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PRILOŽNOSTI ENERGIJSKE UČINKOVITOSTI V URBANISTIČNEM NAČRTOVANJU

OPPORTUNITIES FOR ENERGY EFFICIENCY IN URBAN PLANNING

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IZVLEČEK

Na globalni ravni, je tematika podnebnih sprememb tesno povezana z intenzivno rabo energije, zato je energijska učinkovitost postala eden izmed ciljev trajnostnega razvoja. Energijska učinkovitost igra pomembno vlogo v političnih programih mnogih držav. Urbanistično načrtovanje se že dalj časa spopada s posledicami podnebnih sprememb, zaradi kompleksne narave načrtovanja pa vključevanje vidika energijske učinkovitosti za urbaniste predstavlja velik izziv. Glavni cilj preglednega članka je oceniti stanje raziskav na področju urbanističnega in energijskega načrtovanja ter prepoznati skupne tematike, ki bi jih bilo možno obravnavati v prostorskih načrtih na nivoju mesta, četrti, soseske in na ravni stavbe. Vprašanja, povezana z mestno morfologijo, gostoto, mešanico rabe zemljišč in mešanico urbanih funkcij, mobilnostjo in dostopnostjo ter vprašanja, povezana z mestnim podnebjem in odprtimi prostori, so bila prepoznana kot osrednje skupne tematike v urbanističnih in energijskih študijah. Rezultati pregleda literature so pokazali, da obstajajo priložnosti za izboljšanje energijske učinkovitosti v mestih skozi urbanistično energijske tematike, ki jih je treba obravnavati v prostorskih načrtih.

KLJUČNE BESEDE

urbanistično načrtovanje, energijsko načrtovanje, energijska učinkovitost, energijske potrebe, mesta, prostorski načrti

ABSTRACT

On the global level, the issue of the climate change is tightly connected to the intensive energy use, thus energy efficiency became one of the goals of sustainable development. Energy efficiency plays an important role in political agendas of many countries. Urban planning has long been facing the consequences of climate changes and due to the complex nature of the planning, the integration of the energy efficiency aspect represents a major challenge for urban planners. The main aim of the review is to assess the state of the research on the energy and urban planning and to identify cross-cutting issues which could be addressed in spatial and urban development plans at the city, neighbourhood, districts and the building level. Scale, urban morphology related issues, density, mix land use and mix of urban functions, mobility and accessibility and the urban climate and open spaces related issues have been core cross-cutting topics in energy and urban studies. The results indicated that there are opportunities for improvements of energy efficiency in cities through identified urban energy issues which need to be addressed in spatial development plans.

KEY-WORDS

urban planning, energy planning, energy efficiency, energy demand, cities, spatial development plans

1. INTRODUCTION

The transition process toward a low carbon society to meet the challenges of climate changes is the global trend which is clearly present in Europe (2030 Agenda for Sustainable Development, UN, 2016). Energy efficiency is the most important and the most cost-effective principle for reducing greenhouse gas emissions (Global Energy and Climate Outlook, 2018). It is the principle that delivers more services for the same amount of energy input or the same amount of services for less energy input (IEA, 2014). As a multidisciplinary issue it encompasses spatial and urban planning, architecture, geography and civil engineering (Poggi at al., 2017). Improving energy efficiency in all sectors is expected to play a key role (17%) in reducing CO2 emissions by 2050 (Global Energy and Climate Outlook, 2018).

