

# Assessing barriers for energy-efficient retrofits to derive purposive policy recommendations for the residential building sector

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## ABSTRACT

The European Union aims to reduce its carbon emissions by 55% by 2030, with the building sector accounting for more than one third of its total energy consumption. Therefore, it is imperative that countries with large populations, such as Germany, identify the most relevant barriers for energy-efficient retrofits (EER) to accelerate building retrofit activities. However, policymakers still lack evidence on which barriers are most important in practice, making systematic identification and prioritization necessary to avoid misdirected interventions. Consequently, this study combines a structured literature review with an online survey to derive financial, regulatory, informational and technical barriers empirically assessing their real-world relevance in a survey of 64 building experts from eight different professions using eight quantitative and 14 qualitative questions. This analysis leads to 25 policy implications that provide policymakers with actionable guidelines. Our findings show that experts perceive financial and regulatory barriers as most critical, calling for grant-based subsidies, better tax incentives, legally fixed funding terms, and less bureaucracy, particularly for retrofits of recently inherited buildings. Informational and technical challenges remain significant, with demands for a central coordination office, improved knowledge sharing, and the adoption of smart metering, AI-based analytics, and digital assistants to support decision-making. By aligning academic synthesis with stakeholders' priorities, this study offers a structured approach to overcoming EER barriers in Germany and presents transferable insights for other countries.

## 1. Introduction

Climate change is a global threat to the livelihood of humanity and planetary environmental systems, mainly caused by humanity's demand for energy (IPCC, 2023). As the largest carbon emitters, industrialized nations play a vital role in addressing this crisis on a global scale. Consequently, the European member states pledged to keep the increase of the global average temperature below 2 °C, as proposed by the Paris Agreement in 2016 (European Commission, 2016). The member states must comply with this regulation and develop and implement long-term strategies to reduce carbon emissions. Hereby, the building and construction sector plays a crucial role as it accounts for 40% of the European total energy consumption and 36% of global carbon emissions, offering a significant saving potential (Cao et al., 2016). Tapping into this potential, the EU aims to convert all existing buildings into zero-emission buildings by 2050 and requires all member states to establish a revised National Building Renovation Plan by the end of 2025

(Zangheri et al., 2018; European Commission, 2025). These legislations combine policies, monitoring instruments, and financial support to fulfill the proposed retrofit targets for 2030, 2040, and 2050 (Zangheri et al., 2018; European Commission, 2025).

Germany, as one of the largest carbon emitters within the EU, proposed even more ambitious climate goals and aims to achieve net greenhouse gas neutrality for buildings by 2045 (German Energy Agency, 2021). Although building carbon emissions dropped by 43% since 1990, the retrofit rate for rental apartments declined below 1% (März et al., 2020; Behr et al., 2023). To understand these impediments to retrofitting, it is essential to recognize the unique characteristics of the German housing market. In contrast to many other nations, Germany exhibits a pronounced tenant-dominated market, with a population residing in rental apartments exceeding 50%. This dynamic, in essence, accentuates the inherent "split incentive" dilemma, in which landlords bear the financial burden of retrofits while tenants benefit from the resulting reduction in energy consumption (Lang et al., 2022; Melvin,

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2018; Azimi et al., 2024). Moreover, 24 million residential buildings (60%) were built prior to the implementation of the first Thermal Insulation Ordinance, which would require a high retrofit rate to achieve climate neutrality (Federal Ministry for Housing, Urban Development and Building, 2025a; Federal Ministry for Economic Affairs and Energy, 2014). This exceptionally high proportion of aging, energy-inefficient buildings, coupled with the complex landlord-tenant dynamic, requires severe regulatory interventions and a significantly higher retrofit rate to achieve climate neutrality. For this, policymakers commonly need to balance financial considerations, thermal comfort, and energy savings, among other constraints, which are often in conflict with one another (Li et al., 2021). Consequently, identifying and assessing the most pressing barriers is a prerequisite for effective policy design, as it enables policymakers to target high-leverage barriers whilst constrained by scarce resources. Ultimately, the combination of theoretical and practical expertise points towards actionable policy measures that directly lead to more EERs.

A study among respondents from different countries in the European Union revealed several different problem dimensions ranging from environmental, technical, financial, social, to legal barriers (Camarasa et al., 2021). The financing of energy efficient retrofits (EER), especially initial and life-cycle costs, is a common barrier as it requires an upfront investment, whereas savings from reduced energy expenditure occur later (Rockstuhl et al., 2021; Reaños et al., 2023; Dolšák, 2023). Apart from this, other barriers exist, such as a lack of technological understanding, potentially leading to conflicts between homeowners and professionals, and ultimately to a reluctance to tap into energy-saving potentials (Brown et al., 2014; Morgan et al., 2024). Moreover, behavioral barriers, such as low awareness about energy efficiency benefits and limited information access, complicate EERs (Rodríguez et al., 2024). Knowledge of the relevance of barriers forms the necessary foundation to design effective retrofit policies, as it helps identify and prioritize the most significant barriers and select targeted instruments in a consecutive step. Although previous literature investigates such barriers for EERs within Germany, there is no indication of their perceived severity by stakeholders, such as homeowners and building experts, involved in the EER process, yet this is essential for developing targeted retrofit policies, as it indicates which barriers have a significant influence on stakeholders in the building sector and should consequently be addressed first (Bagaini et al., 2020; März et al., 2020; März, 2018). Therefore, we formulate the following research question (RQ):

RQ: What are the main barriers influencing EER decision-making for residential buildings in Germany across key stakeholder groups, and how can policymakers address them?

To address our research question, we organize the rest of our study as follows: Section 2 covers pertinent literature regarding barriers and policy solutions for EERs. Section 3 highlights our methodology to identify and indicate the severity of retrofit barriers, based on a structured literature review and an online questionnaire. Section 4 presents the results of the literature review and our survey before we discuss relevant insights and possible policy implications in Section 5. We conclude this study with the final Section 6, in which we summarize the work, highlight limitations, and describe areas for further research.

## 2. Related work on retrofit barriers

EER barriers are the subject of multiple scientific investigations, as it is essential to understand the associated decision-making process (Camarasa et al., 2021; Lang et al., 2021). There are various methodological approaches to classify barriers for energy efficient technology (EET), ranging from structured literature reviews to interviews, surveys, and online questionnaires. Table 1 presents recent works that evaluate different barriers by leveraging these methodological approaches, categorized by their research method and main contribution.

**Table 1**  
Recent studies on barriers to EER: methodological approaches and contributions.

Authors	Research Method	Main contribution
Casquero-Modrego et al. (2025)	Online survey	Comparative analysis of three surveys distributed to home occupants and construction professionals in the U.S. focused on energy upgrades and electrification retrofits for residential building decarbonization.
Azimi et al. (2024)	Online survey	Survey of 12 low-income households in Australia to identify the most influential financial and informational barriers.
Reaños et al. (2023)	Telephone survey	Associates the retrofit behavior of Irish homeowners with household characteristics, environmental attitude, and financial budgets.
Blomqvist et al. (2022)	Online survey	Nationwide survey on the perception of financial EER barriers among 216 professionals in the Swedish building sector.
Camarasa et al. (2021)	Online survey	Characterizes perceived obstacles and barriers of nine energy-efficient technologies across eight European countries.
Bagaini et al. (2020)	Online survey	Identification of policy barriers in Bulgaria, Germany, Greece, Estonia, the United Kingdom, Italy, Belgium, and Serbia.
März et al. (2020)	Interviews and postal survey	Investigates reasons why small private landlords in Germany refrain from making EERs and required policy changes to foster such investments.
Liu et al. (2020)	Systematic literature review	Systematic literature review of policy-driven retrofit barriers in China with adaptation recommendations.
Ambrose and McCarthy (2019)	Interviews	Evaluating the attitude of landlords in New Zealand regarding EERs of their properties.
Hrovatin and Zorić (2018)	Telephone survey	Identifying reasons for energy-efficient retrofit decisions in 1000 single-family house owners in Slovenia.
März (2018)	Semi-structured, qualitative interviews	Combining theoretical aspects in an explanatory model to understand the EER decision-making process of small private landlords in Germany.
Yeatts et al. (2017)	Systematic literature review	A systematic literature review of EER barriers regarding knowledge of EET, access to EETs, and desire to use EET.

Based on a survey in 2016 with experts from eight different European countries, Bagaini et al. (2020) analyzed financial, institutional, and behavioral barriers in the building and transportation sector by assessing the relevance of each specific barrier, with financial and behavioral barriers being the most relevant. In a survey, Camarasa et al. (2021) qualitatively confirmed that out of environmental, technical, economic, social, and regulatory barriers, economic restrictions and technical challenges form the most relevant obstacles in Belgium, Germany, Spain, France, Italy, the Netherlands, Poland, and the United Kingdom. In Germany, homeowners frequently state the lack of financial resources and uncertainty of the return on investment as EER obstacles (Achnicht and Madlener, 2014). A survey of 1069 British private landlords further emphasize the gravity of financial barriers, as only 17% of private homeowners receive funding from sources outside of their own means, and more than 85% of respondents used their own financial savings for their EER. Consequently, the majority of respondents expressed a wish for financial compensation (Miu and Hawkes, 2020). Bergman and Foxon (2020) examine the challenges associated with stimulating

large-scale investments in EER, arguing for financial subsidies, better demand management, and less complex policies. Moreover, Liu et al. (2020) identified varying political guidelines and missing long-term objectives as considerable regulatory barriers. Regarding knowledge and behavioral barriers, a telephone survey in Ireland discovered that many homeowners do not have sufficient information about EERs, which was confirmed in a postal survey about the EER decisions in Germany (Reaños et al., 2023; März et al., 2020). Blomqvist et al. (2022) interviewed professionals working in the Swedish building sector who ranked the lack of time or shifting priorities as a relevant barrier to work on EERs, indicating that even organizational structures could hinder retrofit decisions.

