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ARTICLE

Homeowners' barriers and motivations in decisions to adopt government-led energy efficiency renovation in China's Northern Heating Region

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Abstract
Under the national goals of Carbon Peak and Carbon Neutrality, the Chinese government has set higher requirements for energy efficiency renovation (EER) of existing residential buildings in its Northern Heating Region. The decision-making support of homeowners plays a crucial role in achieving these renovation targets. This study investigates the barriers and motivations influencing homeowners' decisions to participate in government-led EER programs. In addition to socio-demographic factors and building characteristics, particular attention is given to homeowners' previous renovation experiences. Based on a questionnaire survey conducted among homeowners in the region, the study identifies the main barriers as high capital costs, perceived unfairness in financial planning, an inefficient renovation process, concerns about decreased comfort, and a lack of incentives. Conversely, motivations include the desire to improve comfort levels, reduced capital costs, a transparent and well-organized renovation process, financial incentives, and trust in government authorities. Homeowners with prior renovation experience report overall lower levels of perceived barriers and motivations compared to those without such experience, with significant differences in several factors. Semi-structured interviews provide further insights into these findings. In addition, the study examines homeowners' willingness to engage in EER. Policy recommendations are proposed based on the results.

Keywords Energy efficiency renovation · Motivations and barriers · Decision-making · Homeowners · Willingness to renovate

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1 Introduction

Globally, the built environment accounts for over 30% of carbon emissions (IEA, 2017). A significant proportion of energy consumption in the building sector originates from existing residential buildings. In China, as urbanization has progressed over the past decades, people's demand for a higher standard of living has led to increased energy use in buildings (Li & Yao, 2009). In the Northern Heating Region, due to prolonged winters, the widespread use of district heating systems, and occupant preferences, annual thermal energy use is particularly high, accounting for 40% of total building energy consumption (BERC, 2010).

In response, the Chinese government has launched large-scale, government-led energy efficiency renovation (EER) programs targeting residential apartment buildings. However, despite these efforts, the actual outcomes of EER projects have often fallen short of policy expectations. Many projects rely heavily on passive homeowner compliance rather than active participation. Homeowners are required to allow construction in their private spaces, adjust energy use habits, and, in some cases, co-finance the renovation. These complexities make homeowner cooperation a prerequisite for the success of EER initiatives.

The challenge is further exacerbated in owner-occupied multi-unit housing (Hugony et al., 2019), especially given the weak institutional presence of homeowners' associations (Ma et al., 2021). Mobilizing residents, aligning their preferences, and securing financial support remain significant hurdles for EER initiators, requiring substantial investment of time and resources (Cairns et al., 2024; Ma et al., 2021; Ossokina et al., 2021). This has become a major bottleneck in the implementation of many EER policies.

Existing literature has primarily focused on the socio-demographic, cognitive, and economic factors influencing homeowners' decisions, often using rational-choice models such as the Theory of Planned Behavior (Ajzen, 1991). However, incorporating behavioral aspects such as motives, barriers, and energy use practices can enhance policy effectiveness (Liu et al., 2015; Michelsen & Madlener, 2013; Stieß & Dunkelberg, 2012). Given that residents are not fully rational actors, it is important to identify and understand the behavioral barriers and motivations shaping their EER decisions.

Moreover, most studies treat homeowners as a homogeneous group, overlooking the role of prior renovation experience in shaping future decisions. While some research suggests that EER programs should identify priority target groups (Wu et al., 2024), few studies have examined the influence of EER experience specifically. Although existing empirical work considers various explanatory variables, such as demographic characteristics, values, beliefs, knowledge, and dispositions (Lang et al., 2021; Kastner & Stern, 2015; Friege & Chappin, 2014), the impact of previous renovation experience remains underexplored. As energy efficiency standards continue to rise, and as earlier renovations may have fallen short due to lower acceptance thresholds (Foroushani et al., 2022), some buildings are likely to undergo multiple rounds of renovation. Particularly in residential settings, a phased renovation approach may align better with occupants' lifestyles, thereby improving acceptance (Saffari & Beagon, 2022; Fawcett, 2014). Thus, renovation experience is an important, yet still overlooked, dimension of homeowners' decision-making.

In many high-density urban contexts, meaningful resident involvement can foster cooperation and improve EER outcomes (Gee et al., 2013). At the same time, EER initiatives in multi-owned residential buildings often encounter tensions between collective action

requirements and individual homeowner behaviors. This challenge is not unique to China, and echoes international discussions on behavioral governance in the EER domain.

In summary, this study adopts a behavioral perspective on EER by systematically examining homeowners' perceived barriers and motivations, willingness to renovate, and how past EER experiences reshape these factors. It aims to answer the following questions and propose differentiated strategies to improve EER uptake by enhancing homeowner acceptance:

1) Do homeowners' EER motivations and barriers differ between those with and without EER experience?
2) What are the main barriers and motivations influencing future renovation decisions among homeowners with different levels of EER experience?
3) How does willingness to undertake future EER vary between these groups?

To address research questions 1 and 2, we conducted statistical comparisons based on questionnaire data. For research question 3, respondents were further categorized, and their stated preferences were analyzed. Semi-structured interviews were conducted to contextualize and enrich the analysis of all three research questions.

The remainder of this paper is structured as follows: Sect. 2 provides background information and reviews recent studies on homeowners' barriers and motivations. Section 3 outlines the methodology and introduces the sample. Section 4 presents the results, while Sect. 5 discusses their implications. Section 6 concludes the paper and offers policy recommendations.

2 Literature review

2.1 EER targets and policies in the Northern Heating Region

In September 2020, China announced its goal to peak carbon emissions by 2030, making the large-scale implementation of EER more urgent (Wang et al., 2021). In the 14th Five-Year Plan (2021–2025) for building energy efficiency and green building development, the Ministry of Housing and Urban-Rural Development (MOHURD) set a target of 350 million square meters of EER to be completed by 2025 (MOHURD, 2021). In May 2024, the State Council issued *The Action Programme for Energy Conservation and Carbon Reduction for 2024–2025* (State Council, 2024), which further emphasized the acceleration of energy-saving and carbon-reduction efforts in the building sector. According to this plan, by the end of 2025, the total EER area should increase by 200 million square meters compared to 2023, accompanied by a 30% improvement in energy-saving performance. Additionally, relative to 2020, heat loss in urban heating pipe networks should be reduced by 2%.

Technical requirements have also become more stringent. Building on the original "75% energy savings" standard, *the Action Programme* mandates a comprehensive set of measures for EER, including the adoption or upgrade of heat pumps, radiators, heating pipe networks, and envelope insulation. While these technologies were mentioned in previous guidelines, they had not been strictly required. Local governments are now urged to promote heat metering and reform heating billing practices, and to establish quantitative targets with specific completion timelines.

Meeting these new EER targets presents considerable challenges. First, the required renovation scale is enormous. An additional 200 million square meters must be completed between 2023 and 2025, which exceeds MOHURD's original 14th Five-Year Plan target by 150 million square meters. Second, although envelope insulation remains the most widely implemented measure, other technologies have yet to be widely adopted (Liu et al., 2020). Furthermore, district heating in the Northern Heating Region is still treated as a form of state welfare and is heavily subsidized. Due to financial and technical constraints, implementing billing based on actual heat metering remains difficult (Liu et al., 2010).

As a result, not only must unrenovated residential buildings be retrofitted at a faster pace, but even some previously renovated buildings may require further upgrades to tap into additional energy-saving potential. The simultaneous demand for greater speed, quality, and depth in EER efforts imposes significant governance and financing pressures on both central and local governments.

