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Research Article

IMPROVING ENERGY EFFICIENCY STRATEGY IN RESIDENTIAL BUILDINGS

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Abstract
Reducing the energy demand of residential buildings is crucial for mitigating climate change, lowering energy costs, reducing health risks associated with fuel poverty, and improving the overall residential environment. Given the global significance of these challenges, this research aims to explore the impact of energy-saving measures in residential buildings, focusing on façade renovation systems in Tirana, Albania. The methodology employed in this research work involved a comprehensive approach combining field assessments, energy performance analysis of completed projects, and case studies of residential buildings in Tirana. The research specifically focused on the implementation of façade renovation systems and evaluated their impact on reducing energy consumption. The results demonstrate significant improvements in energy performance following the renovation of building façades. Enhanced insulation, upgraded materials, and the addition of energy-efficient windows led to reduced heating and cooling demands, contributing to a more stable indoor climate and lower energy consumption. The energy simulations confirmed that facade renovations resulted in a notable reduction in overall energy use, particularly during the colder months. The findings suggest that facade renovation systems are an effective strategy for reducing the energy demand of residential buildings in Tirana. These improvements not only help to mitigate the effects of climate change by lowering carbon emissions but also offer a cost-effective solution for improving the quality of life for residents. This study offers a novel contribution by focusing specifically on the impact of facade renovation systems in the context of residential buildings an area with limited previous research on energy efficiency improvements.

Keywords: Community Fund, Energy Efficiency, Sustainable Architecture

INTRODUCTION

The residential sector, through the consumption of energy in the form of electricity, heat, and water, plays a major role in the energy consumption of a country (Islami, 2016; Gebremedhin et al., 2020; Benöhr et al., 2021; Tyxhari et al., 2023; Bollano et al., 2024; Dhoska et al., 2024; Ningsih, 2024). In any country, a significant portion of energy consumed in residences is due to inefficient construction, lighting, or heating methods (Dorri et al., 2023; IEA 2023; Dorri & Dhoska et al, 2023; Pangestu, 2024; Vrusho et al., 2024; Widodo, 2024). However, energy costs often represent a heavy financial burden on many low-income families; thus, it is paramount for any government to address this issue.

Today, in many countries, energy-efficient programs are being implemented to help people replace old, energy-inefficient equipment with new, energy-efficient models. This allows families to save up to 20% on their total energy bills (Simaku 2017; Murataj et al., 2018; Marik et al., 2023; Dhoska & Bebi et al., 2024; Fadhilah, 2024; Koyursen et al., 2024; Qodri, & Hassan, 2024). However, a major challenge remains by replacing inefficient dwellings with new and energy-efficient housing units. Dwelling energy consumption is influenced by three main factors: the physical characteristics of the buildings where people live and interact daily, the climatic conditions of the residential location, and the habits and attitudes of the residents. However, understanding the technical characteristics of buildings alone is not sufficient to predict residents' behavior, and vice versa. It is evident that variability in heating and hot water demands, which likely account for a substantial portion of electric and gas energy consumption, arises from differing behavioral patterns of residents. In all countries, the significant increase in energy prices over the past decade has led to a reduction in energy usage and a focus on more efficient energy consumption (Azis, & Clefoto, 2024; Mardiati et al, 2024; Naimah et al., 2024; Setiyani et al., 2024;). Additionally, this article provides a general perspective on the positive effects of specific measures implemented in Tirana, Albania, with a particular emphasis on façade renovation systems. The urgency of this research arises from the pressing need to reduce the energy demand of residential buildings in the face of climate change, rising energy costs, and the increasing prevalence of fuel poverty in many urban areas. Tirana, like many cities in Southern Europe, faces significant challenges related to energy inefficiency, with outdated building envelopes exacerbating energy consumption. Given these issues, timely and targeted interventions are necessary to optimize energy use and enhance living conditions.

