A Simplified Methodological Approach Towards the Net Zero Energy District

Sesil Koutra[1], Vincent Becue[2], Christos S. Ioakimidis (*)[1]

[1] ERA Chair (*Holder) 'Net-Zero Energy Efficiency Unit on City Districts', Research Institute for Energy, University of Mons, Mons, Belgium
{sesil.koutra,christos.ioakeimidis}@umons.ac.be
[2] Faculty of Architecture and Urban Planning, University of Mons, Mons, Belgium
vincent.becue@umons.ac.be

Abstract. Zero energy conceptual framework is attracting increasing interest in European target policies aiming at more sustainable and liveable urban and built environments. Despite its compelling context in scientific literature and practical applications, the commonly used approach is principally adopted on the aspect of an individual building. Cases with zero energy concept are few in literature. The aim of this paper is the development of a methodological approach to extend the 'zero energy building' to the 'zero energy district' by taking into account two challenges: (1) the impact of urban structure (typo-morphology) on the actual energy needs and (2) the location. It proposes a simplified methodology within three strategic axes through the systemic approach of the district and thereby opens and addresses future research perspective to be widely investigated to develop 'smart' districts with operational and long-term context by introducing the notion of 'smart ground'.

Keywords: Case-study · Energy · Morphology · Smart · Typology

1 Introduction

The future of the majority of citizens' is undeniably urban. Contemporary cities aim at upgrading and enhancing their attractiveness [1]. In this current context of urbanization and the overall growth phenomenon (projected to reach 60% of the global population by 2030), managing to strategic planning with 'sustainable' terms appears as a policy target. Controversial aspects of the cities' future debate exist in the literature and the term 'smart' ('intelligent') but actually, there is no agreed definition of its concept [2]. What is certain, though, is that it represents a multi-disciplinary rising field of the 21st century.

Cities are undoubtedly the core of economic activities, the sustainable development and the key for the 'smart growth' [3] and are by definition a focal point of energy consumption and production, while buildings are a major consumer of energy worldwide – considered to be responsible for more than 20% of the greenhouse emissions in Europe [4,5]. To respond to these phenomena, energy oriented techniques, incentives, and regulative instruments are held towards the achievement of low carbon (or energy) districts, such as the European and National Directive on Energy Performance of Buildings (EPBD) on nearly Zero Energy Buildings[1] proposing that by 31.12.2020 all newly constructed buildings shall produce as much energy as they consume on-site [5]. Today, the problematic of '**zero energy**' concept is arising an increasing interest as shown in a scientific literature review [4] to alleviate issues regarding the depletion of energy resources and the requirement to minimise the energy needs and adopt alternative sources of energy along with the track of environmental protection [6].

The purpose of this paper is, therefore, to identify the 'Net-Zero Energy' conception in a district scale and, by doing so, it introduces a simplified methodological framework by identifying the drivers of this discourse and reaching to preliminary conclusions regarding its future strategic urban planning. The paper is structured accordingly. Section 2 presents the description of the methodological framework recommended for NZED, Section 3 identifies the correlation between the urban structure, the building sector, and the transport with energy consumption, Section 4 illustrates the state-of-the-art of the ten case studies under a multi-thematic approach, the evaluation and the preliminary results, Section 5 discusses the results that emerged from the research, while Section 6 highlights the future research work with its results.

2 A Net-Zero Energy District (NZED) Framework: Method and Assumptions

2.1 Net-Zero Energy Concept

The concept of '**Zero Energy Buildings**' (ZEB) is proved to act as a key factor in the development of the 'smart city' with the perspective (and at the same time the challenge) to contribute significantly on the energy aspect. It is considered as a progressive evolution of low-energy and passive building designs including - apart from minimising the required energy demand (heating, cooling, etc.) - efficient measures, to cover the residents' actual energy needs by adopting alternative sources and well-balanced operations between consumption and production coupled with successful grid integration [7].

Many developed and developing countries have already adopted their own building energy standards and guidelines specifically to suit, among other things, the local climates as well as the prevailing architectural designs and construction practices (i.e. Energy Performance of Building Directive - EPBD, etc.) ([5],[8]). The EPBD recast clarified the concept of ZEB, the framework, and boundaries that have been set to proceed along this track. Art. 2 defines a 'nearly Zero Energy Building'

---

[1] Directive 2010/31/EU of the European Parliament and the Council of 19th May 2010 on the energy performance of buildings
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF

(nZEB) as *"a building that has a very high energy performance and the very low amount of energy required should be covered to a very significant extent by energy from renewable alternative sources, including energy from renewable sources produced on-site or nearby",* while Art. 9 requires that [9]:

a) By 31st December 2020, all new buildings to be of zero (or nearly) energy
b) After 31st December 2018, new buildings occupied and owned by public authorities to be of nearly zero energy

The timeline for the implementation of ZEBs according to the EPBD recast is schematised in fig. 1 [6]:

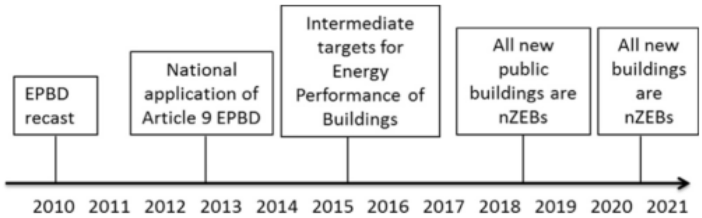


Fig. 1 Timeline for NZEBs' implementation according to EPBD recast (Source: European Commission, 2009)

2.2 The Role of the District

In literature, the zero energy objective is often related and considered on a building scale. However, despite its particular interest, the research of the concept on the individual scale of the building as an autonomous entity ignores the significance of other phenomena linked to larger territorial scales concerning the efficiency and performance of renewable energies, the impact of the transportation system, etc. [10]. Besides, the achievement of a low (or even zero) energy district (Net-Zero Energy District, NZED) depends not only on the energy balance of the building stock but as well on its holistic urban metabolism including the human factor.

'District' level appears interesting in an operational and multi-thematic context for modelling and exemplifying the realisation of a 'smart city' within the introduction and the application of modern technological techniques and practices. 'District', as a micrograph and a constructive element of the city [11] identifies the patterns of energy consumption and concrete solutions towards 'sustainability'. Well-situated to experiment within specific practices to improve the sustainability of the urban and built environment but also the application of the net-zero energy concept in real life. From the authors' point of view, as a result of previous analysis of previous case studies, challenges are important to consider the net-zero energy conceptual framework in a district:

1. The district scale is particularly interesting within its interconnections and interfaces among the diverse components at a larger scale than a building.
2. The challenge of both developing innovative and energetically performative urban structure and concurrently retrofitting the existing building stock.

3. The significant increase in actual energy needs to give the phenomenon of demographic growth in a horizon up to 2050.
4. The impacts of parameters linked to the urban structure on the energy performance of buildings and the energetic hybridisation within the use of renewable energy resources.
5. The impact of location, typology and morphology of the district related to the energy consumption and production to attain the (annual) balance in the district.

2.3 Systemic approach

For this study, the district is understood as an 'urban block' and a complicated system with diverse key parameters and interconnections (fig.2).

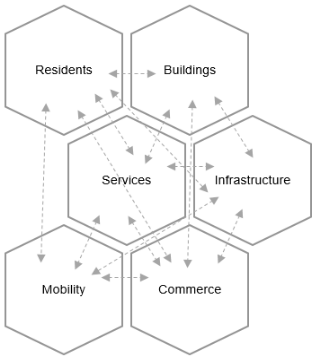


Fig. 2. District components and interconnections

The 'Net-Zero Energy District' idea is conceptualised and described by analogy with the NZEB as a territory in which the balance of the energy consumption and production for buildings (fig. 3) [12]:

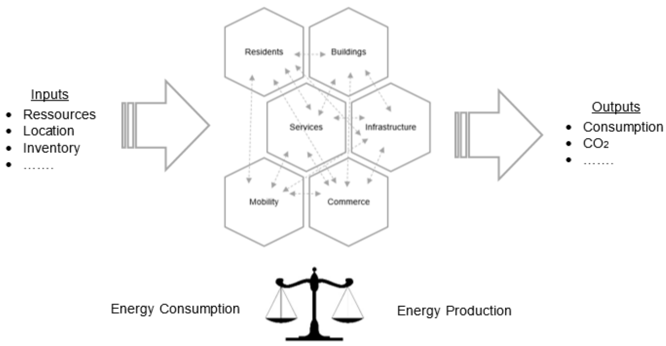


Fig. 3. Systemic approach of a NZED

Generally, the methodological steps are described in fig. 4 briefly:

