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Territorial Characteristics of Energy Modernization: The Case of Panel Buildings in Pécs

ABSTRACT

The energy efficiency of residential buildings is a key issue in contemporary urban development, as appropriate external renovations can result in a significant reduction in harmful emissions. In Pécs, a substantial proportion of the housing stock consists of panel-type apartment buildings, whose distribution across ten urban districts exhibits pronounced territorial differentiation. The aim of this paper is to examine the spatial distribution of energy modernization efforts in these panel buildings. A further objective is to identify the differentiating factors behind the disparities among districts and to propose development strategies for areas that have been partially or entirely excluded from modernization processes. The study primarily relies on secondary data derived from previous energy modernization assessments, provided by the municipal government. Following statistical processing, the data were visualized using geographic information system (GIS) software to reveal and interpret spatial differences. The analysis of influencing factors was complemented by insights gained from semi-structured interviews with the head of the city operations department. Field surveys were documented through notes and photographic records. The findings confirm earlier assumptions: western districts have the highest proportion of renovated buildings, southern districts represent transitional zones, while eastern districts remain the least modernized. The results also highlight territorial influencing factors that lead to significant deviations in the energy modernization status among the districts. The study concludes with recommendations for integrating panel buildings that have so far been omitted from energy modernization programs, outlining potential tools and approaches for their inclusion.

Keywords: *energy modernization, energy efficiency, panel buildings, Pécs, housing estates, urban development*

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INTRODUCTION

In the second half of the 20th century, Pécs played a prominent role in economic development policies, which led to a significant wave of apartment block construction in the city from the 1960s until the political transition. The aim was to alleviate the housing shortage, primarily through the construction of quickly implementable panel buildings. Entire new districts were established using panel technology, while in existing areas such developments occurred only sporadically. Most of the panel buildings were constructed on the urban periphery, thereby expanding the built-up area. Megyerváros—today the largest district of Pécs—was previously an undeveloped area (Sipos, 2015a), whereas a small airport once operated where Uránváros is now located (Pilkhoffer, 2010).

Today, Pécs has become a spatially extensive city, with its districts separated from one another due to their formation in different historical periods. In the western part of the city, the tertiary sector, primarily linked to educational institutions, is dominant, while in Megyerváros residential functions prevail. It is apparent in the cityscape that the panel buildings in various districts have undergone modernization to differing degrees, and their locations have resulted in significant price disparities (Békés et al., 2016).

One of Pécs's strategic development goals is to improve the energy efficiency of panel buildings supported by several funding programs (Municipality of Pécs, 2023, 2024). These initiatives form part of a LIFE programme aimed at improving air quality. With the exception of one, all panel buildings in the city are at least thirty years old, and many are over sixty (Pilkhoffer, 2010). While numerous residential buildings have already undergone energy-related modernization, most of these were implemented in more affluent districts, often financed by the residents themselves. In contrast, less affluent communities could only afford upgrades through external funding (Hungarian Energy Efficiency Institute [HEEI], 2021).

Hungary's accession to the European Union brought the issue of climate neutrality to the forefront (European Commission [EC], 2011). According to studies, outdated residential buildings may account for up to one-third of greenhouse gas emissions (Horkai et al., 2018). As a result, the EU's energy strategy emphasizes the modernization of the building stock. While government subsidies had previously supported housing renovations, since the 2010s this responsibility has largely shifted to municipalities. Given that these municipal funds do not cover the full cost of renovations, only wealthier communities have typically been able to take advantage of them. Modernized buildings not only reduce utility costs but also increase property values (Ertl et al., 2021; Horváth et al., 2013).

Energy modernization has been receiving increasing attention both nationally and internationally. In addition to the environmental aspects of urban development, modernization efforts also have a significant impact on property values and creditworthiness (Hajnal et al., 2022; HEEI, 2024). Moreover, their social effects are substantial (Koltai et al., 2021). Understanding these processes requires energy modelling (Csoknyai, 2022; Bene et al., 2023) and typological classification of the residential building stock (Mándoki, 2024). In the context of urban dynamics in Pécs, the presence of the university is also a key influencing factor (Császár et al., 2021; Erdős et al., 2021).

The available data clearly reveal the spatial distribution of energy modernization, which enables a comparative analysis of the city's districts. It is important to note that Pécs played a prominent role in the national panel programme (2001–2006), covering one-third of the renovation costs through municipal funding, with the remaining expenses borne by the state and homeowners. As a result, initial modernization measures were implemented in many panel buildings. However, following the termination of this tripartite financing model, the pace of renovations slowed down.

Pécs now aims not only to improve air quality but also to develop a comprehensive database that supports prospective homebuyers by providing information on the modernization level and expected utility costs of selected properties. According to plans, this database would be updated annually, though its success depends on the availability of accurate baseline data.

LITERATURE REVIEW

The issue of energy modernization in existing buildings has long been a subject of interest for professionals in regional and urban development, policymakers, and academic researchers alike. Energy modernization has several practical benefits, most notably the local improvement of air quality. The larger and more densely populated a settlement is, the more significant air quality improvements can be achieved through the renovation of outdated buildings and the proper design and implementation of new constructions.

In relation to these themes, our literature review has identified five distinct research directions. In addition to exploring the environmental and property market implications of residential building modernization, these studies examine the energy efficiency of panel-type apartment buildings and their role in urban development. Our review concludes with a logically structured assessment of studies focused on real estate in Pécs, highlighting the scholarly embeddedness of our current research objectives.

It is observable that before the political transition, research in this field was primarily carried out in Western Europe, as territorial and urban development in the socialist bloc was based on a different economic and political model, and climate change was not yet a central concern. In Hungary—and in Pécs specifically—the first investigations addressing not only the causes and effects of climate change but also individual quality of life began in the 1990s.

These studies were partly motivated by the fact that Hungary, following the signing of the Association Agreement, began aligning with the environmental policy frameworks of the European Union from the early 1990s onward. The first step was the PHARE programme (Heil, 1998), which supported the institutional, legal, financial, and infrastructural foundations of environmental protection; however, it did not yet provide funding for building energy modernization.

A major turning point came with Hungary's accession to the European Union in 2004, when the country signed several agreements aimed at reducing harmful emissions. One of the most important of these is the strategy to achieve a low-carbon economy by 2050 (EC, 2011). The strategic priorities published by the European Union in 2011 explicitly address residential buildings, mandating that newly constructed homes be “low or zero energy,” while existing buildings must undergo substantial renovation to reduce emissions (EC, 2011). In response, a number of studies were published in the mid-2010s that outlined the toolsets necessary for implementing these 2011 directives (Boßmann et al., 2012; Cevik et al., 2015). These studies emphasized, among other findings, that poor exterior insulation of residential buildings significantly contributes to emissions, thereby making their modernization a top priority.