2.2 Current status of EER in the Northern Heating Region

Building types requiring EER vary significantly across China's climate zones. For example, Zhao (2022) examined the retrofit potential of traditional courtyard houses in the Hot-Summer-Cold-Winter zone. By contrast, in the Northern Heating Region, the residential buildings requiring renovation are primarily owner-occupied apartment buildings constructed between 1980 and 2000. These buildings are typically over six stories high and consist of multiple units, each owned by a different private homeowner. Suitable technical measures include insulating the building envelope; upgrading the heating supply system; maintaining or replacing heating pipes to improve energy efficiency; adopting heat metering systems and indoor temperature control systems; and incorporating renewable energy sources (MOHURD, 2012). However, not all buildings adopt all of these measures.

A significant portion of current EER efforts focus on improving the insulation performance of the building envelope. However, the use of envelope insulation alone often fails to achieve satisfactory results. Many EER projects have fallen short of meeting the expected energy-saving targets (Yan et al., 2011). One reason is the relatively low cost-effectiveness of envelope renovation. While insulation measures can reduce energy consumption, they are often not economically attractive to investors (Liu et al., 2017).

Moreover, improvements in energy efficiency may lead to increased energy consumption by homeowners, a phenomenon known as the rebound effect. This effect can substantially offset theoretical energy savings (Galvin, 2013; Sorrell et al., 2009), and is particularly notable in China's Northern Heating Region (Rajabi, 2022), where district heating for residential buildings is highly subsidized and billed based on floor area rather than actual usage (Zhu et al., 2021). As a result, homeowners have limited incentive to avoid energy waste. Consequently, only around one-quarter of the expected energy savings are actually realized (Wen et al., 2018).

Therefore, a combination of renovation measures is necessary in addition to envelope insulation. For instance, installing heat meters would allow homeowners to pay for heating based on actual usage (Liu et al., 2019). The adoption of new floor heating systems is another cost-effective option, offering lower investment requirements and greater energy savings (Chen et al., 2013). The installation of adjustable heating valves is also useful, as it enables homeowners to control room temperatures and prevent overheating in certain units

caused by their proximity to heat exchange stations (Lu, 2008). At present, however, the adoption of such EER measures remains limited and needs to be further promoted.

2.3 Homeowners' decision process in adopting government-led EER

In China, residential EER is implemented at the level of entire apartment buildings, as individual unit owners can make only limited modifications to their dwellings. EER tasks are assigned by the central government to local governments across the country. Homeowners are associated with some of the most critical risks in the initiation and execution of EER projects (Jia et al., 2021). These risks are exacerbated by institutional weaknesses in collective representation: due to the limited presence and weak capacity of homeowners' associations, local authorities are directly responsible for communicating with homeowners during EER implementation.

Previous studies have shown that in multi-occupant buildings, the smooth execution of EER projects and the effectiveness of EER measures depend heavily on occupant acceptance. This finding is consistent across countries and regions, including the UK (Cairns et al., 2024), Montenegro (Pajek et al., 2022), Estonia (Mooses et al., 2022), the Netherlands (Ossokina et al., 2021), Portugal (Rolim & Gomes, 2019), France (Buessler et al., 2017), Romania (Turcu, 2016), and Canada (Gee & Chiappetta, 2013). Ideally, homeowners vote on EER decisions, and projects only proceed when a required proportion of owners agree (MOHURD, 2012). However, in practice, Chinese homeowners are rarely involved in the EER decision process (De Feijter et al., 2019). They cannot influence key decisions such as which measures will be used or what impacts these measures may have, and are often merely passive recipients of a predetermined renovation package (Ma et al., 2021).

Because the number of completed projects is often the most important performance indicator in evaluating EER achievements (Jia et al., 2024), local governments have sometimes skipped measures that would require greater homeowner involvement. In order to meet project deadlines and avoid the need for extensive communication, only those measures with minimal disruption to homeowners are implemented. As a result, more cost-effective options are often neglected. This compromises both the scope and quality of EER projects, increases the financial burden on the government, and contributes to negative homeowner perceptions.

This situation creates a vicious cycle. When homeowners are fully involved in the decision-making process, they are likely to request detailed information about expected energy savings, investment costs, and operational expenses (Berg & Donarelli, 2019). In cases where governmental action is perceived as inappropriate or opaque, homeowners are prone to develop negative attitudes and resist EER initiatives (Yang et al., 2023). Addressing homeowner concerns requires local authorities to allocate more staff and invest significant time in communication. When measures involve indoor construction or homeowner co-financing, even greater coordination is needed to reach consensus among all residents (Ma et al., 2017). To enhance the effectiveness of homeowner engagement and maximize acceptance of EER projects, it is essential to understand the barriers and motivations perceived by homeowners.

2.4 Barriers and motivations in homeowners' decision to engage in EER

Studies focusing on Chinese homeowners typically examine their willingness to adopt EER, such as whether they agree to the renovation or are willing to pay for it, and analyze the results based on socio-demographic characteristics. For example, Lai et al. (2021) found that 90% of homeowners are willing to adopt EER, and that their socio-demographic characteristics influence their perceptions. Liu et al. (2015) compared three EER projects with varying levels of homeowner participation and concluded that greater involvement leads to better renovation outcomes. In other cases, homeowners are treated as a homogeneous group alongside other stakeholders, as in Yang et al. (2023).

Beyond differences in socio-demographic characteristics and building conditions, homeowners also vary in their knowledge, opinions, preferences, and other psychological factors when considering improvements to their homes (Liu et al., 2021). While aspects of occupant behavior in collective housing EER have been explored in various international studies, many of these studies focus on tenants (Palm et al., 2020). Some research addresses owner-occupied dwellings, but often under the coordination of homeowners' associations or through bottom-up approaches in which homeowners collectively bundle their needs and make joint decisions (Tiellemans et al., 2021). In other cases, building upgrades involve minor interventions such as installing solar photovoltaic systems or LED street lighting rather than substantial changes to the building itself (Hwang et al., 2017).

Only a few previous studies have investigated the actual experiences and perceptions of Chinese homeowners involved in EER (Ma et al., 2021), the barriers they encountered (Ma et al., 2022), or their reasons for accepting or rejecting EER and related costs (Huang et al., 2021). This study seeks to fill this research gap by exploring the barriers and motivations of Chinese homeowners, incorporating their prior EER experiences to better understand their attitudes toward future participation.

The investigation builds upon previous work by Ma et al. (2022) and was conducted in several steps. First, we reviewed factors cited in the literature as influencing homeowners' EER decisions. Factors irrelevant to the Chinese context, such as difficulty in finding qualified workers, were excluded, as Chinese homeowners do not need to find renovation workers themselves. Next, based on the assumption of bounded rationality and the cognitive biases associated with it, we proposed additional hypothetical factors specific to government-led EER decision-making. For instance, when homeowners are asked to make a decision under time pressure and feel a strong expectation to consent, they may resist to protect their sense of autonomy, a psychological response known as reactance (Brehm, 1966), which can be understood as a source of perceived coercion and thus a barrier.

Some factors can serve as either barriers or motivations depending on context, while others appear exclusively as one or the other. The preliminary list was refined through expert evaluations and homeowner interviews to ensure contextual relevance and resonance with Chinese homeowners (Ma et al., 2022). Finally, all factors were categorized into four dimensions: financial concerns, governance-related issues, impact on the dwelling, and inconvenience and information sources (see Table 1).