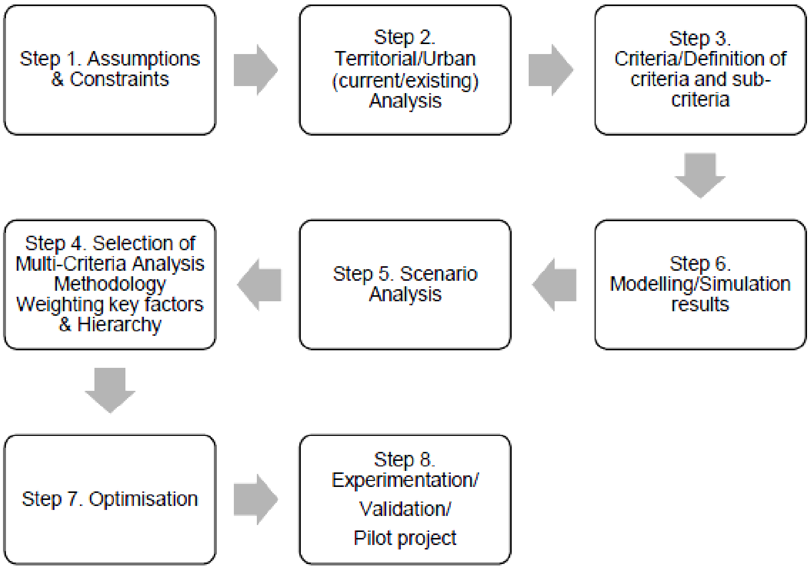


Fig. 4. Description of methodological steps

2.4 Assumptions

The *main assumptions* for the achievement of a NZED are the following ones:

1. The (annual) balance between the energy production and energy consumption (including buildings, production of on-site renewable energy)
2. The 'smart location' emphasized on 'smart geographical site' of a district (regarding its distance to the city centre, the interdependencies with the adjacent districts, etc.)
3. The mixed-use character of the district (social and functional mixing)
4. The maximisation of use of alternative renewable sources and solar gain
5. …..

The processes of optimization, evaluation and monitoring of urban projects require a defined framework and methodology. A typical compilation of qualitative and quantitative criteria as shown in fig. 5:

1. *Optimisation of actual occupants' needs:* key indicators that frame the district's 'anatomy' (profile)
2. *Use of energetic hybridisation*: reflects the successful incorporation and combination of energetic systems' and technologies' variety combining with local production of renewable energy sources
3. *Organisation of storage*: energy performance of technologies, systems, and techniques installed to reduce energy consumption.

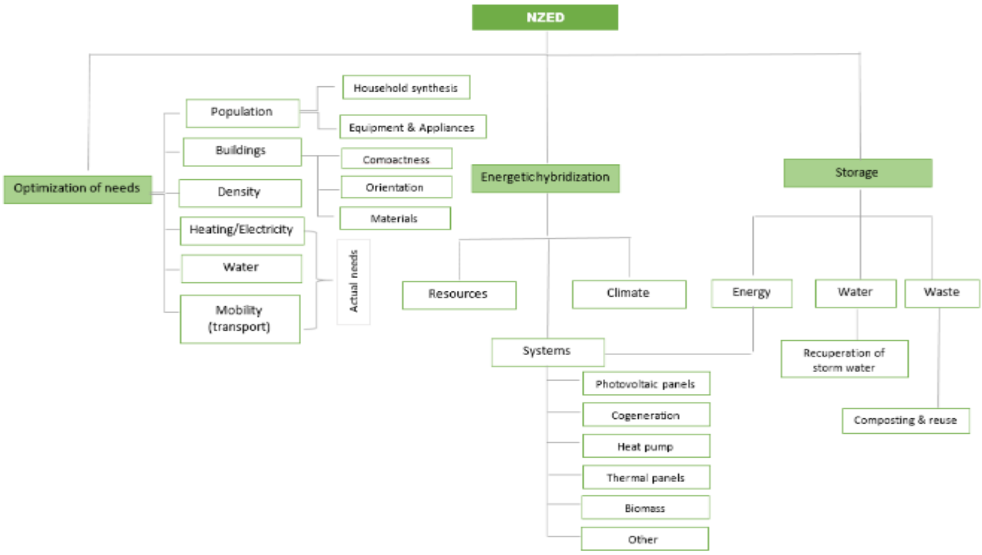


Fig. 5. Analysis of the three pillars of a NZED

2.5 Territorial Analysis

The analysis includes the territorial analysis and the characteristics of the district's profile ('anatomy') among two strategic research questions:

1. Where to locate the NZED (i.e. geographical site, etc.) and what urban characteristics of the district exist presently? (i.e. population, buildings' typology/morphology/construction age, materials, land uses, transportation system, natural resources, meteorological data, etc., definition of residents'/users' energy needs, average number of buildings, etc.)
2. What is the 'optimised' (or appropriate) urban structure (typology and morphology) to give to the NZED? (so that to minimise the energy/heat losses and optimise key parameters, such as solar gain, less car dependency, etc.)

