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Sustainable Urban Development on the Example of the Housing Deveopment of Zielona Góra (Poland), as a Response to the Climate Policy of the European Union

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Abstract. In the world, in Europe, and also in Poland the use of energy is growing rapidly, causing concern about the difficulty of supply, a depletion of non-renewable energy resources and the increase in negative impacts on the environment (ozone depletion, global warming, climate change, etc. caused by increased emissions of CO_2) (Balaras *et al.* 2005). Political or economic attempts to enforce climate change, through the increase in the price of fossil fuels, lead to exclusion and growth of energy poverty therefore they cause social effects (fossil fuels become so expensive that a large part of the population cannot afford their combustion). The ideal solution would be a combination of activities aimed at the energy modernization of cities with sustainable strategies of their rebuilding.
The purpose of the article is a search for the optimal way of spatial policies at the local level that enable implementation of the objectives of the energy policy of the European Union. Factors affecting changes in the pollutant emissions associated with the combustion of fossil fuels, depending on the energy efficiency of selected buildings were modelled with a use of deduction based on radial neural networks.
The observations presented in this article may be relevant for other regions that are interested in reducing polutant emission and energy consumption of buildings, housing estates and cities. Taking the geographical context into account, it is especially important for those regions which benefit from financial support of the European Union.

Keywords: urban structure, sustainable urban development, the local policy, the protection of the environment, neural network.

Conference topic: sustainable urban development.

Introduction

Dimensioning of an urban space is part of the planning process and a method and a technique of space control. This dimensioning (parameterization) of buildings and estates makes social, economic and functional control easier. According to the currently preferred direction of legislation, it should also contribute to creating energy-efficient architecture that becomes the goal of our, but also future generations (Ziobrowski 2012; Tettey *et al.* 2016). Reducing global climate change so as the temperature rise does not exceed 2°C compared to pre-industrial levels has been set an objective of the European Union (EU). The achievement of this objective requires that the level of emissions of greenhouse gases (GHG) by 2050 shall by decreased by 80–95% compared to the level in 1990. In order to achieve the required emission reductions, appropriate policies and actions should be implemented at the level of the Member States and the EU in all sectors of the economy. Various measures are suggested in order to achieve this ambitious goal and the considerable energy savings in all sectors of its final use (Eurostat 2016).

The construction sector accounted for 38% of the total final energy consumption in the EU in 2011. It is expected that the changes associated with it, will greatly contribute to the achievement of the proposed emission factor. The Energy Efficiency Directive 2012/27/EU and the Energy Performance of Buildings Directive 2010/31/EU encourage Member States to implement policies to improve energy efficiency in buildings, and thus reduce greenhouse gas emissions. The global share of energy consumption by residential and commercial buildings, has increased in recent years, reaching a level of between 20% and 40% in developed countries (Harris 2010). For this reason, reducing consumption of energy and increasing equipment efficiency in buildings is the main objective of energy policy at regional, national and international levels today (Dodoo *et al.* 2017; Lazonick *et al.* 2013; Bazan-Krzywoszańska *et al.* 2016). This objective should also be transferred into local policy, and thus on determining the framework for investment activities, which are created in the planning documents-local land-use plans, containing the tools for executing law regulations (Skiba *et al.* 2017; Varholomaios 2015).

Demand for energy in the current forecasting models can be compared to the economic model, which takes into account the GDP, population, the size of the industry and the cost of environmental protection. Long term trends in demand in the country, which are the basis for shaping the local energy policy are predicted. At the same time, at the local level, demand is predicted, depending on a kind of energy supply to the building, considering such factors as the climate, the building condition, its physical properties and facilities, simply summing up this demand. For cities, especially in Central and Eastern Europe, the simulation of energy consumption is rarely used (Mrówczyńska *et al.* 2014; Bazan-Krzywoszańska *et al.* 2016; Skiba *et al.* 2017).