Table 1 Barriers and motivations

Factors	Barriers	Motivations
Category 1: finance		
Capital cost	Cost of the renovation is too high	Cost not too high or no payment required
Payback period	Payback period is too long or cannot be paid back	Fast payback
Energy prices	Increased cost for heating after renovation	Decreased cost for heating after renovation
Incentives	No subsidies available	Subsidies provided
Property value	Not perceived as a barrier	Increased property value after renovation
Spontaneous purchase	Conflict with prior heating equipment purchases	Not perceived as a motivation
Spontaneous renovation	Have undertaken renovation at their own expense	Not perceived as a motivation
Financial plan	Financial plan is not fair and reasonable	Financial plan is fair and reasonable
Category 2: governance		
Process	Process is not open and transparent	Process is open and transparent
Policy	Not perceived as a barrier	Policy support is available
Trust	Unsure about the reliability of agencies	Reliable responsible agencies
Time pressure	Pressure to make a decision in a short timeframe	Not perceived as a motivation
Procrastination	Hesitancy or tendency to delay decision-making	Not perceived as a motivation
Coercion	Feeling forced or pressured into decision-making	Not perceived as a motivation
Lose initiative	Feeling of losing decision-making autonomy	Not perceived as a motivation
Category 3: impact on the dwelling		
Function	The living space of the dwelling may be affected	Enhanced living space
Convenience	The convenience of the dwelling may be affected	Enhanced convenience
Comfort	The comfort of the dwelling may be affected	Enhanced comfort
Aesthetics	The aesthetics of the dwelling may be affected	Enhanced aesthetics
Stick to the status quo.	Preference for current living conditions	Not perceived as a motivation
Uncertainty	Uncertain about the outcomes of renovation	Not perceived as a motivation
Category 4: inconvenience and information sources		
Construction	Noise and dirt during construction	Clean and quiet construction process
Information	Lack of reliable information sources	Not perceived as a motivation
Preference	Preference for other types of renovation	Not perceived as a motivation
Salient events	Intention to move out in the near future	Not perceived as a motivation
Environment	Not perceived as a barrier	Positive impact on the environment
Family's opinion	Family members do not support the renovation	Family members support the renovation
Peer's opinion	Neighbours/friends oppose the renovation	Neighbours/friends support the renovation

3 Methodology

This study adopts a sequential explanatory mixed-methods design (Ivankova et al., 2006), in which a quantitative survey was conducted to investigate homeowners' motivations and barriers, followed by qualitative interviews to contextualize and interpret the statistical findings. We utilized questionnaire surveys and interviews for data collection, aiming to capture a multidimensional understanding of homeowners' perspectives on EER.

3.1 Questionnaire survey

3.1.1 Questionnaire design and implementation

The questionnaire consisted of three main sections. The first section collected background information on homeowners and their dwellings, including age, income, education level, and basic housing conditions. For each item, respondents were instructed to select the single option that most accurately reflected their situation.

In the second section, homeowners were asked to imagine themselves in a hypothetical scenario in which government-led EER was being implemented in their apartment building. A short description of the renovation project was provided, including information on expected costs, technical measures, and implementation procedures. Respondents were then asked to select all applicable barriers reflecting their perceptions of EER. They were also asked to rate the importance of various motivations for participating in government-led EER using a 5-point Likert scale. This enabled the quantification of their value priorities when considering engagement in such programs.

The third section focused on behavioral experience and future intention. Participants were first asked whether they had previously taken part in any EER projects. Those who answered affirmatively were asked follow-up questions regarding the specific measures that had been implemented. Based on the same renovation scenario described earlier, all respondents were then asked whether they would consider participating in such a program in the future.

During the questionnaire design phase, in-depth interviews were conducted with experts in building energy efficiency, sociology, and behavioral economics to ensure the scientific rigor and contextual relevance of the content. Prior to full distribution, a small-scale pilot survey was conducted to test the clarity and comprehensibility of the questions.

The questionnaire was distributed to homeowners in the Northern Heating Region through both paper-based and online formats. A total of 500 hard copies were distributed in person to homeowners in Beijing Municipality, Tianjin Municipality, Hebei Province, and Heilongjiang Province. These areas were identified as key regions for EER. After agreeing to participate, respondents were asked to complete the questionnaire at home within two weeks. A total of 185 valid responses were collected, yielding a response rate of 37%. Considering that typical response rates for questionnaire surveys range from 16.5% to 50.0% (Lund, 2023), this response rate can be regarded as acceptable.

The online version of the questionnaire was created using the survey platform *Wenjuanxing* (问卷星). The platform allows researchers to design and distribute surveys via a shareable link, and also offers paid distribution to registered users. In total, 294 valid responses

were collected from unpaid, anonymous participants across all 15 provinces and municipalities in the Northern Heating Region. Thus, the total sample size in this study was $N=479$.

Before conducting the main analysis, we tested for multicollinearity among socio-demographic and building-related variables using the Variance Inflation Factor (VIF). VIF values exceeding 10 are generally considered indicative of multicollinearity. In this study, all VIF values ranged from 1.111 to 2.345, suggesting that multicollinearity was not a concern and the data were suitable for further analysis.

3.1.2 Sample characteristics

All respondents participated in the research with informed consent, ensuring confidentiality and the protection of personal privacy. Descriptive statistics were used to analyze the data with SPSS software, enabling comparisons of perceptions, barriers, and motivations across different homeowner categories. Table 2 presents the profile of the respondents.

A total of 91 respondents reported that they had participated in EER, representing 19.4% of the total sample (Table 3). Among them, only 20 had made payments for the renovation. This relatively small proportion may suggest either that homeowners are unwilling to contribute financially or that they were not required to do so. In addition, 33 respondents reported having spontaneously upgraded the energy-related features of their dwellings. Since individual homeowners in apartment buildings are generally unable to carry out major renovations, these spontaneous upgrades usually refer to actions like replacing windows or indoor heaters.

As shown in Table 4, and consistent with findings from existing literature, the most commonly implemented EER measures are those related to envelope insulation, including window insulation or replacement, and the insulation of external and internal walls. More than half of the respondents reported adopting these two measures. Typically, envelope insulation would also include roof insulation; however, this was mentioned less frequently in the survey responses, possibly because the roof insulation process is less visible or noticeable to most homeowners. Upgrading indoor heat radiators, which involves replacing aging heaters with low heat transfer efficiency, was also a common measure and was cited by 44.7% of respondents.

By contrast, three other measures - adopting heat metering and control systems, upgrading heating sources and supply systems, and installing heat pumps - were rarely mentioned. This is consistent with our review of the literature, which indicates that renovation measures requiring greater homeowner involvement are more difficult to promote, even though they are cost-effective and can yield additional energy savings through improved user behavior.

3.2 Semi-structured interviews

To gain deeper insights into homeowners' genuine perceptions of EER, a series of semi-structured, anonymous interviews were conducted with selected homeowners. These interviews helped to uncover what homeowners from different groups think about EER, what they expect from it, and the specific reasons they may support or oppose such renovation efforts.

We initially contacted questionnaire respondents who had indicated a willingness to participate in follow-up communication and had provided their contact details. Through

Table 2 Profiles of the sample

	Frequency	Percentage
Gender		
Female	210	48.05%
Male	227	51.95%
Age		
Below 25	95	21.99%
25 to 40	203	46.99%
Above 40	134	31.02%
Occupation status		
Student	90	21.69%
Full-time worker	248	59.76%
Non-working adults	77	18.55%
Highest education level		
College and below	128	29.77%
Undergraduate	182	42.33%
Postgraduate	120	27.91%
Household annual income		
Below 100,000	221	51.40%
100,001–200,000	119	27.67%
Above 200,000	90	20.93%
Total # of floors of the building		
Multi-storey (6 and below)	221	48.36%
High-rise (more than 6)	236	51.64%
Floor area of the unit		
Less than 90 m^2	252	56.12%
90m^2 and above	197	43.88%
Energy consumption		
Low	132	33.50%
Medium	133	33.76%
High	129	32.74%
Satisfaction of indoor comfort		
Dissatisfied	109	23.75%
Satisfied	350	76.25%
Environmental concern		
Unconcern	147	32.52%
General concern	248	54.87%
Very concern	57	12.61%
Knowledge of EER		
Not at all	75	16.03%
Heard about it	223	47.65%
Clearly understand	170	36.32%
Attitude towards EER		
Neutral or negative	32	6.84%
Positive	223	47.65%
Very positive	213	45.51%

Table 3 EER experiences of the sample

	Frequency	Percentage
I don't have EER experience.	378	80.6%
I've participated in a government-led EER that I didn't pay for.	38	8.0%
I've participated in government-led EER, and I paid for it.	20	4.2%
I've done spontaneous EER.	33	6.9%

