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# MEASURING RESIDENTS' INTENTION TO ENERGY RETROFIT EXISTING RESIDENTIAL BUILDINGS: SCALE DEVELOPMENT AND VALIDATION

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## Abstract

Residential building energy retrofitting (RBER) is essential for enhancing energy efficiency in homes. The intention of residents to undertake energy retrofits has increasingly attracted the attention of governments and construction firms. This study develops and tests a multidimensional Residential Building Energy Retrofit Intention Scale (RBERIS) to identify the critical dimensions influencing residents' intentions to adopt energy retrofit technologies for improving the energy efficiency of their existing homes. Drawing on literature related to scale development and measurement theory, we created a 22-item, 4-dimensional scale encompassing retrofit motivation, attitude, subjective norms, and perceived behavioural control, supported by evidence of unidimensionality (all factor loadings >0.5) and reliability (Cronbach's α >0.7). The RBERIS reliably and effectively assesses residents' intentions to undertake RBER, assisting building energy retrofit companies and promoters in formulating development strategies and offering new insights into understanding these behavioural intentions. Future research directions are also discussed.

***Keywords***: Residential Building Energy Retrofit, Retrofit Intention, Scale Development, Intention Survey, Validation

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## INTRODUCTION

Reducing energy loads in residential buildings is a critical issue in urban planning (Hamzah et al., 2023). These structures encompass various forms, including detached houses, semi-detached houses, townhouses, and multi-story apartments. Their energy efficiency significantly varies due to differing construction phases, necessitating retrofitting to meet net-zero standards (Zawawi et al., 2024). Enhancing energy efficiency can effectively reduce urban energy demand and bolster energy security.

Residential building energy retrofit (RBER) is a regenerative technology essential for improving the energy performance of these buildings (Liu et al., 2023). However, global adoption of RBER remains limited (Zhang et al., 2021), resulting in many residential buildings exhibiting "high energy consumption and low comfort," which adversely affects residents' quality of life and health (Gillingham et al., 2021). Consequently, promoting RBER adoption and understanding retrofit intentions are crucial (Li et al., 2022).

Retrofit intention serves as a precursor to implementation, reflecting self-reported predictions about future retrofit behaviours. It can be defined as the extent to which individuals are willing to invest effort into implementing RBER (Conradie et al., 2023), encompassing their motivations, attitudes, and specific plans (Irfan et al., 2021). Such behavioural intention primarily arises from residents' cognitive evaluations and rational judgments regarding RBER, rather than from emotions or habits. The stronger the intention, the more likely residents are to engage in retrofit behaviours (Klöckner and Nayum, 2017).

Current research on measuring retrofit intention predominantly concentrates on singular dimensions, such as residents' willingness to pay (Huang et al., 2021) or their desire to adopt retrofits (Fernandez-Luzuriaga et al., 2022). While these behavioural intentions are relevant to RBER implementation, they address distinct aspects; for instance, a willingness to accept a retrofit does not necessarily imply a willingness to pay for or cooperate in its execution. Few studies have employed a multidimensional approach, and issues with mapping effectiveness remain (Bakaloglou & Belaïd, 2022). Existing scales often lack comprehensive coverage, failing to capture the diverse facets of retrofit intention, which may contribute to the intention-behaviour gap in RBER. Thus, an effective tool for evaluating residents' intentions to engage in RBER is still needed.

To address this gap, we have developed an instrument for measuring and quantifying RBER behavioural intention, termed the Residential Building Energy Retrofit Intention Scale (RBERIS). This study aims to outline development process of this instrument, report its reliability and validity, and provide insights into retrofit intentions.

