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FEASIBILITY STUDY OF RETROFITTING ASSESSMENT FRAMEWORK FOR SUSTAINABLE MULTI-STOREY RESIDENTIAL BUILDINGS: A CASE STUDY OF CHINA

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ABSTRACT

The construction industry is one of the primary sources of carbon emissions. In the context of the global response to reduce greenhouse gas emissions and the impacts of climate change, China implements the Carbon Peaking and Carbon Neutralisation policy. The policy vigorously promotes energy conservation and emission reduction in the construction industry, particularly housing. Due to the large stock of existing old multi-storey residential buildings in China, most of which are not energy-saving, and the lack of a sustainable assessment framework to retrofit such buildings, it is deemed essential to analyse the shortcomings of the current assessment standards and frameworks and formulate a better alternative. Therefore, this paper aims to provide the rationale for proposing a sustainability assessment framework for retrofitting old multi-storey residential buildings in China. It first explains the concepts of sustainable development and housing, then combs the current Chinese government's commitments to sustainable housing agenda. The unsustainable state of this housing type is then reviewed, followed by the issues and gaps in the existing sustainable building assessment standards in China and overseas to justify the necessity of developing a sustainability assessment framework for retrofitting multi-storey residential buildings in China. This framework would assist the retrofit of old multi-storey residential buildings in reducing energy consumption, improving efficiency and achieving sustainable development. It also contributes to the body of knowledge in sustainable building assessments and helps in the planning and design processes within the public and private sectors related to the construction industry.

1. INTRODUCTION

Global warming and climate change are the greatest environmental threats facing humanity today. Greenhouse gas emissions represented by carbon dioxide are the culprit of global warming. About 70% of man-made greenhouse gas emissions come from the combustion of fossil fuels such as coal (China Petroleum News, 2021). According to the International Energy Agency (IEA), with the world economy rebounding strongly from the COVID-19 crisis and relying heavily on coal to drive growth, global energy-related carbon dioxide emissions increased by 6% to 36.3 billion tons in 2021, setting a new historical record (see Figure 1). More than 11.9 billion tons, which account for 33% of the global total, came from China, making the country the world's largest carbon dioxide emitter (see Figure 2). Currently, the building stock in China is 73 billion square meters (Wang, 2022). As shown in Figure 3, more than half of carbon dioxide emissions from urban buildings in China come from existing community housing (Niu, 2021; Special Committee on Energy Consumption and Carbon Emission of China Building Energy Conservation Association, 2022). Hence, taking necessary measures to reduce the energy consumption of existing housing is evident and urgent.

Under China's Double Carbon targets, the construction industry's carbon emission reduction task is particularly urgent, and the construction and improvement of relevant standards are also imminent (Wang, 2022). The country has many old residential buildings, most of which are not energy-saving. Meanwhile, the current assessment standards are still insufficient because of China's late start and weak foundation of sustainable building assessment (Wang et al., 2021). Unsurprisingly, sustainable assessment frameworks for retrofitting old multi-storey residential buildings are lacking. Therefore, addressing this gap towards achieving the Double Carbon targets, carbon emission reduction, and China's long-term sustainable building goals is imperative.

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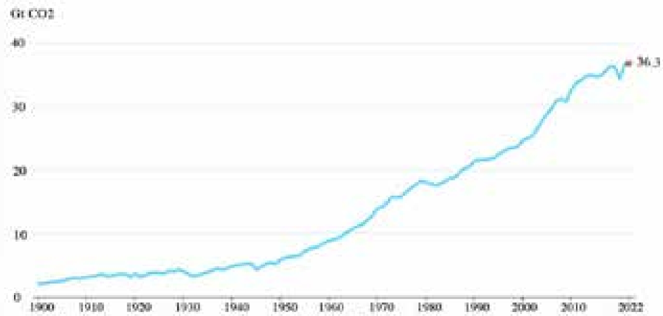

Figure 1: *Global CO_2 emissions from energy combustion and industrial processes (IEA, 2023)*