The presented studies address different dimensions in terms of their research aim. To better analyze other barriers, previous research allocated them into thematic groups such as administration, finance, knowledge/information, and technology (Liu et al., 2020). Ambrose and McCarthy (2019) organized their identified barriers into four groups: economic explanation, lack of knowledge and misinformation, local and regional building market factors, and socio-cultural behavior, including low trust in government initiatives (Ambrose and McCarthy, 2019). Hrovatin and Zorić (2018) utilized a more granular allocation, organizing their barriers into five groups: policy measures, economic factors, socioeconomic information, technical building characteristics, and behavioral aspects (Hrovatin and Zorić, 2018). To perform a structured literature review and build a precise questionnaire, we summarize the largely overlapping nomenclature in four well-fitting categories for the German building sector, namely financial, regulatory, informational, and technical barriers. Most studies focus on one stakeholder group or do not reflect recent global developments. Only a limited number of studies exist that investigate EER barriers in Germany (c.f. Table 1). Moreover, none of the identified studies assesses the perceived relevance of theoretical barriers by stakeholders responsible for EERs and affected by policy measures. As policymakers must prioritize competing barriers when balancing limited budgets with designing regulatory instruments, the perceived relevance of barriers and solutions potentially serves a guideline to formulate actionable policies under the given constraints.

### 3. Methodology

The primary purpose of this study is to investigate the main barriers influencing EER decision-making for residential buildings in Germany and how policymakers can address them. For this, the study follows a two-step approach. First, we perform a structured literature review based on Wolfswinkel et al. (2013) to identify barriers described by academia. Second, we evaluate these barriers in an online survey of practitioners affected by the previously identified barriers to verify the literature results and analyze the perceived severity. We then continue to derive actionable policy recommendations from our results. Fig. 1 illustrates the methodological approach of this study.

#### 3.1. Literature review

We use the grounded theory based on Wolfswinkel et al. (2013) as a structural approach for finding existing barriers for EERs in pertinent literature. For this, we conducted an extensive pre-search to build the utilized search term (c.f. Table 2). Following the structured literature review method of Wolfswinkel et al. (2013), we applied the four steps *Identification*, *Examination*, *Analysis*, and *Inclusion*, illustrated in Appendix A. During the *Identification* phase, we encountered 1117 potentially relevant articles across four different scientific libraries without applying time or geographical search restrictions to build a robust foundation for the following *Examination* phase.

During this phase, we excluded 1023 publications based on their title and additional 123 results after evaluating the corresponding abstracts. As we detected no duplicates, we concluded the *Examination* phase with 31 publications. After the *Analysis* phase and the corresponding full-text

analysis, the results count dropped by one and increased in the *Inclusion* phase by one additional publication after screening the citations of the identified works. The final sample contains 31 selected studies covering 16 different countries. The literature focuses on the UK (4), China (3), Slovenia (2), Germany (2), and Ireland (2). In contrast, the study types that were conducted ranged from structured literature reviews and surveys to data analysis of publicly available household data. We continued thematically organizing the barriers based on the categories identified in the literature and summarized redundant results.

#### 3.2. Survey design

Based on this categorization, we designed an anonymized online questionnaire following the approach of van Selm and Jankowski (2006) to rank the perceived severity of the barriers by utilizing qualitative and quantitative questions (Dillman et al., 2014). We then asked participants to evaluate solutions that mitigate these barriers. Participants can access the survey through a link to the online questionnaire tool *Lime Survey*.<sup>1</sup> The complete survey has an average completion time of approximately 15 min and was published in German. In total we invited 701 German-speaking domain experts from Germany, Austria, and Switzerland to participate in the survey across six cohorts including private landlords, architects and engineering firms, property construction companies, property managements, real estate agency, energy consultants, institutional real estate investors, craft businesses, and one respondent from a local authority district. Participants were recruited primarily through the authors' professional networks in the energy-efficient retrofit and building sectors. In addition, relevant stakeholders in German-speaking Europe were identified via targeted online searches and contacted directly by email invitation. We structured the survey in five short pages, one for general information on the participants and one for each category, to minimize the dropout rate, and published it on March 4, 2025. On the starting page of the survey, we define the term EER as any modernization measures that improve the energy balance of residential buildings to ensure uniform terminology. Afterward, participants provide socio-economic information (e.g., job role, business area, number of properties), whereas the questions depend on the selected job role. Anonymity was ensured by administering the questionnaire via *Lime Survey* in anonymous mode, such that no names, contact details, or explicit company affiliations were collected, and responses could not be traced back to individuals or organizations. Due to data-protection regulations the survey does not include additional information such as gender, age, or educational information to ensure the highest possible response rate. On the following pages, participants rank EER barriers on a 10-point Likert Scale, ranging from strongly disagree (1) to strongly agree (10), and provide supplementary qualitative information (Emerson, 2017). Table 3 provides an overview of all quantitative survey questions, translated from German to English, serving as the foundation for the subsequent analyses in Section 4. For completeness, the corresponding response categories for each question are provided in the explicitly referenced tables. In total, we received 130 responses, of which 66 were partially completed and 64 were fully completed. We reclassified two job descriptions, namely, financial advisor and mechanical engineer, as private homeowners, and the one respondent from a local authority district as a property management given their similar operational responsibilities. Except for one participant with properties in Austria, all properties are in Germany. Most participants are private landlords (25), followed by architects and engineering firms (10), property managements (8), property construction companies (7), real estate agencies (5), energy consultants (4), institutional real estate investors (3), and craft businesses (2). A potential sampling bias arises from the non-proportional recruitment and results in unequal stakeholder group sizes, as all identified contacts were

<sup>1</sup> <https://www.limesurvey.org/>.

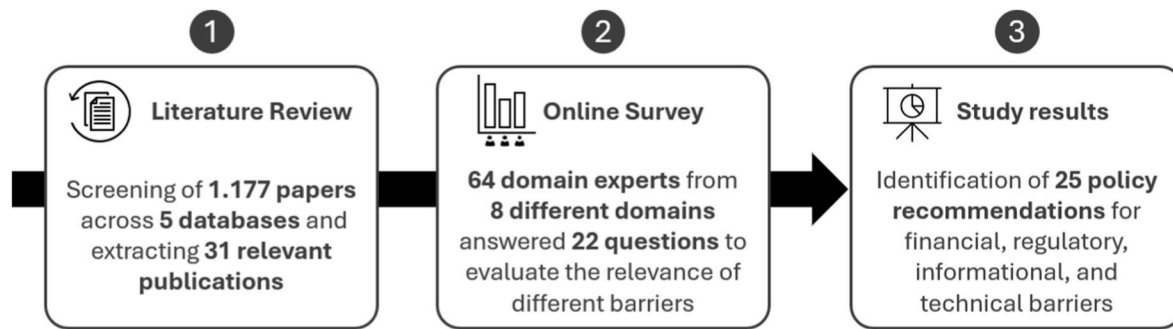


Fig. 1. Summary of the methodological approach.

Table 2

Search criteria for the structured literature review.

Criterion	Characteristic
Databases	ScienceDirect, SpringerLink, AIS, IEEE Xplore Digital Library
Source	Peer-reviewed journal articles, Conference Proceedings
Types	
Search	Title, Abstract, and author-specified keywords
Fields	
Search	"retrofit" AND ("barrier" OR "obstacle") AND "energy efficiency" AND
Term	"residential" AND NOT "commercial" AND NOT "real estate"

Table 3

Presentation of the quantitative survey questions.

Nr.	Question	Response Options (Ref.)
Q1	How would you rate the following barriers for an energy-efficient retrofit?	Table 5
Q2	How would you rate the following reasons for an energy-efficient retrofit?	Table 6
Q3	How would you rate the following reasons against energy-efficient retrofit?	Table 7
Q4	How do you rate the following approaches to addressing financial barriers?	Table 8
Q5	How do you rate the following regulations and political initiatives for your energy renovation plans?	Table 9
Q6	How would you rate the following options for obtaining information about current regulations?	Table 10
Q7	How would you rate the following media for obtaining information?	Table 11
Q8	How relevant are the following digital information systems to you?	Table 12

invited without predefined quotas. Consequently, the distribution of responses reflects differential response rates rather than the underlying population structure.

Furthermore, we added *no response* as an option for all obligatory quantitative questions in case respondents prefer to or cannot answer a question. Our survey regarding financial, regulatory, informational, and technical barriers consists of eight quantitative and 14 supplementary qualitative questions. Besides ranking predefined barriers, respondents can answer open-ended qualitative questions to provide further information. Eight of these qualitative questions are directly linked to one specific quantitative question allowing participants to provide supplementary information on a specific ranking (e.g., for Q1: What other reasons can you think of for energy-efficient retrofits?). The remaining six qualitative questions are used to obtain information about participants' knowledge and domain expertise (e.g., what is your occupation?). Following Emerson (2017), we added a progress bar to depict the participants' advancement during the survey as motivational information.

## 4. Results

Following the approach outlined in Fig. 1, we leverage a structured literature review to identify relevant publications and continue to classify them according to the categories derived in Section 2, namely financial barriers (FB), regulatory barriers (RB), informational barriers (IB), and technical barriers (TB). Consequently, we attribute these non-exclusive categories to each of the 31 publications of our literature review to provide a holistic overview, summarized in Table 4. Our approach reveals that ERR barriers are rarely isolated phenomena. Academia primarily focuses on FB (24), followed by IB (18), whereas TB (9) and RB (8) play a subordinate role.

