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Regional Inequalities in Residential Energy Use of Hungarian Urban Areas

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Abstract

Purpose of the article: Cities account for 60–80% of global energy consumption, and based on projections the development of urban areas will be the main engine of energy use growth in the future. Understanding and analysing the urban energy use and clarifying social and spatial inequalities is essential to make conscious energy policy decisions and gather feedback. A clear road map is needed for implementation of policy on decentralized energy.
Methodology/methods: The analysis covers 23 Hungarian towns with county rights and Budapest during the period of 2010–2015. Simple statistical indices are calculated: the range ratio, range, relative range, dual index, standard deviation, relative standard deviation, absolute average difference.
Scientific aim: The spatial distribution of energy use may contribute not only to understanding the decentralization process of energy systems but to forming a new energy policy that moves towards regional level and is highly decentralized. In this study, our main objective is to examine the Hungarian residential energy use revealing the regional disparities of urban energy use.
Findings: In the case of the examined cities, significant inequalities and large spatial variances were not revealed with regard to the indicators of urban energy consumption (*i.e.* residential electricity consumption per household, residential gas consumption per household). However, the already small territorial differences typically decreased between 2010 and 2015.
Conclusions: We conclude that significant differences regarding urban (23 Hungarian towns with county rights and Budapest) energy use were not experienced.

Keywords: residential energy use, disparities, Hungary, dual index, electricity, natural gas

JEL classification: R10, R11, Q49

Introduction

Cities account for 60% to 80% of global energy consumption and based on projections, the development of urban areas will be the main engine of energy use growth in the future (Sharifi, Yamagata, 2016). According to the World Bank database SE4ALL (2018), globally circa 210 million people without access to electricity live in urban areas and furthermore, approximately 500 million people still lack access to clean cooking facilities.

Energy (energy use and energy management) is managed in a complex way in the theories of sustainability. All three pillars of sustainability (society, environment, and economy) are inseparable from the energy sector, because energy consumption causes so many externalities that threaten welfare in the long run. Most environmental problems are in close connection with energy use and production. According to one report (IPCC, 2014), in 2010 transport as a whole was responsible for 14% of total global emissions, while the contribution of the energy sector was 35%.

Based on the theoretical overview, energy (as a production factor, and energy use, in addition, smart grids, or energy efficiency potential in buildings or resilience) plays only a marginal role in urban research. However, in the field of energy economics, it is a central topic of many studies. Most of them focus on the smart city concept or urban energy resilience (for more details see Drobniak, 2017) as a tool for sustainable development and to improve well-being.

Hereinafter our main objective is to examine the Hungarian residential energy use revealing the regional disparities of urban energy use. This study can be considered as a starting point for comprehensive research focusing on smart energy city concept. Here we note, a part of this study was previously published in Hungarian (Nagy, Sebestyénné Szép, Szendi (2018): Területi különbségek a magyar megyei jogú városok energiafelhasználásában – I–II. rész. Területi Statisztika, 58(5), pp. 447–461; 58(6), pp. 551–566).

1. Literature review

Druckman, Jackson (2008) conclude that two key areas are needed to achieve changes to reach the goals of sustainable development – in line with the report of the Brundtland Commission called *Our Common Future* (UN, 1987). It is important to keep our lifestyle and economic processes within the carrying capacity of the Earth and to decrease resource use and waste production. In addition, the reduction of social disparities and achieving environmental fairness (when a community is poor in environmental goods and rich in environmental drawbacks) is a desirable goal. Understanding and analysing these research fields and clarifying social and spatial inequalities will be essential to make conscious energy policy decisions and gather feedback. The spatial distribution of energy use may contribute not only to understanding the decentralization process of energy systems but to forming a new energy policy that moves towards regional level and is highly decentralized. A clear road map is needed for implementation of policy on decentralized energy (Csák, 2015; Fabók, 2015).

Interpretation of the decentralization of energy systems can be carried out in two ways. The first approach emphasizes technical issues; the second one is based on the (energy and regional) policy. Both approaches are explained below in more detail.