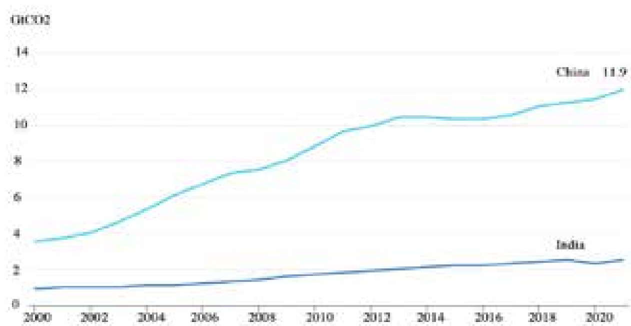

Figure 2: *CO2 emissions in China (IEA, 2023)*

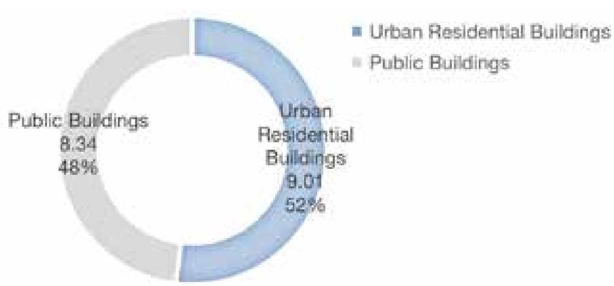

Figure 3: *Distribution of carbon emissions in China's building sector in 2020 (Unit: 100 million tCO2)*

Therefore, this paper aims to analyse the gaps in the current sustainable assessment standards and frameworks and justify the need to establish a sustainable assessment framework for retrofitting existing old multi-storey residential buildings in China. This paper is presented in four sections. The first section explains the concepts of sustainable development and sustainable housing. Then the current Chinese government's commitments to retrofit the existing old multi-storey residential buildings are highlighted in the second section. The third section reviews the current state of this housing type to justify the need for sustainable retrofitting. Then, the issues and gaps in existing building assessment standards in China are discussed in the fourth section. This paper concludes with recommendations for establishing a sustainable assessment framework for retrofitting old multi-storey residential buildings in China.

2. SUSTAINABLE DEVELOPMENT AND SUSTAINABLE HOUSING

Since the early 1990s, the sustainable development concept has gradually become a new influential agenda at national and global levels. It was first proposed in the World Conservation Strategy published by the International Union for Conservation of Nature and Natural Resources in 1980. Sustainable development is defined by the Brundtland Report (World Commission on Environment and Development, 1987) as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The three pillars of sustainability are environment, society and economy, first mentioned in the 1987 Brundtland report (Keeble, 1988). This three-dimensional description is usually presented in the form of three intersecting circles of society, environment and economy, and sustainable development is placed at the intersection (Figure 4). In 1997, the sustainable development strategy was identified as one that must be implemented in China's modernisation (Xi, 2007). To summarise, sustainable development addresses environmental protection, sustainable economic growth and social equity.

Figure 4: *The three-ring model of sustainable development*

Sustainable housing is a part or embodiment of sustainable development in building housing. Sustainable housing refers to a new type of housing that follows the sustainable development concept; specifically, it adheres to energy conservation and environmental protection, functional adaptability, economic rationality, technical suitability and cultural spirit during the whole building life cycle (Song, 2018). Sustainable housing construction and retrofit are a part of the urban renewal strategy. Urban renewal involves rehabilitating declining or decaying city areas by improving their ecological, spatial and cultural environments. Urban renewal is the theory of framework science from the angle of constructing urban ecological balance and exploring a new mode of sustainable development (Wang, 2021).