As a result of the EU’s energy modernization targets, further studies have emerged focusing on the modernization of residential, public, and commercial buildings. The earliest of these addressed not only the benefits of modernization but also the frameworks of financial support and regulation (Copenhagen Economics [CE], 2012). In Hungary, a growing body of research has also examined the outcomes of building modernization efforts, shedding light on the energy condition of the domestic residential building stock and its potential for modernization (Egedy, 2017).

Among the most recent findings, Bene et al. (2023) is particularly relevant to the present study, as it highlights the territorial disparities of certified energy performance data. The research consensus is that modernization has a substantial impact on energy savings, making such investments cost-effective and offering residents tangible economic benefits. Furthermore, these studies point out that a well-designed regulatory framework encourages homeowners to utilize available subsidies more confidently.

A clearly distinguishable thematic strand within the literature involves analyses of the relationship between property prices and energy modernization. Research in this area (Horváth et al., 2013) has primarily focused on international housing markets, but also notes significant price increases observed in Budapest following the renovation of panel buildings. This line of inquiry includes studies evaluating the impact of energy modernization on real estate prices (Ertl et al., 2021) and mortgage interest rates (Hajnal et al., 2022) in the Hungarian context. In line with expectations, the findings indicate that the more energy-efficient a residential building is, the higher its market value. Similar conclusions are drawn in studies examining university towns, which reveal the favorable position of higher-ranked settlements based on student mobility (Császár et al., 2021), the spatial and economic effects of higher education institutions (Erdős et al., 2021), and inter-municipal differences in housing prices (Békés et al., 2016).

Although panel-type apartment blocks are widespread across Europe, they are particularly characteristic of the former socialist bloc. These buildings offered several advantages, such as relatively fast and cost-effective construction. However, their disadvantages include the minimal external insulation and poor thermal performance of windows and doors—features that reflected the building standards of the time and the availability of cheap, Soviet-imported energy. Consequently, their “factory-standard” energy consumption is unfavorable, raising important questions regarding their modernization potential.

In recent decades, many studies in both Hungarian and international contexts have addressed panel buildings and their energy modernization (Egedy, 2000; Farkas et al., 1997; Szabó & Bene, 2019). Some of these investigations have focused on residential building typologies, with particular emphasis on panel structures (Mándoki, 2024). Others have explored the historical context and motivations behind the panel construction boom (Horkai et al., 2018), or outlined possible future scenarios in relation to modernization strategies. The literature also emphasizes that panel buildings provide long-term housing for a significant share of the population, thus their modernization warrants priority attention (Hungarian Central Statistical Office [HCSO], 2016).

Urban development has recently gained growing attention in academic discourse. Many researchers are exploring the potential for upgrading the existing urban built environment. This includes so-called "smart city" research (Egedy, 2017), which integrates modern technologies such as smart ventilation systems to enhance building energy efficiency. The full-scale, one-phase modernization of panel buildings (Perényi, 2008) remains a topic more often addressed in theory than in practice, as renovations are typically implemented incrementally. Nevertheless, the renewal of residential buildings has numerous social and economic impacts. Studies extend beyond factors affecting quality of life (Koltai et al., 2021) to also include economic dimensions (CE, 2012), such as location-induced changes in property value.

The reviewed literature makes it clear that energy modernization of panel-type buildings is not only significant from environmental and economic perspectives, but also plays a vital role in urban development and social policy. Both international and domestic research highlights the benefits of modernization in terms of energy savings, improved quality of life, and increased property values, while also underlining the challenges posed by the outdated design of such widespread building types. Based on the findings, it is evident that the spatial distribution and impact of modernization interventions can vary considerably between districts—especially in cities like Pécs, where the majority of the housing stock comprises panel buildings. Accordingly, the objectives of this study—to map the energy modernization status of panel buildings in Pécs, visualize spatial disparities, analyze influencing factors, and formulate development policy recommendations—are grounded in the existing literature and aim to offer practical insights for local decision-makers by extending its conclusions.

METHODS

The main methodological approach of this study relied on the secondary analysis of statistical data provided by the Department of Urban Management of the Mayor's Office of the City of Pécs. As part of the initial surveys conducted under the LIFE project, the energy efficiency status of all panel-type apartment buildings within the administrative area of Pécs was recorded. Data collection was carried out by PTE Politechnika Ltd., commissioned by the municipality (Gyergyák et al., 2022). The base maps used for visualizing spatial distribution in the geoinformatics environment were also supplied by the Department of Urban Management. Due to the uneven distribution of panel buildings across districts, we applied percentage-based evaluations during data processing.

For spatial visualization, three geoinformatics software platforms were used. First, the base maps from AutoCAD 2022 were exported in .shp format. In the next step, residential buildings were selected and color-coded in ArcMap 10.8 based on their type and external modernization status. Final figure annotations were completed using Inkscape.

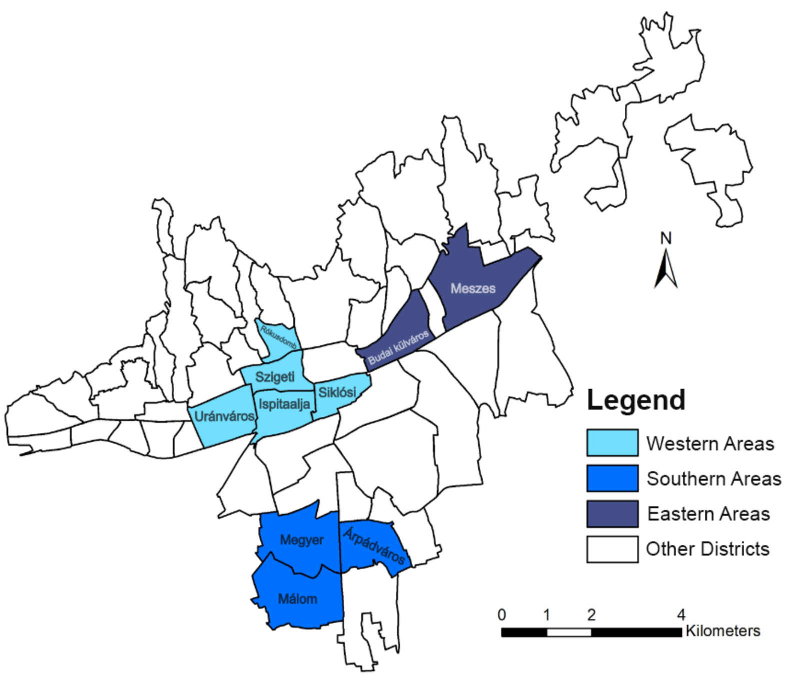
The empirical component of the study began with fieldwork, during which we documented cases of unique energy modernization or visual urban character through photographs. Observational notes were taken to support the evaluative analysis of the secondary statistical data. The results of the primary research were supplemented with semi-structured interviews conducted with the head of the Department of Urban Management. The interview guide addressed the LIFE project database, the role of spatial differentiation factors, and the future tasks and strategic goals of urban management.