Improving energy efficiency is one of the flagship initiatives "Resource efficient Europe" of the most important development strategy, the General European Strategy for a Better Future for Europe 2020, launched in 2010 (Europe 2020, EC 2010). To support the sustainable growth, the EU 2020 launched the 20-20-20 target which beside reducing greenhouse gas emissions by minimum of the 20% and increasing the use of the renewable sources to 20% aims to improve energy efficiency for 20% by 2020 compared to 1990 (Europe 2020, EC 2010). Clean energy for all (2019) has set the new target to improve energy efficiency by at least 32.5 % by 2030. The targets are addressing buildings as the largest energy consumers responsible for 40% of energy consumption and 36% of greenhouse gas emissions in Europe (EP, 2012; Clean energy for all, EC, 2019). To improve energy efficiency in buildings, the European Commission launched the Energy Efficiency Directive 2012/27/EU (EED, 2012) which explains how to achieve the target to improve energy efficiency for 20% but the Member States need to find their ow solutions. Since buildings are the largest energy consumers, they are the greatest potential for implementing energy efficient measures (Poggi et al., 2017). Many studies have been investigating the potential of improving energy efficiency at the building level neglecting the environmental impact of neighbouring buildings and vice versa (Strasser, 2015). Raising awareness that energy saving measures need to be addressed beyond the building scale was leading researchers to develop tools and models for improving energy consumption on the neighbourhood, district and the city scale (Roselt et al., 2015; Poggi et al., 2017; Silva et al., 2018; Yeo & Lee, 2018).

Spatial planning has long been facing the challenges caused by the effects of climate changes, unsustainable exploitation of natural resources, population growth and finally, fluctuations in the economic world, which has a strong impact on the economic development and consequently on the development of society. Due to the complex nature of spatial planning, the integration of the energy efficiency aspect into the spatial planning represents a major challenge for spatial planners. Even though urban and energy planning are closely related, there are weak links among those two (Strasser, 2015).

The main aim of reviewing the literature is to assess the state of research on the urban and energy planning. Based on the assessment, the review would like to answer the following research questions. First, which are the common issues of the studies of urban and energy planning and secondly, which cross-cutting thematics are more present at the city, the intermediate and the building level. The results of the research are important in order to find the gap which could be addressed in the future urban and energy planning research.

2. REVIEW METHODOLOGY

To identify the cross-cutting issues, the review of the most relevant scientific references on urban and energy planning needs was done. The literature review made it possible to get familiar with the relevant research topics. The literature was reviewed through the Digital Library of the University of Ljubljana (DiKUL) which enables the access to electronic resources of the most important publishers such as Elsevier Science Direct, Springer Link, EBSCO host, Taylor & Francis, Oxford University Press, Web of Science, Scopus, etc. To find the latest studies on the urban and energy planning the time period between 2015-2019 was selected. For selection of the literature other filters were selected like English language and scientific peer reviewed articles. Relevant scientific articles were found based on the search terms "urban planning", "energy planning" and "energy efficiency".

The greatest challenge in the process was to find relevant scientific articles for this review due to the differences in the understanding of the terminology used in the studies. This also revealed a number of different tools and approaches that were developed supporting the integration of the energy planning in to the urban planning. The literature review used the qualitative methods to recognize the cross-cutting thematics on the energy and urban planning to identify the approaches behind them.

3. URBAN PLANNING AND ENERGY EFFICIENCY ISSUES

3.1 Scale

Many studies have recognised that the problem of the energy consumption needs to be addressed beyond the building scale. For that reason, the leading researchers have developed various approaches, methods and instruments for integrating energy planning into the urban planning at the neighbourhood, districts and city level and the whole territory of the municipality till administrative borders (Poggi et al., 2017; Yeo & Lee, 2018; Silva et al., 2018; Amado et al., 2016).

Poggi et al. (2017) are arguing that the whole territory of the municipality needs to be addressed if the municipality wants to improve energy efficiency. Territorial areas of cities and municipalities till administrative borders are an important scale also for supporting decision makers in the process of development and implementation of energy efficiency policies (Conticelli et al., 2017, Amado et al., 2016). In the case that the municipality would like to evaluate the alternative developments in order to reduce the energy consumption, they need to be evaluated for the territory of the whole municipality (Silva et al., 2018) and not just for the part of it.