# LITERATURE REVIEW

## Theoretical Framework of RBERIS

Understanding residents' intention to undertake Residential Building Energy Retrofit (RBER) has yet to reach a consensus, as various theories offer different insights. Research has primarily drawn from the Theory of Planned Behaviour (TPB) (Conradie et al., 2023), the Diffusion of Innovations (DoI) (Alam et al., 2014), and the MOA model (Bjørneboe et al., 2018). TPB, developed by Ajzen(1991), explains retrofit intention through psychological factors and rational decision-making. The three dimensions of retrofit intention—attitude towards retrofitting, subjective norms regarding retrofitting, and perceived behavioural control—account for 70.2% of the overall variance in retrofit intention (Scott et al., 2014). The Stieß model (Stieß et al., 2009) and the Michelsen model (Michelsen & Madlener, 2010), both based on TPB, have been employed to investigate the drivers and barriers of RBER (Miller et al., 2018; Stieß & Dunkelberg, 2013). Consequently, the structure of the scale developed in this study is primarily informed by TPB.

However, the theory of TPB does not fully address how residents develop a need for RBER, particularly regarding their motivations, which encompass triggers, interests, and needs. This aspect is critical for understanding technology adoption, as highlighted by the DoI theory (Broers et al., 2019; Wilson et al., 2018). Even if residents possess a positive attitude towards RBER, align with social norms, and have the resources for retrofitting, they may still lack motivation, especially if their building already achieves net-zero energy emissions. This can lead to biased measurement results. Therefore, incorporating retrofit motivation into TPB can enhance its explanatory power and provide a more comprehensive understanding of retrofit intention (Klöckner & Nayum, 2016; Stieß & Dunkelberg, 2013).

## Conceptualisation of the Dimensions of RBERIS

### *Retrofit Motivation*

Retrofit motivation refers to the internal drivers that prompt residents to undertake RBER, including needs and desires. It serves as an incentive for behaviour, explaining why residents engage in RBER. Bjørneboe et al. (2018) identified that motivation is a prerequisite for retrofit behaviours, such as achieving energy cost savings and enhanced thermal comfort. A stronger motivation is positively correlated with higher RBER intensity (Baumhof et al., 2018). Sources of motivation include external rewards, internal rewards, and the desire to maintain a positive self-concept. Economic and non-economic indicators, such as energy cost savings, property value, residential comfort, and environmental protection, also play significant roles (Ebrahimigharehbaghi et al., 2022).

### *Retrofit Attitude*

Retrofit attitude can be assessed using two indicators. The first indicator is residents' approval of RBER, evaluated based on its perceived value, which includes reducing energy costs, protecting the environment, and enhancing residential quality (He et al., 2019; Klöckner & Nayum, 2017). The second indicator is residents' willingness to undertake RBER, which is reflected in positive emotions and enthusiasm following the retrofit (Tan et al., 2023).

### *Subjective Norms to Retrofit*

Subjective norms refer to the social pressures that influence decisions regarding RBER (Klöckner & Nayum, 2017). These pressures can arise from external sources, such as demands from organisations or individuals, as well as internal sources, such as personal psychological needs to conform after observing the decisions of others. Assessment can be made using two indicators: external demands and expectations from decision-making advisors, public organisations, or institutions, and self-imposed requirements stemming from the internalisation of external information or personal values (Conradie et al., 2023).

### *Perceived Behavioural Control to Retrofit*

This dimension involves individuals' perception of factors that facilitate or hinder RBER, including confidence and resource control (Alam et al., 2014). The first indicator is confidence in the implementation of retrofits, which is divided into self-confidence and the ability to meet expected outcomes (Li et al., 2022). The second indicator pertains to control over necessary resources, such as funding, time, capabilities, and technical knowledge (Goh et al., 2024; Stieß & Dunkelberg, 2013).

## METHODS

The scale was developed based on the paradigm proposed by Churchill (1979) and informed by the scale development processes outlined in Mishra et al. (2022) and Yu et al. (2022). Figure 1 illustrates the primary process from development to validation of the instrument. The following sections provide a detailed elaboration of this process.