The examined districts were categorized into three groups based on their spatial concentration: western, southern, and eastern areas (Figure 1). The dataset analyzed comprised 1,311 panel stairwells, encompassing a total of 26,558 housing units. These were distributed unevenly across the city. At one extreme, the Megyer district accounted for 55% of all panel stairwells, while the Budai Suburb had the lowest share at only 0.1% (Figure 2).

The external energy efficiency upgrades carried out resulted in a largely uniform picture across the ten examined districts. In most areas, nearly all buildings had undergone interventions such as external thermal insulation and/or window replacement, and the remaining districts closely approached this rate. It is worth noting that a 100% rate of external modernization does not preclude the future addition of even more efficient insulation or the replacement of existing windows—particularly in buildings where such interventions were completed more than two decades ago.

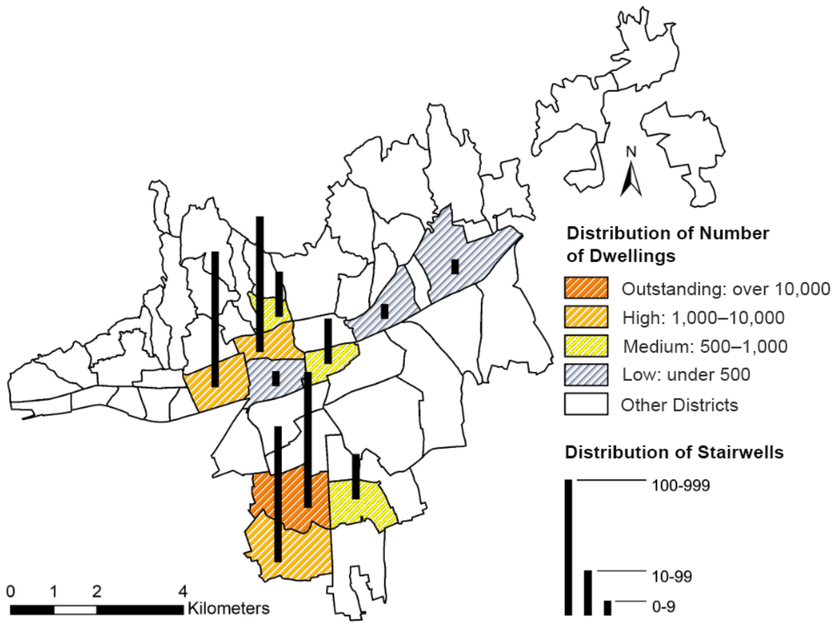
The results of the analysis were grouped into three categories corresponding to the western, southern, and eastern parts of the city. While the buildings show similar energy and technological characteristics across these zones, each area has distinct features rooted in historical, economic, and social development. Based on our hypothesis—founded on these socio-economic differences—we observed a declining trend in the proportion of energy-efficient upgrades from west (98%) to south (93%) and east (86%).

Figure 1. Spatial classification of districts containing panel-type residential buildings.



Source: edited by the authors

Figure 2. Spatial distribution of the number of panel-type dwellings and stairwells.



Source: edited by the authors

RESULTS

Factors Influencing the Energy Modernization Profile of the Western Areas

In the western part of the city of Pécs, there are five areas with panel-type apartment buildings. In descending order based on the number of flats, these are Uránváros, the Szigeti district, Rókusdomb, the Siklósi district, and Ispitaalja (a total of 8,627 flats in 352 stairwells). Compared to the other two examined areas, the western zone has the highest rate of energy-efficient renovations of panel buildings, with only 6 stairwells left unrenovated out of the 352.

Energy Efficiency Characteristics of Panel Buildings in Uránváros

The first panel-type apartment buildings were constructed here starting in 1961 (Pilkhoffer, 2010), meaning that the oldest buildings are now over 60 years old. As these were not only the first panel buildings in Pécs but in the entire country, they still suffer from several "initial design flaws." In terms of the number of panel-type flats, Uránváros is the second largest after Megyer, with 4,093 flats in 133 stairwells. There are a total of eight different standard building designs in the district. Uránváros is well-designed, with a carefully planned layout: the structure is denser in the north and more open in the south. Its sound urban planning is further evidenced by the presence of a large central square (Szilárd Leó Park) and a 17-storey building that marks the district center. Ten-storey buildings line the outer edges of the district, clearly demarcating its boundaries.

Its transport infrastructure is advantageous; Nedtvich Andor Street (Highway 6) runs through it from west to east, providing quick access to the city center. In addition, several smaller roads help relieve traffic from the main route (Figure 3). Among these, Veress Endre Street and Építők Road are particularly noteworthy, as they ensure smooth traffic flow and further enhance Uránváros's relative position among city districts. The local bus network further contributes to this favorable position, with direct connections available to nearly all other districts without transfers.

The area is well-served by economic services, including several large stores and its own market, as well as various sports facilities. Its institutional coverage is also outstanding, with several kindergartens, well-regarded primary and secondary schools, and university buildings. Due to the high age of its building stock, its favorable location and features, and the emergence of a more affluent population, all panel-type apartment buildings in the district have undergone external energy modernization. One consequence of this, however, is the disappearance of several unique visual elements, such as the three-dimensional window paintings once visible on the façades of four-storey buildings—today, these can only be seen on a few buildings. Despite the improvements brought by energy modernization, this visual uniformity must be mentioned as a drawback.

Figure 3. Energy efficiency distribution of buildings in Uránváros.

Panel-type apartment buildings that have undergone renovation are marked in green; other residential buildings are shown in grey. Source: edited by the author based on data from PTE Politechnika Ltd.

Energy Efficiency Characteristics of Panel Buildings in the Szigeti District

Among the neighborhoods included in this study, together with Rókusdomb, this area is considered one of the most prestigious (Békés et al., 2016). The new four- and ten-storey panel buildings were mostly constructed as brownfield investments, replacing older single-storey houses. A noticeable difference between the western and eastern parts of the district is that the former was built according to more detailed development plans, while the latter developed more rapidly and less coordinately, utilizing vacant plots (Figure 4). The district contains a total of 3,263 flats in 154 stairwells, making it the third largest panel-type apartment district in Pécs. Twelve different panel building types are found here, typically in four- and ten-storey designs. One notable example is the D-10 "TV Panel" designed by Ernő Tillai (Sipos, 2015b).

The district's greatest economic advantage lies in the presence of nearby university faculties. On its western side, along Szigeti Street, stands the Faculty of General Medicine; in the central area, on Rókus Street, the Faculty of Pharmacy; and on its northwestern edge, along Ifjúság Street, a shared campus of the Faculty of Science and the Faculty of Humanities. The presence of these institutions is significant because they attract a large number of international students with stable financial backgrounds, who are willing to pay higher rents to local property owners (Császár et al., 2021). As a result, the service sector in the area has undergone dynamic development, with numerous cafés, restaurants, and entertainment venues now operating.