In the case of electrical power generation, transmission and distribution process, it is no longer true that a few big producers supply many consumers (industrial consumers and the residential sector) (Csák, 2015). With an increasing share of renewable energy sources such as solar panels, small hydroelectric power plants, or wind turbines, many consumers are becoming producers as well. Their general characteristic is that they are scattered in space. Today not only large energy companies (*i.e.* load following power plants and base load power plants) do buy and sell their power, and in parallel with that, the function of these power plants changes as well. In relation to this issue, there are many points of view (hereinafter based on Gács (2018) study). According to Szőcs (2017), the necessity of base load power plants is disputed (in his view, the power plants fuelled by natural gas and operating as load following power plants are becoming more and more important). He argues that weather-dependent renewable energy has practically zero variable cost, significantly decreases the market price and generates a great loss for conventional power plants, making them unprofitable. The main role of conventional power plants is to ensure capacity and implement the basic principles of energy security; this is known as the 4A concept. This concept is based on APERC (2007):

1) affordability;
2) availability;
3) accessibility;
4) acceptability.

Ősz (2017), on the other hand, stresses the importance of base load power plants, as in his view 'the increasing renewable generation capacity forces the base load power plants into load following. This changing philosophy recognizes the capability of heat and nuclear power plants for flexible operation.' (Ősz, 2017, p. 29). The spatial variation of generation, transmission, distribution and consumption of energy is undergoing changes: from the one side a decentralization process is happening – renewable energy technologies are stationary and can be interpreted at regional level (Csák, 2015). On the other hand, an integration process of the electricity supply – transmission networks and electricity market – can be observed (see the 3rd Energy Package of the European Union[1]. As Fabók (2015) concludes, even a super system on a Pan-European scale may emerge.

Another approach of decentralization is emerging and raises the issue of integration of energy policy into regional policy. Fabók (2015) describes four different scenarios, from which – from our point of view – the last one is the most interesting. This scenario makes the issue of energy into a central question in regional policy, exceeding the traditional urban development and the frame of local government (Fabók, 2015). The different approaches of the green city, sustainable city, eco city and smart city theoretically can be linked to these topics. Among the empirical evidence (best practices), we can find the initiative called the Covenant of Majors, which brings together thousands of local governments that are voluntarily committed to implementing climate and energy objectives (Covenant of Mayors, 2018).

2. Methodology

In this study, the regional disparities and the spatial distribution of Hungarian urban energy use (electricity use and natural gas consumption) are examined. The analysis covers 23 Hungarian towns with county rights and Budapest during the period of 2010–2015. The 23 towns are the following: Békéscsaba, Debrecen, Dunaújváros, Eger, Érd, Győr, Hódmezővásárhely, Kaposvár, Kecskemét, Miskolc, Nagykanizsa, Nyíregyháza, Pécs, Salgótarján, Sopron, Szeged, Székesfehérvár, Szekszárd, Szolnok, Szombathely, Tatabánya, Veszprém, and Zalaegerszeg.

Annual data as listed below are applied in the calculations collected from the Hungarian Central Statistical Office (KSH): the gross income (local currency unit LCU); the resident population at the end of the year (data

[1] Parts: Directive 2009/72/EC, Directive 2009/73/EC, Regulation (EC) No 713/2009, Regulation (EC) No 714/2009, Regulation (EC) No 715/2009.

calculated further from finalised data of the population census); the number of household electricity consumers; the volume of electricity supplied to households (thousand kWh); of the total volume of gas supplied, the volume of gas supplied to households (not recalculated) (thousand m^3); of household gas consumers, and the number of those using gas for heating.

Based on these data we created the following indicators:

1) of the total volume of gas supplied, the volume of gas supplied to households (not recalculated) per rate of household gas consumers number using gas for heating – hereinafter (simplified): *residential gas consumption per household (m^3);*
2) the volume of electricity supplied to households per number of household electricity consumers – hereinafter (simplified): *residential electricity consumption per household (kWh);*
3) gross income (LCU) per resident population at the end of the year (data calculated further from finalized data of the population census) – hereinafter (simplified): *income per capita (HUF).*

Initially, simple statistical indices are calculated: the range ratio, range, relative range, dual index, standard deviation, relative standard deviation, and absolute average difference. The definitions are presented in Table 1.

3. Results

No significant differences between the rural and urban (23 Hungarian towns with county rights and Budapest) energy use have been found. According to the KSH (2018) database, while in 2015 37.5% of the Hungarian population lived in one of the 23 cities with county rights or in Budapest, 37.3% of the volume of electricity supplied to households and 40.4% of the volume of gas supplied to households were concentrated here. However, the question arises as to what differences can be observed among the energy use of the examined cities.