### Generation of RBERIS

The first step involved developing the structural dimensions, items, and scales of the RBERIS. A comprehensive literature review identified the structural dimensions related to retrofit motivation, attitude, subjective norms, and perceived behavioural control. Subsequently, we drafted 16 items for the RBERIS, ensuring that each item covered the conceptual content of its respective dimension. The items were evaluated using a five-point Likert scale, with ratings

ranging from 1 to 5. Scales were tailored to each dimension, with "not at all strong" to "very strong" for retrofit motivation, and "strongly disagree" to "strongly agree" for attitude, subjective norms, and perceived behavioural control. The mean score of each dimension indicated the respondent's level within that dimension, with possible scores ranging from 1 to 5. The sum of the mean scores across all dimensions represented the overall level of retrofit intention, yielding a total score range of 4 to 20. This score was categorised into five levels: very low (4–7.2), low (7.2–10.4), moderate (10.4–13.6), high (13.6–16.8), and very high (16.8–20).

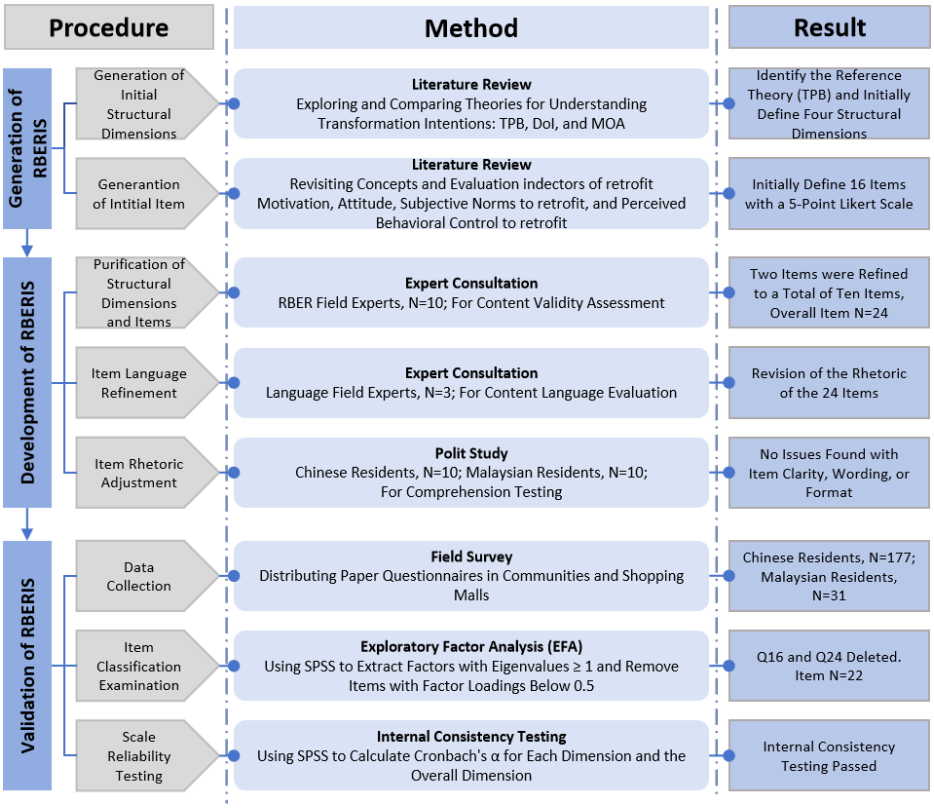


**Figure 1:** Scale Development Process

## Development of RBERIS

Experts (n=11) in the RBER field reviewed and refined the initial draft of the study, focusing on content validity (Jenn, 2006). They assessed the representativeness of the structural dimensions in capturing retrofit intention and identified any redundancies or omissions in the items. While the four structural dimensions were retained, the number of items was modified. Specifically,

additional items were added to the retrofit motivation dimension to address the limitations of simple self-reporting by presenting potential retrofit targets to respondents. This adjustment increased the motivation items from two (economic and non-economic motivations) to nine. A semi-open item was also recommended to capture other potential motivations, bringing the total number of items to 24.