The methodology is designed to capture both the real-world effects of building upgrades and the theoretical outcomes derived from energy effieciency analysis that come from facades, ensuring a comprehensive understanding of the interventions' efficacy. Various façade renovation was designed based on common energy-efficient upgrades. This methodology includes replacing single-glazed windows with double-glazed glass which can reduce energy consumption by 33% and by interventions in façade can reduce energy consumption by 26%. Though mixed residential buildings constitute the majority of the existing building stock in Tirana, the application of international principles that can be implemented on a large scale, based on positive outcomes, has not yet been fully realized. A significant portion of mixed residential buildings was constructed informally and has not been included in the title legalization process (Asmororini et al., 2024; Fernande et al., 2024; Habibi et al., 2024; Syahputra, & Edwards, 2024). Nevertheless, the majority of apartments in these buildings are privately owned, with apartment owners directly responsible for paying energy bills for heating, hot water, and cooling. Some rental tenants experience the economic impact of energy bills indirectly, often without guarantees of efficiency.

Refitting the envelopes of the mixed residential building stock in Tirana can incorporate cost-effective solutions, generating revenues through improvements such as enhanced building appearance, reduced technical costs, better understanding of construction quality (Saad et al., 2024; Bidaj et al., 2023; Golgota et al., 2023; Armando et al., 2020; Vrusho 2024; Jasminarni et al., 2023), and increased property value for investors. However, it is crucial to consider that the energy-related cost burden may be unacceptable for low-income or energy-poor households, potentially impacting housing affordability.

Improving energy-specific policies in ownership taxation could be an effective way to support the renovation of external areas of existing buildings (Xhafa 2020; Kucana et al., 2021; Yunistyna et al., 2023; Apeadido et al., 2024; Khoirunnisa et al., 2024). This approach would facilitate the renovation of each building based on ownership and rental needs, while providing tailored solutions according to real requirements, site conditions, and local participatory democracy. Optimizing administrative procedures

and reducing bureaucratic uncertainties related to regional taxation incentives for energy-efficient renovations, when managed at the appropriate local administrative level, could achieve cost neutrality at the national level.

RESEARCH METHOD

The methodology of this study utilized a multi-faceted approach, incorporating field assessments, energy performance analysis from completed projects, and detailed case studies of residential buildings in Tirana. Each of these components was designed to thoroughly evaluate the effectiveness of façade renovation systems in reducing energy consumption.

- *Field Assessments*. A series of on-site evaluations were conducted across various residential buildings in Tirana. These assessments included physical inspections of building façades, identification of existing insulation materials, and documentation of structural and architectural characteristics. Additionally, the energy efficiency of these buildings was assessed by gathering data on heating and cooling systems, air infiltration, and overall thermal performance. This on-the-ground approach allowed for a direct understanding of the buildings' condition and provided insights into areas where façade improvements could lead to substantial energy savings.
- *Energy Performance from Completed Projects*. To complement the field assessments, the energy performance of previously renovated residential buildings was analyzed. Data from these buildings, where façade renovation systems had been implemented, was reviewed to quantify their impact on energy consumption. Key parameters such as pre- and post-renovation energy use, seasonal variations in energy demand, and any changes in indoor comfort levels were examined. This historical data provided valuable insights into the effectiveness of different façade renovation strategies in real-world conditions.
- *Case Studies of Residential Buildings in Tirana*. In-depth case studies were conducted on selected residential buildings that had undergone façade renovations. These case studies focused on specific renovations involving various façade systems, including insulation improvements, energy-efficient windows, and the application of advanced exterior coatings. Detailed records of each case study were kept, documenting the scope of renovations, associated costs, and energy performance before and after the implementation. Comparative analysis of these case studies helped identify best practices and common challenges faced during the renovation process.

By integrating these three approaches, the study was able to offer a holistic evaluation of façade renovation systems and their potential to reduce energy consumption in residential buildings. The methodology ensured that both theoretical insights and practical, real-world data were used to assess the long-term benefits and feasibility of façade improvements.

RESULTS AND DISCUSSION

Objectives of the Community Fund Program

The Community Fund Program aimed to enhance the participation of communal associations in the planning and execution of energy efficiency activities. This program focused on installing new heating systems that consumed less energy. It also expanded to provide buildings with low-cost heating and hot water. The emphasis was on improving the management capabilities of associations to effectively lead the financing, initiation, management, and maintenance of major building repair projects. This required not only technical skills but also financial, legal, and interpersonal skills to coordinate relationships between homeowners and other stakeholders. The intervention was based on the organization of co-owners and mutual assistance.