Financial considerations consistently prove to be crucial barriers to EERs. In our literature review, 21 of the 31 studies (67%) explicitly identify financial barriers as decisive factors in the decision-making process. Among these, the split incentives problem is particularly relevant, reflecting the discrepancy between those who finance the retrofit, usually landlords, and those who directly benefit from lower energy costs, the tenants (Trotta, 2018; Miu and Hawkes, 2020). This structural discrepancy discourages investments, especially when they are prone to uncertainty about the return on investment (ROI), a problem that often arises in contexts where tenant change can occur before the costs are recouped (Achnicht and Madlener, 2014; Liu et al., 2020). Additionally, high upfront investment costs and general financial constraints have a deterrent effect and impede the decision to retrofit, even though long-term energy savings are proven (Stieß and Dunkelberg, 2013; Reaños et al., 2023). Insufficient government incentives for EERs, such as subsidies, grants, or favorable financing mechanisms, also represent a barrier, influencing the initial financial burden and thus the decision-making process (Tian et al., 2024; Chen et al., 2023). This contrasts with the "free rider" problem, which describes how publicly funded incentives inadvertently subsidize actors who would have retrofitted even without such support, leading to inefficient public spending and undermining the legitimacy and effectiveness of policy measures aimed at accelerating modernization and sustainable retrofitting (Matosović and Tomšić, 2018; Dolšak, 2023).

From a regulatory perspective, the continuity and stability of long-term political strategies are decisive factors for the success of retrofit measures. Well-coordinated and consistently supported policies can accelerate the acceptance of retrofits, while fragmented or short-term measures undermine stakeholder confidence and delay retrofit implementation (Zhang and Wang, 2022; Liu et al., 2020). Poor regulatory conditions delay the administrative expenditure for retrofits, particularly in the field of monumental preservation, where approval procedures are often protracted and legally complex (Panakaduwa et al., 2024; Weatherall et al., 2018). Legal and organizational barriers, such as the obligation to establish a legal entity or obtain the unanimous consent of all co-owners in multi-family buildings, further complicate decision-making and project initiation (Weatherall et al., 2018; Akhatoeva et al., 2024). Fragmentation is also evident in the issuance of energy performance certificates, which in many countries apply to individual

**Table 4**  
Categorization of EER barriers in the literature.

Study authors	Region	Study title	FB	RB	IB	TB
Casquero-Modrego et al. (2025)	United States	Decarbonizing residential buildings in the United States: A comparative analysis of households and construction professionals	x			x
Ricci et al. (2025)	Developed countries	Making energy renovations equitable: A literature review of decision-making criteria for a just energy transition in residential buildings	x		x	
Akhatova et al. (2024)	Netherlands	Who invests in energy retrofits? Mining Dutch homeowners' data	x	x		
Antonopoulos et al. (2024)	United States	Regional assessment of household energy decision-making and technology adoption in the United States	x		x	
Azimi et al. (2024)	Australia	Adoption of energy-efficiency measures by Australian low-income households	x			
Faccioli et al. (2024)	Italy	What are the Policy Drivers to Undertake Green Retrofitting Investments? The Role of Tax Incentives and Communication in Italian Households' Decision-Making				x
Liu et al. (2024)	China	Modeling heterogeneous and adaptive homeowners' decision-making for green retrofit			x	
Panakaduwa et al. (2024)	United Kingdom	Identifying sustainable retrofit challenges of historical Buildings: A systematic review		x	x	x
Tian et al. (2024)	China	Establishing energy-efficient retrofitting strategies in rural housing in China: A systematic review	x	x		x
Chen et al. (2023)	China	Evolutionary dynamics of homeowners' energy-efficiency retrofit decision-making in complex network	x			
Dolsák (2023)	Global	Determinants of energy efficient retrofits in residential sector: A comprehensive analysis	x		x	
Kazemi and Udall (2023)	Iran	Behavioral barriers to the use of renewable and energy-efficient technologies in residential buildings in Iran	x	x	x	x
Reaños et al. (2023)	Ireland	The role of energy, financial attitudes and environmental concerns on perceived retrofitting benefits and barriers: Evidence from Irish home owners	x		x	
Odland et al. (2023)	Canada	What policies do homeowners prefer for building decarbonization and why? An exploration of climate policy support in Canada			x	
Alabid et al. (2022)	United Kingdom	A review on the energy retrofit policies and improvements of the UK existing buildings, challenges and benefits	x			
Bobrova et al. (2022)	Primarily Europe	Process perspective on homeowner energy retrofits: A qualitative metasynthesis		x		
Zhang and Wang (2022)	Global	A Review of 10 years Research on Barriers in the Whole Process of Building Retrofit: Stakeholders' Perception	x	x	x	
Camarasa et al. (2021)	European Union	Drivers and barriers to energy-efficient technologies (EETs) in EU residential buildings			x	x
Pillai et al. (2021)	Ireland	An examination of energy efficiency retrofit scheme applications by low-income households in Ireland	x			
Dolsák et al. (2020)	Slovenia	Factors impacting energy-efficient retrofits in the residential sector: The effectiveness of the Slovenian subsidy program	x		x	
Liu et al. (2020)	China	Building green retrofit in China: Policies, barriers and recommendations	x	x	x	x
Miu and Hawkes (2020)	United Kingdom	Private landlords and energy efficiency: Evidence for policymakers from a large-scale study in the United Kingdom	x		x	
Simpson et al. (2020)	North Western Europe	Data-centric innovation in retrofit: A bibliometric review of dwelling retrofit across North Western Europe	x		x	
Hrovatin and Zorić (2018)	Slovenia	Determinants of energy-efficient home retrofits in Slovenia: The role of information sources			x	
Matosović and Tomsić (2018)	Croatia	Evaluating homeowners' retrofit choices – Croatian case study	x			
Trotta (2018)	United Kingdom	The determinants of energy efficient retrofit investments in the English residential sector	x			
Vogiatzi et al. (2018)	Greece	Energy use and saving in residential sector and occupant behavior: A case study in Athens	x		x	
Weatherall et al. (2018)	England, Scotland	Property law as a barrier to energy upgrades in multi-owned properties: insights from a study of England and Scotland	x	x		
Achtnicht and Madlener (2014)	Germany	Factors influencing German house owners' preferences on energy retrofits	x			
Brown et al. (2014)	United Kingdom	Retrofitting social housing: reflections by tenants on adopting and living with retrofit technology	x		x	x
Stieß and Dunkelberg (2013)	Germany	Objectives, barriers and occasions for energy efficient refurbishment by private homeowners	x		x	x

apartments rather than entire buildings, making it challenging to coordinate the planning of retrofitting measures (Weatherall et al., 2018).

The complexity of regulations is closely linked to informational barriers. Limited public awareness of EER programs, insufficient confidence in the results of retrofits, and inadequate use of advertising platforms restrict informed decision-making (Hrovatin and Zorić, 2018; Kazemi and Udall, 2023). Misinformation, often spread through informal networks such as friends, family, or social media, exacerbates this challenge and leads to misunderstandings about program requirements and over- or underestimation of potential energy savings (Stieß and Dunkelberg, 2013; Liu et al., 2024). Such misunderstandings are particularly detrimental in regulatory environments where approvals require detailed technical justification (Stieß and Dunkelberg, 2013; Panakaduwa et al., 2024).

Consequently, the transition from informational to technical barriers becomes evident. Within the retrofit process, technical barriers are most prominently reflected in the persistent shortage of qualified professionals and skilled workers, which has been repeatedly identified as a bottleneck (Casquero-Modrego et al., 2025; Liu et al., 2020). This also exacerbates stakeholders' difficulties in interpreting technical specifications, understanding performance indicators, and selecting appropriate technologies (Stieß and Dunkelberg, 2013). These challenges are

particularly pronounced among older residents and people with limited technical knowledge. Overcoming technical limitations requires the integration of novel building technologies and innovations capable of simplifying retrofit processes and improving performance outcomes (Tian et al., 2024; Camarasa et al., 2021).

After categorizing the pertinent literature, we leverage the survey design described in Section 3.2 to evaluate the perceived relevance of identified EER barriers and potential solutions to derive actionable policy recommendations. Building on these literature-based insights, the following sections present the results of our survey, which evaluates the real-world relevance of the identified barriers. This transition from theoretical findings to empirical evidence enables us to compare academic perspectives with stakeholder experiences. In the following, we present the results for each survey question in dedicated tables that list all corresponding answer options, together with the literature source on which these options are based. The literature references in all result tables are only an abridged excerpt due to space constraints. Particular answer options without direct literature reference (–) were developed based on conceptual considerations and the overall research context. In addition, for each survey result table in the main text (Tables 5–8), a corresponding table is provided in Appendix B, breaking down the results by stakeholder group.

#### 4.1. Identifying the severity of retrofit barriers

We start by analyzing barriers for EERs (c.f. Table 5) and find that with an average rating (AVG) of 8.70 and a standard deviation (SD) of  $\pm 1.70$ , financial expenditures are by far the most critical barrier across all groups, followed by regulatory requirements rated at 7.99 ( $\pm 1.50$ ). The third most important are knowledge barriers regarding EERs and building conditions, followed by technical barriers, with the lowest rating of 5.41. Notably, private landlords perceive RBs as less severe, whereas property construction companies attribute the highest relevance to RBs and FBs, with all other barriers ranking considerably below average ratings. On the contrary, property managements consider building condition knowledge to be the second most crucial barrier after FBs (c.f. Table B5).