In Figures 1–2, the vertical and horizontal lines mark the arithmetic mean of Budapest and the 23 cities with county rights related to the selected indicators, highlighting whether the examined settlement has a value below or above average. In every figure, four well-separated groups of urban areas can be observed: cities in the upper right quarter have above-average income and energy consumption. Probably these cities are in unsustainable pathways (but here we note that this judgement is based on few indicators,

Table 1. Applied indicators measuring the spatial polarization.

Range ratio	The range ratio is the ratio of the maximum and minimum values in the range.
Range	The range is simply the difference between the highest and lowest observations.
Relative range	The per cent *relative range* refers to the percentage ratio of the *range* to the average value *in* the set.
Dual index	The dual index is defined as the ratio of mean income of those above the population income to those below the mean.
Standard deviation	The *standard deviation* is a statistic that measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance. It is calculated as the square root of variance by determining the variation between each data point relative to the mean.
Relative standard deviation	The relative standard deviation is a standardized measure of dispersion of a probability distribution or frequency distribution.
Absolute average difference	The absolute average difference is the *average* distance between each data point and the *mean.*

Source: Nemes Nagy, 2005, pp. 4–7.

and we cannot make far-reaching conclusions). Cities in the lower right quarter have an above-average income, but the inhabitants appear to be more energy conscious, as the residential energy use is lower (below average). Just a few cities (2–3) tend to fall in the upper left quarter, and actually this is the most unfortunate case: the income is below average, the energy use of households is above average, and this situation cannot be determined as sustainable. In the cities in the lower left quarter, both income and energy use are below average.

In the case of residential electricity consumption per household – in our view – the individual consumer habits have a greater effect. Actually, the economic structure of the cities is less relevant. A significant part of the Hungarian cities with county rights has an average value regarding the residential electricity consumption per household (Figure 1). The difference from the average is more than 15 per cent for Dunaújváros, Nagykanizsa, Zalaegerszeg, Budapest, Érd and Győr. For the latter three cities we can see the combination of above-average income per capita with above-average electricity consumption, which can be explained by a higher living standard (and quality of life).

Examining the residential gas consumption per household (Figure 2), it was found that – similar to the residential electricity consumption per household – the indicator is scattered around the average for a significant part of the selected cities. The difference exceeds 15 per cent in the case of Dunaújváros, Kaposvár, Miskolc, Szeged, Salgótarján, Érd, Szekszárd and Tatabánya. The residential gas consumption per household shows values above average for the latter four cities and this is coupled with income per capita that is also above average (with the exception of Salgótarján).

In order to visualize the differences among the selected cities (regarding the selected variables), the Standard Deviation method is