2.6 Organisation of criteria and sub-criteria

The organisation of the criteria is performed in accordance with the three pillars of evaluation (fig. 5) and within the axis of (1) typology and (2) morphology of the districts. The analytical approach of the diverse criteria is briefly presented subsequently below.

Typology

a) Location/Geographical site/Topography/Natural resources

The potential of natural resources along with the reduction of energy consumption are probably the major aspect of characterising a district as 'net-zero energy'. Girardet [13] proposes the concept of the 'urban metabolism' to explain the use of the natural resources in a city (or a district). The energy needs (heating, cooling, etc.) are minimised from the beginning (conception) of the urban project. The focus on renewable energies (used for heating and electricity) enables the reduction of the environmental impacts and the independence from fossil and gas emissions.

b) Buildings/Physical composition/Land uses

Anon [14] defines the building typology regarding their physical composition and are basically categorised into the following divisions:

1. *Free-standing (or detached or single-family) dwellings*.
2. *Attached or multi-user or multi-family dwellings*: classification of built environment, where multiple separate units are contained within one building.
3. A building comprising two units' *side by side* is typically considered as 'semi-detached' on separate properties sharing a common wall with separate entrances and without common inside areas.
4. *'Duplex house'*: dwelling comprising two units on two different floors. Accordingly, the triplex, four-plex dwelling, etc.
5. *'Apartments'*: building with multiple floors containing multiple apartments on each floor. In contrast with a low-rise and single-family houses, apartment blocks accommodate more inhabitants per unit of area of land.

c) Users/Residents/Occupants

In this category, there is a series of criteria of the 'district typology' that affect the net-zero energy concept:

1. *Household Synthesis*: number of persons per household
2. *Equipment/Appliances*: type and quantity that affect the energy consumption in a household and as a consequence in a district as totality in an annual basis
3. *Population/Residential Density*: choice of housing type is strongly related to the urban form; the odds that a household of a multi-family housing is seven times greater for compact cities than for sprawling counties [15]. The criterion of 'density' is described in two different ways: **compactness** – (architectural viewpoint)– and **population or dwelling unit density** (number of inhabitants or units per ha) (planning perspective).

d) Mobility

The compilation of the criteria focuses mainly on the district's location in relation to the city centre, the distances from the other districts, etc.

Morphology

Key parameters that influence the district morphology of the buildings are:

a) Compactness

The shape of buildings is an aspect strictly related to energy consumption. Two core parameters are (1) **surface-to-volume ratio or compactness** and (2) the **ratio of passive-to-non-passive zones**. Compactness is relevant to the energy consumption of building since and represents the amount of surfaces exposed to the outside environment, responsible for heat losses. It also refers to urban contiguity (and connectivity).

b) Geometry

One of the most important key factors to determine the building's energy use. The 'geometry', or 'urban geometry', influences the energy performance and affects the energy performance in two main ways: mutual shading and microclimate [16].

c) Orientation

The orientation of an urban pattern is a spatial parameter to analyse the accessibility of solar energy and daylight in an urban area and the natural lighting. An overall reflection integrating the benefits of the solar energy are conducted during the planning and architectural composition of the NZED. Briefly, the criteria and sub-criteria defined for a NZED are presented in Tables 1 and 2:

Table 1. Qualitative and quantitative criteria for district typology

	DISTRICT TYPOLOGY			
	Criterion	*Qualitative*	*Quantitative*	*Units*
Location	Geographical site	x		
	Climate/Weather		x	Temperature (°C)
	Natural resources		x	Distance (m or km) from district
Buildings	Land uses (Residential, Non-residential, …)	x		
	Physical composition	x		
	Floors		x	Number of floors
	Rooms		x	Number of rooms
	Dwellings		x	Number of dwellings
	Household synthesis		x	Number of persons per household
	Equipment/Appliances		x	Energy consumption per appliance
Occupants/Residents	Population density		x	Number of people per ha
	Residential density		x	Number of dwellings per ha
Mobility	Transport services		x	Distances (km from

	DISTRICT TYPOLOGY			
	Criterion	*Qualitative*	*Quantitative*	*Units*
				the city centre, etc.)

Table 2. Qualitative and quantitative criteria for district morphology

	DISTRICT MORPHOLOGY			
	Criterion	Qualitative	Quantitative	Units
	Form	x		
Compactness	Size	x		
	Volume	x		
Geometry	Building shape	x		
	Building height		x	Number of m per building structure
Orientation	Angle		x	° of the angle to maximize solar gain and natural lighting
	Dwellings		x	° of the angle to maximize solar gain and natural lighting

2.7 Multi-Criteria Analysis (MCA)

The combination of the multi-criteria analysis method and the procedure of weighting the key factors as defined at Tables 1 and 2.