3. CHINESE GOVERNMENT COMMITMENTS TO SUSTAINABLE HOUSING AGENDA

Under the prevalence of sustainable development and sustainable housing concepts, the Chinese government has taken measures and issued a series of policy documents to promote sustainable housing development. According to the current energy-saving design standards for old residential buildings, the existing urban residential buildings built before 2018 are non-energy-saving buildings, which generally have problems of low energy efficiency and poor living comfort (Guo et al., 2022). According to the 13th Five-year Plan for Building Energy Efficiency and Sustainable Building Development, about 60% of existing buildings in cities and towns are non-energy-efficient (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2017). Historically, the urban development process in China involved two stages: 1) demolition and reconstruction and 2) retrofit. When people realised how expensive the demolition and reconstruction method was, urban development gradually moved to the second stage, i.e. retrofitting for urban protection (Zeng et al., 2007). The same is true for the energy-saving retrofit of existing old houses. Since the stock of existing housing in China is much larger than that of newly built housing (Wang, 2022), adopting the former strategy (demolition and reconstruction) would consume a lot of energy and natural resources. The latter option is more environmentally friendly and in line with the strategy of sustainable development and urban renewal.

At the same time, the Chinese government has also strongly supported the retrofitting rather than the reconstruction of old multi-storey residential buildings. On July 10, 2020, the State Council issued the Guidelines on Comprehensively Promoting the Retrofitting of Old Residential Buildings (General Office of the State Council, 2020). Consequently, the state and society began vigorously promoting the retrofitting of old residential areas. By the end of 2020, 39,000 old urban residential areas were retrofitted, involving nearly 7 million households. At the same time, the state mandated that the government should increase its support and that the central government should give financial subsidies. In August 2021, the Ministry of Housing issued a notice titled Preventing Major Demolition and Construction in the Implementation of Urban Renewal Actions. Since then, old cities can no longer be demolished, and innovative protective repair, restorative construction and other implementation methods have been proposed. This policy aims to avoid the disintegration of urban social structure, the disappearance of historical and cultural accumulation, and the destruction of the natural ecological environment (see Figure 5).

Figure 5: *Documents issued by the Chinese government to support sustainable housing*

Therefore, retrofitting old residential buildings is a significant development project in China. It is significant to promote urban renewal by retrofitting old structures to meet the people's needs for a better life and promote their livelihood towards achieving high-quality economic development. A study focusing on a sustainable retrofit of existing residential buildings in China is deemed critical.

4. THE NEED FOR RETROFITTING EXISTING OLD MULTI-STOREY RESIDENTIAL BUILDINGS IN CHINA

Nationwide, the major problems of existing old multi-storey residential buildings in China include ageing infrastructure, poor living environment, leaking pipe networks, and insufficient and unsmooth water supply. Economically, many people struggle and cannot afford security, cleaning, maintenance, greening and other services. The management fee is insufficient and very difficult to charge. Social issues such as public security cases are rampant. Most of the buildings in old residential areas are non-energy-saving buildings. There are about 170,000 old multi-storey residential buildings and about 42 million households in China, with a total construction area of 4 billion square metres (Qiu, 2020). It would produce substantial energy savings if the 50% or even 65% energy-saving rate can be met (see Figure 6).

