

¹ Majid Baseer² Christian Ghiaus³ Ibrahim Ali
Kachalla

An Overview of Barriers and Potential Solutions for Energy Renovation of Existing Buildings



Abstract: - The renovation of existing buildings has recently gained recognition in the built environment as a viable alternative to the construction of new buildings. Building renovations have become a means of achieving sustainability through efficient and effective practices. However, the depth and rate of current energy renovations are far below what is needed to achieve this goal. Despite government efforts to promote building energy efficiency, various barriers hinder its implementation. This paper conducts a comprehensive analysis of these barriers, identifying and organizing them into distinct clusters: social, technical, financial, and institutional. The findings of this study will facilitate stakeholders' understanding of the barriers facing building renovation and inspire professionals to consider these barriers during the energy renovation of buildings. This approach can potentially reduce long-term energy consumption costs, greenhouse gas emissions, and the carbon footprint in the built environment.

Keywords: energy efficiency, sustainability, barriers, building renovation.

I. INTRODUCTION

The building sector is responsible for 40% of energy consumption and generates 36% of greenhouse gas emissions associated with energy use [1]. Moreover, global efforts to enhance energy efficiency have resulted in a reduced growth rate of energy consumption in the building sector compared to the increase in population and built floor area. Specifically, global final energy use per square meter of floor area has decreased by 25%, dropping from 200 kWh/m² in 2000 to 150 kWh/m² in 2017 [2]. It is estimated that more than 40% of Europe's residential buildings were built before the 1960s, and nearly 75% of these buildings are energy inefficient and are expected to remain in use by 2050 [3, 4]. It is essential to focus on renovating existing buildings, as this can achieve significant energy savings, potentially reducing the European Union's total energy consumption by 5%–6% and lowering greenhouse gas emissions by about 5%. The building sector in Europe has the largest untapped low-cost energy efficiency potential. However, without substantial policy changes, up to two-thirds of this potential might remain unexploited. According to the International Energy Agency, energy efficiency is considered the 'first fuel.' To decrease the European Union (EU) overall energy demand and imports and to achieve the Paris Agreement goals, around 250 million homes in the EU need energy renovations, in addition to other measures. This means renovating almost 23,000 homes daily until 2050, implying an annual renovation rate of 3.4%, which is similar to renovating all homes in Paris, London, and Berlin every year. Given that the majority of homes are in the lower energy performance classes (C–G), many will require deep renovations. Currently, EU Member States have an annual renovation rate of 0.4% to 1.2%, which is inadequate to meet emission targets [5-7]. Most Member States have been promoting voluntary renovations and, although this has resulted in some progress, it is insufficient to double the renovation rate. The adoption of energy-efficient practices in the building sector appears to be lagging behind the goals set by public policy in various European countries. Analyzing the factors that limit the adoption of energy-efficient initiatives in the building sector, despite their cost-effectiveness and availability, has become a significant area of interest. The investment appeal of energy efficiency measures may be lower than expected due to barriers that hinder their widespread adoption. This phenomenon, commonly referred to as the "energy efficiency gap" or "energy efficiency paradox," is defined as the gap between the achievable level of cost-effective energy efficiency and the actual level observed in practice, which obstructs investment in technologies that are both energy-efficient and cost-effective for potential investors [8, 9].

The potential to renovate existing buildings to energy-efficient standards is attracting significant attention from policymakers, social housing corporations, institutional real estate owners, financial organizations, and end-users. To achieve this goal, it is essential to enhance the methods used for building renovation, increasing both their rate and depth. Therefore, it is critical to examine the barriers that influence the adoption of building energy efficiency measures to identify the primary impediments to implementing these practices [10, 11].

¹ INSA Lyon, CNRS, CETHIL, UMR5008, 69621 Villeurbanne, France. majid.baseer@insa-lyon.fr

² INSA Lyon, CNRS, CETHIL, UMR5008, 69621 Villeurbanne, France. christian.ghiaus@insa-lyon.fr

³ INSA Lyon, CNRS, CETHIL, UMR5008, 69621 Villeurbanne, France. ibrahim-ali.kachalla@insa-lyon.fr

This paper outlines the potential barriers to energy efficiency adoption and proposes solutions, highlighting best practices to overcome these barriers, which could guide the development of future policies for enhancing energy renovation in existing buildings.

II. METHODOLOGY

A review of relevant literature was conducted to identify barriers to building renovation practices. A significant number of studies on energy renovation in existing buildings have examined specific countries or regions, including Europe, the United States, Asia, Africa, and Oceania. The majority of these studies focus on European countries. Initially, the emphasis was placed on examining, describing, and classifying the barriers to energy efficiency in existing buildings within a structured taxonomy. These barriers, which impede the implementation of energy renovation, differ across countries and can be categorized into four clusters: social, financial, technical, and institutional [12, 13].

