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АЛТЕРНАТИВНИ АРХИТЕКТУРНИ РЕШЕНИЯ ЗА ЕНЕРГИЙНА ЕФЕКТИВНОСТ НА НИВО РАЙОН ЗА ЕДРОПАНЕЛНИ ЖИЛИЩНИ СГРАДИ: КАЗУС ЗА СИСТЕМАТА БС-69-СФ В СОФИЯ

Рон Аладжем

ALTERNATIVE DISTRICT-SCALE ENERGY EFFICIENCY RETROFIT STRATEGIES FOR LARGE-PANEL RESIDENTIAL BUILDINGS: A CASE STUDY OF THE BS-69-SF SYSTEM IN SOFIA

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Abstract:
Large-panel residential buildings (LPRBs) make up a significant portion of Sofia's housing stock and retrofitting them for energy efficiency presents an opportunity to help Bulgaria achieve its CO_2 emission reduction targets. Despite the EU-wide push for the renovation of residential buildings to improve energy efficiency, progress in Bulgaria has been limited, with over 90% of occupied dwellings failing to meet current energy standards, and about 4% of multifamily residential buildings having undergone renovations.

This research explores alternative retrofit options suited to the specific conditions of LPRBs in Sofia. A detailed case study of the Bs-69-Sf LPRB system with Sofia's Druzhba 2 residential complex provides valuable insights for developing a retrofit proposal applicable at both the building level and across the broader district.

Using a multi-method approach that combines post-occupancy evaluation, international precedent analysis, environmental modelling, and structural assessment, the study evaluates the feasibility of different precedent retrofit models from Germany, France and Israel, and their application to the case study context.

The presented paper summarises ongoing work, a written dissertation in partial fulfilment of the requirements for the Master of Architecture programme at the University of Cambridge.

Keywords:
Retrofit, energy efficiency, large-panel residential buildings, housing, post-socialism, Sofia, Bulgaria.

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1. INTRODUCTION

1.1. The buildings sector’s decarbonisation challenge

As of early 2025, the buildings sector remains off track to achieve its decarbonisation goals for 2030 and 2050. Between 2015 and 2023, CO_2 emissions from building operations rose by 5.4%, a substantial deviation from the 28.1% reduction that ought to be achieved to align with the Paris Agreement. In 2023, the industry was responsible for 34% of global CO_2 emissions, while energy consumption by buildings accounted for 32% of global energy demand. With less than five years remaining, meeting the 2030 targets now demands an annual decrease of 10.8% in emissions [1].

1.2. Research problem

Challenges linked to the retrofit of existing housing stock are prevalent across all EU member countries [2], where, by early 2020, less than 1% of the building stock was renovated annually [3].

This study focuses on Bulgaria, where, as of 2020, 93% of its occupied residential buildings did not comply with the latest EU energy-efficiency requirements [4]. Despite the introduction of the Energy Efficiency of Multi-Family Residential Buildings National Programme in 2015, only 1,968 buildings had been retrofitted as of 2024 [5], accounting for 4.2% of the housing stock [6].

The limited progress of the current programme and the urgency of reducing CO_2 emissions demand a re-evaluation of retrofit approaches. Considering the scale of the problem, a case study of an LPRB system has been selected for this study.

Large panel residential buildings (LPRBs), built predominantly between the 1940s and 1980s, represent approximately 18% of the national housing stock [7] and over 40% of the dwellings in Sofia [8].

1.3. Research questions & objectives

What alternative retrofit strategies can be implemented for LPRBs in Sofia to align with contemporary energy efficiency standards? This central question guides this study, supported by two sub-questions. First, to what extent does the existing renovation programme in Bulgaria meet the needs of LPRB residents, and what limitations are inherent in the current approach? Second, how can successful retrofit models be adapted to Sofia’s context?

Considering the limited progress in renovating LPRBs for energy efficiency in Bulgaria, this research examines both established and emerging renovation precedents to assess their applicability in the local context. A review of various international cases facing similar challenges was conducted to pinpoint successful strategies and their limitations. Concurrently, an analysis of current renovation practices in Bulgaria, encompassing state-supported initiatives under the Energy Efficiency of Multi-Family Residential Buildings National Programme and residents’ informal adaptations, was conducted in comparison with international precedents. This comparison aimed to identify shortcomings within the existing approaches.