We continue our analysis by examining the conflicting arguments for (c.f. Table 6) and against EERs (c.f. Table 7). Among all respondents, the most important reasons for EERs are increasing building value (8.13) and energy savings (7.83), closely followed by increasing the attractiveness of the residential property, rated at 7.73 ( $\pm 1.69$ ). Increasing the building value seems especially important for institutional real estate investors and real estate agencies. For institutional real estate investors, this also holds for higher rental incomes ( $9.33 \pm 0.58$ ), which is notably less relevant for all other groups, especially for craft businesses (3.55). Energy consultants, institutional real estate investors, property managements, and architects and engineering firms each attribute a high importance to energy savings, whereas private landlords rank this reason considerably below average. Overall, carbon emission savings (6.00) are, on average, the second least relevant reason for retrofit, which is especially apparent for craft businesses with a ranking of 2.00 ( $\pm 1.41$ ). In contrast, institutional real estate investors and architects and engineering firms consider energy savings to be relevant. The perceived importance of tax advantages varies greatly depending on the group under consideration. Contrary to all other groups, property construction companies (3.57) and energy consultants (4.50) do not consider tax advantages a relevant reason for EERs. The same division holds for governmental retrofit obligations, which craft businesses and architects and engineering firms ranked well above the group average (c.f. Table B6).

Our findings indicate that long amortization periods (7.94) and different objectives in owners' association (7.81) are the most critical reasons against EERs across all respondents (c.f. Table 7). In contrast, the extended amortization period simultaneously has the lowest SD ( $\pm 1.78$ ). Followed by the risk of cost increases during renovation (7.70) and unsuitable structural conditions (7.14).

Participants considered tenant-related reasons, such as frequent tenant turnover, vacancies after renovations, or poor relationships with tenants, as the least relevant reasons against retrofits. However, the in-depth analysis in Table B7 shows that craft businesses consider poor relationships with tenants (7.0) highly relevant. For property construction companies, shortly expected sales are the most irrelevant reasons (2.20), while they consider unsuitable conditions (6.86) highly relevant.

**Table 5**

How would you rate the following barriers for an energy-efficient retrofit? (Q1).

Response options	Literature references	AVG	SD
Financial expenditure	Azimi et al. (2024), Casquero-Modrego et al. (2025)	8.70	1.70
Regulatory and political requirements	Amoah and Smith (2024), Kazemi and Udall (2023)	7.99	1.50
Other investment barriers	-	6.52	2.01
Insufficient knowledge about EER	Kazemi and Udall (2023), Morgan et al. (2024)	6.36	1.78
Lacking knowledge of building condition	März et al. (2020), Panakaduwa et al. (2024)	6.00	2.39
Missing technical implementation options	Panakaduwa et al. (2024), Behr et al. (2023)	5.41	1.99

**Table 6**

How would you rate the following reasons for an energy-efficient retrofit? (Q2).

Response options	Literature references	AVG	SD
Increase in building value	Amoah and Smith (2024), Lang et al. (2022)	8.13	1.85
Energy savings	Casquero-Modrego et al. (2025), Bergman and Foxon (2020)	7.83	2.05
Increasing attractiveness of residential property	Miu and Hawkes (2020), Mininni et al. (2024)	7.73	1.69
Renovation obligation	Miu and Hawkes (2020), Peel et al. (2020)	6.38	2.56
Increase in rental income	Lang et al. (2021)	6.37	2.00
Tax advantage	Lang et al. (2021), Faccioli et al. (2024)	5.88	2.57
CO2 savings	Amoah and Smith (2024), März et al. (2020)	5.84	2.62

**Table 7**

How would you rate the following reasons against energy efficient retrofit? (Q3).

Response options	Literature references	AVG	SD
Long amortization period	Liu et al. (2020), Trotta (2018)	7.94	1.78
Different owners' association objectives	Weatherall et al. (2018), Akhatova et al. (2024)	7.81	2.08
Risk of cost increases during renovation	Streicher et al. (2020)	7.70	2.51
Unsuitable structural conditions	Amoah and Smith (2024), Peel et al. (2020)	7.14	2.09
Financial resources allocated elsewhere	März et al. (2020), Broers et al. (2019)	6.68	2.23
Rent reduction or loss during renovation	Blomqvist et al. (2022)	6.10	2.69
Shortly expected sale	Galvin (2023), Mininni et al. (2024)	5.68	2.89
Frequent tenant turnover	Ambrose and McCarthy (2019), Mininni et al. (2024)	5.51	2.05
Vacancy after renovation	Souza (2018), März et al. (2020)	4.97	2.87
No/poor relationship with the tenant	Souza (2018), März et al. (2020)	4.75	2.16

Furthermore, property construction company experts seem to disagree regarding the ranking of financial resources allocated elsewhere, reflected in the high SD ( $\pm 4.08$ ). However, they generally consider it, along with institutional real estate investors (SD  $\pm 0.71$ ), the least important reason for EERs. Notably, vacancies after renovations are equally crucial for craft businesses and institutional real estate investors compared to most other reasons.

#### 4.2. Evaluating possible policy solutions

The second part of our survey focuses on overcoming the identified barriers by evaluating the potential to derive financial, regulatory, informational, and technical policies. In terms of financial barriers, listed in Table 8, participants rate subsidy programs in the form of grants on average as the most relevant solution (7.95), followed by higher tax depreciation options (7.23), while the latter has a considerably higher

**Table 8**

How do you rate the following approaches to addressing financial barriers? (Q4).

Response options	Literature references	AVG	SD
Subsidy program in the form of grants for energy-efficient renovation	Liu et al. (2023), Miu and Hawkes (2020)	7.95	1.94
Increase in tax depreciation options	Liu et al. (2023), März (2018)	7.23	2.49
Subsidy program in the form of fixed-rate loans for energy-efficient renovation	Handford (2022), Dolšak et al. (2020)	7.18	2.35
Government loans linked to the energy consumption of the residential unit	Yeatts et al. (2017)	6.07	2.56

SD. Notably, in [Table B8](#), this is the reverse for institutional real estate investors and real estate agencies. Subsidy-based funding programs are particularly high rated by energy consultants (9.33), architects and engineering firms (8.90), and property managements (8.40). Craft businesses (6.00) and private landlords (7.24) ratings are somewhat lower. The average SD ( $\pm 1.94$ ) is comparably low, except for private landlords, institutional real estate investors, and property construction companies, indicating varying degrees of importance within these groups.

Participants consider government loans linked to energy consumption the least important (6.07), although showing the highest overall SD ( $\pm 2.56$ ). Contrary to the general trend, craft businesses rank government loans as the most relevant solution (7.5) and higher depreciation options as the least relevant (5.00).

Out of the regulatory solutions, the reduction of subsidy application bureaucracy achieved the highest average (8.38) with the second smallest SD ( $\pm 1.41$ ), illustrated in [Table 9](#). Abolishing the majority decision requirement for owners' associations achieves the lowest rating (5.69) with an SD of  $\pm 2.35$ . In [Table B9](#) real estate agencies rate this lowest (4.0) with a low SD ( $\pm 1.00$ ), followed by architects and engineering firms ( $4.33 \pm 3.35$ ). In contrast, energy consultants and institutional real estate investors consider this solution to be one of the most important ones, with ratings above 8. Targeted subsidy programs for existing buildings have the second-highest average (8.37), followed by long-term secure subsidy programs (8.33), with the lowest SD ( $\pm 1.37$ ). Energy consultants rate long-term secure subsidy programs with the maximum value of 10.00. The lowest rating is for craft businesses and institutional real estate investors, with an average of 7.00. The second highest is for property management (9.60), with a small SD ( $\pm 0.55$ ). Targeted subsidy programs for existing buildings ( $8.37 \pm 1.78$ ) are considered more relevant than subsidies for new constructions ( $7.20 \pm 2.75$ ), where the average values fluctuate between 5.22 and 9.0. In contrast, for existing properties, they range from 6.50 to 9.60.

Architects and engineering firms rate targeted subsidy programs for new constructions lowest (5.22) and craft businesses highest (9.00). Private landlords rate both targeted subsidy programs similarly (7.17 to 6.54), with a tendency towards existing buildings. Notably, craft businesses rate subsidy programs that mitigate the cost sharing between landlords and tenants with a maximum value of 10.00. For private landlords, such programs are the least relevant (5.85) with a high SD ( $\pm 2.41$ ). The averages of the other groups are similar, ranging from 6.30 to 7.6. Legally prescribed building energy standards are rated lowest by the real estate agencies, with an average value of 4.67 ( $\pm 1.53$ ). Private landlords likewise attribute a low relevance (5.39) but a higher SD ( $\pm 2.69$ ), indicating a wider spread within the category. Institutional real estate investors show the smallest SD ( $\pm 0.71$ ) and a relatively high average value (7.50), while property construction companies attribute the highest average rating (8.00) but with a large SD (c.f. [Table B9](#)).

**Table 9**

How do you rate the following regulations and political initiatives for your EER project? (Q5).

Response options	Literature references	AVG	SD
Reduction of subsidy application bureaucracy	Rodriguez et al. (2024), Peel et al. (2020)	8.38	1.41
Targeted subsidy programs for existing buildings	Hondeborg et al. (2023)	8.37	1.78
Long-term secure subsidy programs	Bobrova et al. (2022), Tian et al. (2024)	8.33	1.37
Subsidy programs to mitigate the cost sharing between landlords and tenants	Azimi et al. (2024), Ricci et al. (2025)	7.21	2.17
Targeted subsidy programs for new construction	Jiang et al. (2022)	7.20	2.75
Legally prescribed building energy standards	Liu et al. (2023), Lang et al. (2022)	6.54	2.07
Abolition of the majority decision requirement for owners' associations	Weatherall et al. (2018), Akhatova et al. (2024)	5.69	2.35

[Table 10](#) summarizes the rated solutions of four informational barriers, while [Table 11](#) shows the participants' evaluation of eight distinct communication channels. On average, a central point of contact is most important (7.23), closely followed by expert training (7.18), while mandatory energy consulting (6.69) and official information campaigns (5.73) were given significantly less weight. Overall, central contact points for information are particularly relevant for property managements (8.80) and craft businesses (8.50) but have a relatively high SD (2.78), especially for energy consultants ( $\pm 4.50$ ) and real estate agencies ( $\pm 3.11$ ).