The mutual fund, developed within the capacity and maturity of existing communal associations, allowed co-owners to contribute private funds at a ratio of 50%. These funds were reinvested from savings generated through energy efficiency measures, linking economic development to energy efficiency investments. The project aimed to provide policy instruments and mechanisms to encourage the residential sector to participate in energy efficiency projects and foster the development of an energy market in Tirana. The communal fund established during the project's phase-out offers a model and valuable experiences for future investments in energy efficiency in residential buildings. These outcomes stem from mutual support and homeowner-driven initiatives.

Involving the Association Treasurer and the leader of the Association in the establishment and development of mutual activities, capacity building, and regulatory frameworks strengthens cooperation

between co-owners, addressing the identified restrictions on the use of the municipal fund. By pre-financing necessary measures, utilizing savings to support management functions, fostering participation, and effectively informing stakeholders, the municipal fund promotes business practices and generates economic transactions. This approach creates interest and drives motivation among shareholders and other stakeholders. The municipal fund can be utilized at various stages of construction projects and is recognized by local financial institutions as a viable instrument for supporting energy efficiency measures.

ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS

Importance and Benefits

Energy efficiency in residential buildings is crucial for several reasons. It helps reduce energy consumption, lowers utility bills, and decreases greenhouse gas emissions. By implementing energy-efficient measures, homeowners can create a more comfortable and sustainable living environment while also contributing to the overall goal of reducing the carbon footprint. Some of the key benefits of energy efficiency in residential buildings include:

a. *Cost savings*: Energy-efficient homes require less energy for heating, cooling, and powering appliances, resulting in lower utility bills for homeowners. By investing in energy-efficient upgrades, homeowners can also increase property values, which is an important factor for the local economy.
b. *Environmental benefits*: These benefits are evident through the reduction of carbon and water footprints, achieved by improving building envelope insulation and installing efficient heating, ventilation, and air conditioning (HVAC) systems.
c. *Health and comfort benefits*: Energy efficiency and comfort considerations promote the adoption of sustainable building designs, technologies, and components. Health-related advantages include improved indoor air quality and reduced exposure to toxins. Additionally, comfort benefits arise from better temperature regulation and noise reduction in residential spaces.
d. *Government incentives and programs*: Energy savings in residential buildings are appealing targets for policymakers due to the relatively low costs of some energy efficiency measures and the short implementation and savings realization periods. While high-income countries have greater awareness of climate change and the capacity to provide financial and technological support to low-income countries, the responsibility for achieving low-energy residential buildings must be shared at both the individual and national levels.

Challenges and Barriers

Energy efficiency is essential for the transformation of the energy system towards a sustainable and climate-friendly supply. The residential sector is an important part of the energy system and is presently one of the largest energy consumers. By implementing energy efficiency measures in residential buildings, a great deal of energy, environmental, and economic benefits may occur. While the potential energy savings are high, in some countries, the measures do not appear to be implemented widely. In general, stakeholders in the real estate sector do not seem to give a high priority to the implementation of those measures. For this reason, there might be existing difficulties that prevent the full exploitation of energy efficiency measures in residential buildings.

THE COMMUNITY FUND PROGRAM

Overview and Structure

The Community Fund Program is an inclusive funding mechanism devised by the Municipality of Tirana to assist co-owners of shared residential buildings in improving energy efficiency at an affordable cost. Residential buildings in Tirana require significant funding for enhancement, often necessitating financial support from communal authorities. The Municipality established the Community Fund Program to address various issues faced by co-owners in residential buildings, including inadequate maintenance, poor internal organization, and insufficient funds, all of which affect energy efficiency. This program aims to integrate different stakeholders such as the Municipality, co-owners, and building administration into a sustainable community fund that addresses energy efficiency challenges in residential buildings in Tirana (Kucana et al., 2021; Tyas, & Suttiwan, 2023; Setiya Rini et al., 2024; Vrusho 2024).