The district's proximity to the city center also plays an important role in its overall development, as the downtown area is easily accessible on foot, offering additional economic and cultural services. Thanks to the university's proximity and the district's advantageous position within the city, the Szigeti district also demonstrates the characteristic trend of the western areas: full-scale external energy modernization across all panel buildings.

Figure 4. Energy efficiency distribution of panel-type apartment buildings in the Szigeti district.

Renovated panel buildings are shown in green; other types of residential buildings are shown in grey. Source: edited by the authors based on data from PTE Politechnika Ltd.

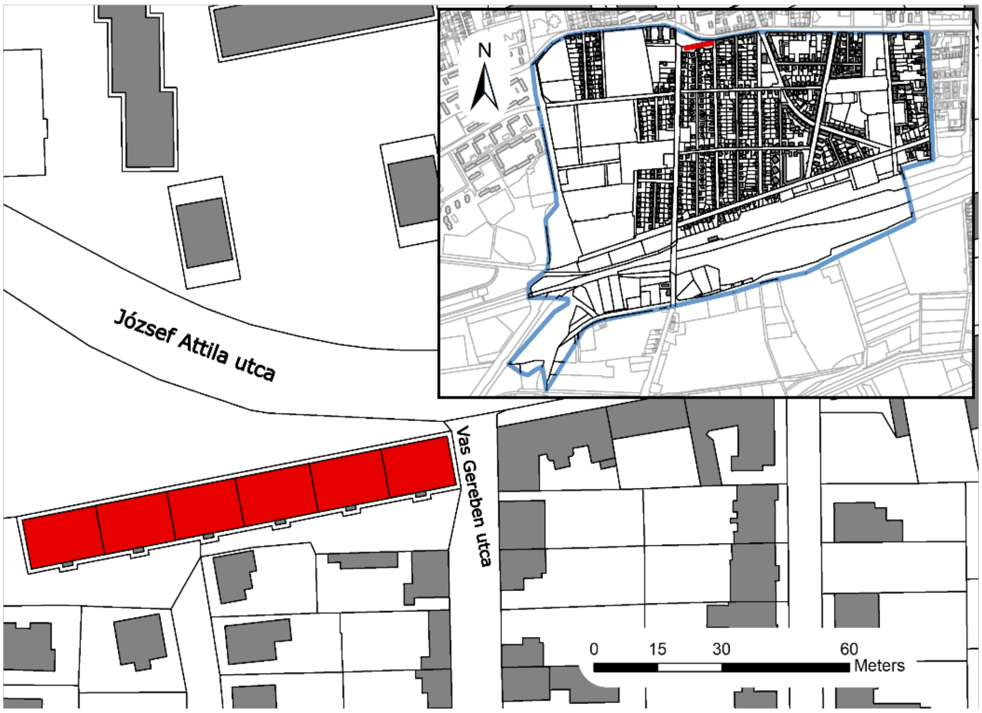
Energy Efficiency Characteristics of Panel Buildings in Ispitaalja

The study area presents a rather peculiar and unique profile. Although its proximity to the Szigeti district might suggest the advantage of analyzing the two areas together, administrative district boundaries necessitate a separate evaluation in this case. The area is not characterized by large-scale housing estate development. The eastern part consists mainly of detached family houses, the southern boundary is marked by Pécs's railway station, and to the west there is a row of small and medium-sized enterprise (SME) facilities. Only in the northern part—adjacent to the Szigeti district—exists a contiguous block of panel buildings, comprising six stairwells and a total of 90 flats, built according to two different standard plans.

Given the proximity to the neighboring Szigeti district, many of its advantages are felt in Ispitaalja as well. Its favorable location within the city, and its closeness to numerous economic and cultural services, contribute to its popularity—even in the absence of external energy modernization. There is, however, a primary reason why such renovations have not occurred. The panel buildings stand directly alongside József Attila Street (Highway 6) (Figure 5), which causes significant noise pollution throughout the day. As a result, these buildings are typical examples of the "good to rent, but not to live in" category. The flats are primarily rented out short-term, mainly to university students (Erdős et al., 2021). Since tenants bear the extra heating costs, owners have little financial incentive to invest in energy modernization.

This is the only district where no such development—as indicated in the section title—has taken place. A functional advantage of this building block is that it provides noise protection for the family houses located directly behind it.

Figure 5. Energy efficiency distribution of panel-type apartment buildings in Ispitaalja, highlighted in red.



Source: edited by the authors based on data from PTE Politechnika Ltd.

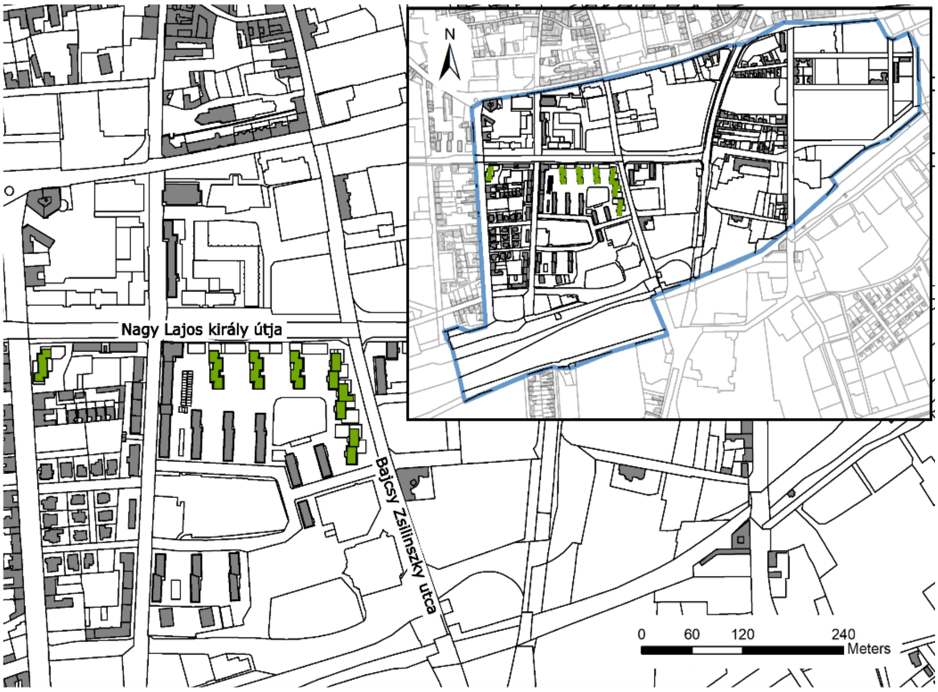
Energy Efficiency Characteristics of Panel Buildings in the Siklósi District

Among the study areas, this district is the closest to the city center, which is reflected in its design. Located in the eastern part of the district (Figure 6), the central market hall exemplifies its core urban role. Also situated here, on a shared campus, are two additional faculties of the University of Pécs—the Faculty of Law and Political Sciences and the Faculty of Business and Economics—which further enhance the district's structural and functional importance within the city. North of Nagy Lajos Király Street (Highway 6), the area is dominated by office buildings and shopping centers, including ÁRKÁD, the largest commercial complex in Pécs.