In [Table B10](#) expert training is rated as the second most important factor (7.18) and is particularly important for energy consultants (8.75) and institutional real estate investors (8.00), while craft businesses (6.50) and private landlords (6.04) show greater variation (up to  $\pm 4.95$ ). Mandatory energy consulting receives a slightly lower average rating of 6.69 but with substantial differences between the groups. Energy consultants rate it as very important (9.00), while property construction companies (3.83) and private landlords (4.89) rate it as very low. However, the responses within private landlords vary greatly ( $\pm 3.30$ ). The SDs are moderate to high, indicating differing opinions. Official information campaigns are rated lower across the board, with an average of 5.51. The highest rating is given by energy consultants with 7.25, but with a high SD ( $\pm 4.27$ ). Except for real estate agencies, all groups have significant differences, as evidenced by SDs greater than 2. The ratings vary greatly, from relatively high for property construction companies (7.00) and energy consultants (7.25) to very low for real estate agencies (3.50) (c.f. [Table B10](#)).

Regarding the preferred media for obtaining information, participants rate expert advice on average (8.66) and across all groups as most relevant, with a low SD ( $\pm 1.58$ ), indicating a high degree of agreement. In [Table B11](#), private landlords have the largest individual SD ( $\pm 2.83$ ) and attribute the lowest score (7.82). On the contrary, energy consultants rate this response option highest among the groups with 9.50 ( $\pm 1.00$ ).

*Lectures & events* are also highly rated (7.58) and enjoy solid approval among most groups, with the SD being slightly higher than for expert advice (1.67). Architects and engineering firms rate it highest at 8.79 ( $\pm 1.57$ ) and institutional real estate investors lowest (6.00). *Internet & websites* were similarly rated as *lectures & events*, with an average of 7.78. However, the SD for some groups is comparably large. Property managements received the lowest rating with a high SD ( $\pm 2.70$ ), whereas energy consultants and craft businesses received the highest average rating (8.5). The results for *Webinars* (6.69) show a comparatively high SD ( $\pm 2.07$ ), indicating that the relevance varies across different groups. The lowest ratings are given by real estate agencies (5.50), institutional real estate investors (5.67), and private landlords (5.70), where each of the three groups has an SD greater than  $\pm 2.5$ . The other groups rate webinars between 6.50 and 8.10 on average, with standard deviations less than 2. *Social networks* score significantly lower (5.48) with a notably high SD ( $\pm 3.07$ ), reflecting a very heterogeneous opinion among respondents: while real estate agencies rate social networks comparably high (7.5), property construction companies attribute a low relevance (3.83) to this information channel (c.f. [Table B11](#)). *Podcasts*,

**Table 10**

How would you rate the following options for obtaining information about current regulations? (Q6).

Response options	Literature references	AVG	SD
Central contact point for information	Bergman and Foxon (2020), Panakaduwa et al. (2024)	7.23	2.78
Expert training	Broers et al. (2019), Bagaini et al. (2020)	7.18	2.52
Mandatory energy consulting	März (2018), Souza (2018)	6.69	2.01
Official information campaigns	Bergman and Foxon (2020), Liu et al. (2020)	5.73	2.71

**Table 11**  
How would you rate the following media for obtaining information? (Q7).

Response options	Literature references	AVG	SD
Expert advice	März (2018), Hrovatin and Zorić (2018)	8.66	1.58
Internet & websites	Broers et al. (2019), Mininni et al. (2024)	7.78	2.14
Lectures & events	März (2018), Blomqvist et al. (2022)	7.58	1.67
Webinars	-	6.69	2.07
Social networks	Hrovatin and Zorić (2018)	5.48	3.07
Podcasts	-	4.99	2.98
Newspapers & magazines	-	4.79	2.37
Television	-	4.49	2.63

*Newspapers & magazines*, and *Television* consistently receive the lowest overall ratings (4.99 to 4.49) with a maximum value of 6.33 for newspapers and television. The responses show a high SD ( $\pm 2.37$  to  $\pm 2.98$ ), indicating inconsistent attitudes toward these formats.

Regarding technical barriers (c.f. Table 12), our study focuses on digital information systems with an average rating of 5.26 to 6.10. *Smart metering systems* receive the highest average rating (6.10) and seem to be especially important to energy consultants (9.25) with a low SD ( $\pm 0.96$ ) compared to the lowest rating from property construction companies (3.17) (c.f. Table B12). Overall, higher ratings correlate with lower SDs (e.g., energy consultants and craft businesses).

*Digital assistants* (5.57) are rated second highest on average. Institutional real estate investors consider them particularly relevant, having the lowest standard deviation (1.15) compared to the other groups. *BIM systems* and *IoT-based monitoring* achieve similar ratings, 5.54 and 5.45, respectively, but have slightly lower SDs. Institutional real estate investors rate BIM systems highest on average (7.33), and craft businesses rate IoT-based monitoring highest on average (8.00). Regarding IoT-based systems, craft businesses stand out significantly from the other groups, whose average ratings range from 3.20 to 6.24. *EMS systems* show the lowest average rating (5.26), but energy consultants consider them highly relevant (8.00) (c.f. Table B12). Overall, the ratings are very close to each other in terms of average and SD. In Section 5, we discuss our findings and deduce actionable policy measures.

## 5. Policy implications

Stakeholders often combine EERs with already planned renovations, especially when technical systems (e.g., heating systems) reach the end of their service life and have become an integral part of sustainable renovation. However, heirs or older people, for example, are often unable or unwilling to renovate residential buildings as their personal situation restricts them, or necessary construction work might burden the residents. Generally, retrofits are seen as an essential contribution to reducing the ecological footprint and primarily serve the goal of lowering energy consumption while simultaneously achieving greater energy self-sufficiency, e.g., through solar panels. Furthermore, our results show that EERs are considered morally right and forward-looking as they increase the well-being and comfort of residential buildings, promote a healthy living environment, and can provide adequate

**Table 12**  
How relevant are the following digital information systems to you? (Q8).

Response options	Literature references	AVG	SD
Smart metering systems	Tian et al. (2024), Akhatova et al. (2024)	6.10	2.21
Digital assistants for consumer education	Arslan et al. (2024)	5.57	2.81
Building information modeling systems	Panakaduwa et al. (2024), Liu et al. (2023)	5.54	2.27
IoT-based energy monitoring	Arslan et al. (2024)	5.45	2.17
Using energy management systems (EMS)	Tian et al. (2024), Bagaini et al. (2020)	5.26	1.98

protection against climate change. In the following, we will discuss and contextualize each of the identified policy recommendations (P). An overview of how the empirically identified stakeholder-specific barriers are systematically linked to the corresponding policy recommendations is provided in Appendix B (c.f. Table B13).

### 5.1. Financial policies

Both in the literature and our survey, financial expenditures are considered the most relevant reasons against retrofits, mainly driven by high costs and interest rates, lack of liquidity, calculation risks, and price increases (Antonopoulos et al., 2024; Dolšák, 2023; Konhäuser and Werner, 2024). Private landlords, owner associations, and financially weak municipalities often lack the capital for necessary EER investments, as high interest rates at banks and the general costs of EERs, especially for energy consulting, require high upfront costs (Rockstuhl et al., 2021). To address this issue, the Dutch government established *limited interest rates for EERs (P1)*, which are considered fiscally neutral (Handford, 2022). In addition, there is uncertainty that funding criteria and subsidies will be changed or canceled at short notice, or that they will lead to rising prices for building materials and services, potentially negating funding benefits. Apart from the direct financial costs, psychological and economic factors persist, such as the split incentive problem, where tenants benefit financially from EERs while the landlord bears the costs. Consequently, März et al. (2020) propose *increasing rents to pass EER costs from landlords to tenants (P2)*, which German homeowners can already do by a maximum of 8% of the total EER costs (Federal Government of Germany, 2024). Furthermore, older people or owners without direct connection to the building (e.g., rental properties) often lack the interest or motivation to make significant investments. To overcome financial barriers, study participants called for *targeted and socially graded subsidies (P3)* in the form of greater financial support for renovation measures, including special subsidies for municipalities. Moreover, *municipal funds or public-private-people partnerships for purchasing residential buildings (P4)* could conduct EERs, and allow the former owners to continue using them, as proposed by (Xue et al., 2022; Domenig et al., 2024; Straub and Meijer, 2025). Such renovations could be used effectively to preserve and increase the value of buildings to prevent stranded assets. Moreover, our study results suggest that EERs should be *economically viable rather than pushing technological limits (P5)*. In addition, *simplified condominium borrowing for owners' associations (P6)* potentially facilitates access to debt capital in combination with structural planning in advance, whereby mandatory maintenance reserves can relieve the burden on future buyers. In any case, the legislature must not become a cost driver but instead focus more on *reducing potential windfall effects (P7)*. All measures mentioned above can increase building values through image improvement and, in the long term, financial relief through energy savings, especially as the energy costs are expected to rise in the future (Liesenklas et al., 2024). However, higher building values resulting from EERs may create conflicts with housing affordability, as retrofit-induced rent increases can disproportionately affect vulnerable tenant groups. To avoid socially regressive outcomes, financial support concepts should therefore be complemented by safeguards such as rent increase limits linked to actual energy cost savings or targeted subsidies for low-income households (Chegut et al., 2016; Copiello, 2015).