The primary beneficiaries of the program are the co-owners of shared premises in residential buildings. The Municipality of Tirana provides a funding scheme designed to help co-owners improve infrastructure and energy efficiency. The program assists co-owners in addressing structural issues that impact energy efficiency, such as poor insulation and inadequate internal climate control systems. Moreover, through this initiative, co-owners can be organized to benefit from co-financed projects targeting specific energy efficiency challenges. These capacity-building measures will equip co-owners with the skills and expertise needed to govern shared premises sustainably and efficiently, thereby enhancing energy efficiency in Tirana's residential buildings.

Co-ownership and collaboration foster collective decision-making regarding infrastructure issues that negatively impact energy efficiency in residential buildings. By funding this program, changes to co-ownership structures can catalyze improvements in energy efficiency across residential buildings in Tirana**.**

Eligibility and Application Process

According to operational guidelines for the 'Communities Fund' Program, Municipality of Tirana, specific objectives of community fund are as folows:

- Financial support of communities that need and desire to improve their common facilities;
- Covering the investment costs of common facilities for the category of families in need.
- Improvement of infrastructure and common spaces;
- Encouraging inclusion and active participation in issues related to the smooth functioning of coexistence in the community;
- Encouraging positive cooperation between communities and local government;
- Supporting community initiatives of citizens in order to encourage and cultivate the mentality of cooperation;
- Civic education for the protection of common premises and the good use of their finances;
- Encouragement by the Municipality for the creation of assemblies of co-owners, the registration of chairmen of assemblies as well as administrators/administrative companies in the Register of Co-Ownership and the Register of Administrators;
- Speeding up the procedures for the employment of Palace Administrators.
- Encouragement to open a bank account for each assembly of co-owners.

Based on the above objectives it is necessary to implement strategies for improvement of the energy efficiency for resiendetial buildings which are as follows:

a. Enhancement of the buiilding enevelope
   - *Terrace maintenance*: This includes waterproofing and thermal insulation of terraces, etc.
   - *Maintenance of Facades*: This includes painting, plastering of facades and cladding of facades with materials that have the same characteristics and colors as the existing ones.
   - *Energy-efficient Windows*: Replace single-pane windows with double or triple glazing and low-emissivity (Low-E) coatings
b. Integration for renewable energy
   - *Solar Panels*: Encourage the use of photovoltaic panels for electricity and solar thermal panels for water heating.
   - *Heat Pumps*: Install air-source or ground-source heat pumps for heating and cooling.
   - *Net-Zero Initiatives*: Develop subsidies or incentives to create net-zero energy buildings.
c. Efficient lighting and HVAC system upgrades
   - *Solar LED Lighting*: Replace incandescent bulbs with LED alternatives.
   - *Energy-efficient Appliances:* Promote appliances with high energy efficiency ratings
   - *Smart Home Technology*: Use automated systems for lighting, heating, and cooling to optimize energy use.
   - *Efficient Boilers and Air Conditioners*: Upgrade to energy-efficient heating, ventilation, and air conditioning systems.
   - *Passive Cooling Techniques:* Promote ventilation, shading, and reflective materials for roofs and walls.

d. Urban planning and green spaces
   - *Tree Planting*: Increase urban greenery to provide shade and reduce the heat island effect.
   - *Green Roofs and Walls*: Encourage vegetation on rooftops and walls to improve insulation and air quality.
   - *Sustainable Drainage*: Use permeable pavements and rain gardens to manage stormwater and improve building surroundings
e. Government, policy initiatives and environmental impact
   - *Subsidies and Incentives*: Offer grants, low-interest loans, or tax breaks for energy-efficient upgrades.
   - *Building Codes*: Enforce stringent energy efficiency standards for new constructions and major renovations.
   - *Energy Performance Certificates*: Make it mandatory for buildings to display their energy performance to encourage upgrades.
   - *Projects maintaining / increasing energy efficiency / positive environmental impact*: This includes thermal insulation of facades, installation of solar panels, etc.
   - Projects for installation / modernization /significant modifications of the elevators.