Energy demand on the urban level depends on local circumstances, such as the climate and geographical location, municipal functions, energy consumption of the buildings and and methods of energy supply. There is relatively little research in literature, about the energy demand on the urban level (Balaras *et al.* 2005; Bourdic, Salat 2012; Bourdic *et al.* 2012; Fabbri *et al.* 2012; Yeo *et al.* 2013; Labiosa *et al.* 2013). Despite this, cities in Western Europe has long been aware of the benefits of spatial and transport policies aimed at energy savings (Kopietz-Unger 2010; Bazan-Krzywoszańska *et al.* 2016; Mrówczyńska *et al.* 2014; Skiba *et al.* 2017). In Polish cities, while making investments, their future spacial consequences and costs, also the energy ones, are often not considered (Ziobrowski 2012).

A researchers' team of Denis and Parker proved that the increase in energy efficiency can be easily obtained, for instance by properly forecasted supply and demand, and by small losses in production and industry. The potential of applied savings estimated at 16% to 56% in 2025, depending on the level of support by the government of Canada (Denis, Parker 2009). In order to reduce greenhouse gas emissions, and reduce the impact of the increase in prices of electricity produced centrally, a shift to a more self-sufficient energy systems should be aimed. It must be assumed that, for the growth of the city energy potential planning local energy and heat generators will be crucial. Creation of energy plans by the local community, while introducing mechanisms for the promotion of renewable energy sources, will create a new, parallel approach – alternative global energy management (Denis, Parker 2009). The three way scheme described by a team that local communities can choose stands for:

– improving the efficiency of energy systems,
– energy saving,
– the choice of renewable energy sources.

Urban indicators

Indicators for monitoring and sustainable management of energy that appear in literature are often difficult to apply, because they are not universal. They are multidimensional, include only the sector of renewable energy or focus on an individual country. Sampaio for example, correlated the increase in demand for electricity with the population, assuming constant consumption of electricity per capita per year (Sampaio *et al.* 2013). Lu and others joined the Gray Prediction Model (GM) with Multiple Linear Regression (MLR) in the model for forecasting emissions of carbon dioxide, in the city of Hangzhou, based on: GDP, the level of household consumption, total energy production and industrial production index (Lu *et al.* 2016). And the dynamic model was used to connect systems of: energy consumption, GDP, population growth (Feng *et al.* 2013). Because these models are intended only for the purpose of forecasting energy at a city level, they are not a useful base of knowledge how really energy is consumed in urban areas.

Cities consume energy in a complex way. Energy efficiency depends not only on the climate and the efficiency of a building, but also on the economic factors and culture (Fabbri 2010). Due to the constant demand for energy and heat, energy consumption also depends on the type of energy systems and their connections (Skiba *et al.* 2017). Urban indicators described in the literature which are used in the world and Poland relate to many aspects, including socio-economic, social, environmental and other, contributing to the quality of life (Ziobrowski 2012). Because most researches on indicators of energy consumption, are focused on one aspect: physical characteristics of climate, how to use space or social determinants, they lack integrated approach. For the purposes of planning the city development and sustainability, integrated, urban-energy methods of forecasting energy consumption in the city are required.

The impact of differences in development on the energy consumption can be seen in the studies carried out by the Greek team of the Institute for Environmental Research and Sustainable Development in Athens (Balaras *et al.* 2005). The study, carried out on the basis of the 193 EU buildings audits have shown that in the 15 Member States (EU-15) primary energy consumption amounted to 1498.1 mtoe (million tonnes of oil equivalent) in 2003, which is the 1.8% increase compared to 2002, that is a 15.4% of the total world energy consumption. 164 million buildings in the EU-15 (193 million in the EU-25) use about 40% of the energy demand. Two-thirds of greenhouse gas emissions, is attributed to the residential buildings and one-third to the commercial buildings. Annual energy consumption in residential buildings of the EU makes an average 150–230 kWh/m^2, while in Central and Eastern Europe, annual consumption of thermal energy is 250–400 kWh/m^2, which is approximately two to three times more, than in the case of similar buildings in Western Europe. In well insulated buildings, annual energy consumption is 120–150 kWh/m^2, while the so called low energy buildings use 60–80 kWh/m^2 (Balaras *et al.* 2005).