2. PRECEDENTS IN RETROFIT

The precedents examined in Germany, France, and Israel represent distinct geographic and policy conditions and architectural approaches. Germany showcases a collection of programmes that address buildings from the GDR period, comparable to the research’s case study. France has established prominent precedents for retrofitting, implemented at both the individual building level and across entire districts.

In contrast to Bulgaria, where affordable housing is not a primary focus, both France and Germany concentrate their housing programmes in this sector. Meanwhile, Israel employs a different funding strategy for seismic retrofitting of private buildings, which, although not specifically addressing energy efficiency, offers valuable insights that can still be utilised.

2.1. Germany: Urban Development Support Programme

After reunification, East Germany adopted the West German housing and planning system, creating a highly regulated rental market in which social, cooperative, and municipal housing play a fundamental role. Large housing estates, including Marzahn, Berlin, were incorporated into this system, which combined market mechanisms with decisive state intervention through subsidies for construction, renovation, and later demolition. Two waves of privatisation in the 1990s and 2000s introduced private financial investors and significantly altered ownership structures. At the same time, population decline and an oversupply of housing led to the federal Stadtumbau Ost programme, lasting from 2001 to 2017, which supported large-scale demolition and required integrated urban-development strategies. Processes such as rapid institutional transfer, continued state funding, privatisation, and state-supported downsizing formed the core framework shaping the governance and redevelopment of large housing estates in eastern Germany [9].

2.2. France: National Urban Renewal Programme [Le Programme National pour la Rénovation Urbaine]

Notable examples are found in France, where the 2003 National Urban Renewal Programme, which sought to demolish underperforming buildings and build new ones, prompted a critical response from the architects Druot, Lacaton, and Vassal. Their Plus manifesto proposed an alternative strategy to alter existing buildings and oppose their replacement [10]. The manifesto presented a catalogue of potential interventions and conceptual designs demonstrating how residential buildings could be transformed through retrofit rather than being demolished [11].

This approach was later realised in the transformation of three fully occupied social housing blocks in the Cité du Grand Parc, Bordeaux, France. Rather than demolition or major structural modifications, the architects focused on building extensions to improve both the energy efficiency and the spatial quality of the dwellings. A defining feature of the renovation was the introduction of winter gardens, which, together with thermal and solar curtains and a double-glazed façade system, enabled a highly energy-efficient retrofit [12].

2.3. Israel: TAMA 38

Israel’s TAMA 38 programme, which ran from 2005 to 2023, established a framework that enabled developers to finance seismic reinforcements by granting additional building rights, such as the opportunity to build additional floors atop existing buildings. While this initiative successfully resulted in thousands of strengthened residential buildings, it also brought to light significant issues of spatial inequality, where over 75% of the completed projects were concentrated in the Tel Aviv metropolitan area, leaving the earthquake-prone northern regions with a mere 1.9% of the upgrades [13].

2.4. Key takeaways

Germany’s model demonstrates the value of long-term state support and integrated urban development strategies. At the same time, precedents from France illustrate how design-led, resident-centred retrofits can deliver significant spatial and energy improvements. The TAMA 38 model exemplifies the potential advantages of incentive-based retrofitting. However, it also raises concerns about the reliance on market forces in areas with uneven land values, a crucial issue for Bulgaria as a whole. However, since this study is focused explicitly on Sofia, the drawbacks of the TAMA 38 programme are less relevant; to the contrary, they may demonstrate market interest.

3. CHALLENGES IN SOFIA

3.1. Demographic changes and home ownership

Between the early years of the Bulgarian Communist Party’s rule and 1989, Sofia’s population quintupled from 300,000 to 1.5 million [14]. To accommodate the rapid growth of incoming workers, more than 184,000 dwellings were built in 5,047 LPRB sections across the capital [15]. Today, LPRBs house more than 450,000 residents, approximately 41.6% of Sofia’s

population [8]. Moreover, today Bulgaria has one of the highest rates of home ownership in Europe, with approximately 87% of households owning their dwellings [7].

3.2. Resident-driven adaptations and structural vulnerabilities

Due to the limited floor area and rigid spatial configurations of LPRB apartments, residents have, over time, made informal modifications, such as removing internal partitions and enclosing balconies, to increase usable space. These alterations introduce additional loads from masonry infill and glazing systems, often leading to structural damage [16]. Additionally, inadequate maintenance over decades of occupancy has exacerbated deterioration, raising significant concerns about structural safety [17, 18]. Given Sofia’s seismicity, these vulnerabilities complicate retrofit designs [19].