Table 4 Implemented renovation measures reported by the renovators

	Frequency	Percentage
Insulating/replacing windows	45	58.4%
Insulating external and internal walls	39	51.3%
Upgrading the indoor heat radiator	34	44.7%
Insulating the roof	24	31.6%
Adopting a heat metering and control system	9	11.8%
Upgrading heating sources and heating supply systems	8	10.5%
Installing heat pumps	8	10.5%

Table 5 Interviewee profile

Number	Age	Gender	EER experience	Number	Age	Gender	EER experience
1	69	Male	Yes	10	31	Female	No
2	68	Female	Yes	11	53	Male	Yes
3	47	Female	No	12	34	Male	No
4	44	Male	No	13	27	Male	No
5	30	Male	No	14	55	Male	Yes
6	39	Male	No	15	36	Male	Yes
7	29	Male	No	16	48	Female	No
8	32	Female	Yes	17	62	Male	No
9	74	Female	Yes				

this method, seven interviewees were recruited. Additional participants with EER experience were identified through alternative recruitment channels, including the dissemination of information via online social media platforms and outreach to eligible neighborhood committees. These efforts resulted in the recruitment of ten more interviewees. In total, we conducted 17 interviews. The interview content covered a range of topics, including general perceptions of EER, motivations and expectations regarding participation, specific barriers encountered during the renovation process, and future willingness to participate in similar programs.

Interviewees were selected based on questionnaire responses to ensure representation and diversity within the sample. All participants were informed that the interview results would be used solely for academic research purposes. Interviews were conducted either face-to-face, via video call, or by telephone, and typically lasted between one and two hours. Background information on the interviewees is presented in Table 5.

4 Results

4.1 Inter-group comparison of non-renovators and renovators

The sample profile was analyzed descriptively using chi-square tests. In this study, respondents were grouped based on their EER experiences. This classification reflects their renovation history, not their willingness or intention. "Non-renovators" refers to homeowners who have not experienced EER, while "renovators" refers to those who have. An inter-group comparison was conducted to provide an overview of differences in basic characteristics between the two groups.

As shown in Table 6, non-renovators and renovators differ in several aspects. Consistent with previous research, EER efforts have primarily targeted multi-storey residential buildings with six floors or fewer. This may be because high-rise buildings are more difficult to retrofit due to their complex structures and the resulting technical challenges (Baldwin et al., 2017). Variations in age, occupation, and income between the two groups are also associated with building type. These multi-storey buildings are often informally referred to as *Laopoxiao*, a term that translates roughly to "old, shabby, and small." It is commonly used to describe properties built decades ago, characterized by outdated infrastructure and poorly designed living spaces. The composition of the respondents is further presented in Fig. 1.

Renovators tend to be older and have lower incomes. Many are retired or unemployed and therefore spend more time at home. Compared with non-renovators, they are more familiar with and supportive of EER. However, the two groups do not differ significantly in terms of energy consumption levels, satisfaction with indoor comfort, or environmental awareness. Nor is there a significant difference in dwelling size, as residential building parameters such as density, floor area, and plot ratio are regulated under national land use policies in China.

4.2 Barriers for homeowners to undertake government-led EER

4.2.1 Overview

As shown in Table 7, overall, renovators perceive barriers as less severe than non-renovators. In particular, concerns regarding higher heating costs after renovation, unfair financing arrangements, and the credibility of authorities were reported significantly less by renovators. Their uncertainty about EER outcomes is reduced, and they experience less stress during the decision-making process.

Only one barrier was reported more frequently by renovators: *spontaneous renovation*. This suggests that if homeowners have independently undertaken energy upgrades without external requirements, they may view this as a barrier to participating in further government-led EER projects. However, the proportion of respondents selecting this option was low among both renovators and non-renovators. This finding may indicate that government-led EER has played a catalytic role in encouraging homeowners to initiate spontaneous upgrades. At the same time, such self-initiated efforts may become a barrier to further participation, as homeowners feel they are "losing out" by having already invested.

Table 6 Comparison of non-renovators and renovators

	Non-renovators		Renovators		*p*-value
	Frequency	Percentage	Frequency	Percentage	
Gender					0.077
Female	178	50.7%	32	48.1%	
Male	173	49.3%	54	62.8%	
Age					0.005**
Below 25	82	23.6%	13	15.3%	
25 to 40	171	49.3%	32	37.6%	
Above 40	94	27.1%	40	47.1%	
Occupation status					0.007**
Student	76	22.8%	14	17.1%	
Full-time worker	206	61.9%	42	51.2%	
Non-working adults	51	15.3%	26	31.7%	
Highest education level					0.167
College and below	96	27.4%	32	40.0%	
Undergraduate	152	43.4%	30	37.5%	
Postgraduate	102	29.1%	18	22.5%	
Household annual income					0.034*
Below 100,000	171	49.6%	50	58.8%	
100,001–200,000	92	26.7%	27	31.8%	
Above 200,000	82	23.8%	8	9.4%	
Total # of floors of the building					0.018*
Multi-storey (6 and below)	166	45.1%	55	61.8%	
High-rise (more than 6)	202	54.9%	34	38.2%	
Floor area of the unit					0.980
Less than 90 m^2	204	56.4%	48	55.2%	
90m^2 and above	158	43.6%	39	44.8%	
Energy consumption					0.937
Low	104	33.2%	28	34.6%	
Medium	106	33.9%	27	33.3%	
High	103	32.9%	26	32.1%	
Satisfaction of indoor comfort					0.979
Dissatisfied	87	23.6%	22	24.4%	
Satisfied	282	76.4%	68	75.6%	
Environmental concern					0.854
Unconcern	121	32.6%	26	32.1%	
General concern	204	55.0%	44	54.3%	
Very concern	46	12.4%	11	13.6%	
Knowledge of EER					0.000**
Not at all	68	18.0%	7	7.8%	
Heard about it	191	50.5%	32	35.6%	
Clearly understand	119	31.5%	51	56.7%	
Attitude towards EER					0.001**
Neutral or negative	28	7.4%	4	4.4%	
Positive	195	51.7%	28	30.8%	
Very positive	154	40.8%	59	64.8%	