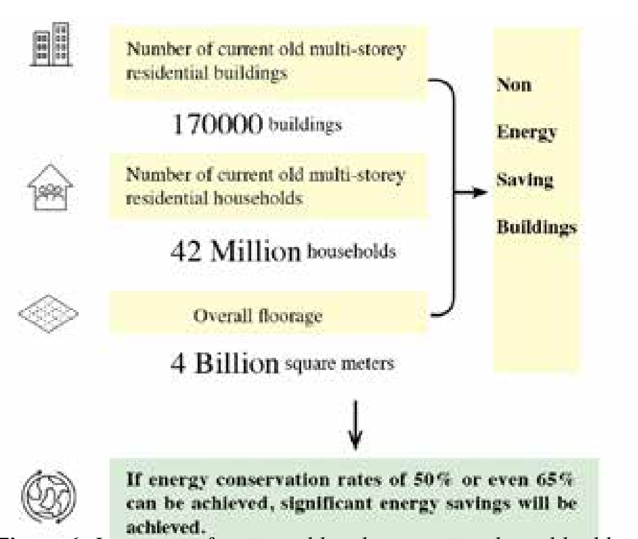

Figure 6: *Inventory of current old multi-storey residential buildings in China*

The same problem exists in old multi-storey residential buildings in China's cold regions. Compared with other climate types in China, buildings should meet the requirements of cold protection, heat preservation and anti-freezing in winter, and heat protection should be considered in summer. So, the insulation and heating requirements of the building are different for different areas. In a nutshell, China's existing old multi-storey residential buildings are unsustainable and urgently require sustainable interventions. Therefore, there is a huge demand for sustainable retrofit of old multi-storey residential buildings in China to reduce their negative environmental, social and economic impacts.

In line with this realisation, assessing the sustainability level of such building retrofitting is deemed necessary. There is an urgent need to accelerate the comprehensive retrofitting of old residential areas in China to conserve energy and reduce carbon emissions (Mu, 2021). A residential building energy-efficiency assessment framework is needed to provide a calculation model for the energy-saving prediction of existing residential buildings in old residential areas (Wang, 2021). Furthermore, the benefits of such a framework for existing old residential buildings are as follows: 1) standardising the energy-saving retrofit strategies, 2) guiding the sound development of the mass retrofitting of energy-saving, 3) guiding the decision-making for optimising energy-saving schemes in the retrofit process, and 4) helping the government to formulate more detailed and feasible policy frameworks and standard frameworks to achieve energy-saving through retrofits. Therefore, it is necessary to establish a systematic, scientific, comprehensive and objective assessment framework for energy-saving retrofit of old multi-storey residential buildings in old residential areas in China.

5. ISSUES AND GAPS IN THE EXISTING BUILDING ASSESSMENT STANDARDS

As of the end of June 2021, nearly thirty national, industry, and local standards exist for sustainable buildings in China (Wang et al., 2021). The current national assessment standards for sustainable buildings are listed in Table 1. The types of buildings targeted by these assessment standards include newly built, renovated, and expanded offices, industrial buildings, engineering, exhibition buildings, shops, hospitals, and hotels. There are two standards for assessing existing residential buildings in China, namely, the Sustainable Building Assessment Standard (GB/T 50378-2019) for new and existing buildings and the Sustainable Building Assessment Standards for Existing Buildings (GB/T 51141-2015) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2015, 2019).

Table 1: *List of current national assessment standards for sustainable buildings*

Year	Standard Name	Building type	Standard No
2013	Assessment Standard for Sustainable Office Buildings	Office	GB/T50908
2014	Assessment Standard for Sustainable Industrial Buildings	Industrial	GB/T50878
2014	Code for Sustainable Construction of Building Engineering	Engineering	GB/T50905
2014	Assessment Standard for Architecture Exhibition Buildings	Exhibition	GB/T51148
2015	Building Assessment Standard for Shop Buildings	Shop	GB/T51100
2015	Sustainable Building Assessment Standards for Existing Buildings	Existing Buildings	GB/T 51141-2015
2015	Building Assessment Standard of Architectural Hospital	Hospital	GB/T51153
2016	Architectural Hotel Building Assessment Standard	Hotel	GB/T51165
2019	Sustainable Building Assessment Standards	Existing and new Buildings	GB/T 50378-2019

Internationally, the relatively mature and influential sustainable building assessment standards or rating tools are BREEAM in the UK (BRE Group, 2016), US LEED (US Green Building Council, 2020), CASBEE in Japan (Institute for Building Environment and Energy Conservation, 2007) and GBTool in Canada (Cole & Larsson, 2002), among others. Their frameworks and operation methods have become an essential reference for countries to establish their own sustainable building assessment standards and frameworks (Wang and Jiang, 2006; Wang et al., 2006). The BREEAM, LEED and CASBEE rating tools have specific tools for different types of existing buildings. The Canada GBTool, on the other hand, is designed as a generic framework that reflects regional practices and goals, so it requires local expertise to customise the system to suit the local context. Hence, it is used in many countries, including China. GBTool allows assessment for various building types, both new and existing buildings, including residential buildings. This study selected these four well-known rating tools as they originated from the Northern Hemisphere with a cold climate type similar to China as a reference. German DGNB rating tool is also relevant in this context. However, its frameworks for the retrofit assessment of different building types are almost identical, with only some details and weights emphasised (Xun et al., 2021). Therefore, German DGNB is not selected for this study.