Language experts (n=3) reviewed the wording and sequence of the scale items in Chinese and English to ensure clarity, conciseness, and accuracy. The items were further adjusted, simplified, and standardised in the first person for improved comprehension (Gonzalez-Franco & Peck, 2018). A pilot study involving ten residents from China and Malaysia was conducted to evaluate the clarity and potential ambiguity of the items. Chinese residents reviewed the Chinese version, while Malaysian residents reviewed the English version. Feedback indicated that respondents understood the items clearly, without ambiguity.

Following statistical validation, the finalised scale was employed for data collection, as detailed in Table 1. The survey included this scale alongside an information page, which provided an overview of the survey's purpose, confidentiality terms, and a brief introduction to the concept and scope of RBER. It distinguished RBER from simple building renovations or daily energy-saving behaviours, emphasising substantial physical modifications to residential buildings (Vasseur et al., 2019).

**Table 1:** The proposed RBERIS scale adapted from literature review and experts' validations

| Dimension | Indicator | NO. | Item | Format Reference |
|---|---|---|---|---|
| Retrofit Motivation | Save energy costs | Q1 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to save on energy costs? | (Touré-Tillery & Fishbach, 2014) |
| | Increase property value | Q2 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to increase its value? | |
| | Enhance property marketability | Q7 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to make it more marketable? | |
| | Improve living comfort | Q8 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to improve living comfort? | |
| | Improve ventilation | Q13 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to improve ventilation? | |
| | Reduce noise | Q14 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to reduce noise? | |
| | Maintenance | Q18 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to maintain it? | |
| | Environmental protection | Q19 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to protect the environment? | |
| | Enhance property appearance | Q22 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home to enhance its appearance? | |
| | Other | Q24 | How strong is my motivation to carry out energy-saving retrofits on my (or my family's) home for other reasons? | |

| Dimension | Indicator | NO. | Item | Format Reference |
|---|---|---|---|---|
| Retrofit Attitude | Acknowledgement of economic value | Q3 | I believe that energy-saving retrofits on my (or my family's) home are beneficial for saving on energy costs. | (He et al., 2019; Klöckner & Nayum, 2017; Scott et al., 2014) |
| | Acknowledgement of environmental protection | Q9 | I believe that energy-saving retrofits on my (or my family's) home are beneficial for saving energy and protecting the environment. | |
| | Acknowledgement of improved living quality | Q15 | I believe that energy-saving retrofits on my (or my family's) home are beneficial for improving the quality of living. | |
| | Acknowledgement of emotional value | Q20 | I would feel pleased about carrying out energy-saving retrofits on my (or my family's) home. | |
| Subjective Norms to Retrofit | Self-imposed requirements | Q4 | Due to my values/beliefs/sense of responsibility, I feel it is necessary to carry out energy-saving retrofits in my (or my family's) home. | (He et al., 2019; Irfan et al., 2021; Klöckner & Nayum, 2017; Scott et al., 2014) |
| | Advisors' hopes and expectations | Q10 | People who can influence my decisions want me to carry out energy-saving retrofits on my (or my family's) home. | |
| | Public organisations' hopes and expectations | Q5 | Some public organisations and institutions (e.g., government, environmental groups, media) want me to carry out energy-saving retrofits on my (or my family's) home. | |
| | Voluntariness after being influenced | Q11 | Seeing people around me (neighbours, relatives, friends) carrying out energy-saving retrofits on their homes motivates/influences me. | |
| | Hopes and expectations of key individuals | Q16 | People important to me want me to carry out energy-saving retrofits on my (or my family's) home. | |
| Perceived Behavioural Control to Retrofit | Self-confidence | Q6 | I believe that I can carry out energy-saving retrofits on my (or my family's) home. | (Alam et al., 2014; He et al., 2019; Irfan et al., 2021; Klöckner & Nayum, 2017) |
| | Confidence in expected outcomes | Q12 | I believe my life will improve after carrying out energy-saving retrofits on my (or my family's) home. | |
| | Perceived economic resources | Q17 | I have enough funds for energy-saving retrofits on my (or my family's) home. | |
| | Perceived time resources | Q21 | I have enough time for energy-saving retrofits on my (or my family's) home. | |
| | Perceived knowledge resources | Q23 | I have enough knowledge (or support from professionals) to carry out energy-saving retrofits on my (or my family's) home. | |