### 5.2. Regulatory policies

The second most crucial barrier to EERs is regulatory policies, which can be divided into the following three areas: bureaucratic and political uncertainty, monument and environmental protection, and legal requirements (Zhang and Wang, 2022; Bobrova et al., 2022). Particularly, the politically driven lack of planning reliability for regulatory requirements and subsidy programs hampers EERs, which might be addressed by *legally fixed terms for funding conditions (P8)* (Behr et al.,

2023). In addition, the bureaucratic effort involved in applying for subsidies is too high, and the approval procedures excessively strict and lengthy. The lack of competence among approval authorities and the shortage of qualified experts exacerbate this problem, which is why our survey's second-highest-ranked requirement was a *reduction of subsidy application bureaucracy (P9)* (Rodríguez et al., 2024). Consequently, in 2025, the German government passed a law requiring local authorities to offer online submission forms for EER applications, eventually accelerating permit processes (Federal Ministry for Housing, Urban Development and Building, 2025b). Municipals often protect historic and architecturally significant buildings with restrictions regarding preserving such monuments, which often hinder EERs (e.g., insulation). Likewise, environmental protection and urban conservation areas limit the possibilities for modernization. Therefore, *adjusting monument protection regulations (P10)* in favor of EERs, especially for historical buildings that cannot meet standard requirements, might increase energy efficiency without neglecting monument protection (Panakaduwa et al., 2024). Especially in Europe, with a vast historic building stock, the simplification of monument protection regulation offers significant leverage towards EER (Simpson et al., 2020). The literature and our survey indicate that renovations are necessary for preserving the building fabric and complying with legal requirements. At the same time, these legal requirements are sometimes contradictory or overly ambitious. In the case of EERs, they often trigger many other regulations (e.g., fire protection, sound insulation, accessibility). *Decoupling EER measures from other regulatory requirements (P11)* would decrease the bureaucratic effort for homeowners and allow more freedom in deciding which measures to take (Akhatova et al., 2024). To further reduce the building sector's ecological footprint and avoid additional land sealing, policy makers should *facilitate the renovation and repurposing of existing buildings (P12)* (e.g., inner-city industrial and commercial brownfields) and promote these measures by issuing *CO2 certificates for completed renovation projects (P13)* or by initiating municipal projects for the insulation and greening of firewalls.

### 5.3. Informational policies

EERs are typically complex projects, yet stakeholders often face a lack of knowledge and transparency regarding their retrofit object and regulatory requirements, many contact points, several communication channels, and mental barriers regarding decision-making. Many homeowners are generally unaware of the problems affecting their own homes, with frequent changes in property managers leading to an additional loss of knowledge (Broers et al., 2019). This includes the need for renovations and the functioning of new technologies such as heat pumps, as there is no accessible overview of the multitude of subsidy programs, their requirements, and the different types of technical solutions available. The European Union issued a building renovation passport directive to address this problem by providing standardized information on a building's EER potential (März, 2018). To this end, survey participants most strongly advocate for a trustworthy *central coordination office at the state or municipal level (P14)* that clearly summarizes and presents all subsidy programs within a region in an understandable way (Bergman and Foxon, 2020; Rodríguez et al., 2024). In addition, it should offer *expert advice on current regulatory policies (P15)* and provide an overview of future developments in the form of information events for citizens, property managers, and energy consultants. Communication channels are vital for conveying information. Our survey results show that experts consider a *combination of trade fairs and online information services (P16)* the most relevant way to address information gaps. In addition, participants indicated that *mandatory disclosure of energy efficiency ratings (P17)* in advertisements for technical devices and a *ban on advertising fossil fuels (P18)* would be effective instruments for more EERs. While addressing information gaps, stakeholders experience considerable mental effort due to the low quality and high quantity of available information. While unclear decision-making

processes in owners' associations often block EERs, *recommendations from the immediate personal environment (P19)* provide a significant incentive to start EERs (März, 2018; Stieß and Dunkelberg, 2013).

### 5.4. Technical policies

Besides financial, regulatory, and informational barriers, the technical implementation process of EERs also poses risks, as it is, for example, difficult in many countries to find reliable and trusted professionals (Casquero-Modrego et al., 2025; Panakaduwa et al., 2024). However, it is highly relevant for homeowners to get a *clear time schedule for EER projects (P20)* to reduce the uncertainty (Casquero-Modrego et al., 2025). Additionally, stakeholders (e.g., property managers or homeowners) often struggle to grasp the technical details of EER projects fully. Therefore, when installing new technical systems, it is imperative to *educate contractors and professionals to explain technical changes in simple terms (P21)* to prevent communication problems (Rodríguez et al., 2024). As the construction business is a traditional industry, investments in Research and Development are less focused, resulting in a slower development of novel technologies and green innovations (Liu et al., 2020). To overcome this barrier, it is recommended to *promote capital investments to accelerate innovations (P22)* (Liu et al., 2023). As the literature has thoroughly investigated technical barriers, our survey focuses on the potential of information systems to address this barrier. Overall, participants perceive technical barriers as less relevant. However, they consider *smart metering systems in combination with data-driven AI models (P23)* for energy consumption prediction and controlling as highly relevant, which is the subject of current research (Konhäuser et al., 2022). In addition, participants expressed the need for *digital assistants for consumer education (P24)*, offering concise and succinct information for individual buildings. Technically, *building information modeling systems that standardize building information intake (P25)* could support such initiatives through digital roof surveying or facade scanning to identify, prepare, and evaluate individual retrofit measures.

## 6. Conclusion

This study combines an extensive literature search with an online survey of 64 German domain experts to identify financial, regulatory, informational, and technical EER barriers and rate their perceived relevance. Afterward, we leverage our survey results and the literature review to derive seven financial, six regulatory, six informational, and six technical policy measures. Our results indicate that financial and regulatory barriers are the most relevant barriers for EERs and are perceived as most urgent by participants, which should be addressed with subsidy programs in the form of grants for energy-efficient renovation or better tax depreciation options. Regarding regulatory policies, we find a need for legally fixed terms for funding conditions, targeted subsidy programs for existing buildings, and, foremost, the reduction of application bureaucracy. To address frequently changing information, we advocate for a central coordination office at the state or municipal level accompanied by a combination of trade fairs, expert presentations, and online information services. The results of our structured literature review in combination with comments by domain experts further point to promising potentials when combining smart metering systems with data-driven AI models and digital assistants for the decision-making process regarding EERs. Naturally, our explanatory study is subject to certain limitations. Due to the number of experts participating and the variety of domains, the analysis relies on descriptive statistics. Consequently, the study does not employ inferential statistical analyses to compare perceptions across stakeholder groups systematically, and our survey results focus primarily on the German building sector. However, from an external validity perspective, the findings of this study offer highly transferable insights for other industrialized nations grappling with analogous retrofit challenges. While the pronounced landlord-tenant split in incentives is particularly evident in Germany, the most

pressing barriers identified in our study, particularly the substantial upfront financial costs and the intricate regulatory bureaucracy, are shared across the EU. Moreover, given that European real estate markets are collectively governed by the Energy Performance of Buildings Directive (EPBD) and employ standardized Energy Performance Certificates (EPCs) as the principal informational tools, the market dynamics and policy recommendations discussed herein establish a critical foundation for other EU member states (Official Journal of the European Union, 2026). As most European nations confront an aging building stock with substandard energy efficiency and a heavy reliance on fossil fuels, our insights into overcoming financial and informational barriers are directly applicable to policymakers designing broader decarbonization strategies. Future research should therefore move beyond merely enlarging samples and instead conduct in-depth evaluations of the proposed policy measures, systematically assessing their economic, social, and administrative trade-offs (e.g., cost-effectiveness, equity impacts, and implementation feasibility). In addition, future studies should explicitly segment key decision-maker groups, such as single-family homeowners, private landlords, and condominium owners, and apply inferential statistical methods to analyze how barrier profiles and policy responses differ across these groups, thereby supporting more targeted

and tailored policy design. Furthermore, we encourage researchers to investigate regulatory barriers more intensively as participants perceive them as the second most relevant category, but they occur least frequently in our literature review. Our findings contribute to a better understanding of current barriers for EERs and offer actionable recommendations for policymakers.

**CRediT authorship contribution statement**

**Koray Konhäuser:** Writing – original draft, Visualization, Methodology, Writing – review & editing. **Constantin Rothdach:** Methodology, Formal analysis, Data curation. **Nina Schwarz:** Writing – original draft, Supervision, Project administration, Data curation, Writing – review & editing. **Tim Werner:** Writing – original draft, Supervision, Methodology, Conceptualization, Writing – review & editing.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Appendix A**