Other studies were presented by the team from Canada-Bourdic, Salat, who proposed in "A new system of cross-scale spatial indicators", in the section on environment and urban form, shape and intensity factors relating to energy (Table 1).

Table 1. A new system of cross-scale spatial indicators for sustainable urban development (excerpt) (Source: Bourdic, Salat 2012)

Term	Factor	Name	Scale				
			city	district	estate	quarter	building
Environment	Intensity	Energy intensity of the area		+	+		
		Local production share		+	+		
		The rate used of renewable energy		+	+		
		The rate of energy re-use	+	+			
Urban planning	Form	Volume density of form	+	+			
		Size factor			+		+
		Form factor			+		+
		Heat capacity ratio			+		+
		Energy consumption for heating		+	+	+	+
		Energy consumption for air conditioning		+	+	+	+

Salat is a researcher, who has been showing the relationship between the urban structure of the city and energy consumption for years (Balaras *et al.* 2005). The system of spatial of indicators proposed by the team should be immediately applied not only to Polish planning documents, so as to allow, due to the unification of legislative, all cities/municipalities to create systems monitoring and managing the development in a sustainable manner and consistent with the objectives of the EU and national rules.

Primary energy, final energy, and usable energy

Final energy (FE) is a measure of the energy efficiency of a building, taking into account not only the quality of the thermal insulation, but also the quality of its installation. By calculation, it is equal to the usable energy divided by the efficiency of the installation, so it determines the amount of energy that must be delivered to the boundary of the building. Part of it is intended to cover energy losses along the whole delivery system of central heating (c.h.) and domestic hot water (dhw). The remainder, "emitted" from the installation is the usable energy. A small difference between the value of usable energy (Eu), and the final energy (FE) usually means high efficiency. The value of the FE is usually given in [kWh/year] and applies to the whole building. The results are presented according to 1 m^2 of temperature-controlled surface. In Poland, a decision to introduce classes of buildings has not been made. The Table 2 presents maximum values of the PE factor, for heating and domestic hot water systems, that will have to be reached by newly built houses. For the purposes of the article (due to the low values of the factors) PE for systems of cooling and lighting the building was skipped.

Table 2. The maximum value of the PE indicator for heating, ventilation, and the domestic hot water [kWh/(m^2 * year)] (Regulation of the Minister of Infrastructure 2015)

	was valid since 1.1.2014	is valid since 1.1. 2017	will be valid since 1.1.2021
for a single-family building	120	95	70
for a multi-family building	105	85	65
for a public building	65	60	45

The difference between the factors of PE and FE derive out of the formula, which is used to calculate primary energy demand of the building.

$$PE = FE \cdot wi \quad (1)$$

where: PE – primary energy, defining the environmental performance of the house, considering the type of heat source; FE – final energy, this is the actual amount of energy needed for heating, ventilation and hot water preparation;

wi – effort factor, depends on the used energy carrier (oil, coal, electricity).

Examples of non – renewable primary energy effort factor (wi) are shown in the Table 3.

The most authoritative assessment of the energy efficiency of the building is an indication of the annual demand for the final energy (FE) The final energy requirement is the amount of energy, assessed on the boundary of the building, which should be provided in standard conditions and taking into account the losses, to ensure the maintenance of the room temperature in calculation, necessary ventilation and production of domestic hot water. Demand for the FE is placed in the certificate, however this value is "in the shadows" of PE demand.