The areas south of this main road are primarily residential, with eleven ten-storey buildings constructed according to three different standard plans, comprising a total of 501 flats. These buildings, like those in the Szigeti district, were developed as brownfield investments (Rozvány, 2003). The designers' original concept was to create a modern socialist downtown to replace the older inner-city areas. However, the proximity to the main road also results in significant noise pollution, making the flats more suitable for short-term rental.

In line with the broader trends observed in the western districts, all buildings here have undergone external energy modernization, largely due to the district's central location. Nevertheless, as in Uránváros, these renovations have led to a number of losses in the urban landscape. A case in point is the removal of the distinctive pyrogranite cladding from the iconic "pajama houses," K-7 type buildings designed by Ernő Tillai (Sipos, 2015b), during the insulation process. The new cladding features a three-color wavy pattern, which, however, lacks the uniqueness of the original design. In addition to this visual uniformity, signs of erosion are already visible on the "new" surface, suggesting that further renovation work will likely be needed in the near future.

Figure 6. Energy efficiency distribution of panel-type apartment buildings in the Siklósi district.



Renovated panel buildings are shown in green, while other residential building types are shown in grey. Source: edited by the authors based on data from PTE Politechnika Ltd.

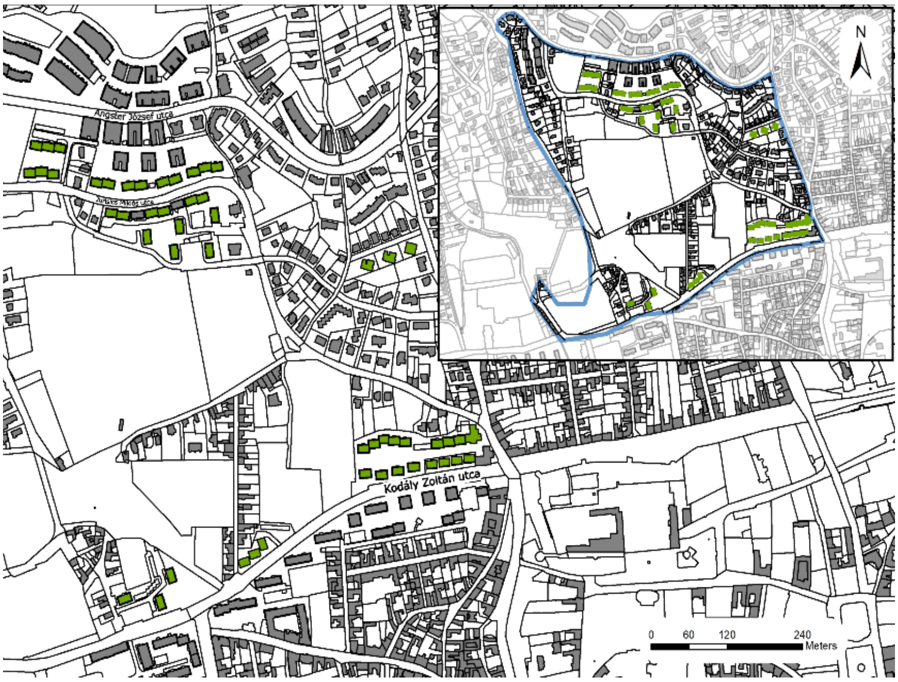
Energy Efficiency Characteristics of Panel Buildings in the Rókusdomb District

Compared to other western districts, Rókusdomb stands out due to its higher elevation and greater social prestige. This area consists of relatively new buildings and offers several advantages, such as its proximity to the city center and its transitional character between the downtown and surrounding green areas. The district contains 680 flats across 48 stairwells, built according to six different panel design types.

Unlike Ispitaalja and the Siklósi district, Rókusdomb was originally developed as a high-prestige residential area. Thanks to its panoramic views and closeness to nature, it provides a desirable living environment. Among all panel-based districts, Rókusdomb contains the most expensive properties (Ertl et al., 2021). Another favorable feature is its generally good utility infrastructure, despite the fact that this may not apply to the more northern parts of the district. The area also hosts a kindergarten and a primary school, as well as the campus of the Faculty of Engineering and Information Technology of the University of Pécs (Figure 7).

Due to the district's higher elevation, access by car or public transport is more time-consuming, making transportation less convenient. Additionally, the availability of economic services lags behind that of other western areas. However, due to its advantageous location and relatively affluent residents, almost all panel buildings in Rókusdomb have undergone external energy modernization. Instances where parts of buildings were not insulated—such as some sections on Jurisics Miklós Street—are exceptional and likely the result of a lack of financial contribution from individual owners.

Figure 7. Energy efficiency distribution of panel buildings on Rókusdomb.



Renovated panel buildings are shown in green, while other types of residential buildings are shown in grey.
Source: edited by the authors based on data from PTE Politechnika Ltd.

Factors Influencing Differences between the Western Areas

This section evaluates three key factors that fundamentally influence the spatial differences observed within the western areas. The first factor is the role of territorial prestige. While Rókusdomb holds a prominent status due to its excellent geographic conditions—reflected in the high rate of energy renovation of panel buildings—the areas tend to show decreasing prestige as one moves further south. A clear example is Ispitaalja, which exhibits the lowest renovation rate not only among the western districts but across all study areas.

The second factor is the role of economic services in shaping spatial differences. The more economic services are available in a district, the more attractive it becomes to wealthier homebuyers. Among the western areas, Uránváros, Szigeti, and Siklósi stand out with a wide range of high-quality economic services. Rókusdomb represents a unique case: despite its high-income residents and prestigious Mecsek Hills location, the district provides fewer economic services compared to the larger western neighborhoods. In Ispitaalja, the low level of economic service provision contributes to its moderate prestige and weaker appeal on the residential property market.

The third factor differentiating these areas is the quality of human services. In this respect, the Szigeti district is the most prominent due to its numerous educational institutions. Uránváros also occupies a favorable position, while the other three western districts fall significantly behind in this regard.

Factors Influencing the Energy Efficiency of Southern Districts

In the southern part of Pécs, three districts contain panel-type apartment buildings: Megyer, Málom, and Árpádváros. These areas differ significantly in terms of their spatial characteristics, structure, and functions, all of which influence their overall energy efficiency. Altogether, these districts comprise 952 stairwells and 11,742 dwellings. Of these, 64 stairwells are still awaiting external refurbishment, resulting in a modernization rate of 93%, which is the second highest among the areas analyzed.