SOCIAL BARRIERS

Social barriers describe the potential obstacles the public may encounter during energy renovation projects, which might cause public dissatisfaction. Energy renovation efforts are influenced by various social factors. For example, limited public awareness of energy renovation may result in conservative views regarding its necessity. **Error! Reference source not found.** presents a list and description of the various social barriers.

Table I. List and description of social barriers.

Social barriers	References
<p>Lack of motivation</p> <p>Residents often lack motivation due to limited information and knowledge of energy efficiency measures and strategies to mitigate greenhouse gas emissions.</p>	[14-19]
<p>Resistance to change</p> <p>Residents, particularly the elderly, are reluctant to adopt residence improvements, convinced that energy-efficient technologies are both too difficult to use and too challenging to obtain.</p>	[14, 16, 17, 19]
<p>Interruption to building operations</p> <p>This challenge involves energy renovation interventions that disrupt the normal operations of existing buildings. It may require temporary area shutdowns, occupant relocation, or limited access to certain areas, potentially influencing the decision to proceed with renovation.</p>	[20-22]
<p>Prebound effect</p> <p>Residents tend to increase their consumption of heating fuels after renovations, resulting in actual post-renovation energy usage that exceeds the initial projections based on calculated energy ratings.</p>	[23-26]
<p>Lack of trust</p> <p>Residents often doubt the advertised benefits of renovation as outlined in cost reports and have limited trust in the contractor's commitment.</p>	[17, 19, 24, 27]

FINANCIAL BARRIERS

Financial barriers describe the financial obstacles that the public or organizations may encounter in managing finances during energy renovation project. These barriers are a primary concern for stakeholders when making renovation decisions. Renovating existing buildings can be costly, with initial costs presenting challenges, even though savings are often realized over the long term. The costs of upgrades can vary depending on the type of upgrade, building size, and the complexity of the renovation. Furthermore, government incentives for renovating existing buildings are limited, which discourages renovation projects for financial reasons. **Error! Reference source not found.** presents a list and description of the various financial barriers.

Table II. List and description of financial barriers.

Financial barriers	References
<p>High investment cost</p> <p>Residents have limited financial resources to allocate towards costly renovation procedures. The initial cost of building renovation is significantly higher compared to other sustainable choices, such as environmentally friendly vehicles, when measured in terms of greenhouse gas reduction per ton. Due to these financial constraints, residents are often reluctant to allocate funds for renovation.</p>	[15-19, 24, 28-31]
<p>Uncertainty about payback period</p> <p>The lack of assessments regarding the impact of price fluctuations on the demand for energy resources can reduce the profitability of renovation investments, extend payback periods, and necessitate investors to bear potential financial losses.</p>	[15-19, 24, 30, 32]
<p>Lack of government support</p> <p>Governments have prioritized energy production industries over energy efficiency initiatives, as evident through tax policies and R&D support, demonstrating a lack of governmental commitment to efficiency efforts.</p>	[33, 34]
<p>Split incentives</p> <p>This issue arises when the entity incurring the costs of energy efficiency initiatives differs from the one enjoying the savings. For instance, landlords may hesitate to invest in energy-efficient solutions because they incur the upfront costs, while residents benefit from reduced energy expenses. As a result, landlords often lack the incentive to pursue energy-efficient upgrades.</p>	[19, 35, 36]
<p>Lack of loan opportunities</p> <p>Attractive loan opportunities are limited for residents with low to medium incomes, who are often not eligible for bank loans.</p>	[33, 34, 37]
<p>Lack of incentives for investment</p> <p>The lack of commercial activities related to energy-efficient renovations also contributes to the failure to attract private sector investors. For these investors, financial returns are the main priority, rather than social and environmental benefits.</p>	[16-19, 24, 30, 34]

TECHNICAL BARRIERS

Technical barriers describe obstacles arising from the complexity of technology, systems, or processes involved in the energy renovation of existing buildings. Buildings constructed before the 1980s typically have outdated systems with limited potential for energy-efficient upgrades. Furthermore, the introduction of new technologies and innovations introduces new renovation trends for existing buildings, necessitating specialized knowledge and skills. **Error! Reference source not found.** presents a list and description of the various technical barriers.

Table III. List and description of technical barriers.