Table 3. The value of the non-renewable primary energy input to produce and deliver energy or energy carrier for technical systems (w_i) (Regulation of the Minister of Infrastructure 2015)

No	A building's kind of energy supply	Kind of energy carrier	w_i
1.	local production of energy in the building	fuel oil	1.10
2.		natural gas, liquid	
3.		coal, lignite	
4.		solar, wind, geothermal	0.00
5.		biomass	0.20
6.		biogas	0.50
7.	heat from cogeneration	coal or lignite	0.20
8.		biomass, biogas	0.15
9.	heat from the heating plant	lignite	1.30
10.		fuel oil or gas	1.20
11.	power transmission network system	electrical energy	3.00

Indicator of unit demand for PE includes, apart from the FE, necessary expenditure of non-renewable primary energy on delivery to the boundary of the building that each energy carrier used. The FE indicator is closely associated with the construction of the building and shows the amount of energy that the building needs, and the PE indicator shows how much non-renewable energy, the building draws from the environment. The PE indicator without a context seems to be not reliable, because it is enough, for instance, to install a fireplace or wood burning stove and claim that this is the main source of heating in the building. The PE value would drastically decrease, due to the low factor of effort.

The indicators are widely used as a tool for submitting and monitoring energy problems to policy makers and the general public. Properly designed indicator or a set of indicators transforms basic statistical information, in order to ensure a better understanding of the problem, and their range helps to create an image of a system with its mutual relationships and compromises. Considering planning a city development, a proper selection of indicators is an essential element of records in the documents that regulate spatial planning.

Zielona Góra

The economic structure of dependance of investment costs on increasing energy efficiency of residential buildings was developed by the University of Zielona Góra, which was a contractor in 2011 strategic project, prepared on behalf of The National Centre for Research and Development. The study presented in the work has been done for the city of Zielona Góra, located in the west of Poland, the South-Eastern part of Lubuskie province (51 ° 56' 23" North and 15 ° 30' 18" East). The study was focused on the urban structure, analyzing the energy characteristics of the development, which is responsible for 40% of energy consumption in the city.

The structure of the buildings in Zielona Góra, as in most Polish cities, is varied. Dense frontage development occurs in the old town and the center, where heating equipment supplied with coal is still in wide use. Residential and service-residential buildings, made in traditional technology are predominant in this area. There are also single-family and multi-family buildings from 50ies–70ies of the last century with gas as a major source of the heat energy. Due to construction technology, quality of materials and the date of construction those buildings are often not insulated and very energy-intensive. Owners of such buildings due to the great demand for heat, often choose the cheapest energy carriers, which still remain solid fuels. The old town and the city center are surrounded by a ring of housing estates with a majority of residential multi-family buildings constructed at various periods from the 1950s to the present. The estates are characterized by traditional, industrialized or mixed technology of the development. The development is supplemented by detached, semi-detached and terraced houses built in traditional technology, located mainly in the suburbs (TEA2011).

Buildings representative for the urban structure of Zielona Góra, showing the observed correlations between adopted critical parameters such as: age, technology, power supply, technical condition, proprietary and current function were selected for the studies. The studies included so-called buildings recommended by the managers, from whom the data about the operational condition had been received. The purpose of the research was to determine the impact and the distribution of energy and economic parameters on spatial unit in the city. Collected research material has allowed to identify the differences in energy intensity of buildings, distinguishing their functions, technology, and the technical condition. In addition, the city area has been divided into energy zones established according to the predominant way of heating buildings (TEA 2011).

On the basis of the analysis of the data concerning energy consumption and operating costs, obtained by a survey, and statements of owners and managers of the buildings, final energy (FE) in the multi-family buildings and, as a result, the energy quality were estimated. The buildings were classified due to: a major function, area, location, age. The kind of fuel and its usage for heating and domestic hot water were analyzed.