Our analysis will start with the completed projects which consist of improvements to building facades and the thermal insulation of perimeter walls. Most of the buildings treated under this program were constructed before the 1990s (with a standard height of five floors) using supporting brick structures and reinforced concrete slabs waterproofed with layers of bitumen and cardboard. Some buildings from the 1990–2000 period were also included. Many of these structures had deteriorated due to humidity and degradation over the years. The facades typically include balconies and predominantly single-glazed windows, with some partially double-glazed.

The facade improvements were achieved using a thermal insulation capot system, consisting of polystyrene, fiberglass nets, two layers of net glue, and graffiti plaster. The information provided in this section, including maps, tables, and pictures, was sourced from the Directorate of Facilities with Co-ownership, Municipality of Tirana as can be seen in Figure 1.

Furthermore, table 1 summarize the number of projects approved through the Community Fund from 2017 to the present.

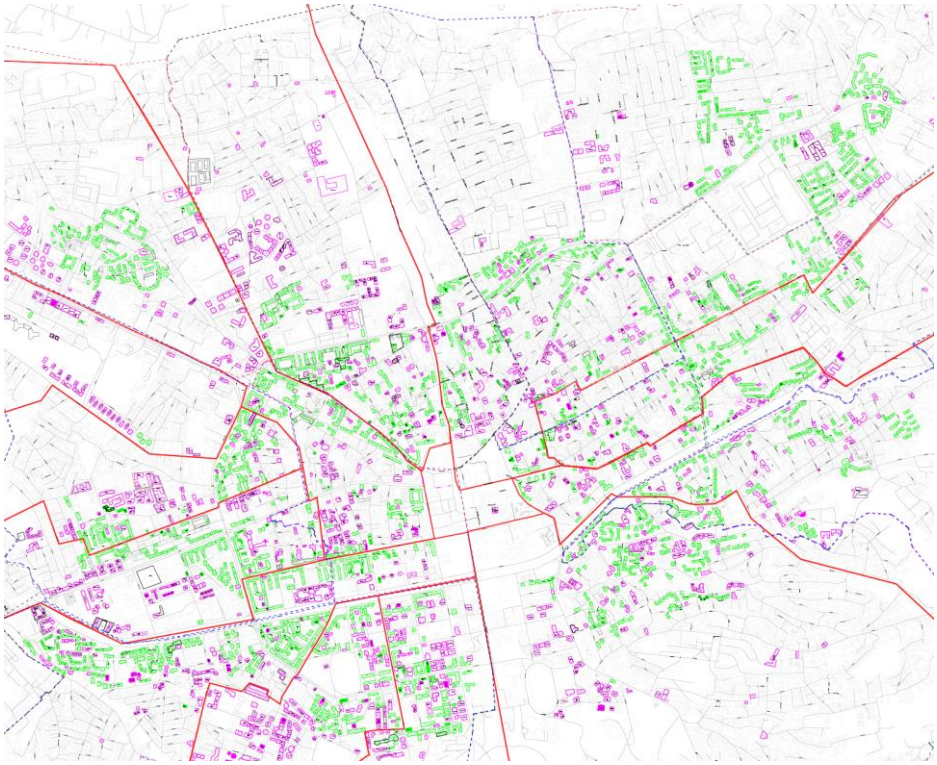


Figure 1. Map of residential objects whicha are in the process or have benefited from the community fund program, elaborated by Directorate of Facilities with Co-ownership

Table 1. Total projects with approval of community fund, Muncipality of Tirana

Year	Winning Projects
2017	8
2018	11
2019	21
2020	21
2021	31
2022	34
2023	51
2024	20 (ongoing)
Total	197

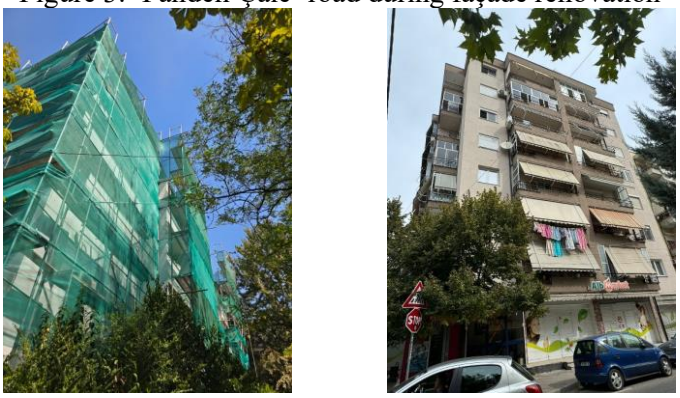
Overall are in the following illustrated some of positive examples of façade renovations of several residential buildings in Tirana, Albania.