4. METHODOLOGY

The research employs a multi-method approach. It includes a literature review that synthesises international and local energy efficiency renovation practices within their respective contexts. Additionally, a case study juxtaposes international precedents with ongoing local renovations. Fieldwork, including technical surveys and post-occupancy evaluations, was conducted to gain insights into the buildings’ conditions and residents’ needs. Furthermore, a case-study specific structural analysis and environmental modelling of the design interventions will be carried out.

5. CASE STUDY

5.1. LPRBs in Bulgaria

The first large-panel residential buildings (LPRBs) [едропанелни жилищни сгради (ЕПЖС)] in Bulgaria were built in Sofia between 1957 and 1958 as experimental projects. Designed by a team from the Scientific Research for Construction Institute (NISI) [Научноизследователски строителен институт (НИСИ)] and the Institute for the Typification and Industrialisation of Construction (NiproITIS) [Института за типизация и индустриализация на строителството (НипроИТИС)], these early designs were 4-story tall. Building on the experience from the first LPRBs, the development of a new panel building system, the Bs-2-63 [Бс-2-63], was commissioned in 1962 to NiproITIS, the Comprehensive Scientific Research and Design Institute for Architecture and Typification “Glavproekt” [Комплексен научноизследователски и проектантски институт по архитектура и типизация „Главпроект“], and the Institute for Research and Design “Sofproekt” [Институт за проучване и проектиране „Софпроект“]. This nomenclature ranged from 4 to 6 stories and was suitable for seismic and non-seismic areas. Based on the Bs-2-63 system, Sofproekt developed the Bs-VIII-Sf [Бс-VIII-Сф], a variant that could reach up to 8 floors tall and suitable for seismic regions. In 1964, NiproITIS introduced the Bs-2-64 [Бс-2-64] system, which could also reach up to 8 floors tall. In 1969, Sofproekt began developing the Bs-69-Sf [Бс-69-Сф] system, and from 1972, the system was widely implemented and eventually became Sofia’s most widespread LPRB system, with approximately 3,567 sections in the capital alone [15].

5.2. Building system Bs-69-Sf, a case study

After a careful evaluation of all systems mentioned, it was determined that the Bs-69-Sf system would serve as the case study for the research. This decision is grounded in several considerations, including the prevalence of the Bs-69-Sf system, which is the most common in Sofia. The Bs-69-Sf system is also the last developed system in Bulgaria, having been operational since 1972, with new units built until the 1990s [15].

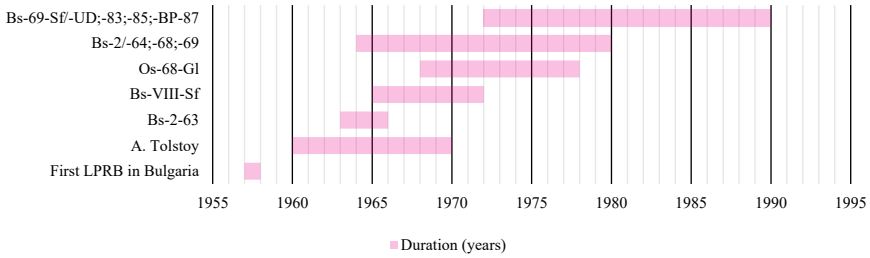

Figure 1. Timeline of the construction periods of LPRB systems in Sofia, Bulgaria. Based on analysis of Stavrev’s work [15].

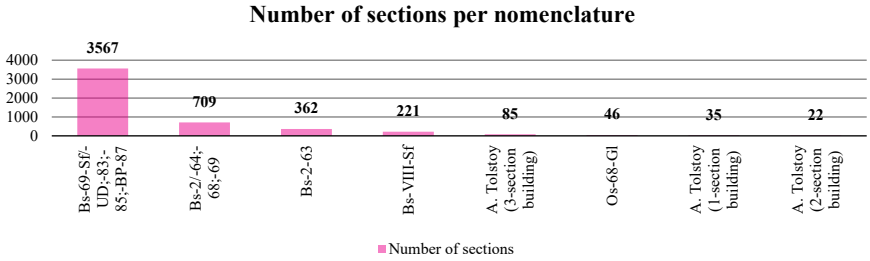

Figure 2. Number of sections per nomenclature in Sofia, Bulgaria. Based on analysis of Stavrev’s work [15].