*p < .05, ** p < .01, *** p < .001

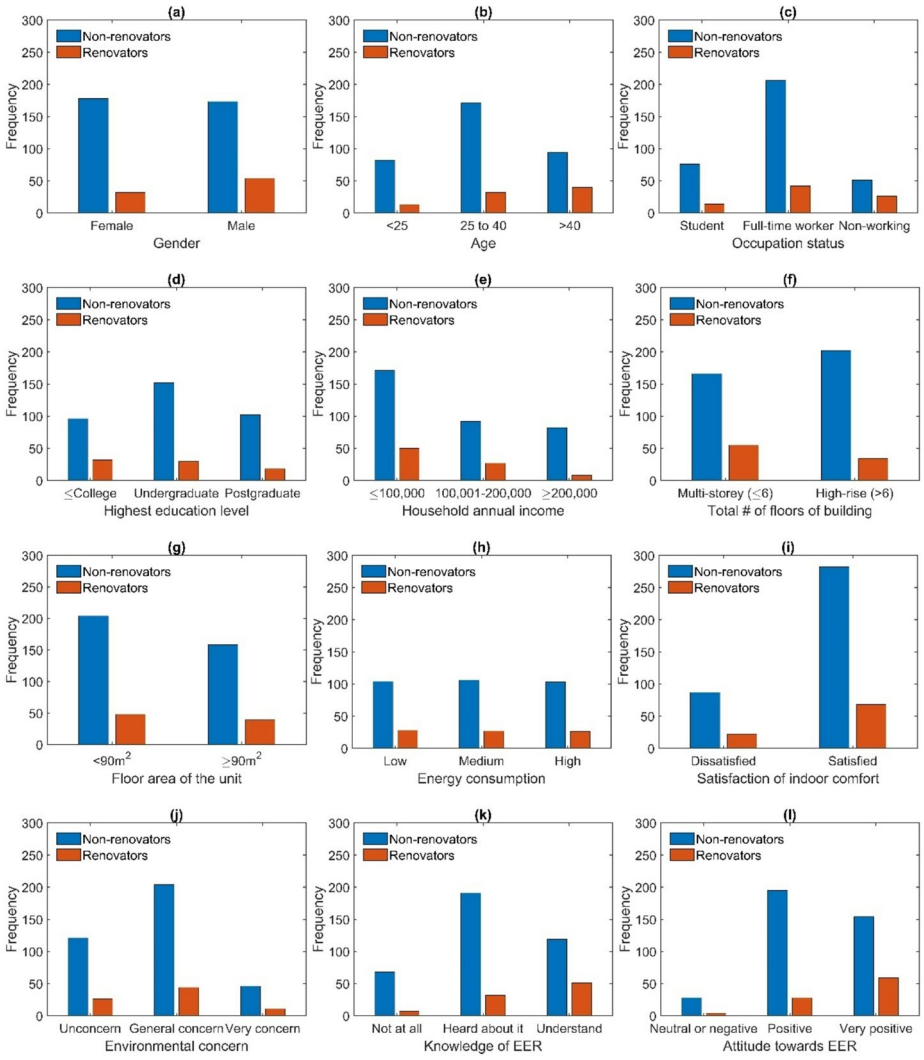

Fig. 1 Composition of the respondents for non-renovators and renovators

Some barriers evolve or intersect during the decision-making process. For example, EER involving indoor construction can damage interior finishes or decorations, prompting homeowners to reject participation in order to maintain the status quo:

> I just had an interior renovation and repainted my interior walls. EER will destroy part of the wall.
>
> (Interviewee 15, male, age 36)

However, this concern may later manifest as a financial barrier:

Table 7 Comparison of the Means for each barrier between non-renovators and renovators

Barrier	Non-renovators		Renovators		*p*-value
	Mean	Frequency	Mean	Frequency	
Finance					
Capital cost	0.51	190	0.58	52	0.226
Payback period	0.25	93	0.16	14	0.062
Energy prices	0.39	128	0.25	16	0.037*
Incentives	0.38	144	0.34	30	0.412
Spontaneous purchase	0.20	76	0.22	20	0.681
Spontaneous renovation	0.09	34	0.17	15	0.035*
Financial plan	0.52	196	0.39	35	0.023*
Governance					
Process	0.45	169	0.38	34	0.211
Trust	0.40	149	0.24	22	0.007**
Time pressure	0.19	71	0.14	13	0.321
Procrastination	0.07	25	0.04	4	0.435
Coercion	0.23	86	0.13	12	0.045*
Lose initiative	0.09	32	0.10	9	0.660
Impact on the dwelling					
Function	0.35	130	0.34	31	0.968
Convenience	0.28	105	0.31	28	0.559
Comfort	0.43	160	0.33	30	0.106
Aesthetics	0.17	64	0.18	16	0.873
Stick to the status quo	0.13	47	0.13	12	0.838
Uncertainty	0.20	75	0.11	10	0.050*
Inconvenience and information sources					
Construction	0.38	141	0.30	27	0.178
Information	0.20	77	0.13	12	0.122
Preference	0.22	82	0.24	22	0.599
Salient events	0.23	87	0.21	19	0.672
Family's opinion	0.14	53	0.11	10	0.453
Peer's opinion	0.11	40	0.08	7	0.415

*p < .05, ** p < .01, *** p < .001

> I want the construction team to help me fix it at the end of the construction, or give me financial compensation. But they do not agree.
>
> (Interviewee 15)

Similarly, indoor construction measures may require homeowners to remain on-site throughout the renovation or temporarily relocate, resulting in both inconvenience and financial burden:

> During the construction period, we will have to stay in a hotel. We are seniors with limited mobility and can't afford the costs.

(Interviewee 9, female, age 74)

Concerns about the physical impact of EER on the dwelling often co-occur. Aesthetic considerations are frequently intertwined with functional and convenience concerns, such as the need to remove decorations from balconies or dormer windows, relocate items stored in corridors, or dismantle privately erected rooftop structures. In some cases, the impact is at the building scale: poor-quality insulation may result in patchy façades and increased fire risks, while roof insulation may alter the building's original appearance and lead to water leakage.

Figure 2 illustrates the main barriers preventing homeowners from accepting EER. *Capital cost*, *financial plan*, and *process-related concerns* emerged as key barriers for both groups, suggesting that, regardless of prior EER experience, Chinese homeowners share similar fundamental concerns. These include uncertainties about total costs, payment mechanisms, and the procedural transparency and fairness of the renovation process.

4.2.2 Main barriers for non-renovators

For non-renovators, the perceived fairness of the financial plan is a major concern—nearly on par with the consideration of capital cost.

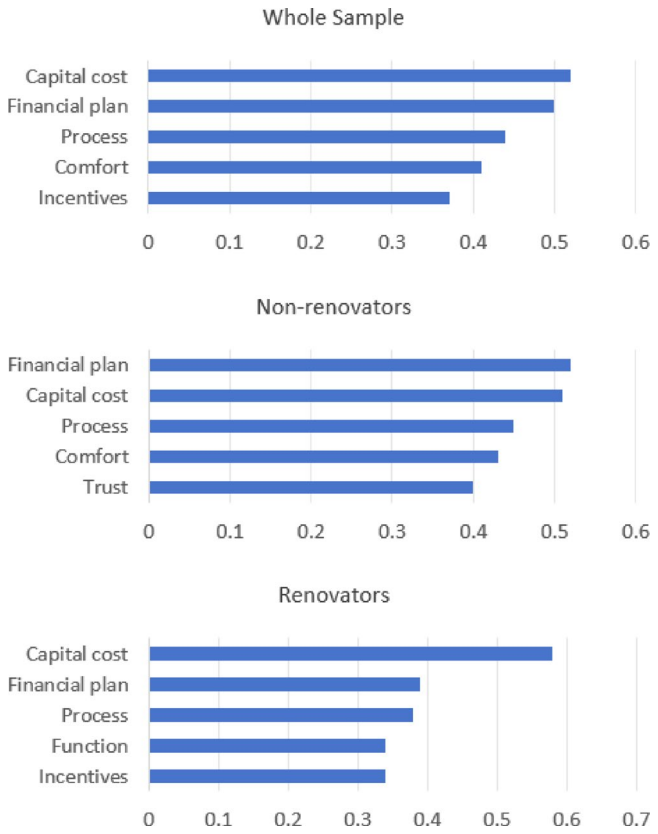

Fig. 2 Top 5 main barriers for both groups

> The cost should not be simply split equally between all homeowners in an apartment; the degree of impact should be taken into account.
>
> (Interviewee 7, male, age 29)

Concerns about fairness often extend to broader contextual comparisons:

> The EER in the neighborhood next to ours was implemented as a pilot project, so the homeowners did not pay for it. Homeowners in our neighborhood naturally feel it's unfair when they have to pay.
>
> (Interviewee 3, female, age 47)

Before homeowners undergo their first EER, they often lack clarity about what will happen and who will communicate with them. As a result, process-related uncertainty and lack of trust become critical barriers. Distrust in the responsible authorities discourages participation.

> The contractor should be selected transparently from qualified teams with specialized credentials.
>
> (Interviewee 5, male, age 30)

In addition, many homeowners emphasize the need for clear communication and procedural transparency:

> Rather than focusing solely on getting things done quickly, the authorities should explain the process clearly to homeowners. What procedures will be followed? How long will the work take? What outcomes can be expected? Who is accountable for unforeseen issues during renovation? Who will manage maintenance afterward? How can we file complaints if the final results deviate from initial promises?
>
> (Interviewee 6, male, age 39)

Questions like these were raised by several respondents. Many hoped that the authorities would provide official, authoritative documentation to reassure homeowners and facilitate informed decision-making.