(a) (b)

Figure 2. ‘Haxhi Hysen Dalliu’ road, (a) before and (b) after façade renovation

(a) (b)

Figure 3. ‘Pandeli Çale’ road during façade renovation



(a) (b)

Figure 4. ‘Ibrahim Dervishi’ road, (a) during and (b) after façade renovation

(a) (b)

Figure 5. 'Hodo Beg' road, (a) during and (b) after façade renovation

The facade cladding was attained with moisture-resistant polystyrene t = 5cm EPS polysterol panels (Sulaiman et al., 2024; Pramoono et al., 2022; Rika et al., 2023, Sedaghati et al., 2024), with thermal conductivity λ=0.03 mK + reinforcing fiberglass mesh 140 gr/m^2 + adhesive for the mesh with two hands (base coat) + graffiti plaster 2 mm, see Figure 6. The additional works that have increased energy efficiency of these buildings rely on implementation of waterproofing and thermal insulation of the terraces, the arrangement of water drainage from the terrace, the air conditioner system in the facade and the arrangement of the thresholds of the windows and balconies.

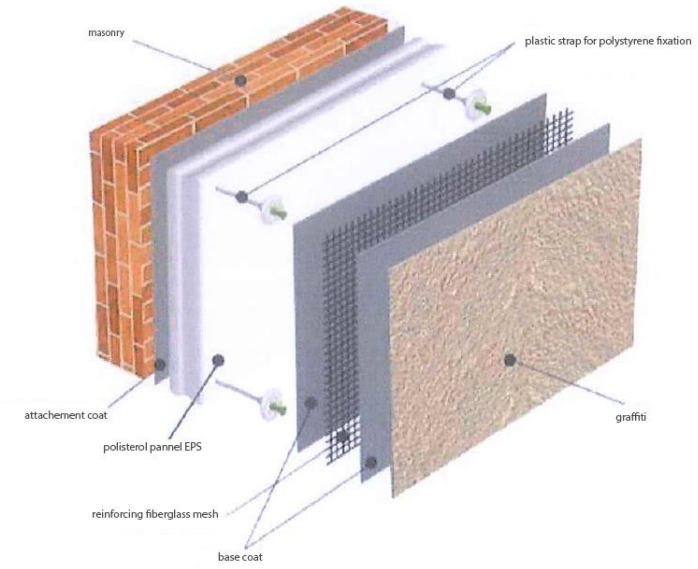


Figure 6. 'Hodo Beg' road (during and after façade renovation)

Based on the façade renovation, the total contribution of the heat loss coefficient R of the building has been calculated by using equation (1).

$$R = \frac{Q}{\Delta t} \qquad (1)$$

Where, Q is necessary heating system and Δt is the temperature differences between outdoor and indoor. In the winter the desing temperature in Tirana correspond to -1^{o}C and indoor 20^{o}C. Figure 7 depict that through implementation of façade renovation we can improve overall energy efficiency for the whole building by 24% in comparison of the previous work (Dhoska et al. 2024) which correspond to 26%.