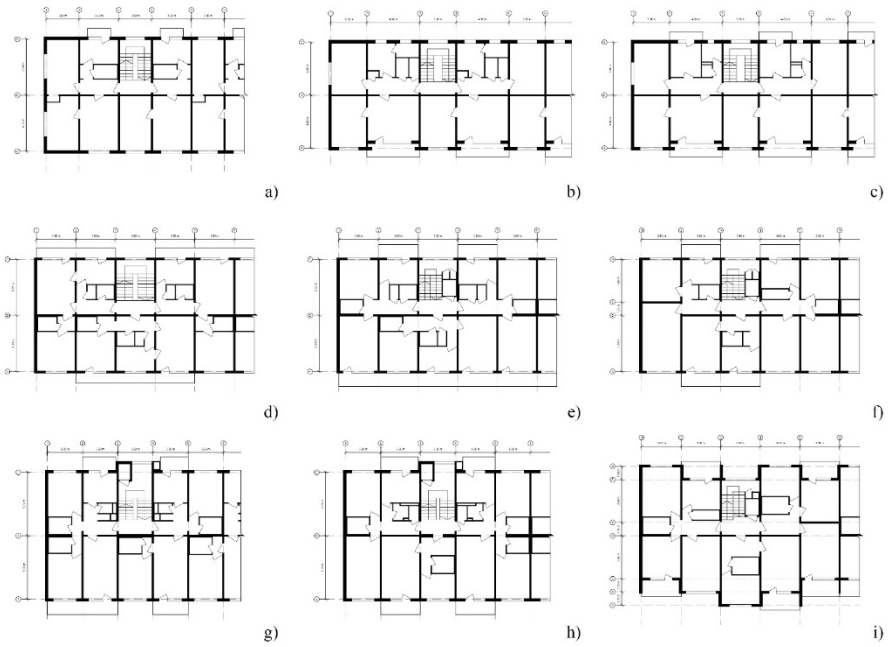

Figure 3. Typical floor plans of LPRB systems in Sofia, Bulgaria. First frameless panel building in Bulgaria (a); A. Tolstoy (33-33) (b); A. Tolstoy (Modified) (33-33) (c); 3-61 (222-222) (d); 2-63 (222-222) (e); Bs-VIII-Sf (213-312) (f); Bs-2-64 (33-33) (g); Bs-2-68 (213-312) (h); Bs-69-Sf (312-312) (i). Plans by author, redrawn from multiple sources [20, 21].

5.3. District choice

Sofia Municipality is divided into 24 administrative districts. Many large-scale housing estates were built in the inner ring, surrounding the city’s core, and in the broader ring [22]. To determine a suitable case study site, districts with a high concentration of the Bs-69-Sf building system were assessed, such as those located on Sofia’s eastern and western peripheries, namely Nadezhda, Lyulin, Studentski Grad, Mladost and Iskar [8]. Further attention was directed to districts near major business centres. The city’s eastern part is the most favourable, mainly due to the presence of Sofia Business Park and Sofia Capital City office centre in the Mladost District [8, 23].

Although both business centres are in the Mladost District, Sofia Capital City, lies near the border of the adjacent Iskar District. While Mladost has been extensively studied [22, 24], Iskar remains largely underexplored. As a district that combines ageing LPRBs with ongoing urban development and is proximate to a key business centre, Iskar has been selected as the case study site, with explicit focus on the Druzhba 2 residential complex.