2.8 Scenario Analysis

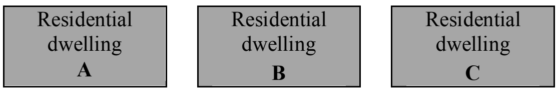
This methodological stage includes the formalisation and structure of scenarios design following the referential district typo-morphologies of the case-studies' selected and the previous analysis.

2.9 Modelling/Simulation Results

After the preliminary scenario analysis (definition of various and possible typo-morphologies), this step models the most interesting urban structures to follow as a NZED (or to exclude).

Typical example of the modelling procedure:

Type A: Scenario 0. Mono-functional residential district, 4 façades and single-family, no compactness (energy losses, etc.)



NZED mono-functional residential building model of 4 façades: to be excluded!

2.10 Optimisation

Before the final methodological step of the experimentation and validation through a pilot project of the procedure is described. At this phase, the model optimises the previous steps according to the prerequisites and assumptions for the NZED context.

Emphasis is given to the attainment of:

1. Mixed-use and compact character of the district
2. Minimisation of the energy needs of residents and district users
3. Maximisation of solar gain and natural lighting (orientation)
4. Maximisation of combined use of natural resources.

2.11 Experimentation/Validation/Pilot project

As a final step, the experimentation and the validation of the previous methodological steps through a pilot project (possibly district of Epinlieu, Mons) are proposed.

3 District Typo-Morphology and Energy

3.1 Urban Typo-Morphology and Energy

The urban tissue of a district is organised within a particular philosophy in a certain period of the city history. The common assumption is the recognition of a systemic organisation of the tissue between the urban morphology and the building typology. However, this relation is absent is contemporary cities characterised by an absence of structure. The objective of a typo-morphological frame is the analysis of the physical and spatial structures and their transformation as well. However, the analysis is a critical evaluation of the urban 'organisms' to preserve the patrimony and cultural landscape [17].

On the other hand, energy consumption in a territory is considered as the total consumption required for the construction, the planning, the use and the maintenance of the buildings (residential, commercial, etc.) in function with the public spaces, the transport or even the production chain and the mobility. A policy for the strategic territorial planning for buildings' energy performance but also the qualification of the urban structure and the maximisation of the production of local renewable resources. The 'intelligent' choice of district location (geographical site, topography, etc.), the renewable sources and the urban structures have a significant impact on energy losses.

For a Net-Zero Energy District, it is proposed [18] :

1. A functional mixing (diversity) and a dense urbanisation to reduce transportation actual needs, car dependency and fossil
2. A compact urban form (multi-family housing, terraced or apartment blocks) to improve the thermal building performances
3. A preservation of vegetation and green spaces

3.2 Buildings and Energy

Since the energy crisis of the 1970s, the scientific review extended from the building design to the impact of urban structure and the building energy use. Thus, the determination of the urban typo-morphology in a district is elusive. Simulation studies focus on the impacts of key variables (i.e. dwelling size, typology, layout, design, etc.), on urban microclimate (i.e. solar access, ventilation, temperature, etc.), comfort or building energy use (fig. 6). On the other side, as the emergent need for policies regarding the energy management and the reduction of greenhouse gas emissions increases, literature focus on strategic urban planning to discuss whether (or not) there is a considerable impact on individual buildings (or districts') energy use [19].

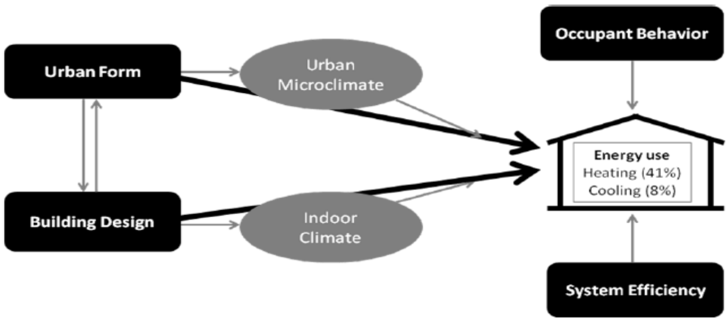


Fig. 6. Building energy use as a function of urban form, building design, energy system efficiency & occupant behaviour (Source: Kang, 2012, p.7)

Generally, the impact of building typology on energy use is significant among different types [19]. Building typology affects the surface area to volume ratio, which is the most relevant key parameter to heat transfer. Given the same building volume, a single-family detached dwelling has a higher ratio and it is more likely to lose or gain heat, thus consuming more energy than a multi-family dwelling. In general, housing type is correlated with housing size and density [19]. It focuses on the connections between the urban morphology and the energy consumption (principally of the residential buildings) in a twofold aspect: (1) the intersection between the morphological criteria and key parameters and the energy consumption as well as (2) the weighting of the factors that influence the energy consumption (i.e. users' behaviour, etc.).