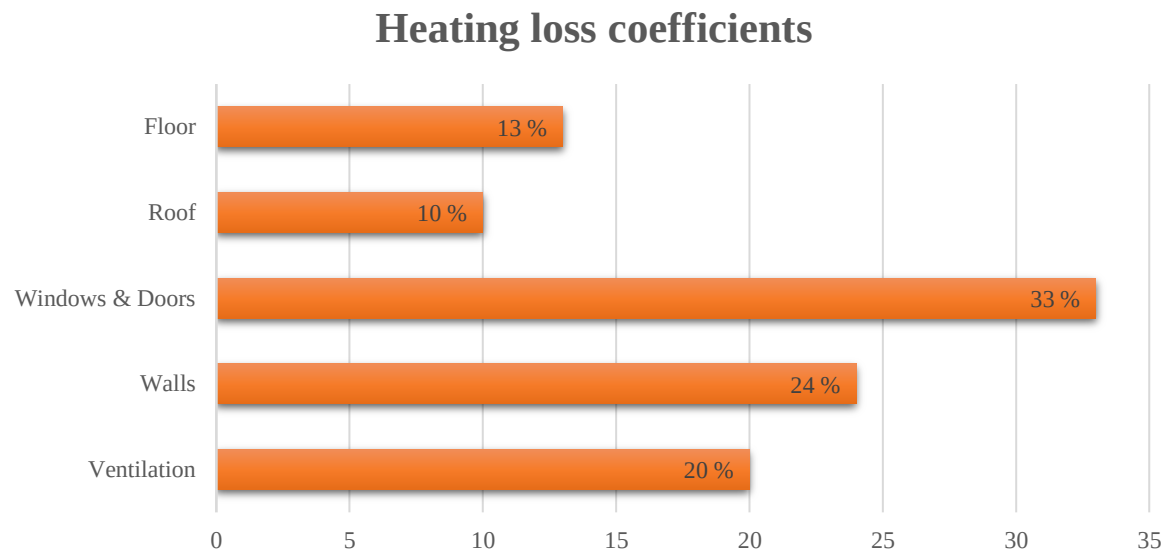


Figure 7. Percentage breakdown for every building heat loss coefficient in our case studies located in Tirana.

Façade renovation is the second most significant energy consumption parameter influencing total energy efficiency. It has been noted that more than 60% of the residential buildings in Tirana are old-style constructions without façade renovation. It is necessary to implement the strategic plan mentioned in the above section to improve energy efficiency, not only through façade renovation but also by addressing other parameters.

CONCLUSION

This paper demonstrates that the use of ventilated facades has significantly improved energy efficiency in housing, with potential for further enhancement through targeted measures. The research highlights the importance of expanding the Community Fund Program, including additional incentives like window replacements, to drive nationwide energy rehabilitation projects. By integrating technical, social, and policy solutions tailored to Tirana's context, this approach offers a practical pathway to improve urban energy efficiency across Albania. Implementation of façade renovation we can improve overall energy efficiency for the whole building by 24% in comparison of the previous work (Dhoska et al. 2024) which correspond to 26%. Additionally, various researchers who have analyzed similar cases of facade renovations for the whole residential building using the capote system in Albania have reported a 62% reduction in annual energy consumption for heating and a 15% reduction for cooling (Islami 2016 and Tyxhari et al., 2023). It is suggested that, in addition to the measures supported by the Community Fund, residents should be made aware of further actions that can directly enhance the energy efficiency of their homes. These measures include replacing single-glazed windows with double-glazed glass (which can reduce energy consumption by 33%) and adopting modern heating/cooling systems. Moreover, it is proposed that the Community Fund Program be expanded in the future to include additional incentives, such as window pane replacements. This program should also be implemented in all cities across Albania, initiating energy rehabilitation projects for buildings as a necessity of modern times. The novelty of this research lies in its innovative framework, which integrates technical, social, and policy-driven solutions specifically designed for Tirana's unique context, offering a significant contribution to urban energy efficiency initiatives. The research contributes new knowledge to the field of building energy efficiency, providing valuable insights that can directly influence the design, implementation, and policy decisions related to façade renovation systems in Tirana and similar urban contexts.

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AUTHOR CONTRIBUTIONS

Methodology, Vrusho, B., Dhoska, K.; Formal Analysis Golgota, A., Vrusho, B.; Investigation, Vrusho, B., Golgota, A., Dhoska, K.; Resources Vrusho, B., Golgota, A., Dhoska, K.; Data Curation, Dhoska, K., Writing –Original Draft Preparation, Vrusho, B., Golgota, A.; Writing –Review & Editing, Vrusho, B., Golgota, A., Dhoska, K.; Visualization, Dhoska, K..; Supervision, Vrusho, B., Dhoska, K.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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