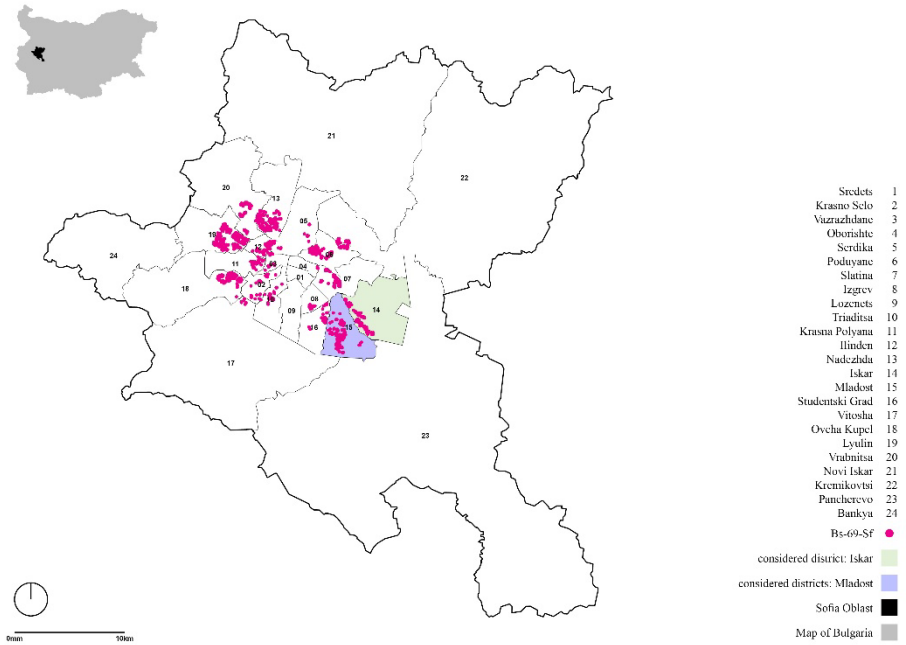

Figure 4. Buildings built under the Bs-69-Sf system in Sofia, Bulgaria. Redrawn by the author based on reports by Vision for Sofia [8, 23].

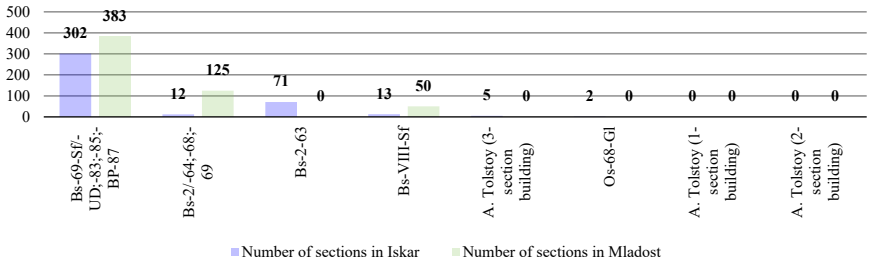

Figure 5. Number of sections per nomenclature in the districts of Iskar and Mladost. Based on analysis of Stavrev’s work [15].

Figure 6. Case study. Bs-69-Sf buildings in Iskar District, Sofia, Bulgaria (a); Case study. Buildings 223, 224 and 225 in Druzhba 2, Iskar District, Sofia, Bulgaria (b).

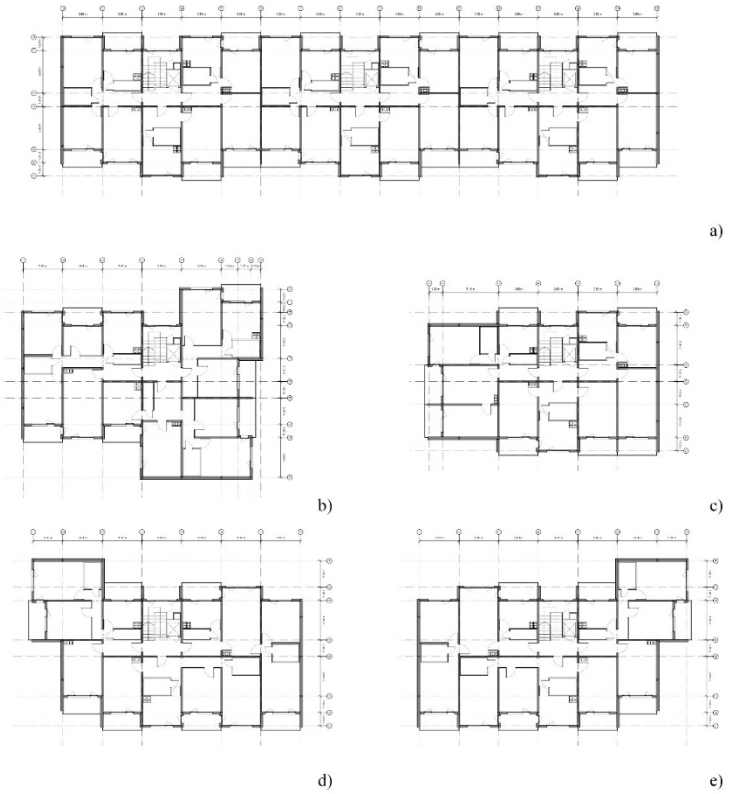

Figure 7. Case study. Buildings 223, 224 and 225. Typical floor plans of the Bs-69-Sf system. Bs-69-Sf (312-312-312) (a); Bs-69-Sf (432) (b); Bs-69-Sf (322) (c); Bs-69-Sf (333 left) (d); Bs-69-Sf (333 right) (e). Plans by author, interpretation from multiple sources [20, 21].