Energy Efficiency Characteristics of Panel Buildings in the Megyer District

Megyer is not only the oldest but also by far the largest district in terms of both area and number of dwellings—not just in southern Pécs, but among all districts analyzed. It contains the highest number of panel-type apartment buildings, with 718 stairwells (Figure 8) and 24 different panel designs, encompassing a total of 14,435 dwellings. Construction of panel buildings began in 1972 and continued until the political transition in the early 1990s. Only one coherent building complex falls outside this timeframe: the 171-unit development on Littke József Street (Sipos, 2015b), which was completed in the 1990s.

The district clearly reflects thorough planning, with the original development plans having been fully realized. Due to its size, it is not surprising that Megyer also contains the largest number of panel buildings without any external energy efficiency upgrades (64 stairwells out of 718). Nevertheless, 91% of the buildings have undergone at least some form of energy-focused modernization, which represents a relatively high rate compared to other districts. Similar to Rókusdomb, some exceptional cases exist—for example, a partially insulated apartment building on Maléter Pál Street.

As a large district, Megyer is well-equipped with services. It hosts several large supermarkets, its own market hall, and a wide range of other economic services. Thanks to the completed urban development plans, it also stands out in terms of institutional infrastructure—especially compared to Árpádváros—with numerous kindergartens, schools, and cultural facilities. Due to this comprehensive service provision and the infrastructural deficiencies of neighboring districts (particularly Árpádváros), Megyer serves not only its own residents but also those in adjacent areas.

Among the three southern districts, Megyer lies closest to the city center, making commuting relatively time-efficient for its residents. It also benefits from the most developed public transportation network in southern Pécs, with multiple bus lines connecting it not only to the city center but also to the eastern and western districts. The district's main transportation axis is Maléter Pál Street, which bisects the area in an east–west direction. Internally, Megyer can be further subdivided into four smaller units: the northern part centered on Diána Square, the central part around Apáczai Csere János Square, the eastern section near Árpád Fejedelem Secondary and Primary School, and the western unit around Testvérvárosok Square.

Figure 8. Energy efficiency distribution of panel buildings in Megyer.

Non-renovated panel buildings are marked in red, while renovated ones are shown in green. Source: edited by the authors based on data from PTE Politechnika Ltd.

Energy Efficiency Characteristics of Panel Buildings in Málom

The southern district of Málom is unique in both its location and building stock. Two key features become evident when examining the area's layout (Figure 9). First, a residential zone of detached houses stretches along a central main road, dividing the district. Second, due to this separation, the panel housing areas are split into two distinct parts. The northwestern section, situated along Malomvölgyi Street, is a flat area characterized by four-story buildings, each containing 15 apartments per stairwell, resulting in a highly homogeneous urban landscape.

In contrast, the eastern section along Illés Gyula Street presents a much more diverse urban structure, located on a plateau and featuring uniquely designed panel buildings. This includes not only four-story buildings but also ten-story *kc-524* type buildings (Sipos, 2015b), marked by alternating floor levels that break up architectural monotony. Furthermore, the area contains completely unique buildings such as the *AP-type* blocks (Sipos, 2015b), which hardly resemble conventional panel structures, and distinctive three-story buildings with gable roofs resembling airplane hangars.

Málom's diversity is reflected in the 24 different panel building types found in the district, comprising 196 stairwells and 2,737 apartments, making it the fourth largest district in terms of panel housing stock. One of its advantages, unlike Árpádváros, is its quiet, peaceful environment, with several shops and schools, giving it a favorable service position.

Its biggest disadvantage, however, is its distance from the city center, which makes access time-consuming—even on weekends with lighter traffic—and particularly problematic during weekday morning and afternoon rush hours due to frequent traffic congestion. These aspects are not negligible in the context of this study, as they can indirectly affect the value of real estate, the income status of residents, and ultimately the feasibility of energy-efficiency renovations. Despite being one of the younger districts—with most panel buildings constructed in the 1980s, apart from a few exceptions—all buildings in Málom have undergone external refurbishment.

Figure 9. Energy efficiency distribution of panel buildings in Málom.

The west–east division is clearly visible. Renovated panel buildings are marked in green, while other types of residential buildings are shown in grey. Source: edited by the authors based on data from PTE Politechnika Ltd.

Energy Efficiency Characteristics of the Panel Buildings in Árpádváros

The third southern district examined is Árpádváros, which is also the youngest among them. It was originally planned to be much larger, but this was thwarted by the political transition around 1990. All of the apartment buildings still standing today were constructed in 1988, and all are panel-type buildings. A total of 38 stairwells were built, each in a four-story design, with 15 apartments per stairwell, providing 570 apartments in total. Only four different standardized building plans were used for these buildings, and even among them, the differences are mainly limited to the arrangement of the rooms. As a result, the district has a fairly homogeneous appearance, and even after renovations, the buildings differ only in their color. The fact that this is a "half-finished" district is clearly illustrated by the absence of other infrastructural elements around the residential buildings, such as kindergartens, schools, shops, or sports facilities (Sipos, 2015b). Due to this lack, residents must leave the district for most services, typically using those available in the nearby Megyer area. Since Árpádváros is located on the outskirts of the city, transportation has been problematic from the beginning. Buses run infrequently, so most residents rely on private vehicles. The district is also subject to considerable noise pollution; the traffic on Kanizsai Dorottya Street (Route 57), which runs along the northern edge (Figure 10), can be heard in many of the apartments during morning and afternoon rush hours. Despite its disadvantages and the relative youth of the buildings, all panel-type apartment buildings in the district have undergone external energy efficiency renovations. These improvements have led to reduced utility costs for residents, decreased emissions from the buildings, and an increase in property values.

Figure 10. Energy efficiency distribution of panel buildings in Árpádváros.

The proximity of the main road and the buildings' exposure to noise is clearly visible. Source: edited by the author based on data from PTE Politechnika Ltd.

Factors Influencing Differences in the Southern Areas

In the southern areas, the primary factors from the perspective of this analysis are residential functions and the economic and human services that support them. There are two key factors across the three southern districts that determine the differences between them. The first factor is the distance from the city center. Two clear examples of this are Málom and Árpádváros. These districts feature lower-priced properties, as residents essentially “pay” for the cheaper housing with longer commuting times.

In contrast, the Megyer district is in a much more favorable position geographically, which is reflected in higher property prices. However, due to its large size, Megyer also has the highest absolute number of panel buildings that have not yet been renovated. The second factor is the level and quality of economic and human service infrastructure. In this regard, Megyer stands out, while Árpádváros lags behind due to previously initiated but stalled development projects. As a result, the neighboring districts are left to provide the necessary services for Árpádváros residents.