Other researches prefer the middle planning level between the building and the city scale (Roselt et al., 2015; Futcher at al., 2017; Yeo & Lee, 2018). The reason is that the city level demands more actors to be involved, which can impede the successful implementation of energy efficient principles (Amaral et al. 2018). Some researchers prefer the districts scale as an intermediate scale (Cajot et al., 2017, Amaral et al., 2018) since it is the closest scale for plan realization (Yeo & Lee, 2018). The district scale is the most suitable scale also for more efficient integration of renewable energy and distribution systems (Amaral et al., 2018). On the other side, the neighbourhood scale is promoted as an intermediate scale with the greatest potential for energy optimization because in that spatial unit maximum energy efficiency may be grouped together (Roselt et al., 2015). And further, to improve energy sustainability also at the building

level, a neighbourhood scale needs to be assessed because of the interactions of neighbouring buildings (Futcher et al., 2017).

3.2 Urban morphology and urban form

Urban morphology is referred to the urban form of cities and their transformation and formation of their spatial patterns at different urban scales. Urban morphology parameters have an important role on one side to reduce the energy consumption in buildings for heating, cooling or lightning and on the other side for their potential for wind and solar energy production (Amaral et al., 2018). Morphological parameters such as the density of the building, the height of the buildings, the building factor, the green open surface factor, energy consumption etc. have an important role in improving energy efficiency in cities (Rode et al., 2014, Chen et al., 2016, Silva et al., 2018, Poggi et al, 2017). These parameters have also a major impact on accessibility and sustainable accessibility solutions, which influence the energy consumption and CO2 emissions (Silva et al., 2018). But different building morphologies require different energy demands (Rode et al., 2013) and they have an indirect role through building physics where architectural, land use and urban design parameters are playing a key role (You & Kim, 2018).

3.3 Density

Density is one of the most addressed issues in urban planning and energy efficiency studies. The most used way to measure the density in urban planning is the floor area ratio[1] (FAR) which is used for the needs of limitation of the construction in the certain area, in zoning regulations and in urban planning guidelines (Lehmann, 2016). Higher density can be achieved even through increasing the average building height or overall surface coverage (Rode et al., 2014). Beside the great impact on the energy efficiency combined with the mix land use it can reduce energy use for mobility by 15% (Silva et al., 2018).

There is also a limit for increasing the urban density. In high density areas, buildings are interacting with each other in a way that they are reducing each other the access to the natural daylight, obstructing the airflow, raising the temperature in the outdoor environment (Futcher et al., 2017; Amaral et al., 2018) which consequently increases the energy demand. Higher density can be the reason also for the heat island effect which can increase the energy consumption for cooling. That can be improved by the increasing green areas and the proper selection of materials and surfaces for minimizing the solar heat gain (Lehmann, 2016). From the social perspective it is possible that raising density will have an effect on the overcrowding, overpopulation and overdevelopment causing the pressure on the existing infrastructure including energy (Lehmann, 2016) and on the other side on the liability conditions in buildings and outdoor spaces for all inhabitants (Amaral et al., 2018).

3.4 Infill development

Solutions for increasing compactness and densities in cities rely also on the infill development as one of the efficient approaches to achieve more energy efficient urban settings. Even though there are many positive effects like the reduction of the urban sprawl, mobility needs and alike there are certain barriers for integration of this aspect into the urban pattern. When tall buildings are integrated in a lower density urban setting, they can have an impact on the energy demand of lower neighbouring buildings (Futcher et al., 2017) - the infill development aspect greatly relates to the shading effects increasing the energy demand especially for heating (Silva et al., 2018).

3.5 Mix land use and mix of urban functions

Successful policies for reducing greenhouse gas emissions in relation to the energy demand in cities lies in promotion of the mix of land use and mix of functions (Futcher et al., 2017; Silva et al., 2018; Conticelli et al., 2017). These have a positive impact on the accessibility to activities. Combined with mixed urban functions with the high densities can reduce the mobility needs for at least 15% (Silva et al., 2018). Promoting mixed land use, high-quality urban services and open spaces are the key factors of the compact cities with a positive impact on reducing greenhouse gas emissions and improving energy efficiency of buildings (Conticelli et al., 2017). While higher densities in cities can reduce the urban mobility needs, higher shares of non-residential uses are more effective in urban blocks which are farther away from the CBD (city business district) since they are mostly used for the residential purpose (Silva et al., 2018).