Studies related to residential building energy consumption remain at the scale of the individual building. Various technical models have been developed and validated to study and simulate the buildings' attitude in order to improve the energetic and environmental performance. Notwithstanding, models adopt, in general, the building perspective by considering it as an autonomous entity but ignoring the importance of a larger territorial scale. Ratti et al. [20] propose that the building energy performance depends on *(1) urban geometry (context) related to the availability of the sunlight and natural lighting on building façades, (2) building design, (3) efficiency of energy systems used* and mainly on *(4) the occupants' (users') behaviour* (fig.7). However, despite the undoubted liaison between the urban geometry and the energy consumption, this link is usually neglected by the simulation models (mainly concentrated on more technical or architectural characteristics), possibly because of its complexity (fig. 8).

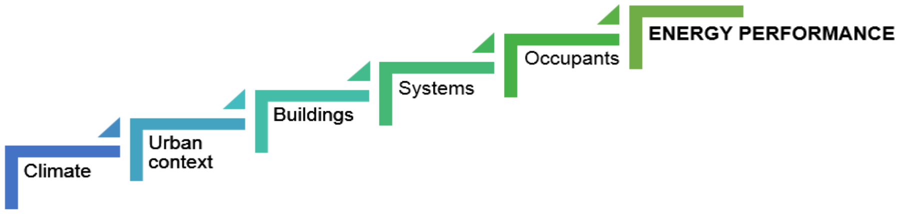


Fig. 7. Factors that affect the energy consumption of the buildings (Source: Baker et al., 2000, p.763)

Ewing and Rong [15] propose the urban structure is a conceptual frame appropriate for the energy efficiency that should be concentrated in a ***'housing (dwelling) level'*** (fig. 7).

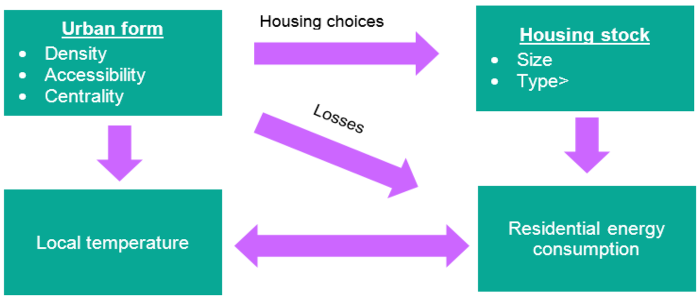


Fig. 8. Conceptual frame: urban structure and energy consumption (Source: Rong, 2008, p.7)

4 Case-Studies

4.1 State-of-the-art Analysis: Description of Ten European Case-Studies

The analysis describes the conceptual frame of the district typo-morphology and the energy consumption as a key parameter for the interpretation of the NZED. Districts with zero energy context are few in the bibliography [4]. The state-of-the-art analysis includes a number of districts with an 'ecological' character developed since the '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 representative case-studies (fig. 9) at a European level is performed in this study as a first reflection 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

The cases studies selected are:

Fig. 9. Presentation of ten case studies

4.2 Evaluation/Comparative Analysis

The evaluation of the case-studies is realized in accordance with the criteria described in two phases:

1. A general comparative analysis of the results that describes the districts' profiles (parameters of the urban context, etc.) focusing also on the issues of energetic hybridisation and the organisation of energy storage.
2. A particular comparative analysis in accordance with the three pillars that consist the systemic approach of the NZED