## Target Population

The target population for this study comprises homeowners and landlords who own completed properties and are the primary decision-makers regarding RBER. Participants must be 18 years or older, proficient in either Chinese or English, and of sound mental capacity. These criteria are essential for ensuring data quality and facilitating efficient questionnaire completion. Tenants and non-primary decision-makers are excluded from the study, as tenants generally lack obligations or responsibilities for RBER, which involves complex construction processes beyond typical tenant renovations (Scott et al., 2014).

**Sampling and Data Collection**

This study employed convenience sampling to collect data from participants in China and Malaysia (n=208) between December 2023 and July 2024. In China, data were obtained from residents of Shanghai, Hangzhou, Hefei, and Shantou, resulting in 177 valid responses. In Malaysia, data were collected from Kuala Lumpur and Selangor, yielding 31 valid responses. Questionnaires were distributed and collected in person at malls and residential communities in these cities. The English version of the RBERIS was used in Malaysia, while the Chinese version was used in China. The questionnaire included a screening question to confirm respondents' role as the primary decision-makers for RBER. Those who did not meet this criterion were instructed to terminate the survey. The survey took approximately 8-15 minutes to complete; responses submitted in less than 5 minutes were deemed invalid, resulting in the exclusion of 21 samples.

**Statistical Analysis**

In addition to presenting descriptive statistics for each dimension's scores, this study utilised SPSS version 26 to conduct several statistical analyses: First, Exploratory Factor Analysis (EFA) was performed using Principal Component (PCA) to identify the underlying factor structure of the scale and determine the factor loadings for each item. Factors with eigenvalues greater than 1 were extracted (Papadas et al., 2017), and Varimax rotation was applied. Variables with communalities below >0.3 were eliminated, and cross-loadings were reviewed to ensure that each item primarily loaded onto a single dimension. Items with factor loadings below 0.5 were removed (Lu et al., 2019), ensuring that each item contributed meaningfully to its respective dimension. Based on these criteria, both convergent and discriminant validity were assessed. Subsequently, Reliability Analysis was performed to evaluate the internal consistency of the scale, including both the overall scale and individual dimensions. Cronbach's α values were calculated, with values greater than 0.7 indicating acceptable internal consistency (Marikyan et al., 2022).

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these criteria, both convergent and discriminant validity were assessed. Subsequently, Reliability Analysis was conducted to evaluate the internal consistency of the scale, encompassing both the overall scale and individual dimensions. Cronbach's α values were calculated, with values exceeding 0.7 indicating acceptable internal consistency (Marikyan et al., 2022).

## RESULTS

The demographic characteristics of the surveyed residents are presented in Table 2. Participants' ages ranged from 24 to 75 years, with 37.5% reporting that their residences were over 20 years old. The majority of residences were multi-story apartments (149, 71.63%), while detached and semi-detached houses were the least common, comprising 8 (3.85%) and 7 (3.37%) of the total, respectively. The mean (SD) score for residents' intention toward RBER, as measured by RBERIS, was 11.88 ± 2.57.