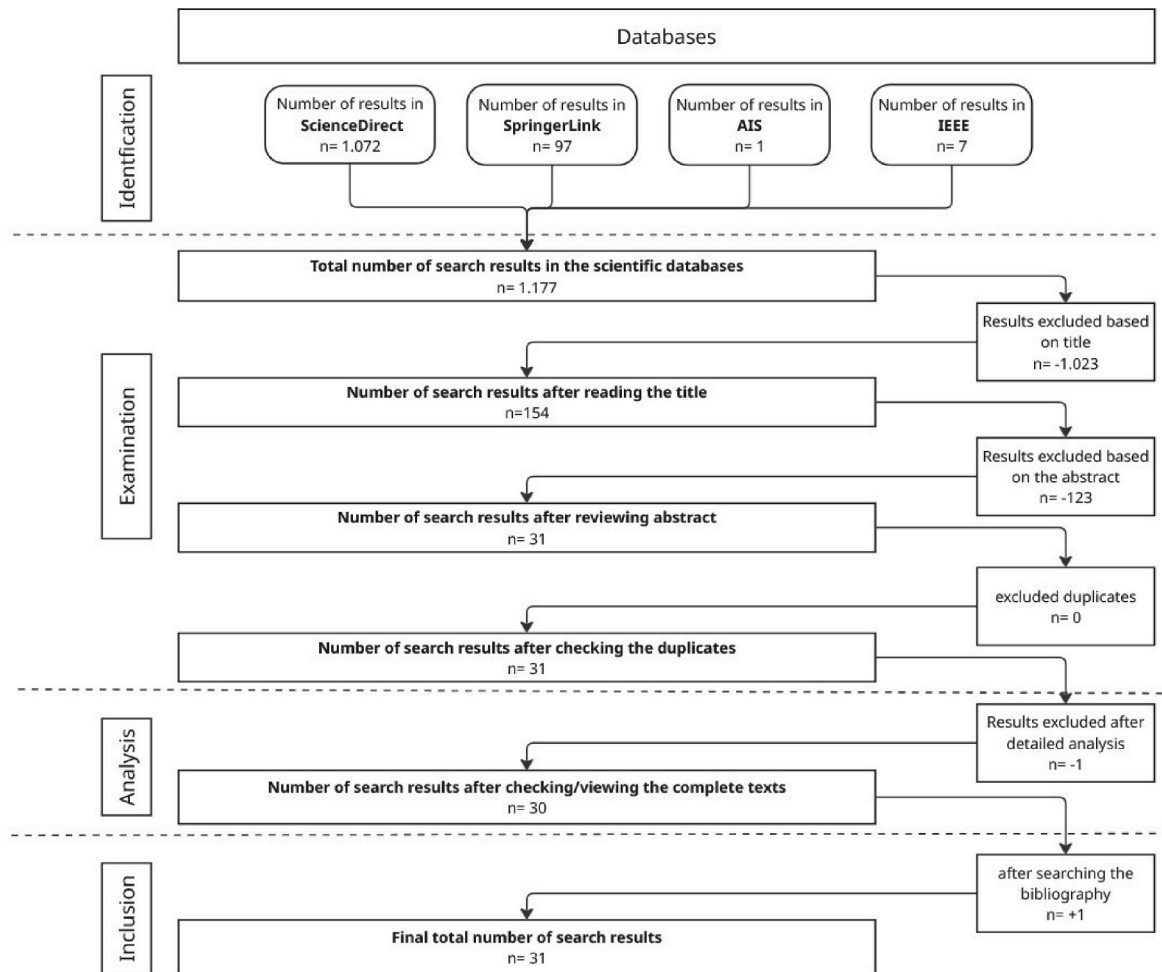


Fig. A1. Screening and selection process of the literature review.

## Appendix B

The following abbreviations are used in the tables below: private landlords (PL), architects and engineering firms (AEF), property construction companies (PCC), property managements (PM), real estate agencies (REA), energy consultants (EC), institutional real estate investors (REI) and craft businesses (CB).

Table B5

How would you rate the following barriers for an energy-efficient retrofit? (Q1)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Financial expenditure</i>	8.70 (±1.57)	8.67 (±1.75)	8.50 (±1.73)	8.50 (±2.12)	<b>9.20</b> (±0.84)	9.00 (±1.73)	8.75 (±1.50)	8.31 (±2.35)
<i>Regulatory and political requirements</i>	7.80 (±1.69)	7.57 (±1.62)	8.5 (±1.29)	<b>9.50</b> (±0.71)	7.80 (±1.64)	8.33 (±1.53)	8.00 (±0.82)	6.41 (±2.73)
<i>Other investment barriers</i>	6.11 (±2.52)	3.83 (±2.93)	<b>8.67</b> (±1.53)	6.00 (±0.00)	8.00 (±3.46)	7.00 (±1.00)	7.00 (±0.00)	5.56 (±2.65)
<i>Insufficient knowledge about EER</i>	7.00 (±2.71)	2.17 (±1.94)	<b>8.50</b> (±1.73)	5.50 (±0.71)	7.40 (±1.52)	6.67 (±1.15)	6.50 (±2.38)	7.11 (±2.06)
<i>Lacking knowledge of building condition</i>	6.60 (±1.78)	2.83 (±2.14)	7.25 (±3.20)	5.50 (±2.12)	<b>8.20</b> (±2.95)	5.33 (±3.06)	6.75 (±1.26)	5.57 (±2.59)
<i>Missing technical implementation options</i>	5.30 (±1.16)	2.17 (±1.47)	5.25 (±2.50)	5.50 (±0.71)	<b>7.00</b> (±2.55)	6.33 (±2.89)	5.50 (±2.38)	6.25 (±2.30)

Table B6

How would you rate the following reasons for an energy-efficient retrofit? (Q2)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Increase in building value</i>	7.44 (±2.07)	8.43 (±1.72)	8.25 (±2.87)	8.50 (±0.71)	6.60 (±2.70)	<b>9.33</b> (±0.58)	9.00 (±1.41)	7.46 (±2.77)
<i>Energy savings</i>	8.20 (±2.39)	7.00 (±3.03)	<b>9.25</b> (±1.50)	7.50 (±3.54)	9.00 (±0.71)	8.33 (±0.58)	6.25 (±2.22)	7.07 (±2.42)
<i>Increasing attractiveness of residential property</i>	6.78 (±2.64)	<b>9.00</b> (±0.82)	<b>9.00</b> (±1.41)	6.50 (±0.71)	7.00 (±2.55)	<b>9.00</b> (±1.00)	7.75 (±1.71)	6.83 (±2.69)
<i>Renovation obligation</i>	7.50 (±1.72)	4.86 (±2.73)	5.25 (±2.22)	<b>8.50</b> (±2.12)	6.00 (±2.74)	6.00 (±3.61)	5.75 (±2.63)	7.21 (±2.69)
<i>Increase in rental income</i>	6.13 (±1.81)	6.00 (±2.31)	3.75 (±2.22)	7.50 (±2.12)	4.40 (±2.41)	<b>9.33</b> (±0.58)	7.00 (±2.16)	6.84 (±2.41)
<i>Tax advantage</i>	5.00 (±2.18)	3.57 (±1.81)	4.50 (±3.70)	7.50 (±3.54)	5.00 (±2.74)	<b>8.00</b> (±1.00)	7.00 (±2.94)	6.50 (±2.62)
<i>CO2 savings</i>	7.10 (±2.42)	6.71 (±2.93)	5.75 (±4.92)	2.00 (±1.41)	5.80 (±3.70)	<b>8.33</b> (±0.58)	5.50 (±2.65)	5.52 (±2.37)

Table B7

How would you rate the following reasons against energy-efficient retrofit? (Q3)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Long amortization period</i>	8.10 (±2.56)	5.29 (±3.55)	8.25 (±1.26)	<b>9.00</b> (±0.00)	<b>9.00</b> (±1.00)	<b>9.00</b> (±1.41)	8.00 (±1.83)	6.86 (±2.65)
<i>Different owners' association objectives</i>	7.60 (±2.17)	5.40 (±4.04)	<b>9.25</b> (±0.96)	7.00 (±0.00)	9.20 (±1.30)	9.00 (±1.41)	8.33 (±1.53)	6.70 (±3.15)
<i>Risk of cost increases during renovation</i>	7.33 (±2.87)	5.20 (±3.27)	8.00 (±2.83)	8.50 (±2.12)	8.00 (±2.35)	8.50 (±2.12)	<b>9.0</b> (±1.73)	7.04 (±2.79)
<i>Unsuitable structural conditions</i>	7.40 (±2.37)	6.86 (±3.76)	5.25 (±1.71)	7.50 (±2.12)	8.20 (±0.45)	<b>9.00</b> (±1.41)	6.50 (±2.08)	6.43 (±2.79)
<i>Financial resources allocated elsewhere</i>	6.80 (±2.39)	4.00 (±4.08)	7.50 (±2.65)	7.50 (±2.12)	7.60 (±1.95)	4.50 (±0.71)	<b>8.67</b> (±1.53)	6.85 (±2.43)
<i>Rent reduction or loss during renovation</i>	5.70 (±2.83)	6.17 (±2.79)	3.50 (±2.38)	<b>8.00</b> (±0.00)	4.40 (±3.36)	<b>8.00</b> (±2.83)	7.25 (±1.50)	5.79 (±3.11)
<i>Shortly expected sale</i>	4.70 (±2.21)	2.00 (±1.41)	6.75 (±2.75)	<b>8.00</b> (±0.00)	6.00 (±3.39)	6.50 (±4.95)	5.50 (±2.38)	5.96 (±3.11)
<i>Frequent tenant turnover</i>	4.22 (±1.72)	2.20 (±1.79)	4.00 (±2.65)	<b>9.00</b> (±0.00)	5.40 (±3.13)	<b>9.00</b> (±1.41)	5.50 (±0.71)	4.76 (±2.92)
<i>Vacancy after renovation</i>	4.00 (±2.69)	3.33 (±3.61)	2.25 (±1.89)	<b>8.00</b> (±0.00)	5.00 (±3.81)	8.00 (±2.83)	5.00 (±2.45)	4.15 (±2.81)
<i>No/poor relationship with the tenant</i>	4.78 (±1.86)	1.50 (±1.00)	3.67 (±2.31)	<b>7.00</b> (±0.00)	4.00 (±3.54)	5.50 (±2.21)	6.67 (±1.53)	4.87 (±2.78)