Technical barriers	References
<p>Lack of skilled building professionals</p> <p>Obtaining technical support presents a significant challenge for stakeholders, primarily due to the limited availability of qualified professionals. This issue is further compounded by the difficulty in assessing the expertise of eligible professionals to address specific issues.</p>	[16, 17, 30, 38-40]
<p>Inability to identify optimal renovation measures</p> <p>Determining the most suitable renovation measures is challenging due to the diverse characteristics of existing buildings in terms of building typology, construction period, and energy efficiency properties. Consequently, the unique characteristics of each building necessitate specific renovation measures.</p>	[16-18, 30, 41]

Technical barriers	References
<p>Lsack of standards and guidelines</p> <p>This challenge involves the lack of clear, enforceable standards and guidelines that professionals can depend on when using innovative technologies in energy renovation projects.</p>	[17, 19, 24, 42]

INSTITUTIONAL BARRIERS

Institutional barriers describe obstacles arising from the organizational structure and practices within organizations, as well as from the stakeholders involved. These obstacles include issues related to ownership, management, and legal agreements, all of which can affect the renovation process. Conflicts among building owners, residents, consultants, and contractors may hinder the decision-making process in energy renovation projects. **Error! Reference source not found.** presents a list and description of the various institutional barriers.

Table IV. List and description of institutional barriers.

Institutional barriers	References
<p>Lack of energy audit databases for energy renovation initiatives</p> <p>The lack of energy audit databases for existing residences presents a significant obstacle in identifying specific residences for energy renovation initiatives.</p>	[17, 24, 43]
<p>Complex workflow</p> <p>Although renovation professionals offer various options, none provide a comprehensive range of energy renovation services. As a result, residents must engage multiple professionals to implement various renovation measures, adding complexity to the renovation process.</p>	[17, 24, 30, 44]
<p>Multi-stakeholder issues</p> <p>The differing interests of public and private stakeholders further complicate the decision-making process for renovation. It is essential to understand the needs and expectations of these stakeholders. For example, local governments may prioritize reducing greenhouse gas emissions to comply with national climate change mitigation goals; however, these priorities may not necessarily align with the interests of other stakeholders.</p>	[14, 17, 18, 30, 45]

III. CONCLUSION AND RECOMMENDATIONS

This research provides a comprehensive reference of barriers, aiding in the understanding of potential challenges encountered during the energy renovation of existing buildings. It helps regulatory bodies and policymakers determine where policies should be focused and assists researchers in identifying areas that need further research to improve the energy efficiency of existing buildings.

Based on the barriers identified in the literature, this study recommends the following potential solutions for addressing these challenges:

- Acknowledge the pivotal role of governments in promoting energy efficiency and sustainability through robust building codes, financial incentives, and educational initiatives.
- Encourage collaboration among various stakeholders, including policymakers, industry experts, researchers, and the public, to foster collective commitment to energy-efficient buildings and address identified challenges.
- Continuously monitor and evaluate the impact of policies, regulations, and incentives to ensure they meet their intended objectives.
- Enhance public engagement and awareness by providing digital tools to dispel misconceptions and reduce resistance to change.
- Conduct case studies on successful energy-efficient building projects worldwide to identify best practices that can be replicated.
- Develop reliable, user-friendly tools for users and property owners to simulate investment costs, payback periods, and returns.

- Establish publicly accessible databases managed by municipalities to demonstrate the energy efficiency of renovated buildings and their transformations, where applicable.
- Provide specialized training for professionals, stakeholders, and public administration officials in the field of building energy renovation.
- Provide financing mechanisms such as soft loans, which feature below-market interest rates and may include additional incentives (e.g., extended maturity, grace periods, minimal administrative charges), to increase relevance and appeal to a broad range of households.
- Engage with local community leaders to ensure that community needs, concerns, and feedback are represented during disruptive interventions, such as renovations.
- Ensure legal flexibility to accommodate case-by-case adaptability in renovation projects.

Addressing these knowledge gaps will lead to a more comprehensive understanding of the barriers to building energy efficiency and support the development of more effective solutions to enhance energy efficiency in the built environment.