6. ALTERNATIVE OPTIONS FOR SOFIA

Four primary pathways for Sofia’s LPRBs are evaluated. First, continuation of the existing programme. Second, complete termination of the current programme. Third, demolition and replacement. Fourth, alternative retrofit strategies.

In line with the principles of the fourth pathway, illustrated in Figure 9., there is the option to adopt a market-led approach similar to TAMA 38 [13]. This would involve adding dwellings by implementing an exoskeleton. The exoskeleton facilitates winter gardens, akin to the design used in Bordeaux for energy-efficient retrofitting [12].

Additionally, district-scale renovation, as a key strategy, is well supported by [25], which demonstrates that district-level interventions can be implemented to reduce energy consumption.

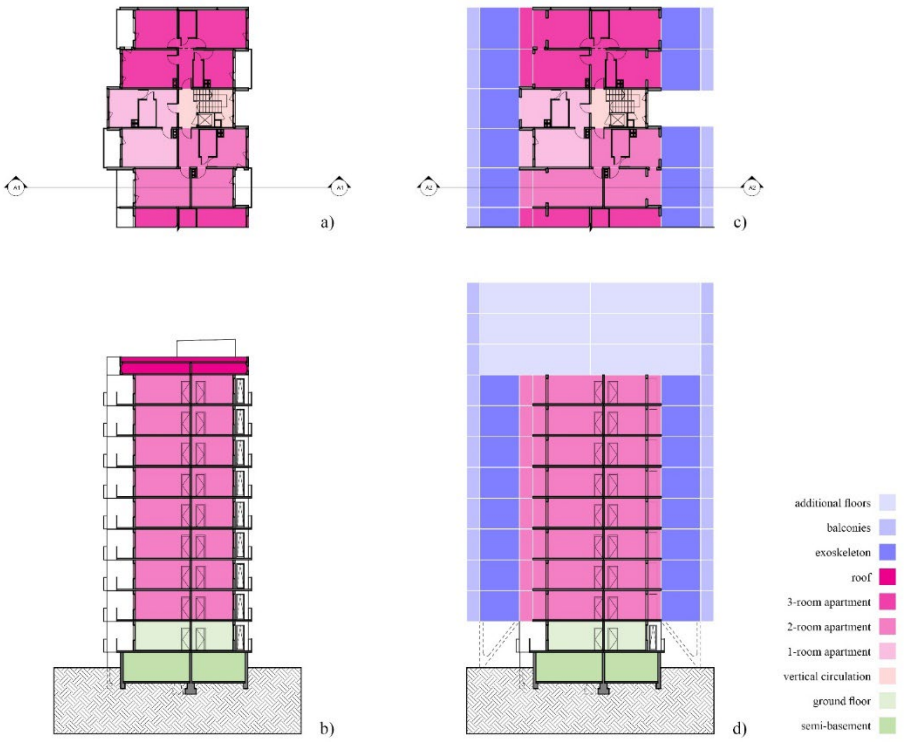

Figure 8. Diagrammatic representation of the extension proposal. Typical floor plans of Bs-69-Sf (312-312-312) (a); Section A1-A1 of Bs-69-Sf (312-312-312) (b); Typical floor plans of Bs-69-Sf (312-312-312) (modified) (c); Section A2-A2 of Bs-69-Sf (312-312-312) (modified) (d). Plans by author, redrawn from [21].

7. CONCLUSIONS

Bulgaria’s current energy-efficiency renovation programme has managed to retrofit only 4% of its multifamily housing, proving insufficient to meet the EU’s climate objectives for 2030 and 2050. Large Panel Residential Buildings (LPRBs), particularly those built using the Bs-69-Sf system, present both urgent challenges and significant opportunities for retrofit.

Examples from other countries show that successful renovation depends on clear direction and approaches that respond to local needs. For Sofia, this means adapting lessons from abroad into solutions that fit its own social and urban conditions.

This study explores whether meaningful progress can be achieved through isolated, building-scale renovations alone or whether it requires alternative retrofit approaches that integrate building improvements, which are coordinated at the district scale.

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