy’ concept in the literature. Most of them are called ‘eco-districts’ and developed in terms of sustainable urbanism. Fascinating the urban development is already taken place in the notion of ‘smart’. The notion of ‘smart ground’ is defined in accordance with the development of effectively performed districts towards the ‘smart city’. Towards this concept, ten representative cases are studied. Four eco-projects fulfil the majority of the criteria defined and promote the perspective to be transformed into ‘net-zero’.

The ‘smart ground’, which implies the development of a net-zero energy district, symbolizes the introduction of technologies and renewable energy for a district with net-zero energy characteristics. The ‘smart ground’ is guided by two strategic axis concerning (Figure 11):

1. The ‘smart location’: the question of the district’s localization and the variables regarding: the resources, the inventory, the climate, etc.
2. The ‘smart morphology’: the question of urban typology of the district concerning the ‘form’ of ‘smart ground’ regarding its orientation, compactness, geometry, etc.

Both axis target the development of ‘smart’ district. These two fundamental issues frame the holistic diagnosis of the district as an urban project and the concept of ‘smartness’ regarding the parameters that influence the perspectives of its implementation in real life.
Figure 11. From ‘Smart District’ to ‘Smart City’

A comparative analysis of the districts’ profile is developed, while the second step includes their evaluation procedure. The preliminary results of the analysis indicate the cases of BO01 (Malmo), Kronsberg (Hanover), Eva-Lanxmeer (Culemborg) and Pic-Au-Vent (Tournai) as potential district transformation of their context into net-zero energy. Further analysis of their typology in buildings, land uses, urban structure, etc. will follow as the main axis of the future work in combination with the potential definition of demonstration sites in the region of Mons.

This work opens numerous future research perspectives that should be investigated widely to develop NZEDs with a concrete and operatible context in real life. The proposed methodological framework (systemic approach of the district and three pillars of the evaluation tool) will be extended and completed as a further step in the scope of defining and transforming contemporary districts into less polluted and energetically performed, more flexible, efficient with a long-term and sustainable character.

ACKNOWLEDGMENTS

This research was funded by the EC under the FP7 RE-SIZED 621408 (Research Excellence for Solutions and Implementation of Net-Zero Energy City/Districts) project.

REFERENCES