Table 2 compares BREEAM (Refurbishment Domestic Buildings), LEED v4.1 (Residential BD+C Multifamily Homes), CASBEE (Housing Renovation Checklist) and GBTool with the assessment standards for existing residential buildings in China, namely Sustainable Building Assessment Standards (GB/T 50378) and Sustainable Building Assessment Standards for Existing Buildings (GB/T 51141). Aspects of comparison are the year of release, targeted building groups, assessment stages, scoring and rating, and assessment categories.

The table shows that regarding targeted building groups, CASBEE and BREEAM have specific tools for refurbished or retrofitted residential buildings. LEED includes renovation projects in its Residential BD+C Multifamily Homes rating tool. Canada GBTool applies to a wide range of building types, and options are available for residential selection. However, the assessment standards in China are mainly for existing public and residential buildings. The retrofitting process has not yet been detailed in these assessment standards. The GB/T 51141 standard emphasises universality and does not classify different types of buildings. This is problematic because different building types have different use functions and retrofitting priorities. Both standards ignore the specific requirements for retrofitting old multi-storey residential buildings.

Regarding assessment categories, BREEAM includes health and well-being, considers the needs of all existing building users, and emphasises the diversity of building users. One of the purposes of sustainable retrofitting of existing residential buildings is to create a comfortable and livable living environment that meets the building users' needs from their perspective (Xun et al., 2021). However, the assessment standards in China do not fully meet this requirement.

Table 2: *Comparison of sustainable assessment standards related to existing residential buildings*

Name	**Sustainable Building Assessment Standards GB/T 50378**	**Sustainable Building Assessment Standards for Existing Buildings GB/T 51141**	**Japan CASBEE Housing Renovation Checklist**
Year	2019	2015	2016
Targeted building groups	Existing buildings and new buildings (All buildings, including residential and public buildings)	Existing buildings (All reconstructed and expanded projects, including residential and public buildings)	Ageing housing with deteriorating performance
Assessment stages	Design, construction and operation stages	Design, construction and operation stages	Design, construction and operation stages
Scoring and rating	Basic: meet all control items One Star: ≥60 points Two Stars: ≥70 points Three Stars: ≥85 points	Basic: meet all control items One Star: ≥50 points Two Stars: ≥60 points Three Stars: ≥80 points	Each assessment item is assessed on a 4-point scale from level 1 to 4 with different levels. Level 1: Does not meet level 2 Level 2: Normal housing standards in need of refurbishment Level 3: Performance improvement can be seen by retrofitting Level 4: High standards to aim for in the future, even for newly built houses
Assessment categories	· Safe and durable · Healthy and comfortable · Convenient life · Resource-saving · Livable environment · Promotion and innovation	· Planning and architecture · Structure and materials · HVAC · Water supply and drainage · Building electrical · Construction management · Operation management · Promotion and innovation	· Comfortable, healthy and safety · Energy saving · Durable

Table 2: *continued*

Name	**LEED v4.1 Residential BD+C Multifamily Homes**	**BREEAM Refurbishment Domestic Buildings**	**GBTool**
Year	2020	2014	2002
Targeted building groups	Multifamily building with two or more units and any number of stories (new construction or major renovation)	Refurbishment of exiting domestic buildings	Existing buildings and new buildings (Including residential buildings and public buildings)
Assessment stages	Design, construction and operation stages	Design, construction and operation stages	Design, construction and operation stages
Scoring and rating	Certified: 40-49 Silver: 50-59 Gold: 60-79 Platinum: 80+	Pass: ≥30 Good: ≥45 Very good: ≥55 Excellent: ≥70 Outstanding: ≥85	-2: Unsatisfactory Performance 0: Minimum acceptable performance 1-4: Intermediate Performance Levels 5: Demanding Performance