Radial neural network

Application of artificial intelligence in different fields of science is becoming more and more common. Fuzzy logic and artificial neural networks are used most often. Fuzzy logic can be used for analysis of inaccurate concepts containing information belonging to certain degrees of membership in the analyzed set of information (Mrówczyńska 2015; Sztubecka M., Sztubecki I. 2016). The term artificial neural networks must be understood as mathematical algorithms that imitate a behaviour of biological neural networks due to solve technical problems they are faced. Neural networks work well wherever a linear approximation is not applicable to describe the phenomena, because models created with the use of neural networks easily reflect non-linear relations. Artificial neural network were created on the basis of a research in the field of artificial intelligence. Particularly important works concerned work of the nervous system of living creatures and construction of models of structures that occur in the brain. One of the neural networks types are neural networks with radial basis functions (radial neural networks, radial networks), which execute the mapping of the input set in an output set, resulting from the adjustment of many individual functions to the elements of a set of values specified in the limited area of a multidimensional space. Such mapping is local, and mapping of the full input vector $\mathbf{x} \in R^N$ in the output vector $\mathbf{y} \in R^M$ is the result in the form of the sum of local mappings. The mapping is accomplished by radial basis functions network, stored in a general form (Mrówczyńska 2015)

$$\varphi(\mathbf{x}) = \varphi(\|\mathbf{x} - \mathbf{c}\|), \quad \mathbf{x} \in R^N, \tag{2}$$

where the vector $\mathbf{c}$ means selected radial base function center.

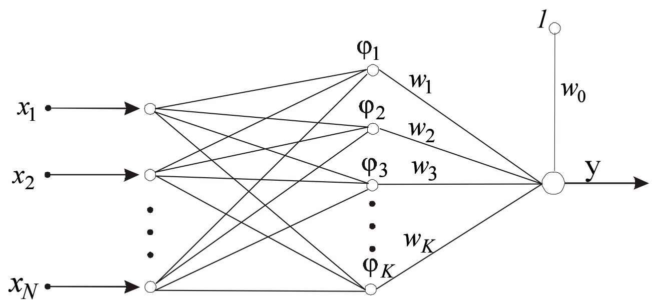

Fig. 1. The general form of a radial basis function network (own study)

The basis function φ, called the kernel, is a function monotonic in relation to the argument. In radial basis functions networks each hidden neuron maps the radial space around a single point or a group of points belonging to a given neighbourhood. The result of the superposition of signals generated by the output neuron allows to achieve a mapping of the whole multidimensional space. In general, the radial network structure is a double-layer (Fig. 1), composed of neurons that perform non-linear mapping in the hidden layer and one linear neuron, representing the output layer. Weight w_0 represents the unit polarity signal (Mrówczyńska 2015).

Radial neural network have been used to modeling PE and FE, consumed in the area of Zielona Góra. In order to model energy consumption, the city was divided into 50 quarters, were the following were considered: predominant development, year of construction of buildings, construction technology and the type of energy supply. The results of analyses carried out with a use of radial networks are presented in Figure 2 (FE and PE) and in Figure 3 (the potential savings in energy consumption).

Figures 2 and 3 presented the results of the modeling of primary energy and final energy usage and the potential energy savings, with the use of radial neural networks. Training and testing the network was implemented in MATLAB Neural Network Toolbox ™, and the graphical representation of the results was made using Surfer® – a product from Golden Software, Inc.

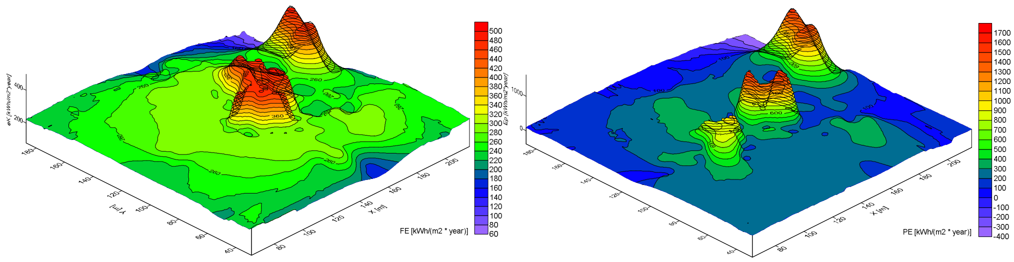

Fig. 2. Modeling of energy consumption of the FE and the PE in the area of Zielona Góra with radial networks (own study)