Another major concern among non-renovators relates to the potential impact of EER on indoor comfort. The fear that post-renovation comfort levels may decline is, for some, a sufficient reason to reject EER altogether.

> I read a news story about poor-quality insulation leading to dampness and mould after renovation. It may be a rare case, but if it happens, it can cause serious trouble.
>
> (Interviewee 3, female, age 47)

4.2.3 Main barriers for renovators

A second EER is more likely to require homeowners to contribute financially than the first. As a result, capital cost is the most frequently cited barrier among renovators, especially for those who previously experienced a government-funded EER. Due to inertia or reluctance to change, many assume that future EERs should also be free of charge.

> Heat metering costs us money to install, and it also makes heating bills more expensive after installation. The heating will have to be saved in the future, and we are not used to it.
>
> (Interviewee 9, female, age 74)

In addition, renovators tend to have more specific expectations and demands regarding fairness.

> Top-floor homeowners should bear more of the cost of roof insulation, while ground-floor homeowners are the most disturbed and should pay less.
>
> (Interviewee 11, male, age 53)

Renovators also place greater importance on the form and reliability of incentives. Their concerns extend beyond individual compensation to whether EER projects can secure sufficient funding for successful completion.

> EER is difficult to generate economic benefits because it's not market-based. Government subsidies and payments from homeowners aren't enough to cover the total cost, and the rest relies on corporate sponsorship. If companies pull out midway and the financial chain breaks, the EER project will be canceled before it's completed.
>
> (Interviewee 15, male, age 36)

Many renovators reported dissatisfaction with the transparency and rationality of the previous EER process. They felt poorly informed and inadequately consulted, which they viewed as a violation of their rights. If a future EER is expected to follow the same approach, many would refuse to participate.

> I don't know who made the EER decision. We weren't even notified as homeowners. I think there should be a one-vote veto system—if even one person disagrees, the EER shouldn't be implemented.
>
> (Interviewee 11, male, age 53)

Since renovators' needs for thermal comfort were already met or partially met during the previous EER, a second renovation is more likely to involve installing new equipment indoors and causing substantial changes to their living environment. Unsurprisingly, their

concerns now shift more toward functionality rather than other aspects under the "impact on the dwelling" category.

> In winter, the balcony used to be very cold, and I stored food there that needed refrigeration. After the first EER, the insulation improved, but I had to buy a new fridge. The impact of the second EER will likely be even greater.
>
> (Interviewee 14, male, age 55)

4.3 Motivations for homeowners to undertake government-led EER

4.3.1 Overview

This section identifies the key factors that motivate homeowners to participate in government-led EER initiatives. Figure 3 presents the results. Since the first EER is often provided free of charge to homeowners, non-renovators tend to be less concerned about costs compared to renovators. For non-renovators, the primary motivation is the improvement of indoor comfort, followed by a transparent process and trust in responsible authorities.

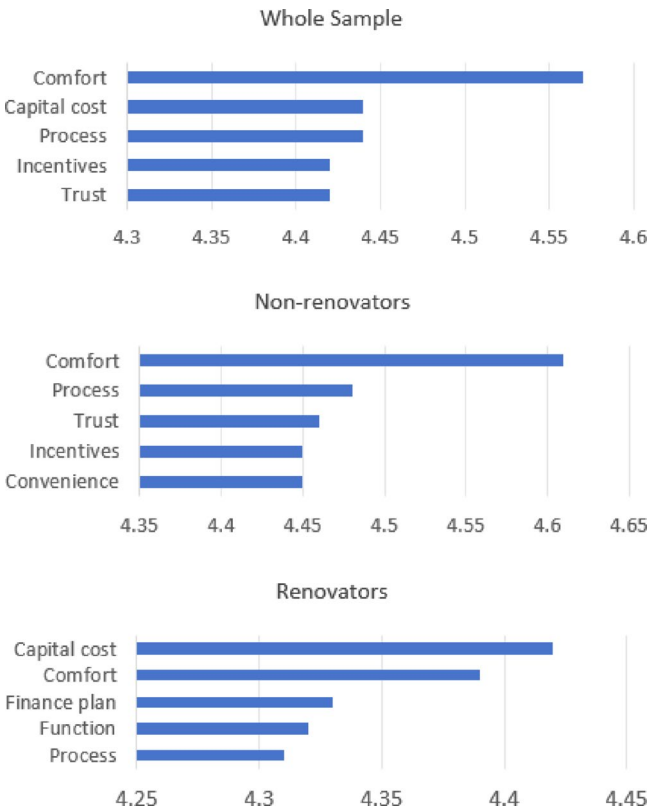

Fig. 3 Top 5 main motivations of both groups

As shown in Table 8, renovators are generally less influenced by most motivational factors than non-renovators, with the exception of a few items, such as capital cost and financial plan, where the reported concern levels are nearly identical.

Renovators rated almost all motivational factors lower than non-renovators, indicating a relatively lower enthusiasm for further participation in EER programs. This could stem from two possible reasons: either their previous EER experience did not meet their expectations, or it already satisfied their needs to a large extent.

Which of these explanations holds true depends on the specific motivational factor in question. For instance, based on existing literature and reports, most homeowners acknowledge the comfort improvements gained from the first EER. Therefore, renovators show less willingness than non-renovators to pursue further comfort improvements. Conversely, motivators such as policy support and increased property value are reported to be less persuasive among renovators, likely due to negative experiences in their previous EER participation.

> The communication process, if it exists at all, is vague. It makes me feel like the process is unimportant.
>
> (Interviewee 8, female, age 32)

Such perceptions diminish their willingness to accept deeper or more complex levels of EER involvement.

Table 8 Means for each motivation and comparison between non-renovators and renovators

Motivation	Mean	Non-renovators	Renovators	*p*-value
		Mean	Mean	
Finance				
Capital cost	4.44	4.44	4.42	0.190
Payback period	3.83	3.90	3.52	0.025*
Energy prices	4.25	4.28	4.10	0.593
Incentives	4.41	4.45	4.26	0.039*
Policy	4.05	4.11	3.81	0.014*
Property value	4.06	4.11	3.81	0.027*
Financial plan	4.37	4.38	4.33	0.478
Governance				
Process	4.44	4.48	4.31	0.171
Trust	4.41	4.46	4.19	0.000**
Impact on the dwelling				
Function	4.42	4.44	4.32	0.080*
Convenience	4.42	4.45	4.28	0.106
Comfort	4.57	4.61	4.39	0.002**
Aesthetics	3.90	3.95	3.71	0.339
Inconvenience and information sources				
Construction	4.15	4.23	3.81	0.005**
Environment	3.97	3.99	3.89	0.209
Family's opinion	3.87	3.94	3.54	0.018*
Peer's opinion	3.40	3.49	3.00	0.010*

*p < .05, ** p < .01, *** p < .001

4.3.2 Main motivations for non-renovators

The expectation of improved comfort is the primary reason why many non-renovators support EER. As some respondents stated:

> I just want a comfortable stay and don't mind if I get my money back.
>
> (Interviewee 10, female, age 31)

> Improving the environment or increasing property values is all government propaganda, and I don't expect EER to achieve that. In the end, only increased comfort is a real benefit.
>
> (Interviewee 4, male, age 44)

A reasonable and transparent EER process also enhances non-renovators' receptiveness and positive expectations. However, this depends on whether clear and reliable information is provided before the renovation begins. Respondents emphasized that trustworthy staff members (e.g., engineers or architects) should be available to explain the process, even if they are not government officials.