Evaluation axis 1. Optimisation of actual energy needs

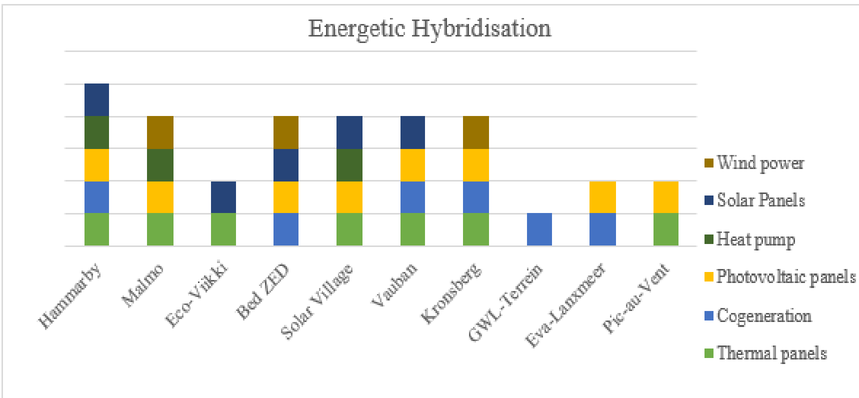
The main findings of this criterion are presented in this section related to the districts' profiles (i.e. period of launch and implementation as well as data including surface, density, etc.):

Diagram 1 to 6. Identification of districts' profiles – Optimisation of actual energy needs

Evaluation axis 2. Energetic Hybridisation

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. The tendency of their hybridization is obvious for the majority of the cases. The use of gas and biomass seem to be reduced (Diag. 7).

Diagram 7. Energetic hybridisation of ten case studies



Evaluation axis 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.

4.3 Preliminary Results

The state-of-the-art and the comparative analysis and the evaluation procedure of the ten cases reveal the potential of four of them (BO01 - Malmo, Kronsberg - Hanover, Eva-Lanxmeer - Culemborg and Pic-Au-Vent - Tournai) to be transformed into the 'net-zero energy' context. Preliminary results regarding their typo-morphological attributes are presented. The results of the comparative analysis of the four evaluated cases are presented in the following diagrams. The analysis conducts a preliminary vision of the NZED typo-morphology (Diagrams 8-15).

Diagrams 8 to 15. Preliminary results of the 4 case studies

From the previous preliminary state-of-the-art analysis and evaluation among ten European representative case-studies, the most interesting conclusions about the NZED type are:

I. Well-situated districts close to city centres (≤10km) and potential of natural resources (energetic hybridisation) and well-served by the public transport (distances between the diverse stops: 200-500m)
II. Diversity on key parameters: i.e. surface (ha), number of dwellings and population
III. Number of floors: 2-5
IV. Mixed-use districts with diverse land uses and building typology (mainly apartments)
V. Organisation of energy storage with focus on the recuperation and reuse of storm water

Further, detailed analysis is expected on the modelling of NZED typo-morphology within the Step of Experimentation/Validation of a pilot project/real case.

5 Discussion

In the previous section, the preliminary typo-morphological analysis of the four case-studies presents the results of the four proposed typo-morphologies of the first approach of the NZED concept. Further analysis is required to frame the district with a net-zero energy concept, however, the study concludes with the introduction of the notion of the '**smart ground**'. The innovative notion of 'smart ground' is defined in accordance with the development of effectively performed districts towards the 'smart city' and symbolises the hybridisation 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 with the authors in accordance with two strategic axes.

5.1 The Smart 'Location'

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

1. *Climate (and micro-climate)*: weather conditions (temperature, daylight, the wind, etc.) that influence the occupants' actual requirements in energy and policies pursued (i.e. impediments for mild modes of transport- in cold climates, etc.).
2. *Potential of natural resources*: constitutive key factor for the 'smart location'.
3. *Proximity*: the 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.).

4. *Mixing*: 'functional autonomy' of the district within its economic centre and diversified services.

5.2 The Smart 'Morphology'

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

1. *Density (residential and population):* central to the urban planning of a district: a) limit displacements and car dependency, b) economy of land use.
2. *Orientation:* spatial district's urban pattern that reflects the integration of benefits of solar gain within its architectural and urban composition. Marique and Teller [12] consider an angle of 25° measured horizontally at a central point of each façade of the NZED to maximise the solar gain.
3. *Compactness:* crucial to reducing energy consumption. Maignant [21] underlines the optimum compactness with spherical geometrical shape, while simultaneously public transport is more cost-effective, accessible and effective in a denser urban tissue.

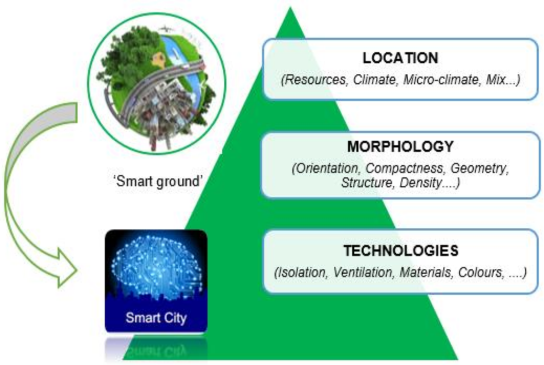


Fig. 10. From the 'smart ground' to the 'smart grid'

6 Conclusions

This paper explores the path from the 'smart ground' to the 'smart city' as a result of the rising interest in the urban metabolism of the contemporary districts and proposes a simplified methodological framework within three interrelated pillars in a multi-criterion concept. The goal of this paper is to contribute to the existing scientific review regarding the 'zero-energy' objective by investigating its feasibility in terms of a district. This work highlights the opportunities for the interest to extend the boundaries of the individual building to a larger territorial unit (i.e. district)

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 (i.e. Epinlieu, Mons, Belgium).