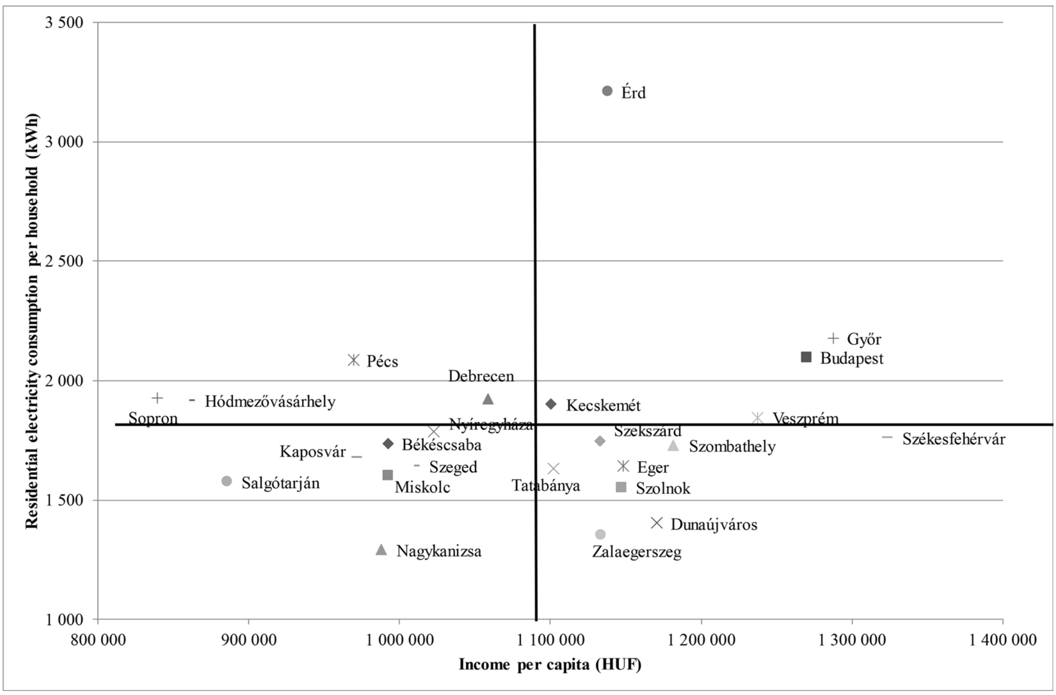

Figure 1. Position of selected cities with regard to the residential electricity consumption per household (kWh) and the income per capita (HUF) (2015). Source: own compilation based on KSH (2018) database.

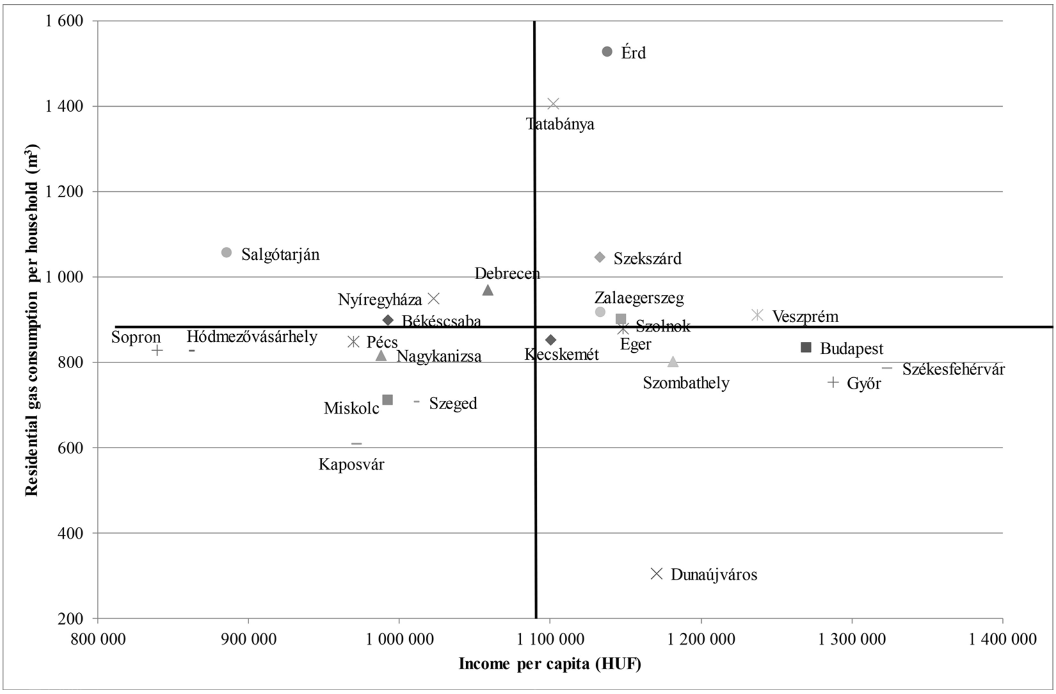

Figure 2. Position of selected cities with regard to the residential gas consumption per household (m³) and income per capita (HUF) (2015). Source: own compilation based on KSH (2018) database.

applied and the distribution of data was displayed with a box plot chart (Figure 3). Here the outliers have been filtered out and the results slightly differ from other empirical