Some non-renovators also expect to receive financial incentives, even when EER is offered at no direct cost. Their reasoning is that other stakeholders, such as local governments and developers, gain tangible benefits from the renovation process:

> EER is essentially a so-called livelihood project, and it can be considered a political achievement for the government. Local governments and developers receive subsidies from the central government. But as relatively passive stakeholders, we homeowners should be financially compensated, since the benefits we receive are limited.
>
> (Interviewee 6, male, age 39)

In addition, some non-renovators hope that EER can improve residential accessibility and be combined with other forms of building upgrades.

> EER not only makes the room warmer in winter but also cooler in summer. In addition to temperature, it improves humidity, noise, lighting, ventilation, and many other things. Perhaps other refurbishments, like adding a lift, can be carried out alongside EER.

(Interviewee 7, male, age 29)

4.3.3 Main motivations for renovators

Based on their previous experience, many renovators have realized that EER does not necessarily entail high costs, and that heating expenses may decrease once heat metering is

fully implemented. As a result, if a subsequent EER is not excessively expensive and is supported by a reasonable financial plan, renovators are likely to accept it willingly.

At the same time, although the first EER has already improved comfort and functionality, reducing the urgency of further upgrades in these areas, comfort and functional enhancement remain an important motivation for renovators.

> Hopefully, the next EER will bring some new equipment based on the latest technology, such as a fresh air system or smart devices.
>
> (Interviewee 8, female, age 32)

Most renovators interviewed expressed dissatisfaction with the governance and procedural aspects of the previous EER, as discussed earlier in the barriers section. However, if the next EER can offer a clear, fair, and transparent implementation process, renovators who are satisfied with the outcomes of the previous project are likely to make a positive decision to participate again.

4.4 Homeowners' willingness to engage in EER

As shown in Fig. 4, there is no significant difference between renovators and non-renovators in their overall willingness to accept EER. The results indicate that approximately 84% of homeowners are supportive of EER. This finding is consistent with previous studies suggesting that Chinese homeowners, based on self-reported data, generally hold very positive attitudes toward EER.

To explore this further, we classified renovators based on the types of EER they had experienced. Three subtypes were identified:

Subtype 1 includes homeowners who received free EER.

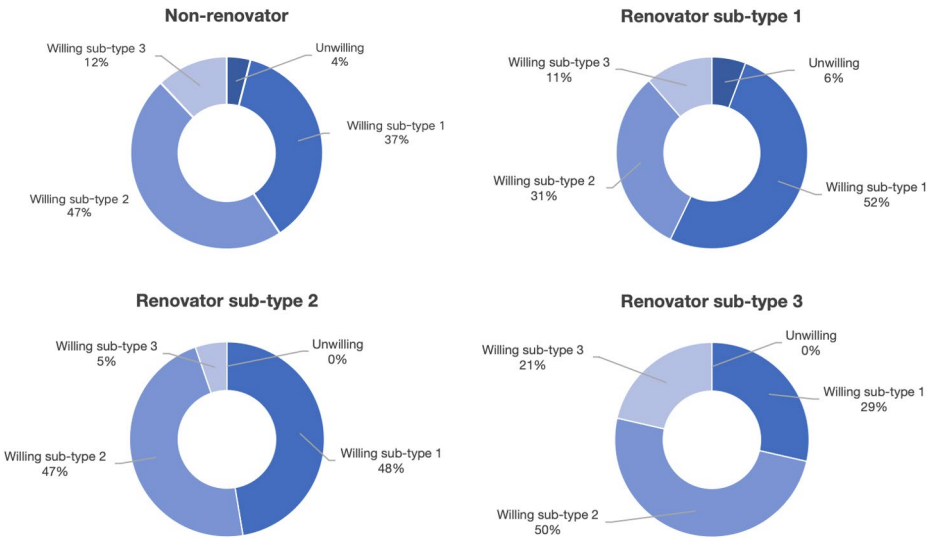

Fig. 4 Willingness to engage in EER

Table 9 Homeowners' willingness to engage in EER

Homeowner groups	Unwilling		Willing subtype 1		Willing subtype 2		Willing subtype 3	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Non-renovator	14	4.0%	128	36.7%	165	47.3%	42	12.0%
Renovator subtype 1	2	5.7%	18	51.4%	11	31.4%	4	11.4%
Renovator subtype 2	0	0.0%	9	47.4%	9	47.4%	1	5.3%
Renovator subtype 3	0	0.0%	8	28.6%	14	50.0%	6	21.4%
Total	16	3.7%	163	37.8%	199	46.2%	53	12.3%

Subtype 2 refers to those who paid part of the renovation cost.

Subtype 3 includes those who conducted spontaneous EER, typically by upgrading their windows to better insulated products.

Homeowner willingness was categorized into four types: (1) unwilling to renovate; (2) willing to join government-led EER but unwilling to pay; (3) willing to join and pay; and (4) preferring self-initiated renovation. The results are presented in Table 9.

The type of past EER experience appears to influence preferences for future EER. For example, among homeowners who did not pay for their previous EER, 51.4% expressed unwillingness to pay for future renovations. This group also showed the lowest level of acceptance for paid EER: lower than both other renovators and non-renovators. However, future EER initiatives are increasingly likely to require at least partial homeowner contributions. Persuading this group to revise their expectations and accept cost-sharing may pose a significant challenge for policymakers.

Homeowners who conducted EER independently, either instead of or in addition to government-led initiatives, were more likely than others to express willingness to self-fund future upgrades. Notably, they were also relatively less inclined to support free EER, possibly because they had already achieved comparable outcomes through self-initiated actions.

Some homeowners explicitly expressed a desire for greater autonomy in choosing EER measures, even if it meant paying out of pocket. They also hoped to bundle EER with other improvements not directly related to energy efficiency, such as adding elevators, increasing parking spaces, or repairing water pipelines.

Conversely, a subset of homeowners expressed disinterest in any kind of renovation:

> No matter how it is upgraded, this flat is what is known as a Laopoxiao, and it's much worse than a newly built home. I no longer plan to stay here. Hopefully, it will be demolished, or I'll sell it.
>
> (Interviewee 12, male, age 34)

When the interviewer suggested that EER might increase the property's market value, the interviewee responded:

> I don't think so. House prices are determined by broader macro-level factors, and EER won't affect that.
>
> (Interviewee 12)

5 Discussion and policy implications

5.1 Contrasting barriers and motivations between renovators and non-renovators

There are notable differences in the barriers and motivations to adopt EER between homeowners who have prior EER experience and those who do not. For non-renovators, government incentives and a positive outlook on the EER process and outcomes can be effective in stimulating interest. However, due to limited knowledge about the specific measures and their actual effects, they often lack confidence in achieving the desired outcomes. Some may also express skepticism toward the government-led model. To address these concerns, offering diversified renovation options can help balance autonomy with administrative coordination, improve transparency, and ensure sufficient decision-making freedom. Showcasing successful EER cases and introducing third-party supervision mechanisms can further enhance trust and alleviate uncertainty.

In contrast, renovators tend to be more concerned about how EER might interfere with the way their homes function in daily life, including temperature control, layout, and interior usability, particularly when more complex technologies are involved. While financial issues remain a common barrier, apprehension about construction disruptions and future maintenance burdens becomes more pronounced. Although these concerns may also affect non-renovators, the renovators' demand for improved comfort tends to be lower, especially when their initial EER was free of charge. In such cases, the prospect of paying for an uncertain second renovation is perceived as a significant risk, leading to hesitancy toward further engagement.

To encourage renovators to participate in future EER projects, relevant authorities can emphasize the long-term benefits, including reduced energy consumption, extended building lifespan, and improved energy efficiency. To increase acceptance of measures such as heat metering, detailed guidance, technical assistance, and convenient implementation options should be provided to minimize disruption to daily life. Flexible financing schemes such as low-interest loans and installment-based payment plans can reduce the financial burden. Moreover, communicating that the payback period for the second renovation is often shorter than for the first may help address concerns about return on investment. Lastly, appealing to homeowners' sense of shared responsibility in promoting energy efficiency can further strengthen their motivation to participate. These strategies may help demonstrate that, despite temporary inconvenience or cost, the long-term benefits of a second EER can be both meaningful and worthwhile.