Name	LEED v4.1 Residential BD+C Multifamily Homes	BREEAM Refurbishment Domestic Buildings	GBTool
Assessment categories	· Integrative process · Location and transportation · Sustainable sites · Water efficiency · Energy and atmosphere · Materials and resources · Indoor environmental quality · Innovation · Regional priority	· Management · Health and well-being · Energy · Water · Materials · Pollution · Innovation	· Resource consumption · Loadings · Indoor Environmental quality · Quality of service · Economics · Management · Commuting transport

In summary, there are still significantly few assessment standards for retrofitting existing buildings, and the ones in China ignore the particularity of multi-storey residential buildings. This supports Wang (2021), who argued that targeted, systematic, and professional assessment standards are still lacking. Considering users' requirements is also not fully emphasised, and they are insufficient to guide users in retrofitting their old multi-storey residential buildings for environmental, social and economic sustainability. It is important to address these gaps as multi-storey residential buildings account for the highest energy consumption and are the building type most relevant to people in China (Xu, 2020).

The literature revealed that most previous studies from China focus on the analysis of sustainable building assessment standards (Pu and Zhu, 2019), comparisons of international assessment standards (Chen et al., 2021), and putting forward strategies and corresponding improvement suggestions (Wang, Wang & Li, 2021; Fu and Xie, 2021). Some studies focus on the application of sustainable building assessment criteria to architectural design strategies (Duan and Li, 2021) from the perspective of carbon emissions (Liu et al., 2021), general contractors (Zhang and Zhang, 2021), and cultural elements (Meng et al., 2021). Others described the sustainable building assessment standards based on the whole life cycle (Wang et al., 2020), BIM software (Guo et al., 2021) and the perspective of public building reconstruction (Meng et al., 2019). Others analysed sustainable building assessment standards for specific areas, such as mild areas (Zeng, 2021) and plateau areas (Liu et al., 2020).

To sum up, little research has been done on sustainable assessment standards for retrofitting existing old multi-storey residential buildings in the cold region of China. Therefore, there is an urgent need to develop an assessment framework to guide building users in carrying out the retrofit or transformation process of their old multi-storey residential building and subsequently assess its sustainability level.

6. CONCLUSION

In summary, by explaining the concepts of sustainable development and housing, sorting out the current commitments of the Chinese government to the sustainable housing agenda, reviewing the unsustainable state of the existing old multi-storey residential building, as well as the problems and gaps in existing sustainable building assessment framework in China and overseas, it has proven the necessity of developing a sustainability assessment framework for multi-storey residential retrofitting in China.

At the same time, this paper has also revealed that the current sustainable assessment standards and frameworks for existing residential buildings in China are still incomplete, but the urgency for improving such frameworks is lacking. It has also shown that changing people's attitudes and actions toward sustainable retrofit of old multi-storey residential buildings and emphasising the urgency and necessity of such actions is imperative. Therefore, an appropriate assessment framework is needed for the sustainable retrofit of old multi-storey residential buildings in China. This study has discovered the gaps in existing sustainable assessment standards and highlighted the urgency of improving them.

Against this background, this research will lay a foundation for establishing a sustainable assessment framework in the next stage. The proposed framework will provide a clear retrofit direction for building owners and designers to improve indoor and outdoor environmental quality, reduce utility bills, and extend the building and service life. At the same time, it will help the government and real estate developers to reduce energy consumption, carbon emissions and other pollutants, and maintenance costs in the building sector. Ultimately, the assessment framework for sustainable retrofit of multi-storey residential buildings would contribute to the body of knowledge in sustainable development and help China's construction industry achieve the Double Carbon targets.

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