REFERENCES

- [1] Baude, M., F.-X. Dussud, M. Ecoiffier, S. Moreau, A. Bottin, J. Duvernoy, and C. Vailles, *Key figures on climate France, Europe and Worldwide. Edition 2018*. 2017.
- [2] Abergel, T., B. Dean, J. Dulac, I. Hamilton, T.J.G.A.f.B. Wheeler, and Construction, *GLOBAL STATUS REPORT: Towards a zero-emission, efficient, and resilient buildings and construction sector*. 2018.
- [3] Irati ARTOLA, T., *Boosting Building Renovation: What potential and value for Europe?* 2016.
- [4] Bagaini, A., F. Colelli, E. Croci, and T.J.T.E.J. Molteni, *Assessing the relevance of barriers to energy efficiency implementation in the building and transport sectors in eight European countries*. 2020. 33(8): p. 106820.
- [5] Broers, W., V. Vasseur, R. Kemp, N. Abujidi, Z.J.E.R. Vroon, and S. Science, *Decided or divided? An empirical analysis of the decision-making process of Dutch homeowners for energy renovation measures*. 2019. 58: p. 101284.
- [6] Wilson, C., H. Pettifor, and G.J.A.e. Chrysochoidis, *Quantitative modelling of why and how homeowners decide to renovate energy efficiently*. 2018. 212: p. 1333-1344.
- [7] Hutton, H., *Renovation Roadmap Making Europe's homes fit for the 21st Century*. 2018.
- [8] Jaffe, A.B. and R.N. Stavins, *The energy-efficiency gap What does it mean?* Energy Policy, 1994. 22(10): p. 804-810.
- [9] Sorrell, S., E. O'Malley, J. Schleich, and S. Scott, *The Economics of Energy Efficiency: Barriers to Cost-Effective Investment*. Fraunhofer ISI, 2004.
- [10] Jensen, K.G., H. Birgisdottir, K.S. Poulsgaard, L. Lind, C.Ø. Christensen, O. Skjelmose, S.J. Carruth, K.K. Jensen, I.O. Canera, and J. Manbodh, *Guide to sustainable building certifications*. 2018.
- [11] Economidou, M., V. Todeschi, P.J.E.S. Bertoldi, and T.R.R.I.J.R. Centre, *Accelerating energy renovation investments in buildings*. 2019.
- [12] Hirst, E. and M. Brown, *Closing the efficiency gap: barriers to the efficient use of energy*. Resources, Conservation and Recycling, 1990. 3(4): p. 267-281.
- [13] Jin, Z., J. Sun, C. Liu, and Y. Zhang, *Economic Incentive Mechanism Design for Green Buildings based on Analysis of Externalities [C]*. in *Criocm International Symposium on Advancement of Construction Management & Real Estate*. 2009.
- [14] Zhang, H., K. Hewage, H. Karunathilake, H. Feng, and R. Sadiq, *Research on policy strategies for implementing energy retrofits in the residential buildings*. Journal of Building Engineering, 2021. 43: p. 103161.
- [15] Jia, J.-J., J.-H. Xu, Y. Fan, Q.-J.R. Ji, and S.E. Reviews, *Willingness to accept energy-saving measures and adoption barriers in the residential sector: An empirical analysis in Beijing, China*. 2018. 95: p. 56-73.
- [16] Djokoto, S.D., J. Dadzie, and E.J.J.o.S.D. Ohemeng-Ababio, *Barriers to sustainable construction in the Ghanaian construction industry: consultants perspectives*. 2014. 7(1): p. 134.
- [17] Boza-Kiss, B. and P.J.J.R.C. Bertoldi, Eur. Energy Effic. Platf., *One-stop-shops for energy renovations of buildings*. 2018.
- [18] Kazemi, M. and A. Kazemi, *Financial barriers to residential buildings' energy efficiency in Iran*. Energy Efficiency, 2022. 15.
- [19] Fasna, M., S.J.B.E.P. Gunatilake, and A. Management, *Overcoming barriers for building energy efficiency retrofits: insights from hotel retrofits in Sri Lanka*. 2020. 10(2): p. 277-295.
- [20] *MORE-CONNECT: Development and advanced prefabrication of innovative, multifunctional building envelope elements for modular retrofitting and smart connections*. 2015. 78: p. 1057-1062.
- [21] Sovacool, B.K.J.N., *Diversity: Energy studies need social science*. 2014. 511(7511): p. 529-530.
- [22] Feige, A., H. Wallbaum, M. Janser, and L.J.J.o.C.R.E. Windlinger, *Impact of sustainable office buildings on occupant's comfort and productivity*. 2013. 15(1): p. 7-34.
- [23] Lopez, E., B. Schlomann, M. Reuter, and W. Eichhammer, *Energy efficiency trends and policies in Germany—An analysis based on the ODYSSEE and MURE databases*. Fraunhofer Institute for Systems Innovation Research ISI: Karlsruhe, Germany, 2018.
- [24] Cristino, T., A.F. Neto, F. Wurtz, B.J.E. Delinchant, and Buildings, *Barriers to the adoption of energy-efficient technologies in the building sector: A survey of Brazil*. 2021. 252: p. 111452.