3.6 Mobility and accessibility

Increasing density and compactness of urban areas are important approaches stimulated by cities to improve sustainable and energy efficient use of energy since such solutions have a positive side effect on the decreasing travels distances (Amaral et al., 2018) and decrease the pressure on the urban infrastructure (Lehmann, 2016) including mobility. Silva et al. (2018) are arguing that most of the energy savings can be achieved through the transit-oriented development which is based on the promotion of new floor area around key public transport stations.

3.7 Urban climate and open spaces

Changing urban patterns are also influencing the climatic conditions and urban microclimates in cities. Growing urban structures with their complexity and urban morphological patterns are forming microclimates with airflows and windspeeds which have an impact on the solar radiation and outdoor temperature causing the urban heat island effect (Amaral et al., 2018). Therefore, the relationship among increasing urban densities and the heat island effect potential needs to be properly addressed (Lehmann, 2016).

What cannot be neglected is also the impact of the greenery on the energy consumption. Compared to the densification strategies it has only a low impact on the energy efficiency but on the other side it has several positive effects on the urban environment (Silva et al., 2018). Quality of living in compact cities demands balancing the density with the increasing green spaces allowing for the natural ventilation and breathability of the city (Lehmann, 2016).

3.8 Building typology

Typology of buildings has a great impact on the energy consumption. Energy consumption is inversely proportional to building density because, energy consumption increases when the building density is low (Chen et al., 2016). The most effective energy reduction for heating can be achieved by the higher building densities or by taller buildings while on the other side the detached houses require the worst energy demand (Rode et al., 2013; Lehmann, 2016). Thus, single family houses have a

1 Floor area ratio (FAR) is measured as the total floor area of buildings divided by the land area of the plot upon which the buildings are built (Lehmann, 2016)

greatest potential for energy efficient improvements as they are responsible for around 50-80% of total energy demand of the housing stock (Csoknyai et al., 2016).

The potential lies also in the architectural design of buildings which can reduce the energy demand from 63 to 76% depending on the climate (Naboni et al., 2015). The orientation, form, openings, sun shading devices and appropriate use of materials are factors which needs to be considered in the architectural energy efficient design (Khalil, 2009; Naboni et al., 2015).

4. DISCUSSION

The main findings of the review are summarized in the following section in order to present new comprehensive and joint insights into the urban and energy planning and highlight the further research needed to better integrate these two fields. The main aim of the review is to identify cross cutting energy issues in urban and energy planning and how they can be addressed in urban planning at the city, district or neighbourhood and building level.

There are many discussions about the most suitable scale for integrating energy efficiency in urban and energy planning, but there is no consensus about the most appropriate scale for energy efficiency improvements. The most suitable scale depends on the context and questions asked (Cajot et al., 2017). Based on the fact, that it is not enough to improve energy efficiency at the level of the building and even at the intermediate level, as the district or neighbourhood scale are, the problem first needs to be addressed on the scale of the whole territory of the city or municipality (Amado et al., 2016; Conticelli et al., 2017; Silva et al., 2018).

Not all identified urban energy cross-cutting issues can be regulated on all scales, the city, the intermediate scale and the buildings scale, in urban planning. For successful improvements of the energy efficiency, it is important to address urban energy issues on each specific scale.

Urban form is one of the most important urban factors with the wide range of positive and negative impacts on build and no--build environment. Today, potentials of the urban morphology in spatial planning are underestimated. On the city and intermediate scale, urban morphology is very important because the shape and the design of the build environment, the size and orientation of buildings, layouts of streets and network of open spaces can have a great impact on the energy consumption of buildings and on the bioclimatic conditions in urban areas (Poggi et al., 2017). The building typology which can be defined and regulated on the intermediate scale and more precisely defined on the building scale shouldn´t be underestimated either. While designing and integrating new buildings in the city or other urban areas spatial attention needs to be on the interactions of other buildings on new ones or vice versa especially because of the shading effect for which additional energy for heating is needed (Amaral et al., 2018).