**Table 2:** Demographics and RBERIS Scores

| | |
|---|---|
| Participants- no. (%) | |
| China | 177 (85.10) |
| Malaysia | 31(14.90) |
| Age – year (SD) | 47.97±13.48 |
| Male - no. (%) | 150 (72.12) |
| Construction Date of the House- no. (%) | |
| Within ten years (2014 to present) | 34 (16.35) |
| 10-20 years (2004 - 2013) | 96 (46.15) |
| 20-30 years (1994 - 2003) | 36 (17.31) |
| 31-40 years (1984 - 1993) | 40 (19.23) |
| 40 years or more (before 1984) | 2 (0.96) |
| Housing Type- no. (%) | |
| Detached House | 8 (3.85) |
| Semi-Detached House | 7 (3.37) |
| Townhouse | 31 (14.90) |
| Multi-story Apartment | 149 (71.63) |
| Other Types | 13 (6.25) |
| RBERIS (SD, excluding Q16 and Q24) | |
| Retrofit motivation | 3.04±0.84 |
| Retrofit attitude | 2.64±0.86 |
| Subjective norms to retrofit | 3.22±0.76 |
| Perceived behavioural control to retrofit | 3.03± 1.01 |
| Retrofit intention | 11.92±2.60 |

The KMO value and Bartlett's Test of Sphericity yielded results of 0.993 and p = 0.000, respectively, indicating that the data were suitable for factor analysis (Shrestha, 2021). Using an eigenvalue cutoff of 1, the initial 24 items were grouped into four main components, accounting for a cumulative explained variance of 65.44%. All items, except for Q16 (Factor Loadings in $D_3 = 0.49$) and Q24 (Factor Loadings in $D_1 = 0.433$; Factor Loadings in $D_2 = 0.405$), exhibited factor loadings greater than 0.5, indicating a positive correlation with their

respective dimensions. Loadings below 0.5 suggest a weaker contribution of the variable to the dimension (Lu et al., 2019); consequently, Q24 and Q16 were excluded. Subsequent EFA revealed that the cumulative explained variance increased to 68.34%, with the classification of the remaining items generally aligning with the preliminary structure of the RBERIS.

The internal reliability of the four dimensions and all items was assessed using Cronbach's α, with results presented in Table 3. All values for the dimensions and the overall scale exceeded the reliability threshold of 0.7, indicating satisfactory internal consistency of the revised RBERIS. Furthermore, the factor correlation matrix showed that none of the correlation coefficients exceeded 0.7, demonstrating that the dimensions are sufficiently independent without excessive correlation.

**Table 3:** Results of Reliability Testing

| Dimension | EFA Analysis Retained Item Numbers | Cronbach's α for Each Dimension | Overall Cronbach's α |
|---|---|---|---|
| Retrofit motivation | Q1,Q2,Q7,Q8,Q13,Q14,Q18,Q19,Q22 | 0.919 | 0.930 |
| Retrofit attitude | Q3,Q9,Q15,Q20 | 0.819 | |
| Subjective norms to retrofit | Q4,Q10,Q5,Q11 | 0.909 | |
| Perceived behavioural control to retrofit | Q6,Q12,Q17,Q21,Q23 | 0.909 | |

## DISCUSSION

Following the testing phase, the RBERIS retained four dimensions: retrofit motivation, attitude, subjective norms, and perceived behavioural control. Exploratory Factor Analysis (EFA) confirmed that the 24 items fit into these dimensions, supporting the initial structure and aligning with prior research on retrofit intention (Klöckner & Nayum, 2017). Item Q24 was removed from the motivation dimension due to cross-loading (0.433 on motivation and 0.405 on perceived behavioural control), which may have been caused by the extensive number of items in the motivation dimension or its semi-open nature. Additionally, Q16 was excluded for its low factor loading (0.490), indicating a weak fit with its dimension and misalignment with rational decision-making (Kastner and Stern, 2015).