Table B8

How do you rate the following approaches to addressing financial barriers? (Q4)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Subsidy program in the form of grants for energy-efficient renovation</i>	8.90 (±0.99)	8.00 (±3.21)	<b>9.33</b> (±1.15)	6.00 (±1.41)	8.40 (±1.14)	7.50 (±3.54)	8.25 (±0.96)	7.24 (±3.09)
<i>Increase in tax depreciation options</i>	7.00 (±2.78)	8.00 (±2.53)	6.67 (±3.06)	5.00 (±0.00)	7.40 (±2.41)	<b>8.50</b> (±2.12)	<b>8.50</b> (±1.29)	6.79 (±3.21)
<i>Subsidy program in the form of fixed-rate loans for energy-efficient renovation</i>	7.10 (±1.52)	6.43 (±3.51)	<b>9.33</b> (±1.15)	6.00 (±0.00)	5.60 (±3.29)	8.50 (±2.12)	7.75 (±2.22)	6.72 (±2.64)
<i>Government loans linked to the energy consumption of the residential unit</i>	5.60 (±2.91)	4.57 (±2.23)	5.67 (±4.51)	7.50 (±0.71)	6.60 (±3.21)	<b>8.00</b> (±2.83)	5.00 (±1.83)	5.62 (±2.27)

**Table B9**

How do you rate the following regulations and political initiatives for your energy renovation plans? (Q5)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Reduction of subsidy application bureaucracy</i>	8.20 (±3.01)	8.57 (±1.99)	<b>9.50</b> (±1.00)	6.50 (±0.71)	8.60 (±1.52)	8.00 (±0.00)	<b>9.50</b> (±0.58)	8.18 (±2.50)
<i>Targeted subsidy programs for existing buildings</i>	<b>9.60</b> (±0.70)	8.67 (±1.97)	8.00 (±4.00)	<b>8.50</b> (±0.71)	9.00 (±1.41)	6.50 (±2.12)	9.50 (±0.58)	7.17 (±2.77)
<i>Long-term secure subsidy programs</i>	8.90 (±2.51)	8.71 (±2.21)	<b>10.00</b> (±0.00)	7.00 (±0.00)	9.60 (±0.55)	7.00 (±1.41)	8.25 (±1.50)	7.19 (±2.80)
<i>Subsidy programs to mitigate the cost sharing between landlords and tenants</i>	6.89 (±2.71)	7.67 (±1.86)	7.25 (±1.89)	<b>10.00</b> (±0.00)	7.20 (±3.63)	6.50 (±2.12)	6.33 (±0.58)	5.85 (±2.41)
<i>Targeted subsidy programs for new construction</i>	5.22 (±3.19)	6.50 (±3.27)	7.75 (±4.50)	<b>9.00</b> (±0.00)	6.80 (±3.70)	8.00 (±0.00)	7.75 (±1.50)	6.54 (±3.10)
<i>Legally prescribed building energy standards</i>	6.00 (±3.61)	<b>8.00</b> (±3.16)	7.00 (±1.15)	7.00 (±1.41)	6.80 (±2.77)	7.50 (±0.71)	4.67 (±1.53)	5.39 (±2.69)
<i>Abolition of the majority decision requirement for owners' associations</i>	4.33 (±3.35)	5.29 (±3.09)	8.25 (±1.71)	5.00 (±0.00)	5.20 (±3.56)	<b>8.50</b> (±0.71)	4.00 (±1.00)	4.92 (±3.03)

**Table B10**

How would you rate the following options for obtaining information about current regulations? (Q6)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Central contact point for information</i>	7.80 (±2.74)	6.60 (±2.88)	7.75 (±4.50)	8.50 (±2.12)	<b>8.80</b> (±1.30)	6.00 (±2.65)	5.50 (±3.11)	6.86 (±2.97)
<i>Expert training</i>	6.90 (±1.79)	6.83 (±2.23)	<b>8.75</b> (±1.89)	6.50 (±4.95)	7.40 (±3.71)	8.00 (±0.00)	7.00 (±2.94)	6.04 (±2.63)
<i>Mandatory energy consulting</i>	6.00 (±2.71)	3.83 (±1.60)	<b>9.00</b> (±2.00)	8.00 (±1.41)	6.80 (±3.63)	8.00 (±0.00)	7.00 (±1.41)	4.89 (±3.30)
<i>Official information campaigns</i>	4.60 (±2.37)	7.00 (±2.12)	<b>7.25</b> (±4.27)	6.00 (±4.24)	6.40 (±2.88)	5.67 (±2.52)	3.50 (±0.58)	5.38 (±2.73)

**Table B11**

How would you rate the following media for obtaining information? (Q7)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Expert advice</i>	8.90 (±0.88)	8.43 (±1.72)	<b>9.50</b> (±1.00)	8.00 (±2.83)	9.00 (±1.41)	8.67 (±1.15)	9.00 (±0.82)	7.82 (±2.83)
<i>Internet &amp; websites</i>	7.60 (±1.58)	7.00 (±2.90)	<b>8.50</b> (±3.00)	<b>8.50</b> (±2.12)	6.60 (±2.70)	8.33 (±1.53)	8.00 (±0.82)	7.71 (±2.51)
<i>Lectures &amp; events</i>	<b>8.70</b> (±1.57)	7.43 (±2.07)	7.75 (±1.71)	8.00 (±0.00)	8.40 (±1.14)	6.00 (±2.65)	6.75 (±2.06)	7.61 (±2.18)
<i>Webinars</i>	<b>8.10</b> (±1.97)	6.83 (±1.94)	8.00 (±1.63)	6.50 (±0.71)	7.20 (±1.48)	5.67 (±3.21)	5.50 (±2.65)	5.70 (±2.93)
<i>Social networks</i>	5.00 (±3.13)	3.83 (±2.64)	6.50 (±4.04)	3.50 (±3.54)	5.00 (±4.18)	6.33 (±2.89)	<b>7.50</b> (±1.29)	6.18 (±2.87)
<i>Podcasts</i>	<b>5.80</b> (±3.05)	3.33 (±1.64)	5.00 (±2.45)	4.50 (±4.95)	5.20 (±3.49)	5.33 (±2.31)	5.00 (±3.16)	5.74 (±2.81)
<i>Newspapers &amp; magazines</i>	<b>5.90</b> (±2.56)	5.50 (±2.07)	3.25 (±2.06)	2.50 (±2.12)	4.40 (±3.65)	6.33 (±2.08)	5.25 (±1.71)	5.21 (±2.69)
<i>Television</i>	4.60 (±2.22)	2.67 (±1.63)	4.00 (±2.58)	3.50 (±3.54)	4.40 (±3.65)	<b>6.33</b> (±2.89)	5.00 (±1.83)	5.45 (±2.68)

**Table B12**

How relevant are the following digital information systems to you? (Q8)

Response options	AEF	PCC	EC	CB	PM	REI	REA	PL
<i>Smart metering systems</i>	5.13 (±2.70)	3.17 (±3.25)	<b>9.25</b> (±0.96)	7.50 (±0.71)	6.40 (±3.21)	6.67 (±1.15)	5.00 (±2.65)	5.72 (±3.04)
<i>Digital assistants for consumer education</i>	4.89 (±2.98)	4.00 (±3.46)	6.25 (±3.77)	<b>6.50</b> (±2.12)	5.40 (±3.51)	7.33 (±1.15)	4.00 (±1.15)	6.18 (±2.82)
<i>Building information modeling systems</i>	4.67 (±2.29)	5.50 (±3.51)	5.25 (±2.22)	5.50 (±0.71)	4.60 (±2.41)	<b>7.33</b> (±1.53)	6.00 (±2.65)	5.44 (±2.89)
<i>IoT-based energy monitoring</i>	3.75 (±2.19)	3.20 (±2.68)	5.75 (±0.50)	<b>8.00</b> (±0.00)	6.00 (±3.81)	5.67 (±0.58)	5.00 (±2.65)	6.24 (±2.82)
<i>Using energy management systems (EMS)</i>	4.44 (±2.35)	3.67 (±2.80)	<b>8.00</b> (±2.16)	5.00 (±0.00)	5.00 (±2.55)	6.00 (±1.00)	5.00 (±2.00)	5.00 (±2.96)

**Table B13**

Mapping of stakeholder-specific most relevant barriers to policy recommendations (P1–P25)

Stakeholder group	Top barriers and corresponding policy recommendations		
	#1	#2	#3
AEF	<i>Financial expenditure (8.70) addressed by P1, P3, P6</i>	<i>Long amortization period (8.10) addressed by P1, P5</i>	<i>Regulatory and political requirements (7.80) addressed by P8, P9, P11</i>
PCC	<i>Financial expenditure (8.67) addressed by P1, P3, P6</i>	<i>Regulatory and political requirements (7.57) addressed by P8, P9, P11</i>	<i>Unsuitable structural conditions (6.86) addressed by P10, P12</i>
EC	<i>Different owners' association objectives (9.25) addressed by P6, P11, P19</i>	<i>Other investment barriers (8.67) addressed by P3, P5</i>	<i>Insufficient knowledge about EER (8.50) addressed by P14, P15, P16, P17</i>
CB	<i>Regulatory and political requirements (9.50) addressed by P8, P9, P11</i>	<i>Long amortization period (9.00) addressed by P1, P5</i>	<i>Frequent tenant turnover (9.00) addressed by P2, P3</i>

(continued on next page)

Table B13 (continued)

Stakeholder group	Top barriers and corresponding policy recommendations		
	#1	#2	#3
PM	Financial expenditure (9.20) addressed by P1, P3, P6	Different owners' association objectives (9.20) addressed by P6, P11, P19	Long amortization period (9.00) addressed by P1, P5
REI	Long amortization period (9.00) addressed by P1, P5	Unsuitable structural conditions (9.00) addressed by P10, P12	Different owners' association objectives (9.00) addressed by P6, P11, P19
REA	Risk of cost increases during renovation (9.00) addressed by P5, P8	Financial expenditure (8.75) addressed by P1, P3, P6	Financial resources allocated elsewhere (8.67) addressed by P4, P6
PL	Financial expenditure (8.31) addressed by P1, P3, P6	Insufficient knowledge about EER (7.11) addressed by P14, P15, P16, P17	Risk of cost increases during renovation (7.04) addressed by P5, P8

## Data availability

Data will be made available on request.

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