Factors Influencing the Energy Efficiency Profile of the Eastern Areas

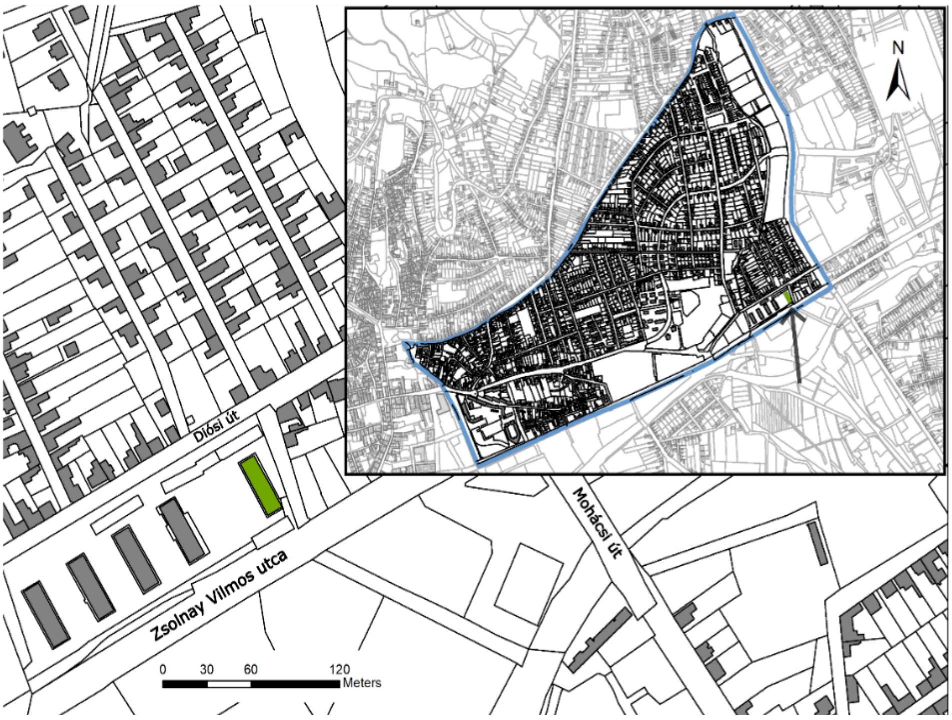
The two eastern districts contain the fewest panel-type apartment buildings—only seven stairwells based on three standard designs, comprising a total of 189 apartments. This area exhibited the lowest level of energy modernization, with a completion rate of 86%.

Energy Efficiency Characteristics of the Panel Buildings in the Budai Suburbs

This area contains the smallest number of panel-type apartment buildings and is primarily characterized by single-family housing. Few apartment buildings were constructed here, most of which were built from brick (Méhes, 2022), while the only panel buildings are two four-story stairwells located at the southern edge of the district, housing a total of 30 apartments. The presence of panel buildings in this area can be seen more as a “colorful anomaly” rather than a defining feature of the district’s housing stock. All apartment buildings in the area are connected to the nearby thermal power plant.

The location of these apartments (Figure 11) can be seen as both advantageous and disadvantageous: they are situated directly along Zsolnay Vilmos Street (Route 6). On the positive side, several shops and a major bus transportation hub—Mohácsi út bus stop—are nearby, providing easy, direct access to many city districts without transfers. On the negative side, the constant noise pollution from the main road is a significant drawback. Despite these disadvantages, the two stairwells have undergone complete external energy modernization, thanks in part to the area’s aforementioned benefits.

Figure 11. In the Budai Suburb, external energy renovations have been carried out on two stairwells (indicated in green).



Source: edited by the author based on data from PTE Politechnika Ltd.

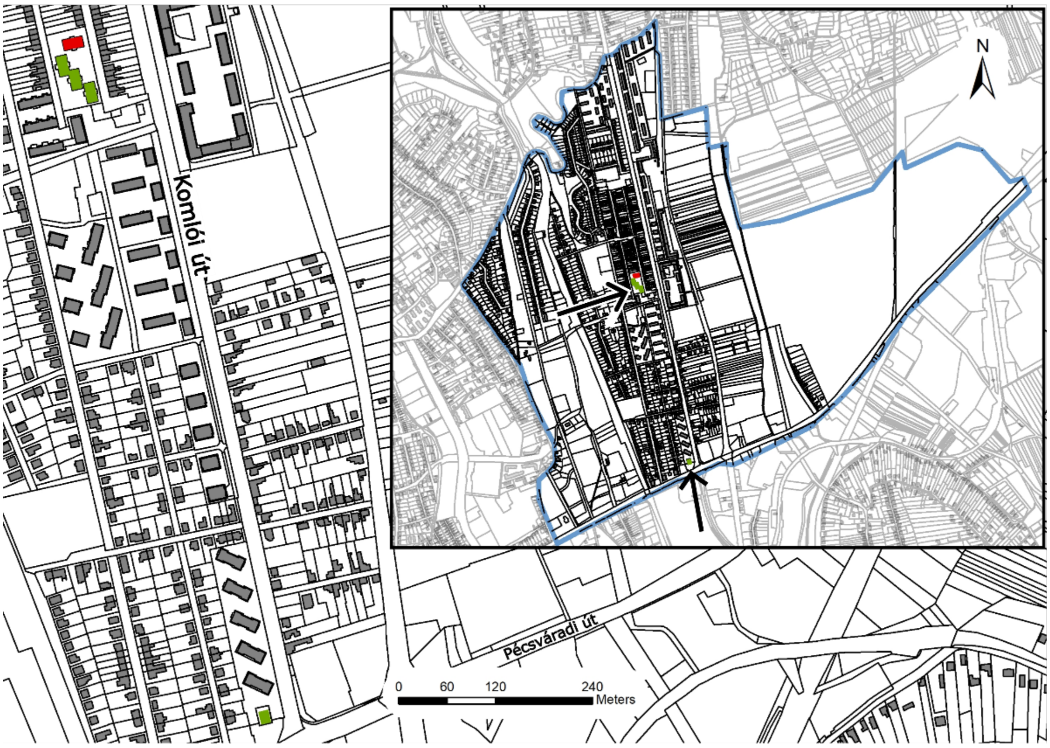
Energy Efficiency Characteristics of the Panel Buildings in the Meszes District

Similar to the Budai Suburbs, panel-type apartment buildings are not characteristic of this district either; they are concentrated in only two small areas (Figure 12). The concentration of socially disadvantaged residents and the district's negative societal perception have suppressed demand on the real estate market (Egedy, 2001). The district's situation is further worsened by its distance from the city center and the relative lack of economic and human services. Based on two standard designs, five stairwells were constructed here, providing a total of 159 apartments. A distinctive feature of the panel buildings in this area is the irregular arrangement of balconies on the 8–10-story buildings located on Bocskai Street. Despite all these limiting factors, the renovation rate in the area has reached 80%. However, this figure still places the district among the lowest in terms of modernization, ranking ninth overall—just ahead of Ispitaalja.

Factors Influencing Differences in the Eastern Areas

The eastern area has the smallest stock of panel-type apartment buildings, as the apartment buildings in the districts concerned were previously built from brick. Additionally, these eastern districts show the lowest rate of external energy modernization, influenced by two main factors. The first factor is their location in lower-prestige, almost peripheral areas within the city—this is especially characteristic of Meszes, while the Budai Suburbs benefit from a more favorable position in this regard. The second factor is the greater variety of housing options available in these districts. Many residents prefer solutions that better suit their individual needs, so panel buildings tend to play a less prominent role.