5.2 Evolving concerns across the EER decision process

This study reveals the temporal dynamics of motivations and barriers in homeowners' EER decision-making. Interview data indicate that initial concerns often center on potential hassle, disruption, or aesthetic damage. However, as implementation becomes more imminent, these concerns tend to evolve into concrete financial worries such as expectations for compensation or perceptions of unfair cost allocation. This progression suggests that motivations and barriers are not fixed categories, but dynamic elements that shift across different phases of the decision process.

These findings highlight the need for phase-sensitive policy instruments that tailor communication strategies, incentives, and support mechanisms according to whether households are in the contemplation, preparation, or implementation stage. For example, in the early phases, visualizations of successful renovation outcomes and testimonials from nearby residents may be effective in shaping expectations and reducing resistance from non-renovators (Bielig et al., 2024). In parallel, for renovators, it is important to investigate any dissatisfaction with the upgraded systems, as prior studies have found that residents may feel frustrated by the lack of control, noise, or insufficient feedback from newly installed technologies (Guerra-Santin et al., 2025). As households approach actual decision-making, more targeted interventions such as flexible financing arrangements and guaranteed technical support become increasingly important in facilitating action.

5.3 The conditional role of information, trust, and autonomy

Even in renovation systems that are more institutionally mature, such as those in Western Europe, issues of accessibility and fairness remain prominent (Fernández et al., 2024). However, contrary to the assumption that more information always leads to better decisions, our data reveal a more nuanced reality: while the absence of clear and credible information is indeed a barrier, the presence of negative or excessive information can equally reinforce opposition. Several interviewees cited online reports about mold, cracking, or contractor negligence as reasons for rejecting EER. These concerns are not purely technical; they are perceived risks, amplified through narrative and social context.

This dynamic aligns with the psychological reactance framework proposed by Brehm (1966), which posits that when individuals perceive threats to their behavioral autonomy, they may resist even beneficial interventions. Similarly, Nyhan and Reifler (2010) demonstrate that corrective information can, under certain conditions, entrench false beliefs. The pattern echoed in our data, where some homeowners dismissed EER initiatives due to pre-existing distrust in official communication.

The European Environment Agency (2022) explicitly warns that poorly targeted information campaigns may backfire, particularly among low-trust households. Judson and Maller (2014) further note that trust in EER processes is often localized: residents may distrust distant authorities but place confidence in peer homeowners who have already undergone renovations.

Our study confirms this pattern. Homeowners are more likely to trust and act on information delivered by technical professionals or neighbors rather than by government officials. This points to the need for trust-rich dissemination strategies, including peer-led knowledge

exchange forums, community EER ambassadors, and third-party technical advisors who are viewed as neutral and credible.

5.4 Homeowners' expectations and governance challenges in second-round EER

Homeowners who previously received free government-led EER exhibit significantly lower willingness to contribute financially to subsequent renovation rounds than those who have never participated. This reflects a classic anchoring effect (Tversky & Kahneman, 1974), whereby the initial "zero-cost" experience becomes a reference point, making any future payment seem unreasonable or illegitimate.

This anchoring tendency has also been observed in broader national surveys. Huang et al. (2021) found that prior subsidy recipients in China reported lower stated willingness to co-finance future EER compared to those who had not received subsidies. Similar patterns were noted by Ameli and Brandt (2014), who analyzed OECD data and concluded that generous upfront subsidies may distort long-term expectations about private responsibility for green investments.

Beyond individual cognitive biases, our findings also point to systemic governance challenges in coordinating multiple renovation rounds. Interviewees who had previously upgraded windows or radiators on their own expressed confusion and frustration when government projects later proposed to redo the same work (sometimes according to inconsistent technical standards). These coordination failures stem from the absence of a unified planning mechanism, a challenge also highlighted by Sun et al. (2019), who compared EER governance structures in China and the Netherlands and found that Chinese cities often lack institutional tools to align bottom-up homeowner initiatives with top-down policy directives.

To address these issues, we recommend developing multi-year EER planning blueprints at the building or community level; creating renovation registries to avoid duplication; and introducing symbolic co-payments from the start to prevent unrealistic expectations.

5.5 Policy and research recommendations for future EER practice

Building on the findings of this study, we recommend a paradigm shift in how EERs are promoted and governed in urban China. The following directions can help improve both policy effectiveness and homeowner engagement.

Behaviorally-informed, stage-sensitive interventions: Design communication and incentive strategies according to homeowners' psychological and practical decision phases. During early contemplation, trust-building and emotional reassurance must be prioritized. The renovation effects are expected to be shown. In later implementation stages, cost-effectiveness and technical reliability should be emphasized. Timely Technical support is supposed to be provided.

Strengthening institutional trust: Leverage credible messengers such as independent technical advisors and peer homeowners with successful experiences. Participation processes should be transparent, inclusive, and respectful of homeowner autonomy.

Coordinated multi-round planning mechanisms: Develop long-term EER frameworks at the building or community level that can accommodate both top-down initiatives and spon-

taneous homeowner upgrades. This helps prevent redundant retrofits and technical conflicts across renovation rounds.

Subsidy reform toward shared responsibility: Transition from full-subsidy models to co-payment schemes that normalize homeowner contribution. Gradual reduction of subsidies over three to five years. Such designs can reduce anchor bias, foster a sense of ownership, and improve long-term sustainability.

Expanding the research frontier: Future studies should investigate intra-household decision dynamics (e.g., intergenerational negotiations), evaluate alternative models of community co-governance, and explore the role of digital platforms in enhancing transparency, traceability, and trust in the renovation process.

5.6 Limitations of the study

This study has several limitations that should be acknowledged.

First, although the total sample size ($N=479$) was sufficient for general regression analysis, the number of homeowners with EER experience was relatively small. This limits the statistical power of comparisons between renovators and non-renovators and constrains further subgroup analyses.

Second, the research design offers only a cross-sectional snapshot of homeowner attitudes. As our findings suggest, motivations and barriers evolve across different decision phases, but the current dataset does not allow for tracking these changes over time. A longitudinal or panel design would be better suited to capture such temporal dynamics, especially in response to major policy shifts or post-renovation experiences.

Third, this study did not investigate intra-household decision-making structures. Many respondents indicated that decisions about EER were influenced by other family members, yet we did not collect data on who holds decision authority or how generational views may differ, potentially overlooking key social mechanisms behind EER adoption.

Finally, the online portion of the survey may be subject to sample bias. Despite anonymity and provincial diversity on the *Wenjuanxing* platform, the sample may over-represent individuals with higher digital literacy or stronger environmental awareness. Future research should diversify recruitment channels, including outreach via neighborhood committees or energy service providers, to improve sample representativeness.

6 Conclusion

This study investigates the barriers and motivations influencing homeowners' decisions to participate in government-led EER projects in China's Northern Heating Region. Drawing on a mixed-method approach combining a questionnaire survey and semi-structured interviews, it distinguishes between two homeowner groups: those with prior EER experience (renovators) and those without (non-renovators), in order to explore how past experiences shape current attitudes and decision-making processes.

The findings reveal that renovators and non-renovators exhibit markedly different behavioral patterns regarding perceived barriers, motivational drivers, and willingness to engage in future EER projects. Renovators tend to have more concrete expectations and pragmatic concerns, while non-renovators demonstrate greater uncertainty and are more influenced by

external signals and cognitive biases. These differences underscore the necessity of tailored policy responses.

Based on these insights, the study outlines several group-specific policy recommendations. These include improving communication and transparency throughout the EER process, fostering trust in implementing authorities, enhancing the visibility of successful cases, and designing incentive mechanisms that are aligned with homeowners' prior experiences and evolving expectations.

In sum, this research advances the behavioral understanding of EER participation in collective housing contexts and offers empirical foundations for developing more adaptive and effective policy tools.

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Declarations

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