Acknowledgements

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.

7 References

[1] De Jong, M., Joss, S., Schraven, D., Zhan, C., Weijnen, M.: Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization. In: Journal of Cleaner Production, vol. 109, pp. 25–38. (2015).

[2] Angelidou, M.: Smart cities: A conjuncture of four forces. In: Cities, vol. 47, pp. 95–106. (2015).

[3] Vollaro, R., Evangelisti, L., Carnielo, E., Gori, P., Guattari, C., Fanchiotti, A.: An Integrated Approach for an Historical Buildings Energy Analysis in a Smart Cities Perspective. In: 68th Conference of the Italian Thermal Machines Engineering Association, ATI2013, pp. 372–378. Bologna (2014)

[4] Marique, A.F., Reiter, S.: A simplified framework to assess the feasibility of zero-energy at the neighbourhood/community scale. In: Energy and Buildings, vol. 82, pp. 114–122. (2014).

[5] European Parliament and the Council of the European Union: Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings (recast). In: Official Journal of the European Union, pp. 13-35. (2010)

[6] Li, D., Yang, L., Lam, J.: Zero energy buildings and sustainable development implications - A review. In: Energy, vol. 54, pp. 1–10. (2013).

[7] Carlisle, N., Geet, O., Pless, S.: Definition of a 'Zero Net Energy' Community. National Renewable Energy Laboratory, Colorado (2009).

[8] Concentrated action: Energy Performance of Buildings (EPBD), http://www.epbd-ca.eu/

[9] Mcallister, G., Pellegrino, A.: Inclusion of Energy Generation in Building Energy Efficiency Standards. Technical Report, Australian Government, Department of Climate Change and Energy Efficiency (2012).

[10] Marique, A.F., Penders, M., Reiter, S.: From Zero Energy Building to Zero Energy Neighbourhood. Urban form and mobility matter., In: 29th PLEA Conference on Sustainable Architecture for a Renewable Future, pp. 1–6, Munich (2013)

[11] Riera Pérez, G., Rey, E.: A multi-criteria approach to compare urban renewal

scenarios for an existing neighborhood. Case study in Lausanne (Switzerland). In: Building and Environment, vol. 65, pp. 58–70. (2013).
[12] Teller, J., Marique, A.: Réferentiel Quartiers Durables. Technical report, SPW Editions, Guides Méthodologiques (2014).
[13] Girardet, H. :Creating Sustainable Cities, The Schuma. UK, (2007).
[14] Anon, R.: Housing Typology. Technical report, Metropolitan Design Center, College of Architecture and Landscape Architecture, University of Minnesota (2005)
[15] Ewing, F., Rong, R.: 'The Impact of Urban Form on U.S. Residential Energy Use,, In: Housing Policy Debate, vol. 19, pp. 1-30. Virginia (2008)
[16] Sattrup, P.: Building Typologies in Northern European Cities: Daylight, Solar Access and Building Energy Use. In: Journal of Architectural and Planning, vol. 30, pp. 1-21. (2013)
[17] Amar, B., Boukedjar, Y., El Sharkawi, A., Oubadji, M., Terkia, S.: Méthode d'analyse: typomorphologie. Technical report (2006).
[18] Astier, M., Contamine, S., Tropini, N., Deboaisne, D., Avril, S.: Urbanisme et énergie: les enjeux énergie-climat dans les documents d'urbanisme. Technical report (2009).
[19] Kang, Y.: The Energy Impact of Urban Form: an approach to morphologically evaluating the energy performance of neighborhoods. University of California, Berkeley. (2012).
[20] Ratti, C., Baker, N., Steemers, K.: Energy consumption and urban texture. In: Energy and Buildings, vol. 37, pp. 762–776. (2005).
[21] Maignant, G.: Compacité et forme urbaine, une analyse environnementale dans la perspective d'un développement urbain durable. In: Développement urbain durable, gestion des ressources et gouvernance, pp. 1-17. Lausanne (2005)