Figure 12. Energy renovation status of panel buildings in Meszes. Green indicates renovated buildings, red shows those not yet renovated, and grey represents other types of residential buildings.



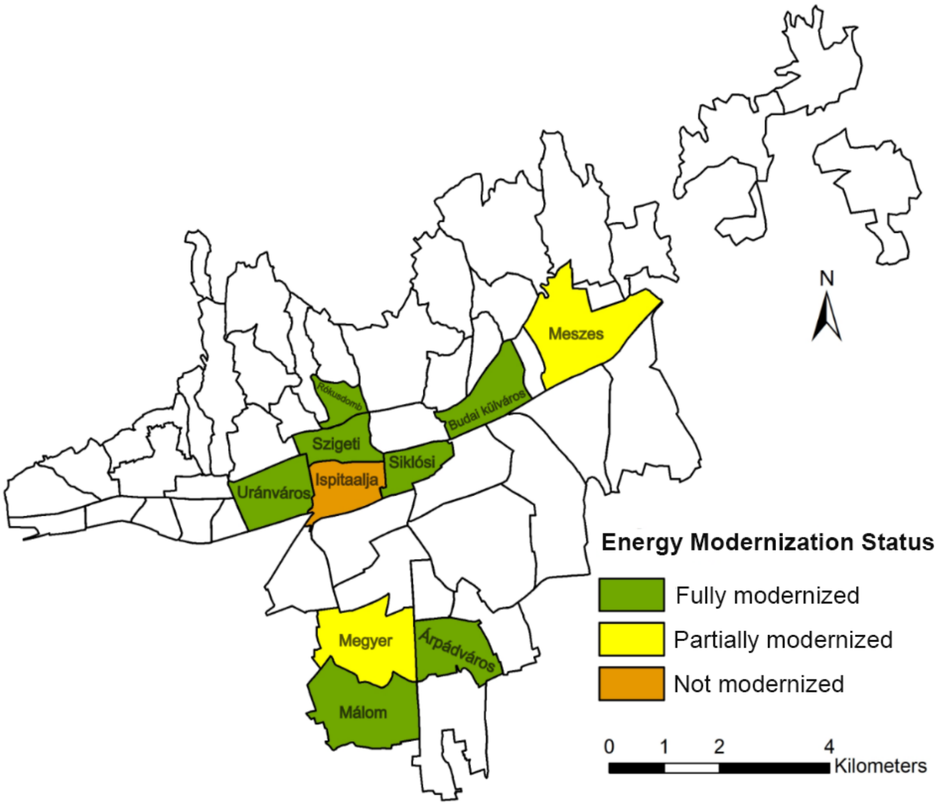
Source: edited by the author based on data from PTE Politechnika Ltd.

CONCLUSIONS

In summary, the differences between the examined urban districts are primarily shaped by socio-economic conditions, their roles within the urban structure, and the varying presence of factors that incentivize renovations. The findings of this study not only reveal the spatial distribution of energy-efficient upgrades in prefabricated housing in Pécs, but also highlight the economic and social determinants that influence these developments. The disparities among the three studied areas cannot be explained solely by geographic location, but are rather the result of more complex territorial characteristics.

The high renovation rate in the western districts is linked to the presence of public institutions, university buildings, and services, as well as proximity to the city center and a more affluent population. In contrast, the lower ratio in the southern districts can be attributed to greater distance from the center, a large housing stock, the relatively recent construction of some buildings, and more limited access to services. In the eastern districts, the limited renewal is not only due to the smaller number of panel buildings but also to unfavorable social conditions (Figure 13).

Figure 13. Ranking of the examined districts based on the extent of external energy renovations of residential buildings.



Source: edited by the author.

Although the study confirmed initial expectations—that western districts show the highest, southern districts a moderate, and eastern districts the lowest renovation levels—data from three specific neighborhoods add nuance to this general pattern. All three areas contain at least one panel building that has not yet undergone external renovation. In the west, Ispitaalja is the only exception, likely influenced by the proximity of a major roadway. In the south, Megyer has unrenovated buildings, which can be linked to its large housing stock and the cost-efficiency challenges this presents. Statistically, these buildings are more likely to remain unrenovated, even if their proportion is similar to other districts. In the east, Meszes is the sole area affected, where distance from the city center and negative social perception likely play a role. In the remaining seven districts, all panel buildings have undergone external energy renovations, largely facilitated by building age and previous subsidy programs.

It can be concluded that over the past two decades, the majority of prefabricated housing in Pécs has undergone external energy-efficient upgrades. These primarily focused on facade insulation, though window replacements were also common—not only in privately owned units but also in communal areas such as stairwells. Thus, the most cost-effective renovations that offer substantial savings have largely been completed. For the remaining buildings, future upgrades are likely, depending on residents' willingness, financial capacity, and available funding sources.

Further reductions in harmful emissions are now more likely to result from internal system upgrades rather than exterior renovations. However, these interventions are significantly more expensive and often yield smaller energy savings, making them less common. Such upgrades are typically only undertaken in cases of urgent need—for instance, when outdated and undersized electrical wiring in stairwells must be replaced. It should also be noted that earlier renovations often used thinner insulation materials; in these cases, additional insulation layers could generate further savings.

By 2025, passive energy interventions alone are no longer sufficient. Replacing radiators or windows in isolation does not provide the necessary savings. Although household appliances have become more energy-efficient in recent decades, their number has increased substantially, leading to higher overall electricity consumption. Thus, reducing energy use now largely depends on changes in residents' habits. Key examples include the efficient use of radiators—such as lowering indoor temperatures instead of opening windows for cooling—and avoiding unnecessary use of electronic devices like televisions.

While external renovations contribute to environmental goals, they also raise concerns from an urban design perspective, particularly due to the homogenization of building appearances. Renovation projects often removed distinctive architectural elements meant to preserve the unique character of streetscapes, which were typically not rebuilt due to cost. For example, the pyrogranite cladding of the former K-7 "pajama buildings" on Szalay András Street has disappeared (Sipos, 2015b). Nonetheless, some characteristic features—such as the unique balconies of ten-story buildings with "TV balconies"—have retained their form-shaping role to this day.

The findings of this study reinforce previous academic literature from multiple angles. Districts that enjoy structural or social advantages tend to undergo more renovations, while areas lagging behind in this regard typically face multidimensional socio-economic challenges—not merely a lack of upgrades. This further confirms the correlation between a property's location and its market value.

Based on these results, the majority of prefabricated housing has already undergone external energy-efficient renovations, meaning that future municipal support should be targeted primarily at the remaining unrenovated buildings. To achieve this, direct engagement with building managers and informing homeowners about potential savings and financial benefits would be advisable.

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