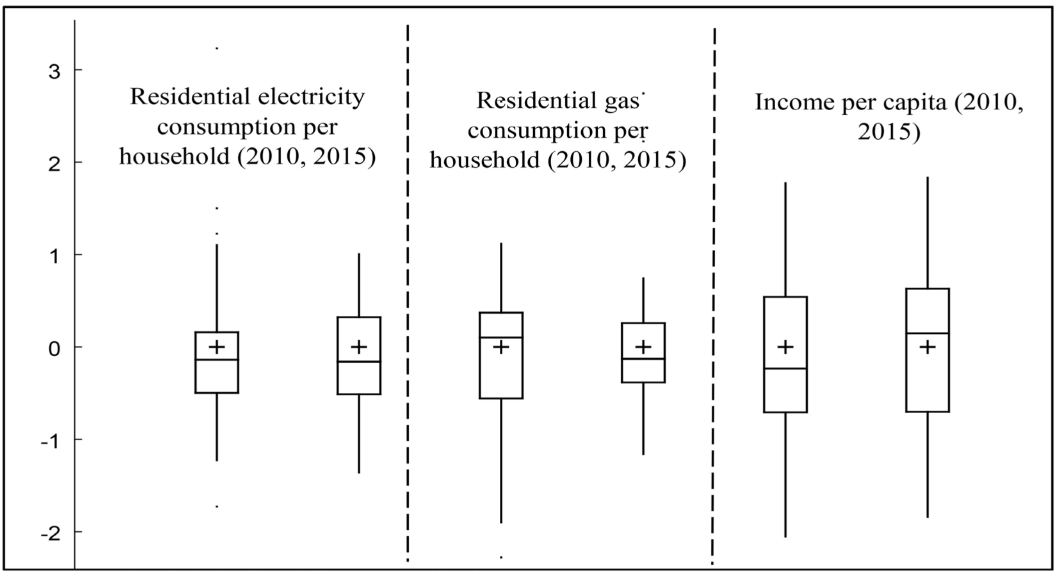

Figure 3. Box plot graph with regard to the residential electricity consumption per household (kWh), residential gas consumption per household (m³), and income per capita (2010, 2015). Source: own compilation based on KSH (2018) database.

Table 2. Empirical results of spatial polarization.

	Residential electricity consumption per household (kWh)	Residential gas consumption per household (m^3)	Income per capita (HUF)
2010			
Max	3,106.39	1,631.85	1,087,438.94
Min	1,233.43	258.88	678,824.00
Arithmetic mean	1,886.01	892.73	898,106.29
Range ratio	2.52	6.30	1.60
Range	1,872.96	1,372.96	408,614.94
Relative range	0.99	1.54	0.45
Dual index	1.31	1.57	1.22
Standard deviation	377.62	278.22	106,824.73
Relative standard deviation	20.02	31.17	11.89
Absolute average difference	247.37	194.10	87,787.24
2015			
Max	3,209.85	1,527.40	1,323,747.90
Min	1,292.70	306.06	839,022.91
Arithmetic mean	1,801.89	881.21	1,081,828.14
Range ratio	2.48	4.99	1.58
Range	1,917.15	1,221.34	484,724.99
Relative range	1.06	1.39	0.45
Dual index	1.32	1.40	1.23
Standard deviation	374.44	235.45	132,020.89
Relative standard deviation	20.78	26.72	12.20
Absolute average difference	239.77	147.64	109,082.97

Source: own calculations based on KSH (2018) database.

results (Table 2). Table 2 indicates the main results of the simple statistical methods measuring the spatial disparities in 2010 and in 2015. The change of dual index may reveal social differences (hereinafter we highlight this indicator). The spatial differences regarding the residential electricity consumption per household and the income per capita are stabilized between 2010 and 2015. The inequalities significantly decreased in the case of natural gas consumption (per household). This is almost certainly related to the fact that between 2010 and 2012 a significant part of the society (the 1st–3rd–4th–5th–6th–8th–9th income deciles) decreased their energy expenditures. These households restrained their consumption and many switched energy sources, at least partly, from natural gas to cheaper sources (typically the expenditures on solid fuels, especially on fuel wood, increased). In subsequent years, the positive effects of energy efficiency improvements financially supported by the European Union funds could be realized. As a result of the utility cost reduction programme (2013–2014), with special regard to the price effect, the social disparities related to the energy expenditure per household declined. However, residential energy consumption increased (this complex process is presented in detail in Sebestyénné Szép, 2018).