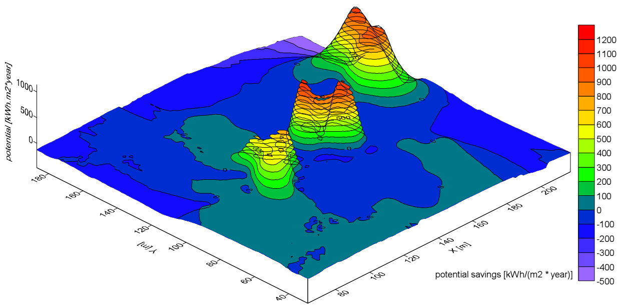

Fig. 3. The potential savings in energy consumption in the area of Zielona Góra with a use of radial networks (own study)

Figure 2 presents the use of the previously mentioned types of energy: blue represents the consumption of about 100 kWh/m^2 year, red is above 500 kWh/m^2 year. Figure 3 shows the potential energy savings: blue represents potential savings of up to approximately 100 kWh/m^2 year, red is the saving potential of 1000 and more kWh/m^2 year. The top values, in the scale, have been allocated to the most intense colors (red and its derivatives).

Discussion and conclusions

There is no consensus in the EU on calculating the PE, there are often differences even at a country level. There are different sets of indicators and different ways of allocation of environmental impact, both between electricity and heat in cogeneration (CHP), plants and the energy sector, and waste management services, when wastes are used as a source of energy.

The presented study shows differences between the consumption of the PE and the FE in the same research area – the town of Zielona Góra. The difference between the consumption of primary energy and final energy in a year is two-and-a-half times, which shows how big are possibilities of environmental protection. The difference in consumption of the PE and the FE for heating and domestic hot water preparation shown in Figure 3, emphasized the importance of a choice of a system for of heat and energy supply in different types of buildings (TEA 2011), in the city. Reducing the impact on the environment depends not only on basic energy efficiency, but above all from heat supply systems, the technology of heat production and the type of fuel used. When the heat supply comes from alternative renewable energy sources or combined heat and power plant, the primary consumption of the PE energy for heating rooms is two-and-a-half to three times lower than in the case of the supply of heat from the power grid. This is consistent with the results presented by Tettey and the team (Tettley *et al.* 2016).

The value of the PE provided tin Poland does not decrease as fast as the FE, which is associated with an increase in the energy efficiency of the building substance, mainly due to the excessive use of fossil fuels and still insufficient use of energy from renewable energy sources. Therefore, it is important that the method of calculating the impact on the environment in the form of the PE indicator, was consistent and comparable in all EU countries, because less of the FE energy does not necessarily mean that the impact on the environment is lower.

Participation of cities in the global energy consumption also continues to grow. There is no indication that this trend will change, as the population growth, increasing demand for construction services and raising level of comfort, with the increase in time spent in buildings, will provide the continuation of the upward trend in energy demand. Therefore, understanding how cities consume energy becomes extremely important in order to mitigate the growing environmental problems and the increase in global energy consumption. Scientists proposed methods for prediction of a city energy consumption in for planning purposes. Not in any case the applied model will identify the optimal solution. Study of energy efficiency in buildings have proven, that the reason for less efficient use of the sources allocated to increase energy efficiency can be the lack of users' experience, and lack of expertise needed to make the thermal insulation of buildings and mistakes made during renovations (Zvaigznitis *et al.* 2015; Mrówczyńska *et al.* 2014). Hence it is important to minimize the consumption of primary energy with, at the same time, optimal selection of ecological quality of the energy carriers.