- [25] Sunikka-Blank, M., R.J.B.R. Galvin, and Information, *Introducing the prebound effect: the gap between performance and actual energy consumption*. 2012. 40(3): p. 260-273.
- [26] Galvin, R.J.B.R. and Information, *How prebound effects compromise the market premium for energy efficiency in German house sales*. 2023. 51(5): p. 501-517.
- [27] McCarty, J., A. Scott, and A. Rysanek, *Determining the retrofit viability of Vancouver's single-detached homes: an expert elicitation*. Buildings, 2021. 2(1).
- [28] Kim, A., Y. Sunitiyoso, and L. Medal, *Decision Making of Building Energy Efficiency Retrofit in Higher Education Institution*. 2019.
- [29] Ascione, F., N. Bianco, R.F. De Masi, G.M. Mauro, and G.P. Vanoli, *Energy retrofit of educational buildings: Transient energy simulations, model calibration and multi-objective optimization towards nearly zero-energy performance*. Energy and Buildings, 2017. 144: p. 303-319.
- [30] Du, P., L.-Q. Zheng, B.-C. Xie, and A. Mahalingam, *Barriers to the adoption of energy-saving technologies in the building sector: A survey study of Jing-jin-tang, China*. Energy Policy, 2014. 75: p. 206-216.
- [31] Carlander, J. and P. Thollander, *Barriers to implementation of energy-efficient technologies in building construction projects — Results from a Swedish case study*. Resources, Environment and Sustainability, 2023. 11: p. 100097.
- [32] Galvin, R. and M. Sunikka-Blank, *Quantification of (p)rebound effects in retrofit policies – Why does it matter?* Energy, 2016. 95: p. 415-424.
- [33] Cristino, T.M., A. Faria Neto, F. Wurtz, and B. Delinchant, *Barriers to the adoption of energy-efficient technologies in the building sector: A survey of Brazil*. Energy and Buildings, 2021. 252: p. 111452.
- [34] Sebi, C., S. Nadel, B. Schlomann, and J. Steinbach, *Policy strategies for achieving large long-term savings from retrofitting existing buildings*. Energy Efficiency, 2019. 12: p. 1-17.
- [35] Amoruso, G., N. Donevska, and G.J.E.E. Skomedal, *German and Norwegian policy approach to residential buildings' energy efficiency—A comparative assessment*. 2018. 11: p. 1375-1395.
- [36] Caputo, P., G.J.S.C. Pasetti, and Society, *Boosting the energy renovation rate of the private building stock in Italy: Policies and innovative GIS-based tools*. 2017. 34: p. 394-404.
- [37] Foxon, T., M. Nye, and L. Whitmarsh, *Sociopsychological Perspectives on the Active Roles of Domestic Actors in Transition to a Lower Carbon Electricity Economy*. Environment and Planning A, 2010. 42: p. 697-714.
- [38] Weiss, J., E. Dunkelberg, and T. Vogelpohl, *Improving policy instruments to better tap into homeowner refurbishment potential: Lessons learned from a case study in Germany*. Energy Policy, 2012. 44: p. 406-415.
- [39] Liu, G., X. Li, Y. Tan, and G. Zhang, *Building green retrofit in China: Policies, barriers and recommendations*. Energy Policy, 2020. 139: p. 111356.
- [40] Sebi, C., S. Nadel, B. Schlomann, and J. Steinbach, *Policy strategies for achieving large long-term savings from retrofitting existing buildings*. Energy Efficiency, 2019. 12: p. 89-105.
- [41] Wu, R., G. Mavromatidis, K. Orehounig, and J. Carmeliet, *Multiobjective optimisation of energy systems and building envelope retrofit in a residential community*. Applied Energy, 2017. 190: p. 634-649.
- [42] Tohinaka, K., N. Kuhn, R. Faesy, and D. Quinlan, *Technical assistance program residential retrofit program design guide contact information*. Oak Ridge National Laboratory, 2011.
- [43] Delmastro, C., G. Mutani, and S.P. Corgnati, *A supporting method for selecting cost-optimal energy retrofit policies for residential buildings at the urban scale*. Energy Policy, 2016. 99: p. 42-56.
- [44] Cluett, R. and J. Amann. *Residential deep energy retrofits*. 2014. American Council for an Energy Efficient Economy.
- [45] Elsharkawy, H. and P. Rutherford, *Energy-efficient retrofit of social housing in the UK: Lessons learned from a Community Energy Saving Programme (CESP) in Nottingham*. Energy and Buildings, 2018. 172: p. 295-306.