The results (small territorial differences in the case of selected cities) can be explained by the rebound effect and by the high human development index (HDI) values. According to Sorrell (2009) 'the rebound effect is an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency' (Sorrell, 2009, p. 1457). The rebound effect shows as a result of energy efficiency improvements, how much the additional residential energy use is, and what percentage of potential energy savings are lost. Madlener, Alcott (2009) conclude that the size of the rebound effect in the long run is between 10% and 30%. A previous study of ours (Sebestyénné Szép, 2013) identifies a lower result: the rebound effect associated with the residential energy consumption was 15% in East-Central Europe between 1990 and 2009. This finding is crucially important from the point of this study; this fact can explain why no significant difference can be detected among the residential energy use patterns in the selected cities. Probably in the richer, more successful cities (with higher income per capita), the residents can afford to buy modern (more energy efficient) household devices. They heat with better boilers (and probably they use gas for heating), but in the poorer and less successful towns many of the households switched the energy source for heating from electricity and natural gas to wood (in the context of rising energy prices). So the residents living in cities with higher gross income use more appliances and other energy-consuming devices, but their equipment is newer and more efficient, so its energy use is lower as well. By contrast the urban population in the poorer cities (with lower gross income per capita) is less able to afford to replace household appliances. The two processes actually balance each other: the richer use more, but in more efficient way, the poorer uses less, but with higher energy intensity.

Many studies focus on the relation between the degree of development of a country and its energy consumption development (this former is usually measured with HDI) (*e.g.* Arto *et al.*, 2016; Steinberger, Roberts, 2010; Martínez, Ebenhack, 2008; Dias *et al.*, 2006; Pasternak, 2001). These papers emphasize that the energy use patterns of countries with HDI of 0.7–0.9 are similar, while significant growth in the energy use level is achieved in countries with HDI over 0.9. Pasternak (2001) concludes that there is no country with annual electricity consumption below 4,000 kWh per capita that has an HDI of 0.9 or higher (the examined time period in this case was 1980–1997). Above 5,000 kWh per capita, no country has an HDI under 0.9 (cited in Arto *et al.*, 2016). These publications describe this relation at national level, but analysis of the lower spatial levels (especially the urban analysis) is quite rare. This can be explained by limited data and methodological problems. Probably – if we start from the context described above – a similar process can be experienced at the urban level as well. So above a certain level of HDI – naturally it is achieved in all examined cities – increase in per capita energy consumption is no longer expected (the Hungarian HDI was 0.836 in 2015 according to UNDP (2018)). So development, or success, is separate from the additional energy use – and partly related to the Kuznets curve – the dematerialization is achieved. This is confirmed by Csák (2015). He concludes that the consumer culture is homogeneous – including also the opportunities as well – so the consumption of an area is determined by the intensity of its economic activities.

4. Discussion

Our current study focuses on the environmental dimension of smart cities as a critical field of the smart city concept. Investigating the smart solutions that are running and under implementation, it can be stated that the application of environmental solutions plays a significant role. The smart environment subsystem contains factors such as the use of renewable energy resources, ICT solutions in smart grids, smart metering, pollution monitoring and control, building reconstruction, green architecture and energy efficiency. Furthermore, it covers the issues of waste and water management as well. From our perspective, efficient energy use is the most important. Most of the concepts emphasize it, such as Nam, Pardo (2011); Lados (2011); Lombardi *et al.* (2012); Cohen (2014); Stankovic *et al.* (2017) and the ISO 37120 standard as well. Energy efficiency improvements can bear many positive external effects, such as direct effects (increasing the value of real estate, enhancing quality of life, intensifying tourism, development of the local smart business environment). Based on Giffinger (2007) the development of a smart environment can also lead (directly or indirectly) to negative impacts, and this phenomenon is called the rebound effect. This suggests that the energy use of smart cities should be examined in more depth and the smart developments have to have a strong environmental focus.

5. Conclusion

In this study, we examined the regional disparities of urban energy use (electricity use and natural gas consumption) in Hungary. The analysis covered 23 Hungarian towns with county rights and Budapest during the period of 2010–2015. Simple statistic methods (such as spread, range, mean, standard deviation, dual indicator – applicable indicators for measuring the spatial polarization) are applied. The following findings have been made:

Significant differences between the rural and urban (23 Hungarian towns with county rights and Budapest) energy use have not been experienced.

In the case of the examined cities, significant inequalities and large spatial variances have not been revealed with regard to the indicators of urban energy consumption (*i.e.* residential electricity consumption per household, residential gas consumption per household). Furthermore, the already small territorial differences typically decreased between 2010 and 2015.

In summary, focusing on the dimension of smart environment, it can be concluded that significant spatial inequalities do not arise among the Hungarian cities with county rights in relation to the examined indicators of electricity use and natural gas consumption.

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