Density is a highly promoted topic for improving not just sustainability but also the energy efficiency in cities. Increasing density has many positive effects on the urban environment. It promotes the sustainable use of land leading towards the reduction of potential soil sealing, urban sprawl and decrease travel distances leading toward more sustainable mobility and transportation. Density is strongly related to the compactness where compactness is desirable but if the density is too high, it can have a negative effect on the quality of life (Lehmann, 2016). Alongside many positive effects on the sustainable mobility, energy saving in buildings, there are also negative effects of the density among which are shading effect, potential for the urban heat island effects, raising temperature within the urban areas because of the interactions among buildings and others. Thus, it is important to find the right balance of the density in the city and this represents a big challenge.

Mix use functions are important on all three levels, the city, the intermediate and the building one Mix use functions are having a great impact on the mobility and accessibility. With proper organisation of urban functions on the city level, the energy demand for transportation can be reduced. More detailed energy efficiency solutions can be achieved further also at the neighbourhood or the districts level and in some cases also at the level of the building. Previous researches evaluated mainly residential energy consumption, while other activities like economy and social activities have been neglected as they are more complicated and have their own energy demand. There is a need for the research methods and tools for defining symbiotic relationships between different uses.

Urban climate is an important issue which needs to be addressed when improving not just quality of air within urban areas but also to avoid the negative effects of the urban transformation of the build environment. With proper balance of buildings and open spaces and their orientation and sizes many negative effects can be reduced. One of them is an urban heat island effect causing overheating urban areas. The risk of the heat island effect can be reduced also through integration of the greenery (Silva et al., 2018) planned at the city, neighbourhood, district and the building level. Such solutions could not just reduce the energy consumption but on the other side can improve the quality of living in cities (Lehmann, 2016) and raise the attractiveness as a desirable living environment.

city scale	intermediate scale (district/neighborhood)	building scale
urban form	urban form + building typology	building typology
urban density	urban density	building density
mobility and accessibility	mobility and accessibility	accessibility
mixed land use	mixed land use	mixed urban functions
urban climate and open spaces	urban climate and open spaces	-

Table 1: Urban planning and energy efficiency issues at different levels of planning.

However, the role of the local governments as decision makers have and important role in developing and implementing energy efficiency policies. They are in charge of defining policies for improving energy efficiency for the whole city or municipality within territorial borders of official administrative units (Conticelli et al., 2017), and then measuring which could address energy efficiency improvements in parts of the city on the intermediate scale, which is the closest to implementation of the project (Yeo & Lee, 2018). Also, for the needs of the evaluation of the energy efficiency potentials, it is necessary to evaluate the entire territories of municipalities till the administrative boundaries (Poggi et al., 2015) because administrative units are the basis also for spatial development plans. In parallel with the limits and scope of measures, the complexity and obstacles with the impact on energy consumption are also growing because the bigger scale needs to engage more stakeholders than the district or the building scale (Amaral et al. 2018).

5. CONCLUSION

Previous research has highlighted that urban planning has an important role in achieving energy efficiency at the local level. Potentials of the urban planning today are not sufficiently used in the process of designing energy-efficient environments. Due to the challenges of finding solutions to adapt to climate changes the planning processes are becoming increasingly complex, including the complexity of stakeholder's inclusion. Review and evaluation of the past and current approaches represents an important step in understanding the relationships between energy systems and spatial interventions and enables the development of the more advanced models and tools that will incorporate more sophisticated systems.

The article presents a set of cross-cutting issues which have been commonly researched in urban and energy planning. It highlighted some potential core areas where urban planning can meaningfully contribute to the energy efficiency of the city and its systems at the city, district or neighbourhood and building levels. Scale, urban morphology related issues, density, mix land use and mix of urban functions, mobility and accessibility and the urban climate and open spaces have been recognized as core cross-cutting topics in energy and urban studies. Even if there is a wide range of opportunities within these topics, they are largely underestimated in the current urban planning practice thus it is important to highlight these opportunities for improvements of energy efficiency in cities through identification of the urban energy issues which need to be addressed in spatial development plans.

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