The relationship between the urban structure of the city, and energy consumption, taking EU policy directions into account, indicates the urgent need to introduce documents that shape the local spatial policies, and the indicators system, to ensure the implementation of these directions, and creating systems monitoring and managing the development in a controlled and balanced way. Management at the local level is desirable because it fulfills specific objectives by improving in three areas: increased energy efficiency of buildings in designated urban areas, energy savings and reduction emmisions of CO_2. Regardless, it seems that a necessary condition for energy management at the city level is a development of complex programs, especially for inner-city zones, that will contribute to energy savings. Another instrument of energy policy is informing buyers about buildings' energy efficieny in terms of fuels and energy costs. Municipalities and cities in Poland do not supervise energy costs balance in details by districts, estates in the city structure. Due to a lack of examples, experience and detailed regulations, the methods and scope of activities and priorities must be created from the very beginning (Grossmann *et al.* 2016). The need to link city-level activities with wider monitoring of the effects of local politics seems to be the key. Lack of knowledge, skills, and data in municipalities generate high costs of making local policy plans. City policy should support changes to increase the energy efficiency of buildings. Energy policy should be more diverse. It would be advisable to run programs to promote energy-efficient construction, so as to recommend potential investors beneficial solutions along with a possibility of financial support (Fig. 4).The new financial perspectives 2014–2020 enables the modernization of the technical infrastructure in order to reduce transmission losses. These measures may also be used to increase energy efficiency, mainly through the thermal upgrading and the modernization of energy sources. However, it requires strategic action of local authorities.

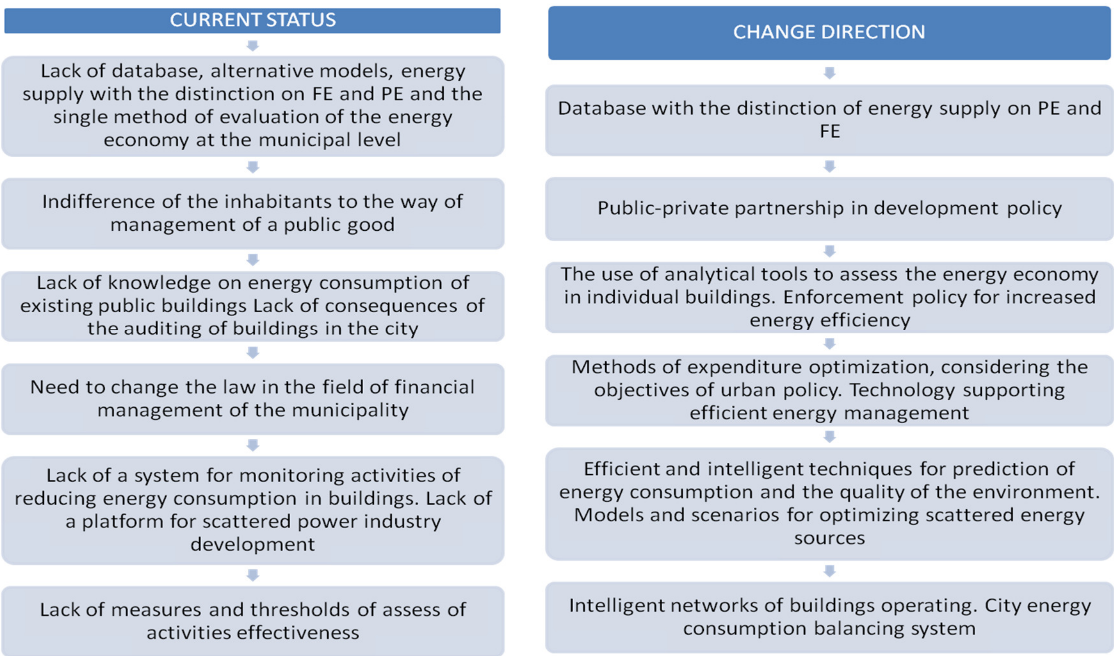

Fig. 4. Recommendations for shaping local policy

EU energy policy indicates the purpose to be reached by Member States (Giacomarra, Bono, 2015). Each State must build your its own way to reach it. First of all, a convenient and uncomplicated legal system for promoting investment in construction to reduce energy consumption needs to be created.

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