After these adjustments, the RBERIS demonstrated acceptable discriminant validity and internal consistency. The motivation dimension now comprises nine items that focus on the respondents' motivations for RBER, a crucial factor influencing retrofit intention (Klöckner & Nayum, 2016; Wilson et al., 2018). The remaining three dimensions—retrofit attitude (4 items), subjective norms (4 items), and perceived behavioural control (5 items)—align well with respondents' views, values, and perceived capacity to undertake RBER, consistent with studies by Xiao et al. (2023) and Irfan et al. (2021).

Theoretically and practically, this study significantly contributes by addressing the need for tools that assess residents' intention to undertake RBER. It advances the literature by revealing that retrofit intention is multidimensional, emphasising the necessity of considering multiple factors when understanding and predicting these intentions (Klöckner & Nayum, 2017; Wilson et al., 2018). By providing a structured approach to developing and evaluating tools for measuring retrofit intention, the study fills a critical gap in the literature. The rigorous scale development methodology ensures the reliability and validity of the RBERIS, identifying four key dimensions that capture the psychological complexity and latent aspects of residents' intentions to engage in RBER (Irfan et al., 2021). Furthermore, the RBERIS distinguishes itself from previous research on technology acceptance (Alam et al., 2014; Broers et al., 2019) by focusing specifically on retrofit intention and highlighting the importance of environmental and social considerations alongside utilitarian and hedonistic aspects. The identification of motivation as a crucial factor offers new insights, distinguishing RBERIS from earlier models.

Practically, the RBERIS serves as a valuable tool for practitioners, researchers, and policymakers. Practitioners can utilise the RBERIS to gauge and manage retrofit intentions, providing essential data for market research and investment planning, particularly in developing countries. For example, the study finds that respondents' retrofit intentions are moderate (score: 11.92±2.60), indicating limited market demand and suggesting caution in industry expansion, which aligns with expectations of energy-efficient retrofit progress in China, as noted by Jia et al. (2021). Researchers can analyse the impact of each RBERIS dimension to understand the obstacles residents face in undertaking retrofits, leading to more targeted recommendations for practitioners and policymakers. For instance, enhancing residents' attitudes toward RBER, which were found to be lower than motivation and perceived behavioural control, could be a key area for development. Additionally, RBERIS can assist government and public organisations in understanding and improving residents' views on RBER by assessing retrofit intentions across different regions, housing types, and development stages. This understanding can contribute to formulating more effective retrofit policies, reducing free-rider effects and promoting wider adoption (Egner et al., 2021). Finally, it supports resident self-assessment, enabling individuals to better understand their retrofit needs and conditions, leading to more informed decisions and robust support for family retrofit plans.

## Limitations and Future Research

The primary aim of this study was to develop and validate the RBERIS. However, several limitations must be acknowledged. Firstly, the sample size is relatively small, with data collected solely from China and Malaysia. This limitation may

affect the generalisability of the results and the applicability of practical recommendations for retrofit practices in other countries, particularly in developed regions. Secondly, the RBERIS is based on cross-sectional data, which means retrofit intentions may fluctuate due to changes in local policies, such as energy prices, retrofit subsidies, and loan policies (Wilson et al., 2018). As a result, the scale's ability to predict and assess these dynamic changes is limited.

These limitations highlight several areas for future research. Firstly, revalidation of the scale is necessary, focusing on different cultural and technological contexts and expanding the sample size to enhance its reliability and validity. Further research should explore residents' intentions to undertake RBER in varied empirical contexts to provide practical recommendations for promoting and implementing retrofit practices.

Secondly, future studies should develop models to understand retrofit intention more comprehensively by examining longitudinal changes from intention to actual retrofit behaviour. This approach will help elucidate the relationships and mechanisms of the RBERIS dimensions and enhance the understanding of behavioural intentions. Additionally, investigating retrofit intention from the perspectives of other stakeholders, such as community managers or government officials, could yield valuable insights. Incorporating objective measures, such as residents' daily energy-saving behaviours and pro-environmental indices, could also address the limitation of relying solely on self-reports.

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